Superfund Strategy

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Foreword

The cleanup of hazardous waste sites under the Federal Superfund program has received much attention since Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act in 1980. As Congress debates reauthorization and possible expansion of the program, it is instructive to examine the "lessons learned" from the initial Superfund program.

The objectives of this OTA study are, as requested by the House Energy and Commerce Committee and the House Science and Technology Committee: 1) to understand future Superfund needs and how permanent cleanups can be accomplished in a cost-effective manner for diverse types of sites; 2) to describe the interactions among many components of the complex Superfund system; and 3) to analyze the consequences of pursuing different strategies for implementing the program. The study brings together a great deal of information on what can be learned from the initial Superfund program in order to improve it. In particular, the study focuses on the choice between continuing and improving the current program and adopting a new strategy on the basis of improved information. Such a new strategy has been defined and analyzed by OTA in considerable detail to provide Congress with an understanding of critical policy trade-offs,

As Congress and the Nation attempt to address major economic and budgetary issues, it is important to examine the economic as well as the environmental dimensions of the Superfund program. In the face of scientific uncertainties, limited information, fiscal constraints, public demands for cleanups, and real threats to health and the environment, how can Congress assure effective and efficient spending of Superfund resources? How can it determine how much to spend? How can it decide on whether to proceed with costly cleanups in the absence of national cleanup goals and with technologies that may not be effective? Is there a need to perceive Superfund as a long-term program that would require money to be spent in improving institutional capabilities and cleanup technologies?

Because of the strong emotions surrounding this major national environmental program, comprehensive analysis can assist all interested parties in their quest for technically sensible, cost-effective, and equitable solutions. The present reauthorization process provides an opportunity to examine the latest information and alternative strategies.

This report builds on the analyses and findings in OTA's earlier work on hazardous waste issues, specifically our March 1983 report, Technologies *and Management Strategies for Hazardous Waste Control.* That report identified many of the problems with long-term containment of newly generated hazardous wastes; these problems are of direct relevance to the Superfund program, both in understanding the likely size of the uncontrolled hazardous waste site problem, and in examining technology choices for Superfund wastes,

A number of other OTA studies bear on the issues surrounding the Superfund program. Interested readers are referred to *Habitability of the Love Canal Area—A Technical Memorandum* (June 1983), *Protecting the Nation Groundwater From Contamination* (October 1984), *Technologies for Disposing of Waste in the Ocean* (in progress), and *Hazardous Materials Transportation: Technology Issues* (in progress).

The viewpoints of the private sector, community and environmental groups, academia, and State officials were sought in conducting this study. Many private and public groups cooperated in surveys performed for this study, and provided useful information. OTA thanks the many people—advisory panel members, workshop participants, reviewers, and consultants—who assisted in this work. As with all OTA studies, the information, analyses, and findings of the report are the sole responsibility of OTA.

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Chapter 1

Summary and Introduction

OVERVIEW

The Federal Superfund[1] program for cleaning up toxic waste sites has made progress, and much can be learned from its initial efforts to improve protection of public health and the environment.

The Environmental Protection Agency's (EPA) low estimate of Superfund costs can be traced to a lack of detailed planning for the program and optimism about both the number of toxic waste sites that will require cleanup and the effectiveness of cleanup technologies. *While EPA estimates that about* 2,000 *sites will reach the National Priorities List [NPL), OTA estimates that* 10,000 *sites (or more) may require cleanup by Super fund.* With Superfund's existing resources, it is not technically or economically possible to permanently clean up even 2,000 sites in less than several decades. OTA defines permanent cleanups to be those where the likelihood of recurring problems with the same site or wastes have been minimized through the use of treatment rather than containment technologies,

Only 50 percent of the 538 sites now on the NPL are receiving remedial cleanup attention, even though about $1 billion (two-thirds of the initial 5-year program's funding) have been committed. Initial actions and cleanups now emphasize the removal of wastes to land disposal facilities, which themselves may become Superfund sites, or wastes are left on the site. Current "remedial cleanups" tend to be impermanent. *Some sites get worse, and repeated costs are almost inevitable. Environmentally, risks are often transferred from one community to another, and to future generations,*

Underestimating national cleanup needs could result in an environmental crisis years or decades from now. With many more NPL sites, repeated responses, and uncertainty about private cleanups and contributions, cleanup needs could outstrip financial, personnel, and technological resources. Environmental damage could escalate. The issue now is not so much about whether or not to have a continued, expanded Superfund program as it is to choose to continue with the current approach or, on the basis of what we have learned so far, to restructure the program,

OTA finds that a two-part strategy (see below) offers cost and time advantages over the current program with its lack of attention to long-term factors. Even so, costs to Superfund could easily be $100 billion—out of total costs to the Nation of several hundred billion dollars, and it could take 50 years to clean 10,000 sites. The two parts of the strategy would overlap in time, but differ in focus and priorities. *This two-part strategy could be advantageous regardless of the size of the Superfund program.*

(I) In the near term, for perhaps up to 15 years, the strategy would focus on: a) early identification and assessment of potential NPL sites, b) initial response to *reduce near-term threats at all NPL sites and prevent sites from getting worse, c)* permanent remedial cleanups for some especially threatening sites, and d) developing institutional capabilities for a long-term program. A substantially larger Superfund program would be needed to carry out these efforts. Initial responses that accomplish the most significant and cost-effective reduction of risks and prevent sites from getting worse might cost about $1 million per site for

[1]This study is limited to one use of the Superfund program established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): the cleanup of uncontrolled hazardous waste sites. However, the Superfund program is very broad and other threats from releases of hazardous *substances* are managed, such as leaking underground storage tanks, spills from transportation accidents, and groundwater contaminated from pesticide use. The demands on Superfund from these uses in the future are uncertain but may also increase, This study does not consider federally owned uncontrolled sites, which are recognized to pose a large problem, but which do not qualify for cleanup under Superfund.

most sites. This is three times the current cost of immediate removal actions and about 10 percent of currently projected remedial cleanup costs. Case studies by OTA and others reveal that both immediate removals and remedial cleanups are ineffective for their intended purposes, Under the two-part strategy, initial responses would emphasize covering sites and temporarily storing wastes and contaminated materials to reduce groundwater contamination and, where technically and economically feasible, excavating wastes to minimize releases into the environment.

(II) Over the longer term, the strategy would call for more extensive site studies and focus on *permanent cleanups,* when they are technically feasible, at all sites that pose significant threats to human health **and** the environment (unless privately or State-funded cleanups offering comparable protection have taken place), These cleanups would draw on the institution building that occurred during the first phase. Spending large sums before specific cleanup goals are set and before permanent cleanup technologies are available leads to a false sense of security, a potential for inconsistent cleanups nationwide, and makes little environmental or economic sense.

Federal support could contribute in five areas. Such efforts take time, but cost little relative to Superfund's total costs and could result in more environmental protection at lower costs. The five areas are:

1. *Intensify Federal efforts to obtain more information on health and environmental effects and develop specific national cleanup goals,* Without this effort, selecting technologies, estimating costs, and evaluating public and private cleanups will be difficult and contentious. Cleanup goals could employ site classification based on locally decided site use, in combination with other information such as risk assessment, cost-benefit analysis, and existing environmental standards.
2. *Provide substantially more support for developing and demonstrating innovative, permanent cleanup technologies for a variety of problems,* The immediate costs for cleanups based on waste containment and redisposal omit much: monitoring, operation and maintenance, and the costs of future cleanups, especially for groundwater. Also, they are highly uncertain and can add greatly to total costs. For some geological settings, like the Stringfellow site in California, containment does not work. Permanent remedies, which destroy, detoxify, or otherwise treat wastes will be necessary to any cost-effective, long-term Superfund program; many innovative approaches exist, but they face substantial barriers to demonstration and use, such as the absence of protocols to evaluate their effectiveness.
3. *Provide increased support for EPA and perhaps the States so they can improve technical oversight of contractors and thus ensure quality cleanups,*
4. *Provide Federal support for technical training programs,* An expanded national cleanup effort could increase the need for certain technical specialists fivefold by 1995; shortages of experienced technical personnel such as hydrogeologists have already been noticed.
5. *Improve the Superfund program, and public confidence in it, by supporting public participation in decisionmaking about initial responses and remedial cleanups and providing technical assistance to communities.* Improved public participation could address the intrinsic tension between the desires of communities to obtain fast, effective, and complete cleanups at their sites and the limitations and goals of a national program.

OTA has considered only one use of Superfund, the remedial cleanup of hazardous waste sites that are "uncontrolled" because actual or potential releases of hazardous substances into the environment must be managed. A number of other applications exist and could increase in the future (e. g., leaking underground storage tanks, pesticide contamination areas, and transportation accidents). There is little doubt about the need to clean up sites that now get placed on the NPL, but additional sites are likely to require clean up. OTA's estimate of additional waste sites include: 5,000 sites from the more than 600,000 open and closed solid waste facilities, such as sanitary and municipal landfills, which can release toxic substances to groundwater; 2,000 from an improved site identification and selection process; and 1,000 from hazardous waste management facilities operating with ineffective groundwater protection standards.

A much larger Superfund program would likely mean that more reliance would have to be placed on general tax revenues or some other broadly based tax. Along with continued use of the tax on chemical and petroleum feedstocks, a tax on hazardous wastes could raise significant sums, but this latter tax would generate significant revenue only in the near-term, if less hazardous waste is generated over time. If such "waste-end" taxes, already adopted by 20 States, were made simple to administer, they would aid in reducing the generation of hazardous waste and the use of land disposal and, hence, the creation of still more Superfund sites.

Finally, OTA has stressed estimating future national needs, without making specific assumptions about non-Federal spending. Other research has assumed significant cost recovery of Superfund expenditures through enforcement actions and a fairly high level of privately and State-funded cleanups. Such assumptions often are not made clear, tend to be quite optimistic, and lead to "adjusted" costs for Superfund that could prove to be substantially low. Cost recovery to date has amounted to about 1 percent of Superfund spending, but EPA assumes cost recoveries of 47 percent for removals and 30 percent for remedial actions. To date, about $300 million has been committed by responsible parties for cleanups, an amount commensurate to what EPA has spent. EPA assumes that 40 to 60 percent of sites will be cleaned by responsible parties. Current obstacles to private cleanups, such as uncertain future liabilities, could discourage private spending. Continued, substantial spending by the private sector on cleanups is desirable and incentives (or the removal of barriers) may be necessary. However, clear cleanup goals and technical oversight are still essential to assure that effective cleanups are performed. Furthermore, it is not necessarily correct to assume that current policies on required matching funds from States will remain, as significant concerns exist about the willingness of some States to provide these funds.

BACKGROUND

Proved releases of hazardous substances have occurred from uncontrolled sites throughout the Nation. Groundwater and surface waters have been contaminated, drinking water supplies have been lost, and people have been evacuated or, in some cases, permanently relocated. There have been some fires and explosions. Most sites must be strictly off limits to unprotected people. Across the Nation, from Love Canal in New York, to Times Beach in Missouri, to the Stringfellow Acid Pits in California, people are worried about acute and chronic threats to their health, loss of natural resources, and sharp declines in the value of their homes and property,

After Federal legislation was enacted to manage newly generated hazardous wastes, it became apparent that a separate Federal program was needed to tackle the cleanup of uncontrolled waste sites. The Resource Conservation and Recovery Act (RCRA) of 1976 was followed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980. CERCLA established the Superfund program to handle emergencies at uncontrolled sites, to clean up the sites, and to deal with several other related problems.

At the very beginning of Superfund, the full scope of the uncontrolled site problem was unclear. Several releases of hazardous substances into the environment had been documented, and limited and often anecdotal evidence of adverse health and environmental impacts had been gathered. But unambiguous, comprehensive, and scientific understanding of the effects, particularly of the long-term effects, of such releases was lacking. For these reasons, Congress limited the Superfund program. The Environmental Protection Agency was directed to establish an NPL of at least 400 sites which needed remedial cleanup;[2] considerable flexibility was allowed to respond to emergencies. In addition, Congress directed the Department of Health and Human Services to gather data on health impacts from uncontrolled sites. Although in 1980 and earlier some people thought the evidence showed that a very large program would be necessary, many uncertainties and the new, highly technical challenge of performing large numbers of cleanups, caused Congress to limit the program to $1.6 billion over 5 years.

Now, as we approach the end of the initial Superfund program, Congress and the Nation have the benefit of more information about uncontrolled sites and can learn much from the early experiences of the program. This study concentrates on what can be learned from the results of the initial program; but it must be stressed that the Superfund program has made progress, especially considering that the program was created as a fast public policy response to a newly recognized and highly complex, technical, and diverse set of problems.

Much uncertainty about health and environmental effects remains. But EPA and the States have obtained more information about the number and kinds of uncontrolled sites, and they have studied the nature of releases from the sites. Thus, EPA has expanded the NPL to 538 sites, has proposed several hundred more, and has estimated an eventual NPL of some 2,000 sites.

Responses to emergencies, such as transportation accidents, have been swift and effective in dealing with immediate threats. However, although responses at many sites have been limited, they usually consist of moving the waste to land disposal sites (which themselves may become Superfund candidates] or leaving the waste in the ground. Sites that pose threats only to the environment have received little attention. In a number of cases, even expensive "cleanups" quickly proved to be ineffective because hazardous substances continued to be released. The public has started to demand permanently effective cleanups; that is, cleanups which minimize the likelihood of future actions for the same sites or wastes. This usually means treatment of wastes and contaminated materials. But little progress has been made toward permanent cleanups, particularly for the expensive, difficult, new, and uncertain task of cleaning up contaminated groundwater. Moreover, detailed goals for permanent cleanups remain unclear, and without them it is difficult to select cost-effective cleanup technologies and evaluate their effectiveness, Finally, how much private parties and the States can or will contribute has not been settled. At first, it was generally thought that Superfund would deal only with the Nation's worst sites, especially those without identifiable responsible parties. Now, however, some believe that Superfund must move beyond this early limitation to address many more sites if national environmental protection goals are to be met expeditiously,

Congress faces a number of complex issues and policy trade-offs in its debate on the new Superfund program. Evidence on the number of sites and the extent of pollution is clearer, but much of the uncertainty about health and environmental effects remains unresolved. How should risk assessment techniques be used? Can cleanup goals be established more quickly? Moreover, a multibillion dollar pro-

[2] To qualify for remedial cleanup, a site must be placed on the NPL. EPA's Hazard Ranking System is used to obtain a numerical rating for sites; currently sites receiving a score of 28.5 or above qualify, plus each State may designate one priority site for inclusion. However, non-NPL sites may receive emergency attention and some limited, low-cost initial response.

gram raises questions about impacts on the Federal budget and the national economy, Experts disagree on how much money Superfund needs and have different opinions on how the money should be raised. Deciding how many sites need cleanup, how to clean them up, how much money to make available, and other policy judgments will determine how long the national cleanup program will last. A consensus has not yet emerged on many issues, including how long the public is willing to wait for permanent cleanup.

Lastly, performance of the Superfund program to date raises questions about institutional capabilities for an expanded program. How should Superfund operate, in terms of decisions regarding what sites get selected and acted upon, and in what order? Many people viewed the Superfund as lasting 5 or 10 years. Therefore, relatively little emphasis has been placed on work important for a long-term program, such as research, development, and demonstration of innovative, permanent cleanup technologies, and building up an adequate supply of technical personnel.

The principal goals of this study are: 1) to understand future Superfund needs and how permanent cleanups can be accomplished in a cost-effective manner for diverse types of sites, 2) to describe the interactions among the components of the complex Superfund system, and 3) to analyze the consequences of pursuing different strategies for implementing the program. A number of policy options are presented for congressional consideration.

THE KEY POLICY OPTION: CONSIDERING A NEW STRATEGY FOR THE SYSTEM

The initial Superfund program was viewed as temporary and was assembled quickly to deal with a technically complex and unique environmental threat defined in a preliminary way, Its strategy was oriented to taking limited responses at the *worst* sites, to addressing, for the most part, *immediate* threats to human health, and to gathering information on the extent of the national problem and its solution.

In identifying the following key policy option for congressional consideration, OTA recognizes that *as an initial Federal effort the Superfund program has been effective in limited ways*. To be considered now is the evolutionary development, restructuring, and improvement of the Superfund program. The opportunity is to move from a program that generally considered immediately threatening sites on a case-by-case basis to a comprehensive approach for effective control of all NPL sites, whether 2,000, 5,000, 10,000, or more. This reappraisal] of the program is possible because of the experiences, both positive and negative, with the initial program and because of recent data on the magnitude of the national uncontrolled site problem and information about the potential solutions, In order to devise a more cost-effective risk management strategy, it is useful to: 1) recognize how large the uncontrolled site problem is nationally, and 2] evaluate the long-term economic and environmental *performance* of the program rather than just the *numbers* of actions taken.

If OTA is correct in its assessment of future cleanup needs, then *it is technically and economically impossible to permanently clean up all uncontrolled waste sites in the near term*, But how can the Superfund program equitably address public demands for an effective, timely, national cleanup program when there are constraints involving budget, technology, and technical personnel? OTA has analyzed the long-term aspects of different strategies for implementing Superfund. This has been done by using a systems analysis of major interrelated variables of the program to examine how they affect certain outcomes such as program cost and duration.

The complexity of the Superfund system confronts policy makers with difficult decisions and trade-offs. For example, yielding to pressures to increase and speed cleanup actions, both by Superfund and private parties, can be counterproductive if such actions are impermanent and have a high probability of leading to substantial future costs. But perhaps the most difficult issue is the choice of either staying with the basic structure of the current program (on the assumption that it will improve substantially in response to lessons learned from early experiences), or restructuring the program to achieve greater environmental protection and cost effectiveness. OTA's analysis has found that if a new strategy is to be considered, the following two-part strategy appears advantageous.

A Superfund program that tackles a very large number of sites over several decades could be based on two parts that overlap to some degree in time, but differ in their focus and priorities.

Part I: In the near term, for perhaps up to 15 years, the strategy would focus on: a) early identification and assessment of potential NPL sites, b) initial responses to reduce near-term threats at all NPL sites and prevent sites from getting worse, c) permanent remedial cleanups for some especially threatening sites, and d) developing institutional capabilities for a long-term program.

A substantially larger Superfund program would be needed to carry out these efforts. Initial responses to accomplish the most cost-effective and significant reduction of risks and to prevent sites from getting worse might cost about $1 million for most sites. This is three times the current cost of immediate removal actions and about 10 percent of currently projected remedial cleanup costs. Case studies by OTA and others reveal that both immediate removals and remedial cleanups are ineffective for their intended purposes. Under the two-part strategy, initial responses would emphasize covering sites and temporarily storing wastes and contaminated materials to reduce groundwater contamination and, where technically and economically feasible, excavating wastes to minimize releases into the environment.

Part II: Over the longer term, the strategy would call for more extensive site studies and focus on permanent cleanups, when they are technically feasible, at all sites that pose significant threats to human health and the environment (unless privately or State-funded cleanups offering comparable protection have taken place). These cleanups would draw on the institution building that occurred during the first phase. Spending large sums before specific cleanup goals are set and before permanent cleanup technologies are available leads to a false sense of security, a potential for inconsistent cleanups nationwide, and makes little environmental or economic sense.

Under the current program, cleanups have tended to be both costly and impermanent, and thus likely to lead to substantial future spending for the same sites or wastes. However, in some cases the ad hoc nature of the current program has resulted in use of the two-part strategy, such as cases where large amounts of contaminated soil have been removed for temporary storage. Moreover, cleanups have not progressed rapidly, and many sites have received little attention, although the pace is picking up. For example, 30 percent of the current 538 NPL sites are receiving some form of cleanup attention.

Having few permanent cleanups in the first part of the two-part strategy makes sense for several basic reasons, and it does not represent a slowdown in cleanups which are as thorough and permanent as possible for critical sites. First, it is both technically and economically impossible to permanently clean up all sites—even for an NPL of 2,000 sites—in the near term, certainly not within 20 years. Cost-effective permanent cleanup technologies have not been developed for some problems, particularly for the extremely difficult (and possibly intransigent) problem of decontaminating entire aquifers. It will take time to demonstrate the effectiveness and costs for innovative technologies. There is also too little information on most sites to decide about permanent cleanup, particularly when there are no detailed national cleanup goals. Furthermore, there are not enough people with experience in this area to implement a large permanent cleanup effort.

In the two-part strategy, initial responses would not be designed for long-term effectiveness; they would probably be impermanent and, thus, in almost all cases permanent cleanups would have to follow. Their purpose is to quickly and *sharply* reduce exposure to hazardous substances at NPL sites without simply transferring the threat somewhere else. Initial responses can be thought of as a subset of the interim, impermanent approaches now being used and described as "cleanups. " The public, however, must be assured that initial responses can be environmentally effective both to deal with immediate risks and the critical need to stop sites from getting worse. When there are continuing releases of hazardous substances into the air, land, and water, the difficulty and costs of cleanup increase drastically. Both in terms of environmental protection and economics, the most important thing to do is to quickly reduce risk once a site has been found to present significant hazards. It is quite possible to know that a site poses significant risk even though it is not possible to know *precisely* what the risk is, how to eliminate it, or what constitutes an eventual safe level of permanent cleanup. For initial responses it is necessary to think not solely in terms of "cleanup," but also in terms of isolation, stabilization, and recontrol of the site.

Relatively low-cost initial responses could include pumping to contain plumes of contamination in aquifers, covers to keep out water, excavation of buried wastes or removal of wastes from surface impoundments for above ground *temporary* storage, and environmental monitoring. However, in contrast to current immediate removals and interim ''cleanups, ' wastes would not be moved to operating land disposal sites and reliance on the use of underground material barriers to prevent migration of wastes offsite would be limited to special conditions. Substantial long-term economic benefits would result from avoiding costly "cleanups" based on containment and land disposal, which, despite their high initial expense, also require major future spending.

In contrast to the present program's use of immediate removal actions, which do not necessarily include actual removal of materials from the site, the initial responses defined here place great emphasis on reducing present and future exposures to hazardous substances under the assumption that no further action may take place for some years. For example, if the site is exposed to water intrusion, partially draining or building berms around a surface impoundment containing liquid waste is unlikely to be effective because of the potential for repeated overflows. Nor will removing some surface waste and contaminated soil be effective at a landfill exposed to rain if other contaminants can reach groundwater. Waste removal and excavation, temporary storage, and surface capping can be more effective. As with the current program, there will be sites where it will be necessary to take actions such as supplying alternate water and relocating residents, rather than or in addition to tackling the site itself.

In examining the costs of a variety of technical actions, OTA finds that effective initial responses might average about $1 million for most sites; at some sites where there is extensive groundwater problems initial responses would cost substantially more. The current program spends an average of about $300,000 for immediate removals and estimates about $10 million for remedial cleanups, neither of which meets their intended purpose very well (i. e., sites often get worse, exposures may continue, and problems often persist). In other words, by spending more money initially it is possible to receive more benefits per unit cost. This is consistent with the fact that in addressing environmental problems, substantial benefits are generally achieved with the first response although more work may have to be done to reach the ultimate or permanent solution.

In the near term, say 5 years, the two-part strategy would result in a Superfund program substantially larger than the present one. The two-part strategy would lead to a different distribution and type of spending, not to decreased or level spending. While spending under the two-part strategy would be focused, in large part, on taking many initial responses, there would also be spending for expensive permanent cleanups at some high priority sites, and (as discussed in chapter 2) significant spending for several efforts aimed at strengthening institutional capabilities (e.g., expanding the information base for establishing cleanup goals, development and demonstration of innovative cleanup technologies, training programs for critical technical specialists, and increased funding for EPA and States to expand technical oversight). With the two-part strategy, much more money is spent on efforts to ensure that future spending on cleanups produces cost-effective results. If Superfund is a short-term program, such investments are not likely to be made. The current program has not addressed these kinds of investments.

Furthermore, if the current program were simply expanded, many expensive and time-consuming Remedial Investigation / Feasibility Studies ($800,000 is the average figure used by EPA) as well as a number of expensive but impermanent cleanups would need to be done. With the two-part strategy, more money is spent on initial responses and less money is spent on studies to select permanent cleanups and / or expensive cleanups (which are often done in stages).

To decide which sites should eventually receive permanent cleanups, we will need much more sophisticated methods than are now being used. For example, EPA's recent groundwater protection strategy uses a classification system for aquifers to set priorities. As discussed later, some sort of classification approach may be useful to establish cleanup goals and priorities in an objective, orderly fashion; these might include classification for restoration, rehabitation, and reuse of NPL sites. Without well-defined cleanup goals it is not possible to know if a permanent cleanup technology exists for every site that needs permanent cleanup, or even to know how to decide which sites need permanent cleanup.

Concluding that a much larger Superfund program is necessary is not the same as quickly implementing the program. Moreover, if the Superfund program is viewed as a short-term effort, then large sums of money will probably be spent ineffectively and future generations will pay repeatedly *for* cleaning up wastes *that should have been rendered harmless years earlier, or that should have been safely managed until they could, if possible, be treated.*

From a policy perspective, substantial costs and risks could result if the number of sites on the NPL is *underestimated.* Thus, another important objective of the strategy's initial period is to resolve uncertainties about future needs. This issue cannot be delayed without encountering high costs. Many festering sites may go unattended, spreading contamination and getting worse. Should impermanent "cleanups" continue at many sites, they and the sites receiving cleanup wastes could also get worse, eventually requiring more expensive work and large amounts of drinking water might become contaminated. The resulting "environmental deficit" could come due eventually and the Nation would face thousands of sites requiring cleanup; few cost-effective, permanent cleanup technologies; not enough technical specialists; little time to control sites to prevent great damage to public health and the environment; and costs so great that they might be impossible to meet. *In other words, a planning mistake now based on an underestimate of the national cleanup problem could result in an environmental crisis years or decades from now.* Therefore, this study emphasizes the importance of greatly reducing the uncertainty about future needs as soon as possible.

Policy Options: More specifically, Congress may wish to consider the following legislative options for CERCLA: 1) a policy statement on the long-term nature of the program, 2) a policy statement on the explicit strategy to be pursued so Congress can evaluate the program's performance, and 3) a redefinition of the types of responses to NPL sites and their intended purpose.

CLEANUP OF HOW MANY SITES, AND AT WHAT COSTS?

Most assessments have underestimated the number of uncontrolled sites that may require Superfund action. OTA's work indicates that 10,000 sites (only considering waste sites) is a more realistic figure for planning purposes than EPA's projection of about 2,000 sites. Even OTA's figure may prove conservative, but the main goal here is not determining the precise number of future NPL sites. Rather it is important to consider the confidence policy-makers can have in current estimates. OTA does not dispute the need to clean the sites already qualifying for placement on the NPL. But many sites not now listed on or considered for the NPL may also require cleanup.

At least 5,000 of the 621,000 operating and closed solid *waste* facilities may require cleanup (see table l-l). Hazardous substances often leak from these facilities and contaminate groundwater; at least 20 percent of current NPL sites were solid waste facilities. About 1,000 operating *hazardous waste* facilities may require cleanup, chiefly because of problems with RCRA groundwater protection standards that regulate about 2,000 of these land-based facilities (see table 1-2). Finally, OTA estimates that an improved site identification and selection process would add some 2,000 sites now listed in EPA's inventory of uncontrolled sites to the 2,000 projected by EPA for the NPL. Important changes include: recognizing environmental as well as human health threats, using national guidelines to evaluate sites, increasing emphasis on site identification, and removing the arbitrary cutoff score for placement on the NPL. These changes will qualify more sites that pose threats to public health or the environment for cleanup,

OTA's estimates are only semi-quantitative, but an effort has been made to be conservative, especially in view of the uncertainties of cleanup actions by States and responsible parties. Furthermore, there is no reason to conclude that the additional sites pose substantially smaller or more easily managed risks than EPA's 2,000. OTA's projection of an NPL with 10,000 sites is consistent with the results of a survey conducted by State officials which indicated a need to clean up about 8,000 sites.[4]

Table 1-1 .—Summary Data on Solid Waste Facilities

Percent of uncontrolled sites that are solid waste facilities:	
Of 1,389 sites with actual or presumed problems of releases of hazardous substances	180/0
Of *550* sites on National Priority List	20°/0
Two most prevalent effects at problem solid waste sites:	
Leachate migration, groundwater pollution: at 89°/0 of sites	
Drinking water contamination: at 49°/0 of sites	
Mean size of problem solid wastes sites	67.4 acres
Median hazard ranking score:[a]	
Solid waste sites on the NPL	40.8
All NPL sites	42.2
Estimates for national number of solid waste sites:	
Operating sanitary, municipal landfills	14,000
Closed sanitary, municipal landfills	42,000
Operating industrial landfills	75,000
Closed industrial landfills	150,000
Operating surface impoundments	170,000
Closed surface impoundments	170,000
Total	621,000
Estimate of need for future cleanup:	
Low: 5°/0 landfills, 1°/0 impoundments likely to release toxic substances	17,400
High: 10°/0 landfills, 2°/0 impoundments likely to release toxic substances	34,800
Conservative figure used for cleanup by Superfund	**5,000**

[a]28.5 required for placement on National Priorities List; current highest site score IS 756

SOURCE Office of Technology Assessment

[3]Solid waste facilities are governed by Subtitle D of the Resource Conservation and Recovery Act (RCRA) regulatory program, There are a number of sources of hazardous substances in these facilities, including some household wastes and industrial wastes not regulated as hazardous waste by RCRA or the States. Concerning the latter, a forthcoming report by the Congressional Budget Office estimates that in 1983 over 26 million metric tons of hazardous waste were disposed of in sanitary landfills nationwide. A study for EPA has found that hazardous wastes not so defined by RCRA are being disposed of in surface impoundments. (M. Ghassemmi, et al, "Assessment of Hazardous Waste Surface Impoundment Technology—Case Studies and Perspectives of Expert s," May 1984.)

[4]The survey, funded by EPA, was conducted of its members by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO). With responses from 44 of its members, a report issued in December 1983 presented the following

Table 1-2.—Summary of Problems With RCRA Groundwater Protection Standards Governing Operating Hazardous Waste Facilities[a]

- Interim Status Facilities: Groundwater protection standards for these facilities are less stringent than for new facilities, and most of them already are, or are likely to become leaking sites.
- **Fixing Leaks:** With confirmed groundwater contamination there are no requirements that a facility be closed until the leak is found and corrected, nor to even find or stop the leak.
- RCRA **Coverage Limited to 30 Years: New** facilities must be designed not to leak for 30 years after closure during which time the operator must maintain the facility, but later when leaks are more likely CERCLA becomes responsible.
- **Contaminants Which Are Regulated:** Because CERCLA regulates more substances than RCRA, and detection levels for other substances are set lower by CERCLA than by RCRA standards, a permitted but leaking RCRA facility can become an uncontrolled site under CERCLA.
- Tolerance Levels of Contaminants: Acceptable levels of groundwater contaminants are not based on health effects, and using detection limits of analytical techniques may not be protective of human health.
- **Geological** Standards: There are difficulties in predicting groundwater movement or the rapid movement of contamination in some geological environments which make early detection and correction uncertain at some sites. However, RCRA has no facility siting standards to restrict hazardous waste sites to geologically suitable locations.
- **Groundwater Monitoring:** Technical complexity and site specificity make it difficult for government rules to set the conditions for effective groundwater monitoring.
- **Monitoring in the Vadose Zone:** Although the technology exists, RCRA standards do not require monitoring in the land between the facility and underground water; hence, an opportunity to gain an early warning of leaks is lost.
- **Test for Statistical Significance:** Tests required by RCRA keep the probability of falsely detecting contamination low at the expense of high probability that contamination might go undetected.
- **Corrective Action Delays:** Complex RCRA procedures can lead to delays of several years, increase cleanup costs, and increase the chances of CERCLA financing of cleanup.
- **Compliance Monitoring and Corrective Action:** Technology does not necessarily exist to meet the RCRA standards for taking corrective action, nor in all cases for compliance monitoring, required after contamination is found.

[a]Because of these problems, OTA has estimated that 50 percent of these facilities may require cleanup by Superfund

SOURCE Office of Technology Assessment,

findings: "At least 7,113 sites nationwide require some form of remediation. These figures understate the extent of the nation's uncontrolled hazardous waste site problems because they do not take into account the states not responding to our questionnaire. Our members' judgments on the number of sites needing response were significantly greater than the number of sites now on the NPL. " When EPA used the survey for its CERCLA 301 (a)(l)(E) study on State participation given to Congress in December 1984, the following statement appeared: "The most important observation . . . is that states' estimate that over 7,000 sites require response (sic), although the scope of response for these sites is likely to be less than for sites listed on the National Priorities List. " The latter observation did not appear in the original report which also indicated that only about 10 percent of known sites had been scored to evaluate eligibility for placement on the NPL. The States' estimate of Superfund sites was not used by EPA in its CERCLA 301 (a)(l)(C) study on future Superfund needs also issued in December 1984. The usefulness of ASTSWMO data has been shown by the fact that the States were the basis for the 1983 estimate by OTA of hazardous waste generation in the United States of about 250 million metric tons annually, a figure over six times greater than the then current EPA estimate, The figure of about 250 million metric tons annually was later verified by EPA and will be substantiated shortly by the Congressional Budget Office.

The principal reasons why EPA's projection of a 2,000 site NPL differs so substantially from OTA's estimate of 10,000 are summarized in table 1-3. (Note that EPA considered several categories of sites that OTA ignored, such as mining waste sites and leaking underground storage tanks.) EPA has stated that a full examination of the problem of future sites could lead to a situation where the costs "would overwhelm" the Superfund program. But OTA's point is that by acknowledging the full extent of future needs, rather than underestimating them, effective planning could prevent a crisis.

For planning purposes, an NPL with 10,000 sites implies a need for a much larger Super-

Table 1.3.—Factors in EPA's Examination[a] of Potential NPL Sites That Lead to a Low Projection

Site category: Factor

Solid waste facilities:
- Surface impoundments are not included, even though all types now account for one-third of NPL sites, and they are recognized as a major problem in EPA's Groundwater Protection Strategy
- No accounting for closed industrial landfills
- The basis for saying that there are only twice as many closed municipal landfills as open ones is not given

Hazardous waste facilities:
- ***No*** accounting for the more stringent 1984 amendments to RCRA and effect on number of failures of companies
- No consideration of the sites created due to failure of EPA's RCRA groundwater protection standards as acknowledged in EPA's Interim Status Ground-Water Monitoring Implementation Study

Site selection process:
- Limited considerate ion of current site selection process and potential changes in it

[a]U.S Environmental Protection Agency, "Extent of the Hazardous Release problem and Future Funding Needs—CERCLA Section 301(a)(l)(C) Study, " December 19s4.

SOURCE: Office of Technology Assessment.

fund than previously contemplated, easily $100 billion or more over some decades. A better estimate of future Superfund needs could be made if more were known about the extent of environmental contamination. For example, it is unclear how many sites will require groundwater cleanup, which is the most costly type of cleanup. Nor is it yet clear how advanced technology might reduce the costs of permanently effective cleanups and provide solutions that do not now exist. For example, although it is sometimes possible to pump and treat contaminated groundwater at considerable cost and time, it is not clear that an aquifer, once contaminated, can be restored to a drinkable condition.[5]

[5]See U.S. Congress, Office of Technology Assessment, *Protecting the Nation Groundwater From Contamination,* OTA-0-233 (Washington, DC: U.S. Government Printing Office, October 1984).

In addition, it is difficult to estimate how much money will be recovered from responsible parties and will be spent by industry and the States for cleanups (for non-NPL sites and for their share for NPL sites). A number of States have not yet earmarked enough money to provide their expected share of cleanup costs. OTA has stressed estimating future national Superfund needs, without making specific assumptions about non-Federal spending on the problem. Other estimates of future Superfund needs often make explicit assumptions (leading to "adjusted costs" for Superfund) even though they are highly speculative. Table 1-4 is a brief summary of several recent estimates of future national unadjusted cleanup costs and program lengths.

COSTS AND STRATEGIES

OTA has considered the implication of two primary strategies (see chapter 3) on the costs and duration of a program that must deal with about 10,000 sites. The variable used by OTA in its modeling of these strategies called the "impermanence factor" describes in an average, statistical sense the extent to which interim actions result in unforeseen future costs. It is an attempt to examine the consequences of currently employing cleanup technologies that are less than totally effective in the long term. The impermanence factor can be interpreted in several ways, and the particular interpretation does not affect the results of this simple model. One simple way to think of the impermanence factor is that it is the ratio, averaged over all sites, of the costs of successive interim actions at the same site or on the same wastes. That is, for example, for an impermanence factor of 0.5, 100 first interim actions will result at some time in 100 second actions at one-half the cost, which in turn result in 100 third actions at one-quarter the cost of the first action, and so on. Other more complicated interpretations of the impermanence factor are possible; these incorporate continuous operating and maintenance costs in addition to the probability and/or cost of discrete repeated actions.

Increasing impermanence factors signify increasing environmental risks and damages, High impermanence factors indicate the use of cleanups that are on average ineffective and lead to future spending. Later in this chapter, when the results of several case studies are given, it is seen that an impermanence factor greater than 1 for a specific site is possible. Experience to date with cleanups indicates that rather high impermanence factors are likely with the widespread use of containment and land disposal for cleanups because these methods are known not to be permanently effective.[6] Continuing operating and maintenance costs can also account for a high impermanence factor.

[6]See U.S. Congress, Office of Technology Assessment, *Technologies and Management Strategies for Hazardous Waste Control,* OTA-M-196 (Washington, DC: U.S. Government Printing Office, March 1983).

Table 1-4.—Current Estimates for Cleaning Up Uncontrolled Hazardous Waste Sites

	EPA (1 984)[1]	EPA (1983)[2]	GAO[3]	Department of Commerce[4]	ASTSWMO[5]	CMA[6]	National Audubon Society[7]
Total costs (unadjusted) billion)	$10.0 -33.3	$10.3-20.6	**$5.6-33.8**	**$10.5**	**$14.6-42.7**	NA	$29-92
Number of sites requiring cleanup	1,500-2,200	1,400-2,200 23-56°/0 require groundwater cleanup	1,270-2,546 23-56°/0 require groundwater cleanup	546 NPL 1250 non-NPL 41 municipal	7,113 (43 States surveyed); 1,500 most serious sites	1,000 (27 States surveyed) 3,681 (potential)	2,200-7,000 56°/0 require groundwater cleanup
Projected years to clean sites.	NA	14 for 1,800 sites	NA	10-15	16-23 if constrained by personnel; 28-90 if constrained financially	NA	26-84

SOURCES
(1) U S Environmental Protectlon Agency, "Extent of Hazardous Release Problem and Future Funding Needs, " CERCLA Sectlon 301(a)(l)(C) Study, " December 1984
(2) U.S Environmental Protection Agency, Superfund Task Force Preliminary Assessment, December 1983.
(3) U.S General Accounting Office, *EPA "s Preliminary Estimates of Future* Hazardous Waste *Cleanup Are Uncertain*, GAO/RCED-84-152, May 7, 1964.
(4) U.S Department of Commerce, "Estimated Costs and Expenditures for Cleanup of the Nation's Uncontrolled Hazardous Sites" (draft), Feb 22, 19334
(5) Association of State and Territorial Solid Waste Management Officials, "State Cleanup Programs for Hazardous Substance Sites and Spills, " Dec. 21, 1963
(6) Arthur D Little, Inc , Report to the Chemical Manufacturers' Association, "An Analysis of the Number of Inactive Hazardous Sites That Will Use Superfund,'' July 1963.
(7) National Audubon Society, Testimony of Leslie Dach Before the House Subcommittee on Commerce, Transportation, and Tourism, Mar. 1, 1964

Two strategies are modeled: an interim strategy (which simulates the approach of the current EPA program) and a two-part strategy. Both strategies are described and compared in table 1-5 and figures 1-1 and 1-2. The impermanence factor is used in interim strategy; but for the two-part strategy, it is simply assumed that 90 percent of the initial cleanups will have to be followed by a permanent cleanup during the second part of the program. The total adjusted cost and duration of the program depends on a number of assumptions, such as the average cost of site cleanup; the important assumptions are summarized in the table. The program duration and costs shown in table 1-5 and figure 1-1 do not represent what will happen in the future, but only what might happen under certain conditions and policy decisions. If a program duration of more than about 50 years is unacceptable, then under most conditions (i.e., levels of "impermanence" as discussed above) a two-part strategy offers both cost and time advantages over an interim strategy. The results are similar for the other computer-simulated scenarios described chapter 3, including those with a smaller NPL.

Table *1-5.*— Illustrative Scenarios for Two Different Cleanup Strategies

Scenario 1: Interim Strategy	Scenario II: Two-Part Strategy
Brief description:	
Cleanups result in repeated future costs.	Initial response (at most one per site) over first 15 years (Part l). After 15 years, for 90 percent of sites, permanent cleanups, with no future costs (Part II}.
System assumptions: • In Scenario 1, future costs depend on the impermanence factor and the average interim cleanup cost, In Scenario II, future costs of initial actions depend on the cost of permanent cleanup, which is taken at 900/0 of sites, • Total number of sites requiring cleanups = 10,546[a] • 20°/0 of sites require groundwater (gw) cleanup. • Initial period (5 yr) budget = $5 billion; growth @ 100% for each of next three periods then @ 20°/0 each successive period. [b]	
Scenario assumptions:	
Average interim cleanup costs: $6M per site $12M per site, with gw cleanup	Average initial response costs: $1M per site $3M per site, with gw cleanup Average permanent cleanup costs: $24M per site $60M per site, with gw cleanup
• Breakeven program cost at $313 billion, breakeven program length is 45 years. • On the basis of program cost alone; the interim strategy is chosen if its average impermanence factor is less than 0.73, • On the basis of program length alone, the interim strategy is chosen if its average impermanence factor is less than 0.25, • Overall, when the average impermanence factor is less than 0,25, the Interim Strategy is preferred; when it is greater than 0.73, the two-part strategy is preferred; for values in between, reduced program length can be obtained with the two-part strategy at a cost above that the interim strategy.	

[a] Initially 546 sites; 200 new sites per year for years 1-5: 800 new Sites Per year for years 6.10 and 1,000 new sites per year for years 11-15

[b] Budgets and total costs reflect total spending by all parties, not lust by the Superfund program

[c] Time to initiate 9000 of work Times are given for future costs incurred over 30 years

SOURCE Office of Technology Assessment

However, to the extent that the interim strategy modeled by OTA approximates the current program, there are conditions under which the current program could be viewed in a positive manner. Much depends on the values for the average impermanence factor for the remedial cleanup technologies now being used. As discussed above, there are several reasons why OTA believes that the average impermanence factor is likely to be high, at least 0.5 to 0.7. If this is the case, then a two-part strategy offers time and probably cost advantages over the current program (i.e., the interim strategy). If the average impermanence factor were to be low, say about 0.1 or 0,2 (i.e., remedial cleanups which had a low probability of leading to unforeseen future costs), then a decision to continue with the current program would not lead to undesirable consequences. Adoption of a two-part strategy would still be a valid option to consider because of the opportunities it affords for institution building, for quickly addressing most sites through initial responses, and because the medium-cost, low impermanence actions of the interim strategy could then be appropriate for part two. If, however, the current program continued and it became clear that the average impermanence factor was high, then much money and time could be wasted. The *conclusion of OTA's*

Figure 1-1 .—Program Length v. Impermanence Factor (Scenario 1USG)

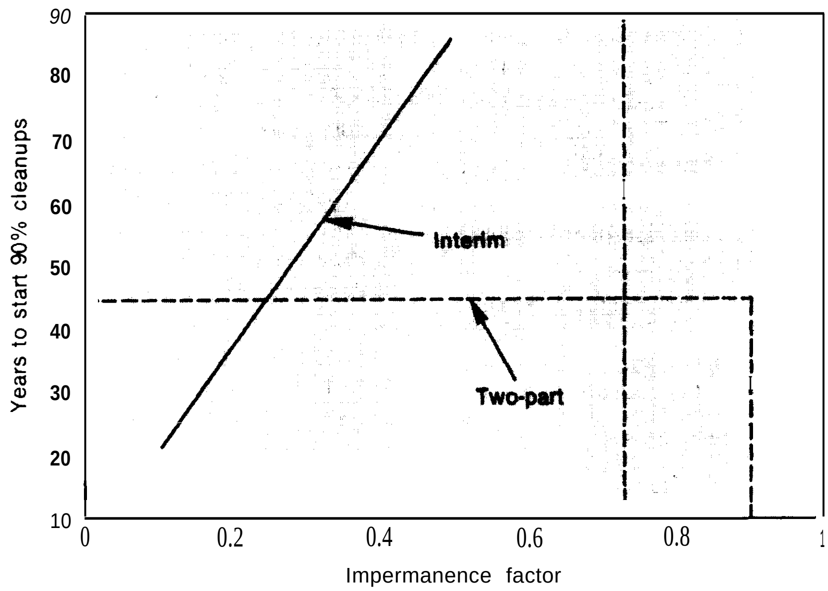
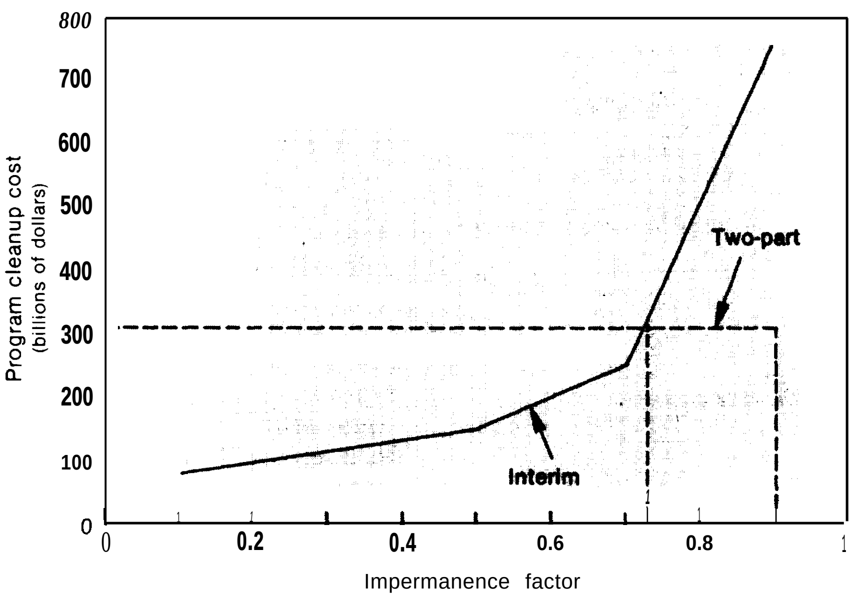


Figure l-2.—Program Cost v. Impermanence Factor (Scenario 1USG)*



"See also table 1-5 and "Costs and Strategies" section One simple way to think of the Impermanence factor is that it is the ratio, averaged over all sites, of the costs of successive interim actions at the same site or on the same wastes *analysis is that, in the face of important uncertainties, the two-part strategy is less risky and more "fail-safe" in the sense that proceeding with it is less likely to result in ineffective spending.*

policy Options: Congress may wish to consider including in CERCLA a statement on what strategy the program is to pursue. More specifically, Congress may wish to consider directing EPA to: 1) examine the potential cleanup problems of RCRA Subtitle D solid waste facilities and to strengthen and hasten the development of Federal regulations for: a) the monitoring of a broad range of hazardous substances at both open and closed sites, and b) the future operation of open and new solid waste sites; 2) reexamine its RCRA Subtitle C regulatory program for hazardous waste land disposal facilities, particularly the groundwater protection standards, from the perspective of minimizing the creation of future uncontrolled sites; and 3) redesign its system of identifying, assessing, and ranking sites for the NPL to reduce the likelihood of excluding sites that merit cleanup. Congress may also wish to reexamine the policy requiring matching funds from States, particularly the 50 percent match for State and municipally owned and operated facilities. Already, the 10 percent State matching requirement for private sites presents an obstacle to cleaning up some sites. The unwillingness, but not necessarily the inability, of many States to provide their matching requirement might slow the national cleanup as much as or more than almost any factor.

RESOLVING THE "HOW CLEAN IS CLEAN?" ISSUE

Identifying and quantifying risks to health and the environment for the extremely broad range of conditions, chemicals, and threats at uncontrolled hazardous waste sites pose formidable problems, Risk management will have to proceed even though there is no quick way to determine the precise levels of cleanup. For example, quantitative risk *assessments* cannot be performed for most cases, except at considerable cost and time, as the necessary technical data do not now exist.

The paucity of documented, unambiguous findings of adverse health and environmental effects caused by uncontrolled sites does not mean that such effects have not occurred or will not occur. Nor is it inconsistent to say that enough information exists to know that a site presents significant risk to warrant action, but not enough to know *precisely* what the level of cleanup should be. Much better understanding is needed of adverse health effects from uncontrolled sites, and the work required by Congress is proceeding slowly. However, society must understand that multiple exposures to toxic chemicals at home, in the workplace, and in the general environment make it difficult to attribute causality to any one source of exposure,

A detailed framework for determining and achieving cleanup goals that are nationally consistent in themselves or in the *process* used to reach them, effective in protecting human health and the environment, and appropriate for site-specific conditions does not yet exist. While there are a number of approaches to establishing cleanup goals, none are simple or easily administered. OTA has examined the current ad hoc, highly flexible, and nonspecific approach and six others. It finds that the current approach is not satisfactory and that more explicit attention is warranted for this issue at the highest policy levels. *Without clear and well-supported cleanup goals the selection of cleanup technologies and the ultimate evaluation of cleanup performance will remain contentious.*

Two approaches to establish cleanup levels are not practicable technically or *economically;* they are: 1) requiring sites to be restored to pristine or background levels, and 2) using best available technology. A third approach, the use of existing environmental standards or criteria for particular chemicals, will cover only a small fraction of the broad range of the health threats at uncontrolled sites and does not address all environmental problems. However, this approach can be used to some extent. Two other approaches, risk assessments and cost-benefit analyses, present many difficulties and uncertainties but also offer ways to establish cleanup levels.

One approach has been found to offer a policy framework for moving more forcefully toward clear cleanup goals: it is to use information and decisions about restoration, rehabitability, and reuse of the site to establish cleanup levels. In particular, it appears worthwhile to examine in more detail how classifying sites according to their future use and other site conditions can be used to select the process to set cleanup levels, as well as determine how the site is managed more generally. For example, the use of costly risk assessments could be limited to high-priority sites where reuse and rehabitation is certain. Cost-benefit analyses could be used for sites where future use may be limited or where risk management options other than site cleanup (e.g., relocation of residents) is practicable. For some sites where exposures are small and reuse not an issue, use of existing standards may be sufficient. Since this approach relates to land use, it is clear that local communities would have to be involved in decisions.

It is also necessary to address the extent of action needed in initial responses. Generic standards that consider both immediate reduction of exposures to hazardous substances and the prevention of further deterioration while the site is awaiting remedial cleanup would be useful.

Policy Options: For risk management purposes, Congress could consider a Superfund policy that: 1) first establishes environmentally effective cleanup goals for a site, then 2) determines the cost-effective site response, and lastly 3) implements the fund-balancing provision of the statute by considering how a site cleanup or risk management decision affects actions taken at other sites. Congress may also wish to consider two more specific options: 1) having EPA develop an implementation plan that establishes cleanup levels on the basis of a classification of sites according to their future use and other site conditions, and 2) designating a well-funded, high-priority interagency program (e.g., EPA, Department of Health and Human Services, Department of the Interior) whose purpose is to more expeditiously and comprehensively deal with the problem of obtaining more complete information on the health and environmental effects of toxic wastes.

DO WE HAVE AND USE EFFECTIVE CLEANUP TECHNOLOGIES?

The problems with using containment and land disposal approaches to cleanup have already been discussed. These technologies are not likely to be effective over the many decades corresponding to the lifetimes of some toxic chemicals of concern. Even though they may be proven technologies for their original applications in construction engineering, they are not proven for long-term effectiveness in containing hazardous wastes. Nor are their immediate costs indicative of the likely total long-term costs, including monitoring, operation and maintenance, and the costs of future cleanup actions, especially for cleaning up contaminated groundwater. Table 1-6 projects future uses of conventional containment technologies. Table 1-7 gives similar projections for conventional treatment technologies; these existing technologies that can permanently clean up sites are underused. These projections are

Table I-6.—Future Use of Containment Technologies

Technique	Applicability	Effectiveness	Confidence	Capital cost	Cap/O&M	Projected level of use
Barriers:						
Slurry wall	**2**	1	**2**	**2**	1	**Extensive**
Grout curtain	**2-3**	1	**2**	**2-3**	1	**Limited**
Vibrating beam	**2**	1	**2-3**	**2-3**	1	**Moderate**
Sheet pile	3	1-2	2	2-3	1	Nil-Limited
Block displacement	3	1	4	3	1	Nil
Hydraulic controls (wells)	2	1,3	1	1	3	Extensive
Subsurface drains	2	1	2	1	2	Moderate
Runon/runoff controls	1	3	1	1	2	Extensive
Surface seals and caps	1	2,3	2	1	1	Extensive
Solidification, etc.	2	1,3	3-4	2	1	Moderate-Limited

KEY'
Applicability:
1 = Very broadly applicable, little or no site dependency
2 = Broadly applicable; some sites unfavorable
3 = Limited to sites of specific characteristics
Effectiveness
1 = Can produce "leak-tight" containment
2 = Can reduce migration—some leakage likely
3 = Used as supporting technique in conjunction with other elements
Confidence
1 = Well *proven—long-term effectiveness—high*
2 = Well proven—long-term effectiveness—unknown
3 = Limited experience, used in other applications
4 = Developmental; little data
Capital cost for function provided:
1 = Low
2 = Normal
3 = High
Capita/ to *operation and maintenance (O&M) cost* ratio:
1 = Capital higher than O&M
2 = Capital about same as O&M
3 = Capital lower than O&M

SOURCE A D Little, "Evaluation of Available Cleanup Technologies for Uncontrolled Sites, " contractor report prepared for the Office of Technology Assessment, Nov. 15 1984

Table 1-7.—Future Use of Treatment Technologies

Technique	Applicability	Effectiveness	Confidence	Capital cost	Cap/O&M	Secondary disposal	Projected level use of
Biological treatment	Or, 1-2	2	1	1	1-2	3	Moderate
Chemical treatment:							
Neutral ization/precipitation	In, 1	1	1	1	2	4	Moderate-Extensive
Wet air oxidation	Or, 2	2	2	3	1-2	1	Limited
Chlorination	In, 3	1	2	2	2	1	Limited
Ozonation	Or, 3	2	3	3	2-3	2	Nil
Reduction (Cr)	In, 3	1	2	2	2	3	Limited
Physical treatment:							
Carbon adsorption	Or, In, 1	1	1	2	2-3	2-3	Moderate-Extensive
Sedimentation/filtration	Or, In, 1	1	1	1	2-3	4	Moderate-Extensive
Stripping	Or, 2	1	1	1	2	4	Moderate
Flotation	Or, 2	2	1	1	1	4	Limited
Ion exchange	In, 3	1-3	3	3	3	4	Nil
Reverse osmosis	Or, In, 3	1-2	3	3	3	4	Nil
Gas stream controls:							
Thermal oxidation	Or, 1	1	1	3	3	1	Limited-Moderate
Carbon adsorption	Or, 1	1	1	3	2-3	2-3	Limited-Moderate
Incineration							
Onsite	Or, 1	1	2	3	1	3[a]	Limited
Off site	Or, 1	1	1	3	NA	3[a]	Moderate
In situ biodegradation	Or. 3	2	3	2	3	1	Limited

NOTES:
a Must dispose solid residues
b Depends on reactive material used.
KEY
Applicability
Class.
Or = Organic compounds
In = Inorganic compounds
Range
1 = Broadly applicable to compounds in in. dicated class
2 = Moderated applicable" depends on waste composition concentration
3 = Limited to special situations
Effectiveness
1 = Highest levels available
2 = Output may need further treatment; may have pockets untreated (in-situ)
Confidence"
1 = Well proven—easily transferable to site cleanup
2 = Well proven—but not in clean-up settings
3 = Limited experience
4 = Developmental; little data
Capita/ cost *for function provided*
1 = Low
2 = Normal
3 = High
Capital to *operations and maintenance (O&M) cost basis*
1 = Capital higher than O&M
2 = Capital about the same
3 = Capital lower than O&M
Secondary treatment or disposal
1 = None
2 = Minor
3 = Major, but does not require hazardous waste techniques.
4 = Basically a separation process; must be used with subsequent hazardous waste treatment or secure disposal step.

SOURCE A D Little, "Evaluation of Available Cleanup Technologies for Uncontrolled Sites, " contractor report prepared for the Office of Technology Assessment, Nov. 15, 1984 based on OTA's evaluation of how these technologies meet the goals of permanently effective cleanups.

Not enough research, development, and demonstration (RD&D) is devoted to innovative cleanup technologies. Many innovations exist, but few have overcome institutional barriers to their use. A major barrier is the lack of clear criteria developed by EPA for judging their effectiveness for certain types of cleanups. Cleanup technologies should be judged effective according to their ability to destroy, detoxify, or immobilize hazardous wastes and to decontaminate soil and groundwater (although it may not be possible to clean or restore an entire aquifer or even a portion of an aquifer). Summary data on some innovative cleanup technologies are given in table 1-8.

The long-term environmental and economic benefits of permanent cleanups have not been assessed properly or considered when cleanup technologies are being chosen. Considering the large cost of the Superfund program, spending more RD&D money on innovative cleanup technologies could offer considerable economic advantages in the long term. To date, EPA has not made a major commitment to assist the development of innovative technologies. For the first 5 years of Superfund, EPA will have spent no more than about $25 million on cleanup technology RD&D.

Policy Options: Congress may wish to consider establishing a program to fund RD&D of innovative cleanup technologies that offer promise for effective permanent cleanups at lower total costs for a range of uncontrolled site problems. Funding of perhaps $25 million to $50 million annually for some years could lead to substantial economic and environmental benefits when applied to a multibillion dollar program over a number of decades. Removing institutional barriers to the demonstration and use of innovative technologies also can be examined. Such actions could include directing EPA to: 1) reduce the time and cost of obtaining RCRA permits for waste treatment facilities, 2) establish protocols to evaluate new cleanup technologies, 3) make it easier to obtain samples of waste and contaminated materials from uncontrolled sites and transport them to test facilities, 4) streamline the RCRA procedure for delisting harmless residues of waste treatment operations (residues are now *presumed* to be hazardous wastes), and 5) continue to remove the bias in favor of land disposal over waste treatment options in Superfund cleanups, particularly by establishing a procedure for performing cost-effectiveness analyses that more accurately reflect the full, long-term costs of impermanent technologies. There is a particular need to address the problems facing small businesses (e.g., inability to afford demonstration) attempting to enter the cleanup market with new technologies.

ARE SUPERFUND EFFORTS RESULTING IN QUALITY WORK?

In case studies of Superfund cleanups by OTA and others there is evidence of significant problems in the quality of technical work. Federal oversight of contractor work, State efforts, and private cleanups is not adequate. Lack of coordination, redundancy of efforts, delays, and high costs also result from the use of many contractors, sometimes selected more because of cost than technical competence, and from the involvement of a number of Federal and State agencies at each site.

Moreover, a shortage of *experienced* technical experts in several fields may explain a lack of quality performance now and it may cause a major bottleneck in an expanded Superfund program. OTA estimates the demand for technical professionals (primarily, bachelors level) to work on cleanups of uncontrolled sites may rise from the present 3,750 to about 21,000 by 1995 and then stabilize at that level. This projection assumes an increased national cleanup effort of about $4 billion annually from all

Table 1-8.—Summary Data on Some Innovative Cleanup Technologies

	Technology	Development stage	Removal/ destruction capability	Estimated relative costs: Capital	Estimated relative costs: Treatment	System applicability[a]: In situ	System applicability[a]: On-site	System applicability[a]: Off-site	Mobile (M) Transportable (T) Permanent (P)	Primary waste applicability: Class[b]	Primary waste applicability: Form[c]
Gard	Dehalogenation	pilot	medium	low	low	N	Y	Y	M,T	O,I	L,SL
Zerpol	Chemical reaction	pilot	?	?	?	N	Y	N	T	I	GW,L
Bend Research	Coupled transport	pilot	medium	low	low	N	Y	P	M,T	I	GW,L
DeVoe-Holbein	Metal extraction	pilot	medium	low	low	N	Y	N	M,T	I	GW,L
MODAR	Supercritical water	pilot	high	medium	medium-high	N	Y	Y	P,T	O	GW,L
Zimpro	Wet air oxidation	full	low-medium	medium	low	N	P	Y	P,T	O	GW,L
Methods Eng.	Submerged reactor	pilot	?	medium	low	N	P	Y	P	O	GW,L
IT Corp.	Wet oxidization	bench	low-medium	?	medium-high	N	P	Y	P	O	L
Huber .	Adv. elec. reactor	pilot	high	high	medium-high	N	Y	Y	T	O	S,L
Thagard	Fluid wall reactor	pilot	high	?	?	N	Y	Y	T	O	S,SL
Pyrolysis	Plasma arc	pilot	high	medium	high	N	Y	N	M,T	O	L
Westinghouse .	Plasma arc	pilot	high	high	high	N	Y	N	M,T	O	L
Lockheed	Microwave plasma	bench	medium-high	?	?	N	P	Y	P	O	L
RoTech	Rotary kiln	pilot	high	medium	low-medium	N	Y	Y	M,T	O	S,SL,L,S
Midland-Ross	Rotary pyrolytic	full	?	high	medium	N	P[d]	Y	P,T	O	SL,L
Waste-Tech . . .	Fluidized bed incin.	pilot	medium	medium	?	N	P[d]	Y	P	O	SL,L,S
G.A. Tech. . . .	Circulating bed	pilot	medium-high	medium	?	N	Y	Y	M,T	O	S,SL,L
Rockwell	Molten salt	pilot	high	medium	high	N	N	Y	P	O	L,SL
Sandpiper	Segas process	pilot	?	medium	medium	N	Y	Y	T,P	O	L
Detox	Biotechnology	pilot	medium	?	low	Y	Y	N	T	O	GW,S,SL,L
GDS	Bio. degradation	full	medium	low	low	P	Y	N	T	O	GW,L
SBR	Batch reactor	pilot	medium	?	?	N	Y	Y	P,T	O	GW,L
Univ. Gottingen	Bio. degradation	research	high	?	?	P	P	P	T	O	SL,L
Battelle Pacific	Vitrification	pilot	na	?	low	Y	P	N	T	O	S,SL
Lopat/K-20 . . .	Chemical treatment	pilot/full	high	low	low	Y	Y	Y	T	O,I	S,SL,L
NMT/Fujibeton	Chemical treatment	pilot/full	high	low	low	Y	Y	Y	T	O,I	S,SL,L

NOTES: ? = data not available; na = not applicable
[a]Yes—Y, No—N, P—Perhaps, with further testing. Pretreatment may be required
[b]Class
O = organics I = inorganics

[c]Form
GW = groundwater (dilute aqueous); S = soils/solids (low concentration);
L = liquids (concentrated); SL = sludges/solids (concentrated)
[d]For large sites; i.e., high volume of waste to be treated.

SOURCE: Office of Technology Assessment.

sources. Current educational programs may not be able to prepare sufficient numbers of some professionals, particularly hydrogeologists, and perhaps toxicologists, geologists, civil engineers, and some types of chemists. But a more critical problem is that the already strong demand for people with a masters degree and 3 to 5 years of experience may increase and not be met for the next decade.

Policy Options: If the Superfund program is to be a long-term one, the Congress may wish to consider: 1) funding various expanded training and educational programs, perhaps $5 million to $10 million annually for some years; 2) providing funding for EPA to build up its in-house professional staff in disciplines appropriate for cleanup work and oversight, perhaps increased funds of $25 million to $50 million annually; 3) making direct grants to the States for their staff development, perhaps $25 million to $50 million annually for some years; and 4) directing EPA to reexamine: a) how it selects and uses contractors, particularly with respect to its emphasis on the cost of proposals rather than technical qualifications; and b) how it involves government agencies at Superfund sites.

IS PUBLIC INVOLVEMENT ADEQUATE?

More emphasis is needed to address the legitimate concerns of the public, improve public confidence in the Superfund program, and promote effective public participation in site identification, site assessment, initial responses, cleanups, and long-term monitoring. EPA has concentrated on providing information *to* the public rather than involving the public in decisionmaking. An expanded public role in the Superfund program might reduce delays by dealing with community concerns before substantial actions are taken and by providing useful oversight of activities. Public participation, if given Federal support for obtaining technical assistance, could lead to more effective cleanups for all communities, not just for those who happen to be better organized or fortunate enough to have citizens with political or technical expertise. Concerns about delays caused by more public participation could be addressed by using established methods of arbitration and mediation, for example. Public education is also critical.

policy Options: Congress may wish to consider incorporating in CERCLA a mandate, similar to that in other environmental statutes, for public involvement in decisions that determine which sites are placed on the NPL and the type of cleanups or other actions to be used at Superfund sites. Providing Federal support to aid communities in obtaining technical assistance is also worth consideration.

FINANCING MECHANISMS

Many of the results of this study suggest the need for a considerably larger Superfund program than the present one. A larger Superfund program would need to consider broadly based funding and more extensive use of general tax revenues in contrast to the current emphasis on the tax on chemical and petroleum feedstocks. While this study did not assess the financing question in depth, it did examine the use of a tax on hazardous wastes currently generated (generally referred to as a waste-end tax) to help finance a Superfund program for the near term.

A summary of the three principal sources of funds—feedstock tax, waste-end tax, and general tax revenues—is given in table 1-9. These three sources could generate considerable sums annually. If Superfund is expanded greatly it may prove necessary to rely much more on general tax revenues or some other broadly based tax, as there are limits–perhaps $1 billion to $2 billion annually–to the amount that could be raised with feedstock and waste-end taxes. It should also be noted that this study has examined uncontrolled hazardous waste site cleanups only. Should other major uses of Superfund be mandated by Congress, such as a victim compensation program, long-term Superfund requirements could be far greater than $100 billion.

A waste-end tax could provide funding to complement other sources, but of equal or greater importance, it should be designed to slow the creation of still more uncontrolled waste sites. The tax could be large enough to provide an economic incentive for generators to reduce the amount and degree of hazard of their wastes and to shift management of waste away from land disposal, the chief cause of Superfund sites. Indeed, the greater the future cleanup needs facing the Superfund program, the greater is the need to stop creating still more uncontrolled sites and to stop adding to the mass of hazardous wastes at existing sites. OTA and others have found that 20 States are using waste-end tax systems effectively and without major problems, A Federal waste-end tax could be made simple to administer and could generate from $300 million to $1 billion annually over the next several years, before waste reduction efforts reduce the tax base substantially. It would not be necessary or productive to displace State waste-end taxes, however; a deduction for waste-end taxes paid to States is possible.

Table 1-9.—Summary Comparison of Several Major Financing Schemes

Feedstock tax[a]		Waste-end tax[b]		
Current	Expanded	Low	High	General tax revenues[c]
Fairness:				
Very few companies pay most of the taxes	Improved	Good, many parties pay	Improved if land disposal gets high tax	Parties most directly responsible for problems do not bear burden
Administrability:				
Easy, established	Probably easy	Probably easy on basis of States' experience	Possibly more enforcement necessary	Very easy
Secondary impacts:				
None apparent	Might reduce international competitiveness of some companies	None likely	Provides economic incentive to reduce wastes and shift away from land disposal, thus capacity to raise basic revenue declines	With large amount may have undesirable effect on Federal budget

[a]Based on taxes imposed on chemical and petroleum feedstocks which can be expanded by increasing tax rates and number of materials taxed
[b]Based on taxes on hazardous wastes generated or managed, and may vary according to how wastes are managed and what hazards wastes pose, If the rates are high enough current management decisions may be affected *Low* less than about $10 per dry ton, *high* about $30 to $50 per dry ton
[c]currently a small fraction (12 5 percent) from this source, but much larger amounts could be raised

SOURCE Office of Technology Assessment

CLEANUPS BY RESPONSIBLE PARTIES

To a substantial extent, future Superfund spending depends on how many sites are cleaned up by responsible parties. Although considerable sums have been spent by private parties, the original users and operators of uncontrolled sites are worried that the current program does not facilitate private responses. The most frequently heard concern is that after private cleanup many uncertainties about future liabilities remain. Both in government and the private sector there is interest in providing greater incentives for cleanups by responsible parties. Although various approaches can be considered, including reducing future liabilities, sharing costs, and aiding attempts to use innovative cleanup technologies, sensitivity is needed to two problems addressed in this study. Explicit, environmentally effective cleanup goals are needed whoever does cleanup, and public awareness and effective technical oversight by the Government are important for private cleanups.

OTA is aware that there now exists what might be called a "quiet market" for cleanups. Responsible parties are cleaning up sites, usually on their property, before the sites enter the Superfund system and before public awareness is awakened. Although these cleanups may be done well, there are no *assurances* that these actions (which will often make detection of the sites difficult) are environmentally sound. Interestingly, one positive aspect of this situation is that some new cleanup technologies are being given a chance to prove themselves under field conditions. However, it is not clear that information about positive and negative results is being disseminated.

THE ROLE OF THE STATES

Congress has always envisioned the Superfund program to be a joint Federal-State effort. States could clean up some uncontrolled sites on their own (this has occurred to a limited extent), and States are required by statute to pay for some of the costs undertaken under Superfund. However, there is evidence that a number of States are unwilling to meet their share of cleanup costs, T At the beginning of the Superfund program, States may have faced financial constraints; however, this does not now appear in general to be the case. The effect is that some cleanups have not and will not take place because *some* States are not providing and may not provide future required matching funds, However, it must also be stressed that several States, usually those with many uncontrolled sites, have established means to raise substantial sums for cleanups and do have extensive State programs (e. g., New York, California, New Jersey, and Illinois).

Under Superfund, States are required to pay 10 percent of capital costs (50 percent for publicly owned and operated sites) but all future operating and maintenance (O&M) costs. The selection of the cleanup approach used at sites has been influenced by the availability of State funds. The result is a bias on the part of States for high "up-front" costs, usually meaning more expensive and permanent remedies. But this understandable State preference is counter to EPA's general preference for the use of containment and land disposal, which usually have uncertain and high O&M costs.

[7]For example, a recent study of State efforts to clean up uncontrolled waste sites reached the following conclusions: "States appear less willing to shoulder the financial burden associated with hazardous waste correction actions . . . While state legislatures respond to the hazardous waste problem with policy statements, the allocation of state dollars does not necessarily follow . . . The availability of federal dollars strengthens the [needed response] linkage, the influence of hazardous waste-related industry in state politics depresses it. " (A. O'M. Bowman, "Explaining State Response to the Hazardous Waste Problem," *Hazardous Waste,* vol. 1, No. 3, 1984, pp. 301-308.)

OTA finds little reason to believe that most States could play a stronger role in the Superfund program, particularly if it were to be greatly expanded, However, a small number of States with many NPL sites could do so. On the other hand, questions can be raised as to why some States have not confronted their own current and future needs in cleaning up sites. The slowness of some States to devise ways to raise funds for cleanups may be explained by many factors, including: State priorities that do not give a high rank to this environmental problem; a "wait-and-see" attitude concerning the matching share requirements of Superfund; local obstacles to raising revenues for this purpose; and a perception of an uncertain and still ineffective Federal program.

Another problem is that many States lack technical know-how and people to assume major responsibilities for leading cleanups, or to carry out other aspects of the Superfund program such as site identification, selection, and long-term monitoring. For the most part, States have difficulties obtaining experienced technical professionals, Even with current spending, the demand for such professionals is so great that most States cannot offer competitive salaries.

Policy Options: If OTA is correct in its estimate of much greater future cleanup needs, then Congress may wish to consider two options. First, Congress may wish to accept the trend toward reducing the matching fund requirements for the States (as EPA has done) or it may wish to allow de facto decisions on what sites get cleaned up because of the unwillingness of some States to supply matching funds. Alternatively, Congress may wish to provide incentives for the States to retain or expand their role in the Superfund program. This could be done by providing near-term aid to improve States' technical staffs, arranging for more effective Federal oversight, and directing EPA to establish an information transfer program about cleanup technologies.

SCOPE AND OBJECTIVES OF THE SUPERFUND ASSESSMENT

Congress has decided, and has reaffirmed through oversight, the need for a national Superfund program to clean uncontrolled waste sites. Everyone understands that information on the scope of the problem is imperfect and incomplete. Scientific uncertainty about adverse health effects is substantial and data on environmental contamination are incomplete. But in the absence of an effective and substantial cleanup program, releases of hazardous substances into the environment could cause widespread damage to public health and the environment long before these uncertainties can be resolved.

This Superfund report addresses the problems and issues in implementing and continuing the Superfund cleanup program, not in justifying its fundamental need. The Superfund program has achieved much, especially considering that it was a fast public policy response to a diverse set of newly recognized, highly complex, technical problems. The basic issue at hand, however, is to decide whether it is necessary to change and improve the program so it can achieve its goals and, if so, how to do this in the most economical and efficient way by learning from the experiences of the past 5 years.

OTA has not addressed all the issues surrounding Superfund. As in its earlier study, *Technologies and Management Strategies for Hazardous Waste Control,* a work that was chiefly concerned with the RCRA program, the focus has been placed on those issues with a significant technical content,

Chapter 2 presents *policy options* for congressional consideration. The options are supported by the results and conclusions of the other chapters. Some of these options are

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broad, while others are specific. Several broad policy issues directly and indirectly related to the Superfund program, such as approaches to financing Superfund and the role of the States in the program are also discussed.

Chapter 3, a systems *analysis,* ties together a number of technical and economic variables of the national cleanup program. Two different strategies are examined for their effects on total program duration and costs under various assumptions and constraints, such as number of sites requiring attention and budget limitations, The strategies make use of an important concept, the "impermanence" of cleanup actions, which assesses currently unforeseen long-term costs following the immediate costs of a cleanup. The difficult choices and tradeoffs facing policy makers are illustrated through the use of scenarios comparing the two strategies.

Chapter 41 addresses the issue of *strategies to achieve cleanup goals* and examines the difficult issue of how to establish cleanup goals that are protective of the environment, nationally consistent, flexible enough to deal with site-specific situations, and administratively feasible and practical. Resolution of this issue affects the selection of cost-effective cleanup technologies, selection of sites for action, and evaluation of cleanup performance.

Chapter 5 considers the *number of sites requiring cleanup* and examines the future needs of Superfund by assessing the extent to which certain types of sites may merit cleanup, This is an area of considerable uncertainty, but one which is fundamental to policy decisions about the nature and size of the national program, The benefits of investment in a stronger institutional infrastructure—such as developing innovative cleanup technologies—increase with increasing size of the NPL.

Chapter 6 discusses *cleanup technologies*. The purpose is to provide a more comprehensive understanding of the capabilities and limitations of existing cleanup technologies, and the problems involved in choosing among them. It also examines the need for, potential benefits of, and problems facing emerging, innovative technologies, and the need for additional or different Federal research, development, and demonstration efforts. A variety of cleanup technologies are necessary to meet environmental protection goals, and meet them in the most cost-effective way.

Chapter 7 examines issues related to *achieving quality work* and assesses current and future problems in achieving timely and effective cleanups at reasonable cost. Three areas are examined: a) the performance to date of the Superfund program; b) EPA's oversight function at cleanups undertaken by EPA, States, and private parties; and c) problems associated with the need for highly specialized technical personnel for site investigations and cleanups.

Chapter 8 considers *public confidence and participation* and examines how the public currently is involved in Superfund cleanup activities. Perhaps more than other Federal environmental programs, Superfund has been shaped by public demands. Yet the formal role of the public in decisionmaking is limited by statute.

SUPERFUND SEEN THROUGH CASE STUDIES

OTA performed several major case studies of Superfund sites to understand the problems confronting the program and better define the issues facing Congress in its deliberations over the extension and possible expansion of the program. It is common to introduce the subject of Superfund with statistics. Such a review usually focuses on numbers of various types of actions, numbers of sites and types of problems at the sites, actual and potential damages to health and the environment, levels of spending, and how these and other factors have changed over time. Such statistics are used throughout this report.

However, to introduce both the general subject and this report, OTA believes it is useful to present summaries of case studies. OTA's engineering case studies, based on in-depth analysis of how each site has been managed, illustrate the difficult and diverse set of challenges facing the national cleanup program. While there is some truth to the proposition that each uncontrolled site is unique, it is also true that sites share some common characteristics that become more obvious as the cleanup program progresses. It is likely, therefore, that these case studies can be instructive in learning how to improve the Superfund program. For example, these studies reveal problems associated with the current approach to establishing cleanup levels, with the quality of cleanup work, and with inadequate technical oversight by the Government.

The *case* study sites were selected because they had received a good deal of response action that could be examined for effectiveness. These sites all had major problems, though not necessarily typical of all Superfund sites.

The Seymour Site

The Seymour Recycling Corp. (SRC) site in Seymour, Indiana, was one of the first major cleanup actions under Superfund. Although land disposal sites are the most common operation requiring cleanup, the Seymour site illustrates how a processing or treatment facility can also create substantial problems. Over a lo-year period SRC established and operated a facility where large amounts of hazardous waste were sent for recycling and treatment. Eventually, authorities discovered that these wastes were not well managed. By 1978 the State of Indiana found it necessary to file a lawsuit to get SRC to clean up an estimated 40,000 drums of waste in various states of decay, leakage, and disarray.

In 1980, after SRC had ceased operations, EPA became involved through the Clean Water Act. Limited containment actions costing less than $1 million were taken, and two companies voluntarily spent slightly more than $1 million to remove their drums and place them in a commercial land disposal facility. EPA estimated that total cleanup costs would be $25 million. Throughout 1980 EPA took legal actions against a number of parties, spent more than $700,000 removing some wastes for incineration, and hired contractors to investigate the groundwater.

In 1981, EPA took the position that Superfund should not be used at SRC because the site did not present an emergency. The State maintained it did not have the resources to cover the 50 percent match ($15 million at that time) required under Superfund for the city-owned site, As a result, EPA pursued an enforcement strategy based on getting responsible private parties, chiefly the generators of the wastes, to pay for cleanup, To some extent, EPA's policy now is to use Superfund to clean up NPL sites first and later try to get responsible parties to pay for the cleanup. Much seems to depend on how urgent the cleanup is deemed and on whether responsible parties are known and financially able to contribute to the costs.

Although the problem of States not being able to pay for their matching requirement still exists, current policy requires the 50 percent match only when the local government also operates the facility. This was not the case at SRC. However, the State might have had difficulty providing even 10 percent of the $30 million required at that time. Currently the State and city face the problem of the operating and maintenance costs of an onsite treatment facility. This facility cleans surface water runoff before the water enters the local sanitary sewer system. The runoff is quite contaminated, revealing that the surface cleanup (described below) left substantial contamination in place.

During 1982 and 1983, two important events took place. EPA reached a settlement with some of the companies that had used the site. Those companies agreed to spend as much as $15 million for a surface cleanup, and EPA agreed to eliminate their responsibility for future subsurface cleanup, The issue of collecting money for groundwater cleanup (estimated at $15 million but quite uncertain), is not resolved; $5 million has been collected from some parties. A major issue raised in this approach is the question of whether it is technically possible and administratively reasonable to make a distinction between surface and subsurface cleanup.

Indeed, the case study has revealed that the negotiated surface cleanup was not technically sound. Although 1 foot of soil was removed, there is no reason to think that all contaminated soil was removed. No testing was done before or after the removal to demonstrate that all contaminated soil was removed. No cleanup goals were set for acceptable levels of residual contamination in the remaining soil. Leaving significantly contaminated soil at the site could worsen groundwater contamination over time. It should be noted that an early estimate judged that 5 feet of soil would need to be removed; removal of only 1 foot reduced removal costs substantially to about $8 million. The surface cleanup was completed in early 1984.

The surface cleanup simply extended the fundamental approach used from the beginning; that is, for the most part, cleanup consisted of removing wastes and contaminated soil from the site and sending them elsewhere for land disposal. The issue of future problems associated with land disposal sites that have received removed wastes has become important, as the problems with the technical soundness of and regulatory control over operating hazardous waste land disposal facilities have become more evident.

During 1982 and 1983, the SRC site was scored to determine its eligibility for placement on the NPL. The site received a relatively high score, in large part because an observed release of hazardous substances into both surface and groundwater was recognized, There are indications that there were problems with the attempts to assess air pollution from the site. The air route for migration of hazardous substances off the site appears to be the most troublesome one for the NPL scoring system.

The scoring of the site, results of various studies, and the need to supply alternate drinking water to some residents suggest that a potentially large, costly groundwater cleanup may be required. It is not clear yet, however, exactly what the extent of groundwater contamination is, what the difficulty and costs might be, what cleanup goals would be used, and what the effect of the surface cleanup has had on the groundwater problem. Nor is it clear if groundwater cleanup will be delayed until responsible parties agree to pay for it or whether Superfund will be used,

Finally, the Seymour site illustrates the concept of impermanent cleanups leading to high future costs (as discussed in chapter 3). About $12 million has been spent thus far at Seymour for initial responses involving site containment and waste removal, surface cleanup involving waste removal, and many studies and investigations, including the ongoing groundwater work. Nevertheless, no permanent cleanup can be said to have occurred. Future actions will be required, including a probable groundwater cleanup, a possible need to remove or treat much contaminated soil, possible cleanup actions at land disposal sites that have received wastes from Seymour, and continuing O&M costs for the water treatment plant. Altogether, future spending for this site is likely to surpass what has already been spent,

The Stringfellow Site

The Stringfellow Acid Pits site near Glen Avon, California, was used as a surface impoundment between 1956 and 1972, during which time over 30 million gallons of a large variety of liquid hazardous wastes were disposed there. The history of investigations and actions at Stringfellow is longer than at most Superfund sites. Much of the work, and many of the misinterpretations of the site hydrogeology, occurred before Superfund was even passed; EPA and Superfund are therefore late arrivals on the Stringfellow stage. However, just because the history is so long, and so much happened so early, this case study is especially rich,

Original geological studies concluded that the site was on impermeable bedrock and that, with the installation of a downstream concrete barrier, there would be no damage of groundwater contamination. Therefore, the canyon site was legally sanctioned as a hazardous waste facility. Subsequent information and events have revealed that the site was quite unsuitable for such a facility, and there have been substantial amounts of surface and groundwater contamination over a period of years. In fact, the site sits over the Chino Basin aquifer, a major source of water for drinking and other uses in an area serving about 500,000 people. Even now, it is not clear whether there is a far more serious groundwater contamination problem than previously recognized, but recent data suggest there is.

Early findings of groundwater contamination in 1972 were wrongly interpreted to be a result of surface water runoff rather than groundwater contamination. The same mistake was made by other consultants in 1977. Undue optimism about the suitability of land disposal sites for hazardous waste disposal is not uncommon, as detailed data on the characteristics of a location are usually lacking. One lesson to be learned from Stringfellow is that problems can arise from having many different consultants, contractors, and government agencies involved with cleanup studies and decisions. The record indicates problems with inadequate oversight of work by qualified government people, problems with redundant activities, and problems associated with conflicts among many local, State, and Federal agencies.

Now there is little doubt about the moving plume of contamination in the groundwater, and it is likely that it will enter the main flow of the Chino Basin sometime in 1985. Downgradient wells 1 mile and more from the site have revealed substantial contamination by toxic chemicals in concentrations sufficient for recertification of a drinking water supply. Alternate drinking water is being supplied to some local residents.

In 1977, the option of total removal of all contaminated liquids and solids from the site was estimated to cost $3.4 million. Two years later, after inaction and heavy rains, this option was still the preferred one, but the estimated cost was four times higher. A State agency, therefore, chose a lower cost option based on containment, which involved removing contaminated liquids and some contaminated soil, onsite neutralization of soil with kiln dust, placement of a clay cap, and installation of monitoring and interceptor wells to deal with groundwater. Both before and after this approach was implemented, large discharges of contaminated water from the site flowed into the downhill area of Glen Avon (800,000 gallons) and 4 million gallons of contaminated water was disposed of at considerable expense in a California land disposal site. This site (BKK in West Covina) is now recognized to be leaking as well and was closed recently to hazardous waste. The Casmalia Resources landfill that now receives 70,000 gallons per day from Stringfellow was fined recently by EPA for inadequately monitoring the groundwater. Thus, Stringfellow illustrates the problem of transferring risk from one community to another when cleanup is based on removal of wastes to land disposal sites.

Already about $15 million has been spent at the site and all concerned acknowledge that no permanent cleanup has been achieved. A permanent cleanup is still being studied by EPA, but its cost could be very high. The State estimates it would cost $65 million. A program for onsite treatment of contaminated groundwater is now underway. But this, too, is not a permanent solution. The OTA case study has concluded that the unfavorable hydrogeology of the site (e. g., fractured bedrock and underground springs) has frustrated all containment attempts to date. Therefore, a commitment is needed to excavate toxic wastes and contaminated soil, and store them onsite until the materials can be treated to render them as harmless as possible. As long as these materials remain in the ground it will be necessary to attempt to extract contaminated water and treat it at considerable O&M costs to the State. Even so, there may well be further spread of contaminated groundwater in the surrounding aquifer as extraction is not likely to be completely effective, It is not clear whether ongoing studies to determine a cost-effective cleanup are adequately considering total removal and treatment of hazardous materials. For about 15 years, dependence on land disposal and containment at the site has not provided either environmental protection or cost effectiveness, but it is still not clear that the cleanup solution preferred originally—total removal of all contaminated liquids and solids—is being seriously considered, since its near-term costs would be quite high.

In all likelihood the eventual cleanup costs for the site will far surpass what it would have cost some years ago to remove materials and even treat them. (The original plan was for removal followed by redisposal in land disposal facilities.) As time continues to pass, cleanup costs are likely to mount, and cleanup may become infeasible if there is widespread contamination of more soil and groundwater. Indeed, actions other than cleanup may have to be considered eventually. As in the previous case, much money has been spent on impermanent "cleanup" of the site with a high probability that much more money will be spent in the future for more permanent cleanup, expensive groundwater monitoring of a large aquifer, and possibly for cleanup of the site that has already received much waste from Stringfellow.

The Sylvester Site

The Sylvester site in Nashua, New Hampshire, was a former sand and gravel pit where hazardous wastes were dumped illegally along with solid wastes for 5 to 10 years through 1979, In addition to large quantities of nonhazardous materials, drums of hazardous waste, bulk materials, and liquids were disposed in a 3-to 4-acre area. Various consultants who have worked on the site used a figure of about 240,000 pounds for the total weight of hazardous waste deposited, based on an estimated 800,000 gallons of dilute liquid wastes, and exclusive of 1,314 drums removed from the site (see below). OTA finds that this figure could be a significant underestimate.

State officials are confident, however, that the figure of 240,000 pounds is substantially correct, based on: 1) affidavits submitted by several potentially responsible parties; 2) records of inspection and surveillance at the dump; and 3) exploratory test pits and borings in the solid materials in the pit above the water level. But the purpose of test pits and borings is to sample the site, not to examine all of it. Based on the number of solid samples, and what they contained, considerable amounts of waste could be present, but undetected, in the volume above the water level; that is, the possibility of a significantly higher figure for total hazardous waste deposited cannot be rejected with confidence on the basis of the sampling of solid material at the site. (Groundwater sampling seems to have well delineated the amount of hazardous materials currently in the groundwater.) State officials have put considerable confidence on the affidavits, inspection, and surveillance, and OTA cannot judge how well placed that confidence is. OTA notes, however, that various documents speak of the site being used for hazardous waste disposal for about 5 years, through late 1979, and agree that the site was used for waste disposal of some sort for 10 years. A legitimate question can be raised about how perfect inspections and surveillance were likely to have been over this long period. For example, such inspections and surveillance did not prevent illegal disposal of hazardous wastes at the site,

This site became eligible for Superfund cleanup because in 1980 a wide variety of hazardous substances were found in groundwater, surface waters, and air. It became clear that a plume of contamination had seeped into a brook which eventually fed into the Merrimack River, a source of drinking water for Lowell, Lawrence, and Methuen, Massachusetts. Several nearby private drinking water wells were also threatened, and air pollution threatened a nearby trailer park.

Early actions included supplying municipal water to replace the private wells, removal of 1,314 drums (roughly 70,000 gallons) that were visible and accessible from the surface for land disposal elsewhere, installation of a security fence and a number of groundwater monitoring wells, and, for about a year, operation of a groundwater interception and recycle system to delay further seepage of leachate into the nearby brook. The latter system has been restarted because of the delay in completing the chosen remedial cleanup and because there is an indication of greater than expected water flow off the site.

The strategy adopted to cleanup the site was to: 1) minimize the amount of water entering and leaving the site through use of a slurry wall around the area and a cap over it, and 2) clean up the contaminated groundwater and contaminated soil through a complex water treatment system. The latter system includes pumping contaminated groundwater downgradient of the site and discharging it upgradient, and treating contaminated water by several techniques to remove a variety of contaminants. On the one hand this strategy was bold and innovative. However, there are several uncertainties with this cleanup approach.

The slurry wall and cap system has been much less effective than anticipated, The design predicted a 95 percent reduction in water flow through the site, A year after installation of the cap and slurry wall system, measurements of the outflow showed only a 39 to 67 percent reduction of the original flow; that is, over five times as much water is flowing through the system as was predicted. A hydrogeological study is underway to evaluate this problem. On the basis of extensive modeling, the hydrogeological contractor believes that the cause of the leaky containment is water flowing under the wall, Some underflow was predicted because the bedrock is fractured, and the contractor and the State officials now think that the bedrock is more highly fractured than originally estimated. Another possible contributing factor is problems with construction during the installation of the wall. A further possibility, which State officials reject based on the hydrogeological modeling, is leakage through the wall because of the degradation of the wall by the contaminants in the water. The possibility of chemical degradation of the slurry wall has come up several times in contractor reports, and a recognized side-benefit of the water treatment systems is that the flows it sets up would protect at least part of the wall from the contaminated water in the site.

The reduced effectiveness of the containment system will not cause major problems if the treatment system removes the contamination to the degree predicted. The design of the treatment system assumes that nearly all contaminants will be flushed out during the relatively brief period (about 2 years) currently planned for treatment. However, to the extent that there is uncertainty about the quantity and particularly the nature of waste that may remain in the soil and in the portion of the site above the water level, there *is* uncertainty about the long-term effectiveness of the groundwater cleanup. The cleanup may succeed in removing contaminants from groundwater in several years, as the operation of the pilot plant indicates, and still leave waste that will leach out over time, recontaminating groundwater. If this should occur, the containment system will not be capable of preventing the new contamination from flowing offsite. Prudence suggests that extensive monitoring of groundwater will be needed at Sylvester for a long time, and that a contingency plan be developed to deal with recontamination should it occur.

The cleanup goals established for the site required a hundredfold reduction in the release of contaminants from the site. The goals were based on: 1) meeting the acceptable lifetime exposure level for inhalation of chloroform, the most serious of the airborne pollutants from the site; and 2) meeting water criteria at the Lowell intake of the Merrimack River, with arsenic as the chemical of greatest concern.

This attempt to set explicit goals was commendable. As EPA and the State recognize, however, the early emphasis on arsenic was misplaced, The background levels of arsenic in the area are very high; the arsenic levels in the Merrimack are about 1,000 nanograms per liter (rig/l), and the contribution of Sylvester to Merrimack of arsenic would be only about 15 rig/l. This contribution is relatively unimportant, and by itself, probably not worth the cost of stringent cleanup. However, there are several other toxic chemicals predicted to exceed water quality criteria at the Lowell intake, and other toxic chemicals at high levels for which criteria have not been formulated; the background levels at Lowell for these are likely to be lower, relative to the Sylvester contribution, than is the case for arsenic. If so, these chemicals are appropriate ones on which to formulate cleanup goals based on water quality. When only the chemicals for which water quality criteria exist are considered, the cleanup goal is similar to that originally proposed on the basis of arsenic.

In the case of Sylvester, it is not yet possible to evaluate the effectiveness of the cleanup strategy. If State officials are correct in their estimate of the nature and quantity of the hazardous waste disposed at Sylvester, the cleanup will be permanent. If not, future costs could raise the total cleanup costs significantly above the currently estimated $13 million,

Other Case Studies on Completed Cleanups

Recently a study was performed on six NPL sites cleaned up under the Superfund program. These six sites had fewer problems than the OTA case study sites, but they too can be instructive.[8] The report questions the widespread impression that the Superfund program has permanently cleaned up six dangerous hazardous waste sites. According to its evaluation, which OTA finds valid, there were thorough cleanups at two of the sites (Chemical Minerals Recovery and Walcott Chemical) which posed only minor hazards. A thorough cleanup was done at the Luminous Processes Site, but some problems remain, including the need for medical testing of former workers exposed to radium. But actions at three sites (Chemical Metals Recovery, Butler Tunnel, and the Gratiot Country Golf Club) have not been permanent cleanups. Surrounding communities still could be exposed to serious hazards, and future cleanups may be necessary.

The Luminous Processes, Inc., facility (Athens, Georgia) was a radioactive watch and clock dial painting operation initially licensed by the Atomic Energy Commission in 1952. The plant used considerable quantities of radium until it was forced to close in 1978 due to repeated violations of Federal and State regulations. The company was also required to decontaminate the facility, which was heavily contaminated with radium-226. Investigation and limited removal of contaminated materials began in 1979. However, most of the cleanup was accomplished with Superfund assistance, This work began in 1982, 3 years after the site was abandoned by Luminous. Overall, the study finds a thorough job was done. About 15,000 cubic feet of radioactive soil was barreled and transported to a low-level radiation facility in Richland, Washington. The building was also cleaned. A slab of concrete was removed from the floor; testing revealed that soils below the building were not contaminated, The study does point out that monitoring and cleanup may have missed contaminated layers below the level of testing (3 feet in most cases). No monitoring of test wells was conducted to detect potential radiation at deeper levels or possible groundwater contamination. Furthermore, the grounds were not surveyed for the possibility of waste burial, a frequent practice at many plants. Also, there has been no medical testing of former employees for radium contamination effects.

The Chemical Minerals Recovery site (Cleveland, Ohio) was a warehouse that had been used for less than 1 year as a temporary storage facility. The warehouse was closed down by judicial order after a fire, It was near collapse, and contained 700 drums of various chemicals, plus another 700 drums outside. Both the company and the property owner refused to clean up the site. EPA approved immediate funding of $205,000 in November 1981. The removal was completed in May 1982. There was little reason to believe that significant amounts of chemicals had been spilled

[8] R. C. Bird, Jr., and M. Podhorzer, "Evaluations of the Six National Priority List Sites Delisted by the Environmental Protection Agency" (Washington, DC: National Campaign Against Toxic Hazards, Oct. 24, 1984).

into the ground or remained below the surface, Cleanup in this case consisted of removal to another land-based facility.

The Walcott Chemical Co. site (Greenville, Mississippi) consisted of two warehouses. Both were in poor condition, but only one was designated as a Superfund site. It became an NPL site because the State chose it as its priority site, not because it scored high enough. The first problem with the site in April 1981 occurred when a fire official filed a fire and explosivity hazard complaint. EPA investigated the site in July 1981 and soon thereafter the property owner cleaned up the site by removing the wastes to a land disposal facility, There was no evidence of spilled materials and in July 1982 the site was judged clean.

The Butler Tunnel (Pittston, Pennsylvania) cleanup dealt with discharges of oily wastes into the Susquehanna River, but not with the remaining wastes and contamination in the tunnel itself. The initial incident occurred in July 1979 prior to the Superfund program. At that time, tens of thousands of gallons of wastes began discharging from the old coal mining tunnel; discharges continued through March 1980. Pollution was detected in the drinking water of Danvers, 60 miles downstream. Federal funding for the response came entirely from funds provided under Section 311 of the Clean Water Act. The original discharge drew a quick and thorough response, EPA and State agencies cleaned up the large spill on the river and took steps to monitor and prevent future damage. Substantial evidence exists, however, to indicate that significant quantities of toxic chemicals still exist in the tunnel, These pose threats to residents living above the tunnel, Cyanide gases in dangerous concentrations have reached the surface through boreholes to the tunnel, which are common in the area and, for the most part, not tested. In June 1980, EPA believed that it had identified the location of the "mother lode" of the wastes in the tunnel, but funding was suspended. Further cleanup was abandoned, In 1983, the State investigated whether dangerous chemicals from sediment contamination may be accumulating in fish, which are caught and eaten, The study has not been made public,

The Gratiot Country Golf Club site (St. Louis, Michigan) was a sanitary landfill; cleanup consisted of relocating the problem. The Velsico Chemical Co. used the 3,5-acre site on the Pine River to dump and burn toxic industrial chemicals between the 1930s and 1970s. In November 1982 Velsico signed a consent agreement with the State and EPA, under which it agreed to spend $38 million to clean up the site and two others across the river. Velsico was to remove soil to a level of 3 feet below where any chemicals were identified through testing. About 68,000 tons of soil were removed to the company's site across the river, where they were placed on a clay liner and under a clay cap. In other words, wastes were land disposed in a sensitive area. In addition, 1.25 million gallons of contaminated water were disposed of in a deep well, raising questions about future leakage. The company was not required to conduct a health effects study, nor was it required to consider the feasibility of removing highly toxic chemicals from river sediments. Even now, for 60 miles downstream, the State warns against fish consumption.

The Chemical Metals Industry site (Baltimore, Maryland) consists of two properties in a commercial and residential section, on both sides of a group of 20 row houses. Initially, there were reported complaints of eye, nose, and throat irritation during spills that occasionally forced residents to leave. There were also burns to children and animals playing in the area, and runoff into one of the neighboring basements. The company never had a permit to handle hazardous materials, and it was shut down in August 1981, EPA investigated the facility, determined that it presented an immediate threat, and that it warranted an immediate removal action. Approximately 1,500 drums of hazardous materials were removed for land disposal, Significant levels of contamination were detected as deep as 15 feet, but less than 1 foot of the contaminated soil was removed for disposal. No action was taken to intercept the migration of chemicals into groundwater, despite evidence of contamination. Although local residences do not use the groundwater, there is a threat of contamination of the Gwynn Falls tributary. It is also likely that toxic gases are escaping into neighboring basements.

Chapter 2

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CHOOSING A STRATEGY FOR THE SUPERFUND SYSTEM

OTA finds that a detailed strategy for planning and evaluating the Superfund program has not been formulated explicitly. Instead, a combination of alarmed public responses to events, congressional mandates, Federal policies, and Environmental Protection Agency (EPA) management decisions have resulted in ad hoc program policies. Consequently, a national consensus has not yet emerged on whether Superfund is to be a well planned, multi-decade program, or a short-term, emergency effort.

Congressional] debate on reauthorization of the Superfund program and its funding levels can be viewed in two ways. Both views recognize that much can be learned from the program's early efforts:

- The first view is that the current program is progressing and evolving and becoming more effective, The ad hoc nature of the program provides flexibility to respond to new information and experiences,
- An alternate view is that the early lessons learned from Superfund can be applied now to change the program, and that enough information has been collected to define a more explicit strategy for policy and program implementation.

OTA has examined the accomplishments of the Superfund program to date. Some significant changes have already been made. Although EPA is discussing still more changes in the program and has made some proposals, it is not possible at this time to know what changes will be made and, importantly, how they will be implemented.[1] Thus, a critical choice for Congress centers around how much confidence it and the public have in EPA's determination and institutional capabilities to improve the Superfund program in an evolutionary manner.

The situation is complicated by Superfund's relationship to other national issues. For example, increases in Superfund budgets are related to national budgetary and fiscal issues and the state of the economy. It is inevitable that Superfund will be compared to the progress of Resource Conservation and Recovery Act (RCRA), enacted in 1976, the other major Federal environmental program that deals with hazardous waste, Congress recently culminated extensive examinations of the RCRA program with a reauthorization that includes substantial changes in its policy and implementation, It is not clear whether the Superfund program could evolve into a more effective program in a smoother fashion than RCRA has, but it might.

Many of the findings of this study support the second view—that it is time to change the Superfund program—because: 1) proceeding with the current program poses significant uncertainties and risks, and 2) the absence of an explicit Superfund strategy makes it difficult for Congress to evaluate the long-term consequences of important decisions.

There are three concerns with continuing with the current program. First, a program focused on site-specific problems and needs does not necessarily lead to a national program that

[1] For example, on Jan. 28. 1985, EPA announced proposed revisions in Superfund's National (contingency Plan; the public has an opportunity to respond to the proposal and, hence, it is not known what changes will finally be made. one of the major changes resembles what OTA has stressed in the first part of the two-part strategy: quickly taking more effective initial responses at NPL sites, without requiring State matching funds unless the facility was owned by the State. However, there remains considerable emphasis on using removal for redisposal. Another change would be the circumvention of the Hazard Ranking System, which (I'I'A be] i eves could be i m proved, for sites where health effects were known to be important. Other changes concerning cleanup goals and public participation do not fully address the problems OTA found.

is effective environmentally and economically. This study indicates that as the National Priorities List (NPL) increases (even if only to EPA's projected 2,000 site level), it will no longer be efficient or effective for the program to respond to problems that capture public attention on a site-by-site basis. Nor is it prudent to ignore inter-site effects. The technical and institutional complexities of *individual* uncontrolled site problems should not overshadow the interlocking technical, social, and economic components of the national Superfund system. Conflicts arise between the needs of individual sites and the limits on a national program. The future will demand a thoroughly discussed and explicit Superfund strategy.

Second, there is evidence that the scope of the national uncontrolled site problem has been underestimated. If this is true, an unmanageable environmental crisis might occur years or decades from now. The environmental deficit created today could come due in the future. Many cleanups in the current remedial cleanup program are costly and, because they are not effective in the long term, all too frequently need repeated expensive work at the same sites or on the same wastes. Detailed national cleanup goals or a process to achieve them and to select cleanup technologies and evaluate their performance have not been formulated. In the absence of goals, the least costly alternative may look effective because of the way the cleanup requirements are set. Even best available technology may not be able to achieve adequate or effective environmental protection at some sites over the long term (see chapter 4).

Third, many, if not most, uncontrolled sites have not received significant cleanup attention of any sort other than removal of waste. This may get worse as more sites are added to the NPL, It is likely that *every* site which merits placement on the NPL, because it is found to require a long-term (i.e., permanent) remedial cleanup, would also benefit from an initial response to: 1) provide environmental protection during the long time it is awaiting remedial cleanup, and z) ensure that the site does not get worse during this period. While it may be suggested that some sites may not need initial responses, the benefits of doing so for all NPL sites, if the costs are kept low, are likely to outweigh the costs of not doing so.

However, a case can be made for continuing with the current Superfund program. Chapter 3 shows that, to the extent that the interim strategy modeled by OTA approximates the current program, there are conditions under which the current program can be viewed in a positive manner. Much depends on the values for the average impermanence factor (described in chapters 1 and 3) for the remedial cleanup technologies now being used, It has not been possible for OTA to obtain data on a large number of current Superfund sites to calculate values for the impermanence factor (i.e., basically the extent of unforeseen future costs). However, detailed work on several case studies of Superfund sites (see chapter 1), an analysis of future operating and maintenance costs (see chapter 3), and the conclusion that containment and land disposal technologies are not permanently effective, z indicate that rather high impermanence factors are possible for many sites. OTA believes that the current program's average impermanence factor is likely to be at least 0.5 to 0.7. If this is the case, then the two-part strategy defined below offers time and probably cost advantages over the current program.

If the average impermanence factor were to be low, say about 0.1 or 0,2 (i.e., remedial cleanups that had a low probability of leading to unforeseen future costs), then a decision to continue with the current program would not lead to undesirable consequences. Adopting the two-part strategy would still be a valid option, however, because of the opportunities it affords for institution building, for quickly reducing risk at most sites through initial responses, and because low impermanence actions of the interim strategy could also be used. If, however, the current program continued and it became clear that the average impermanence factor was high, much money and time could be wasted.

'See U.S. Congress, Office of Technology Assessment, *Technologies and Management Strategies for Hazardous Waste Control*, OTA-M-196 (Washington, DC: U.S. Government Printing office, March 1983).

OTA concludes that, in the face of important uncertainties, the two-part strategy is less risky and more fail-safe than Superfund's current ad hoc strategy and less likely to result in ineffective spending.

For all these reasons, OTA finds that: 1) even though some sites are being worked on, from a national perspective *the current strategy can be judged to be both environmentally and economically unsound;* and 2) the two-part or permanent strategy OTA has examined offers a number of advantages.

A Two-Part Strategy

The two parts of OTA's strategy overlap in time, but differ in their focus and priorities.

(I) In the near-term, for perhaps up to 15 years, the strategy would focus on: a) early identification and assessment of potential NPL sites, b) initial responses to *reduce near-term threats at all NPL sites and to prevent sites from getting worse, c)* permanent remedial cleanups for some especially threatening sites, and d) developing of institutional capabilities for a long-term program (see below). A substantially larger Superfund program would be needed in the next 5 years to carry out these efforts. Initial responses that accomplish the most cost-effective and significant reduction of risks and prevent sites from getting worse might cost about $1 million for most sites. This is three times the current cost of immediate removal actions and about 10 percent of EPA's currently projected remedial cleanup costs. Case studies by OTA and others find that both immediate removals and remedial cleanups are ineffective for their intended purposes. Under the two-part strategy, initial responses would emphasize covering sites and temporarily storing wastes and contaminated materials to reduce groundwater contamination and, where technically and economically feasible, excavating wastes to minimize releases into the environment.

(II) Over the longer term, the strategy would perform more extensive site studies and focus on *permanent cleanups,* when they are technically feasible, at sites that pose significant threats to human health and the environment (unless private or State-funded cleanup actions offering comparable protection have taken place). These cleanups would draw on the institution building that occurred during the first phase. Spending large sums before specific cleanup goals are set and before permanent cleanup technologies are available leads to a false sense of security, a potential for inconsistent cleanups nationwide, and makes little environmental or economic sense.

This two-part strategy resembles what is sometimes done in the current program. For example, in the case of the sites in Missouri contaminated by dioxin, large amounts of contaminated soil may be temporarily stored until cost-effective permanent solutions become available. Testing and evaluation of permanent solutions are proceeding.

One of EPA's most experienced Superfund contractors has proposed a strategy almost identical to this one:

> Realizing that there are significant shortfalls in or current knowledge of destruction technologies and that permanent containment is not a solution, I propose the following strategy: Destroy what contamination we can and hold the rest in temporary containment until a permanent solution can be found. a

Similarly, another of EPA's major Superfund contractors has cited the need for a two-phase approach:

> At these complex sites, although not widely recognized, there are typically two distinct phases or remediation. The first is an immediate action which usually lasts from 1 to 2 years. This phase is very site-specific and is very effective for the amount of money spent in that it dramatically and quickly reduces the threat to public health. The second is a complex and expensive long-term action which could last from 2 to 20 years or even 30 years.[4]

[3]William A. Wallace, CH2M Hill, Inc., testimony at hearings before the House Subcommittee on Commerce, Transportation, and Tourism, 1983, Serial No. 98-128,

[4]Gary A. Dunbar, Camp Dresser & McKee Inc., testimony at hearings before the House Subcommittee on Commerce, Transportation, and Tourism, 1983, Serial No. 98-128,

Generic Strategic Goals

OTA suggests four major goals that the two-part strategy or indeed *any strategy for a long-term Superfund program* should be able to meet:

1. provide nationally effective, long-term protection of public health *and* the environment at the lowest possible cost from the threats posed by uncontrolled hazardous waste sites.
2. Rapidly identify all uncontrolled sites and avoid underestimating the national cleanup problem. Use site selection criteria for the NPL that are consistent with the first goal.
3. Assure the public that they are being protected while they wait for remedial cleanups. That is, in the near-term give the highest priority to providing *initial responses at all NPL sites* in order to quickly and sharply mitigate immediate threats to public health and the environment.
4. Address the institutional needs of a long-term program. For example, develop and demonstrate the effectiveness of new permanent cleanup technologies, improve institutional capabilities of Federal and State agencies, resolve scientific uncertainties, improve public participation in decision-making, and develop a detailed strategic plan to implement a decades-long effective Superfund program.

OTA finds that the present program falls short of meeting these goals. Discussion of these goals, the means for their implementation, and the policy issues they raise are given below. References are made to the findings and conclusions of other chapters which the reader can consult for further details.

GOAL 1: COMPREHENSIVE AND EFFECTIVE NATIONAL PROTECTION

Because of urgency and limited resources, the initial Superfund program has fallen short of providing comprehensive and effective protection. This is probably a consequence of the original emergency nature of the program. For example, contrary to the statutory mandate, sites that pose threats to the environment but not to human health do not enter the Superfund system. A different strategy responding to the same conditions and constraints might have brought such sites into the program, but with a different priority and management approach. Loss of natural resources and effects on sensitive elements of the ecosystem, important in themselves, may also lead to substantial indirect effects on human health and welfare. Even for threats to human health, the current system is likely to exclude sites that threaten relatively small numbers of people. Sites that pose uncertain long-term health effects may not be given as high a priority as less ambiguous acute effects.

Congress can meet this goal through clear policy directives, provision of adequate budgets, and effective oversight of Federal programs.

A Long-Term Program

A most important policy issue for Congress to consider is whether Superfund should be continued as a long-term program. If so, the initial steps would include directing EPA to plan for a long-term program and providing it with resources to implement a multi-decade program. Without a commitment to long-term funding, comprehensive protection based on a long-term strategy will be difficult to achieve.

Therefore, Congress might reconsider the current approach of authorizing Superfund for 5-year periods. Should a longer period than 5 years be used for authorization, budgeting could still be done for shorter periods based on the scope of the national problem and the progress of the program,

Funding Levels

Based on the analyses in chapters 3 and 5, OTA concludes that a multi-decade Superfund program could easily require about $100 billion of Superfund resources out of total costs to the Nation of several hundred billion dollars. Note that an NPL considerably smaller than 10,000 sites would not alter OTA's principal conclusions about the need for an improved, better defined Superfund strategy encompassing well understood cleanup goals and the development of new technologies effective over the long term. (See chapter 5 for derivation of the 10,000-site figure.)

The estimate of the costs to Superfund contains many uncertainties. Consequently, the estimate could be too high or too low depending on:

- The number of sites that qualify for the NPL.
  - —OTA's estimate that 5,000 solid waste sites (RCRA Subtitle D sites) may become future Superfund sites might be low; this figure is only about 1 percent of OTA's estimate of the Nation's open and closed solid waste sites. Moreover, improving the site-selection process by, for example, removing the cutoff score for NPL placement and recognizing environmental threats, might lead to more than the 2,000 additional sites estimated by OTA. OTA did not include in its estimate of future uncontrolled sites several categories which even now are being addressed by Superfund and which will almost surely increase in number. Examples are leaking underground storage tanks, mining waste sites, and pesticide contamination sites.
  - –However, it is also possible that OTA may have overestimated the number of sites to be placed on the NPL. In particular, perhaps groundwater problems and threats from solid waste facilities have been overstated. With EPA's current groundwater protection strategy, many aquifers may not be classified so as to require cleanup; this possibility deserves detailed examination by Congress.
- National cleanup goals and the costs of cleanup.
  - —National cleanup goals might lead to levels of cleanup that would be more expensive than indicated by experience so far, and cleanup costs for treatment of wastes may be underestimated, Waste treatment costs are typically two to eight times greater than the immediate costs for land disposal. But the costs of waste treatment technologies may decrease because of technological innovation, and savings may be realized from learning curve and economy-of-scale effects.
  - —Furthermore, the costs of groundwater cleanup are very uncertain. Groundwater problems exist at more than three-quarters of current NPL sites although fewer sites than that may eventually need groundwater cleanup. Experience with groundwater cleanup is scanty and costs may be extraordinarily high, depending on cleanup goals.
  - —Finally, a 10,000-site NPL resulting, in part, from increased site identification efforts might include some sites with far higher cleanup costs than are now typical; for example, very large solid waste landfills which contaminate important aquifers, very large mining waste sites, and deep injection wells. [5]
- The size of expenditures by private parties and States.
  - —To date, expenditures by private parties and the States have contributed significantly to cleanup (although cost recovery has been extremely low so far), These contributions are discussed below, and could increase or decrease in the future depending on several factors, also discussed below, In particular, under current policies that require matching funds

[5] There are now about 70() deep injection wells which could be receiving hazardous wastes but for which there are not Federal requirements for monitoring nearby underground sources of drinking water.

from the States, some States may not provide these funds and consequently large numbers of sites may not get cleaned up under the Federal program.

Coping With Uncertainty

There is no analytic way to resolve all uncertainties. Chapter 3 addresses the consequences of making important policy decisions in the face of uncertainty. OTA's analysis indicates that there are substantial costs and risks in underestimating future Superfund needs. Prevention is far less costly than remedial action when it comes to hazardous waste problems. Furthermore, technically speaking it is possible to conceive of a situation where, as EPA says, the system could be "overwhelmed. " Simply put, releases of hazardous substances from many uncontrolled sites could cause pollution so widespread that it would either be technically impossible, very costly, or too time-consuming to redress. In particular, contamination of underground drinking water, if indeed it could ever be cleaned up, would be an exceedingly expensive and lengthy job. The *task is to reduce risk while developing information and technology to reduce uncertainty*.

Funding Increases Over Time

If OTA is correct that a much larger, longer program will be necessary, how might Congress reshape Superfund? A much larger Superfund program cannot be implemented immediately. To the contrary, many of OTA's findings from case studies and other work (see chapters 5, 6, 7, and 8) indicate that capabilities are strained at the *current* level of funding. Thus, although very large amounts of money will be needed for the program, in the near-term funding could be increased gradually as policies are developed and institutional capabilities improved. This is an important dimension of the two-part strategy examined by OTA. The first part of the strategy might last up to 15 years. (In OTA's model discussed in chapter 3, a period of 15 years is used, but this figure should not be regarded as certain or as rigid.) A major uncertainty during part one of the strategy is how fast sites are added to the NPL; this will determine, to a large degree, annual budget needs, The second part of the strategy, with its emphasis on permanent cleanups, might last for as long as 30 to 410 years, The major uncertainties are cleanup goals and the costs of cleanup, with costs depending in part on goals.

For example, under the two-part strategy, funding might build up from current levels of about $300 million to $400 million annually to perhaps $800 million for the first year of the initial period, *$1.2* billion for the second year, and $1.6 billion for the third year. Afterwards, funding might be stabilized at about $2 billion to $3 billion per year to address more costly permanent cleanups. These figures would result in a total spending of about $7 billion to $10 billion for a 5-year period, These near-term increases in annual spending are very large. But the efforts stressed in the first part of the strategy are those that EPA is best able to implement; they require fewer technical specialists than the later period with its emphasis on remedial cleanups rather than initial responses, Moreover, as discussed later, these figures would include significant sums devoted to improving institutional capabilities.

Spending by Responsible Parties

Higher levels of cost recovery and non-Federal spending are likely in the future. Even so, projections of future Superfund needs seem overly optimistic about these two contributions. Optimism about cost recovery is hard to justify from the experiences so far, with recovery amounting to about 1 percent of Superfund commitments. A recent audit by EPA's Inspector General criticized EPA's system to identify and track the status of cost recovery cases and to file a cost recovery case before the 3-year statute of limitations expires. However, recovery may improve when more sites, such as industrial surface impoundments, having only a single or several responsible parties are tackled.

Although responsible parties have spent considerable sums to date on cleanups (about $300 million), there are obstacles to and uncertainties about their future spending. These center around uncertain future liabilities after cleanup. Incentives may be required if responsible parties are to maintain or increase the pace of cleanup, However, it is not necessarily desirable to have more non-Superfund cleanups without effective cleanup goals and Federal oversight to ensure environmentally effective work. Even for sites cleaned up by responsible parties under agreements with EPA or States there appears to be little effective technical oversight, and already it is clear that a "quiet market" exists for cleanups. These are done by or for responsible parties, usually on their property, without government involvement, and usually before public awareness is awakened, (These cleanups are not included in the $300 million estimate given above. Their total is unknown, but probably large.) One interesting and positive aspect of this situation is that some new cleanup technologies are being given a chance to prove themselves under field conditions. However, it is not clear that information about positive and negative results is being disseminated.

Matching Funds From States

The issue of the States' share of the national cleanup effort is also important in considering funding decisions, Beyond initial studies and investigations, States must pay 10 percent of cleanup costs and all operating and maintenance costs after the first year. The States have spent perhaps 15 percent of Superfund funding to date. Some suggest removing or reducing the current requirements for matching funds from the States.

The chief reason to consider such a change is that many sites might not receive cleanup because some States are unwilling to provide the required matching funds. In December 1982 the head of the Superfund program said that about 50 Superfund sites had received no attention because States had not provided their shares of the money, an estimated $97 million. In February 1983 the same official said that 42 States do not have the money to complete cleanups, Although the situation may not be as severe today because of the improved economy, it still appears to be a problem. Should OTA's estimates of future needs be correct, the problem could get considerably worse. This is especially true if a large number of municipally owned and operated solid waste facilities become Superfund sites, because the current matching requirement for these sites is at least 50 percent of cleanup costs. Thus, an increase in the matching State share might sharply curtail cleanups.

The current dependence by States on Superfund for remedial cleanups is shown by data from a survey conducted for EPA. For fiscal year 1983, $103.7 million (82 percent) of a total of $126 million (for 37 responding jurisdictions) came from Superfund, and projections for fiscal year 1984 indicated that $201 million (76 percent) of a total of $263.2 million [for 35 responding jurisdictions) would come from Superfund. This survey also found that for fiscal year 1983 through fiscal year 1985 a total of $293 million was available in State budgets for dealing with uncontrolled sites. Of that, $194 million (66 percent) was available for cost sharing under Superfund (these data are for 42 States and the District of Columbia). This would indicate more than enough potential to adequately meet the matching requirements currently in effect (i. e., Superfund spending of about $2 billion for those three years). However, it should be noted that there are considerable differences among the States; some States with substantial numbers of NPL sites have strong, well-funded programs (e.g., New York, New Jersey, California, and Illinois).

Information on State budget surpluses suggest that it is not necessary to remove or reduce requirements for matching funds from States. The National Governor's Association reports that the 50 States will end fiscal year 1984 with $5.8 billion in budget surpluses and that for fiscal year 1985 the total surplus will be $4.3 billion. From 1979 through 1984, the total States' surpluses amounted to $43.5 billion. Although there are significant variations among the States, with some having small, unreliable, or no budget surpluses, the data suggest that money alone does not explain the difficulties some States have in supplying matching funds to clean up Superfund sites.

Therefore, a policy change may be viewed as unnecessary because many States have the potential to supply the matching funds; indeed, a number of States have developed a variety of means to do so, Moreover, the obligation currently placed on the States to pay for all future operating and maintenance costs provides considerable incentive to use either lower cost initial responses or more permanent remedies rather than containment at the site.

The reasons why some States have been less enthusiastic about helping to pay for Superfund cleanups include: a) spending priorities that give cleanups low rank; b) uncertainty about the Federal program, with a "wait-and-see" attitude about changes in the matching funds requirement; c) dissatisfaction with the Federal program and the States' limited role in deciding policy; d) conflicts among State agencies and between legislatures and executive branches that result in inaction; e) the influence of hazardous waste-related industries on State decisionmaking or the perceptions of potential negative impacts on industry; and f) obstacles to establishing highly technical programs, such as limits on salaries or hiring freezes.

Other Uses of Superfund

It must be emphasized that OTA has considered only the hazardous waste site cleanup function of Superfund in estimating future needs. Should other major uses be mandated for this program, such as for victims compensation or cleanups of Federal sites, these would have to be taken into account. Moreover, OTA has not considered uncontrolled sites under the responsibility of Federal agencies which, although placed on the NPL, do not now qualify for funding from Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Program Duration and Equity

Program duration is an important factor and it probably will become more of an issue. It will likely take several decades to address even a 2,()()()-site NPL. OTA has assumed that about 50 years is the longest practical program, but it is not clear how the public will respond to such a long program.

In developing the two-part strategy, OTA stresses the importance of taking initial responses that are effective in managing immediate risks, but that, in most cases, are not cleanups. Nevertheless, there is an inherent tension in a program that places priority on taking initial responses at all sites, while most sites wait a long time for permanent cleanup. This is why it is necessary to develop detailed plans to decide when sites receive a permanent cleanup, to develop goals to decide whether all sites need permanent cleanup, and to involve the public early in the entire process, from site identification through initial response and remedial cleanup.

Some may view an initial period where few permanent cleanups occur as unacceptable. But there are two basic reasons to support this approach. *First, it is both technically and economically impossible to permanently clean up all sites—even for an NPL of only 2,000 sites—in the near term, certainly not within 20 years.* Cost-effective permanent cleanup technologies for some problems do not yet exist; there is not enough information on most sites to make decisions about permanent cleanup; there are no detailed national cleanup goals; and there are not enough people to implement a large permanent cleanup effort,

Second, the current Super fund program does not offer equity, as it assures neither rapid reduction of risk at all NPL sites nor permanently effective cleanups. Furthermore, the way particular sites are chosen for cleanup in the current program is not clear. EPA has said that the hazard ranking scores given sites as part of the site selection process for the NPL do not establish exact priorities for responses, However, according to EPA's latest data on the 538 NPL sites the site scores seem to have an effect; for example, 30 percent of all sites on the NPL are receiving some type of remedial attention, but out of the top 50 ranked sites 60 percent are receiving attention. For the next

50 sites, 40 percent are receiving attention, and for the remainder just over 20 percent. This may be viewed with some concern because of criticisms of the Hazard Ranking System (HRS).[6]

There is evidence that decisions to take action at a site also depend on which EPA Region the site is in, the resources available from the State, the ability of the local community to present a forceful case for action, and news media attention, The time it takes for EPA to get responsible parties to agree to pay for cleanup may also have some effect, but perhaps more on the nature of the cleanup than on when it takes place.

Financing Superfund

This study has focused on estimating future needs rather than on analyzing how to raise funds for the program. In suggesting to Congress that a much larger, longer Superfund program may be necessary, OTA is sensitive to broader financing issues. A multibillion dollar Superfund program raises issues about potential impacts on the national economy and the Federal budget which are beyond OTA's capabilities to examine.

When Congress was considering CERCLA, various financing mechanisms were examined for Superfund. In 1980, Congress adopted a tax on chemical and petroleum feedstocks supplemented by general tax revenues. Discussions on the extension and expansion of Superfund have examined a number of other approaches. OTA has analyzed only one of these, a tax on the generation and/or the management of newly produced hazardous wastes—generally referred to as a "waste-end tax." This approach was considered but judged unworkable in 1980. A brief comparison of the feedstock tax, waste-end tax, and general tax revenues as funding sources for Superfund is given in table 2-I.

Note that there are limits to the amount of money that could be raised from feedstock and waste-end taxes, perhaps $1 billion to $2 billion annually from both, Feedstock taxes raise concerns about adverse secondary impacts on industry, such as a loss of international competitiveness. With a waste-end tax, the tax base will gradually shrink as waste reduction efforts proceed. Thus, although a combination of all three sources is possible, a larger Superfund program increases the likelihood of reliance on general tax revenues to a greater extent or

[6]See chapter 5. Also "Workshop on Selection of Hazardous Waste Sites for Superfund Funding," U.S. Senate Committee on Appropriations, March 1982.

Table 2-1.—Summary Comparison of Several Major Financing Schemes

Feedstock tax[a]		Waste-end tax[b]		General tax revenues[c]
Current	Expanded	Low	High	
Fairness:				
Very few companies pay most of the taxes	Improved	Good, many parties pay	Improved if land disposal gets high tax	Parties most directly responsible for problems do not bear burden
Administrability:				
Easy, established	Probably easy	Probably easy on basis of States' experience	Possibly more enforcement necessary	Very easy
Secondary impacts:				
None apparent	Might reduce international competitiveness of some companies	None likely	Provides economic incentive to reduce wastes and shift away from land disposal, thus capacity to raise basic revenue declines	With large amount may have undesirable effect on Federal budget

[a]Based on taxes imposed on chemical and petroleum feeds tocks which can be expanded by increasing tax rates and number of materials taxed
[b]Based on taxes on hazardous wastes generated or managed, and may vary according to how wastes are managed and what hazards wastes pose; if the rates are high enough current management decisions may be affected *Low* is less than about $10 per dry ton *high* is about $30 to $50 per dry ton
[c]Currently a small fraction (12.5 percent) from this source but much larger amounts could be raised

SOURCE Office of Technology Assessment

adopting some new, broadly based tax. This also becomes more likely if non-cleanup uses of Superfund are mandated.

Waste-End Tax Approach

OTA examined the waste-end tax option because it concluded in its 1983 report on hazardous waste that a waste-end tax was an important option to deal with the national hazardous waste problem. Its importance stems from its potential to generate funds while it serves as an economic incentive to reduce waste generation and shift management away from land disposal. However, to use a waste-end tax as an economic incentive, the tax must be structured carefully. This means varying tax rates depending on the nature of the waste, the way it is managed, or both. Moreover, the tax rates must be sufficiently high to act as an economic incentive. This requires an understanding of current market conditions and management policies.

Many of the original objections to using the waste-end tax have less force today. Because of the gradual development of the RCRA program, many States have found it practical to use a waste-end tax. OTA, EPA, and others have concluded that a Federal waste-end tax could be made administratively manageable.[7] For example, for the past several years EPA found that State income from waste-end taxes as a percent of projected revenues were: California, 89 percent; Connecticut, 71 percent; Illinois, 83 percent; Ohio, 98 percent; Minnesota, 102 percent; New Hampshire, 107 percent; New York, 101 percent; and South Carolina, 96 percent. For comparison, EPA reports that collections from the feedstock tax ranged from 78 to 84 percent of projected revenues from 1980 to 1983.[8]

But there remain different viewpoints on whether to structure the tax to provide an economic incentive for changing waste generation and management practices, or to use it simply to generate revenues, OTA has concluded that the benefits of using a waste-end tax for preventing more Superfund problems are likely to outweigh the costs of implementing such a measure. It is possible to structure a waste-end tax both to raise substantial revenues in the near-term and to act as an economic incentive to modify waste disposal practices and reduce waste generation.

To act as an economic incentive, that is, to affect waste generation and waste management practices significantly, tax rates would have to be about $30 to $50 per ton of hazardous waste. This is because of the current costs faced by waste generators: about $50 to $100 per ton for most land disposal, and usually from $200 to $800 per ton for waste treatment. Most of the 20 States that have adopted waste-end taxes have relatively low rates (see table 2-2). Only six States have maximum tax rates high enough to significantly affect waste disposal practices. The States have not encountered major problems in implementing waste-end taxes, although at the beginning some States made rather imprecise estimates of revenue generation.[9] Note that States are concerned about whether a Federal waste-end tax could seriously reduce State sources of revenue, This could be dealt with by explicitly allowing States to have their own waste-end taxes or by providing for a deduction to Federal taxpayers for waste-end taxes paid to a State.

Several illustrations of a Federal waste-end tax are given in tables 2-3, 2-4, and 2-5. These are based on 1981 EPA data that are imprecise and may not be valid today because the Federal RCRA and Superfund programs have increasingly influenced waste management practices. The tax rates chosen were based on industry concerns, the costs of waste management options, and what some States found effective. These examples show how the degree of hazard of a waste can be used, and how dif-

[7] U.S. Environmental Protection Agency, Office of Policy Analysis, "Survey of States' Experience With Waste-End Taxes," September 1984; Howard J, Hoffman, "Workability of the Waste-End Tax," testimony before the House Ways and Means Committee, July 25, 1984.

[8] "Survey of States' Experiences With Waste-End Taxes," op. cit.

[9] For more detail on States' experiences and waste-end taxes, see the EPA report referenced above and testimony of Joel S. Hirschhorn on behalf of OTA for the hearing record of the Senate Committee on Environment and Public Works, Sept, 10, 1984,

Table 2-2.—Summary of State Waste-End Tax/Fee Systems

State	Treated wastes taxed	Higher rate for offsite management	Generators pay	Facility operators pay	Highest possible tax rate[a] (per ton)
Alabama	X	X	X	X	$10.00
California			X	X	$45.66
Colorado	X			X	$2.00
Connecticut	X	X	X		$10.00
Illinois	X	X		X	$6.60
Indiana				X	$1.50
Iowa	X	X		X	$50.00
Kansas	X	X	X	X	$5.00
Kentucky	X	X	X		$11.00
Louisiana	X	X		X	$10.00[b]
Maine	X	X		X	$33.00
Minnesota	X		X		$70.40
Mississippi		X		X	$9.00
Missouri	X		X	X	$26.00’
New Hampshire	X	X	X		$36.60
New York	X	X	X		$12.00[d]
Ohio		X		X	$8.99’
South Carolina				X	$7.00
Tennessee		X	X		$7.00
Wisconsin				X	$0.135

a More than one tax rate may be applied to achieve per ton rate

b Dry weight ton

c The 2 percent charge on disposal receipts is not included

d Higher rates may soon be Implemented

e Based on 1982 disposal charges and 6 percent charge on disposal receipts

SOURCE Office of Technology Assessment

Table 2-3.—illustration of Applying a Hazardous Waste-End Tax by Management Activity

Tax category	Annual quantity[a] (million metric tons)	Scenario 1 Tax rate	Scenario 1 Revenue ($ millions)	Scenario 2 Tax rate	Scenario 2 Revenue ($ millions)
Well injected waste	**32.0**	**$ 5/tonne**	**$ 160**	$ 3/tonne	$ 96
All other[b] land disposed waste	**22.4**	**$50/tonne**	**1,120**	$30/tonne	672
Treated waste	176.0	$ 2/tonne	352	$ 1/tonne	176
Total revenue			$1,632		$944

a Waste quantities data from National Survey of Hazardous Waste Generators and Treat merit, Storage and Disposal Facilities Regulated Under RCRA in 1981 prepared for the EPA by Westat Inc April 1984

b Land fills surface impoundments land application etc

SOURCE Office of Technology Assessment

Table 2-4.—illustration of Applying a Waste-End Tax to Land Disposed Waste: Degree of Hazard Based on Toxicity (waste quantities in millions of metric tons)

Land disposal[b] excluding well injection:			
Toxic waste[c]	$50/tonne	19.8	$ 990.0
Nontoxic waste[d]	$10/tonne	1,3	13,0
Well injection:			
Toxic waste[c]	$ 5/tonne	8.3	41.5
Nontoxic waste[d]	$ 3/tonne	17,7	53.1
Total revenue			$1,097.6

a Waste quantities data from National Survey of Hazardous Waste Generators and Treatment, Storage and Disposal Facilities Regulated Under RCRA in 1981 prepared for the EPA by Westat, Inc April 1984 Waste quantity considerations

- Survey only requested top 10 waste streams so quantities based on waste type differ from total disposal quantities
- Survey results are subject to statistical reliability assumptions
- 4200000 tonnes of injected waste and 100,000 tonnes of al I other land disposed wastes were assumed to be nontoxic no hazardous waste code was explicitly assigned in data
- Generation land disposal and waste definitions may have changed since 1981

b Landfills surface Impoundments land application etc

c As defined in 40 CFR 261 24, 261 302261 33

d Wastes that are only ig n I table corrosive and /or reactive

SOURCE Office of Technology Assessment

Table 2-5.—Illustration of Applying a Waste-End Tax to Land-Disposed Waste: Degree of Hazard Based on Reportable Quantities (RQ) (waste quantities in millions of metric tons[a])

Tax category	Tax rate	Scenario 1		Scenario 2	
		Quantity[b]	Revenue ($ millions)	Quantity[b"].	Revenue ($ millions)
Land disposal[c] excluding well injection:					
RQ = 1	$50/tonne	<0.1	$ 1.5	18.0	$ 900.0
RQ > 1, ...	$10/tonne	21.1	211.0	3.0	30.0
Well injection:					
RQ = 1	$ 5/tonne	0	0	6.1	30.5
RQ > 1	$ 3/tonne	*26.1*	*78.3*	20.0	60.0
Total revenue			$291		$1,020-

a Waste quantities data from "National Survey of Hazardous Waste Generators and Treatment, Storage arid Disposal Facilities Regulated Under RCRA in 1981." prepared for the EPA by Westat, Inc., April 1984 Waste quantity considerations:
– Survey only requested top 10 waste streams so quantities based on waste type differ from total disposal quantities
— Survey results are subject to statistical reliability assumptions.
— 4,200,000 tonnes of injected waste and 100,000 tonnes of all other land disposed wastes were assumed to be RQ > 1; no hazardous waste code was explicitly assigned in data
— Generation, land disposal, and waste definitions may have changed since 1981
b Reportable quantity designations from the *Federal Register*, vol 48, No 102, May 25, 1983, proposed Rules
" Only those wastes with a proposed reportable quantity of 1
. . Wastes with a proposed reportable quantity of 1 plus wastes with presumed reportable quantity of 1 pending reassessment
c Landfills, surface impoundments, land application, etc

SOURCE. Off Ice of Technology Assessment.

ferent types of waste management can be taxed. Where judgments have been necessary, OTA has used data that reduce revenue estimates in its examples. One way to deal with estimates that might be overly optimistic and with a trend toward increasing waste reduction and shifting away from land disposal is, within limits, to steadily increase the tax rate (as California has done). For example, the tax rate for each category might be increased by 10 percent annually until some limit was reached.

Reducing the Generation of Hazardous Wastes

If a waste-end tax is successful as an economic incentive, the tax base will shrink over time as less waste is produced and as it is managed in more desirable ways. Thus, a waste-end tax to raise money for Superfund has limits. Nevertheless, the more serious the national uncontrolled site problem is perceived to be, the stronger is the reason to use an approach that will reduce the number of new uncontrolled sites. To a large degree, the need to encourage waste reduction has been better recognized by some States than by the Federal Government. A handful of States (e.g., Massachusetts, Illinois, North Carolina, and Minnesota) have started efforts to foster waste reduction, particularly by smaller companies. Most of these efforts emphasize information and technology transfer, and local technical assistance. The connection between hazardous waste reduction and the Superfund program is likely to become sharper if the program is seen more as a long-term, high-cost effort.

GOAL 2: ACCURATE ESTIMATES OF THE NATIONAL PROBLEM

The importance of accurate estimates of the national cleanup problem for planning purposes is discussed in chapter 3. Substantial risks and penalties result if the problem is underestimated; for example, if too small a future NPL is assumed, or if the future costs of impermanent cleanups are ignored, or if the costs of more permanent cleanups are underestimated. The findings in chapter 5 on future NPL sites, the case studies given in chapter 1 and elsewhere, chapter 4 on the difficulties of developing national cleanup goals, chapter 6 on the limitations of current cleanup technologies, chapter 7 on problems in implementing the

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Colorado	X			X	$2.00
Connecticut	X	X	X		$10.00
Illinois	X	X		X	$6.60
Indiana				X	$ 1.50
Iowa	X	X		X	$50.00
Kansas	X	X	X	X	$5.00
Kentucky	X	X	X		$11.00
Louisiana	X	X		X	$10.00[b]
Maine	X	X		X	$33.00
Minnesota	X		X		$70.40
Mississippi		X		X	$9.00
Missouri	X		X	X	$26.00[c]
New Hampshire	X	X	X		$36.60
New York	X	X	X		$12.00[d]
Ohio		X		X	$ 8.99[e]
South Carolina				X	$ 7.00
Tennessee		X	X		$7.00
Wisconsin				X	$0.135

a More than one tax rate may be applied to achieve per ton rate.
b Dry weight ton.
c The 2 percent charge on disposal receipts is not included.
d Higher rates may soon be implemented,
e Based on 1982 disposal charges and8 percent charge on disposal receipts

SOURCE: Office of Technology Assessment,

Table 2-3.—illustration of Applying a Hazardous Waste-End Tax by Management Activity

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a Waste quantities data from " National Survey of Hazardous Waste Generators and Treatment, Storage and Disposal Facilities Regulated Under RCRA in 1981 ," prepared for the EPA by Westat, Inc , April 1984.
b Landfills, surface impoundments, land application, etc.

SOURCE: Office of Technology Assessment,

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— Survey only requested top 10 waste streams so quantities based on waste type differ from total disposal quantities.
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– Generation, land disposal, and waste definitions may have changed since 1981.
b Landfills, surface impoundments, land application, etc.
c As defined in 40 CFR 281.24, 281.30-2261.33.
d Wastes that are only ignitable, corrosive, and/or reactive.

SOURCE: Office of Technology Assessment,

Table 2.5.—illustration of Applying a Waste-End Tax to Land-Disposed Waste: Degree of Hazard Based on Reportable Quantities (RQ) (waste quantities in millions of metric tons[a]

Tax category	Tax rate	Scenario 1 Quantity[b]	Scenario 1 Revenue ($ millions)	Scenario 2 Quantity[b].“	Scenario 2 Revenue ($ millions)
Land disposal[c] excluding well Injection:					
RQ = 1	$50/tonne	<0.1	$ 1.5	18.0	$ 900.0
RQ > 1	$10/tonne	21.1	211.0	3.0	30.0
Well injection:					
RQ = 1	$ 5/tonne	0	0		30.5
RQ > 1	$ 3/tonne	26.1	78.3	20.0	60.0
Total revenue			$291		$1,020

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– Generation, land disposal, and waste definitions may have changed since 1981.

b Reportable quantity designations from the *Federal Register,* vol. 48, No. 102, May 25, 1983, Proposed Rules.
•Only those wastes with a proposed reportable quantity of 1.
•* Wastes with a proposed reportable quantity of 1 plus wastes with presumed reportable quantity of 1 pending reassessment.

c Landfills, surface Impoundments, land application, etc.

SOURCE: Office of Technology Assessment.

ferent types of waste management can be taxed. Where judgments have been necessary, OTA has used data that reduce revenue estimates in its examples. One way to deal with estimates that might be overly optimistic and with a trend toward increasing waste reduction and shifting away from land disposal is, within limits, to steadily increase the tax rate (as California has done). For example, the tax rate for each category might be increased by 10 percent annually until some limit was reached.

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Several other aspects of using removals for redisposal merit attention. First, there is little doubt about EPA's reliance on such removals. In establishing a priority list of 31 activities for all of EPA during fiscal year 1985, the first priority is given as, "Stabilize imminent threats at uncontrolled hazardous waste sites through *Superfund removal actions.*"[12]

Second, the head of the Superfund program noted recently that with regard to the use of RCRA facilities "the requirement for inspection is not applicable to removal actions due to time constraints,"[13] However, if removal is part of a remedial action, an inspection is necessary if there has not been one within the past 12 months,

Third, in EPA's January 1985 proposal for a revised National Contingency Plan there is evidence that removal for redisposal will not necessarily be limited in the future. For example, EPA gives some examples where RCRA regulations would not be applicable which seem to ignore the basic nature of the waste: 1) a case where RCRA wastes are indiscriminantly disposed on a roadway, and 2) contaminated river beds. Apparently a waste that might be prohibited from land disposal, but which became a Superfund waste in a transportation accident or through purposeful midnight dumping, could be land disposed, and a river sediment contaminated with polychlorinated biphenyls (PCBs) could also be land disposed even though PCBs would not normally be allowed to be so managed. Finally, it is also stated that interim measures might not have to be consistent with existing standards, "If the selected remedy is not the final remedy for the site, it might be impractical or inappropriate to apply other environmental standards." This raises the possibility of Superfund wastes being taken to a RCRA facility which is not in compliance with existing regulations.

Finally, it should be noted that the States also perform a considerable number of removal actions at uncontrolled sites without the use of Superfund. Removal of wastes for redisposal is typical for small sites where hazardous materials are easily accessible from the surface, A survey of States performed for EPA found that in 1981 and 1982 for 29 responding States there were 350 immediate removals; there were 106 Federal removals for these same States in that period, and nationwide in that time there were 212 Federal immediate removals. (There are also other types of removals in the Superfund program.)

Better Use of an Improved Hazard Ranking System

Choosing the correct initial response is an important decision, which could be helped if the initial site evaluation were improved. Currently preliminary assessments, site investigations, and the Hazard Ranking System are limited to arriving at a score to determine eligibility for the NPL. There is little linkage between the initial hazard assessments and subsequent studies to decide on action at the site. If the early assessment system were improved, it could help determine the appropriate initial response more rapidly, Costly and lengthy studies could be avoided in the first part of the strategy.

[10] This conclusion about land disposal sites for Superfund wastes is supported by the analysis in chapter 5 on operating hazardous waste facilities. The recently reauthorized RCRA with its planned prohibition on the land disposal of some hazardous wastes will not necessarily eliminate redisposal. The prohibitions may not take effect for some years. EPA may also be able to grant waivers for Superfund wastes, especially for situations where it would take time to verify that the wastes were covered by RCRA prohibitions.

[11] Some companies are making considerable money from waste removals even though they themselves have been responsible parties at Superfund sites, Even though they may not have paid for cleanup, they have been funded by the government to take wastes and dispose of them and, for the Stringfellow and Seymour sites, the redisposal sites have either been shut down or fined by EPA for substantial violations of existing RCRA regulations.

[12] U.S. Environmental protection Agency, memorandum by Alvin L. Alm, "Development of Operating Year Guidance for FY 1985 and FY 1986," Nov. 2, 1983.

[13] William N. Hedeman, Jr., "The Pursuit of Consistent Decision making Under Superfund, paper presented at American Bar Association Conference, 1984.

Technical Issues

The widespread use of initial responses would raise several technical issues. To what extent can above ground temporary storage be effective? There are a variety of existing technologies to store waste in a safe and cost-effective way. For example, containerization as used in transportation and traditional storage of chemicals would be possible for small amounts of waste. Stronger materials with greater corrosion resistance have been developed for such containers. Containers can be placed in structures that are protected from the weather. For larger amounts, bulk storage in tanks, vaults, and other structures is possible. Here, too, much conventional storage technology exists in the chemical and petroleum industries,

Considerable opportunities to use offsite storage facilities, perhaps even some constructed on a regional basis to manage Superfund wastes, may be possible, Indeed, this may be necessary when there is not enough space at the NPL site. However, the use of offsite facilities raises the issue of public opposition to siting new hazardous waste management facilities, as well as problems obtaining RCRA permits for facilities, Furthermore, some States will not want to receive wastes from other States, There is no simple solution to this, but it does suggest that some initial responses may be contingent upon the State or local community providing a site or storage facility for Superfund wastes, Finally, innovative ideas are being developed for temporary storage (see chapter 6).

An associated issue is: over what length of time will storage be effective? Any container or storage structure will have some finite engineering lifetime. Generally speaking, it should be possible to safely store wastes for 5 to 20 years. Moreover, above ground storage provides the important advantage of accessibility, That is, it is relatively easy to visually inspect containers and structures to detect damage or leakage. Many types of monitoring devices are also available.

EPA could develop information on above ground storage and other initial response techniques for general use by contractors, States, and companies, Some R&D in this area might be warranted.

Another issue is waste treatment. Some hazardous materials might be treated immediately to render them as harmless as possible, Over the past several years there has been considerable unused waste treatment capacity at many facilities, Furthermore, in some cases it might be cost effective to build onsite treatment facilities immediately; regional treatment facilities serving the Superfund program are also possible, If initial responses are used for all NPL sites, it is likely that the private waste treatment industry will respond to the demand. However, this could lead to problems with siting new facilities.

The issue of determining the extent of an initial response is discussed in chapter 4. Simple generic standards could be developed to satisfy the two primary goals of these actions.

Economic Issues

The advantages of initial responses at all sites depend on keeping the the costs are kept low relative to permanent cleanup costs (see chapter 3). On average, initial responses should cost about 10 to 20 percent of permanent cleanup costs, If the cost of initial responses are too high, they would resemble the current high-cost impermanent cleanups. But if the costs are too low, the actions would be no more effective than current removal actions, As a result of examining the costs of specific technical actions (see chapter 6), OTA finds that initial response costs would probably average about $1 million per site. This is about three times greater than the costs of immediate removal actions (i.e., an average of $302,000 per action for 165 sites from December 1980 through February 1984). Impermanent remedial cleanups (consisting of initial remedial measures, surface cleanups, phase one remedial cleanups, and final remedial cleanups) typically cost from $5 million to $10 million per site, but additional costs may be incurred later.

Questions may arise concerning who is responsible for operating, maintaining, and monitoring an initial response before permanent cleanup is achieved. Since so many NPL sites are likely to receive only initial responses for some time, the public must be assured about several things: 1) that the initial response measures are effective, and that there are no significant uncertainties about their continued effectiveness over the limited period of time before cleanup, and z) that the site will receive a remedial cleanup. Therefore, a policy to assure adequate funds for each site to cover future costs may be necessary. Where possible, these could be obtained from responsible parties. Perhaps the costs of initial responses should not require matching State funds. Furthermore, an explicit program is needed to gather information on the site for remedial cleanup as is a decision making process to determine objectively the timing of the remedial cleanup.

Lastly, there are circumstances that will tend to favor the rapid use of a remedial, permanent cleanup. First, there will be some sites that are so bad that it would be unacceptable to delay permanent cleanup. Second, some responsible parties may want to resolve the cleanup cost issue as soon as possible.

Possible specific congressional actions to address Goal 3 are:

- Simplify the categories of responses to NPL sites to initial responses and remedial cleanups. Modify the statute to allow initial responses to have costs exceeding $1 million.
- Require initial responses at all NPL sites to be initiated within one year of placement on the NPL.
- Require EPA to establish simple generic standards to determine the extent of an initial response by setting goals to deal with immediate threats and to prevent the site from deteriorating.
- Require EPA to establish procedures to assure communities that sites will be selected for remedial cleanups in an equitable and objective manner.
- Direct EPA to perform an analysis of the potential demand for new storage and treatment facilities for Superfund wastes and recommend ways to address obstacles to siting and permitting these facilities.

GOAL 4: IMPLEMENTATION NEEDS OF A LONG-TERM PROGRAM

Because it is almost inevitable that Superfund will be a long-term program, Congress may wish to consider ways to improve the Superfund delivery system.

Resolve the Cleanup Goals Issue and Address Scientific Uncertainties

The discussion in chapter 4 on establishing cleanup goals demonstrates the difficulty of resolving the issue of "How clean is clean?" It appears necessary to elevate policymaking on the degree of cleanup to the statutory level and clarify the role of the Federal Government in determining levels of cleanup performed by States and responsible parties.

It is vital to obtain more information on health and environmental effects, both laboratory and epidemiological data. Without more complete information, it will be difficult to implement any approach to establish national cleanup goals and determine the magnitude of the national problem. Although it is impossible to remove all scientific uncertainty, the goal should be to steadily reduce uncertainties over time. In this regard, although cleanup actions cannot wait indefinitely, the two-part strategy does offer some opportunity to significantly improve the information base before large sums of money are spent,

Specific options for congressional consideration are:

- Establish an interagency group (e.g., EPA, Department of Interior, and the Department of Health and Human Services) to report periodically to Congress on the state of information on health and environmental effects of uncontrolled sites, gaps in the data base, and proposed means to address these deficiencies. Such an effort would benefit from the participation of people from outside the Federal Government.

- Increase spending on laboratory and field research to obtain more data on health and environmental effects,
- Direct EPA to develop and implement a classification system based on the present and future use of NPL sites to help establish cleanup goals and determine other site management priorities. Classification based on reuse, restoration, and rehabitation of the site could help determine the extent of cleanup and the applicability of health and environmental effects in the cleanup decision.
- Direct EPA to better define how the Superfund program evaluates the performance and effectiveness of remedial cleanups financed under Superfund, by the States, and by private parties, over both the short and long terms. This should include explicit attention to unintended consequences involving transfer of hazardous chemicals among environmental media, transfer of risks among populations, and residual contamination.

Technology

The results of chapter 6 on cleanup technologies support the need for greater Federal involvement in the research, development, and demonstration (RD&D) of innovative cleanup technologies. For the first 5 years of Superfund, EPA will have spent about $25 million on cleanup RD&D. Although some conventional containment, disposal, and treatment technologies will continue to be used, and may be improved, substantial opportunities exist to advance treatment technologies that are geared to the needs of cleaning uncontrolled sites. These technological advances offer the promise of permanently effective cleanups for a variety of uncontrolled site problems and, possibly, reduced cleanup costs over time.

OTA has identified a number of innovations that have advanced beyond the laboratory stage. The chief problem is that some institutional barriers stand in the way of using these innovative technologies, It is in the environmental and economic interests of the Nation to foster a competitive market for cleanup technologies. For example, currently the major alternative to land disposal and waste containment is incineration, which has a long history in the management of newly generated hazardous waste. But even though it can be effective in treating Superfund wastes, the costs are high, and regulation may be inadequate (e.g., few standards for air emissions of toxic chemicals), Other technical approaches are less familiar to the regulatory community and waste generators and face more severe obstacles to their evaluation and use.

A number of specific Federal initiatives could prove effective:

- Analyses of cost effectiveness could be directed to include: a) a clear statement of the total cleanup objectives for the site; b) a discussion of whether alternative technologies have proven capabilities or uncertainties for the application under consideration; c) a discussion of which (if any) innovative technological approaches might be demonstrated at the site and how demonstration would aid the national cleanup effort for similar sites; d) an estimate of all short- and long-term costs for each alternative which takes into account: i) uncertainties about effectiveness in meeting the cleanup objectives, and ii) the likelihood that further cleanup and corrective actions will be required; and e) a discussion of technical and economic needs and uncertainties, including institutional considerations, for long-term monitoring, operation, or maintenance of the site.
- Federal support could be substantially increased to help private companies and universities develop and demonstrate innovative permanent cleanup technologies, These are the most costly phases of technological innovation, but they are necessary to prove technical feasibility under

operating conditions and to obtain accurate cost data. Demonstrating a particular application of a new technology often requires several million dollars. The work should focus on techniques that can reduce permanent cleanup costs, A program funded at the level of perhaps $25 million to $50 million annually for some years could pay off handsomely for a long-term Superfund program. These funds would be in addition to what EPA now spends on R&D. Special attention should be given to small businesses; these firms face major problems in getting money and coping with institutional barriers, even though they often have attractive innovations. It should be noted that increased spending in this area would also benefit the RCRA program because some cleanup technologies could also treat newly generated hazardous waste.

- EPA could be directed to develop protocols by which technologies can be evaluated by the government and companies; such protocols should address different generic types of problems at uncontrolled sites (e.g., decontamination of soil, groundwater, or buildings; destruction of wastes). Without evaluation protocols, innovations struggle with the Catch-22 of not being able to prove themselves and not being used because they are not proven.
- EPA could be directed to help companies: a) obtain samples from uncontrolled sites, and b) conduct field demonstrations and pilot cleanups at NPL sites to better establish technical performance and reliability and provide more accurate estimates of actual costs. If public resistance to the use of new technologies is feared, incentives could be considered, such as a high priority for cleanup and financial support for direct citizen involvement in the cleanup effort. However, the public may be quite receptive to new technologies, provided they are kept informed and have some voice in the decisions (see chapter 8).
- EPA could be directed to develop incentives for responsible parties to use or demonstrate innovative cleanup technologies,
- EPA could be directed to provide a simplified means of determining whether residues from waste treatment operations qualify as RCRA hazardous wastes; those that are not can be disposed of simply and at low cost.
- EPA could be directed to expeditiously establish appropriate RCRA regulations for waste storage and treatment facilities of particular importance to Superfund efforts.
- EPA could be directed to expand its information and technology transfer functions and make better use of what has been and will be learned from cleanups throughout the Nation, There does not appear to be any central repository of information and insights obtained by EPA's Regions and contractors, who often repeat the similar work at different sites.

Technical Staffs, Support, and Oversight

Chapter 7 shows the need to improve the capabilities of EPA and the States to implement Superfund and, particularly, to carry out various oversight functions. EPA has a responsibility to oversee its Regions, its contractors, the States, and private parties carrying out cleanups. The States must oversee its contractors and, sometimes, local government units. Increased funding may be required. Also, more appropriately trained and experienced technical professionals are needed in a number of critical disciplines, plus an assurance that the most qualified contractors are used. Working with hazardous waste is a relatively new area and, therefore, many technical specialists do not have the specific experience with hazardous waste necessary for cleanups. For example, hydrogeologists maybe experts about the flow of water but not about the movement of contaminants, which can be much more complex.

Options for congressional consideration are:

- Provide Federal funding for training programs in disciplines of particular importance to Superfund, such as hydrogeology, toxicology, environmental engineering, and chemistry. Emphasis should be placed on continuing education and training programs to increase the pool of *experienced* specialists who know how to deal with the specific problems of hazardous waste sites. A program costing perhaps $5 million to $10 million annually for some years could yield great benefits in the long term.

- Provide increased funding, perhaps $25 million to $50 million annually, to EPA to build up its in-house professional staff and emphasize the need to carry out technical oversight. There has been a steady drain of experienced people from EPA's Superfund program to its contractors and the private sector, whose cleanup work often receives little EPA scrutiny.
- Provide direct grants to States to develop and expand their technical staff. This would be similar to the RCRA grants program. Over a period of perhaps 5 years, such grants could do much to strengthen the States' capabilities and perhaps their willingness to participate in the national program. As with the RCRA program, some formula could be devised to determine how much money a State received; for example, basing the amount on its number of sites in EPA's national inventory of uncontrolled sites, on its number of NPL sites, on the number of cleanups where it has assumed the lead role, and on its number of cleanups funded without Federal funds. Nationally, such a grants program might require from $25 million to $50 million annually. This compares to $80 million annually authorized for RCRA Subtitle C and D grants to States for fiscal year 1986 through fiscal year 1988. Total annual Federal spending on RCRA is roughly one-quarter of current annual Superfund spending.
- Direct EPA to reexamine how it selects and uses contractors and involves government agencies at Superfund sites. The performance of contractors on work already completed and underway in the Superfund program needs to be evaluated. The already rapid expansion of the Superfund program often has resulted in poor technical performance by contractors eager, but not necessarily qualified, to enter this market. Another possibility is to use a single contractor for a site, rather than a succession of contractors who each start from scratch. EPA could examine its procurement procedures and place more emphasis on technical qualifications rather than cost proposals.
- Improve the relationships between EPA and State agencies by providing more opportunities for the States to participate in decisionmaking (even though they may only be paying for 10 percent of the costs) and in policy development.

Detailed Strategic Planning

Detailed strategic planning is fundamental to any long-term program. In the case of the Superfund program, this is a particularly difficult problem because there are so many interrelated technical, social, and economic factors to consider (see chapter 3). The two-part strategy stressed in this study is not the only possible alternative strategy. Nor has OTA considered in detail the myriad problems facing implementation of any long-term strategy. If it did not wish to change Superfund now, Congress could direct EPA to submit a detailed strategy (or several options) for a long-term Superfund program. The proposal should make clear how critical decisions about the choice of sites to be cleaned are to be made, the specific criteria by which the performance of the program can be measured, and how institutional capabilities assure that funds are spent efficiently and effectively.

The inherent conflict between the current cost-effectiveness and fund-balancing provisions of the CERCLA statute must be addressed. As discussed previously, there is often an inherent conflict between what is viewed as necessary on a site-by-site basis and what is possible for the national program, What may be a cost-effective cleanup to provide maximum protection at a single uncontrolled site may be unreasonable considering the resources that are available from the national program for other sites. As the Superfund grows (even if only to the 2,0(10-site NPL envisioned by EPA), this inherent conflict will become more acute. The problem intensifies even more when costly permanent cleanups are deemed necessary for some sites, particularly for groundwater cleanup. To some degree, the current program has trapped itself. If it stressed more permanent cleanups, it could not take so many actions. It tries to get many sites into the pipeline. But the actions are ineffective and meanwhile the number of sites increases steadily. The pipeline never seems to end. Any strategic plan must address this issue and introduce objectivity and equity into decisions about the allocation of scarce resources to address many sites over time.

Public Participation

Chapter 8 supports the need to involve the public more directly in decisionmaking in all phases of the Superfund program—from site identification and selection for the NPL, to choosing an initial response and remedial cleanup, to measuring the effectiveness of the cleanup measure. Congress could consider making CERCLA more similar to other environmental statutes, such as RCRA, by mandating specific roles for the public in the decisionmaking process.

Whatever is done, however, it must be recognized that the interests of affected communities often conflict with the limits and goals of a national program. But it is possible that early and steady public participation in decisionmaking could lead to more effective site cleanup and a more effective national program. It is necessary, however, to consider whether such participation might incur delays. This potential problem could be addressed by trying to resolve conflicts equitably and expeditiously through, for example, mediation, binding arbitration, and ombudsmen. More specifically, Congress may wish to consider providing funds to communities and other groups to help them obtain independent technical expertise so, even when they lack economic and technical resources, they can fairly evaluate the technical complexity and options available to decisionmakers. Where this has been done, it has proved beneficial.

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Chapter 3

A Systems Analysis of Superfund

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Chapter 3

A Systems Analysis of Superfund

INTRODUCTION

In the Superfund program so far, more attention has been paid to short-term costs and budgets than to total program costs and program durations which can cover decades. A Superfund program designed from a short-term perspective may not be consistent with the need for long-term programs to permanently deal with the problems posed by thousands of uncontrolled hazardous waste sites. Without adequate planning, the result may be a cleanup program that extends beyond several decades, presenting uncertain and possibly serious health and environmental risks.

This chapter examines how future financial needs of the Superfund program may be assessed and what program strategy can meet these needs. A simple simulation model is presented which illustrates how cleanup *costs,* present and future, might be taken into account. The past performance of the program is considered, the uncertainty of historical costs is recognized, and alternative strategies are compared. The results indicate there will be trade-offs between program cost and the time required to mitigate the threats posed by large numbers of uncontrolled hazardous waste sites.

Finally, a two-part cleanup strategy is identified that shows promise as a sound, long-term approach to the problem, especially in the face of many uncertainties.

Current Estimates of Future Superfund Needs

Recent estimates of future financial needs of the Superfund program confirm the need for an expanded fund. The studies summarized in table 3-I estimate that the cost to clean up the Nation's uncontrolled hazardous waste sites will be substantially greater than the current fund of $1.6 billion. Their estimates range from $6 billion to $92 billion, with all but one calculating the Federal share of these costs at $5 billion to $26 billion. Only the Department of Commerce (DOC) study predicts that the current Superfund of $1.6 billion can meet requirements for cleanup. However, DOC assumed that only 546 sites would be eligible for the Fund; this estimate is already out-of-date since over 200 new sites have been proposed for listing on the current 538 site National Priority List (NPL).

Several sources of uncertainty are responsible for the wide range of estimates in table 3-1; the most important are the number of sites requiring cleanup and the costs of cleanup. Estimates for the total number of sites to be cleaned ranged from 1,400 to over 7,000. While this may appear large enough to encompass true lower and upper bounds, there is evidence to the contrary. OTA finds that a more appropriate estimate is 10,000 sites (see chapter 5), without including several categories of candidates for Superfund sites, e.g., as many as 75,000 mining wastes sites and 100,000 currently leaking underground storage tanks, projected to increase to 350,000 within the next 5 years.[1]

Similarly, estimates of cleanup costs vary a great deal, from $1 million to $30 million per site. Also, most of the predictions of total cleanup cost assumed that the worst sites, those requiring the most costly response, were captured in the current estimates of the numbers of sites. This may not be so. For example, DOC estimated that those sites not already on the NPL will cost much less to clean up than NPL sites ($3.2 million per site v. $9.7 million per

[1] Donald V. Feliciano, "Leaking Underground Storage Tanks: A Potential Environmental Problem," U.S. Library of Congress. Congressional Research Service, Jan. 11, 1984.

Table 3-1.—Current Estimates for Cleaning up Uncontrolled Hazardous Waste Sites

EPA (1 984)'	EPA (1983)[2]	GA0[3]	Department of Commerce[4]	ASTSWMO[5]	CMA[6]	National Audubon Society
Number of sites requiring cleanup:						
1,500-2,500	1,400-2,200 23-56°/0 require groundwater response	1,270-2,546 23-56°/0 require groundwater response	546 NPL 1,250 non-NPL 41 municipal	7,113 (43 States surveyed) 1,500 most serious	1,000 (27 States surveyed) 3,681 (potential)	2,200-7,000 38-56°/0 require groundwater response
Total average cleanup costs per site (million):						
$6.7 -$13.3	$6-$12 including groundwater response	$2.25-$6.75 constr. $5.25-$15.75 constr. including groundwater response $1 .5-other costs	$9.7 NPL $3.2 non-NPL $30 municipal	$1-$6 $6 serious sites	$4-$7 studies, removal, and containment $17-$30 studies, removal, containment, and groundwater response	$8 including O&M $17 including ground-water response
Total costs (unadjusted) (billion):						
$10.0 -$33.3	***$10.3 -$20.6***	***$5.6 -$33.8***	$10.5	$14.6 -$42.7	NA	$8-$92
Total costs to Fund (billion):						
$7.6-$22.7[a]	***$8.4 -$16***[b]	***$5.3-$26***[c]	(***$1.5*** surplus)-$1.5[f]	NA	$4.5[e]	NA
Projected years to clean sites:						
NA	14 for 1800 sites	NA	10-15	16-23 if constrained by personnel 28-90 if constrained financially	NA	17-26 for 2,200 sites 53-84 for 7,000 sites

NOTES
[a]Assumes 40 to 60 percent of sites cleaned b, Principal Responsible Parties (PRPs); Federal cost share is 90 percent; cost recovery is 47 percent for removals and 30 percent for remedialactions; 85 percent interest earned quarterly on previous year's balance. and 65 percent inflation on removal actions, assumed 190 per year at $75 million per year
[b]pRp lead actions deducted
[c]Assumes RPRs clean 29 to 44 percent of Sites
[d]Annual O&M costs are $3 I .500. $20,900, and $117,600 for NPL, non-NPL, and municipal Site.$ respectively
[e]Statement of E C Holmer, on behalf of th, Chemical Manufacturers Association, June 13, 1984 (This esti mate assumes no groundwater cleanup Also might include estimate that only 10 percent are orphan sites)
[f]Assumes 45 t. 55 percent cost recovery; 1 t. 15 percent of sites cleaned b, PRPs: 6,5 percent annual Construction inflation: 5 percent annual general inflation: and 85 percent annual interest on cash balances
[g]Low estimates reflect $1.2 billion per year budget; high estimates are for $1.5 billion per year budget

SOURCES
(1) U S Environmental Protection Agency, "Extent of the Hazardous Release Problem and Future Funding Needs, CERCLA Section 301(a)(l)(c) Study, " December 1964
(2) U S Environmental Protectlon Agency, Superfund Task Force Preliminary Assessment, December 1983
(3) U S General Accounting Office, EPA's Preliminary Estimates of Future Hazardous Waste Cleanup *Costs* Are *Uncertain*. GAO/RCED-64-152, May 7, 1964
(4) U S Department of Commerce "Estimated Costs and Expenditures for Cleanup of the Natlon's Uncontrolled Hazardous Waste Sites" (draft), Feb 22 1984
(5) Association of State and Territorial Solid Waste Management Of ficials. "State Cleanup Programs for Hazardous Substance Sites and Spills," Dec 21. 1964
(6) Arthur D Little, Inc , Report to the Chemical Manufacturers" Association. "An Analysis of the Number of Inactive Hazardous Waste Sites That Will Use Superfund," July 1983
(7) National Audubon Society, Testimony of Leslie Dach before the House Subcommittee on Commerce, Transportation and Tourism, Mar 1, 1984

site), However, the Environmental Protection Agency's (EPA] recently released list of proposed NPL sites contains contaminated aquifers on the island of Oahu. Although this is only one very expensive site, it suggests that other large contaminated aquifers might be addressed by Superfund in the future.

All the studies share one common assumption in their cost estimates, however—a complete effectiveness of cleanup technology. This leads to some critical questions:

1. Should the effectiveness of cleanup technologies be considered in evaluating cleanup costs and program planning?
2. Is the assumption that these technologies are completely effective, warranted, and, if not, how should cost predictions be changed?
3, How certain are the "givens" of these predictions, namely continued use of historical cleanup technologies in the future program?

UNCERTAINTY AND THE NEED TO EVALUATE THE SUPERFUND PROGRAM

The Superfund program was established in response to an emergency situation of uncertain proportions. Both the threats and the measures to control hazardous waste sites were uncertain, but Congress decided that action was imperative. Little attention to uncontrolled toxic waste sites existed at the State level. Precedents existed for legislating and developing regulatory programs in difficult areas. Indeed, the preamble to the Resource Conservation and Recovery Act (RCRA) states that "the courts have repeatedly sanctioned . . , other EPA statutes where, as here, the Agency is implementing a complex program in an area 'fraught with scientific uncertainty where Congress has directed EPA to act quickly and decisively despite the lack of exact data'. "[2]

To resolve the many uncertainties, Congress mandated several information-gathering tasks in the Superfund legislation, such as:

- the designation of additional hazardous substances; s
- the development of notification procedures for hazardous substance spills;[4]
- the identification of all possible hazardous waste sites;[5]
- the collection of information about hazardous substances at those sites for preliminary assessments;[6]
- the establishment of the Agency for Toxic Substances and Disease Registry to establish and maintain: a) a national registry of serious diseases and illnesses and a national registry of persons exposed to toxic substances, b) an inventory of information of health effects of toxic substances, c) listing of areas closed to public or restricted in use because of contamination, and d) programs to study the relationships between exposure to toxic substances and illness; p and
- reports and studies on the experience with the implementation of the Superfund program, including one to project "any future funding need remaining after the expiration of authority" and another to determine "the extent to which the Act and Fund are effective . . ."[8]

The uncertainties and complexities connected with releases of hazardous substances are also reflected in the National Contingency Plan (NCP), which outlines the regulatory mechanisms for Federal response to these re-

[2]45 Federal Register 33088.
WE RCLA, Section 102(a),
[4]1 bid., Section 103(a),
[5]Ibid.

[6]Ibid., Section 104(e).
[7]1 bid., Section 104(i).
[8]Ibid., Section 301(a)(1).

leases. Throughout the preamble to the modified NCP, including the comments section, there is explicit mention of the need for flexibility in program design.[9] In part, the need for flexibility reflects the site-specific nature of the release and appropriate response. But flexibility was also built into the NCP "to incorporate our expanding knowledge and experience in developing remedies."[10]

In conclusion, there were both legislative and regulatory motivations to address uncertainty. In particular, Congress mandated EPA to evaluate effectiveness and project future financing requirements, and EPA, in the NCP, acknowledged the need to continue to develop and improve its program, Evaluating the effectiveness of cleanup approaches is a key step in meeting these congressional mandates.

Alternative Approaches to Projecting Superfund Needs

Projecting future funding needs of the Superfund program can be approached in two ways. A descriptive approach was used in making the estimates summarized in table 3-I. This approach assumes that the program will, for the most part, continue to operate as it has historically, using the same methods for selecting sites for remediation and implementing the same cleanup technologies. An average cost of cleanup is derived from historical data, perhaps subject to various rates of inflation. Next, the expected number of sites requiring remediation is estimated, again relying largely on examinations of past and current information, The percentage of sites requiring response in the past is applied to an updated universe of potential sites. A range of values may be assumed for these parameters, to reflect sampling errors or the inherent problems of projection, Future funding needs are determined by multiplying the estimate for average cleanup cost and the number of sites to be cleaned.

An alternative method of prediction is *prescriptive,* incorporating new information as well as historical experience, It proposes and evaluates a number of cleanup strategies, not limited to those used in the past. Each strategy is then compared to the others on the basis of evaluation criteria and a preferable strategy is selected, The cost of the preferred strategy provides projections for fund requirements, as mandated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The best way to evaluate the usefulness of the descriptive method, which is based on past practices, is to look at the historical performance of the Superfund program. If the program has been operating at an acceptable level of efficiency and effectiveness, if uncertainties in cost are adequately accounted for, and/or if no other alternatives exist, then the descriptive method is acceptable. The analysis below indicates that none of these conditions exists.

Historical Performance of the Superfund Program

As of September 30, 1984, the Emergency and Remedial Response Information System (ERRIS), the inventory of uncontrolled hazardous substance sites from which NPL sites are selected, contained 18,900 sites. EPA anticipates that the list will grow to between 22,000 and 25,000 sites.[11] Preliminary assessments had been conducted at 10,700 sites and site inspections completed at 3,600 sites.[12] Of the 1,700 sites scored with EPA's Hazard Ranking System, 538 have been selected for the National Priority List and an additional 238 sites have been proposed for listing.[13]

The first 2½ years of the Superfund program progressed slowly, but the pace has accelerated since May 1983. At the end of fiscal year 1982, 57 removal actions at both NPL and non-NPL sites had been initiated; after 2 more years, a total of 422 had been started. Of this total, only 17 were planned removal actions.[14]

[9] 47 Federal Register 31180-31202.
[10] 47 Federal Register 31182.

[11] U. S. Environmental Protection Agency, "Extent of the Hazardous Release Problem and Future Funding Needs, CERCLA Section 301(a)(l)(C) Study" (Washington, DC: Office of Solid Waste and Emergency Response, December 1984).
[12] Ibid.
[13] Ibid.
[14] U.S. Environmental Protection Agency, "The Effectiveness of the Superfund Program, CERCLA Section 301(a) (1)(A) Study" (Washington, DC: Office of Emergency and Remedial Response, December 1984). These statistics include CERCLA-financed, enforcement-lead, and responsible party actions.

The remedial aspects of the program, which pertain to long-term cleanups, are occurring more slowly. By the end of fiscal year 1982 only about 60 remedial investigation and feasibility studies (RI/FS) had been initiated; but by the end of fiscal year 1984, 315 RI/FSs had been started.[15] Remedial design has begun on 56 sites. Six sites have been designated as clean. Of the remedial cleanup actions currently underway or approved, most responses have been removal of hazardous materials for offsite disposal, or onsite containment, or both. Table 3-2 summarizes remedial actions taken for 24 sites.[16]

The institutional framework for responding to uncontrolled sites is in place. Despite initial problems, the program is beginning to operate more swiftly and smoothly. Many more sites have moved into the RI/FS and design study stages, As more studies are completed, more sites will move into the construction phase. However, only 30 percent of the 538 sites now on the NPL are receiving remedial cleanup attention.

It is also necessary to understand what is being done, and what the implications of current actions are for the future. Most of the cleanup actions approved so far involve removal and/or excavation, followed by offsite disposal. Although the facilities where Superfund wastes are taken are regulated under RCRA, these regulations do not assure detection and prevention of groundwater contamination. There is a strong likelihood that a number of RCRA facilities may become Superfund sites, some might even be able to qualify as Superfund sites now, and some already have.

This issue is examined in more depth in chapter 5 and leads to the conclusions that *removal followed by disposal is not an effective or efficient cleanup option, environmentally or economically,* unless removed wastes are destroyed, detoxified, treated, or stabilized in some fashion prior to redisposal.

Without the measures just specified, offsite removal will probably only relocate the hazard and transfer the risk. Furthermore, offsite removal usually leaves some (often considerable) residual surface waste in the form of contaminated soil that can threaten groundwater. Offsite removal does not address problems of groundwater already contaminated at the site. While partial cleanups have been common, source control and containment have also been used after removal to address groundwater problems, While the short-term costs of these remedial methods often compare favorably with other options, their long-term effectiveness can be greatly limited by site conditions, such as hydrogeology, rainfall, and geomorphology.[17]

Another response to groundwater contamination is to provide an alternative drinking water supply. (Note that water for other uses, such as bathing, often is not supplied even though health effects may be significant.) Sometimes this response is appropriate, for example when the alternate water is easily accessible and not too costly and when the affected population is not large. However, with groundwater now providing 50 percent of the Nation's drinking water, this can be a viable long-term alternative for only a limited number of sites. It is not an alternative for large populations. There is a limit to how many aquifers can be foresaken.

The groundwater problem is receiving attention; EPA has recently established an Office of

[15] Ibid.
[16] Ibid.

[17] The experience at the Stringfellow Acid Pits illustrates many of the problems that can arise with continued use of containment (see chapter 1],

Table 3-2.—Summary of Remedial Cleanup Actions Approved

Cleanup actions approved	Number of decisions
Removal/offsite disposal with or without source control	14
Removal/offsite disposal with some incineration	1
Alternative water supply	3
Alternative water supply with treatment	2
Treatment (1 aeration; 1 air-stripping)	2
Source control and onsite treatment	2

SOURCE: U.S. Environmental Protection Agency, "The Effectiveness of the Superfund program, CERCLA Section 301(a) (1)(A) December 1984

Groundwater and developed a groundwater protection strategy.[18] The EPA has also acknowledged that groundwater contamination at Superfund sites has not yet been extensively addressed. When it is addressed, it will greatly increase the cost of the program,

The performance of cleanup actions during the last 4 years of the Superfund program do not support the use of the descriptive method for predicting future costs. The approved actions are weighted heavily in favor of least-cost options that are available now. While they are often called proven, the long-term effectiveness of these options is highly uncertain, and they may be ineffective even in the short term. The total costs of cleanup using these technologies are not accurately represented by the sum of their construction costs and first year operating and maintenance costs, On the contrary, these options are likely to prove costly in the long term. Additional remedial measures at the original sites or at other redisposal sites may be required as a consequence of the original cleanup technology decisions. In a sense an environmental deficit is created for future generations.

The final consideration is whether new, more efficient technologies exist or can be developed. The descriptive prediction method, relying on historical cleanup decisions, assumes little technological change or improvement. OTA has found that there are substantial opportunities to develop permanent, cost-effective cleanup technologies (see chapter 6). Many innovative cleanup technologies, ranging from methods of biological and chemical treatment to thermal destruction show great promise, but their development and demonstration are hampered by several institutional problems, including the fact that the Superfund program has not recognized their potential long-term cost effectiveness.

Thus, when the state of knowledge is considered, coupled with the experiences of the program and the potential for new technologies, it is clear that projections of the costs of the Superfund program must be based on:

- a comparison of alternative strategies; and
- future development, demonstration, and use of innovative, permanent cleanup technologies,

The desirability of defining a preferred long-term strategy becomes greater as evidence accumulates that many more sites may need cleanup. The long-term costs of traditional cleanup technologies, possibly acceptable with a relatively small number of sites, grows burdensome as the number of sites rises–with the number going as high as 2,000, 10,000, or more, Policy and planning decisions based mostly on low short-term costs may hamper program progress, if site after site deteriorates and must be recleaned, and as still more sites are discovered, Under such conditions, the total cost and time required to fulfill the Superfund mandate may become unacceptable to society,

The need to reevaluate and perhaps define a new program strategy is not a new concept. It was suggested by William Hedeman, EPA's Superfund chief:

> And it seems to me that the more fundamental question that has to be asked is whether or not the program and the structure and statutory base that has been established thus far to deal with this problem is really the most sensible way to go. Whether indeed we don't have as much of a national problem in the area of abandoned hazardous waste as we had in the 1930s and 40s in terms of flood control, or as we had in the 1970s with contaminated air and contaminated water? And we haven't inadvertently set into motion a system with a problem that is so convoluted and complex and difficult to manage that it could collapse of its own weight rather than accomplishing the results that were ever intended?[19]

[18] For more information see U.S. Congress, Office of Technology Assessment, *Protecting the Nation Groundwater From Contamination*, OTA-O-233 (Washington, DC: U.S. Government Printing Office, October 1984).

[19] "A Conversation With Superfund Chief Bill Hedeman," *The Environmental Forum*, August 1983.

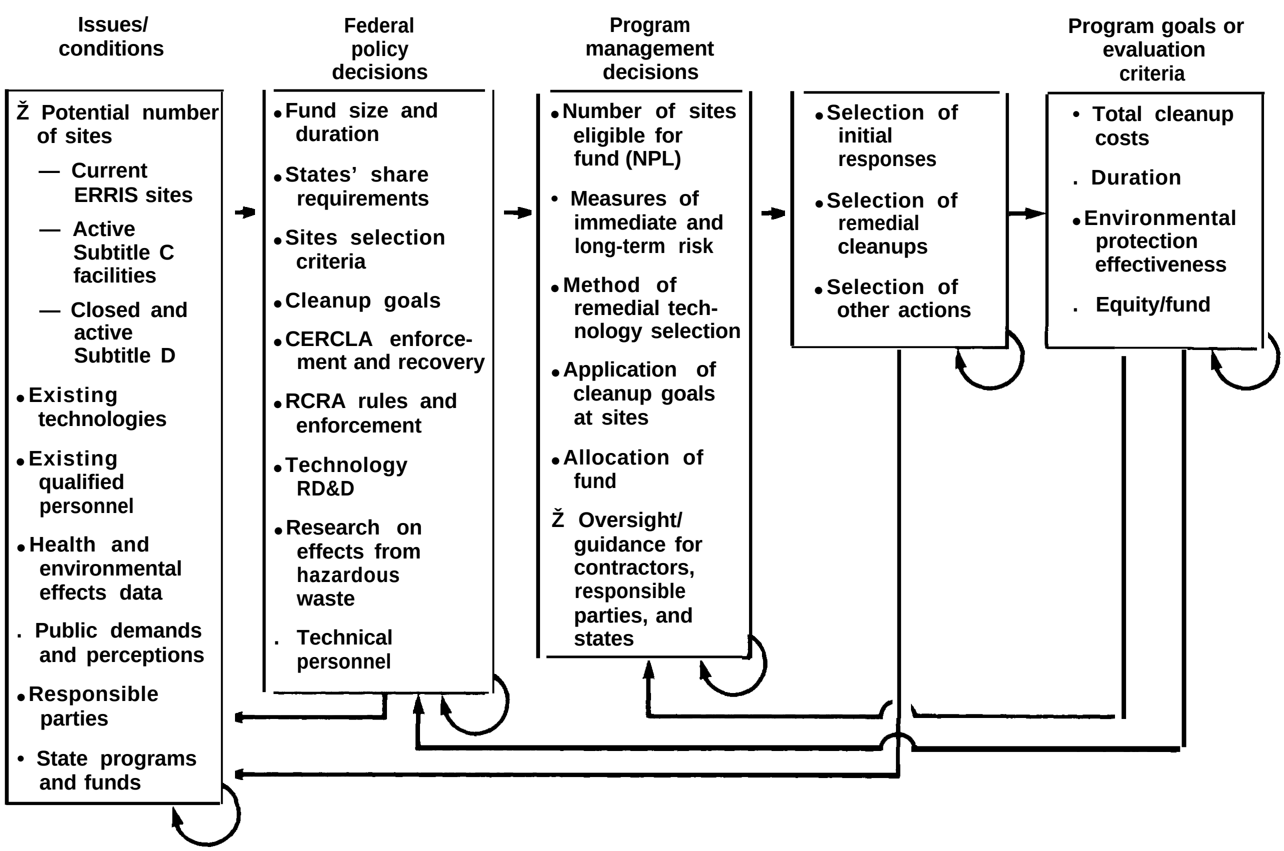
A SYSTEMS ANALYSIS APPROACH TO DEFINE A LONG-TERM STRATEGIC PLAN

Has the current Superfund program "inadvertently set into motion a system with a problem that is so convoluted and complex and difficult to manage that it could collapse of its own weight rather than accomplishing the results that were . . . intended?" The critical step toward developing a better program strategy is to realize that, in fact, the Superfund program, with its response mechanisms for threats posed by uncontrolled hazardous waste sites, is a complex system,

The Superfund system can be viewed as a series of interacting issues, conditions, and decisions. The mechanics of the system are depicted in figure 3-1. The primary inputs are listed in the box labeled issues/conditions. These include the potential number of Superfund sites, public demands and perceptions about the threats posed by these sites, and the technologies available to deal with them. All of these components affect Federal policy decisions.

Superfund policy decisions at the Federal level define an upper limit on the resources to manage the problem, provide the framework for management, and set the goals of the program, Furthermore, Federal policy dictates what sites are eligible for consideration. For

Figure 3.1.—Superfund System



SOURCE: Off Ice of Technology Assessment instance, EPA has decided that sites with only environmental problems, which do not pose threats to human health, do not now qualify for Superfund attention, The Hazard Ranking System has no component to account for natural resource damages that do not affect human health directly. Even though Congress did not establish this policy, it did limit resources for the program.

In addition, non-Superfund policy decisions may influence the Superfund program, For example, policy changes in the RCRA program for hazardous and solid waste land disposal facilities may alter the frequency at which new Superfund sites enter the pool, depending on improvements in prevention, detection, and correction of leaks and groundwater contamination. Federal policy also affects how the financial requirements placed on the States might affect the cleanup of facilities. Many sites may fall into the 50 percent State matching share category.

Broad Federal policies are eventually translated into a program strategy via program management policies. Management decisions on ranking criteria and methodology determine which sites are included on the NPL. Program management policies also govern the allocation of resources to eligible sites and define which cleanup technologies are employed. These decisions are extremely complex because they, too, entail many interdependencies and interactions. For example, cleanup technology decisions are dependent not only on what technologies are available and at what cost, but also on the availability of funds and qualified personnel, the nature of cleanup goals, and the threats posed by uncontrolled hazardous waste sites. Management decisions by *EPA define the scope and form the strategy, even if unintentionally, of the cleanup program.*

The resultant program strategy may in turn lead to secondary, long-term consequences that also affect the system, The remedial actions alter the risks associated with the remediated sites but, if they are not wholly effective, they may impose future costs and risks. Decisions to remove and dispose of waste offsite may pose threats at other sites, which, in turn, may result in further demands on Superfund resources. Thus, current program decisions affect future system inputs and needs. The historical emphasis in the Superfund program has been on detailed site-by-site analyses, with little, if any, analysis of intersite effects. This is one reason why responses have usually entailed offsite disposal. *But cleanup on a site-by-site basis is not necessarily an effective national cleanup.* Considering each uncontrolled site independently may also lead to inconsistency; sites posing similar risks in different locations may be dealt with differently. Moreover, the long-term effects of all the interactions may not be obvious unless viewed systematically.

The complexity of the Superfund program suggests that projections of needs or changes of the program strategy should be tackled in a systems framework, using the discipline of systems analysis, With the interdependencies and interactions defined, program strategies can be evaluated more objectively and thoroughly,

Definition of Goals

An obvious Superfund objective is to minimize the cost of cleaning up uncontrolled sites. This goal raises an interesting question, namely, costs to whom? Focusing only on the costs to the Fund can lead to distortions. For instance, long-term operating and maintenance (O&M) costs are the States' responsibility. Concern with only the costs to the Fund, therefore, might emphasize cleanup technologies with lower capital costs even if the total cleanup costs will ultimately be very high (and higher than other options) because of high operating and maintenance costs. Although the current methodology used in feasibility studies for selecting remedial action does deal with O&M costs, three points should be made. First, funding estimates currently include only the initial year of O&M costs regardless of estimates made in the feasibility studies. Second, the feasibility studies often choose optimistic estimates despite limited experience with the O&M costs of the remedial technology options, Furthermore, limited experience with the application of the current technology options to hazardous waste problems coupled with undue concern about short-term costs might lead to technology decisions that fail to accomplish a long-term, permanent remedy,

Thus, to prevent distortions, all expenditures—from the Fund, from the States, and from responsible parties—must be included in the estimate of total long-term costs. This approach is highly flexible. In considering alternative or additional goals, the costs to specific parties can be derived, assumed, or compared *after* preferred solutions to the problem are generated, and the results can affect the criteria for the next iteration on the solutions.

If minimizing cleanup costs were the only goal, the solution would be to do nothing at zero cost. The goal that forces the program to operate is maximizing effectiveness in protecting human health and the environment. In the CERCLA 301(a)(l)(A) study, effectiveness is related to the "Government's ability to respond to and mitigate the effects of releases of hazardous substances, " This implies that effectiveness is the avoidance or mitigation of risks to health *and* the environment. This is the congressional mandate.

One CERCLA provision specifies that remedial actions are to be chosen that:

> . . . provide for that cost-effective response which provides a balance between the need for protection of public health and welfare and the environment at the facility under consideration and the availability of amounts from the Fund .. .[20]

According to this provision, cleanup actions are supposed to be cost effective and, at the same time, the Fund is to be allocated in a balanced fashion nationwide. The cost effectiveness criterion could be viewed as total program cost effectiveness as well as site-specific cost effectiveness. However, if affected by real or perceived budget limitations, choosing what appears to be the most cost-effective way of dealing with each site individually could reduce the cost effectiveness of the national system. *The analysis in this chapter addresses the problem of how to simulataneously achieve site and national cost effectiveness.*

The fund-balancing requirement raises a complex issue of equity, costs, and effectiveness. Furthermore, without a *reliable measure of effectiveness*, there is no way to determine whether a particular Superfund strategy is cost effective, nor can adherence to the fund-balancing provision be evaluated (see chapter 4).

Another goal that has received limited attention is minimizing *the time required to complete the program.* This goal is reflected in the idea of a mandatory cleanup schedule. The longer a site remains uncontrolled, the greater the risk may be. The risks may be the same each year and simply accumulate or they might increase over time as leaching progresses and as contaminants migrate further into the environment.

Whether or not total program length is a valid measure for risk, the public perceives it as such. For this reason, a Superfund program that emphasizes permanent cleanup actions might still pose problems if it left sites, and their affected communities, waiting for cleanup for extended lengths of time (e. g., beyond 50 years). Program length defines the planning horizon for the program and, therefore, the period over which the costs and benefits of each program strategy should be evaluated. The effects of excluding longer term costs in the planning horizon may be dramatic, as shown later in this chapter,

Such goals—proper accounting of costs over time, effective cleanup, and timeliness—can be used to evaluate different Superfund program strategies and choose among them. Because Federal and program management policies determine the cleanup strategy, the evaluation process can elucidate how these policies affect the performance of the strategy. Understanding the system dynamics can help to define how Federal policy and program management policy might change to improve program performance.

[20]CERLA, Section 104(c)(4)

Simulation: A Systems Analysis Method for Comparing Two Strategies and Incorporating Long-Term Uncertainty

Systems analysis can be used for simulation—a model that mimics events occurring in the real system. In the context of the Superfund program, the primary event is a cleanup action. A wide range of policy and management decisions may alter the numbers, types, and rates of occurrence of the responses. These decisions can be tested using simulation for their effects on the performance of the system, In the discussion that follows, the objective is to evaluate the effects of the uncertainty in costs on program duration *after* a first site response and on total program costs under different program cleanup strategies.

Future Costs and an Impermanence Factor

The importance of examining the *effects of uncertain and unforeseen future costs* associated with a site cleanup cannot be overstated. As has been shown, effects of uncertainty about long-term costs of cleanup technologies have not been considered to any great extent, despite evidence that the technologies typically employed today may incur total costs significantly in excess of their short-term costs. Program planning based on short-term costs may result not only in an unexpectedly costly program, but in one that lasts over a very long time. It *is* particularly *important to evaluate the effects of uncertainty on long-term cleanup costs before more money is spent on costly remedial cleanups*.

An "impermanence factor" is defined to reflect the uncertainty of near-term cost estimates for response. Additional future costs, above the near-term costs of "impermanent" actions, may be incurred due to the need for additional actions, or operating and maintenance costs, or compensation for health and environmental damage. How the impermanence factor is integrated into the model differs according to the cleanup strategy chosen.

Program Cleanup Strategies

Two *extreme* cleanup strategies are examined. These *interim* and *permanent* strategies are useful as boundary conditions, clarifying the importance of certain cleanup strategies toward which the actual Superfund program could move. A third strategy, a variation of the permanent strategy and representative of the two-part plan described in chapters 1 and 2 is also analyzed.

In the interim strategy, successive interim actions, which are not permanent, are taken. Future costs are incurred and are a function of the impermanence factor and the cost of interim cleanup, In the basic permanent strategy, initial actions (with technologies and costs the same as the interim actions of the interim strategy) are undertaken for the first 15 years of the program. Like the interim responses, initial actions are impermanent, but no site receives a second impermanent action. After 15 years, cost-effective permanent technologies are assumed available; permanent cleanups are then performed on all sites, both those never responded to and those requiring a second action because of a previous impermanent action. Explicit in this strategy is the concept of concerted but limited *initial actions* with plans for *long-term permanent cleanup*. Future costs in this strategy are a function of the impermanence factor (from the early responses) and the costs of permanent cleanups.

Under the two-part cleanup strategy, less costly, impermanent initial actions are performed (only once) on all NPL sites until permanent cleanups are cost effective and available. As in the basic permanent strategy, after the 15-year development period, permanent actions are mandatory. In this variation, a larger number of initial actions are taken, but they are less extensive, less expensive actions, thus preserving funds for developing and implementing permanent cleanup plans. This strategy is discussed later; the model description will focus on the two primary strategies.

Model Description

In OTA's simulation model actions are undertaken annually; a particular class of actions—interim or initial—incurs future costs depending on the degree of impermanence and the distribution of costs over time.

The usefulness of the model lies not in projecting actual Superfund program costs or Superfund program duration, but rather in understanding the dynamics of the system under uncertainty. The model tells us what might happen. To correctly interpret the results of the model, the elements that characterize the system must be understood. In this modeling exercise, these elements fall into two categories: 1) system definitions and assumptions, and 2) uncertain elements to be tested.

The values of system definitions and assumptions are specified and are not varied. This is done because their behaviors and values are known with relative certainty, or the uncertainty inherent in them is not suspected to influence the aspects of the system being tested, or the effects of the uncertainty can be easily intuited. Table 3-3 summarizes the system definitions and assumptions of the model. The system definitions, such as how the budget is allocated among the different sites, relate to the system as a whole. The assumptions about parameters relate to specific cleanup actions.

The first definition given in table 3-3 is the number of uncontrolled sites eligible for the Federal fund; this figure changes as the NPL is revised periodically. Parameters such as cleanup costs and appropriate cleanup technology differed enough to warrant dividing the sites into two categories: those with only surface contamination and those with both surface and groundwater contamination. This breakdown, and the costs for each class of site, correspond to early estimates by EPA.[21] The cleanup costs, $6 million for a surface cleanup and $12 million including groundwater remedial action, include only the short-term costs of those remedial technology actions currently used. These costs, therefore, are the average costs of interim responses. The model conservatively estimates that 20 percent of the sites would require groundwater response, although more than three-quarters of NPL sites have groundwater problems,

A method of allocating a fixed annual budget (or total, unadjusted costs to all parties) to the sites is also defined. The annual budgets are distributed to surface and groundwater responses so that the same percentage of each type of site is addressed. This allocation method may be overly optimistic with regards to the attention that groundwater has received historically.[22]

Table 3.3.—System Definitions and Assumptions (not varied in model)

System definitions:
- 546 sites currently (initially) eligible for Superfund money
- Two categories of sites:
  - —Sites with only surface contamination
  - —Sites requiring groundwater response and surface response
- 20°/0 of sites eligible for Fund use require groundwater response[a]
- Each annual budget is distributed between surface and groundwater responses so that the same percentage of sites of each type are responded to annually

Assumptions about parameters to be held constant:
- Average interim action costs (estimates of currently used technologies)[b] (for interim strategy and initial action of the basic permanent strategy):
  - –$6 million/site for surface response only
  - —$1 2 million/site including groundwater response
- Average initial action costs (for two-part strategy only):
  - –$1 million/site for surface response only
  - —$3 million/site including groundwater response
- Time required to complete actions:
  - —3 years: Interim surface response
  - —6 years: Interim groundwater response
  - —3 years: Permanent surface cleanup
  - —10 years: Permanent groundwater cleanup

a 56 percent of the N PL sites exhibited groundwater contamination but only 23 percent were estimated to require treatment (U S Environmental Protect Ion Agency, *Superfund Task Force Preliminary Assessment,* Dec 8,1984) Ground water releases have been recorded at 75 percent of the N PL sites For NPL sites where releases have not yet occurred 90 percent had potential ground water release scores over 15 and 70 percent had scores over 30 out of 45 These data suggest that this is a very conservative estimate

bA average cleanup cost of about $9 million was given in the 301(a)(l)(C) study This figure was for all types of cleanup actions (over 13 types) not accounting for States' shares, recovery and voluntary cleanup This estimate corresponds to a 50 percent rate of sites requiring groundwater cleanup

SOURCE Off Ice of Technology Assessment

21 U.S. Environmental Protection Agency, *Superfund Task Force Preliminary Assessment,* Dec. 8, 1983.

22 A statistical analysis performed on those sites for which monies were obligated prior to mid-1 983 revealed that sites with higher levels of groundwater contamination, as reflected by their HRS scores, bore a negative relationship with Fund-financed actions, See Harold C. Barnett. "The Allocation of Superfund, 1980-1 983, " Department of Economics, University of Rhode Island.

Only two NPL sites now have an active remedial program for contaminated groundwater.

Finally, because the program length is an evaluation criterion, certain assumptions about time are made. It has been estimated that the average remedial response takes 3 years to complete.[23] Since surface responses provide most of the experience, this estimate is increased to 6 years for groundwater actions. These estimates are for interim actions. Since no *permanent* cleanup has been implemented, its duration is speculative. It is assumed that permanent surface cleanups take 3 years to complete, and permanent cleanups of groundwater contamination take 10 years.

For those elements of the system that are ill-defined, different options are tested for their effects on the system. A simulation scenario is defined by choosing one option for each element. These choices are summarized in table 3-4.

Because this model could not consider site-specific data on risk and fund balancing, only total program cost and total program length are examined in any detail. Undiscounted total costs are used, but later an analysis of discounting is presented, While some of the following findings are deductive, others refer directly to particular results from the scenarios tested. Complete scenario results are given in the appendix to this chapter, along with a more detailed examination of the model.

The Interim Strategy

The primary element of uncertainty to be tested is the cleanup strategy, The interim strategy assumes no permanent cleanup technology is used; thus all cleanups are interim actions and their short-term costs do not represent the total costs of dealing with the site or the wastes. Use of interim responses implies the need for involved operation and maintenance (O&M), the costs of which have not been included in the short-term costs, The possibility of subsequent and repetitive remedial actions involving additional future costs and additional O&M costs also are not included, Interim actions include offsite disposal of wastes and contaminated materials, and traditional onsite control and containment techniques.

To capture future costs, the impermanence factor is used. This factor is itself uncertain, so values for the factor between O and 1 are tested in different scenarios. The impermanence factor averages the future costs of all interim actions over the whole system. (Note that the future costs of interim actions may vary

Table 3-4.—Summary of Simulation Scenarios (choose one from each element of uncertainty)[a]

Element of uncertainty: Options

Cleanup strategy:
- Interim strategy— Interim actions result in repeated future costs.
- Permanent strategy—An interim action during the first 15 years results in a future cost, which is a permanent cleanup. Permanent cleanups start after 15 years and result in no future costs themselves.
- Two-part strategy —Less costly initial response only (not more than once per site) over first 15 years. Afterwards, if required, a permanent cleanup with no future costs.

Future costs of impermanent cleanup actions:
Impermanence factor varied between O and 1.

Average permanent cleanup costs:
1. $24 M—surface cleanup
   $60 M—groundwater cleanup
2. $12 M—surface cleanup
   $30 M–groundwater cleanup

Time distribution of future cleanup actions:
- **U.** Future actions occur *uniformly* **over** 30 years after an interim action.
- E. Future actions occur *ear/y,* i.e., 5 years after an interim action.
- L. Future actions occur *late,* i.e., 30 years after an interim action,

Budget:
- A. Initial period (5 yr) budget is $1.6B; growth @ 100°/0 each successive period.
- B. Initial period (5 yr) budget is $1.6B; growth @ 10°/0 each successive period.
- C. Initial period (5 yr) budget is $9B; growth @ 30°/0 each successive period.
- D. Each period (5 yr) budget is $9B.
- S. Initial period (5 yr) budget is $5B; growth @ 100°/0 for each of next 3 periods then @ 20°/0 for each successive period.

Number of new sites per year for the first 15 years:
- **0.0**
- F. 100
- M. ***200***
- ***G. 200*** for years 1-5; 800 for years 6-10; and 1,000 for years 11-15.

[a] For example, scenario 1UAF has the following values option for average permanent cleanup costs, option U for time distribution of future cleanup actions, option A for budget, and option F for the number of new sites per year The scenario is run for both strategies, the Interim and Permanent, and the impermanence factor is varied in both strategies between zero and one

SOURCE. Office of Technology Assessment

[23] "Extent of the Hazardous Release Problem and Future Funding Needs, CERCLA Section 301(a)(1)(C) Study, ' op. cit.

widely among the individual responses, but this model can deal only with averages.) An illustration of how an average impermanence factor might be derived from various cleanup actions is given in table 3-5.

The average impermanence factor can be interpreted in a number of ways. To illustrate one interpretation, suppose each initial interim surface response, costing $6 million, has an impermanence factor of 50 percent (0.50). Then the second action required for *each* interim action will cost only $3 million per site. But this second action will also be interim, and therefore will result in a third response, at half the cost of the second, and so on. The result is a decreasing geometric series with a finite sum. That is, each interim action requires another interim action, whose cost is related to the cost of the previous action by the impermanence factor. In other words, the sites slowly approach cleanliness, or the repeated cleanup process finally becomes effective.

The second way to interpret the impermanence factor is that an interim action only has a *probability* of requiring another interim action. If required, the future action will have the same unit response cost. An impermanence factor of 50 percent (0.50], in this case, would mean that half of all interim actions require an additional interim action, In other words, out of 100 initial interim actions performed at a cost of **$6** million per site, 50 interim actions will be required at the same unit cost, These in turn will result in 25 interim actions and so forth. (As before, cleanup of the system of sites slowly becomes effective.) More complicated interpretations that explicitly incorporate long-term operating and maintenance costs could also be constructed. However, the model may underestimate such costs since they are represented as decreasing with time for impermanence factors less than 1.

Another uncertainty is the timing of future costs. Because the program ends when the expenditures stop, it is necessary to investigate a number of alternatives. One option is that the future costs of an interim action occur uniformly over 30 years after completing the action. The other options are that the future costs occur every 5 years or every 30 years, choices which represent optimistic and pessimistic estimates of the time over which interim responses are effective. (Note that interim actions are performed over time, so that the entire program lasts substantially beyond 30 years.)

The Permanent Strategy

For the permanent cleanup strategy, the model assumes that permanent remedial technologies for all types of site problems will be available in 15 years. (Some are available now.)

Table 3-5.— Illustration of How an Average Impermance Factor of 0.5 Might Arise

Cleanup actions: Type	Cleanup actions: Percent	Potential source of future cost	Sites incurring future costs: Percent[a]	Sites incurring future costs: Impermanence factor	Contribution to average impermanence factor
Partial removal (off site disposal)	10	• Future action at disposal site • Future action onsite	50	2.0	010
Partial removal (offsite disposal) plus onsite containment	40	• Future action at disposal site • Future action onsite • High O&M costs	30	1,5	0.18
Onsite containment	*20*	• Future action onsite	75	1,0	0.15
Onsite containment/treatment . . .	*20*	• High O&M costs	50	0.5	0.05
Alternative water supply or relocation of residents	10	• Future action onsite	20	1.0	*0.02*
			Average impermanence factor		0.50

[a]Remai rider of sites have a zero Impermanence factor

SOURCE Off Ice of Technology Assessment

Technologies that might fall into this class are discussed in chapter 6. Under this strategy, permanent cleanups become not only available but mandatory after 15 years. During the first 15 years only initial actions where an impermanence factor is applicable are used, but no future impermanent actions may follow, only future permanent actions. The number of initial actions depends on funding during the first 15 years. Therefore, the effect of different budget levels is tested. When the permanent cleanups become available, they are used on sites that have never been treated as well as sites that received initial responses. The 15-year period simulates the time needed to develop and demonstrate more cost-effective permanent cleanup technologies, as well as other efforts to improve institutional capabilities (see chapters 1 and 2).

Models and Reality

Systems models have been used in a variety of disciplines to aid in planning and decisionmaking. Some models are dependent on natural phenomena that are easily quantifiable; this facilitates the analysis of model results. Other models cannot be easily verified because they depend on difficult-to-measure phenomena, such as behavior. The strategies modeled in this analysis are of the latter type. Other models could have been chosen. Some might define the concept of impermanence differently; others might have modeled impermanence in a more complex way. To effectively use models, it is important to understand their assumptions and limitations.

A basic assumption of the interim strategy is that there is no learning from experience. This assumption leads to drastic results, As the system's average impermanence factor approaches the value 1, total program costs and duration approach infinity, The model does not represent reality at average impermanence factors of 1 or greater; in reality, program costs cannot approach infinity. The program costs may become very large, but in reality decisions will be made to stop the program—any program—from approaching infinity. The interim strategy does, however, represent a boundary condition for what the future could be. The lack of an explicit long-term strategic plan for the uncontrolled site problem, and the continued emphasis on remedial actions with substantial unforeseen future costs suggest that the interim strategy approximates current reality. The purpose of the modeling exercise is to compare a strategy that emphasizes seemingly more expensive cleanups that have low or highly predictable future costs (modeled here as zero) with one that follows the historical path. Even without such a plan, the cleanup program will evolve and improve, but how long will the process take and what will be the costs? The interim strategy gives insights into these questions by addressing the costs of not learning fast enough from experience,

USE OF MODEL AND FINDINGS

OTA has used its model to perform an analysis of Superfund, not to attempt to design a program. Thus, it is only meant to be illustrative. Other models could be devised. Following are examples of how OTA's model can be used as an aid to decisionmaking and the findings that it generates in terms of program costs and duration, Various scenarios under both the interim and permanent strategies are compared and a variation of a permanent strategy (representing the two-part strategy proposed in chapters 1 and 2) is illustrated. [24]

Question: Is it possible that after taking an interim cleanup action, each additional future interim cleanup action will cost as much or more? That is, can a given class of interim

[24] Detailed information on all components of OTA's model, the mathematical formulations, and how the results were generated can he found in the appendix to this chapter,

cleanup technologies have an impermanence factor of *1* or greater? What would happen in the long term under an interim cleanup strategy if this were true?

Findings: The experience of the Superfund program to date, although limited, suggests that it is possible that second interim actions can cost as much or more than the first interim responses.[25]

If only interim cleanup technologies are available and if each additional interim action costs as much or more than the first, the total undiscounted program cost will be infinite and the program will continue indefinitely (unless terminated). It is unlikely that this would be the case for all sites, but repeated, expensive, ineffective cleanup at even a few sites could have serious consequences for the program.

Another possibility, however unlikely, should also be mentioned: an interim technology might accomplish little besides dispersing the contamination, This might be appropriate at some sites. Eventually, with extensive dispersion, hazardous concentrations might become low enough to be regarded as acceptable or the toxic substances might degrade. If this occurred, an interim cleanup strategy with an impermanence factor of 1 or greater might result in finite program cleanup costs and length. However, attempts at isolating hazardous wastes would have to be abandoned and society would have to accept the health risks that were present *before* very low concentrations of hazardous substances were attained, Furthermore, dispersion might increase exposure.

[25]For instance, at Stringfellow an interim remedial action was taken to prevent overflow of contaminated liquid into the community of Glen Avon. The action increased the capacity of the site from about 4 million to 8.2 million gallons. However, this also "Increased the driving potential for contaminants in the residual sludges and pond alluvium to leach into the underlying groundwater. Furthermore, the addition of lime and kiln dust to neutralize materials at the site increased the volume of contaminated soil. For these and other reasons, further cleanup at Stringfellow will exceed the costs of the first interim action, (George J Trezek, "Engineering Case Study of the Stringfellow Superfund Sites," contractor study prepared for the office of Technology Assessment, August 1984,]

Question: Will an interim cleanup strategy always lead to infinite program costs and length?

Findings: As long as the average impermanence factor is less than 1, the total cost and duration of the program will be finite because additional future costs will decrease over time. Consider a case when the impermanence factors for both interim surface and interim groundwater cleanup are 5 percent **(0.05).** The first interim surface cleanups cost $6 million per site. Under the assumption that future actions are required, 5 years after each interim action, the second cleanups average **$300,000** per site. Ten years after the first action, the additional costs will be$15,OOO per site, and after **15** years, only $750 per site. So after **15 years,** for all practical purposes, a permanent cleanup will have been achieved by a series of four interim cleanups at a total cost of slightly over **$6,300,000** per site. Similarly, the long-term undiscounted average cost per groundwater cleanup would be about *$12,600,000.*

These two costs can be thought of as the per site interim cleanup costs adjusted for future costs. Just as the cost of cleanup for one site is finite, the total cleanup costs for all sites requiring remedial action are also finite. The time it will take to complete the program also will be finite but will be determined by several factors, which will be explored later. Furthermore, depending on the costs of permanent cleanups and preferences on program length, an interim cleanup strategy might be the preferred strategy.

Question: Based on evaluation criteria of total program cost (to all sources, not just Superfund) and program length, under what conditions would the interim cleanup strategy be preferable to the permanent cleanup strategy?

Findings: Many of the assumptions listed in table 3-3 may affect the values of these two evaluation criteria. But it is primarily the average costs of an interim cleanup technology class and permanent cleanup technology class, and the impermanence factor (signifying the level of future costs) that determine total program cost and length. For example:

- Under some conditions the interim cleanup strategy is clearly preferable: when future costs of interim cleanups are very low (i.e., impermanence factors are very low), and the cost of permanent cleanups is high compared to the cost of interim cleanup. If health and environmental risks do not exist or are small, it makes sense not to spend money to develop and use permanent cleanup technologies because the interim strategy costs less and the program progresses about as quickly.
- Under other conditions, the permanent strategy is preferable, Even when the costs of interim cleanups adjusted for future costs are equal to the costs of permanent technologies, the interim strategy progresses more slowly than the permanent strategy, Because greater health and environmental risks may be incurred with the longer program, the permanent strategy is preferred.
- When the adjusted interim cleanup costs are higher than the costs of permanent cleanups, program costs under the interim strategy skyrocket *and* the program progresses much more slowly. Total long-term costs and risks would be minimized by devoting resources to the development and use of permanent cleanup technologies.
- If the adjusted costs of interim cleanups are moderately lower than those of permanent cleanups, there will be trade-offs between program cost and duration; the permanent strategy will cost more but progress more rapidly, Strategy decisions would have to be made based on other criteria, most importantly the reduction or avoidance of risk, which would favor the permanent strategy.

Figures 3-2a and 3-2b illustrate how the impermanence factor influences program cleanup costs and the time to initiate 90 percent of the work[26] under each strategy, according to Scenario 1UAF. (See table 3-4 for scenario specific at ions.)

With an impermanence factor of 15 percent **(0,15),** the program length under each strategy is the same. However, at this impermanence factor the total program cost under the interim strategy is about $18 billion, considerably less than about $32 billion under the permanent strategy, Under Scenario 1UAF, then, for impermanence factors less than or equal to the relatively low value of about 0.15, the interim cleanup strategy is preferable in terms of total program cost and program length.

In contrast, in Scenario 1UAF, when the impermanence factor reaches 0.76, the total costs of both strategies are equal, but the interim strategy leads to a much longer—probably unacceptably longer—program, Cleanup takes several decades with the permanent cleanup strategy, but well over 100 years with the interim strategy, For impermanence factors above **0,76,** the interim cleanup strategy costs rise rapidly; the cost, as well as the program duration become highly unfavorable.

In the range of impermanence factors between 0.15 and 0.76, choices must be made between program cleanup cost and program length, For example, at 0.5 the permanent strategy costs $50.8 billion; under the interim strategy it is only $29.5 billion. The program length under the interim strategy is, however, **83** years, about double that of the permanent strategy (41 years), The trade-off between program duration and cost is **$507** million for each year the program is shortened. If it were worth $507 million per year to eliminate the risks in the entire system (an average of only several hun-

[26] For impermanence factors less than 1.(), the interi m strategy represents a decay process. Thus, a progress percentile must be used to measure program duration. The progress percentile of 90 percent, used in the findings, is the number of years after the start of the program to initiate 90 percent of all the cleanup actions ultimately required. Results for progress percentiles are found in the appendix,

Figure 3-2a.— Program Length v. Impermanence Factor
Scenario 1UAF

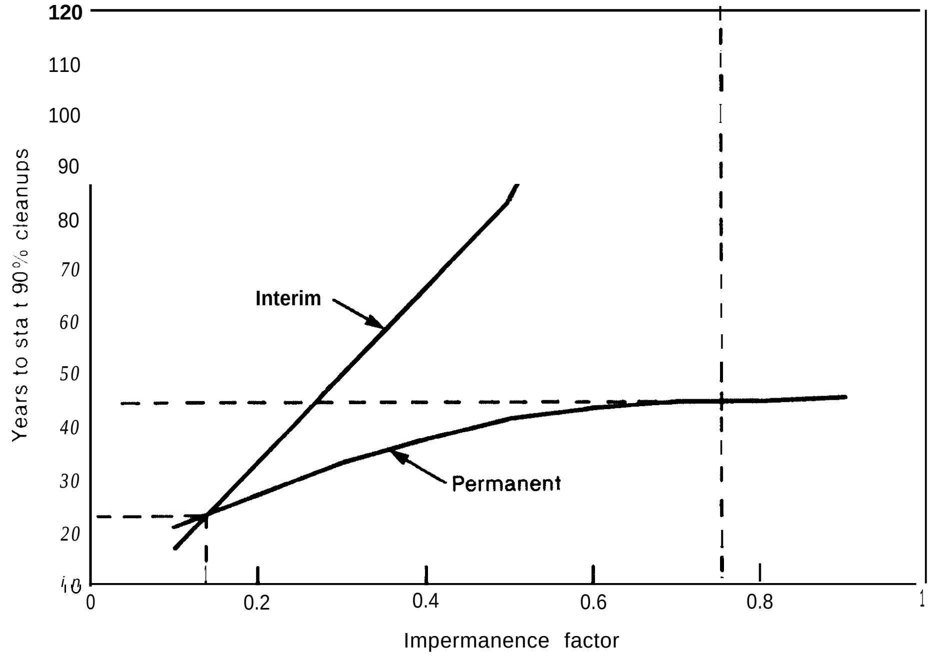


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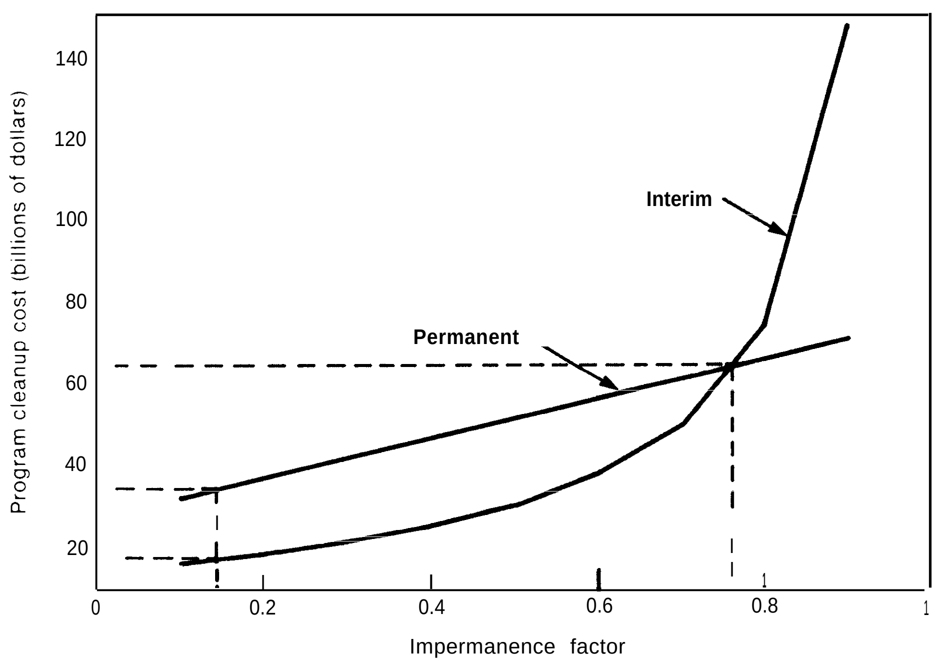
Figure 3-2b.– Program Cost v. Impermanence Factor
Scenario 1UAF



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dred thousand dollars per site per year), then the permanent strategy would be preferred. Knowing the risk consequences of interim cleanups is important to an intelligent program selection.

In general, as the impermanence factor rises, the cost advantage of the interim strategy (dollars saved for each additional program year) shrinks (see table 3-6). If 50 years is judged, for example, to be the longest program the public is likely to accept, then in Scenario 1UAF the permanent strategy is always preferred for impermanence factors greater than 0.3.

Knowledge about actual future costs is vital to understanding the relative benefits of the different strategies. As it becomes clearer that certain cleanup technologies are impermanent (e.g., containment and land disposal), then the economic and environmental advantages of developing and using permanent cleanups become clearer. Only with low impermanence factors is the interim strategy advantageous.

Question: Since the costs of permanent technologies are quite speculative, how would program strategy preferences change if the average costs of the permanent technologies changed?

Findings: If the costs of permanent cleanups were to decrease, as might happen over time with experience or improvement, the permanent cleanup strategy is preferred to the interim cleanup strategy over a wider range of impermanence factors. The impermanence factor at which the costs of both strategies is equal drops, narrowing the trade-off range. In Scenario 2UAF, the cost of a permanent surface cleanup averages $12 million (versus $24 million per site as in Scenario 1UAF) and the cost of a permanent groundwater cleanup is $30 million (versus $60 million). The results of Scenario 2UAF are given in figures 3-3a and 3-3b. The point where costs are equal drops to slightly below 0.53, compared to 0.76 in Scenario 1UAF (see figures 3-2a and 3-2 b). Additionally, where trade-offs occur (impermanence factors between 0.1 and 0.53), the penalty for choosing the permanent strategy, higher program cost, is reduced.

This static analysis of two different sets of permanent costs can be extrapolated to understand the effects of permanent cleanup costs decreasing as the program gains experience (i.e., the "learning curve" effect). As cost-effective permanent technologies are used more, program costs and duration both decrease.

The opposite may occur. If the cost of the permanent cleanups were higher than anticipated, the interim strategy would be preferred over a broader range of impermanence factors and the differences in the costs of the two programs over the trade-off range would be larger.

Certainly as the costs of permanent cleanups decline, the permanent strategy becomes more appealing. If, however, permanent cleanups costs are underestimated, there is a risk of incorrectly choosing the permanent strategy.

Question: How does the budget affect cleanup strategy decisions and the evaluation criteria values under each strategy?

Table 3-6.–Scenario 1UAF

	Average impermanence factor						
	0.1	0.3	0.5	0.6	0.7	0.8	0.9
Interim *strategy:*							
Program cost (in billions)	$16.4	$21.0	$29.5	$36.8	$49.1	$73.7	$147.3
Program duration[a] (years).	17	49	83	113	>140	>140	>140
Permanent strategy:							
Program cost (in billions)	$31.4	$41.1	$50.8	$55.6	$60.5	$65.3	$70.2
Program duration[a] (years).	21				44	44	45
Trade-off [b] ($ B/year)		$1.256	$0.507	$0.269	<$0.119		

[a]Measured by the time to start 90 percent Of the cleanup work
[b]Only applied in range where tradeoffs occur

SOURCE Off Ice of Technology Assessment

Figure 3-3a. —Program Length v. Impermanence Factor
Scenario 2UAF

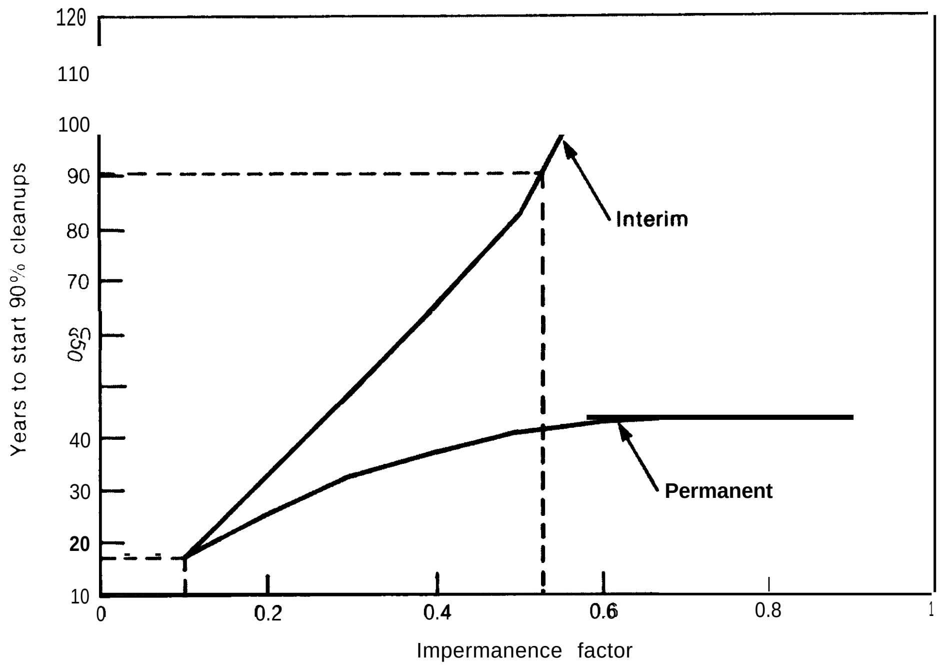

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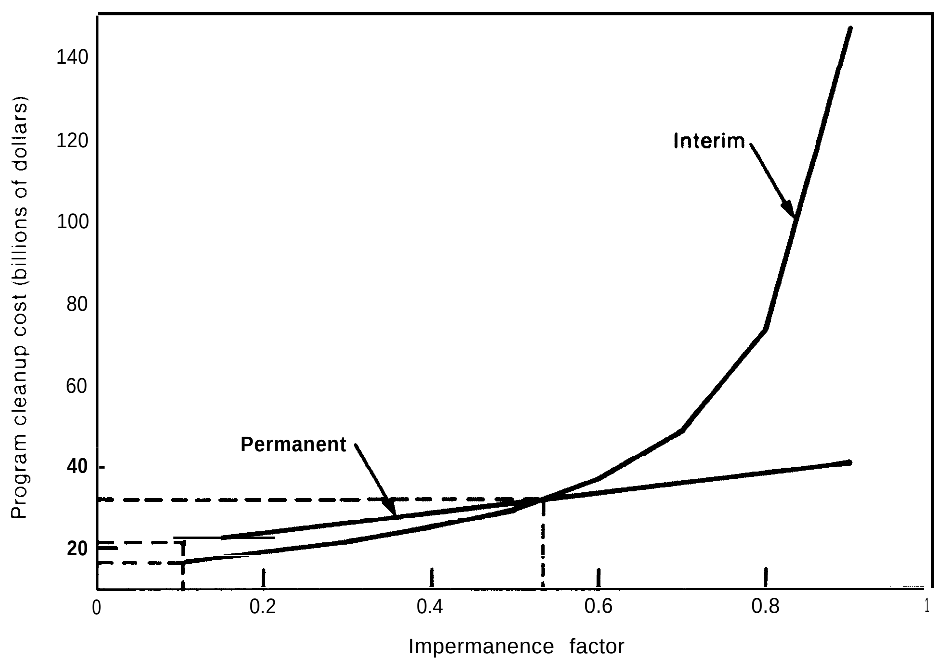
Figure 3-3b .—Program Cost v. Impermanence Factor
Scenario 2UAF



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Findings: The size of the budget (for all revenue sources, not just Superfund) devoted to cleanup activity influences cleanup strategy decisions differently,” depending on the level of the future costs of impermanent cleanups. *Inadequate budgets can bias selection toward the interim strategy and increase long-term risks from cleanups.*

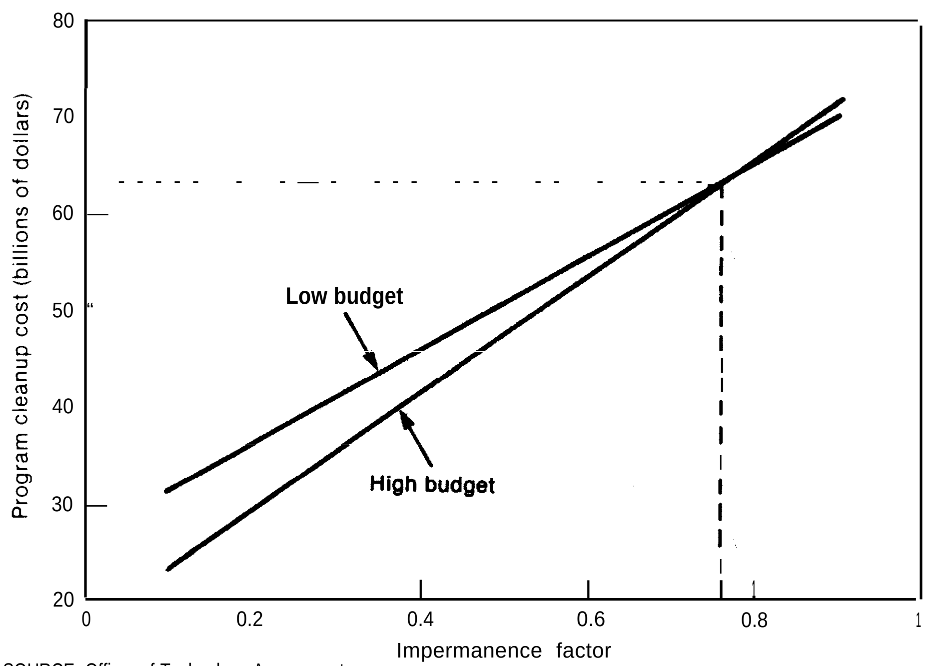
If the adjusted costs of interim cleanups are equal to or greater than the permanent cleanup costs, *then the less spent on interim cleanups when permanent technologies are being developed, the greater the program savings.*

First, consider the permanent strategy. During the first 15 years, only initial actions are undertaken. A higher budget during the early years of the program permits more initial actions and therefore results in greater total costs, The program costs under the permanent cleanup strategy with two different budget levels are compared in figure 3-4. Over the range of impermanence factors where the permanent strategy has the lower cost, program costs are greater for the larger budget scenario (Scenario 1UCF) than for the more limited budget scenario (Scenario 1UAF). While this suggests that no initial actions be taken if future costs are very high, recall that there are no explicit risk criteria in this model. It may be necessary to take some interim actions to mitigate risk when no permanent cleanup technology is available, or to consider other options, such as relocation of residents.

Now compare the interim strategy and the permanent strategy, If the adjusted costs of interim cleanups are less than those of permanent cleanups, more confidence is needed about low levels of future cost before a larger budget is devoted to interim cleanups. This makes sense: *it is desirable to be more certain about the effectiveness of a particular cleanup strategy before more money is invested in it.* The effect of increasing the annual budget is demonstrated by comparing Scenarios 1UAF (low budget) and 1UCF (high budget) in figures 3-2a and 2b and 3-5a and 5b. As the budget is increased, the interim cleanup strategy leads

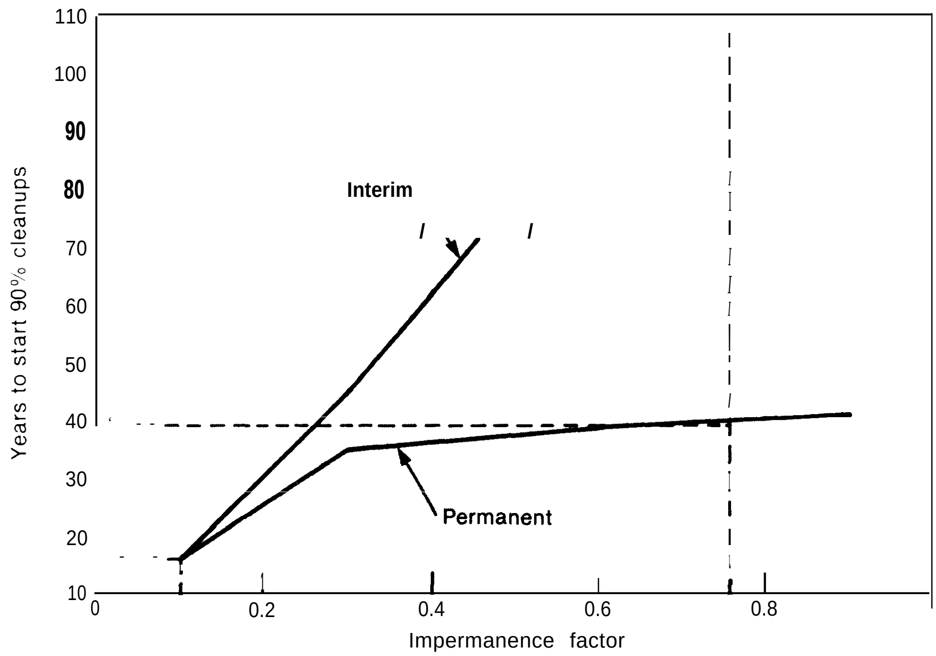
[27]Note that even though the budget continues to grow (for all options but D) through the duration of the program, after time, not all the available budget is used. Since future actions are taken only as required, as they taper off, less and less money is required.

Figure 3-4.— Program Cost v. Impermanence Factor
Permanent Strategy (Scenario 1UAF & 1UCF)



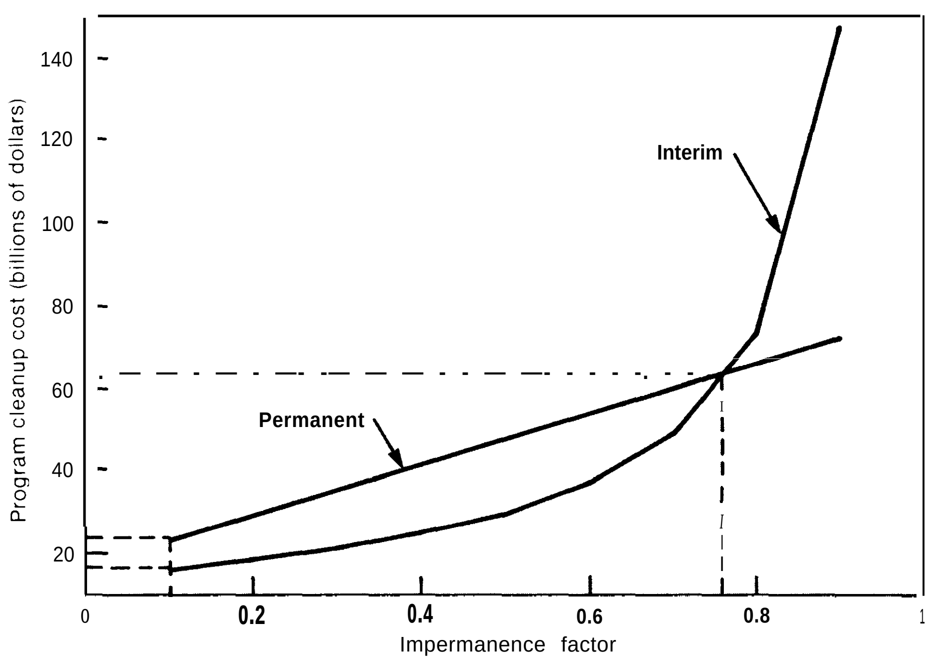
SOURCE :Office of Technology Assessment

Figure 3-5a.— Program Length v. Impermanence Factor
Scenario 1UCF



SOURCE Off Ice of Technology Assessment

Figure 3-5b.—Program Cost v. Impermanence Factor
Scenario 1UCF



SOURCE Off Ice of Technology Assessment

to a shorter program over a narrower range of impermanence factors: up to 0.15 for the low budget scenario versus up to 0.10 for the high budget scenario. The downward shift occurs because the program duration is reduced under both strategies as the budget increases.

Thus, an increased annual budget can affect cleanup strategy decisions. Similarly, reducing the annual budget also can affect the strategy decisions. In particular, *a lower annual budget (e.g., lower spending by Superfund and responsible parties) makes the interim cleanup strategy appear attractive over a wider range of future cost levels.*

Spending less on unproven technologies is a logical way to conduct cleanups where many uncertainties exist. However, this approach to strategy selection does not eliminate the uncertainty of future costs or risks resulting from program delay and inaction—it only minimizes potentially ineffective expenditures. It does not assure that the real future costs be reasonable or that the interim strategy is preferable. Furthermore, limiting this type of spending may hamper the cleanup program. Therefore, pressures to limit expenditures on cleanup *together with uncertainty resolution or alternative planning* would be preferable. One answer is to use the two-part strategy, as discussed below.

Question: Will a substantial increase in the number of sites affect cleanup strategy decisions?

Findings: As chapter 5 points out the number of sites that will require cleanup is uncertain. An increase in the number of sites will obviously increase program costs and duration; in addition, increasing the number of sites to be cleaned up exaggerates some of the above findings, Most notably, *increasing the number of sites without a comparable increase in the budget has the same effect as a more constrained budget.* The consequence is that the interim cleanup strategy is preferred, with more uncertainty in future costs (i.e., over a wider range of impermanence factors).

The program length under the interim cleanup strategy is more sensitive to the time distribution of the required future actions than to budget constraints. The converse is true of program duration under the permanent cleanup strategy; program length will be extended primarily due to budget constraints. Therefore, *an interim cleanup strategy can be made to appear more attractive than the permanent strategy by not providing enough money fast enough.*

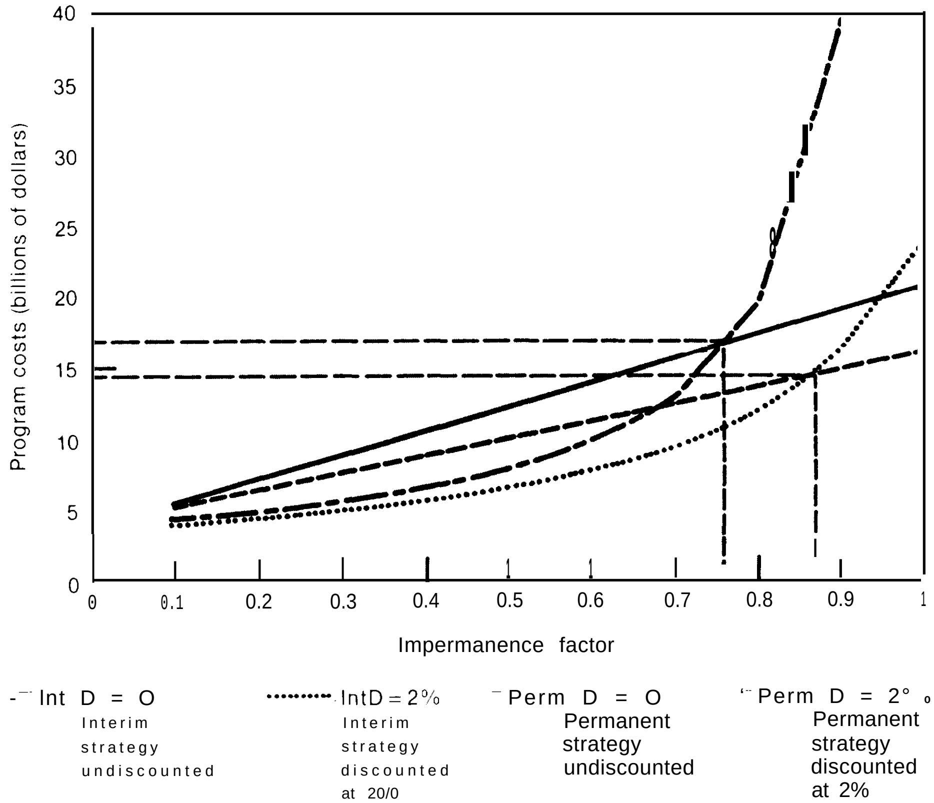
Question: How would discounting future costs affect cleanup strategy decisions?

Findings: Discounting places more weight on near-term costs and less on long-term costs. For both the interim and permanent cleanup strategies, as the impermanence factor increases, long-term costs become greater and are stretched over longer periods of time. Therefore, as impermanence increases, discounting reduces the program cost. Under the interim cleanup strategy, impermanent actions continue through the course of the program; however, under the permanent strategy, future costs result only from impermanent actions taken in the first 15 years. For this reason, the interim strategy has greater costs occurring later in the program. Thus, *program cleanup costs under the interim strategy are more sensitive to discounting than are program costs under the permanent strategy.*

Low and moderate discount rates affect strategy decisions by increasing the trade-off range between the two strategies, The application of a 2 percent per year discount rate to Scenario 1ECO is illustrated in figure 3-6. The trade-off range is extended because the impermanence factor at which the present value of both the program costs is equal is shifted higher (from 0.76 to over 0.85). Even though the range of impermanence factors over which the permanent strategy costs less is shortened, the program duration remains high so long that choosing the interim strategy is difficult to justify,

As higher discount rates are applied, a decisionmaker becomes indifferent to the two strategies in terms of cost and prefers the permanent strategy because of its shorter length. At a 10 percent per year discount rate, both strategies become almost insensitive to future cost levels. Figure 3-7 illustrates a 10 percent discount rate applied to Scenario 1ECO. Because the two cleanup strategies are similar over the

Figure 3-6. —Program Costs v. Impermanence
Undiscounted and discounted costs (Scenario 1ECO)



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first 15 years, at very high discount rates the present value of both program costs do not differ by much. Costs incurred beyond year 15 contribute little to the present value cleanup costs of either program. At high discount rates, the permanent strategy is preferred because it provides a much shorter program,

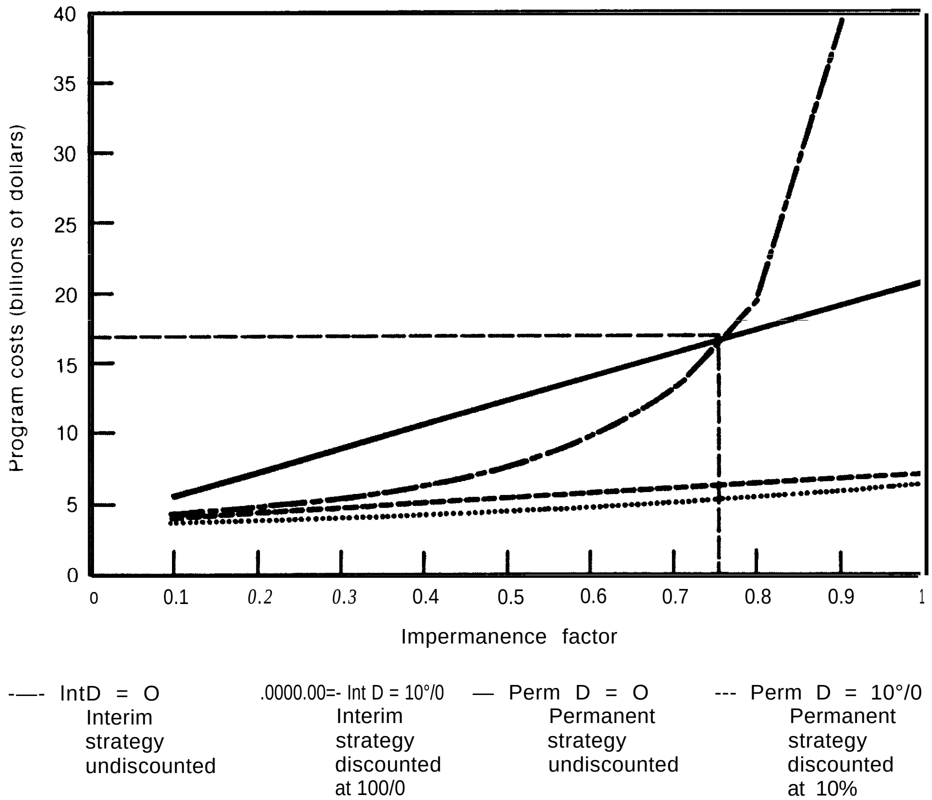
This application of discounting is limited to program evaluation, It helps make long-term strategic decisions. With this model, the strategic decisions made with discounted future costs generally are the same as those with undiscounted costs; preference for the interim strategy occurs only with certain and low future costs. No useful information for year-by-year financial planning is generated. Furthermore, to accurately identify the total costs of the cleanup program, other factors such as inflation and interest earned on cash balances, would have to be considered.

A Two-Part Strategy

What are the implications of these comparisons between interim versus permanent cleanup strategies for a variation of the permanent strategy with *initial responses at all NPL sites* (representing the two-part strategy described in chapters 1 and 2)?

Under the two-part strategy, technologies similar to those defined as interim technologies would be used for lower cost initial responses than those considered in the basic permanent strategy, Initial responses are not designed to be effective for long periods. The purpose of this cheaper, more limited response is to prevent sites from getting worse, and to control near-term releases of hazardous substances into the environment and, hence, exposures to them. Low-cost initial responses are one part of interim, impermanent approaches now be-

Figure 3-7.—Program Costs v. Impermanence
Undiscounted and discounted costs (Scenario 1ECO)



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ing described as cleanups. Low-cost initial responses could include pumping to contain plumes of contamination in aquifers, covers to keep out water, excavation and *temporary* storage of wastes and contaminated soil above ground (greatly reducing the use of below ground barriers), and environmental monitoring. In contrast to the current immediate removals, more money would be spent and removal of wastes to operating land disposal sites would be avoided.

A strategy of low-cost initial responses would achieve rapid risk reduction at many sites, thereby responding in an equitable manner to public demands for protection and visible progress. OTA's modeling, however, suggests that the costs of initial responses should be low (about 10 percent of permanent cleanup costs), and that they should be followed not by other impermanent responses, but rather by a permanently effective response. In this strategy the conservative assumption is made that 90 percent of all sites will need a permanent cleanup; that is, 10 percent of the initial responses will subsequently be found to be sufficient.

In this variation of the permanent strategy the costs of initial responses are: $1 million per site for surface response and $3 million per site to initially respond to groundwater contamination, Additionally, to examine the effect of many more sites, after all sites are discovered, 10,546 sites are to be cleaned and a higher budget is allocated. (Table 3-4 defines Scenario

1USG.) This variation was compared with the interim cleanup strategy under the same scenario.

The results are illustrated in figures 3-8a and 3-8b. They show that at an assumed impermanence factor of 0.9, the total program cost of the two-part strategy is about $310 billion. At an impermanence factor of about 0.73 in the interim strategy, the two strategies have the same program cost ($310 billion).

The two-part strategy is preferable to the interim strategy on the grounds of program duration, except for impermanence factors under about 0.25. If the impermanence of the interim responses is greater than 0.73, then the two-part strategy is preferred both in terms of total cost and program duration. When total program costs are the same for both strategies, the interim strategy results in an unacceptably long program (longer than 100 years).

Strategy decisions between the two-part strategy and the interim strategy are interestingly altered if high discount rates are used. With very high discount rates, the present value of program cleanup costs under either strategy become insensitive to the impermanence of the cleanup response. The costs incurred in the earliest years of the program determine the (present value) program cost. However, since initial actions are less costly than interim actions, with high *discount rates* the two-part strategy will result in lower discounted program costs, in addition to shorter programs, than the interim cleanup strategy. If there is sufficient justification for a high discount rate, then the two-part strategy with low-cost initial responses is preferable over all levels of impermanence.

In summary, the two-part strategy used initial (and emergency] responses as a first priority for allocating program resources, with remaining funds spent on permanent cleanups at sites that have been "isolated, " "decontrolled," or "stabilized." Exactly how funds would be allocated (the order of actions and cleanups) under this third strategy considering budget, qualified personnel, and technology constraints is an extremely difficult problem. Its solution depends on the resolution of the cleanup goals issue (see chapter 4) and a systematic approach to the problem that illuminates trade-offs.

CONCLUSIONS: PROGRAM PLANNING UNDER UNCERTAINTY

The results of the simulation exercise indicate that cleanup costs and program duration show a high degree of sensitivity to a number of uncertain factors. The potential effects of planning without considering these uncertainties also can be derived from the simulation findings. The probability of adverse effects of uncertainties could be limited in a carefully planned program, Table 3-7 presents the sources of uncertainties in the Superfund program as identified by OTA, the dangers posed by planning without considering them, and offers options to mitigate their adverse effects.

Effectiveness and the Future Cost of Cleanups

A primary element of uncertainty is *the* effectiveness of the cleanup responses and their future costs. OTA's findings indicate that *it is desirable to develop, demonstrate, and use permanent cleanups if the effectiveness of the interim cleanup and its future costs are uncertain. The interim cleanup strategy is preferred only if future costs are known to be small,* This is because the interim strategy results in an extremely long program (despite an advantage in total cleanup cost) for a wide range of interim

Figure 3-8a.—Program Length v. Impermanence Factor
Scenario 1USG

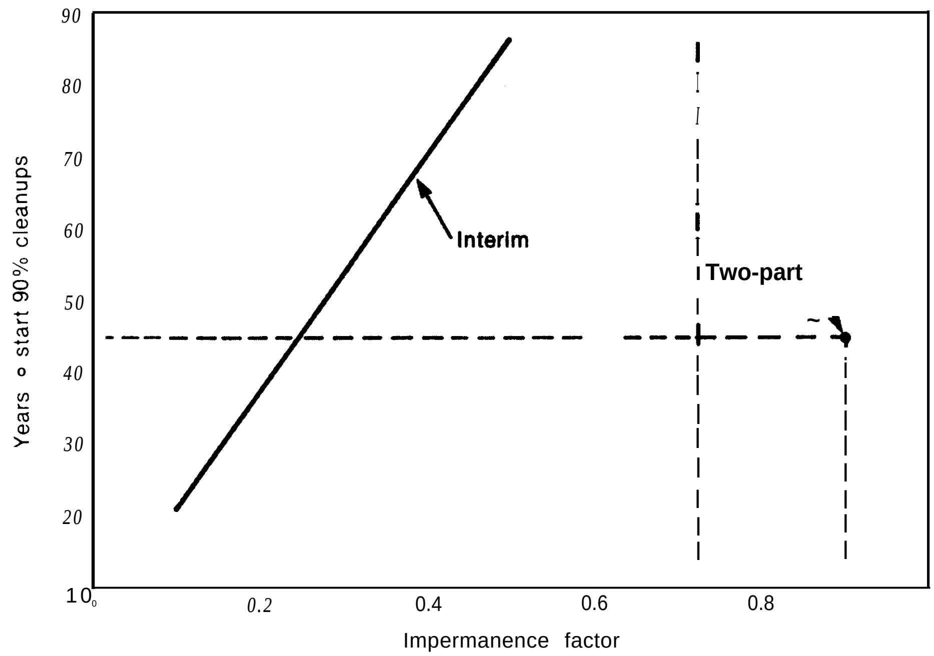

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Figure 3-8b.—Program Cost v. Impermanence Factor
Scenario 1USG

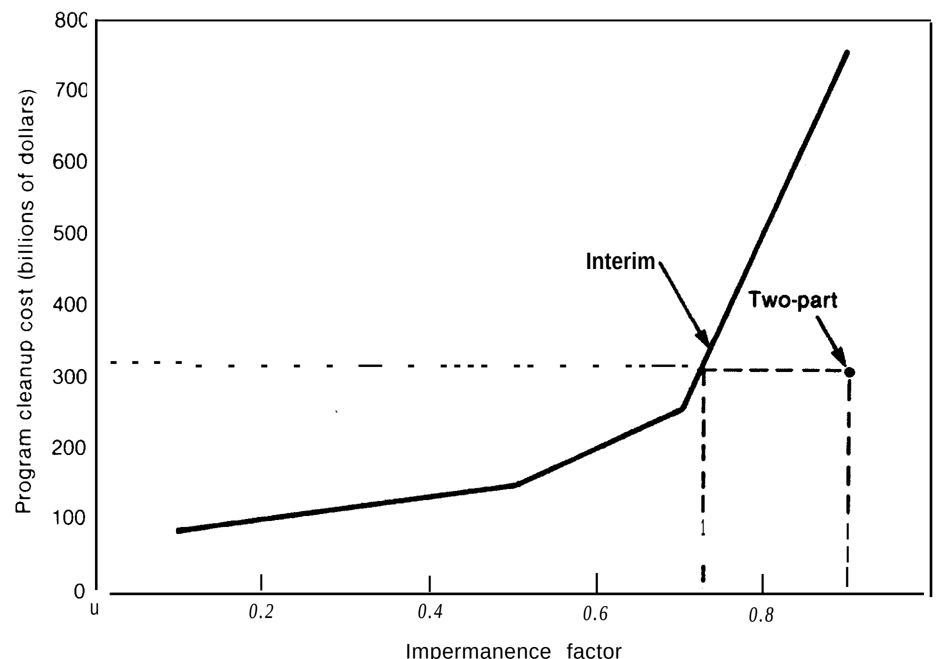

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Table 3-7.—Program Planning With Uncertainty

Dangers of planning without consideration of uncertainty	Options to hedqe against adverse effects
Effectiveness and future cost of cleanups:	
Inadequate funds and program infrastructure; • Cleanup delays . Increasing risks and cleanup costs Inefficient resource expenditures and cleanup choices: • Cleanup is not cost effective in the long term • Risks are aggravated rather than mitigated Loss of public confidence	• Incorporate future costs and cleanup effectiveness in cleanup strategy decisions • Limit costly impermanent cleanups • Develop long-term strategic plan for developing and using permanent cleanups
Number of sites requiring response:	
Inadequate funds and program infrastructure; • Cleanup delays . Increasing risks and cleanup costs Inefficient resource allocation: • Worst sites are not addressed —Risks and cleanup costs increase —Cleanup delays • Less hazardous sites are "over-cleaned" Loss of public confidence	• Consider all likely sources of sites; and potential for sites to enter program over long term • Develop long-term strategic plan based on revised estimates
Health ***and environmental effects:***	
Inefficient resource allocation: • Worst sites are not addressed —Risks and cleanup costs increase —Cleanup delays • Less hazardous sites are ''over-cleaned" . Ineffective technologies continue to be used Loss of public confidence	Ž "Recontrol" responses at maximum number of sites . Resolve cleanup goals sequentially as improved information is available • Develop detailed strategic plan for long-term permanent cleanups
Non-Federal money:	
Inadequate funds and program infrastructure: • Cleanup delays • Increasing risks and cleanup costs Inefficient resource expenditures and cleanup choices • Cleanup is not cost effective in long term • Risks are aggravated rather than mitigated	• Use conservative estimates; refine estimates with experience
Discount rate:	
Inadequate funds: • Cleanup delays . Increasing risks and cleanup costs Inefficient resource expenditures and cleanup choices: Ž Cost effective responses not chosen . Risks are transferred,	• Exclude discount rate or use conservative discount rate; test sensitivity of cleanup strategy decisions to rates

SOURCE Off Ice of Technology Assessment

cleanup future costs. *A mistake in estimating future costs of interim cleanups carries the penalty of a drastic, unanticipated, lengthening of the program—and of a period of perhaps high risk–under the interim strategy*. For higher levels of future cost, the interim strategy results in both unacceptably high cleanup costs and program duration.

A program designed without consideration of cleanup response effectiveness and future costs is likely to result in a lack of money and inadequate program infrastructure. Even if more money is expeditiously provided, it is unlikely that the program infrastructure, or institutional delivery system, will be able to grow rapidly enough for timely responses. Indeed, a contributing factor to the slow startup of the 1980 program was simply the time required for organization and staffing. Further delays in the cleanup program may result in site deterioration and increasing risks. In turn, the costs of cleanup may escalate, impose greater financial burdens and delays; a crisis situation could ensue, In EPA's words, the program could be "overwhelmed. " In addition, *delays in cleanup and the use of ineffective cleanups may contribute to loss of public confidence.*

To deal with uncertainty about cleanup effectiveness and future costs, more realistic estimates can be used. For instance, *life-time* or *life-cycle* O&M costs could be included in cleanup cost estimates. The implications of incorporating realistic O&M costs can be significant, EPA has estimated average annual O&M costs at $400,000 per site, The average Federal cleanup cost per site, less the first year O&M, is about $7.5 million, This is comparable to the average cleanup costs used in the model which shows that if O&M costs are the only future costs of interim cleanup, and are incurred over only 5 years, then the corresponding impermanence factor is about 0.27. Thus, the inclusion of realistic O&M costs can reduce the margin for error.

Number of Sites

The number of sites that will ultimately require cleanup is another source of uncertainty which, if not adequately taken into account, could seriously impact the cleanup program. Insufficient money and an underdeveloped program infrastructure could result from overly optimistic (under) estimates of the number of sites to clean, The program grows too slowly for effective response and further delays result in site deterioration and increasing risks, increasing costs, further delays, and loss of public confidence.

Health and Environment Effects

Although health and environmental issues could not be incorporated into OTA's simple model, high uncertainties of their effects exist and their importance is felt in making tradeoffs, *If health and environmental effects are not better understood, and cleanup goals better defined, any program will potentially misallocate resources*. Without effective cleanup goals it is difficult to judge the effectiveness of cleanups, A rush to "cleanup" sites by, for example, mandating cleanup schedules, before goals are established could result in too many initial resources being devoted to: 1) the use of ineffective technologies; and 2) the less hazardous sites, depriving worse sites of attention.

One reliable way to plan with uncertainties in a dynamic system is to resolve the cleanup goal issue sequentially, incorporating new information as it becomes available, while taking more limited initial responses, and "recontroling" a maximum number of sites. At the same time, other initiatives should focus on planning for more extensive, permanent cleanups that will be needed at some sites, and which can be accomplished gradually.

Non-Federal Money

How much of cleanup costs will be provided by potentially responsible parties (PRPs), income from cost recovery, and States' shares? EPA estimates it will recover 47 percent for removals and 30 percent for remedial actions (see table 3-1).

The limited experiences of the program suggest that lower contributions will be received. As of September 30, 1984, cost recoveries have totaled $6.6 million, less than 1 percent of total obligations and disbursements toward hazardous substance response.[28] One cause of these high estimates is the assumption that rates of recovery will be comparable to those for early removals conducted under the Clean Water Act.

Direct cleanup actions by responsible parties are projected by EPA at 40 to 60 percent, Similarly, estimates from GAO range from 29 to 44 percent for RP lead activities (see table 3-1). The uncertainty of both these estimates may be heightened by the much larger numbers of sites and sums of money that could be involved. Additionally, it might be expected that it will become more difficult to identify some responsible parties as the program progresses and older, abandoned sites are identified, While many sites in the larger estimate maybe smaller, industrial surface impoundments, which may have associated with them lower remedial costs and fewer (often single), identifiable responsible parties, others may be large munici-

[28] U.S. Environmental protection Agency, "Hazardous Substance Response Trust Fund Receipts, Obligations, and Disbursements, CERCLA Sections 301(a)(l)(B) and (D)" [Washington, DC: Office of Solid Waste and Emergency Response, December 1984).

pal landfills. This broader, more costly aspect of the program may stress the States' willingness to provide their matching shares of construction costs.

Discount Rate

The differences between present and future values of cleanup expenditures and risks result from uncertainty over future values of money, inflation, and risks. Cleanup costs and risks may occur over a period of decades. Discounting is used in program evaluations and planning to adjust the costs and risks to present value. The discount rate, an expression of the time value of money, should reflect how society values current versus future consumption.

To illustrate how costs and risks might be valued differently over time, consider a decisionmaker faced with the choice of a program that costs $5 billion now and $5 billion over the next 20 years and a program that costs $10 billion now. The choice might be simplified if it could be shown that the $10 billion program reduces risk more over the next 20 years and if a reliable dollar number could be calculated for the risk reduction. However, in reality, the difference in risk reduction associated with program options is rarely simple.

Controversy arises over the choice of discount rates for public investrnents.[29] One school of thought holds that society should have a longer planning horizon than individuals, which means that public discount rates should be lower than private rates, Furthermore, since future generations have no way to express their preferences, an unimaginative society may err on the side of too high discount rates, from the point of view of their descendants. Many would argue that this is happening now.

OTA makes no attempt here to resolve these issues. However, discounting often has utility, and the selection will influence the allocation of resources, the level of social welfare, and cleanup strategy. *If the discount rate is too high the Superfund program may be underplanned.*

Means to Address Uncertainties

The potential risks arising from uncertainty can be mitigated in several ways. Clearly, resolving the uncertainties would be the most efficient approach, Resources can be devoted to learning how many sites will require cleanup, understanding health and environmental risks, developing cleanup goals, and deciding on a realistic, achievable level of non-Federal contributions. However, *the cleanup program can not wait for total and perfect knowledge.* Rather, the program plan should be sequentially refined as new information is available.

The effectiveness of currently used cleanup technologies and the extreme sensitivity of program duration and cost to these uncertainties suggest that efforts are needed to develop permanent cleanup technologies. *Limited initial responses in the near-term make economic and environmental sense only if they are part of a long-term, flexible strategic plan whose goal is permanent cleanup.* Otherwise, public confidence will not be obtained.

There are intrinsic conflicts between maximizing the number of limited initial responses, and their effectiveness over time, and keeping their costs low to save enough money for expensive permanent cleanups. In addition, there will be competition for money and people for research, demonstration, and use of permanent technologies, and enforcement. Furthermore, a method to allocate and schedule cleanups efficiently must be part of a long-term strategic plan,

[29] For private sector investments, the discount rate is applied to known investment costs and anticipated benefits, both of which can usually be calculated easily in dollars. The appropriate discount rate is usually the corporate internal rate of return on capital or the rate of return on alternative investment opportunities.

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APPENDIX A

This appendix provides detailed information on the mathematical formulations and assumptions used in OTA's model discussed in chapter 3.

Undiscounted Program Cost Definitions of Cleanup Strategies

If costs are not discounted, total program costs can be derived without the use of simulation. Three strategies are defined and discussed in terms of costs and cost comparisons.

Interim Cleanup Strategy

The total undiscounted program costs adjusted for future costs, TC_I, under the interim cleanup strategy can be expressed mathematically as:

$$TC_I = C_I X + iC_I X + i^2 C_I X + i^3 C_I X + i^4 C_I X + \ldots \quad (1,1)$$

where:

C_I = average near-term cost of an interim action.
X = number of sites to clean up.
i = average system impermanence factor of interim actions.

In equation (1.1), the first term is total near-term costs of interim actions. The remaining terms, which constitute a geometric series, represent total future costs of all future actions. (It should be noted that if O&M costs are included in i, they may be understated if $i < 1$, since the terms decrease,) For all $i < 1$, this series converges, so that:

$$TC_I = C_I X/(1 - i) \quad (1.2)$$

Thus, the average adjusted cost per site under the interim strategy is:

$$Avg(TC_I) = C_I/(1-i) \quad (1.3)$$

Equation (1.2) elucidates the use of the impermanence factor in the interim strategy. Rearranging terms reveals:

$$TC_I = C_I X + iTC_I \quad (1.3a)$$

The total cost of the interim strategy is composed of the total near-term cost, $C_I X$, plus total future costs, iTC_I. In the model, however, equation (1,2) was only used as a tool for terminating scenarios that exceeded computer memory. Actual cost calculations were made on the basis of equation (1.1). Clearly, no scenario with a system impermanence factor equal to or greater than 1 was run since, on the basis of either equations (1.1) or (1.2), total cost will be infinite.

Basic Permanent Cleanup Strategy

The total undiscounted program costs adjusted for future costs, TC_I, under the permanent cleanup strategy can be expressed mathematically as:

$$TC_P = C_I YX + C_P iYX + C_P(1 - Y)X \quad (1.4)$$

where:

C_P = average cost of a permanent action
Y = percent of all sites addressed by an initial action during the first 15 years of the program. This percentage will be dependent on funding availability during the 15 years.

The first term in equation (1.4) represents near-term costs of the impermanent interim actions taken in the first 15 years. In the basic permanent cleanup strategy, the interim actions are the same as the interim actions under the interim strategy: the technologies are the same, the costs are the same, and the impermanence factor is the same. The second term is the future costs of initial actions relating to the need for second but permanent actions. This term may misestimate total costs since permanent cleanup costs after an initial action may be more or less than costs of permanent cleanups at sites that have had no response, The last term is the costs of permanent cleanup at sites that have no response. The average cost per site under the permanent cleanup strategy is:

$$Avg(TC_P) = C_I Y + C_P(iY + \quad (1.5]$$

Two-Part Strategy

The two-part strategy is a variation of the permanent strategy and differs from the basic permanent strategy in that the initial responses are not necessarily the same as those of the interim strategy, The unit cost is less for an initial response than for an interim response. Therefore, the impermanence factors may be different for initial responses and interim responses. The total cost of the variation of **the** permanent strategy, TC_{PV}, may be expressed as:

$$TC_{PV} = C_{IV} YX + C_P i_V YX + C_P(1 - Y)X \quad (1.6)$$

where:

C_{IV} = average near-term cost of an initial action.
i_V = impermanence factor for initial actions.

New Sites

In all of the strategies, new sites are discovered during the first *15* years of the program. These sites may be responded to in the following year. Slight deviations from the above cost formulae occur as a result of sites entering the system in the 15th year. In the basic permanent strategy and the two-part strategy, these sites only receive permanent cleanups.

Cost Comparisons of the Interim and Basic Permanent Strategies

Since the interim actions considered in the interim and basic permanent strategies are identical, equations ***(1. 1)*** and ***(1.4)*** can be equated and solved for in terms of i. The impermanence factor at which either total program costs or average program costs are equal under either strategy, i*, is called the critical impermanence and is expressed as:

$$i^* = 1 - C_I / C_P \qquad (1.7)$$

At this impermanence factor, we are indifferent to the cleanup strategies, on a cost basis. For all i < i*, the interim strategy is preferred if only cost is considered and duration [discussed below) is ignored. For all i > i*, the permanent strategy is unambiguously preferred.

Cost Comparisons of the Interim and Two-Part Permanent Strategies

The difference between the interim actions of the interim strategy and the initial actions of the two-part permanent strategy demand a different cost comparison method than that stated above. Given equations (1. *1)* and (1.6), a total cost for the two-part strategy can be based on a specific value for i_v. The impermanence factor for the interim strategy, i, can then be determined and results in the same total cost. If the impermanence factor for interim actions is above this level, then the two-part permanent strategy is unambiguously preferred.

Program Duration With Uncertain Technology Effectiveness

While undiscounted program costs can be derived mathematically, simulation must be employed to determine program duration under each strategy and to determine the effects of discounting, which is time dependent, on cleanup strategy decisions. A simulation model, programmed using LOTUS **1-2-3,** was developed to mimic cleanup actions, the impermanence of those actions, and additional actions resulting from impermanence, over time, The following discussions are focused on the interim and basic permanent strategies. While the discussions are related to the two-part permanent strategy, modifications in analysis would have to be made.

Impermanence Factor

In the model, two impermanence factors were used: i(sc), the impermanence factor for interim surface actions, and i(gw), the impermanence factor for interim groundwater actions. This breakdown is consistent with previous calculations since these two cleanup types are assumed to be independent of one another. The independence assumption may compound the conservative estimate of the percent of sites requiring groundwater response (20 percent) since it does not permit sites with surface contamination to deteriorate in a way that causes groundwater contamination. In fact, surface contamination often leads to ground water contamination. If, however, the impermanence factor for surface contaminated sites is high, it may capture the future costs associated with deterioration. Total program costs under the interim strategy can be expressed as:

$$TC_I = C_{Isc}(1 - Y_{gw})X/(1 - i(sc)) + C_{Igw}(Y_{gw}X)/(1 - i(gw)) \qquad (3.1)$$

where:

C_{Isc} = average near-term cost of an interim surface action.

C_{Igw} = average near-term cost of an interim groundwater action.

Y_{gw} = percentage of all sites requiring groundwater response.

Similarly, total program costs under the permanent strategy are:

$$TC_P = C_{Isc}Y(1-Y_{gw})X + C_{Igw}YY_{gw}X + C_{Psc}(1-YY_{gw})(i(sc)Y + (1-Y))X + C_{Pgw}Y_{gw}(i(gw)Y + (1-Y))X \qquad (3.2)$$

where:

C_{Psc} = average cost of a permanent surface action.

C_{Pgw} = average cost of a permanent groundwater action.

Separability of costs relating to surface actions and groundwater actions permits the derivation of individual critical impermanence factors, i*(sc) and i*(gw), the impermanence factors where costs associated with surface actions and groundwater actions, respectively, are equal under either strategy. These are:

$$i^*(sc) = 1 - C_{Isc}/C_{Psc} \qquad (3.3a)$$

$$i^*(gw) = 1 - C_{Igw}/C_{Pgw} \qquad (3.3b)$$

The composite or average impermanence factor can be determined from equations (3.3a and b). For example, the average critical impermanence factor, i*, can also be expressed as:

$$i^* = i^*(sc)(1 - Y_{gw}) + i^*(gw)Y_{gw} \quad (3.4)$$

The simulation was verified using equations (3.3a,b, and 3.4). These results are discussed and were also used to ascertain program durations when the undiscounted program costs of both strategies were equal.

Base Case Simulation

To model the system, various system definitions and assumptions about model parameters are required. These model definitions (presented in table 3-3) represent conservative estimates of their real world analogs.

To calibrate the model, a base case is generated where the uncertain estimates are defined to closely match current real world estimates. Although it is incorrect to use the term interim cleanup strategy if the impermanence factor is zero, simulation of this case provides a base case and comparison with current EPA estimates of program costs and length. The zero impermanence assumption appears to be consistent with EPA's exclusion of future costs from cost estimates for currently used technologies. Budget options A and C were the lowest budgets that gave base case program durations similar to EPA estimates (see table A-l).

Uncertain Assumptions and Model Sensitivity

To determine program durations under each strategy, it is necessary to make assumptions about the impermanence of interim actions, the number of sites that will require cleanup, the annual budget devoted to cleanup actions, how the budget is allocated among sites, when future costs are incurred, average costs of permanent technologies, and discount rates. The performance of each strategy was tested under different scenarios defined in table 3-4. The goal of this exercise is to clarify a cleanup strategy toward which the Superfund program could move if there is uncertainty about the permanence of currently used technologies. If the model is overly sensitive to some assumptions (namely, when the future costs occur, the annual budget, the costs of permanent technologies and discount rates), then few if any general unqualified statements can be made about cleanup strategy decisions under uncertainty, If, however, the results remain generally the same while each element of uncertainty is varied, then the model can provide meaningful conclusions about cleanup strategy decisionmaking. First, the methods of incorporating these assumptions into the model are discussed; the sensitivity of the model to these assumptions follows.

Assumptions About Timing

While the assumptions about how long it takes to perform an interim cleanup are founded in experiential data, little data exists on which to base assumptions about how long after an impermanent action future costs are incurred, That future costs do, indeed, result from impermanent actions has not been recognized much less quantified. The sensitivity of the model to assumptions about the timing of future costs was tested, Three options were used: 1) early occurrences (every 5 years), 2) late occurrences (every 30 years), and 3) occurrences uniform over 30 years. In the early option, there

Table A-1 .—Comparison of Simulation Base Case With Current Estimates[a]

	EPA (1984)	EPA (1983)	Base case
Total costs (billion)	$7.6 -$22.7	$10.3 -$20.6	$14.7
Projected time to clean sites	NA	14 years for 1,800 sites	16-17 years[b]
Number of sites	1,500-2,500	1,400-2,200	2,046
Total average cleanup cost per site	$8.84'	$6 M $12 M including groundwater response	$6 M $12 M including groundwater response
Percent of sites requiring groundwater response	NA	23-560/o	20%
Average length of response	NA	3 years[d]	3 years 6 years including groundwater response

a F., sources and additional information see table 3-1 of this chapter
b Range corresponds to Budget Options A and C
c Does not include initial remedial measures
d U s Environmental Protectlon Agency, "CERCLA 301(a)(l)(c) Study, " draft, December 1984

SOURCE As noted

would be rapid response and early information on the level of impermanence. The late option corresponds to the 30-year period required under RCRA for post-closure care of disposal facilities. The uniform distribution reflects that sites and cleanups will vary.

Some Examples of Timing

The mathematical formulation follows, but several simple, nonmathematical examples are given first.

(I) Assume the interim strategy, surface cleanups only, with an impermanence factor of 0.5, and the 5-year timing option. Then, of every 100 primary cleanups started in year 1 of the program, there will be 50 secondary cleanups at the same cost as the primaries (or 100 secondaries at half the cost of the primaries) started in year 9 of the program, and 25 tertiaries at the same cost as the primaries (or 100 tertiaries at one-quarter the cost of the primaries) started in year 17 of the program. The secondaries are started in the ninth year of the program, rather than the sixth, because they are started 5 years after the completion of the primaries, and it takes 3 years to perform a surface cleanup.

(II) Assume the interim strategy, surface cleanups only, impermanence factor of 0.5, and the uniform timing option. Then, 120 primary cleanups started in year 1 of the program will be followed by three sets consisting of: a) 10; b) 20; and c) 30 secondaries at the same cost as the primaries (or: a) 20; b) 40; c) 60 secondaries at half the cost of the primaries) which will be started in years 9, 19, and 34 of the program. That is, the "uniform" distribution is not continuously uniform, but is clumped in three bunches. (This choice was made for ease of computing; a more accurate representation of a discrete uniform distribution using more and smaller intervals could have been used with a faster computer.) Note also, that tertiary and higher order actions following early secondary cleanups overlap with later secondary cleanups of the same primary set.

(III) Assume the permanent strategy, with surface cleanups only, and impermanence factor of 0.5 and the uniform timing option. This means that, if 120 initial responses are started in year 1 of the program, 10 require a future action in year 9, 20 in year 19, and 30 in year 34; these 60 sites are slated for permanent cleanup. The sites that require additional action in year 9 cannot be addressed until year 15 or later; they go into a pool of sites that will receive permanent cleanup in the future.

How the Model Handles Timing, Mathematically

Future costs are incorporated into the model by pooling future action requirements. Let $F_{sc}(t)$ and $F_{gw}(t)$ denote the **costs** of future actions that become necessary at time t due to previous interim surface and groundwater actions, respectively. Let $X_{sc}(t)$ and $X_{gw}(t)$ indicate the number of interim surface and groundwater actions started in year t. For future costs incurred on the early schedule, the undiscounted costs of actions that enter the pool for future action in year t are related to previous actions so that:

$$F_{sc}(t) = i(sc)C_{Isc}X_{sc}(t-8) \qquad \textbf{(4.1a)}$$

$$F_{gw}(t) = i(gw)C_{Igw}X_{gw}(t-11) \qquad (4,11))$$

The 8-year lag in future costs for interim surface actions reflects the 3 years required to complete the action and the 5 years after that before which future actions are required. Similarly the 11-year lag for interim ground water actions includes 6 years to complete the action.

If the future actions are required after 30 years, the lags become 33 years for interim surface response and 36 years for interim groundwater response, so that:

$$F_{sc}(t) = i(sc)C_{Isc}X_{sc}(t-33) \qquad (4.2a)$$

$$F_{gw}(t) = i(gw)C_{Igw}X_{gw}(t-36) \qquad (4.2b)$$

For future actions that are required on a 30-year uniform schedule, the time distribution is represented discretely in the model, with costs incurred 5, 15, and 30 years after completion of the interim actions. The undiscounted costs of actions required in year t are related to previous actions as:

$$F_{sc}(t) = 1/6[i(sc)C_{Isc}X_{sc}(t-8)] + 2/6[i(sc)C_{Isc}X_{sc}() - 18)] + 3/6[i(sc)C_{Isc}X_{sc}(t-33)] \qquad (4.3a)$$

$$F_{gw}(t) = 1/6[i(gw)C_{Igw}X_{gw}(t-11)] + 2/6[i(gw)C_{Igw}X_{gw}(t) - 21)] + 3/6[i(gw)C_{Igw}X_{gw}(t-36)] \qquad (4.3b)$$

As before, the lags of 3 and 6 years reflect completion time for interim surface and groundwater response, respectively,

In all of the cases above, the future costs of an interim action are a function of the number of actions taken, the costs of those actions, and their impermanence.

In the permanent strategy, impermanence of the initial actions results in permanent response. Let $P_{sc}(t)$ and $P_{gw}(t)$ denote the **number of permanent** actions taken in year t due to previous impermanent actions, The future costs associated with the initial actions can be represented mathematically' in a way similar to equations (4.1a-4.3b), depending on the time distribution of future actions. For example, if future actions are required under the early time distribution, they are:

$$P_{sc}(t) = i(sc)C_{Psc}X_{sc}(t - 8 \quad (4.4a)$$

$$P_{gw}(t) = i(gw)C_{Pgw}X_{gw}(t - 11 \quad (4.4b)$$

In this case, costs resulting from impermanent actions are a function of the number of impermanent actions taken, the impermanence of those actions, and the costs of permanent cleanup.

Comments on Timing

The assumptions about the time distribution of future actions may directly determine the program duration, although it is typically these assumptions together with budget assumptions that do so. If the budget is large enough, and grows quickly enough, then the bulk of the cleanup efforts can be achieved earlier in the program. However, the results of impermanent actions linger. For instance, if there were no budget constraints, under the permanent strategy all initial responses would be taken in the first year. The latest future groundwater actions that would result from these impermanent actions would be dealt with in the 37th year (6 years to complete the action and 30 years until additional action is required), The shortest program attained in the modeling effort for the permanent strategy was 26 years. This reflected the last initial groundwater cleanups starting in the 15th year. Six years is required to complete the initial response, then future actions can be started 5 years later, under the early time distribution of future action occurrence. Of course, with expensive enough permanent cleanups, high enough impermanence factors, and/or a low enough budget, the program would be longer, as there would not be enough money to do all permanent cleanups in the year they came due.

Any of the time lags before future actions are taken may be lengthened because of the budget constraints. Because the model incorporates no measure of risk, future actions may be deferred without penalty, *Therefore, in this model, no distinction is made in allocating the budget between sites requiring first time* ***response and sites*** *requiring additional response.* (The only exception is for permanent responses under the permanent strategy during the first 15 years; they are not permitted,)

Budget Allocation

Each annual budget is allocated so that the fund is distributed in a deterministic way among surface and groundwater responses, primary and follow-on responses, Consider first the interim strategy, If $S_{sc}(t)$ indicates the number of sites that have never been addressed requiring surface response in year t, and $S_{gw}(t)$ is similarly defined for sites requiring groundwater response, then an allocation percentage, Y_t, is defined for an annual budget in year t, B(t), as follows:

$$Y(t) = B(t)/[C_{Isc}S_{sc}(t) + C_{Igw}S_{gw}(t) + F_{sc}(t) + F_{gw}(t)] \quad (5.1)$$

The percentage is similar during the first 15 years of the permanent strategy except there are no terms for future costs. Instead, the future costs enter the model when permanent cleanups are pursued, after the 15th year. The percentage then becomes:

$$Y(t) = B(t)/[C_{Psc}S_{sc}(t) + C_{Pgw}S_{gw}(t) + P_{sc}(t) + P_{gw}(t)] \quad (5.2)$$

The effect of this allocation is response to sites with surface and groundwater contamination in the same proportion as their occurrence. If the impermanence factors for interim and initial actions for surface and groundwater contamination are the same, this proportion is maintained through the simulation; that is, the initial 80 percent surface to 20 percent groundwater occurrence assumed in the model stays constant as the program runs. (Note that groundwater responses are more expensive than surface response by a factor of 3 in most simulations; therefore if the ratio of occurrence is 80:20, the budget is split as 0.57 :0.43, the ratio of cost.) If, however, the impermanence factors are different the proportion will change. For example, if the groundwater responses have higher impermanence, more attention and money will be devoted to groundwater response as the program progresses.

One outcome of this allocation method is that no preference is given to primary actions under either strategy. It is possible, therefore, that with a low enough budget and high enough impermanence factor, nearly all funds could be devoted to secondary and higher order interim actions in the interim strategy and secondary but permanent actions in the permanent strategy. This is particularly striking if future actions are required on the early time distribution schedule, While the real-world implications of this are unappealing, i.e., sites are not addressed and deteriorate, this poses few problems in terms of affecting the performance of the strategies in the simulation. The correct amount of money is spent and it is the length of time these expenditures continue that determines program length,

Measuring Program Duration

To evaluate the strategies in terms of program length and examine the effects of different time distributions of future cost occurrences, a method of measuring program duration was required. Program duration could be measured in terms of the last year where expenditures are made for an action. Since responses extend over time, this way of measuring duration would shorten program length by at most 10 years, the time required to complete the longest response—the permanent groundwater cleanup.

By definition the interim cleanup strategy for i < 1 represents a decay process, meaning that fewer and fewer interim actions are taken over time. It would be misleading to measure program duration by the time needed to initiate the final single action (or fraction, thereof, since real variables were used). By the same token, it would be equally misleading to only consider the time required to initiate all first interim actions since these might constitute only a very small fraction of the total program under the interim strategy.

To resolve this dilemma, program progress was measured in terms of the year at which different percentages of all expected cleanups were undertaken. The percentiles are 30, 50, 70, 90, 95, and 100 percent. Assuming that the model did delineate between primary and future actions, a simple interpretation of progress percentiles can be given. For instance, under the interim cleanup strategy, if i(sc) = i(gw) = 0.7, the 30 percent program progress might mean (depending on the timing of future actions) that at most all first interim cleanups were completed, and no future actions had started. For i(sc) = i(gw) > 0.7, the 30 percent program progress mark would have to include additional future actions. In general, the minimum program progress level required to cleanup all sites with an interim action exactly once, under the interim strategy is:

$$X(\%) = 100(1 - i) \tag{6.1}$$

The inverse relationship may bias strategy decisions toward the interim strategy for low impermanence factors if low program progress percentiles are used to measure duration. For example, if a 30 percent program progress level is used for i = 0.1 under the interim strategy, this represents no more than the first cleanup of only one-third of the sites. *For this reason, the* **90** *percent program progress level, which could represent first cleanup of all sites if the i* = 0.1 *(the lowest impermanence factor tested], was used to measure program progress.*

Model Sensitivity

Each strategy was simulated for impermanence factors where total costs were supposed to be equal for the two strategies. Varying budgets (options A, B, C, and D) were run to verify that cleanup actions were modeled properly and that correct program costs were generated, and to derive corresponding program durations. Results are given in table A-2. All program costs were equal at the critical impermanence factors, i*(sc) = 0.75 and i*(gw) = 0,8, thereby verifying this aspect of the model,

Despite the mathematical justification for measuring program duration in terms of the 90 percent program progress level, to arrive at a verifiable conclusion each strategy was compared in terms of program duration at all program progress levels. (See tables A-3a and A-3b for simulation results at different impermanence factor levels.) At the critical impermanence factors for permanent cost option 1, where program costs of the two strategies are equal, the interim strategy performs poorly in terms of program duration even at the 30 percent program progress level (refer to tables A-4a and A-4 b).

Table A-2.—Simulation of Cleanup Program Progress Ranges of Years in Which Required Cleanups are Initiated[a] Total Program Cost $63.6 Billion

	Selected percentages of sites					
	30%	50%	70%	90%	95%	100%
I. ***Initial Budget = $1.6 B; i(sc) = 0.75; i(gw) = 0.8***						
Cleanup strategy:						
Interim	19-48	31-90	48-140+	84-140+	110-140 +	140 +
Permanent ...	12-19	16-47	22-65	26-79	26-82	27-85
II. ***Initial Budget = $9.0 B; i(sc) = 0.75; i(gw) = 0.8***						
Cleanup strategy:						
Interim	14-37	25-75	42-140+	79-140+	104-140+	140 +
Permanent	7	14	19-40	24-53	25-56	26-59

[a]Range definitions
I Shortest programs correspond to scenario 1 EAF longest programs to scenario ILBF
II Shortest programs correspond to scenario 1 ECF longest programs to scenario 1 LDF

SOURCE Office of Technology Assessment

Table A-3a.—Trade-offs Between Program Cost and Program Progress: Scenarios 1-AF

Time distrib.	Program progress	Impermanence factors for impermanent surface actions (sc) and groundwater (gw) cleanups															
		i(sc) = i(gw) = 0.1		i(sc) = i(gw) = 0.3		i(sc) = i(gw) = 0.5		i(sc) = i(gw) = 0.6		i(sc) = i(gw) = 0.7		i(sc) = 0.75 i(gw) = 0.8		i(sc) = i(gw) = 0.8		i(sc) = i(gw) = 0.9	
		Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent
Uniform (U):																	
	90%	17	21	49	33	83	41	113	43	>140	44	>140	44	>140	44	>140	45
	70%	16	15	17	18	45	21	56	21	82	22	109	23	132	24	>140	27
	50%	13	13	15	14	17	15	33	15	48	16	62	16	75	17	>140	18
	30%	11	10	12	11	14	12	15	12	17	12	31	12	39	12	81	13
Total program cost:		$16.4 B	$31.4 B	$21.0 B	$41.1 B	$29.5 B	$50.8 B	$36.8 B	$55.6 B	$49.1 B	$60.5 B	$63.8 B	$63.8 B	$73.7 B	$65.3 B	$147.3 B	$70.2 B
Early (E):																	
	90%	17	21	25	22	38	24	48	25	64	25	84	26	97	26	>140	26
	70%	16	15	17	18	24	20	28	21	38	22	48	22	55	22	105	23
	50%	13	13	15	14	17	15	20	15	25	16	31	16	34	17	64	17
	30%	11	10	12	11	14	12	15	12	17	12	19	12	22	12	37	13
Total program cost:		$16.4 B	$31.4 B	21.0 B	$41.1 B	$29.5 B	$50.8 B	$36.8 B	$55.6 B	$49.1 B	$60.5 B	$63.8 B	$63.8 B	$73.7 B	$65.3 B	$147.3 B	$70.2 B
Late (L):																	
	90%	17	21	51	44	111	46	>140	46	140	47	>140	47	>140	47	>140	47
	70%	16	15	17	18	49	21	78	35	112	39	>140	40	>140	40	>140	41
	50%	13	13	15	14	17	15	45	15	51	16	81	16	105	17	>140	18
	30%	11	10	12	11	14	12	15	12	17	12	44	12	48	12	111	13
Total program cost:		$16.4 B	$31.4 B	$21.0 B	$41.1 B	$29.5 B	$50.8 B	$36.8 B	$55.6 B	$49.1 B	$60.5 B	$63.8 B	$63.8 B	$73.7 B	$65.3 B	$147.3 B	$70.2 B

SOURCE: Office of Technology Assessment.

Table A-3b.—Trade-offs Between Program Cost and Program Progress: Scenarios 1-CF

Time distrib.	Program progress	Impermanence factors for impermanent surface actions (sc) and groundwater (gw) cleanups															
		i(sc) = i(gw) = 0.1		i(sc) = i(gw) = 0.3		i(sc) = i(gw) = 0.5		i(sc) = i(gw) = 0.6		i(sc) = i(gw) = 0.7		i(sc) = 0.75 i(gw) = 0.8		i(sc) = i(gw) = 0.8		i(sc) = i(gw) = 0.9	
		Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent	Interim	Permanent
Uniform (U):																	
	90%	16	16	45	35	79	38	108	39	>140	39	>140	40	>140	40	>140	41
	70%	12	12	16	14	39	17	52	20	78	22	105	23	127	23	>140	25
	50%	7	7	10	9	16	11	28	12	42	13	56	14	71	14	>140	15
	30%	3	3	5	4	8	5	11	6	15	6	25	7	35	7	76	7
Total program cost:		$16.4 B	$23.2 B	$21.0 B	$35.3 B	$29.5 B	$47.5 B	$36.8 B	$53.6 B	$49.1 B	$59.6 B	$63.8 B	$63.8 B	$73.7 B	$65.7 B	$147.3 B	$71.8 B
Early (E):																	
	90%	15	16	22	19	33	21	43	22	59	23	79	24	91	24	>140	25
	70%	11	12	14	14	19	17	24	18	33	19	42	19	49	20	100	21
	50%	7	7	10	9	13	11	15	12	20	13	25	14	30	14	59	15
	30%	3	3	5	4	8	5	10	6	12	6	14	7	17	7	32	7
Total program cost:		$16.4 B	$23.2 B	$21.0 B	$35.3 B	$29.5 B	$47.5 B	$36.8 B	$53.6 B	$49.1 B	$59.6 B	$63.8 B	$63.8 B	$73.7 B	$65.7 B	$147.3 B	$71.8 B
Late (L):																	
	90%	16	16	49	40	105	43	>140	44	140	44	>140	44	>140	45	>140	45
	70%	12	12	16	14	46	34	73	35	106	36	>140	36	>140	36	>140	37
	50%	7	7	11	9	16	11	38	12	49	13	75	14	100	14	>140	15
	30%	3	3	5	4	8	5	11	6	16	6	37	7	42	7	105	7
Total program cost:		$16.4 B	$23.2 B	$21.0 B	$35.3 B	$29.5 B	$47.5 B	$36.8 B	$53.6 B	$49.1 B	$59.6 B	$63.8 B	$63.8 B	$73.7 B	$65.7 B	$147.3 B	$71.8 B

SOURCE: Office of Technology Assessment

Table A-4a.—Summary of Simulation Results With Budget Options A and B[a] Program Duration Ranges for i = 0.1 to 0.9[b] (in years)

Time distribution option: Program progress	Permanent strategy cost range: $31.4	$70.2B[c]	Interim strategy cost range $16.4	$147.3B[c]
Uniform (U):				
100%	51		101	140 +
95%	28	47	38	140 +
90%	21	45	17	140 +
70%	15	27	16	140 +
50%	13	18	13	140 +
30%	10	13	11	81
Early (E):				
100%	26	28	41	140 +
95%	21	27	22	140 +
90%	21	26	17	140+
70%	15	23	16	105
50%	13	17	13	64
30%	10	13	11	37
Late (L):				
100%	51		119	140 +
95%	42	48	47	140 +
90%	21	47	17	140 +
70%	15	41	16	140 +
50%	13	18	13	140 +
30%	10	13	11	111

[a]Permanent cleanup costs option 1 and new sites option F
[b]Short programs correspond to budget option A and i = 0.1 Long programs correspond to budget option B and i = 0.9
[c]Low cost corresponds to budget option A and i = 0.1 High cost corresponds to budget option B and i = 0.9

SOURCE Office of Technology Assessment

Table A-4b.—Summary of Simulation Results With Budget Options C and D[a] Program Duration Ranges for i = 0.1 to 0.9[b] (in years)

Time distribution option: Program progress	Permanent strategy cost range $23.2	$71.8B[c]	Interim strategy cost range: $16.4	$147.3B[c]
Uniform (U):				
100%	51		98	140 +
95%	29	45	35	140 +
90%	16	41	16	140 +
70%	12	25	12	140 +
50%	7	15	7	140 +
30%	3	7	3	76
Early (E):				
100%	26	27	39	140 +
95%	17	26	16	140 +
90%	16	25	15	140 +
70%	12	21	11	100
50%	7	15	7	59
30%	3	7	3	32
Late (L):				
100%	51		115	140 +
95%	38	47	41	140 +
90%	16	45	16	140 +
70%	12	37	12	140 +
50%	7	15	7	140 +
30%	3	7	3	105

[a]Permanent cleanup costs option 2 and new sites option F
[b]Short programs correspond to budget option C and i = 0.1 Long programs correspond to budget option D and i = 0.9
[c]Low cost corresponds to budget option C and i = 0.1 High cost corresponds to budget option D and i = 0.9

SOURCE Office of Technology Assessment

Since under either strategy, for i < i*, the interim strategy is preferred on the basis of cost. But program durations under the interim strategy so greatly exceed those of the permanent strategy at the critical impermanence factor that trade-offs between program cost and duration are expected. Therefore, the hypothesis for cleanup strategy decisionmaking based on two evaluation criteria at this point is: *Regardless of when future costs occur and how we choose to measure program progress:*

1. The permanent strategy is preferred unequivocally for i > i * because it is both cheaper and shorter.
2. For i < i*, there are trade-offs between program cost and length.
3. At some level of impermanence, the interim strategy is preferred both in terms of program cost and duration.

To be sure the method of measuring program progress or assumptions about the time distribution of future costs do not disprove this hypothesis, sensitivity analysis is performed.

All program progress levels for each strategy were calculated while varying values of i = (O. 1, 0.3, 0.5, 0.6, 0.7, 0.8, and 0.9). To properly ascertain the shortest and longest program duration, the time distributions of future costs and budgets were also varied. The shortest program under each strategy is achieved for the high growth rate budget options, A and C, and for the early future cost time distribution. The longest program under each strategy occurred for the low growth budget option B and D and for the late future cost time distribution. This information is given in tables A-5 and A-6.

Examination of these tables shows that the hypothesis is supported, since parts 1 and 3 are true, and 2 is intuitive. Regardless of when future costs occur and our measurement of program duration, the permanent strategy is preferred for i > i*. Again regardless of these assumptions, the interim strategy is preferred only at low impermanence values and/or if program duration is measured at biased low program progress levels.

Solving the Allocation and Scheduling Programs: Systems Modeling as a Management Tool

While simulation models enable comparison between strategies, they require that the strategies first be defined. The simulation so far defined only two extreme and inflexible strategies. It is not likely, in a real program, that choice would be reduced to a very expensive permanent solution on the one hand or an ineffective impermanent solution, which is not even cheap, on the other, More likely, different levels of cleanup would be warranted at sites according to their different levels of health risks and environmental threats. There appears to be a trend emerging at EPA where cleanup would be approached in stages. The notion of "operable units" has been put forth in draft versions of the revised NC,. Essentially, the remedial response system will be approached in terms of phased-in cleanup, which for most sites will separate surface from subsurface cleanups (this is not necessarily technically sound). Cleanup will assume the form of a three-stage process.[1] This approach could be somewhat consistent with the "hedge-against-uncertainty" strategy defined earlier,

With cleanups structured into three-stage processes, a cleanup strategy could define or provide guidance for long-term allocation and scheduling policies, i.e., the tactics of the program. Decisions must be made about which sites are cleaned to what level and when each stage of cleanup is implemented. These are difficult management policy decisions for a number of reasons.

First, the crucial element for evaluating scheduling and allocation tactics is a measure of risk and/or cleanup goals. Such measures or goals could: 1) define the urgency and level of cleanup on a site-specific basis; 2) aid in designating sites requiring different levels of cleanup; 3) provide information for assessing cost effectiveness on an intersite basis, which could be used to measure the equity of cleanup schedules and allocations over all sites; and 4) maintain consistency within the cleanup strategy.

Second, it is necessary to relate various cleanup actions to levels of risk reduction or avoidance. Without defining such relationships, it is not possible to evaluate the site-specific cost effectiveness of cleanup options, In evaluating the cost effectiveness of the cleanup options it may be necessary to not only consider immediate risks but potential risks as well. A particular option may not appear very cost effective when considering only the near-term risks but may be extremely cost effective in light of longer term risks,

This complication touches on the third difficulty, that of evaluating cleanup action cost effectiveness on an intersite basis, The problems arise due to the interrelationship between allocation and scheduling. Limitations on budget, the availability of permanent cleanup technology, or the degree to which program infrastructure is developed will likely delay some remedial actions or some stages of remedial action. While initial responses may retard the deterioration of a site, some sites will continue to degrade. For this reason, scheduling and allocation of the Superfund among sites are deeply linked with projected or potential risks and costs of remedial measures. Trade-offs are likely between more extensive actions and initial responses in the near term, and between permanent cleanup actions at different sites in the long term,

The fourth management problem to address is the enormous number of possible allocation and scheduling sequences. There will be many possible cleanup action-risk reduction relationships, all of which may have different levels of cost effectiveness depending on when the actions are undertaken. The possibility of 2,000 to 10,000 sites and three stages of response represents well over a trillion possible sequences, Even though some will be patent nonsense and experience can eliminate others, a method for evaluating allocation schedules will be indispensable to efficient and equitable fund distribution, especially in a program of such magnitude and subject to intense public scrutiny.

Simulation could provide valuable comparative information among schedules if measurements of risk and the interrelationships of allocation and scheduling were reflected in the model. However, to arrive at preferred schedules, simulation methods would require defining them all and exhaustively testing them; this would most likely be computationally infeasible. Thus, simulation may not be the most useful tool for deciding management policies at the tactical level.

Fortunately, there are systems techniques that offer greater flexibility than simulation. Such techniques might include linear and nonlinear programming, dynamic programming, and decision analysis methods, all in a multicriteria context given that there would be more than one evaluation criterion. One of the largest applications of such mathematical models is in financial and investment planning, e.g., capital budgeting, cashflow analysis, portfolio management, etc. z Mathematical models would not require predefining tactics; the preferable tactics would be the output solution,

Modeling the system might begin with site classification, a step that might also be time dependent.

[1] *Inside E.P.A.*, June 15, 1984

[2] F J Fabozzi and J. Valente, "Mathematical Programming in American Companies: A Sample Survey," *Interfaces*, vol 7, No 1, November 1976, pp. 93-98

In addition to the classification scheme presented in EPA's ground water protection strategy, certain States, e.g., New York, have already implemented a site classification scheme as a method of allocating cleanup actions. The effects of deferring cleanup actions at particular site classes could be reflected by a deterioration coefficient. The deterioration coefficient might transform deferred sites from one classification to another. The variables in the model could relate specific classes of sites and cleanup actions that would also be time dependent. Again it is the value of these variables in the model solution that would provide the tactics.

These variables might represent how many actions using a specific technology were applied to how many sites of a particular class in a given year. Remedial actions would also alter the site classification. This problem might be formulated to minimize program cost and duration subject to a cleanup goal (constraint. The level of cleanup might be increased to reflect the effects of increasing margins of safety, and solutions could be compared on the basis of *system* cost effectiveness. The solution-the distribution of remedial technologies over sites as a function of time-could also be used as a management tool. This could be done by more closely examining site-specific data to determine which sites would actually undergo cleanup using that type of technology.

While it may appear to be an ambitious undertaking, efforts are being taken already to incorporate limited but useful health information into decisionmaking. EPA is formalizing its risk assessment guidelines and attempts are being made to apply them to hazardous waste disposal site cleanup, Furthermore, site-specific hazardous waste information is accumulating as RI/FSs are completed. Other data are becoming available as the Hazard Ranking System is applied to more and more sites. For example the HRS has been applied to over 1,700 sites.[3] The next step is to develop and formalize a risk management strategy that would account for intersite cost-effective trade-offs over time. More extensive and systematic use of the information available now and in the future is desirable. Developing a strategy for the partial system that could be refined as health and environmental effects data are enhanced is also appropriate. To capture the dynamics of the system, a systems approach could be considered.

[3] U.S. Environmental Protection Agency, "Extent of the Hazardous Release Problem and Future Funding Needs (CERCLA Section 301(a)(1)(C) Study)," Final Report, December 1984.

Chapter 4

Strategies for **Setting Cleanup Goals**

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Chapter 4

Strategies for Setting Cleanup Goals

INTRODUCTION

Establishing goals for cleanup by Superfund, the States, and private parties will depend on scientific, technical, economic, and legal analyses. Ultimately, however, the answer to "How clean is clean?" will be a major policy judgment that must strike a delicate balance among certain and uncertain health and environmental risks, available resources, technological capabilities, and public concerns. OTA's analysis does not produce a simple answer to this key question. However, one approach has emerged that offers a way to choose among several processes for determining cleanup goals; it is based on a classification of sites according to their present and future use.

When a site has been identified as a potential source of dangerous chemical releases, decisions are made on how to respond.[1] Removal actions are short-term responses to immediate threats. Remedial actions are long-term responses designed to provide permanent remedies and are the focus of this chapter. A critical component of the Superfund program is determining the extent of cleanup that is required at sites, i.e., defining the residual level of contamination or exposure that is acceptable. Unfortunately, it is possible to know that a site poses significant threats, but not know *precisely* what those threats are or what constitutes a safe level of cleanup.

[1] Uncontrolled release of chemicals from Superfund sites presents the potential for various types of damage. Some releases can harm people directly, others primarily affect the environment. Some damage may be immediately observable while other harm may manifest itself only after years of exposure.

While certain criteria, such as the necessity of fund balancing and use of cost-effective remedies, are present in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP), they do not actually prescribe a course of action. This lack of clear direction has led to problems.

The current methods for determining the extent of cleanup at Superfund sites may not meet statutory goals of public protection. Current actions appear to be ad hoc and inconsistent; no national goal on the extent of cleanup has been defined. Without specific cleanup goals [with which to confirm cleanup), the selection, use, and evaluation of cleanup technologies will be difficult and contentious. Moreover, goals can help determine whether a technology is technically feasible and guide the development of new technologies.

The chapter begins by examining the current institutional framework within which goals are now structured, It then discusses six factors to evaluate alternative approaches to establishing cleanup goals and outlines seven alternative approaches. Finally, the chapter the cleanup goals issue might be resolved.

CURRENT INSTITUTIONAL FRAMEWORK

CERCLA: Summary of Key Provisions

CERCLA, or Superfund, was enacted to address the problem of uncontrolled releases of hazardous substances into the environment. Removal actions are short-term responses to prevent or mitigate immediate threats. Remedial actions (the focus of this chapter) are longer term responses designed to provide permanent remedies, The statute does not provide explicit guidance on how to decide on the extent of a cleanup. The statute does, however, impose constraints on the choice of removal and remedial actions. Removal actions are limited to $1 million or 6 months unless certain statutory conditions are met,

Remedial actions are restricted by *fund-balancing* and *cost-effective* requirements. The fund-balancing requirement limits the selection of a remedial action to one that provides a balance between the need to protect public health and welfare and the environment at that site and the availability of Superfund money for response to other sites. The NCP is directed to require that remedial actions be cost effective over the period of potential exposure to the hazardous substances or contaminated materials. It is commonly accepted that cost effectiveness pertains to a fixed goal that different approaches may meet.

National Contingency Plan: Summary of Key Provisions

The NCP establishes the process for determining appropriate removal and remedial actions at Superfund sites. The NCP can be revised periodically, which was last done on July 16, 1982. EPA proposed revisions to the NCP on January 28, 1985, pursuant to a settlement agreement reached in *Environmental Defense Fund and the State of New Jersey v. EPA.*

The existing NCP authorizes two types of removal actions: immediate and planned. EPA is empowered to conduct immediate removal actions when it determines such actions are necessary to prevent or mitigate an immediate and significant risk to human life or health or to the environment. There is no explicit provision establishing the required extent of cleanup. Immediate removal actions are considered "complete" when there is no longer an immediate and significant risk to human life or health or to the environment, and the contaminated waste materials have been treated or disposed of properly offsite.

Planned removals are authorized when the Environmental Protection Agency (EPA) determines that continuing an immediate removal action will result in a substantial cost savings or that the public or the environment will be at risk if response is delayed at a site not on the National Priorities List (NPL). *As with immediate removals, there is no explicit provision establishing the extent of cleanup for planned removals.* They are "terminated" when the risk to the public health or the environment has been abated.

The current NCP provides extensive guidance for choosing an appropriate remedial action plan. There is a process EPA uses to evaluate the nature and extent of contamination at a site; propose and evaluate possible remedial alternatives; and select a remedial action plan, As with removal actions, *the NCP does not provide explicit guidance on what degree of cleanup must be achieved by a remedial action.* The appropriate extent of remedy is determined by selecting the most cost-effective remedial alternative (i. e., the lowest cost alternative that is technologically feasible and reliable and which effectively minimizes damage to and provides adequate protection of public health, welfare, and the environment). As with CERCLA, the NCP requires that the need to respond to other releases with Fund monies be considered in determining the appropriate extent of remedy,

Applicability of Other Laws to Determining Extent of Cleanup at Superfund Sites

The proposed draft revisions to the NCP incorporate EPA's policy on CERCLA compliance with the requirements of other environmental statutes. For removal actions, EPA proposes to meet applicable or relevant standards of other Federal environmental and public health laws to the maximum extent practicable, considering the exigencies of the situation.

For remedial actions, EPA proposes to comply with applicable and relevant standards of other Federal public health and environmental laws, with limited waivers. Specifically, the draft revisions would require that the appropriate extent of remedy be determined by selecting a cost-effective remedial action that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment. In particular, the remedy must, at a minimum, attain or exceed applicable or relevant existing Federal public health or environmental standards. *Applicable* standards are those standards that would be legally applicable if the actions were not taken pursuant to Section 104 or 106 of CERCLA. Relevant standards are those that are based on scientific or technological considerations that are similar to conditions at the site.

Where two or more alternatives achieve comparable levels of protection of public health and welfare and the environment, the most cost-effective alternative will be selected; one which provides the most favorable balance between cost and protection. Selection can consider the reliability of the remedy, available technology, administrative concerns, and other relevant factors. According to EPA, an alternative that does not meet applicable or relevant standards may be selected for one of the following reasons:

- fund-balancing;
- the selected alternative is not the final reined y;
- technological infeasibility;
- unacceptable environmental impacts; or
- overriding public health concerns,

Thus, it is not clear that EPA's approach necessarily leads to a cleanup decision consistent with the level of protection originally intended for a site.

Use of Hazard Ranking System

Sites that are included on the NPL are ranked by the Hazard Ranking System (HRS). The score assigned to each site is intended to reflect the relative potential of the hazardous substances present to cause damage, the rapidity with which the damage will occur, and the magnitude of the impact. Three scores are combined to produce the final rank. These scores reflect the potential for harm by chemicals that have migrated away from the facility and are found in the groundwater, surface water, or air. If the final priority score is equal to or above 28.5, the site is placed on the NPL and is eligible for remedial action.

The HRS addresses the possibility that a site will cause harm. Since it neglects actual exposures and effects, however, it does not provide a qualitative assessment of the risk presented by the site. Moreover, sites where data are lacking may have lower scores than appropriate because zero is generally assigned for any specific points lacking data (see chapter 5).

Some of the factors used in the HRS model indicate the types of concerns that should be addressed in determining cleanup goals. The model estimates hazard based on limited data and can lead to scores which other information could increase or decrease. For example, an increasing number of points are given for decreasing distance to surface water, buildings, or local populations. The *current model* cannot incorporate additional knowledge that would substantially affect the danger posed by the site, e.g., whether the geologic conditions are likely to allow the chemicals to contaminate the surface water, whether the buildings are occupied, or whether the activities of the local population cause frequent contact with the site. The presence of an observed release, an unusual smell, or a large number of drums or tanks increase the score in the model. Thus, some parts of the current model address issues of concern for determining extent of cleanup, but not all important issues are considered. The model was not designed to and is not used to determine extent of cleanup and, as currently structured, is inadequate for this purpose. But a *revised, improved model* could be used to determine, at least partially, the extent of response, even if only the *initial* response (see chapter 2).

Use of Cleanup Goals

At the four sites OTA examined closely, all the remedial strategies were based primarily on waste containment and groundwater *treat*ment, rather than waste removal and treatment. Several factors seemed to influence these decisions. Costs required for complete site cleanup appeared to be important factors at the Love Canal and Seymour sites. At Stringfellow, incorrect assumptions regarding the permeability of underlying bedrock formed the basis for remedial action decisions that have proven ineffective. Little consideration was given to the long-term effectiveness of containment, continually increasing operating and maintenance costs, possibilities of containment failure and continuing groundwater contamination, and practical problems resulting from the very long times (hundreds or thousands of years) required to manage these hazardous waste sites.

At three of the sites (Seymour, Stringfellow, Love Canal), initial actions were required prior to remediation. These actions were short-term solutions to immediate problems, and in some cases may have actually worsened the problem. At these sites, there was also a lack of specific cleanup goals specifying acceptable residual levels of contamination.

The Sylvester site was the only one where environmental goals were set prior to remedial action. The specific cleanup goals involved a hundred-fold reduction in the offsite release of contaminants in groundwater, compliance with EPA water quality standards at Lowell drinking water intakes, and compliance with certain EPA air quality criteria at a nearby trailer park. In particular, the goals were aimed at meeting standards for several contaminants in water and chloroform in air emissions. The cleanup goals did not consider other sources of toxic chemicals entering the water supply.

APPROACHES TO ESTABLISHING CLEANUP GOALS OR STANDARDS

This section will evaluate some alternative approaches to establishing the extent of cleanup at Superfund sites. No attempt has been made to consider all possible approaches. The approaches selected were those that appear most reasonable given current knowledge and past experience with remedial actions at Superfund sites.

The analysis of each approach will consider six major factors that define the nature and extent of cleanup that is possible at Superfund sites: 1) inherent hazard of the chemical wastes found at the sites; 2) site-specific considerations and exposure; 3) assessment of risks to human health, environmental biota, and natural resources; 4) available technologies and remedial action alternatives; 5) resource limitations; and 6) institutional constraints. While *many of these factors involve scientific and technical issues, it is important to recognize that the choice of a cleanup goal or standard is ultimately a policy decision.*

Factors for Evaluating Alternatives

Inherent Hazard of Chemical Wastes Found at Superfund Sites

The inherent hazard of the chemicals present at a site determines their potential to cause harm to human health or the environment. When inherent hazard is combined with potential exposure, the potential risk (i.e., the possibility of an adverse effect) for harm to human health or the environment can be assessed. Inherent hazard of chemicals can be evaluated by the type of damage they cause, the amount present as compared to existing standards and acceptable levels, the extent of reliable knowledge about them, and the mixture of hazardous substances present at the site.

Several types of hazard can occur from the release of chemicals into the environment. For example, some chemicals are likely to ignite or explode, causing both the danger of physical damage and the potential for the chemicals to be spread over a large area. The corrosive properties of chemicals can directly damage human health or the environment and can affect the stability of the site by causing a breach of natural or engineered barriers, The chemicals can also present a toxicological risk to people or local flora and fauna.

Each chemical can present one or several types of toxicological hazards. The compound can be acutely toxic, i.e., exposure for minutes or hours can produce an effect that is generally observed within a very short period of time. Somewhat longer exposures may also produce adverse effects, either a more severe consequence or an entirely different effect, including cancer. Certain more sensitive populations may be affected by lower levels of exposure than the general population, For instance, some chemicals are most toxic to developing fetuses *in utero* but cause little harm to the pregnant woman, Still other effects may be observed in young children or the elderly,

Adverse health effects range from reversible effects, e.g., skin or eye irritation, to irreversible damage, e.g., malfunction or cancer of vital organs. A chemical may cause predominantly one effect or may cause several diverse toxic reactions. Moreover, each chemical can produce a variety of effects depending on the level of exposure. *While all chemicals can produce an adverse effect at some level of exposure, the level of exposure will determine both the type of damage and the severity of the harm*. Thus, low levels of some chemicals will produce dizziness or headaches while higher levels may cause unconsciousness or death. Similarly, a dilute acid may cause skin irritation while a more concentrated solution will burn the skin. Knowledge of both the inherent toxicity of the chemicals present at the site and levels of potential exposure is, therefore, necessary to determine what hazard exists.

Standards or levels that have been deemed acceptable exist for some of the chemicals found at Superfund sites. Some standards, which have had some peer and public review, and other established levels (e. g., judicially established action levels) can be used to evaluate inherent hazard. Care must be taken to ensure that the standard or other acceptable level is appropriate for the Superfund site. *Standards are usually developed for one medium and one route of exposure*. For example, a standard of 1 part per billion of dioxin in soil has been set for Superfund sites, but not for water or air. A standard developed for one medium is frequently inappropriate for another since the medium may determine the extent and route of exposure. The severity and type of toxicity of a chemical can also vary with route of exposure. Furthermore, some standards are for acute (short-term) exposures while others are for chronic (long-term] exposures. Occupational standards for exposure assume a limited time exposure for healthy adults. Other standards may be partially based on cost or available technology and should not be considered a measure of inherent toxicity.

Although the inherent toxicity of several chemicals has been studied in depth, a recent study by the National Academy of Sciences concluded that most chemicals have not been adequately examined for all potential toxic effects.[2] Based on an examination of randomly selected compounds, the report estimates that no toxicity information is available on 76 to 82 percent of chemicals in commerce included on the Toxic Substances Control Act Inventory, 38 percent of pesticides and inert ingredients of pesticides formulations, 56 percent of cosmetic ingredients, 25 percent of drugs and excipients used in drug formulations, and 46 percent of food additives. Less than 18 percent of the chemicals in these categories were estimated to have a sufficient data base to provide a complete health hazard assessment. The lack of data is a particular concern for chemical wastes, i.e., chemicals that are unwanted byproducts of chemical synthesis or other manufacturing process. Until recently, there has been little economic incentive to study the potential toxic effects of such chemicals. Moreover, there have been few studies on health ef-

[2]National Research Council, *Toxicity Testing, Strategies to Determine Needs and Priorities* (Washington, DC: National Academy Press, 1984).

fects associated with actual uncontrolled sites, and those completed have generally posed significant scientific uncertainties.

Finally, few waste sites contain only one chemical; thus, chemical and toxicological interactions need to be considered. Chemical reactions can result in new compounds whose physical, chemical, and toxicological properties differ significantly from those originally at the Superfund site, Chemical reactions can also cause fire or explosions. The potential of toxicological interactions is poorly understood. While some chemicals have been shown to enhance or interfere with the toxicological effects of another (e.g., synergism or antagonism), only a few such mixtures have been examined. In *the absence of knowledge, the hazards of combinations of chemicals is generally ignored and may present a large uncertainty* in the assess*ment of the site.*

Site-Specific Considerations and Exposure

For chemicals to pose a hazard to health and the environment, people, flora, and fauna must be exposed to them. Geology, geography, and weather conditions are some of the factors that will affect the routes and levels of exposure. Thus, *site-specific factors will affect which media are contaminated and the routes and extent of potential exposure.*

Site-specific factors will determine the probability that chemicals will leach into groundwater, drain into rivers, or evaporate into the air. For example, soil with high organic content will tend to retain hydrophobic chemicals such as polychlorinated biphenyls (PCBs) while soils with less organic content will tend to release these chemicals into the groundwater or air. Soil composition and permeability will influence the rate at which contaminants leach from the site, which in turn can affect the rate and extent of exposures, e.g., via drinking water wells or via contamination of nearby surface water. Weather, including temperature, amount and type of precipitation, and wind strength or direction can affect the movement of chemicals and their transfer among media. Conditions that affect the route of exposure, e.g., exposure to contaminated soil via dermal contact versus inhalation of dust particles, can affect the amount absorbed into the body and, thus, the extent of exposure.

Models can be used to predict environmental fate and potential levels of exposure by various routes. Confirmation of the accuracy of environmental fate models is limited by the paucity of data on the actions and reactions of chemicals in the environment. For example, predictions of a chemicals's movement for several decades is often based on data collected over several months. Small errors in initial measurements or in assumptions can be compounded for long-term predictions.

Modeling potential exposure will also depend on the ability of the assessor to estimate human activity. Route and level of exposure will depend on the activities of the local population, e.g., digging in soil, swimming in or drinking of water. Inhalation exposure levels will vary with breathing rate which, in turn, depends on factors such as age and level of activity. The average exposure for a population can differ significantly from the exposure of a person whose habits or occupation cause more or less contact with the site. Exposure models also make assumptions about the extent to which an individual's activities will change over a lifetime and the likelihood that people will remain in their current residence and/or occupation.

The size and sensitivity of the local population and the nature of the flora and fauna will determine the extent of the effects of exposure to the chemicals. The size of the local population and its proximity to the site will determine the number of people potentially exposed. The presence or absence of particularly sensitive populations (e.g., children, the elderly) needs to be known to adequately assess the level of exposure that will produce an adverse effect, Knowledge of activities on or near a site will indicate potential routes of exposure and allow reasonable estimations of durations of exposure, e.g., children at Love Canal faced potentially high exposure because of the location of their school and playground.

A Superfund site should not be examined in a vacuum, Other factors in the surrounding environment can affect the nature and extent of remedial action at a site. Naturally occurring chemicals can present a hazard when combined with residual levels from a cleaned site. Even *if a Superfund site is cleaned to a level that is acceptable by itself, the background level of some toxic chemicals, such as heavy metals, may be sufficiently high that exposure to the background levels combined with the residual contamination can raise exposure to an unacceptable level.* Local sources of pollution need to be considered when determining the potential risk to an exposed population. Some of these other sources may cause concomitant exposures, especially if they contaminate the same resource, e.g., the same aquifer. Other sources may cause exposure to the same chemicals but by different routes, for instance, organic solvents may be in the drinking water or in the air.

Assessment of Risks to Human Health, Environmental Biota, and Natural Resources

An assessment of a site's potential health and environmental risks is based on the inherent hazard of the chemicals present and the routes and levels of potential exposure. Risk assessment is the use of available data to estimate the potential effects of exposure to particular hazardous materials or situations on an individual, species, or populations. Results of risk assessments are frequently expressed as the probability of the occurrence of a particular effect under specific conditions. The National Academy of Sciences has identified four processes that comprise a risk assess ment:[3]

- *Hazard identification:* The determination of whether a particular chemical is or is not casually linked to particular health effects,
- *Dose-response assessment:* The determination of the relation between the magnitude of exposure and the probability of occurrence of the health effects in question.
- *Exposure assessment..* The determination of the extent of human exposure before or after application of regulatory controls.
- *Risk characterization:* The description of the nature and often the magnitude of human risk, including attendant uncertainty.

The first three issues were discussed during considerations of inherent hazard and site-specific conditions. Risk characterization is discussed below.

Risk assessments should explicitly consider the uncertainties in knowledge about the inherent hazard of the chemicals at the site and the routes and levels of exposure. Thus, if the toxicological data limitations were greatest for chemicals that would be expected to volatilize easily and if the greatest exposure were expected to be by inhalation, a greater uncertainty factor might be incorporated into the risk assessment to account for these compounds' potential toxicity, Similarly, if the toxicity of the compound that poses the most significant risk at the site were estimated from incomplete data or from experiments that were inadequately performed, a greater uncertainty factor would be included in the risk assessment or, alternatively, the next most toxic chemical might be used for the evaluation,

A site-specific risk assessment is comprised of a series of such assessments: for each route of exposure, for each duration of exposure (i.e., acute, short-term, or chronic), and for various adverse effects (e. g., cancer or organ toxicity) for each organism (e.g., human, animal, or plant) potentially affected. Usually the exposures producing the highest risks based on preliminary assessments for the populations of concern are more carefully evaluated.

In addition to uncertainties associated with conditions at a site, *the process of risk assessment itself has inherent uncertainties.* For example, toxicological risk assessments are based on current knowledge and assumptions about biological processes use models that have been developed to describe them, Often the models are designed to overestimate rather than underestimate risk. While such prudence is reasonable given the limitations of toxicological

[3] Ibid

knowledge, it must be recognized that such decisions are based on considerations other than those provided by science alone. This is one example of the difference between risk assessment and risk management.

Risk *assessment* is defined as the calculation of the probability of adverse outcomes such as injury, disease, or death. *Risk management* incorporates other considerations such as acceptability of risk, costs and benefits, and policy into a determination of a course of action. Although theoretically distinct parts of the decisionmaking process, risk assessment and risk management are too often interwoven. In the case cited above, deciding which risk extrapolation model to use is a risk management decision, Evaluating and selecting data to be used in the extrapolation model, as well as the extrapolation process, are elements of risk assessment. Decisions about what actions to take based on the extrapolated risk are risk management judgments. When elements of risk management are imbedded in risk assessment processes, confusion about the "scientific" or "objective" content of policies and decisions can result.

Site-specific risk can be compared with risk levels that are considered to be acceptable. Non-chronic toxic effects are thought to have a threshold of exposure below which no toxicity will occur. Acceptable exposure levels for these compounds are frequently based on a no-observed-adverse-effect level which is lowered by uncertainty factors that consider concerns such as variation in individual susceptibility and extrapolation of results from animals to man. The resultant levels are often called acceptable daily intakes or ADIs. EPA has published draft guidance on the use of ADIs for assessment of the risk to human health from nonchronic effects. *

Acceptable exposure levels for carcinogens are usually based on the estimated increase in an individual's probability of contracting cancer. In the past, EPA has regulated carcinogens at individual risk levels in the range of 10^4(1 in 10,000) to 10^8(1 in 100,000,000). The breadth of this range is caused by many factors including cost-benefit analysis (when applicable under the appropriate legislation), availability of substitute chemicals (e.g., for regulating pesticides), or feasibility (e. g., ability to remove chemicals from groundwater). In general, EPA recommends that residual risk levels for carcinogens at Superfund sites be in the range of 10^4 to 10^8 before consideration of site-specific factors,[5] with a risk of 10^8 (1 in 1,000,000) as the point of departure for an acceptable level.

Available Technologies and Remedial Action Alternatives

The ability to detect the identity and levels of contaminating chemicals and achieve cleanup goals depends on currently available technology. Although technology continues to advance, it has limitations that cannot be exceeded regardless of situation or intentions; there can be no *a priori* assurance that even a proven technology will work for each particular situation. Technological limitations affect several aspects of cleanup goals and procedures.

The state of the art of sampling technology limits the extent to which the identity and levels of chemicals contaminating a site can be determined. Sampling can represent the most difficult problem at large sites with diverse chemical contaminants and geologic conditions.

Analytical procedures do not exist for the unambiguous identification of all chemicals that may be encountered at Superfund sites. Procedures have been developed for some chemicals, but they only detect that compound above a certain level, As analytical procedures limit knowledge of the presence of chemicals, they also limit the extent to which cleanup can be achieved with certainty. After a remedial cleanup, the presence or absence of a compound can at best be determined to be at or below the lim-

[4] U.S. Environmental Protection Agency, *Guidance and Methods for the Use of Acceptable Daily intakes in Health Risk Assessment*, 1984,

[5] U.S. Environmental Protection Agency, Memorandum by Lee M. Thomas on International Paper ACL Demonstration, Nov. 19, 1984.

its of detection. These may be above or below levels of concern for threats to health or environment.

Cleanup technologies are similarly limited. Public expectations usually ignore the limitations of even the best technology to eliminate exposure to a waste once it is released into the environment, particularly groundwater, or to completely prevent future releases. Current options for handling waste chemicals include destruction (e.g., incineration), blocking movement (e. g., slurry walls), or removal (e. g., offsite disposal). Many prospective cleanup technologies are in the R&D or the pilot plant stages of development (see chapter 6).

The unintended consequences of the use of any remedial technology may include transfer of toxicants among media, transfer or risks among populations, and residual pollution resulting from the technology. Transfers of toxicants among media may involve the same chemicals (e. g., when chemicals are stripped from water by aeration) or chemical byproducts of processing the orginal contaminants (e.g., transfer of combustion products of solids or liquids into air pollutants by incineration), Although such processes can remove the contaminants from the Superfund site, the residual risks posed by the chemicals or their byproducts in new media need to be considered.

Remedial technologies can also involve the transfer of risks among populations. Offsite disposal of waste chemicals will potentially expose additional populations during transit, treatment, or disposal of the waste chemicals. Risks to new and previously unexposed populations should be considered when evaluating the effectiveness of any remedial action.

Most technologies will leave some level of residual contamination, either at the original site, in aquifers distant from the site, or at the ultimate site of treatment or redisposal. Some residual contamination results from the inability of any process to completely eliminate a chemical. Risks posed by this residual contamination should be considered when cleanup goals are established. Other remedial processes produce new wastes (e.g., contaminated carbon from filtration systems), While not always immediately obvious, generation of such wastes must be considered in establishing cleanup procedures and goals.

Resource Limitations

A number of resource limitations significantly affect the nature and extent of remedial actions. First, there is a finite amount of public and private money that can be devoted to the cleanup of Superfund sites. In addition to financial limitations, other resources such *as* the number of trained personnel, laboratories for sampling and analysis, and equipment to achieve the desired cleanup response are also limited and may not be available even if money were (see chapter 7). Similarly, decisions to use offsite hazardous waste management facilities assume that these facilities have sufficient capacity,

Dividing the total available resources among all NPL sites involves difficult decisions based on limited data and can result in inconsistencies in the extent of cleanup among sites. Whatever the allocation of resources for any site, the cleanup should obtain the highest level of cleanup for resources spent. But this still begs the issue of cleanup goals. It is becoming increasingly clear that at this time the potential number of Superfund sites is not accurately known, nor is it known what resources will be needed for remedial actions at those sites. Consequently, the resources made available for any single site must be carefully considered. Without such consideration, several intractable sites could significantly deplete the available funds and necessitate less extensive cleanup at serious sites that are discovered or investigated later (see chapters 2 and 3).

Institutional Constraints

As discussed, CERCLA and the NCP as currently drafted provide little guidance about how to determine the extent of cleanup required at Superfund sites. Draft revisions to the NCP would require that in most cases, cleanups must attain or exceed relevant and applicable Federal standards. It is not clear that this requirement would really resolve the issue of extent of cleanup, especially in light of the exceptions incorporated in the draft provision,

The extent to which other laws and regulations may define the extent of cleanup and the manner in which the cleanup is achieved also lacks clarity. For example, it is obvious that material removed from a Superfund site for offsite disposal must be handled in compliance with the provisions of the Resource Conservation and Recovery Act (RCRA), (However, see chapter 5 for a discussion of the problems with RCRA facilities.) Less clear is the impact of the provisions of RCRA if the material is to be disposed, stored, or contained on site. Does the site become a de *facto* RCRA facility that must comply with all RCRA requirements? The resolution of these issues could substantially affect the nature of remedial actions.

Other laws such as the Safe Drinking Water Act (SDWA), Clean Water Act (CWA), and Clean Air Act (CAA) regulate contaminants in the environment, Current provisions of these acts are insufficient to define the extent of cleanup under CERCLA. The number of chemicals regulated under each act is small compared with the number of compounds already identified at Superfund sites, The standards developed under these laws consider one medium and/or route of exposure: SDWA, drinking water (ingestion); CWA, surface water; CAA, air (inhalation). SDWA health advisories only consider short-term effects (1 day to 2 years) and do not, therefore, consider carcinogenic effects. While none of these existing standards are alone sufficient to determine the extent of cleanup, they may provide guidance for a particular medium or route of exposure.

Hazardous waste sites have generated considerable public, political, and media interest. These concerns have focused attention on the problem in general, and decisions about actions at Superfund sites are being examined with increased intensity, While the high level of interest may increase the probability that all alternatives are examined and that appropriate action is ultimately taken, this interest can also present problems. The issues involved in determining the extent of cleanup at any site are technically complex and contain large uncertainties. Oversimplification of the issues can lead to an overstatement or understatement of the risk that, in turn, can lead to unnecessary concern or complacency. Public, political, or media pressure may cause cleanup based on notoriety rather than hazard. When the method or extent of cleanup is well-publicized at one site, public perception of fairness may require that the same method or extent of cleanup be used at another site, even if site-specific considerations would suggest a different action.

Actions of the local population, media, or elected officials can be based on calculated, potential adverse effects or on their perception of risks that may not exist, Studies of *real* versus *perceived risk* have clearly demonstrated that the risk perceived by the public may differ significantly from the calculated risk, not that calculated risk is necessarily a complete indicator of actual risk, b Both perceived and actual risks may have to be addressed in the remedial action program, perhaps through more effective public participation in decision-making (see chapter 8).

One factor influencing public perception of risk will be actions taken at other sites where remedies have been instituted, Public reaction may be adverse if actions that are perceived to be less stringent are implemented at one site as compared with another, Because of site-specific factors affecting the design of remedial action programs, comparison of one cleanup plan with another will be difficult and in many cases unfair. *What is ultimately important and realistically achievable is consistency in the process of determining what the cleanup of sites should be, rather than necessarily making all cleanups the same.*

Discussion of Alternative Approaches

This section analyzes seven alternative approaches for determining the extent of cleanup

[6]V. T. Covello, W.G. Flare m, J.V. Rod ricks, and R.G. Tard iff, 'l-he *Analysis of Actual* Versus *Perceived Risks (New* York: Plenum Press, 1983).

at Superfund sites. The primary focus of four of the approaches is to establish cleanup goals based primarily on current scientific and technical considerations: *site-specific risk assessments, national levels of residual contamination, background or pristine levels of chemicals, or best available technology.* The fifth approach, the use of *cost-benefit analysis,* balances the extent of cleanup at each site against cost, with or without a site-specific resource limitation, A potential-use driven approach is designed around *a classification system based on present and future use of sites.* Also discussed is a continuation of the current ad hoc practices,

Continued Use of Current Ad Hoc Practices

Description of Approach.—In general, the present reliance on ad hoc practices has not provided a consistent explicit process for determining goals. Nor is it likely that the remedial actions thus far have resulted in consistent levels of cleanup among sites posing similar threats. A review of remedial actions at various Superfund sites indicates that the inherent toxicity of the chemicals present has, in part, determined the chosen remedy. Site-specific factors, especially as they affect feasibility, have also been considered. Risk assessments of the potential for sites to harm human health or the environment have rarely been explicitly included in the decision process.

Availability and *presumed effectiveness* of best available remedial technologies have been driving factors in determining the extent of cleanup. This may be due, in part, to the comparative ease of analyzing the cost, feasibility, and reliability of existing technologies contrasted with the difficulty of making such judgments regarding health and environmental risks. There has been some sensitivity to the concerns of the local population, elected officials, and the media.

Analysis of Approach.—Continuation of current practices, possibly with additional guidance, would provide an increased opportunity to evaluate remedial actions. One might then have a stronger basis for deciding on the preferred approach to establishing cleanup goals. On the other hand, CERCLA was enacted over 4 years ago; considerable resources have been expended and continue to be spent with mixed results, Now may be the time to resolve an issue which is critical to the remedial action program.

Site-Specific Risk Assessment

Description of Approach.—One alternative approach to determining cleanup goals involves the *explicit use of risk assessment coupled with a site-specific or national determination of acceptable risk levels.* Uniform procedures and methodologies would also need to be used. Risk assessment would involve determining the potential hazards of the chemicals at each site, characterizing exposures based on site-specific considerations, and calculating risks based on the inherent toxicity of chemicals at the site and potential exposures to humans and the environment.

Various models can be used to determine site-specific risk. One model illustrates some of the issues that need to be resolved in site-specific risk assessment.[7] In this model, the individual chemicals to be used in the risk assessment are selected by a ranking scheme that evaluates each chemical's potential for toxicity (based on ADI and/or carcinogenic potency) and exposure (based on quantity present and physical-chemical properties). For each selected chemical, potential exposure is estimated by all appropriate routes, for each remedial action plan considered. The risk for each chemical for each route is calculated and compared with the predetermined acceptable level for the toxic effect. Remedial actions are compared, and the appropriate response is selected to achieve the maximum difference between the residual and acceptable level of risk at the lowest cost.

For the sake of consistency and defensibility, uniform procedures and methodologies should be used in risk assessment; therefore, a num-

[7] J.V. Rodricks, "Risk Assessment at Hazardous Waste Disposal Sites, " *Hazardous Waste,* vol. 1, 1984, pp. 333-362.

ber of choices must be made. A site-specific risk assessment of human health effects can be expressed in terms of individual or population risk. Individual risks estimate the risk of any person exposed under the conditions stated in the estimate and are independent of the size of the population exposed. Population risks are derived by multiplying the individual risk by the number of people exposed by that route of exposure. *If individual risks are used for setting the standards for extent of cleanup, cleanups will be consistent throughout the country regardless of the size of the potentially exposed population. If population risks are used, Superfund sites in sparsely settled locations may have higher residual individual risk than those in more populated areas.*

Since most Superfund sites contain many chemicals, the risk assessor, for a variety of reasons, including cost and expediency, may choose to determine the risk on the basis of a few indicator substances. If the selection of indicator chemicals is based on their relative abundance at the site, the most toxic chemicals may be overlooked. If the selection is based on inherent toxicity, compounds that have been extensively studied may be favored since knowledge about lack of toxicity is not always distinguished from lack of knowledge about toxicity. Clearly making such a choice without doing assessments for the alternatives could lead to results that are not indicative of the site's greatest risks.

Similarly, choices must be made for predicting potential exposure. These choices are often between the use of models to predict exposures and collecting more extensive data on actual exposure. After the site has been generally characterized for factors such as geology, weather, and local population, models can provide an estimate of exposure, albeit with some uncertainty. Gathering more data can reduce this uncertainty, but can delay action, cause more exposure to the pollutants, and be quite expensive.

Analysis of Approach.—By definition, a cleanup goal determined by risk assessment must give appropriate consideration to the inherent hazard of the chemicals present at a site, the site-specific factors affecting exposure, and the potential risks to human health, environmental biota, and natural resources. All of the previously discussed uncertainties and concerns associated with these factors would still apply, It is possible to structure conservative risk assessments through a "worst-case" perspective, or to consider "average" or "likely" risks.

This approach's sensitivity to technology and resource limitations depends to a large extent on whether the cleanup would need to achieve a national or site-specific standard (perhaps within a nationally established range of acceptable residual risk). For example, an inflexible risk goal for a chemical or for the total site may not be achievable for technical reasons. The goal may be below the limits of detection with current analytical procedures. Technologies may not exist to remove low levels of specified chemicals from air, water, or soil. Alternatively, the technologies may exist but may require resources disproportionate to the incremental reduction of risk. TO *attempt to achieve a national risk goal might allow a few sites to virtually bankrupt the system, unless considerable resources were provided.* A site-specific standard would be more sensitive to the particular circumstances of a site and the resources and technologies that are available to effect cleanup, but does not assure national consistency for protection at similarly contaminated sites,

In any event, performing a risk assessment is a costly, time-consuming process that requires highly trained technical specialists in a number of disciplines. Thus, a critical issue is how to choose *when* to use risk assessment,

A risk assessment approach to establishing cleanup goals is not inconsistent with CERCLA, Because of the uncertainties that are likely to be associated with a particular site and the uncertainties in the risk assessment process itself, public acceptance of the outcome of risk assessment is likely to be mixed. This would be especially true when the "real" risk is quite different from the "perceived" risk, Considerable effort to educate and inform the public would need to accompany this approach, The choice of a national or site-specific standard of acceptable risk (i. e., a probability) would have a significant impact on public reaction, A single, minimal national standard for acceptable risk, if perceived to provide adequate protection, would be easy to explain and would result, at least in theory, in consistent cleanups. A site-specific standard (even within a range of acceptable risk) would probably result in inconsistent cleanups and cause more public concern.

National Goals for Residual Contamination

Description of Approach.—This approach would involve *setting new residual levels and using available ones for all chemicals or classes of chemicals found at Superfund sites.* These levels would be the same for all sites and not consider site-specific conditions. A major issue that would need to be resolved in the use of this approach is what factors to consider in establishing new levels, i.e., inherent hazard, cost and/or available technology, or some combination of them.

Existing standards, criteria, and guidelines will be of limited utility in establishing national goals. They currently exist for only a small number of chemicals found at Superfund sites. Most were designed for a specific environmental medium and none suit all possible routes of exposure that may exist at Superfund sites. Many were developed for exposures that are not compatible with those at Superfund sites. For example, a standard developed for an occupational exposure (the calculated risk would be for a group of healthy adults for a daily duration of 8 hours, 5 days per week) would not match the conditions of exposure of most Superfund sites,

This is not to say that existing standards, criteria, and guidelines cannot be used, only that one needs to be careful in doing so. In fact, as discussed previously, draft revisions to the NCP would require remedial actions in most cases to comply, at a minimum with "applicable" and "relevant" Federal standards. Under this approach to establishing cleanup goals, for those chemicals for which there are no existing applicable or relevant standards, new ones would need to be developed, or perhaps some other approach to setting cleanup goals used. *Hence, what at first appears to be an expeditious approach may be just the opposite.*

Analysis of Approach.—Establishing national goals for residual contamination would certainly consider, to some extent, the inherent hazard of the chemical wastes. As discussed, there currently exists limited knowledge of the inherent hazardous properties of chemicals at Superfund sites. Consequently, the establishment of standards for all hazardous substances or classes at Superfund sites would be hampered by a limited data base and would involve extrapolation of current knowledge beyond limits of verification.

This approach would not consider site-specific conditions, and the extent to which risk assessment is considered would depend on how the standards were established. For example, if the standards were established in a way so that, under any conditions of exposure, the resulting risks would be acceptable, then a site-specific risk assessment would be of no additional value.

Resource and technological limitations could be addressed in the development of the goals. For example, the cost and/or availability of cleanup technology could be the determining factor in establishing a goal for particular chemicals. Such a standard might not achieve an acceptable level of risk. On the other hand, goals established solely on the basis of inherent hazard may be only theoretical benchmarks if the resources and technologies are not available to attain them.

Establishing national goals is certainly consistent with the direction that EPA is moving in the draft revisions to the NCP and would satisfy the need for national consistency. But if this approach was based on a commitment to develop standards for all or most chemicals and conditions, the system would be slow to initiate and the costs would be substantial, If the goals are set at levels generally perceived to protect health and the environment, public concern would focus almost exclusively on the effective implementation of those goals. On the other hand, if the driving force behind the goals is perceived to be resource limitations, public confidence could quickly erode.

Clean to Background or "Pristine" Levels

Description of Approach.—This approach for establishing the extent of cleanup would require that the cleanup continue *until the levels of all contaminants were indistinguishable from those of the surrounding background.* A variation of this approach would require that the cleanup continue until the site were "pristine, " i.e., as if the pollution had never occurred.

The first issue that would need to be resolved with this approach is how to determine background or pristine levels. Historical background levels are not usually available for most sites, for a diversity of chemicals and media. Frequently, background is determined by sampling nearby locations and can include pollution from other sources. In most cases, pristine would be a cleaner level than background, especially if the site is in an industrial area.

Analysis of Approach.—Cleaning to background or pristine levels does not explicitly consider the inherent hazard of the chemical wastes on site. *Only the environmental context of the site is considered in determining the levels of cleanup.* This approach includes an implicit risk assessment, i.e., it assumes that any level above background or pristine is an unacceptable risk and levels at or below background or pristine are acceptable. These assumptions may not be true. For example, certain industrial contaminants do not exist naturally in the environment and the pristine levels for these chemicals would be zero, Putting aside the financial or technical capability of reaching a zero level of residual contamination, it is hard to imagine that such a result would be necessary from a public health or environmental perspective. Further, "background" levels might not necessarily provide the desired level of protection, especially in heavily industrialized areas with multiple sources of industrial contamination.

This approach to establishing a cleanup goal is not particularly sensitive to resource limitations or available technologies. In general, this approach would be expensive and difficult to implement.

Because this would likely be the most expensive approach, its successful implementation would be significantly constrained by the fund balancing provision of Superfund. Public acceptance of this approach could be expected to be mixed. *There would be inconsistencies among cleanup of sites with similar wastes depending on where they are located.* Moreover, because this is a costly approach, fewer sites could be expected to be cleaned up at any one time.

Technology-Based Standard: Best Available Technology or Best Engineering Judgment

Description of Approach.—This approach would involve examining all available remedial technologies that address the chemical contamination at a Superfund site, A remedial action plan would be developed that used the best available technology to minimize exposure to the waste chemicals at the site.

Analysis of Approach.—A detailed analysis of the inherent hazard of the chemical wastes found at a site would not be an integral part of this approach, However, it might be important to at least identify the wastes of major health and environmental concern at a site as a guide to the designers of remedial action. Site-specific factors would be critical. Knowledge of the quantity and identity of wastes present; of the geology and geography of the area; of the identification of potentially affected natural resources and local populations; and of the routes and levels of exposures would be essential to reach a best engineering judgment as to what remedial measures to take,

A risk assessment would not need to be performed. Implicit in this approach would be the assumption that, by using the best available technology, the risks from the site would be reduced to the lowest level that is technically feasible. (It may be suggested that technical feasibility is a practical limitation of any approach to establishing cleanup goals for remedial action, However, delaying cleanup or taking other risk management actions can be considered also.)

A technology-driven approach would be sensitive to the strength and weaknesses of currently available remedial procedures, The less confidence there is in existing technologies, the less satisfactory is this alternative, Since risk assessment is not an integral part of this approach, concerns about the transfer of risks among populations and the risks associated with residual pollution from the disposal technology would not be central to the decision-making process.

Unless limits were imposed on cleanup costs, this approach could be perceived as providing a blank check for those in the cleanup business. The designers of the remedial action program should employ a cost-effective use of resources. But can this be done without pre-established cleanup goals? Without some assessment of the risks, significant resources could be spent on a site that posed little or no risk. Unproven technologies might be used with little protection obtained, The incremental public health or environmental protection provided by a technology that is substantially more expensive than the second choice might be insignificant, but this could not be evaluated without a risk assessment. How would one know exactly what constituted a complete cleanup, or when to cease operations such as groundwater treatment? Moreover, advances in technology could raise the possibility of subsequent expensive retrofits to achieve higher levels of protection.

This approach would make it difficult to make informed decisions under the fund-balancing provision of CERCLA. Public reaction is likely to be mixed. A policy that Superfund sites will be cleaned up using the best available technology is initially appealing and appears to offer the best that can be provided. Realistically, limited resources are available to devote to cleaning up uncontrolled hazardous waste sites. This approach might create enormous pressure to be among the first sites where resources are spent, without attention to the uncertainties of cleanup effectiveness and the benefits of waiting for different technology or specific goals more related to exposures. Compromises would need to be made that would likely result in inconsistent cleanups.

Cost-Benefit Approach

Description of Approach.—A quantitative cost-benefit approach to establishing cleanup goals would require that the costs of any initial or incremental remedial measures be compared with the benefits (reduction of potential adverse effects to health and the environment) to be derived from such expenditures. Only if the (total or incremental) benefits are greater than the (total or incremental) costs would the expenditures be made. All this assumes that the benefits are measurable and the unit of measurement is comparable to costs. Benefits and cleanup goals are variables weighed against available funds. A less formal cost-benefit analysis based on articulation rather than quantification also could be used,

Analysis of Approach .—This approach requires an understanding of the benefits to be derived from remedial measures at a site, i.e., the reduction in risk to public health or the environment that those measures are likely to produce, To determine this, an analysis of the inherent hazard of the chemical wastes on site, a consideration of site-specific factors, and a risk assessment would be required. All of the uncertainties about the hazards of the materials of concern, the site-specific conditions, and the process of risk assessment would need to be recognized in a quantitative approach, especially when *uncertain additional health or environmental protection would be compared with certain expenditure of resources.* The more uncertain the benefits, the more dubious the results of the analysis. An assessment of risk and reduction of risks would need to be determined on a site-specific basis, This approach would not use national standards for residual risks, If there were national goals for residual risk levels, a cost-benefit analysis would be superfluous.

Calculating the benefits of a reduced risk is difficult, In the first place, regulatory decisionmakers are generally unwilling to assign dollar values to human lives, additional cases of cancer, or even the value of natural resources.

The evaluation of costs would need to be done carefully. Not only should the initial costs associated with a remedial measure be included but its impermanence and long-term (often uncertain) costs associated with the monitoring and maintenance of the technology need to be included in the calculation as well.

This approach would certainly be consistent with the fund-balancing provisions of CERCLA. However, public reaction is likely to be mixed, Attractive in theory, this approach would cause decisionmakers at individual sites to be tested publicly, especially when the uncertainties and value judgments implicit in this approach became apparent. Inconsistent levels of cleanup among sites could result unless very specific national procedures and policies were used.

Site Classification: Determining Cleanup Levels by Present and Future Use of a Site

Description of Approach.—To date, little attention has been given to what will happen to a site after it is cleaned. Under this approach, the extent *of cleanup would be based on the present and future use of a site and its surrounding area,* as determined by local government and communities. How a particular site is classified as to its present or future use (i. e., restoration, rehabitation, and reuse) would be the driving force in the selection of a remedial plan. Classes could be established early in the program, for example, when a site is placed on the NPL. For purposes of classification, the site would include any land or waters already or likely to be contaminated.

A classification system based on current and potential use has been recommended as part of EPA's groundwater protection strategy.[8] In establishing this strategy, EPA considered its inability to protect all groundwater from contamination, its fundamental purpose of protecting human health and the environment, and the cost and difficulty of monitoring and cleaning groundwater. These same considerations apply to NPL sites. In EPA's groundwater protection strategy, three classes of groundwater are recommended. Class I includes special groundwater, so designated because it represents irreplaceable sources of drinking water or ecologically vital areas, e.g., contamination would destroy a unique habitat. Class II includes current and potential sources of drinking water. Class III includes groundwaters that are not a potential source of drinking water and are of limited beneficial use, e.g., with total dissolved solids over 10,000 mg/l or already so contaminated that they cannot be cleaned by methods reasonably employed in public water treatment.

Analysis of Approach.—Implicit in the development of such a classification system is the policy decision that the extent of and the initiation of cleanup would differ among sites. Consequently, *some of the cleanup approaches previously described could be used with such a system,* For example, certain sites might be classified as so valuable as present or future resources that the goal would be developed through use of a site risk assessment. Other sites might not require any cleanup. Based on a cost-benefit analysis, the provision of an alternative water supply or the relocation of nearby residents might comprise the remedial (risk management) response.

For sites where only minimal remedial measures are taken because of limited future use (e.g., a site "paved over" and used for an airport runway or a large parking lot), methods such as deed restrictions must be used to communicate these decisions to future generations so that these contaminated resources are not unknowingly used for unforeseen purposes. The uncertainties in future land use must be weighed against the costs of more extensive cleanup. Transfer of liability to future land users or developers might be effective in enforcing land use restrictions.

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[8]U.S. Environmental Protection Agency, *A Groundwater Protection Strategy for the Environmental Protection Agency*, August 1984.

The development of a classification system would be consistent with the fund-balancing provision of CERCLA. *In many ways, it would be the most nationally cost-effective approach discussed in this chapter.* Public reaction would be mixed depending on the classification system developed, the proposed response at individual sites, and the degree of local participation in deciding on land use.

CONCLUSION

On the basis of its analysis OTA finds that:

- There is a need to raise the cleanup goals issue to the highest levels of policymaking and to have open, public debate on it. The effectiveness of the Superfund program and private and State cleanups depend on an equitable and technically sound resolution of this issue.
- What is ultimately important and realistically achievable is consistency in the *process* of determining what the cleanup of sites should be, rather than necessarily making all cleanups the same.
- In setting cleanup levels, it is necessary to examine whether the remedial technologies under consideration can lead to unintended consequences, including transfer of toxicants among media, transfer of risks among populations, and residual pollution.
- It is no longer acceptable to continue cleanups under the current ad hoc approach. As a large number of sites enter the program, dealing with each site as a unique case is inefficient and there is increasing likelihood that sites with similar problems will not be cleaned to comparable levels of environmental protection,
- Pursuing a strategy of establishing cleanup levels on the basis of background or pristine chemical levels does not make environmental, technical, or economic sense, This approach does not assure protection of health and the environment, in many cases is not possible to achieve, and it would cost excessive sums.
- Although seemingly attractive and extensively used, best available technology or best engineering judgment do not offer environmental protection comparable to the likely high costs of implementation. This approach does not directly address actual or potential exposures threatening health and the environment.
- Although the use of existing standards, risk assessment, and cost-benefit analysis approaches pose considerable problems and have substantial limitations, they could be used.

The most important conclusion is that a cleanup strategy based on site classification could be the most beneficial approach to pursue. The present and future use of an uncontrolled site is now sometimes considered prior to cleanup decisions. What this approach would do is to explicitly and uniformly incorporate a decision about site use as the key element of a policy framework. To do this, however, means that a decision about land use must be made. Such a decision would generally need to be made at the local level. This is crucial to proceeding with this approach. It is consistent with the need to have public participation in cleanup decisionmaking (see chapter 8).

Developing a classification based on site use also presents an opportunity to have a hierarchy for establishing priorities for site response. It can provide a policy framework that objectively decides what process is used to set cleanup levels for a site on the basis of the most important site-specific consideration—how the site is or will be used and, hence, what exposures must be considered to determine health and environmental effects.

An illustration of how this approach might be used is given in table 4-I, Under this classification, the most technically sophisticated but

Table 4-1.— Illustration of a Site Classification System for Selecting Cleanup Goals

Classes of NPL sites (established when site placed on NPL)	Cleanup goals for remedial cleanup set by	Likely course of action	For comparison purposes, EPA classes of ground water[a]
I. Known or likely exposures to people or sensitive ecological elements requiring restoration of site (for possible rehabilitation or reuse), including cleanup of contaminated groundwater if technically feasible,	Site risk assessment.	1. High-priority initial response to recontrol site using HRS[b] information, 2. Obtain necessary data and perform risk assessment. 3. High-priority full-scale permanent cleanup when technology available to meet cleanup goals.	I. Special groundwaters vulnerable to contamination *and:* **a)** irreplaceable source of drinking water to substantial populations, *or* **b)** ecologically vital,
II. Known or likely exposures exist, but limited number of people and sensitive environments. Clear alternatives to site cleanup such as relocation and use of alternative water supply; site restoration or reuse not critical,	Cost-benefit analysis.	1. Initial response. 2. After cost-benefit analysis choose risk management option.	II. Current and potential sources of drinking water or have other uses.
III. Site not likely to lead to exposures to people and not situated near sensitive environment. No site restoration or reuse anticipated,	Applicable and relevant environmental standards,	1. Low-priority initial response. 2. Reevaluation every 5 years to assess need for remedial cleanup.	III. Not potential source of drinking water and of limited use,

[a]U S Environmental protection Agency, *Ground-Water Protection Strategy,* August 1984
[b]Assume an Improved Hazard Ranking System
SOURCE Office of Technology Assessment, except as noted

expensive process of risk assessment is used for the highest priority sites. These sites unequivocally require a remedial cleanup, the extent of which depends on the exact nature of the site's use. The next category of sites are those where site use suggests risk management options that would allow delay of a remedial cleanup, or a less complete cleanup, or conceivably no cleanup. For example, the risk management options could be relocation of residents, supplying alternate water, and creating an area where all use is prohibited. For this category, therefore, it is reasonable to use a cost-benefit process to establish cleanup levels in a context that allows comparison to non-cleanup alternatives.

Lastly, the third category of sites are those where exposures and damages are minimal. For this category, existing standards might be used to set cleanup levels; indeed, it might be unlawful or unacceptable to do otherwise. However, cleanup may not be necessary or it may be delayed. Also shown in the table, for comparison, are the analogous categories established by EPA in its groundwater protection strategy, However, it must be emphasized that cleanups of uncontrolled sites often involve much more than dealing with contaminated groundwater.

The table also shows site management decisions other than cleanup that could be associated with the site categories. For example, decisions concerning initial responses and timing of cleanups could be consistent with the hierarchy based on site use,

This discussion pertains to remedial cleanups that are expected to be effective in the long term, There is also a parallel question concerning actions known in the current program as immediate removals (comparable to initial responses in OTA's suggested two-part strategy). These actions are acknowledged to be temporary. Such actions must proceed quickly on the basis of limited information. Hence, a practical approach might be to establish generic standards to direct actions based on: 1) reducing the immediate threats to health and the environment by blocking or preventing releases of hazardous substances into the environment; and 2) assuring that the site, exposed to known environmental conditions, would not deteriorate further over a substantial period of time, perhaps some years before it could receive remedial cleanup. Such standards would not imply that the site is cleaned, but rather that it is isolated, stabilized, and decontrolled. A generic standard could also require continued monitoring and/or inspection consistent with the nature of the site and the likely exposures.

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Chapter 5

Sites Requiring Cleanup

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Chapter 5
Sites Requiring Cleanup

SUMMARY

OTA's assessment of major sources of waste sites and improvements in site selection methods indicates that 10,000 sites might eventually be included on the National Priorities List (NPL), and that even this figure might rise substantially. Sites that now get placed on the NPL do merit cleanup, but many other sites also require cleanup.

At least 5,000 of the 621,000 operating and closed *solid* **waste** facilities in this country, such as sanitary and municipal landfills, may require cleanup. About 20 percent of the current NPL sites were such facilities. More than 1,000 operating hazardous waste land-based facilities may require cleanup under Superfund because of the limitations of the Environmental Protection Agency's (EPA) groundwater protection standards.

An improved site selection process could place some 2,000 more sites on the NPL. Improvements would include attending to environmental threats as well as threats to human health, removing the cutoff score which has no technical basis or merit, and providing national guidance for preliminary assessments and site investigation.

EPA's estimate that about 2,000 sites will eventually be placed on the NPL is likely to significantly underestimate the future needs of Superfund. This chapter will discuss the basis for OTA's higher estimates.

INTRODUCTION

A major uncertainty in the Superfund program is the question of how many-uncontrolled waste sites may require cleanup. OTA has examined three areas in order to assess future needs; they are: 1) solid but not hazardous waste facilities governed by Subtitle D of the Resource Conservation and Recovery Act (RCRA), 2) hazardous waste facilities regulated under Subtitle C of RCRA, and 3) sites in EPA's inventory of uncontrolled sites that under current procedures are not likely to be placed on the NPL but that may warrant cleanup.

To determine whether or not a site merits cleanup under Superfund requires considerable information about the hazards it presents. OTA's analysis estimates in a statistical or probabilistic sense the number of sites not adequately accounted for in EPA's projections of future national needs.

From a policy and planning perspective such an attempt cannot be anything other than semiquantitative. The key point, however, is whether EPA's projection of an NPL of about 2,000 sites might be off by as much as 100 percent or more. Each of the three areas listed above will be examined in detail,

The reader is cautioned, however, about several limitations of these analyses. For example, OTA has not considered nonwaste sites that also qualify for inclusion on the NPL, such as leaking underground storage tanks and areas contaminated by pesticides. Evidence of a threat from such nonwaste sites is likely to increase. Nor has OTA considered sites associated with mining wastes. It may also be argued that OTA's estimates represent a worse-case scenario because companies and States may clean-up sites on their own without the use of

Superfund. But a low estimate may result from the exclusion of some sites from the analysis.

As discussed in chapter 3, underestimating the future size of the NPL could lead to cleanup strategies and allocation of resources that eventually incur higher costs and environmental risks than necessary.

Consider this scenario: a large number of sites go unattended or receive highly impermanent cleanups. These sites get worse over time and lead to large amounts of environmental contamination, particularly of drinking water. At some time, after Superfund resources have been depleted, the costs to cleanup the sites become staggering, perhaps impossible, if permanently effective cleanup technologies or adequate numbers of technical personnel are not available. Overestimating future needs appears to be far less likely, and it presents fewer problems because Congress could adjust the program to account for smaller expenditures.

SOLID WASTE FACILITIES

Our society produces exceptionally large amounts of solid waste from households, commercial establishments, industrial facilities, and virtually every other place where materials are consumed, processed, or examined. The traditional, convenient, and cheap way of disposing of these vast quantities of waste has been to place them in landfills if they were mostly solid or in surface impoundments if they were mostly liquid. Solid waste disposal has been managed both by local governments and private industry. Only recently has it become clear that the land disposal of solid wastes might pose threats to public health and the environment similar to those stemming from the disposal of what are now called hazardous wastes.

There are three reasons why solid waste facilities may become uncontrolled sites that can release hazardous substances into the environment and, therefore, be eligible for the NPL. First, prior to the creation and implementation of the Federal RCRA Subtitle C program, hazardous wastes were generally disposed of along with ordinary solid wastes. Prior to the 1970s few people recognized the dangers of hazardous wastes and the toxic chemicals in them. Thus, hazardous waste produced over many decades simply were placed in land disposal sites, many of which have since been closed. This became particularly significant after World War II, with the widespread production, use, and disposal of synthetic organic chemicals, many of which are toxic and very stable. These closed facilities present unique problems because by now their locations may not be known and there are few, if any, records of what was placed in them. Now they are part of the landscape on which new, often suburban, housing and other buildings have been placed. The technology used to build those facilities and contain the waste was far less sophisticated and safe than today's still-limited containment technologies. Furthermore, because there was little consideration of environmental threats, they were more likely to be placed near sensitive areas such as aquifers that supply drinking water.

Second, even after the regulation of hazardous waste on a broad national level various statutory and regulatory exemptions and exclusions continue to make it possible for some hazardous waste to be disposed of legally in solid waste facilities. A forthcoming report by the Congressional Budget Office estimates that in 1983 over 26 million tons of hazardous wastes were disposed of in sanitary landfills nationwide. It is important to note that relatively small amounts of hazardous waste from individual sources, including households and small businesses, can add up to substantial amounts in a particular solid waste facility. The fact that solid waste facilities may be very large, often hundreds of acres, and that the hazardous waste may be only a small fraction of, and widely dispersed within, the total waste does not preclude major environmental problems. To the contrary, although it might take longer, often decades, for hazardous substances in these sites to reach the environment, eventually large amounts of a broad variety of substances may be released, Moreover, cleaning up such large operations or closed sites presents major engineering problems and is very costly.

Third, even with a well-enforced regulatory program for hazardous wastes on both the Federal and State levels, which is not yet the case, there will be illegal disposal of hazardous waste in solid waste facilities. It is virtually impossible to examine and monitor all incoming waste to detect the broad range of hazardous substances that might be present, perhaps in small amounts and in containers. In many cases it is also possible for midnight dumpers to gain access to a solid waste facility and bypass normal inspections of incoming materials.

Current Recognition and Evidence of the Problem

There are several reasons that explain why the solid waste facility problem for Superfund has received little detailed attention. State and local officials, closest to the problem, comment to OTA that they are aware of the likelihood of release of hazardous substances from solid waste facilities. Because of limited resources, including a nearly total ending of Federal support for solid waste programs, they have tended to focus on hazardous waste facilities and there has been little testing and monitoring of solid waste sites, Where testing has been done, the broad range of hazardous substances of concern to Superfund may not be tested for. Moreover, although some monitoring results have indicated a significant problem of leachate leaving the site, such results generally are not made public. There is considerable concern that once there is public documentation connecting toxic waste problems with *solid waste* facilities there will be public pressures against their operation and the siting of new facilities. How would the vast amounts of solid waste be managed?

Nor is it likely that States could finance cleanups of large numbers of leaking solid waste facilities, either by themselves or even under the current Superfund program. Superfund requires a contribution from the States for cleanups, and for publicly owned and operated facilities that contribution is 50 percent.

At the Federal level, little attention and funding has been given solid waste programs. EPA has only recently recognized that solid waste facilities might be a major source of sites for Superfund. In a congressionally mandated study to evaluate the first period of the Superfund program, EPA states:

> Municipal landfills, both large and small, can cause potentially serious problems, Some facilities have already been closed down, some are still operating. Although such facilities can no longer accept hazardous wastes, many especially in large urban areas and in heavily industrialized areas did in the past accept industrial waste which could include hazardous waste. In addition, people may continue to dump small quantities of paints, solvents, pesticides and other household chemicals which are hazardous. In big landfills, these can potentially add up to big problems. In small towns and rural areas, while the problem may be small, it can be significant to the surrounding community. [1]

Similarly, municipal and private landfills are widely used for sludges from wastewater treatment, generally in very large quantities, The National Research Council recently concluded:

> Landfills have been increasingly used to isolate wastewater sludges containing trace contaminants at levels high enough to be of regulatory concern. The assumption has been that remobilization of such contaminants is minimized by using landfills and that release of contaminants to the environment is unlikely. The panel believes that the data supporting such a conclusion are scant and that remobilization of contaminants in surface and ground waters as well as to the atmosphere is possible.[2]

[1] U.S. Environmental Protection Agency, "Supporting Analysis for CERCLA Section 301(a)(1)(c) Study," draft, July 1984, p. 5.

[2] National Research Council, Disposal *of Industrial and Domestic Wastes* (Washington, DC: National Academy Press, 1984), p. 166.

The above statements, however, consider only one part of the solid waste facility universe, municipal landfills. The following statement contained in EPA's Ground-Water Protection Strategy provides a more comprehensive view of the problem, although only with respect to groundwater contamination rather than the full range of environmental problems that solid waste facilities pose:

> In addition to facilities receiving hazardous wastes, other facilities that may contaminate ground water are of concern. In the mid 1970s, EPA and the States became increasingly concerned that all waste disposal landfills (not just those receiving hazardous wastes under RCRA) may be creating a substantial problem for ground water. There are an estimated 93,000 such landfills in the United States. Of these, 75,000 are classified as on-site/industrial, and we know little about them. Another 18,500 are classified as municipal. Fewer than 10 States require any form of regular monitoring for ground-water quality at these facilities. Landfills are invariably located on land that is , . . susceptible to ground-water contamination problems.
>
> A similar situation obtains at pits, ponds, and lagoons—usually grouped and referred to as surface impoundments—that receive both hazardous and non-hazardous wastes. EPA's recently completed Surface Impoundment Assessment (S IA) surveyed the numbers and locations of surface impoundments, and estimated their potential effects on ground-water quality ., . The SIA identified a total of 181,000 surface impoundments. Most of them are unlined, About 40 percent of municipal and industrial impoundments are located in areas of thin or permeable soils, over aquifers currently used for drinking or that could be used for drinking. About seven percent of all sites appear to be located so as to pose little or no threat to ground water. Because of the lack of generally available knowledge, ground-water protection was rarely, if ever, considered when these facilities were sited . . . facilities handling non-hazardous wastes and hazardous wastes produced by small generators are covered by RCRA Subtitle D criteria (enforceable under citizen suits), but they are not regulated under the Federally enforceable provisions of RCRA. These facilities may be significant sources of ground-water contamination.[3]

Within the context of Superfund, EPA has acknowledged, but only to a limited degree, the contribution to the future size of the NPL by solid waste facilities. These sites, along with several other types of sites "not currently included in the determination of NPL sites, " caused EPA to conclude that as many as 800 more NPL sites might result.[4] This brought the total projected NPL to a maximum of 2,200 sites, but EPA has generally used a figure of 2,000 sites.

Congress recently has acknowledged the significance of the solid waste facility problem for Superfund. However, improvements in regulations and their enforcement would not occur for several years and might significantly affect only new facilities. The Conference Report on the recent reauthorization of RCRA noted:

> Subtitle D facilities are the recipients of unknown quantities of hazardous waste and other dangerous materials resulting from the disposal of household waste, small quantity generator wastes, and illegal dumping. Since construction, siting, and monitoring standards for these facilities are either nonexistent or far less restrictive than those governing hazardous waste disposal facilities, environmental and health problems caused by Subtitle D facilities are becoming increasingly serious and widespread. A high proportion of sites listed on the National Priority List were sanitary landfills. Without the additional environmental protection that the implementation of this provision will provide, even more Subtitle D facilities are destined to become Superfund sites.[5]

Solid waste facilities continue to attract attention at the State and local levels across the Nation. For example, a New York State legis-

3 U.S. Environmental Protection Agency, *A Ground-Water Protection Strategy for the Environmental Protection Agency*, August 1984, pp. 14 and 38.

4 Alvin R. Morris, U.S. Environmental Protection Agency, memorandum to Alvin L. Alm and Lee M. Thomas on the results of a Superfund Task Force assessment, Dec. 8, 1983, p, 5.

5 U. S. Congress, *Hazardous and Solid Waste Amendments of 1984*, Conference Report 98-1133.

later brought to pub lic attention that a high fraction of solid waste landfills could be contaminating groundwater:

> In late 1983, at least 50 of the state's 538 legal landfills were known to be polluting ground water. Officials at the state's Department of Environmental Conservation estimate that the number could be zoo or more.[6]

Similarly, an official in the Puerto Rican legislature indicated the severe nature of the problem there:

> The major problem is underground water contamination caused by inadequate disposal of hazardous wastes. For more than 10 years, these industries have been disposing of waste in sanitary landfills in a region where the underground is basically permeable to liquids.[7]

For a closed landfill in Southwest Philadelphia for which Superfund cleanup had not yet been obtained the following was reported:

> The state Health Data Center recently released a study that showed the cancer mortality rate in Sharon Hill, Darby Township, and Darby Borough—which are adjacent to the landfill—is 22 percent higher than in the state and the nation. . , . The landfill was ordered closed in 1972 by a court order, but documents and photographs . . . show that the landfill is still operating. . . . EPA officials confirmed the findings of a study that showed a number of carcinogens and other toxic substances were leaking from the landfill into Darby Creek. Although EPA officials said toxic wastes were only found in small quantities, they said it posed a hazard to children who may swim or fish in the creek.[8]

In Maryland an aluminum smelting plant's waste has been interpreted to be an exempted mining waste, but controversy has continued:

> Residents have complained, without much success, about the threat of wastes produced by the plant, particularly contamination of well water with the cyanide they say is leaching out of disposed materials. . . . In *1981,* after receiving no public comment to the contrary, EPA pulled pot liners off its list [of hazardous wastes], pending completion of the study. . . . As a result of that action [the company] terminated an agreement to recycle the pot liners . . . and instead decided to bury them on its 2,000-acre plant site here. The company received a landfill permit from the state last year, but a consultant report released in April found cyanide in groundwater at the plant site. g

In a more systematic way, a study performed for OTA analyzed three data bases on sites already known to be or likely to become uncontrolled sites eligible for Superfund cleanup. The three data bases, which contained sufficient detail to make a judgment as to whether a site could be characterized as a RCRA Subtitle D facility, were: 1) a computerized data base maintained for EPA on about 1,000 mismanaged waste facilities, 2) 550 NPL site descriptions, and 3) a survey of 365 sites where remedial actions have been performed,

Out of 1,389 sites, 245, or nearly 18 percent, were Subtitle D facilities. For the 550 sites proposed or included on the NPL, 108 sites, or nearly 20 percent, were classified as Subtitle D facilities. Examination by OTA of recent proposed additions to the NPL and other data indicate that these percentages are low. The distribution for the 245 solid waste facilities according to EPA Region and State is given in table 5-1,

The greatest number of problem solid waste sites were in EPA Region II, which contained 33 percent of the sites. Regions III, IV, and V also had relatively large numbers of sites. Together these correspond to the Eastern (Atlantic coastal area) and Midwestern portions of the Nation. New York had the greatest fraction with 17.5 percent, followed by New Jersey with 15 percent, Pennsylvania with 7.5 percent, and Tennessee with 5 percent, with these four States containing 45 percent of the sites identified, These statistics should not be interpreted to mean that other regions and States do not have current or potential problems with solid waste facilities; but the older, more densely

[6] John J. Marchi, *The New York Times*, June 16, 1984, Op-ed page.
[7] *The New York Times*, Feb. 21, 1984.
[8] *The Philadelphia Tribune*, June 5, 1984.
[9] *The Washington Post*, Nov. 22, 1984.

Table 5.1 .—Known Problem Subtitle D Sites by EPA Region and State

Location	Number
Region 1:	
Connecticut	5
Maine	2
Massachusetts	3
New Hampshire	5
Rhode Island	3
Vermont	1
	19
Region II:	
New Jersey	36
New York	43
Puerto Rico	2
	81
Region III:	
Delaware	8
Maryland	2
Pennsylvania	18
Virginia	6
West Virginia	4
	38
Region IV:	
Alabama	2
Florida	10
Georgia	1
Kentucky	4
North Carolina	1
Tennessee	13
	31
Region V:	
Illinois	5
Indiana	4
Michigan	12
Minnesota	1
Ohio	11
Wisconsin	5
	38
Region VI:	
Arkansas	2
Louisiana	2
Oklahoma	5
	9
Region VII:	
Missouri	1
Nebraska	1
	2
Region VIII:	
Colorado	6
Montana	3
South Dakota	1
Utah	2
	12
Region IX:	
Arizona	4
California	3
Nevada	1
	8
Region IX:	
Guam	1
Idaho	1
Washington	5
	7
Total	245

SOURCE: JRB Associates, "Evaluation of RCRA Subtitle D Facilities," contractor report prepared for the Office of Technology Assessment, June 1984

populated and more highly industrialized areas may find more environmental problems with larger numbers of solid waste facilities.

Table 5-2 presents the waste mismanagement events identified at the solid waste sites, Mismanagement events are categorized as documerited or suspected based unavailable information. For example, a documented leachate mismanagement event would be one where groundwater monitoring data showed downgradient contamination by leachate. For a suspected event there would be some evidence of leachate movement from the site, such as contamination of surface water, but insufficient hydrogeologic data to establish a causal connection between the site and groundwater contamination. Leachate migration was the most common problem, occurring at 80 percent of the sites and leading to groundwater contamination; at 65 percent of the sites surface water was affected (see table 5-3).

Table 5-4 gives the data on affected receptors of hazardous releases. Drinking water was the most frequently affected receptor at 49 percent, followed by human health at 23 percent.

Table 5-2.—Mismanagement Events at Problem Subtitle D Sites[a]

Event	Documented	Suspected	Total frequency
Erosion	24	11	35
Flood	2	6	8
Fire/explosion	15	6	21
Gaseous emission	20	15	35
Leak	17	23	40
Leachate	129	66	195
Spill	15	9	24
Other	11	3	14

[a]Individual facilities may be classified in several categories Therefore. totals do not add to 245

SOURCE JRB Associates, "Evaluation of RCRA Subtitle D Facilities," contractor report prepared for the Off Ice of Technology Assessment, June t984

Table 5-3.—Affected Media at Problem Subtitle D Sites[a]

Exposed media	Documented	Suspected	Total
Air	27	23	50
Groundwater	119	77	196
Soil	63	71	134
Surface water	74	85	159

[a]Individual facilities may be classified in several categories Therefore, totals do not add to 245

SOURCE JRB Associates, "Evaluation of RCRA Subtitle D Facilities," contractor report prepared for the Office of Technology Assessment, June 1984

Table 5.4.—Affected Receptors at Problem Subtitle D Sites[a]

Affected receptor	Documented	Suspected	Total frequency
Drinking water	54	67	121
Fauna	8	29	37
Flora	13	15	28
Human health	8	48	56
Property damage	22	7	29

[a]Individual facilities may be classified in several categories Therefore, totals do not add to 245.

SOURCE JRB Associates, "Evaluation of RCRA Subtitle D Facilities," contractor report prepared for the Off Ice of Technology Assessment, June 1984

Various other information was obtained on the sites. Ownership data showed that nearly half of the sites were owned and probably operated by municipalities. About 80 percent of the facilities were landfills, and nearly 20 percent surface impoundments, Generally the contaminants found at the facilities and their frequency resemble what has been found at all sites evaluated for the NPL. The most common contaminants, found at at least 30 sites, were lead, benzene, phenol, toluene, and trichloroethene.

Data on the size of 92 sites were available; the mean size was 67.4 acres if one 5,000 acre site is excluded. Hazard Ranking System (HRS) scores for placement on the NPL were available for 77 of the solid waste facilities. The median score for the solid waste facilities was 40.8 and for the original 406 sites on the NPL it was 42.2. The range for the solid waste sites was from 19.5 to 75.6. All the information suggests that solid waste sites on the NPL score similarly to NPL sites that dealt solely with hazardous wastes.

Limited information on Superfund expenditures was found. Average Remedial Investigation / Feasibility Study costs for 41 sites averaged $450,000, which is about half of what EPA now estimates to be average RI/FS costs. Estimated remedial cleanup costs (including RI/FS costs and excluding operating and maintenance costs) for six sites averaged $3 million, less than half of the average figure for remedial cleanups now being used by EPA,

Case Studies

As part of the effort to examine the current problem with solid waste facilities two sets of detailed case studies were performed. In the first set, four landfills already on the NPL were examined; in the second set, four landfills believed to be typical of solid waste facilities, but which have not been considered for the NPL, were examined, These eight case studies are summarized below.

The Combe Fill South Landfill, Chester Township, New Jersey, received an HRS score of 45.2. The 60- to 100-acre site was privately owned and operated before the last owner filed for bankruptcy in 1982. The original 30-acre landfill operated from the 1940s and was closed in 1972; a newer, engineered landfill was approved by the State in 1972 for nonhazardous waste disposal and it was closed in 1981. The site is atop a hill in a wooded, rural residential area. Within one-half mile are 90 residential drinking wells; within one-quarter mile are 38 residentially zoned lots; 1 mile away is a State park; and the immediate area is the headwater for several local streams and a brook that receive runoff from the site, In 1981, State agencies sampled surface and groundwater near the site, found contamination and a threat to drinking water supplies, Later, air emissions of volatile organics were found. Even if RCRA Subtitle C regulations for a hazardous waste landfill had been applied to this site, they probably would not have been effective. The site is fundamentally unsuitable for land disposal.

The Laurel Park Landfill, Naugatuck, Connecticut, received an HRS score of 46,8. The facility is a 35-acre, privately owned and operated sanitary landfill, active since 1951, and is atop a hill. About one-half mile downhill are homes; one side of the hill is heavily wooded and abuts a State forest; the area comprises part of the headwaters of two watersheds, Roughly 200 tons per day of municipal and industrial wastes, and septic and sewage sludge are discharged at the site. Since the early 1960s the site has been subject to numerous citizen complaints and regulatory actions. There were fires, spills on roads, noxious fumes, and findings of contaminated leachate affecting surface and groundwaters. Various actions have allowed the facility to remain in operation, including: monitoring groundwater, installing leachate collection and treatment systems, and supplying potable water to some residents. As the site is not particularly well suited for land disposal, even RCRA Subtitle C regulations would not have been totally effective in combating these problems.

The Marshall Landfill, Boulder, Colorado, received an HRS score of 46.5. Marshall Lake is about one-quarter mile east and receives runoff from the site; the town of Superior is 2 miles west; industrial and cattle grazing areas are nearby; and Boulder is 3 miles southeast of the site. Several bodies of water that ultimately receive runoff from the site are used as drinking water supplies. There is an inactive 80-acre portion and an active 80-acre portion of the site. The inactive portion was operated under various owners from 1955 to 1974 and received municipal solid wastes, septic tank wastes, secondary wastewater treatment sludges, and unknown industrial liquid wastes. The active portion accepts sewage sludge, but suspicions have arisen concerning the disposal of radioactive waste and polychlorinated biphenyls (PCBs). There is evidence of contamination of surface and groundwaters, as well as methane generation. If the facility had been regulated under Subtitle C, many of the problems could have been reduced or prevented.

The Syosset Landfill, Syosset, New York, received an HRS score of 54.3. It is located in a residential and light industrial area of Long Island with five public water supply wells within 6,000 feet of the site. The 40-acre landfill was opened in 1936 by the local municipality and closed in 1975, because of suspected groundwater contamination. The water table is only about 30 feet below the bottom of the fill; the landfill is in a recharge zone (where new water enters) of a sole source aquifer. In 1968 the landfill stopped receiving municipal waste. Prior to 1968 and up until 1975 the site received much industrial waste. A study in 1982-83 revealed evidence of migrating contamination, but public water supply wells were not yet contaminated. Compliance with Subtitle C regulations would have mitigated, or at least delayed, the environmental impacts of this facility. Further, the facility probably would not have been located in a recharge zone of a sole source aquifer.

The second set of case studies was performed on four currently operating or recently closed Subtitle D facilities that *are not* on the NPL. (Three of these sites have not been named at the request of the operators.) Sites selected for the case studies had to have groundwater monitoring data, which are not generally available for most solid waste facilities, but not all of the sites made the data available. Two HRS scores were calculated for each site.[10] The methodology, however, was altered because rigid adherence to the current procedure would lead to zero values when certain data were absent; this is a major criticism of the current scoring procedure.

Site A is a closed, county-owned municipal landfill in Maryland that operated from 1962 to 1982. The 161-acre site is hilly and part of the site was originally a ravine. The site is bounded by two streams which discharge to a river that is not a source of drinking water. Groundwater monitoring data obtained by the county over an 8-year period indicate that groundwater leaving the site and discharging into local streams is contaminated with acidic leachate from the landfill, Although probable sources of hazardous substances were being dumped in the unlined site, there is little information about the specifics of the situation, *At this point, although human health problems do not appear imminent, environmental damage is likely and there is a potential for future remedial action at the site.* It is important to note that the site monitoring does *not* monitor for halogenated organic toxic chemicals nor for some toxic metals, Lead, however, has been found downgradient, There are no Federal or State requirements to perform such monitoring. HRS scores calculated for this site were 3.5 and 4.4; these low scores currently preclude placement on the NPL and result because the contaminated water does not affect people downstream,

Site B is a municipally owned and operated landfill in Pennsylvania and was officially permitted by the State in 1983. The 175-acre site is surrounded mostly by cropland. Several houses within 1 mile downgradient have pri-

[10]For the first score, the lowest non-zero rating value was used to score items for which data on waste quantity and toxicity were missing. For the second score, certain assumptions were made; for example, it was conservatively assumed that 0.01 percent of the total amount of waste was hazardous. This approach to the HRS provides an indication of the *possible level* of scores. 'l'his exercise also confirms two other problems with the HRS procedure, a discounting of sites which affect small populations or which affect environmental quality but not human health directly.

vate wells. There is shallow, diffuse, and slow groundwater flow at the site, and surface water discharges into a tributary of a large creek. The facility receives mostly domestic waste, some debris from construction demolition, and some industrial wastes. Before the open dump was turned into a municipal facility, industrial wastes were disposed there, including chemical and fertilizer wastes, dyes used for textiles and printing, sludges from foundries, and shoe factory wastes, Now, surface runoff and leachate are treated and the discharged water appears to meet its National Pollution Discharge Elimination System (NPDES) permit requirements, Groundwater monitoring began in 1983 but it does *not* measure organic pollutants nor most inorganic chemicals of importance in Subtitle C facilities, Monitoring, however, has revealed evidence of contamination, including some toxic metals, attributed to migrating leachate from the unlined site. *There is a significant potential for future remedial action to prevent contamination of drinking water supplies downgradient.* The HRS scores for this site were 14.8 and 18.5, which are below the current NPL cutoff of **28.5** primarily because the affected population is small.

Site C opened in 1972 and is a municipal} owned sanitary landfill in Virginia, operated by a contractor. It is located in a generally rural area, but with some nearby commercial development and light industry, The 57-acre site, with ***20*** acres still operating, is in marshy area, although the site itself is not marshland. With 50 feet of land buffer, there is a wooded rural residential area to the south and a cattle grazing area to the west. One mile downstream is a small lake used infrequently for irrigation. Surface runoff also enters streams used for recreational fishing.

A shallow aquifer near the site is used by residents to the south and east. A higher quality but deeper aquifer is used by a company to the north. The facility is unlined and has no leachate collection system, Waste received is primarily residential and commercial refuse, with some industrial waste, including chemical-resistant fabric, residues from plastic processing, and residues from glues for paper products. Much emphasis has been placed on not accepting hazardous waste. Groundwater monitoring of the shallow aquifer has occurred for about 2 years, but *not* for toxic organic chemicals. *There is evidence of groundwater contamination by leachate from the site and, hence, future remedial action may be required.* HRS scores calculated for this site were 3.5 and 26, too low for placement on the NPL.

The last site is the Marathon County landfill, Wisconsin, owned and operated by the county. The landfill comprises 27.3 acres and could be expanded greatly. The surrounding area is mostly woodlands and forest. A small number of nearby residences are believed to have private wells and there is a dairy nearby, but both are separated by the 572 acres of the overall site. The site does not drain into locally used surface waters. The site is in a recharge zone for aquifers used for some residences.

A clay liner is used together with leak detection and leachate collection systems; contaminated leachate is treated in a nearby industrial wastewater treatment plant. Just over half the wastes accepted originates from industry, including wastewater treatment sludge, fly ash, alkaline sludge, foundry sand, and papermaking waste, none of which are RCRA hazardous wastes. There is extensive air, surface, and groundwater monitoring by the county, as well as various State-imposed financial responsibility requirements. To date, the containment technology appears to be presenting any migration of leachate offsite. The HRS scores were zero for this site, and *it is unlikely to require remedial actions because of the care applied to its location, design, and operation.* However, the groundwater monitoring program does *not* measure for a number of toxic chemicals, and some hazardous substances are probably in the wastes accepted.

The case studies support the general] proposition that many, if not most, solid waste facilities have and will continue to pose threats associated with the release of hazardous substances into the environment. Subtitle D facilities already identified for Superfund attention resemble hazardous waste sites, Just as important, the solid waste facilities that have been placed on the NPL are basically similar to typical ones, such as the three out of four in the second set of case studies that might qualify someday for the NPL. Moreover, those solid waste facilities, closed or operating, that have not been judged appropriate for the NPL have not been monitored closely for the range of hazardous substances that might qualify them for the NPL, even though considerable evidence often exists for migration of leachate off site. This suggests that the 20 percent of the NPL now accounted for by solid waste facilities could rise substantially. *The concerns of citizens, the media, some State and local officials, and the EPA about the Subtitle D facility problem for Superfund appears well founded.*

Estimate of Possible Future Contribution to the NPL

It appears very likely that many solid waste facilities will become uncontrolled sites requiring cleanup under Superfund. The next question, then, is how will this affect the size of the NPL? OTA first examined the total number of Subtitle D facilities and then estimated what fraction of this total might someday be placed on the NPL.

Data on Operating and Closed Facilities

There is considerable uncertainty about how many Subtitle D facilities there are in the Nation, The uncertainty is greater for closed, older facilities than for operating ones. Table 5-5 presents survey data by EPA Region and State on operating landfills for the years 1981-83, The table also gives the number of open dumps identified by States in their 1983 inventory and projected numbers of dumps that will be upgraded to landfill status (sites not upgraded are usually closed). The numbers of open dumps reported may be low because additional dumps probably exist and remain uninventoried. The data also presents problems because there are varying definitions of landfills. Some States may include industrial landfills, perhaps only offsite ones, while most include only municipal landfills. Definitions may also change from year to year, explaining, for example, the large increase in Texas from 1981 to 1982; 793 sites surely were not built in 1 year in Texas. Considering the transformation from open dumps to landfills and what appears to be a rate of approximately 500 new landfills being permitted annually, the number of operating and presumably chiefly municipal or sanitary landfills in 1984 was probably about 14,000, up from 13,000 in 1983.

The same survey indicates that in 1983 the estimated number of landfills with groundwater, gas, and/or leachate monitoring wells was 1,609, although 14 States did not report this information. An estimated 37 facilities had artificial liners in 1983, with 12 States not reporting this information. In 1983, 30 percent of the facilities were publicly owned, 65 percent privately owned, and 5 percent had some combination of ownership.

There must, in addition, be many closed municipal and sanitary landfills, To estimate their number, OTA obtained data from several States on operating and closed landfills. For six States there was a minimum of 2,784 closed facilities and a total of 895 operating ones. This ratio of about 3:1, applied nationally, yields an estimate of 42,000 closed municipal and sanitary landfills in 1984,

EPA estimates that approximately 75,000 onsite, nonhazardous waste industrial landfills operate nationally, Although this figure has been used in 1984, it is based on an estimate made in 1978 and the advent of the RCRA and Superfund programs may have reduced it significantly. There are no estimates for the number of closed, onsite industrial landfills, but an estimate of twice the above number—l50,000—may be reasonable,

Surface impoundments falling under the Subtitle D classification include wastewater treatment lagoons, potable water treatment lagoons, pits, ponds, basins, mining waste disposal facilities, evaporation ponds, agricultural waste disposal facilities, and others. Often a site may consist of several impoundments, EPA's Surface Impoundment Assessment for 1978-80 gives the best available data. Table 5-6 summa-

Table 5-5.—RCRA Subtitle D Facilities by State

State	Number of all landfills 1981	1982	1983[b]	Number of open dumps[ab]	Open dumps to upgrade[a]
Region 1:					
Connecticut	170	155	151	36	24
Maine	336	328	308	45	NA
Massachusetts	286	273	283	81	NA
New Hampshire	450	250	101	26	0
Rhode Island	35	22	18	4	1
Vermont	73	85	92	4	0
Region 2:					
New Jersey	240	185	185	5	1
New York	641	525	525	56	38
Puerto Rico	68	NA	NA	NA	NA
Region 3:					
Delaware	NA	4	35	4	4
District of Columbia	2	3	NA	NA	NA
Maryland	NA	64	47	0	0
Pennsylvania	1,400	847	925	94	75
Virginia	NA	250	209	50	34
West Virginia	228	127	127	41	36
Region 4:					
Alabama	146	135	135	12	11
Florida	209	214	248	55	17
Georgia	517	299	284	6	4
Kentucky	210	112	128	34	NA
Mississippi	286	120	253	133	10
North Carolina	170	225	167	1	0
South Carolina	128	78	225	0	0
Tennessee	134	160	161	6	2
Region 5:					
Illinois	260	450	329	42	0
Indiana	149	129	348	191	2
Michigan	470	NA	362	150	0
Minnesota	371	105	185	60	0
Ohio	680	235	318	54	NA
Wisconsin	1,050	1,100	1,085	66	10
Region 6:					
Arkansas	490	141	311	78	NA
Louisiana	NA	532	532	532	95
New Mexico	228	231	228	0	0
Oklahoma	215	225	225	66	60
Texas	250	1,043	1,075	11	8
Region 7:					
Iowa	NA	95	94	0	0
Kansas	243	220	224	1	0
Missouri	107	108	128	2	1
Nebraska	277	500	400	2	0
Region 8:					
Colorado	205	206	206	32	26
Montana	221	250	222	16	13
North Dakota	84	97	130	0	0
South Dakota	30	NA	200	140	5
Utah	300	290	296	26	8
Wyoming	NA	86	210	0	0
Region 9:					
Arizona	130	122	116	28	27
California	450	443	542	40	31
Hawaii	24	NA	25	9	4
Nevada	114	120	99	52	10

Table 5-5.—RCRA Subtitle D Facilities by State—Continued

State	Number of all landfills 1981	1982	1983b	Number of open dumps[a,b]	Open dumps to upgrade[a]
Region 10:					
Alaska	80	NA	NA	NA	NA
Idaho	220	130	132	42	20
Oregon	226	249	226	28	3
Washington	NA	136	136	36	18
Guam	3	NA	NA	NA	NA
Total	12,606	11,704	12,991	2,396	598

[a]Data for 1983
[b]There may be some overlap between these column entries

SOURCE Nancy Peterson, 1983 Survey of Land fills,' *Waste Age,* vol 14, No 3, March 1983 "Land Disposal Survey, " *Waste Age,* vol 12, No 1, January 1981

Table 5-6.—Types of Surface Impoundments

	Active sites[a]	Active impoundments	Abandoned sites	Abandoned impoundments
Agricultural	14,677	19,167	173	270
Municipal	19,116	36,179	630	1,006
Industrial	10,819	25,749	941	2,163
Mining	7,100	24,451	264	587
Oil and gas	24,527	64,951	463	537
Other	1,500	5,745	53	168
Total	77,739	176,242	2,524	4,731

Total active and abandoned sites: 80,263
Total active and abandoned impoundments: 180,973

[a]A site may have more than one (impoundment

SOURCE U S Environmental Protection Agency, *Surface Impoundment Assessment National Report,* EPA 570/9-84.002, December 1983

rizes the results of this survey, which found a total of 176,242 active facilities and a minimum of 4,731 closed ones. The latter is a minimum because the survey did not attempt to count closed impoundments and a more realistic figure might be as high as the number of active impoundments.

Table 5-7 gives the data broken down according to purpose of the impoundment. An unknown fraction of the 96,443 storage and treatment facilities may pose environmental problems similar to disposal impoundments and thus may affect future Superfund needs. For example, both during storage, which may be for long periods, and treatment, which may only constitute settling or evaporation, hazardous substances may migrate into the land and water. Evaporation of volatile organic toxic chemicals also presents problems. Only 29,250 of all impoundments had any sort of liner, artificial or natural. Based on limited data, only 1,359 impoundments had any type of monitoring. EPA found that about one-quarter of impoundments potentially would affect groundwater supplies.

Table 5-7.—Purpose of Impoundments (by percent[a] and number)

Category	Storage Percent	Storage Number	Disposal Percent	Disposal Number	Treatment Percent	Treatment Number
Agricultural	55	10,542	26	4,983	19	3,642
Municipal	5	1,809	31	11,215	64	23,155
Industrial	17	4,377	31	7,982	52	13,390
Mining	18	4,401	27	6,602	56	13,693
Oil and gas	29	18,836	67	43,517	4	2,598
Total		39,965		74,299		***56,478***

[a]Percent storage disposal and treatment per category

SOURCE U S Environmental Protect Ion Agency *Surface Impoundment Assessment National Report* EPA 570/9 84002, December 1983

The above data suggest a total of as many as 281,000 landfills, and 340,000 surface impoundments, including both open and closed facilities. These figures are only approximate but are based on the best available, albeit limited and imprecise, data,

Estimates of Future Superfund Needs

The key question is what fraction of the above total of 621,000 Subtitle D facilities might require cleanup under Superfund? There is, of course, no precise means of answering this question. One approach is to consider several possible percentages that appear conservative and reasonable, based on the information from case studies, the lack of current monitoring for hazardous substances, and on the very small numbers of facilities with 1iners and monitoring wells. Information presented earlier on Subtitle D facilities on the current NPL suggest that landfills may pose more serious problems than surface impoundments. This is consistent with the fact that many impoundments may be used for dilute aqueous wastes that pose less serious problems than do the more concentrated hazardous materials often placed in landfills.

Table 5-8 presents two scenarios for sites that might release significant amounts of hazardous substances. The low scenario estimates that 5 percent of landfills and 1 percent of impoundments might require cleanup and leads to a total of 17,4oo cleanups. The high scenario estimates that 10 percent of landfills and 2 percent of impoundments might require cleanup and leads to a total of 34,800 cleanups. If these figures, which OTA believes to be conservative, are even approximate} correct, they suggest that very large sums of money will be needed just to perform studies of Subtitle D facilities, and much more to clean them up. The figure could be hundreds of billions of dollars. Even a fraction, say 5,000 sites or one-third, of the lowest estimate, together with other contributions to be discussed, would quintuple the size of EPA's projected 2,000-site NPL.

Table 5-8.— Estimates of Sites With Potentially Significant Releases into the Environment

	Low scenario		High scenario	
Landfills (281 ,000) ., ...,	5°/0	14,000	1OO/o	28,000
Surface impoundments (340,000)	1 0/0	3,400	2%	6,800
		17,400		34,800

SOURCE Off Ice of Technology Assessment

HAZARDOUS WASTE FACILITIES

The expectation has been that effective protection of public health and the environment from hazardous wastes eventually would be achieved by Superfund's cleaning up past problems and RCRA's preventing future ones. The purpose of this section is to examine the extent to which operating RCRA Subtitle C hazardous waste facilities might become candidates for cleanup under Superfund.

OTA has studied the groundwater protection standards covering land-based facilities regulated by RCRA. Although other types of environmental pollution are possible from hazardous waste facilities, groundwater problems exist at most NPL sites. Moreover, other types of environmental problems are not addressed by the RCRA regulatory program to the same extent as groundwater contamination, For example, there are few regulations covering air emissions of toxic chemicals.

A recent report by EPA's Superfund Task Force[11] indicates that as of December, 1983, groundwater contamination was the number one problem in uncontrolled sites. For example, for the 881 sites rated for the NPL, 526 had observed releases of hazardous substances into groundwater. *Over* 8 *million Americans are potentially exposed to* the groundwater *from these*

[11] X 101.1, ismemo.op.cit

sites, and for about 350 *of these sites the contaminated groundwater is the only source of drinking water for the affected population.* Another 6.5 million people are potentially exposed to contaminated surface water at 450 sites. EPA acknowledges that most of the 444 commonly encountered toxic pollutants found at these 881 sites exhibit chronic toxicity and pose health threats at extremely low levels of human exposure. Of the 538 sites on the NPL, 40 percent were originally landfills and 30 percent were surface impoundments.

Furthermore, most of the cleanups being conducted under Superfund involve either leaving the wastes in the ground and attempting to contain them, or removing contaminated materials to land disposal sites, Land disposal sites that have and continue to receive Superfund cleanup wastes may themselves become Superfund sites (although not solely because of the redisposal of wastes), so this issue is particularly important, We are beginning to see examples of this already (e. g., the BKK facility in California). This is to be expected, as EPA estimates that 50 to 60 precent of interim status land disposal facilities are leaking. Over 50 RCRA interim status facilities regulated by EPA are already on the NPL.[12]

EPA's Dependence on Current Groundwater Protection Standards

Current Federal regulatory control of hazardous waste land disposal facilities is *critically dependent* on EPA's groundwater protection standards. Because of the admitted deficiencies and uncertainties of land disposal technology, such as the unproven long-term effectiveness of leachate liners and collection systems, protection of human health and the environment rests ultimately on the protection afforded by the groundwater monitoring requirements. For example, EPA's director of its Office of Solid Waste has said:

> While *no* method of hazardous waste management is failproof, our rules should protect human health and the environment. Even if a containment system fails, groundwater monitoring will identify leakage and the pollutant plume will have to be cleaned up.[13]

However, no mention is made of dealing with the leak itself, nor of stopping the disposal of hazardous materials in the leaking site. Cleaning up the pollutant plume is of limited effectiveness if the leakage continues.

The director for air and waste management in EPA's Region VIII has said:

> In the Agency's view, the cornerstone of our land disposal program rests on the groundwater protection standards. They were devised to provide essential environmental and health controls.[14]

More recently, EPA has formulated a national groundwater protection strategy that recognizes that "cleaning up contaminated groundwater is difficult, expensive, and often unsuccessful, These facts clearly argue for future programs to focus on better protection of the resource while efforts to detect and deal with serious contamination resulting from past actions continue, " EPA's new national groundwater protection strategy guidelines indicate that the RCRA groundwater protection standards will still be used.[15] OTA finds that, because of the inadequacies of the RCRA groundwater protection standards, the goal of protecting the resource rather than cleaning it up after the fact is in jeopardy,

RCRA and Land Disposal

Several aspects of the RCRA regulations have already received considerable analysis. For example, OTA completed a major study of hazardous waste control in March 1983.[16] Another

[12] U.S. Environmental Protection Agency, computer printout from the "Hazardous Waste Data Management System, " provided by Jeffrey Tumarkin, June 19, 1983.

[13] John N. Skinner, U.S. Environmental Protection Agency, letter to Keith H. Gordon, Aug. 12, 1983.

[14] Robert L. Duprey, U.S. Environmental Protection Agency, letter to Leo Younger, Aug. 10, 1983.

[15] *A Ground-Water Protection Strategy for the Environmental Protection Agency, 01).* cit.

[16] U.S. Congress, Office of Technology Assessment, *Technologies and Management Strategies for Hazardous Waste Control,* OTA-M-196 (Washington, DC: U.S. Government Printing Office, March 1983).

major study was done by the National Academ}' of Sciences.17

These works show that even with the best available land disposal technology, hazardous wastes placed in land disposal facilities will likely migrate into the broader environment sooner or later. Moreover, there are commercially available waste reduction and waste treatment alternatives to the land disposal of many hazardous wastes. Finally, RCRA regulations present technical and economic disincentives to industry that limit the use of alternative technologies.

More resources continue to be allocated to the regulation of fundamentally flawed land disposal technology than to the development and demonstration of alternatives to land disposal. EPA frequently has been criticized for not encouraging alternative technological approaches to the land disposal of hazardous waste. EPA's response has been: a) that the technology for recycling and alternative treatment to land disposal may not exist for all or most wastes, b) that the technologies are not "on-the-shelf" but are in some stage of development, and c) that to the extent to which technology does exist, the necessary plant capacity may not be in place. However, EPA's land disposal groundwater protection regulations do not meet these standards either.

To sum up, RCRA regulations do not overcome the fundamental inadequacies of land disposal technology because: 1) experience has shown that regulatory enforcement efforts do not assure compliance with regulations; and 2) as the following analysis shows, even with *compliance with RCRA groundwater protection standards, land disposal will still pose serious risks to health and environment.*

Interim Status

When Congress passed RCRA in 1976, it provided a grandfather clause for existing facilities so that they could continue to operate *as if they had a permit* until EPA issued them a permit .18 This interim status was to allow for a smooth transition to a condition of federal1y permitted hazardous waste facilities,

There remains considerable uncertainty as to the exact number of interim status sites covered by the groundwater protection standards. According to applications for RCRA permits, as of December 1983, 2,000 out of 8,000 interim status sites were required to monitor groundwater.[19] To date only about a dozen of these 2,000 facilities have been issued permits by EPA, thus most continue to operate under interim status. EPA estimates that it will not complete the permitting of the 2,000 facilities for 10 more years,[20] In the following discussions the use of the terms "new" or "permitted" facilities refers to either newly built facilities or interim status ones that have received permits.

EPA's Implementation

In May 1980, EPA issued "interim status standards "[21] as the "minimum requirements" for interim status facilities. These interim status standards (or Part 265 standards) are "in lieu of" the more stringent Part 264 standards[22] that go into effect only after the facility is permitted by EPA. This action cut off any means of bringing an interim status facility into compliance with standards "adequate to protect human health and the environment" short of issuing (or denying) a permit. 's The RCRA re-

[17] National Materials Advisory Board, *Management of Hazardous Industrial Wastes: Research and Development Needs*, NMAB-398 (Washington, DC: National Academy Press, 1983).

[18] RCRA, Section 3005(a).

[19] U.S. Environmental Protection Agency, "Summary Report on RCRA Activities—January 1984" (Washington, DC: Office of Solid Waste, January 1984); As of mid-1984 EPA had status sheets on only 972 facilities, but a number of State officials indicate that more facilities exist in their areas than EPA is aware of. To date EPA has permitted only a few disposal facilities under RCRA.

[20] U.S. General Accounting Office, *Interim Report on Inspection, Enforcement, and Permitting Activities at Hazardous Waste Facilities*, GAO/RCED-83-241 (Gaithersburg, MD: U.S. General Accounting Office, Sept. 21, 1983).

[21] 40 CFR 265

[22] 40 CFR 264.3

[23] There are provisions in both RCRA and CERCLA for EPA to seek an injunction to require action if it can be demonstrated that there may be an imminent and substantial endangerment to health or the environment. These provisions may have been used in a few cases to require corrective action for groundwater pollution at an active interim status site. Their use at an active RCRA regulated site would indicate that there are no pertinent regulations with which the agency can require compliance.

authorization has addressed this issue in part (see below).

Although the interim status groundwater monitoring requirements have only recently gone into effect, as of mid-1984 210 out of 972 facilities were "in assessment" because their groundwater monitoring systems indicate that they are polluting groundwater.[24] Some of these are receiving wastes from Superfund cleanups, Of the 210 facilities, only 72 were found by EPA to have adequate monitoring programs, with 86 not evaluated by a State or EPA office. Of the 586 facilities in the normal detection mode, only 175 were found to have adequate monitoring programs; 85 had no monitoring wells at all, and 173 never were evaluated. Thus, more than the 210 facilities might be required to be in the assessment monitoring mode if they were performing adequate detection monitoring, perhaps as many as 400, A 1983 study by the General Accounting Office of several States with above-average regulatory programs found that only 22 percent of the regulated facilities were complying with the interim status groundwater monitoring requirements.[25]

EPA estimates that 50 to 60 percent of the interim status land disposal facilities are leaking and will require corrective action.[26] There is some evidence that the figure might be closer to 90 percent. A study conducted by EPA in 1975 investigated 50 randomly selected facilities and found that over 90 *percent* of them were leaking into groundwater,[27] Therefore, even before the passage of RCRA, the poor state of these interim status facilities was known.

EPA could have written regulations for financial assurance for corrective action, regulations to monitor and gather necessary environmental data, and regulations to bring facilities promptly into compliance or close them down, Instead, the interim status standards abrogate most of EPA's authority to regulate interim status sites until their application for a permit is acted upon by EPA.

Indicator Parameters

EPA has identified four indicator parameters to determine whether an interim status hazardous waste facility is leaking. The four indicator parameters are: specific conductance, pH, total organic carbon, and total organic halogen. EPA limited the groundwater monitoring requirements for purposes of leak detection to these four parameters,[28] EPA gave the following reason for choosing these parameters:

> Increases in specific conductance indicate the presence of inorganic substances in the groundwater. Likewise, increases or decreases in pH suggest the presence of inorganic contamination, Total organic carbon (TOC) and total organic halogen (TOX) concentrations in groundwater tend to increase as a result of organic contributions from a hazardous waste facility. The methodology to sample and analyze for these indicators is presently available, EPA believes that monitoring these indicators will be sufficient to make the threshold assessment of whether a facility is leaking.[29]

However, the more stringent Part 264 standards for EPA permitted sites[30] give the EPA permit writer the option that the actual waste constituents or their reaction product be monitored rather than the four indicator parameters. EPA's guidance to the permit writers says this about the four indicator parameters:

> In some cases, these parameters may not be the most appropriate, and this use should be carefully reviewed before they are included as indicator parameters in a detection monitoring program. For example, TOC and TOX will be of little value at a facility where no organic wastes are present, and even at facilities handling organic wastes, background levels may reduce the utility of these parameters. The use of pH and specific conductance may also not always be appropriate. There are so

[24] U.S. Environmental Protection Agency, "Interim Status Ground-Water Monitoring Implementation Study," draft, 1984.
[25] GAO/RCED-83-241, op. cit.
[26] *Inside E.P.A.*, Feb. 17, 1984, p. 3.
[27] U.S. Environmental Protection Agency, *The Prevalence of Subsurface Migration of Hazardous Chemical Substances at Selected Industrial Waste Land Disposal Sites*, SW-634 (Washington, DC: Office of Solid Waste, 1977).

[28] 40 CFR 265, W(b).
[29] 45 Federal Register 33194.
[30] 40 CFR 264.98,

> many geochemical controls on pH, such as natural buffering capacity, that it is difficult to predict what changes in pH might occur in a leach ate migrating through the unsaturated and saturated zones. In addition, unless extremely acidic or basic, the addition of large amounts of leachate will likely be required to significantly alter pH. [consequently, pH may be suitable only as an indicator of gross contamination. Detectable changes in specific conductance will similarly require a relatively large increase in ion concentrations. Consequently, it may also be useful as an indicator of gross pollution, and then only at facilities where constituents migrating to ground water are primarily inorganic ions .[31]

Further criticism of the ability of the indicator parameters to detect toxic contaminants at critical concentrations was made at a recent groundwater symposium:.

> . . . there can be highly selective migration of contaminants that are hazardous to human health in drinking waters at concentrations far less than those that would be detected using the ''indicator' parameters .[32]

More recently, EPA has acknowledged that "the indicator parameters are not functioning in either an efficient or effective manner . . . "[33]

Number of Monitoring Wells

The interim status standards require only three wells for detecting groundwater contamination. This is true regardless of the size of the facility, the size of the aquifer, the extent of pollution, or the potential for damage to human health and the environment. In many cases, three wells are far too few to give a reasonable probability of detecting pollution early. In processing RCRA permits, the number of required detection wells is generally 4 to 20 for interim status sites currently operating with 3 wells. On the State level, one interim status site in Illinois was required by the State to install 40 wells and another over 50,[34] and three sites in New Jersey are required to have over 100 wells.[35]

RCRA Reauthorization

Congress has addressed several aspects of the interim status facility issue. The lifetime of interim status has been limited. Existing facilities will lose their interim status 12 months after enactment (November 1985) unless application is made for a final RCRA permit and the site is certified to be complying with the groundwater monitoring and financial responsibility requirements. Existing facilities that become subject to Subtitle C have 6 months to apply for a final permit. Interim status surface impoundments become subject to minimum technological requirements for at least two liners, leachate collection, groundwater monitoring, and early leak detection, unless certain stringent conditions are met and evidence to allow an exemption is submitted within 24 months. Furthermore, upon closure an exempted impoundment (e.g., because of a natural clay liner being present) must remove or decontaminate all waste residues, all contaminated liner material and contaminated soil. If the latter is not removed the operator must comply with postclosure requirements. EPA is also given additional means to seek corrective action at interim status sites by obtaining an administrative order through a civil Federal court action,

Summary

The facilities that are most likely to leak, about 2,000 interim status facilities, have a much less stringent groundwater monitoring standard then the three permitted and presumably far better designed new facilities. According to EPA, these standards are "minimal and are specifically designed not to be burdensome."[36] *There are no corrective action re-*

[31] GeoTrans, Inc., "RCRA Permit Writers Manual, Groundwater Protection, 40 CFR Part 264 Subpart F", Oct. 4, 1983, p. 192.

[32] G. Fred Lee and R. Anne Jones, "Water Quality Monitoring at Hazardous Waste Disposal Sites: Is Public Health Protection Possible Through Monitoring Programs?" paper presented at the *Third National Symposium on Aquifer Restoration and Groundwater Monitoring* sponsored by the National Water Well Association, Columbus, OH, May 1983.

[33] U.S. Environmental Protection Agency, "Interim Status Ground-Water Monitoring Implementation Study," op. cit.

[34] Michael Nechvatal, Illinois Environmental Protection Agency, private communication, Mar. 23, 1984.

[35] William Brown, Supervisor with the New Jersey Bureau of Groundwater Discharge Permits, private communication, Mar. 19, 1984.

[36] U.S. Environmental Protection Agency, SW-634, op. cit.

quirements or requirements to stop disposal should groundwater contamination be detected. Sites found to be polluting will be put on a "fast track" for issuing a permit so that corrective action may be required, but so far few Federal permits have been issued to interim status facilities requiring groundwater monitoring. Although the recent legislative changes reduce the risks associated with interim status, a likely effect may be to *hasten the closure of interim status facilities prior to applying for, or obtaining, full permits.* To the extent that a facility operator perceives that a permit is unlikely to be issued, or very high costs would be required, closure could lead to placement on the NPL.

Limitations on Coverage

EPA's strategy, as evidenced in the groundwater protection provisions of Part 264 of RCRA, is to determine when groundwater is becoming polluted enough to threaten public health and then to require the groundwater to be cleaned up, However, groundwater monitoring is not a substitute for techniques such as leak detection systems to analyze the engineering soundness of the waste management facility, e.g., to locate a ruptured liner in a landfill or a leaking storage tank.

Permitted facilities are required to be built to exacting EPA engineering standards whose goal is to "minimize the formation and migration of leachate to the adjacent subsurface soil or groundwater."[37] However, when leachate does appear in groundwater, facility operators are not required to find out what went wrong, "a landfill liner which has been designed not to leak does not violate the design standards if the liner fails at some future time."[38] *RCRA regulations for fully permitted facilities do not require that the leak be fixed or that the waste disposal activities be halted.* When pollution may be coming from one of several sources, there is no requirement to determine which of them it is. In short, *it is not a violation of any RCRA regulation to pollute.* Nor is there currently any evaluation of the implications of a leak for the continued operation of a facility. There is only the requirement that the pollution that has reached groundwater be cleaned up. This, as will be discussed later, is a very limited requirement.

Under RCRA jurisdiction, EPA limits the site owner's responsibility for site maintenance to 30 years after site closure.[39] Since EPA (and many others) have concluded that it is "inevitable" that landfills and disposal lagoons will leak,[40] many of these facilities are likely to eventually fall under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As firms go out of business, cleanup costs would shift from facility owners and users to the government.

RCRA Reauthorization

Several of the above problems have been addressed legislatively, but it is not yet clear how the new legislative provisions will be implemented. The minimum technological requirements for almost all types of land disposal facilities include the use of early leak detection systems; however, the requirement applies only to *new* units. Another change concerns regulations and permits issued after enactment. Facilities must act to control and clean up all releases of hazardous constituents from all units at the facility, including inactive ones. This requirement may hasten the closure of some facilities in ways that result in their eventual placement on the NPL.

Groundwater Monitoring Wells

The hydrogeology of the site is important in the design of a groundwater monitoring system for interim status and permitted facilities. A good knowledge of the hydrology and geology in the immediate area of a waste disposal site is necessary to know where, how many, and how deep to locate detection monitoring wells. In addition, for compliance monitoring it may also be necessary to create a mathematical model to get some understanding of the

[37] 47 Federal Register 32312.
[38] 47 Federal Register 32330.
[39] 40 CFR 264.117 and 265.117.
[40] 46 Federal Register 11128.

speed and direction of the movement of contaminants,

In determining the location, depth, number, and type of monitoring wells a great many assumptions have to be made about the underground geological structure and the location, depth, quantity, direction, and speed of underground water. Furthermore, the proper location of monitoring wells depends on a knowledge of how all the above parameters may vary with season, rainfall, tidal water, and groundwater usage. These latter factors can cause groundwater flow to greatly increase, decrease, or even change direction over time.

Hydrogeological structures have physically hidden characteristics that must be inferred from limited data, Data are obtained from sources such as core samples, well drilling logs, and historical records of rainfall, The difficulty of doing this was summarized picturesquely in a recent review by the Princeton University Water Resources Program:

> Imagine that we cannot see the sky, we cannot tell the direction or velocity of the wind, and we ask: Is the factory (with its thousands of little chimneys) polluting the air? That is our ground water monitoring problem—at its easiest. It is made more difficult because the geological properties of the soil vary with depth and direction, and this variation is unknown or uncertain. When we look up in the sky, we observe the spatial variation of the pollutants. If we could look up only through a small tube or telescope, then the information we gathered from the one sighting might not be representative of what we would see if we looked everywhere. The small tube into the sky is like our groundwater monitoring well: the data we gather may not tell us too much about what is occurring in other nearby locations.[41]

One of the few studies of operational land disposal sites was an investigation of 50 typical hazardous waste disposal sites conducted in 1976-77 for EPA.[42] This study concluded:

> At sites presently monitored the use of wells as an aid in evaluating groundwater conditions is generally poor, due to inadequacies with respect to one or more of the following parameters: number of wells, distance of wells from potential contamination source, positioning of wells in relation to ground water flow, selection of screened intervals, use of proper well construction materials, sealing against surface water contamination, or inter-aquifer water exchange, completion methods (such as development, maintenance, and protection against vandalism),

Of the 50 sites evaluated, 32 had existing groundwater monitoring systems, usually installed to meet the requirements of State law. Of the 32, the study found seven monitoring systems (or 22 percent) so inadequate that they had to install new wells to conduct the relatively basic monitoring required by the contract.

More recently, EPA has found considerable problems with monitoring wells. Of 148 interim status facilities that had implemented groundwater monitoring programs in response to RCRA interim status regulations, 64 facilities (or 43 percent) had "deficiencies related to the number, depths, and/or locations of monitoring wells."[43] Among the problems encountered were:

- background wells not in the uppermost aquifer,
- background wells affected by the facility,
- downgradient wells not located in the direction of expected contamination movement, and
- downgradient wells not located at depths which would intercept contaminants.

These studies show that the percentage of unsatisfactory monitoring systems was 22 percent in the 1977 study and 43 percent in the 1983 study. These two studies are not comparable, so it is simplistic to conclude that groundwater monitoring had deteriorated in those 6 years.

[41] Princeton University Water Resources Program, *Groundwater Contamination From Hazardous Wastes* (Englewood Cliffs, NJ: Prentice-Hall, 1984).

[42] U.S. Environmental Protection Agency, SW-634, op. cit.

[43] U.S. Environmental Protection Agency, "Resource Conservation and Recovery Act, Ground-water Monitoring Interim Status Regulations—265.90-94, Evaluation of the Requirements, Phase II Report to OMB, Implementation of the Requirements" (Washington, DC: Office of Solid Waste, Mar. 10, 1983).

But there is no basis for believing, in spite of improvements in technology, that the practice has gotten better, There are several possible explanations (not mutually exclusive) for this state of affairs, First, monitoring may be mostly a procedure to reassure the public.

One expert pointed to limitations in the state of the art as a second explanation. He observed, for example, that "contamination migration in fractured rock is complex and generally unpredictable" and that "prediction . . . is generally beyond the state of the art. Pollutant movement is easiest to predict in sand and gravel. Ironically, sand and gravel make the worst base for land disposal because pollutants move very rapidly in these porous soils. Soils that have good containment properties and are hydrogeologically predictable are found in only about 10 to 20 percent of the United States,[44]

There are many other hydrogeological conditions that make the design of groundwater monitoring systems very difficult:

- There can be connections between different aquifers that are difficult to detect.[45]
- Groundwater flow can change direction because of intrusion of tidal water, seasonal recharge patterns, or nearby production wells.
- Leachate does not always flow straight down to an aquifer, but under some geological conditions would flow at an angle and enter an aquifer downstream of the monitoring wells.[46]
- Liquid contaminants in an aquifer do not always flow in the same direction as the groundwater.

A third possible explanation for lack of progress is that a proper groundwater monitoring system takes a great deal of money, time, and expertise. In order to meet governmental regulatory requirements without spending too much, reliance is placed on engineering judgment rather than hard data. This warning appears in the EPA RCRA permit writers guide:

> Experience with the installation of monitoring systems for compliance with the Interim Status Regulations has indicated that most owners/operators who have hired a groundwater consultant to install the groundwater monitoring system have not envisioned spending the time or money to conduct as thorough an investigation as is suggested in this chapter. To retrieve all of the information necessary to design the system in accordance with considerations in this document, test-boring and piezometer installation programs will be necessary, Though some local geologic reports usually exist in the region of most facilities, site specific considerations almost invariably require extensive test borings. Because of the lack of time and funds, in most cases parameters such as the direction of groundwater flow and the nature of subsurface materials have been determined through evaluation of local topography and, to the extent possible, evaluation of existing building foundation borings. Monitor wells are usually located on the basis of this information and completed to just below the water table. Variations in ground-water flow direction and geologic variability have usually not been considered because of lack of information. The primary factors for minimizing the pre-monitor well installation field investigation have been time and cost.[47]

A similar point about cost was made at a congressional hearing in 1982 on EPA's Part 264 groundwater protection standards:

> There are, of course, certain geologic environments in which monitoring becomes extremely expensive and may not be cost-effectively employed, In order to obtain credible information, dozens of wells and hundreds of groundwater samples may be required to develop an adequate analysis of the hydrogeologic system, Although there are probably a large number of existing land disposal sites located in such areas, it is my recommenda-

[44] J. A. Cherry, "Contaminant Migration in Groundwater With Emphasis on Hazardous Waste Disposal," *Workshop on Groundwater Resources and Contamination in the United States*, Mar. 14 and 15, 1983 (Washington, DC: Division of Policy Research and Analysis, National Science Foundation); J. A. Cherry, personal communication, Dec. 7, 1983.

[45] U.S. Environmental Protection Agency, "Permit Writers Training Course on Groundwater Monitoring, RCRA 264, Subpart F" (Washington, DC: Office of Solid Waste, July 1983), pp. 3-7.

[46] Burnell Vincent, U.S. Environmental protection Agency, private communication, Oct. 21, 1983.

[47] GeoTrans, Inc., op. cit., p. 16.

tion that no new land disposal facilities be allowed under these conditions regardless of engineering design.[48]

What is required for a facility operator to detect groundwater pollution? The hazardous waste disposal facility operator must want to detect groundwater pollution and must determine how effective monitoring will be, given the geology of his site. The operator must be willing to hire experts, spend time, and spend money (probably far in excess of EPA's minimum requirements), Finally, sampling and analysis procedures must be designed that optimize the ability to detect contamination, even if they are more stringent than EPA's procedures (see the section in this chapter on statistical procedures). Some facilities operate this way, although they are not required to do so, but they are not required to report to EPA the results of anything over the minimum requirements,

At the other extreme is the facility operator who fulfills only the minimum requirements of the law. Consultants may not be used to optimize the efficiency of the groundwater detection system, Under these circumstances, groundwater detection systems have a low probability of detecting contamination. Many of the sites on the National Priorities List had such groundwater monitoring systems.[49]

The latest EPA Part 264 regulations (July 26, 1982), while an improvement over the Part 265 standards, do not acknowledge the past failure of regulatory groundwater monitoring systems, nor the unsuitability of many geological formations. They continue to rely on regulatory groundwater monitoring in any terrain to detect leaks. But the minimum requirements of the regulations are inadequate to-ass ıre a high probability of detection.

Contaminant Tolerance Levels

The RCRA regulations for EPA permitted land disposal facilities,[50] unlike those for interim status facilities,[51] provide for detection monitoring of the specific contaminants being disposed as an alternative to the use of the four indicator parameters (at the discretion of the EPA permit writer). This would overcome the problem of indicator parameters mentioned in the section on "Interim Status. " Upon close examination, however, this process raises other issues having to do with the tolerance levels of these contaminants.

In regulatory parlance, the tolerance level of a chemical is the concentration that is acceptable to the regulatory agency. The Part 264 RCRA regulations do not have explicit tolerance levels for groundwater contaminants except for the 16 chemicals listed in the EPA primary drinking water standard. However, for the hundreds of toxic constituents listed in the RCRA regulations[52] there is an implicit tolerance level. The regulations specify that the EPA publication "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods"[53] be used to determine whether a sample contains a given toxic constituent.[54]

For most substances, this publication lists more than one analytical method, Some methods are more sensitive than others. In issuing permits, EPA plans to use relatively low-cost scanning techniques, which are the least sensitive methods, explaining:

> The Agency feels that a special hierarchical approach is appropriate for this purpose. These approaches will first use scanning techniques designed to detect broad classes of compounds. If the presence of a particular class of compound is detected, more specific analysis to determine which constituents are actually present can then be initiated. Although some sensitivity may be sacrificed by

[48] *David W. Miller, Geraghty & Miller, Inc., testimony before hearing of the House Subcommittee on Natural Resources, Agriculture Research and Environment, Nov.* 30, 1982.

[49] U.S. *Environmental Protection Agency, Hazardous Waste Site Descriptions: National Priorities List, Final Rule, and Proposed Update* (Washington, DC: Office of Solid Waste and Emergency Response, August 1983).

[50] 40 CFR 264.

[51] 40 CFR 265.

[52] 40 CFR 261 appendices VII and VIII.

[53] U.S. Environmental Protection Agency, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846,* 2d edition (Washington, DC: office of Solid Waste, 1982).

[54] 40 CFR 261 appendix III.

> such an approach, the range of detection of certain scanning methods are clearly adequate . . .

Therefore, *the detection limit of the scanning methods, which are the least sensitive of the required test methods, constitutes a de facto tolerance level,* since no further action will be taken if the scan does not detect contamination. Furthermore, there are more sensitive test methods than those chosen, and EPA has demonstrated in the case of dioxin that more sensitive methods can be developed when required. The RCRA regulations do not explain why certain test procedures were chosen and others were not. Finally, tolerance levels are implicit rather than determined for most cases,

Table 5-9 illustrates that these implicit tolerance levels are quite high, when certain EPA health effects projections are considered. The first column shows the minimum concentrations at which 12 selected chemicals can be detected using the RCRA procedures," The second column shows EPA's estimate of the concentration that EPA projects will cause one cancer per 100,000 people drinking 2 liters a day of the water over a lifetime. These cancer estimates are based on animal studies. There are substantial disagreements about the accuracy of such projections, and the values listed in table 5-9 are not universally accepted. However, they continue to be used by EPA, although they may be changed. Since it is EPA's criteria which determine whether a site should be included in CERCLA, these projections are relevant to this study.

The projected number of cancers per 100,000 is estimated in column three. For example, table 5-9 shows that a hazardous waste disposal site operator, permitted by EPA, may, without violating his permit, pollute groundwater with up to 2,500 nanograms per liter of dieldrin, This is a concentration which EPA projects may cause 3,500 cancers per 100,000 people who drink the water over their lifetime,

EPA is currently seeking to ban the use of pesticides for which the cancer risk is as low as 1 in 100,000.[58] Therefore, it is likely that a facility which is polluting groundwater at a level projected to cause 3,500 cancers per 100,000 would come to the attention of CERCLA.

Next, consider the explicit tolerance levels associated with the 16 contaminants for which there is an EPA drinking water standard. EPA allows that for pollutants for which there is an

[55] U.S. Environmental Protection Agency, SW-846, op. cit.

[56] *Pesticide & Toxic Chemical* News, vol. 12, No. 4, Jan. 11, 1984, p. 15,

Table 5-9.—EPA Detection Limits for Some Carcinogens

Chemical	Highest permitted EPA detection limit (nanograms/liter) (†)	Concentration projected*• to cause one cancer per 100,000 people†† (nanograms/liter)	Projected •• cancers per 100,000 people
aldrin	1,900	0.74	2,600
dieldrin	2,500	0.71	3,500
1,1 ,2,2 -tetrachloroethane	6,900	1,700	4
3,3' -dichlorobenzidine	16,500	103	160
heptachlor	1,900	2.78	680
PCBs	36,000	0.79	46,000
benzo(a)pyrene	2,500	28	90
benzidine	44,000	1.2	37,000
chlordane	14	4.6	3
DDT	4,700	0.24	20,000

"A nanogram is a billionth of a gram One nanogram per liter is approximately one part per trillion.

" 'Projections based on the consumption of 2 liters (a little over 2 quarts) a day of the contaminated drinking water over a lifetime Projections are also based on animal studies that include assumptions on the transfer of results from animals to humans, and extrapolate ion from high doses to low doses Despite the uncertainties introduced by these assumptions, these are the projections EPA uses Column 3 has been calculated by OTA by dividing column 1 by column 2 This calculation converts back to high doses Uncertainties Introduced into column 2 by high.to-low dose extrapolations are thus partially corrected for in deriving column 3. Column 3 contains no correction for uncertainties Introduced by applying animal results to humans

†U S Environmental Protection Agency, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, 2d ed. (Washington, DC Office of Solid Waste, EPA, 1982)

††Reference 45 FR 79325-79341

existing EPA primary drinking water standard, RCRA permitted facilities may contaminate up to the standard.[57] The primary groundwater pollution standards are shown in table 5-Io. As in table 5-9, this table also projects the cancers per 100,000 for those substances for which data are available from the EPA. In addition, the fourth column indicates the substances known or believed to be carcinogens.

For some of these pollutants, there may be no zero effects level and any amount of the substance is considered a risk to human health. For example, cadmium is carcinogenic[58] and is not considered without risk at any level.[59] Arsenic, lindane, and toxaphene are thought to be carcinogens and, as shown in table **5-10**, are associated with significant cancer risks at the EPA tolerance level.

[57] Toney Baney, RCRA/CERCLA hotline, U.S. Environmental Protection Agency, private communication, Nov. 29, 1983.

[58] U.S. Department of Health and Human Services, *Registry of Toxic Effects of Chemical Substances* (Washington, DC: Public Health Service, Centers for Disease Control, National Institute for Occupational Health and Safety, February 1982).

[59] U.S. Environmental Protection Agency, *Scientific and Technical Assessment Report on Cadmium*, EPA-600-75-003 (Washington, DC: Office of Research and Development, March 1975).

Regarding tolerance levels, not all toxic pollutants that can cause a site to be regulated under CERCLA are monitored under RCRA. A conspicuous example is dioxin contaminated soils. Although sent to RCRA regulated landfills, EPA has not been able to require that the soil be monitored for some dioxins, although they have proposed doing so.[60]

Table 5-11 lists other hazardous substances regulated under CERCLA that are not regulated or monitored under RCRA.[61] A reportable quantity (RQ) is the quantity of a hazardous substance which if spilled must be reported to the National Response Center[62] to determinate if any response under CERCLA is necessary. RQs are based on six criteria: aquatic toxicity, mammalian toxicity, ignitability, reactivity, acute toxicity, and carcinogenicity. They are in five reporting levels: 1, 10, 100, 1,000, and **5,000** pounds, The lower the RQ, the more hazardous the substance.

[60] 48 Federal Register 14514.

[61] 48 Federal Register 23552.

[62] CERCLA, Section 103.

Table 5-10.— Data on RCRA Pollutants With Primary Drinking Water Standards

Pollutants	EPA Primary Drinking Water Standard (µg/l)*	Concentration projected" • to cause one cancer per 100,000 people† (fig/l)	Projected •' cancers per 100,000 people	Comments
arsenic	50	0.022	2,300	a
barium ., ...	1,000	—	—	b
cadmium	10	—	—	a
chromium	50	—	—	—
lead	50	—	—	—
mercury .	2	—	—	—
nitrate (as N)	10,000	—	—	—
selenium	10	—	—	—
silver	50	—	—	—
fluoride ., ...	1,400-2,400	—	—	—
endrin	0.2	—	—	—
lindane	4	0.186	22	b
methoxychlor . . .	100	—	—	—
toxaphene ...	5	0.0071	700	b
2,4-D	100	—	—	—
2,4,5,-T, Silvex	10	—	—	—

[a] known human carcinogen (††)

[b] probable human carcinogen based on animal studies (††)

* µg/l microgram Per liter or millionth of a gram per liter 1 µg/l is approximately one part per billion

" Project Ions based on the consumption of 2 liters (a little over 2 quarts) a day of the contaminated drinking water over a lifetime Except for arsenic projections are also based on animal studies that include assumptions on the transfer of results from animals to humans, and extrapolations from high doses to low doses For arsenic projections are extrapolated from the effects of high doses in humans Despite the uncertainties int reduced by these assumptions these are the projections EPA uses Column 3 has been calculated by OTA by dividing column 1 by column 2 This calculation converts back to high doses Uncertainties Introduced into column 2 by high to low dose extrapolations are thus partially corrected for in deriving COlumn 3 Except for the arsenic number which is based on human data column 3 retains the uncertainties introduced by applying an [real results to humans

preference 45 FR 7932579341

†† U S Department of Health and Human Services *Registry of Toxic Effects of Chemical* Substances (Washington DC Public Health Sew Ice Centers for Disease Control, National Institute for Occupational Health and Safety February 1982)

Table 5-11 .—Some Pollutants Regulated Under CERCLA (Reportable Qualities) But Not Under RCRA

Pollutant	Proposed reportable quantity (pounds)†	Oral (mammal) LD50* (mg/kg) (23)
carbofuran. . . .	10	11
chlorpyrifos. . .	1	97
diazinon	10	76
dichlone	1	—
alpha-endosulfan	1	—
beta-endosulfan . .	1	—
endosulfan sulfate. .	1	—
endrin aldehyde . . .	1	—
guthion	1	13
mercaptodimethur . .	10	34
mevinphos	10	3.7
naled	10	250

†48 FR 23552.23595
. LD_{50}—Lethal Dose Fifty—a calculated dose of a substance which is expected to cause the death of 50% of an entire defined experimental animal population It is measured in milligrams of substance Ingested per kilogram of animal body weight For comparison purposes note that the oral toxicity of iodine is 14,000 mg/kg, arsenic acid is 48 mg/kg, and potassium cyanide is 10 mg/kg

Table 5-11 lists those hazardous substances that have proposed RQs in the two most hazardous categories (1 and 10 pounds) and which are *not regulated under RCRA.* The proposed rules do not indicate the basis of the rating for each substance; therefore, it is possible that it is inappropriate to regulate some of these hazardous substances under RCRA, but no discussion of this issue has been found.

The significance of table 5-11 is that these substances could be leaking into groundwater from a RCRA permitted facility without violating the permit, yet would be candidates for regulations under CERCLA. Even more to the point, if these substances are spilled in transportation or manufacturing operations in excess of their RQ, they must, under CERCLA, be cleaned up and disposed in a RCRA regulated facility where RCRA regulations would not require their monitoring.

Table 5-12 addresses those contaminants of concern to CERCLA that are also regulated under RCRA. In many cases, *the groundwater detection levels are higher under RCRA,* as much as 1,000 times higher, This is another example of the puzzle that occurs in comparing RCRA regulations with CERCLA. The cure is considered more protective of public health than the prevention, *Thus a RCRA regulated site may pollute groundwater to a level tolerated by RCRA but come to the attention of CERCLA for the same pollution.*

Table 5-12.—Some Examples of Groundwater Detection Levels of Hazardous Chemicals Which Are Higher Under RCRA than Under CERCLA

Pollutant	CERCLA detection levels (ng/l)†††	RCRA detection levels (rig/l)
dieldrin	5	2,500†
DDT	10	4,700†
DDE	5	5,600†
DDD	10	2,800†
heptachlor	5	1,900†
heptachlor epoxide	5	2,200†
aldrin	5	1,900†
antimony.	20,000	32,000††
arsenic	10,000	53,000††
cadmium	1,000	4,000††
lead	5,000	42,000††
selenium	2,000	75,000††
thallium	10,000	40,000††

†U.S Environmental Protection Agency, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, 2d ed (Washington, DC Off Ice of Solid Waste, EPA, 1982)
t tLee M Thomas, Assistant Administrator, U S Environmental Protect Ion Agency, Memorandum to the Admi nistrator Pro Posing additional test methods for reference 17, Oct 17, 1983
†††U S Environmental Protect Ion Agency, "Statement of Work, Organics Analysis, Contract Laboratory Program" (Washington, DC EPA, September 1983) U S Environmental Protect Ion Agency, "Statement of Work, Inorganics Analysis, Contract Laboratory Program" (Washington, DC EPA, May 1982)

The last, and perhaps most important point with regard to tolerance levels, is that for many of the several hundred hazardous constituents for which EPA has published test procedures to monitor groundwater, the level at which these contaminants can be detected has not been published or determined by EPA.[63] Moreover, the test protocols were set more by considerations of analytical chemistry than human health effects; thus some of the detection limits might be too high to protect human health, while others might be lower than necessary. Some of the hazardous constituents for which EPA does not yet know the detection limits are listed in table 5-13. The substances shown were selected because they are alleged carcinogens and preliminary EPA research has given them high hazard ratings, Although research is underway to determine detection levels, RCRA rules permit groundwater contamination by these and other substances to a currently undetermined level.

[63] U.S. Environmental Protection Agency, SW-846, op. cit

Table 5-13.—Some Carcinogenic Chemicals for Which EPA Has Not Yet Determined the Levels at Which They Can Be Detected in Groundwater by the Methods of Reference

aflotoxin
4-aminobiphenyl
aziridine (ethyleneimine)
bis-(chloromethyl)ether
chloromethyl methyl ether
1,2-dibromo-3-chloropropane (DBCP)
diethylnitrosamine (n-nitrosodiethylamine)
diethylstilbesterol[a]
dimethylaminoazobenzine
7,12-dimethylbenz(a)anthracene
dimethylcarbamoyl chloride
1,2-dimethylhydrazine
ethyl methanesulfonate
hydrazine
methyl nitrosourea
nitrosomethylurethane (n-nitroso-n-methylurea)
n-nitosopiperidine
n-nitrosopyrrolidine
streptozotocin[a]
2,3,7,8-tetrachlrodibenzo-p-dioxin (TCDD)
ethylene dibromide (EDB)

[a]Test methods not ye! published by EPA as of Jan 19 1984

SOURCE U S Environmental Protect (on Agency *Test Methods* for *Evaluating Solid Waste Physical Chemical Me(hods,* SW 846 2d ed (Washington DC Off Ice of Solid Waste, EPA 19821

In addition, the RCRA test procedures manual indicates that when several chemicals are mixed together, as is usually the case in groundwater monitoring, the ability to detect a specific chemical by a given test procedure is reduced. These analytical interferences raise the detection limits by an undetermined amount.[64] Not being able to detect carcinogens reliably, which can be of concern at very low levels of contamination, is dangerous to human health and increases the likelihood of CERCLA involvement.

The effects of this can be illustrated with the example of ethylene dibromide (EDB). EPA recently has canceled the use of EDB as a fungicide because of its carcinogenicity. In congressional testimony, EPA's pesticide program director said:

> . . . we believe that the risks posed by EDB in drinking water at levels in the low parts per billion are roughly comparable to the risks posed by grain fumigation. In both cases we consider these estimated risk levels to he unacceptable for a lifetime of exposure . . . According to our information, the State of Florida has acted to provide alternative drinking water for approximately 500 wells found to contain EDB at or above 0.1 parts per billion (ppb). This appears to be a responsible and effective way of dealing with these potential risks. In short, the risks of EDB being reported in Florida ground water (typically 1 to 20 ppb) are probably similar to risks posed by grain products.[65]

EPA does not list a detection level for EDB, but it does list detection levels for 21 other volatile organics. These range from 1.6 to 7.2 parts per billion. Thus, the RCRA tolerance level for EDB might be substantially greater than the 0.1 parts per billion indicated as "responsible" in the EPA testimony quoted above.

In summary, CERCLA is required to address releases of any "hazardous substance, " that is, any substance designated under CERCLA and four other acts administered by EPA, EPA has chosen to have RCRA regulate a narrower universe of substances and many of those are not regulated with the same stringency as in other EPA programs. Therefore, *compliance with a RCRA permit will not necessarily be sufficient to prevent a site from becoming a CERCLA site*. However, proposals being considered by EPA might lower CERCLA requirements rather than increase RCRA ones.

Monitoring in the Vadose Zone

EPA regulations for permitted facilities require that groundwater detection monitoring wells be placed in the uppermost aquifer at the edge of the waste disposal area.[66] Any contaminant detected by the well may first have traveled anywhere from a few feet to several hundred feet under the waste disposal area *before* it reaches the aquifer. Then the contamination may have traveled anywhere from a few feet to several thousand feet in the aquifer before it reached the well, Then, if the leading point

[64] Ibid

[65] Edwin L. Johnson, Director of the Office of Pesticide Programs, U.S. Environmental Protection Agency, testimony before the Senate Committee on Agriculture, Nutrition and Forestry, Jan. 23, 1984.

[66] 40 CFR 264.98(h)

of the plume of contamination is between two monitoring wells, it could travel some distance past the wells before it is detected, Therefore, even if a detection monitoring system works well, considerable environmental damage could occur *before* the contamination is detected.

The vadose zone is the ground above the uppermost aquifer. In humid areas of the United States it is rarely over 100 feet deep and is usually much less. In arid western areas, however, the vadose zone can be several hundred feet deep. Water and associated contaminants from a land disposal facility will travel through the vadose zone to an aquifer at a rate determined by the soil characteristics, the depth of the vadose zone, the amount of fluids in the waste, and the amount of water. It can take anywhere from a few months to many decades.

By the time contamination is discovered in a groundwater monitoring well, the vadose zone could have stored significant amounts of contamination. Thus toxic materials could continue to pollute the groundwater for many decades even if disposal is halted and the groundwater is cleaned. Furthermore, the trend is to require land disposal facilities to be located in areas with low-porosity clay soils, with great depth to groundwater, This may postpone the time it takes contamination to reach groundwater, but also increase the amount of contamination stored in the vadose zone,

Not all contamination that reaches the aquifer is carried away by the groundwater. Some contaminants may be adsorbed on solid surfaces or otherwise contained in the aquifer and gradually released or desorbed in small amounts to pollute the groundwater, One important example is the class of halogenated immiscible hydrocarbons such as paint thinners, pesticides, and PCBs. Thus, by the time this type of contamination is detected in groundwater the vadose zone may be significantly contaminated. Thus it would be useful to detect leachate contamination in the vadose zone beneath a hazardous waste disposal site before it reaches groundwater. It might help avoid the costs of groundwater and contaminated soil cleanup and human health and the environment would be better protected. EPA does require vadose zone monitoring for land treatment of hazardous wastes[67] in the standards for EPA permitted facilities of July 26, 1982. The preamble to the regulations states that "EPA believes that adequate technology and expertise is available to develop effective and reliable systems."[68] Yet in the same regulations vadose zone monitoring is *not* required for landfills, surface impoundments, and waste piles where the need and the benefits would appear to be far greater.

The technology for which there is the most experience in waste disposal monitoring in the vadose zone is the suction lysimeter, a porous ceramic cup placed in the vadose zone to collect a sample of the fluids. In the interim status standards for existing land disposal facilities, EPA rejected the use of lysimeters with this explanation:

> Available leachate monitoring technology generally involves the placement of probes (lysimeters) beneath the disposal facility. Since each probe is not generally capable of monitoring a large area, many of them would have to be placed under a facility in order to detect a localized flaw in the landfill design. It may not be possible to place such devices below an existing landfill or surface impoundment without completely removing the waste and redesigning the facility. Moreover, once such a system is in place, the probes tend to fail over time due to deterioration or plugging. It is difficult to determine when such a failure occurs and, if discovered, the damage is generally irreparable. Under these circumstances EPA does not believe that leach ate monitoring should be a general requirement for landfills and surface impoundments during interim status.[69]

Other commentors have pointed out that lysimeters do not work well in subfreezing or conditions of low soil moisture[70] or very hot and

[67] Th is method is used for less than 1 percent of wastes that are land disposed; it is also known as land spreading or land farming of wastes.

[68] 47 Federal Register *32329*.

[69] 45 Federal *Register 33191*, May 19, 1980.

[70] Law Engineering Testing Co., "Lysimeter Evaluation Study" (Washington, DC: American Petroleum Institute, 1983).

dry conditions.[71] Are these arguments valid? The first point, that the "probe is not generally capable of monitoring a large area" is contradicted by field experience. Some data indicate that a suction lysimeter located 10 feet below an impoundment could measure a distance of 10 to 30 feet laterally .72 Second, placing suction lysimeters under existing land disposal sites can and has been done by the technique of drilling at a slant. Third, the plugging problem can be largely overcome by packing the sampler with silica flour,[73] a standard technique which appears in EPA manuals.[74] Fourth, the statement that the "damage is generally irreparable" is unclear since what has been placed ought to be replaceable.

As for the other comments, it is not very relevant that lysimeters do not work well in conditions of freezing or low soil moisture since these are not conditions in which there would be much leachate. And as for hot and dry conditions, vadose zone monitoring is currently being conducted in Beatty, Nevada. In any event, it is not necessary that lysimeters work perfectly (no technology does) or that they be convenient to use. The important question is whether they are cost effective in reducing groundwater cleanup costs through early detection of contamination.

Lysimeters have been used for many years for monitoring land disposal sites. At least one State, Texas, uses them for regulatory monitoring. Wisconsin has been requiring vadose zone monitoring since the mid-1970s and there are 19 solid waste sites there with either suction lysimeters or collection lysimeters.[75] California has proposed regulations that would require vadose zone monitoring in new installations.

The U.S. Geological Survey (USGS) has installed suction lysimeters (albeit, not without difficulty) at two existing low-level nuclear waste landfills. This research projected was started by USGS in 1981.76

A 2-year study of three sanitary landfills by the Illinois State Geological Survey placed lysimeters under the existing landfills; all three had contamination in the vadose zone that had not been detected by groundwater monitoring wells.[77] In one site the lysimeters showed that a clay liner had ruptured and in another site lysimeter monitoring showed that contamination detected by a monitoring well was coming from a different site. The researchers did not experience the difficulties reported by EPA,

There is also field experience with geophysical vadose zone monitoring techniques. A commercial hazardous waste disposal facility in Oregon uses a vadose zone monitoring system that "integrates lysimeters, dual purpose tensiometers/lysimeter units, and geophysical arrays to provide an early warning leak detection and sampling system."[78] A firm in Las Vegas has installed three resistivity grids since 1980 at hazardous waste lagoons, and they are all reported to be working well.[79]

Many techniques available for monitoring in the vadose zone for both new and existing land disposal facilities have been evaluated. In 1980, the University of Arizona Water Resources Research Center reviewed a number of techniques for vadose zone monitoring below waste disposal sites for EPA.[80] Many of these are

[71] 'f'r r\ 1,. Thoem, Conoco Inc., letter to U.S. Environmental Protection Agency docket for regulations of July 26, 1982 (47 FR 32274), docket No. PLDF II 090.

[72] Robert D. Morrison, Kenneth A. Lepic, and John A. Baker. "Vadose Zone Monitoring at a Hazardous Waste Disposal Facility," paper presented at the conference *Characterization and Monitoring in the Vadose Zone* sponsored by the National Water Well Association, Las Vegas, NV, Dec. 8-10, 1983.

[73] Dr. L. G. Everett, Kamen Tempo, private communication, Mar 23, 1984.

[74] L. G. Everett, L. G. Wilson, and E. W. Hoylman, "Vadose Zone Monitoring for Hazardous Waste Sites," performed under contract No. 68-03-3090 for the U.S. Environmental Protection Agency (Santa Barbara, CA: Kamen Tempo), pp. 5-63.

[75] Peter hmet, Wisconsin Department of Natural Resources, private communication, Mar. 20, 1984.

[76] Dr. John B. Robertson, U.S. Geological Survey, private communication, Mar. 23, 1984.

77 Thomas M. Johnson and Keros Cartwright, *Monitoring Of Leachate Migration in the Unsaturated Zone in the Vicinity of Sanitary Landfills*. Circular 514 (Urbana, IL: State Geological Survey Division, Illinois Institute of Natural Resources, 1980).

[78] Morrison, et al., op. cit.

[79] Dr. Robert Kaufmann, Converse Consultants, Las Vegas, NV, private communication, Mar. 20, 1984.

[80] L. G. Wilson, *Monitoring in the Vadose Zone: A Review of Technical Elements and Methods*, EPA-600/7-80-134 (Las Vegas, NV: U.S. Environmental Protection Agency, June 1980),

commercially available and are in common use. Another survey for EPA evaluated state-of-the-art techniques and techniques under research or development that are capable of localizing liner leaks.[81]

EPA, in rejecting the use of vadose zone monitoring in 1982, referred to the University of Arizona work but discussed only one of the 26 techniques evaluated, the suction lysimeter.[82] This technique was rejected largely because of cost, although no analysis was made of the trade-off of avoiding the cost of cleaning the contaminated groundwater. The many applications of vadose zone monitoring were not reviewed. The extent to which the requirements in the reauthorized RCRA for leak detection systems might lead EPA to require vadose zone monitoring is not clear.

Vadose zone monitoring techniques are not generally easy to use nor are they inexpensive. No one technique is universally applicable and to get a reasonable assurance of detecting leachate, several may have to be used at any given site. However, the techniques for groundwater monitoring are also difficult, fallible, and expensive. The cost of cleaning groundwater can be tens of millions of dollars, depending on the amount of contamination. Thus, even if the technology for vadose zone monitoring is more difficult and less reliable than groundwater monitoring there can be substantial benefits from detecting pollution early.

Delays in Starting Corrective Action

Under the Part 264 EPA standards for EPA permitted facilities in a detection monitoring mode,[83] if hazardous constituents are detected by the groundwater monitoring system a "compliance monitoring" program must be instituted. This program consists of two parts, First, the EPA permit writer will establish a "groundwater protection standard" for the unit, which will be specified in the permit for the facility. Second, a new groundwater monitoring program will be instituted to determine whether the unit is in compliance with its groundwater protection standard. This new program will consist of monitoring at the compliance point, i.e., the edge of the disposal area, to detect any statistically significant increase in the concentration levels of hazardous constituents.

The groundwater protection standard includes the hazardous constituents to be monitored or removed if necessary, the concentration limits for each hazardous constituent that trigger corrective action, the "point of compliance" for measuring concentration limits, and the compliance period,

The regulations require that the concentration limits be set at the background level of the constituent in the groundwater or the maximum concentration limits for drinking water established for any of the 16 hazardous constituents covered by the National Interim Primary Drinking Water Regulations, The facility owner may ask for a variance to establish an alternate concentration limit (ACL) if he can demonstrate that the constituent will not pose a substantial present or potential hazard to human health or the environment.

If the groundwater protection standard is exceeded, then another step, the corrective action program, is instituted. This program attempts to bring the facility into compliance with the groundwater protection standard by removing the hazardous waste constituents from the groundwater or treating them in the aquifer. The regulations require that corrective measures be taken to clean up the plume of contamination that has migrated beyond the compliance point but not beyond the property boundary.

Earlier it was shown that even in a well designed and properly functioning groundwater detection monitoring system, a long time (even, in some cases, decades) could elapse before contamination from a leak from a hazardous waste disposal site reached a detection monitoring well. However, because of the structure

[81] M. J. Waller and J. L. Davis "Assessment of Techniques to Detect Landfill Liner Failings," *Land Disposal of Hazardous Waste*, EPA-600 /9-82-002 (Cincinnati, OH: Municipal Environmental Research Laboratory, March 1982), p. 239.

[82] U.S. Environmental Protection Agency, "Summary and Analysis of Comments (40 CFR Part 264, Subparts F, K, L, M and N)" (Washington, DC: Office of Solid Waste, July 9, 1982), p. 72.

[83] 40 CFR Part 264, Subpart F.

of the EPA regulations, a long time could also elapse between the time the contamination reaches a monitoring well and the time anything is done about it. Table 5-14 shows a scenario where this elapsed time is over 2 years. This example does not present a "worst case" scenario, but simply illustrates times required to work through the many steps prescribed by the regulations.

The action required is that the plume of groundwater contamination be cleaned up from the edge of the disposal area to the property line. *There is no requirement to find the source of the leak and to repair it; and there is no requirement t to stop disposal operations.*

Table 5-14.—Scenario for Instituting Corrective Action at a RCRA Permitted Site in Detection Monitoring

Jan. 1, 1984. —Contamination reaches groundwater detection monitoring well.

Apr. 1, 1984. —Sample is drawn from monitoring well. Well must be sampled semi-annually (40 C.F.R. 264.98(a)). Assume average time to detect contamination is 3 months,

May 1, 1984. —Determination is made that there is a statistically significant increase over background. This determination must be made "within a reasonable time period" (264,98(g)(2)). Assume 1 month, however, discussion in next section will show this is optimistic.

Aug. 1, 1984, —Submit request to EPA for permit modification to establish compliance monitoring program. This must be done within 90 days (264.98(h)(4). Include notice of intent to seek a variance for alternate concentration limits under part 264.98(b) (264.98 (h)(4) (iv)).

Nov. 1 1984.—Submit data to justify variance under part 264.94(b) for every hazardous constituent identified under part 264.98(h)(2), This must be done within 180 days of the time that a determination is made that there is a statistically significant increase over background (264.98(h)(5)(ii)(B)).

Mar, 7, 7985. —EPA rejects request for variance and issues draft revised permit for compliance monitoring. No time limit specified in the regulations. Assume it takes 4 months for EPA to review the data and prepare a draft permit. Notice is given for public comment.

Apr. 15, 1985.—End public comment period. Regulations require 45 days (124.10(b)).

May 15, 1985. —EPA issues revised draft. No time limit specified in regulations. Assume it takes EPA 1 month to review public comments and revise permit accordingly. Compliance monitoring begins.

Aug. 15, 1985.—Submit request to EPA for permit modification to establish corrective action program. This must be done within 90 days (264.99(i)(2) and 270.14(c)).

Sept. 1, 1985. —Submit engineering feasibility plan for corrective action program. This must be done within 180 days of the time that the request for variance is rejected, i.e., Mar. 1, 1985 (264,98(h)(5)(ii)).

Dec. 1, 1985. —EPA issues draft revised permit for corrective action. No time limit specified i n the regulations. Assume it takes 4 months for EPA to review the data and prepare a draft permit. Notice is given for public comment.

Jan. 15, 1986. —End public comment period, Regulations require 45 days (124.10(b)).

Feb. 15, 1986. —EPA issues revised permit. No time specified in the regulations. Assume it takes EPA 1 month to review public comments and revise the permit, Corrective action begins,

Total **elapsed time: 2** years 1½ months not including delays from statistical analysis.

SOURCE Off Ice of Technology Assessment

Statistical Analysis

Contamination in a well must be shown to be a statistically significant increase over background levels, But doing this within 1 month (see table 5-14) is very unlikely,

In sampling groundwater, there is considerable variability due to factors other than the introduction of waste-related contamination. These include seasonal fluctuations, geochemical processes, perturbations introduced by the monitoring well, contamination or other changes introduced by the sampling technique, natural and nonwaste contamination, variability in chemical analysis, and a great many others. It is necessary to distinguish changes in groundwater due to contamination from those due to random or periodic effects. The EPA regulations for both Part 264 and Part 265 state that when a sample of the groundwater is taken from a monitoring well and analyzed for the required contaminants, the results should be compared with the previously determined background levels to see if there is any "statistically significant " increase in contamination .84 Statistical significance is determined by one of several mathematical formulas approved by EPA.

There are four possible outcomes from such a calculation:

1. The test could indicate that groundwater is contaminated when in fact it is not (false positive),
2. The test could indicate that groundwater is contaminated when in fact it is (true positive).
3. The test could indicate that groundwater is not contaminated when in fact it is (false negative).

[84] 40 C F R 264 .9 7(h) and265.93(b).

4. The test could indicate that groundwater is not containinated when in fact it is not (true negative).

A test for statistical significance attempts to minimize the false positives and the false negatives. This can be done by increasing the sample size, i.e., by increasing the number of monitoring wells, the frequency of sampling, and the number of samples taken. But for a given sample size, any test of statistical significance that reduces the probability of false negatives also increases the probability of false positives and vice versa.

There are two ways to design a test for statistical significance. One is to decide in advance the probability of detecting groundwater contamination one wishes to achieve (the probability of detection being one minus the probability of a false negative). In this case the probability of a false positive will be a function of the sample size and the variability of the data. Another way is to determine in advance the probability of a false positive and allow those same factors to determine the probability of detection. In the former case the probability of a false positive will not be known in advance and in the latter case the probability of detecting contamination will not be known in advance, EPA has chosen the latter approach.

The cost of a false positive could be several thousand dollars; e.g., the cost of additional sampling and testing to establish that there is actually no contamination. The cost of a false negative, groundwater contamination that goes undetected, could be large additional cleanup costs and increased threats to human health and the environment. And if the owner cannot afford the necessary corrective action, the site might become a candidate for CERCLA action. Minimizing the occurrence of false positives reduces the short-range costs of disposal site operators but OTA found no mention in any EPA document of why this approach was chosen over the other.

EPA proposed standards for monitoring interim status sites on December 18, 1978,[85] which included a statistical test with a probability of false positives (the level of significance] of 5 percent. In the final regulations adopted in 1980, EPA decreased the probability to 1 percent, But this *increased* the probability of false negatives. In the preamble of the regulations,[86] it is implied that the change was made because of industry concerns over the cost of a false positive. There does not seem to have been an attempt to balance this against the cost of false negatives borne by industry and the public.

In the 1982 regulations for EPA permitted sites, EPA raised the probability of false positives to 5 percent once again, explaining:

> EPA is fixing the level of significance for the Student's t-test at 0.05 for each parameter at each well. When the Agency proposed this significance level for interim status ground-Water monitoring, it received some criticism that this would produce too many notifications of contamination where none had actually occurred.
>
> EPA recognizes that this could be a problem, particularly when there are many comparisons being made for different parameters and for different wells. However, EPA is concerned that a lower significance level would unduly compromise the ability to detect contamination when it did, in fact, occur.[87]

EPA did not, however, raise the probability of false positives from 1 to 5 percent at the interim status sites. No explanation was given for not including interim status facilities in this decision,

OTA has tried to find an estimate by EPA of the probability of detecting groundwater contamination by this statistical procedure. While EPA documents contain many discussions and calculations of false positives, OTA could not find an estimate of the probability of a false negative. The only related material is a study for EPA that was to "estimate the false positive and false negative probabilities for various statistical procedures. "[88] However, the study esti-

[85] 43 Federal Register 58982.

[86] 45 Federal Register 33195.

[87] 47 Federal Register 32303.

[88] RB Associates, "Evaluation of Statistical Procedures for Groundwater Monitoring" in U .S. Environmental Protection Agency, *Ground-water Monitoring Guidance for Owners and Operators of Interim Status Facilities, SW-963* (Washington, DC: Office of Solid Waste and Emergency Response, March 1983).

mated the probabilities of false negatives for only one statistical procedure, and that one is not the one that EPA uses.

More recently, EPA has acknowledged that:

> ... the t-test, as it is currently being applied, is ill equipped to deal with the very small data sets being generated ... nor can it effectively handle the wide and largely unknown variabilities due to spatial, temporal, sampling, and analytic problems.[89]

The conference report for the recently reauthorized RCRA that deals with surface impoundments notes that in addition to a statistically significant increase over background concentrations "other evidence of leaking, such as visible leaks or sudden drops in liquid level of the impoundment, also would be sufficient,"[90] It is not clear, however, to what extent EPA might act on this use of adjuncts to statistical analysis.

Compliance Monitoring

Compliance monitoring at permitted facilities measures the degree and extent of the ground water contamination. Results are especially important in designing and evaluating corrective actions. Such monitoring is difficult and expensive:

> In a typical case ... determining the extent and severity of a plume emanating from one single source in a shallow aquifer requires dozens of monitoring wells and hundreds of samples. It also takes a great deal of time and several hundred thousand dollars. If the geology is more complex or several potential contamination sources exist, the cost will be on the order of half a million dollars. In a case where the aquifer is deep or surface features cannot help in determining the hydrogeology, costs could soar to $2 or $3 million.[91]

Here again, as with the placement of the monitoring wells, the science of hydrogeology enters, but with the additional requirement to model and predict underground *contaminant flow*. Such modeling is not a routinely available technique like well drilling or chemical analysis; it is state-of-the-art scientific research generally carried out by universities and a few companies. Where modeling groundwater flow is possible, predicting contaminant flow may still be very difficult if possible at all (see the section on the vadose zone in this chapter]. As pointed out in **1982**:

> It is not presently possible to determine how thousands of individual chemicals will react in the groundwater environment or to confidently predict the aggregate effects of numerous processes such as attenuation, dispersion, and diffusion. A vast amount of field data would be required to develop a reliable basis for such predictions.
>
> It is frequently suggested that modeling could serve as an adequate predictive tool for this purpose. However, even detailed investigations which might cost on the order of $250,000 to $500,000 per site may not provide enough data to develop a model to be used in this capacity. Furthermore, a relatively successful model based on adequate data can only be expected to yield results within an order of magnitude of the actual situation. This level of accuracy may not be acceptable when public health is at risk and critical concentrations are measured in parts per billion.
>
> The process of obtaining the data for predicting ground water conditions, interpreting the information and making accurate decisions to implement compliance monitoring is a scientific endeavor. It can only be carried out in a confident manner by well trained groundwater technicians. There is presently a severe shortage of trained groundwater scientists in the public and private sector, and it is doubtful that there is sufficient talent available to work on more than a relatively small percentage of the existing sites that would fall under the compliance monitoring aspects of the new hazardous waste regulations.[92]

[89] U.S. Environmental Protection Agency, "Interim Status Ground-Water Monitoring Implementation Study," op. cit.

[90] U.S. Congress, Report 98-1133, p. 99.

[91] Swep T. Davis, Associate Assistant Administrator for Water and Waste Management, U.S. Environmental Protection Agency, statement before the joint hearing of the Subcommittee on Health and the Environment and the Subcommittee on Transportation and Commerce, Aug. 22, 1980.

[92] David W. Miller, Geraghty & Miller, In testimony before hearing of the House Subcommittee on Natural Resources, Agriculture Research and Environment, Nov. 30, 1982.

EPA seems to understand these shortcomings for modeling and predicting contaminant flow. The preamble to the regulations states:

> The way to meet this objective [of protection] is to avoid regulatory schemes that principally rely on complicated predictions about the long term fate, transport, and effect of hazardous constituents in the environment. Such predictions are often subject to scientific uncertainties about the behavior of particular constituents in the hydrogeologic environment and about the effects of those constituents on receptor populations.[93]

However, the RCRA permit writers' manual in its instructions for evaluating the design of a corrective action program takes a somewhat different view of the capability of hydrogeology in predicting contaminant flow:

> Predictions of groundwater flow patterns throughout the contaminated areas, including the drawdowns and hydraulic gradients, that will be established by the recovery system should be provided. On the basis of predicted withdrawal rates, estimates should be provided for the time required to exchange an amount of groundwater equivalent to that originally contaminated,
>
> The applicant will need to use either analytical solutions or numerical (computer) models to provide these predictions of the response of groundwater on site to the proposed recovery system.

To summarize, the *requirement that compliance monitoring predict plume movement is a regulatory requirement t that depends on a technology which does not really exist. Thus, EPA is putting more reliance on state-of-the-art technology to clean up pollution than it does to prevent pollution.*

Corrective Action

Corrective action regulations for permitted facilities require that contaminated groundwater be cleaned to background levels. Background contaminant levels can be, and frequently are, extremely low if they are known at all. The regulations require technology which is capable of removing contaminants to below the level of detection. But again, the corrective action requirements ask for technology that does not really exist. This is acknowledged by EPA in the preamble to the regulations which states:

> . . . the technology of performing corrective action is new. The Agency's and the regulated community's experience in conducting remediation activities (beyond the feasibility study stage) is fairly limited to date.[94] The standards are based on the hope that technology will become available in the future as stated in the preamble. The national experience with groundwater cleanup . . . is relatively limited at this time. EPA expects that over time, the state of knowledge about groundwater cleanup measures will improve.[95]

The most comprehensive study of attempts to clean up sites where groundwater had been polluted was made by EPA in 1980.[96] This was a study of 169 hazardous waste sites requiring remedial action. Groundwater was polluted at 110 sites. In most cases the groundwater supply was abandoned and replaced by a pipeline to another source. In very few cases, because of the high costs, was there any attempt to clean up the groundwater, and none were cleaned to background levels.

Although experts have little experience in restoring polluted groundwater to below detection levels, some attempts have been made to restore groundwater to some degree. It is difficult, very expensive, and the results have been mixed. Typically, treatment of a plume is considered adequate when levels of volatile organics are at or below 100 µg/l. Operating costs for a single site can run over a million dollars a year for 20 or 30 years. One expert summed up the situation:

> Substantial efforts are now being made to reclaim polluted groundwater. In the southwestern U. S., where highly prolific alluvial aquifers are common, a number of problems

93 47 Federal Register 32283

94 47 Federal Register 32313.

95 47 Federal Register 32286.

96 N. Neely, D. Gillespie, F. Schauf, and J. Walsh, U.S. Environmental Protection Agency, *Remedial Actions at Hazardous Waste Sites: Survey and Case Studies*, EPA 430/9-81-05, SW-91O (Washington, DC: Oil and Special Materials Control Division, January 1981).

can be encountered when attempting to reclaim polluted groundwater. First, many of the zones of polluted water are large—often in the range of thousands or tens of thousands of acre-feet. This results in the need to pump substantial amounts of water, which must then be treated and/or disposed. Decades will be required to remove polluted water in many situations. Second, pumpage of groundwater for reclamation often has legal constraints. Third, land ownership often presents a formidable problem, because polluted zones frequently extend beyond property controlled by the responsible entity. Fourth, relatively deep water levels usually allow substantial amounts of pollutants to be in the vadose zone, where pumping is not effective. Fifth, pumping schemes are inherently inefficient in heterogeneous, non-isotropic alluvial aquifers, due to inflow of unpolluted water during pumping. Because of the many limitations of reclamation, groundwater quality management should focus on aquifer protection.[97]

The regulations permit two basic corrective approaches. The first is to pump out the contaminated groundwater. This is not always simple:

> in very arid portions of the country, groundwaters are generally located well below the ground surface. Therefore, it may be extremely difficult, if not impossible, to pump such underground waters. In complex geologic environments, contaminants may perch on clay layers, In such circumstances, even if pumping of surrounding waters were possible, such pumping would not succeed in bringing contaminants to the surface. In addition, in these circumstances, the depth of the contaminant layer may prohibit trenching to reach the contaminants . . . Shallow aquifers may not have sufficient waters to permit effective pumping. In addition, certain tight clay formations may prohibit effecting pumping from shallow aquifers. In these circumstances, if excavation is not possible, it is impossible to remove all contaminants.[98]

The EPA RCRA permit writers' guide recognizes these difficulties and gives technological approaches for handling them. Where there is insufficient groundwater for efficient pumping, then fresh water must be injected into the aquifer by injection wells to flush out the plume of contamination. But the plume itself is the lesser problem:

> . . . the removal of additional amounts of water, frequently many times in excess of that originally contaminated, will be required to reduce contaminant concentrations to acceptable levels . . . Many of the hazardous constituents present in any plume of contamination migrating from a hazardous waste management facility will likely be subject to some amount of adsorption to the geologic materials on site . . . as contaminated groundwater is removed from the subsurface and replaced by water of lower contaminant concentrations, contaminants will desorb from subsurface solids and establish new equilibrium concentrations of contaminants in the groundwater. Thus, the process of restoring groundwater quality will become a process, in most cases, of not only removing contaminants originally present in groundwater but also of removing contaminants adsorbed to subsurface solids.

The expensive process of pumping huge amounts of water for decades does not guarantee that cleanup standards will be met. The issue of whether EPA will insist on full compliance with its standards when faced with such costs becomes important. In addressing such public concerns, an EPA official wrote: "It may be costly and take decades, but it can be done and under the regulations the owner is required to undertake it."[99] However, EPA's instructions to their permit writers are less optimistic:

> . . . the permit writer should also consider the relative costs of these measures when determining the adequacy of flushing rates predicted for proposed recovery systems. In-

[97] Kenneth D. Schmidt, "Limitations in Implementing Aquifer Reclamation Schemes," paper presented at *Third National Symposium on Aquifer Restoration and Groundwater Monitoring* sponsored by the National Water Well Association, Columbus, OH, 1983.

[98] "Comments on Interim Final Hazardous Waste Regulations Promulgated by the United States Environmental Protection Agency Pursuant to Sections 3004 and 3005 of the Resource Conservation and Recovery Act, Docket 3004, Permitting Standards for Land Disposal Facilities" (Washington, DC: The American Petroleum Institute, Nov. 23, 1983].

[99] Lee M. Thomas, Assistant Administrator, U.S. Environmental Protection Agency, letter to Senator Robert C. Byrd, Dec. 30, 1983.

creasing flushing by increasing pumping rates and the number of wells, well points, and/or drains will certainly increase the costs associated with the recovery system. Similarly, requiring the use of injection wells and/or increasing their number and rates of injection will increase cost. In some cases, particularly as flushing rates become higher, the cost of increasing flushing rates by requiring these design changes will become disproportionally high relative to the additional flushing achieved and the advantages gained.

Thus, the permit writer will need to balance a number of factors when reviewing the adequacy of flushing rates expected from a proposed recovery system.

The EPA permit writers' guide also points out many problems that may be encountered in attempting corrective action and it does not have solutions to all of them. For example, the problem of cleaning up immiscible fluids is poorly understood.

Once contaminated water is pumped out of the ground, something must be done with it. One solution is to remove the contaminants and return the cleaned water to the aquifer. This has been tried at some CERCLA sites. Table 5-15 shows some examples of the kind of levels of cleanup that can be practically (albeit at great cost) achieved using the most common techniques. Although impressive, these results are far from background levels, and are higher than generally accepted safe levels.

A second technology that the RCRA groundwater protection standards allow for corrective action is "in situ" treatment. This is the introduction of chemical or biological agents into the aquifer to react with and destroy the hazardous constituents. If anything, even less is known about these technologies than those discussed above, as the permit writers' guide points out:

> ... to date in situ treatment has been applied in only limited circumstances, and little experience is available that can be related directly to the cleanup activities required in Part 264 corrective actions programs. In most cases, use of' these techniques will assume the character of a field experiment.

Table 5.15.—Removal of Selected Specific Organics From Groundwater

Organic compound	Process effluent concentration range[a]		
	Adsorption	Stripping	Biological
phenol	<10	—	10-50
toluene	<100	<10	10-50
benzene	<50	<10	1o-1oo
ethyl acetate	—	—	10-20
formaldehyde	—	—	50-100
aceton	—	—	10-20
methyl ethyl ketone	—	25,000	10-20
aniline	<10		10-50
nitroaniline	50-100	-	10-50
methanol	—	15,000	10-50
isopropanol	—	10,000	10-50
isobutanol	—	40,000	10-50
methylene chloride	<100	200	<50
trichloroethylene	<10	5-1o	<10
1,1 ,1-trichloroethane	<10	50	10-50
1,1,2-trichloroethane	<10	50	10-50
tetrachlorethylene	5-1o	5-1o	10-200
nitrobenzene	<10	—	100-1,000

[a]Note: All values in $\mu g/l$ or ppb.

SOURCE: J. R. Absalon and M. R. Hockenbury, "Treatment Alternatives Evaluation for Aquifer Restoration" (paper presented at the Third National Symposium on Aquifer Restoration and Groundwater Monitoring sponsored by the National Water Well Association, Columbus, OH, May 19s3).

The purpose of this discussion is not to condemn available technologies for cleaning up contaminated aquifers. However, it is possible to see the predicament facing a facility operator with a need to take corrective action. To abandon his facility, thus making it a Superfund site, may seem an attractive option.

Estimating Future Needs

Data to Illustrate the Scope of the Problem

About 2,000 hazardous waste land disposal facilities required to conduct groundwater monitoring have filed for interim status. Many more may require regulation, particularly surface impoundments. (Note that injection wells are regulated under another statute and not by the RCRA groundwater protection standards although they are used for hazardous waste disposal.) Various EPA data provide some indication of the number of hazardous waste management facilities that might threaten groundwater: surface impoundments, 770; landfills, ZOO; injection wells, 700; land treatment, 70; waste piles, 170; and storage and treatment tanks, 2,040.

OTA has analyzed the data from EPA's 1981 study of waste management to examine the extent 'to which land disposal facilities receive toxic hazardous wastes. Toxic wastes present long-term chronic health risks and are to be contrasted with wastes that are hazardous only on the basis of characteristics such as reactivity, ignitability, and corrosivity. The *data indicate that a significant t fraction—perhaps a majority—of the wastes being placed in land disposal facilities nation wide are toxic chemicals that would pose long-term health problems if released into the environment.* For surface impoundments and landfills almost all the wastes may be toxic, while for injection wells about one-third of the wastes ma}' be toxic.

Number of Future NPL Sites

Planning needs to take into account the possibility that currently operating RCRA hazardous waste facilities will become future NPL sites. The reasons are:

- Hazardous waste land disposal facilities have a poor record of performance. They continue to be used for toxic materials posing long-term problems. Even with the many changes in the recent RCRA reauthorization, including the *eventual* limits on some land disposal, low' -cost land disposal will remain widely used for some time.
- The current groundwater protection standards are so inadequate that, even with perfect compliance, the} would not *prevent* the release of hazardous substances from many of the facilities they cover. Releases are unlikely to be detected early enough in all cases to limit contamination to levels that would or could be effectively cleaned up by RCRA facility operators.
- One important consequence of the reauthorized RCRA may be to hasten the closing of the worst hazardous waste facilities. Man\ owners and operators may escape near-term and possibly long-term responsibility for cleaning up sites that have serious enough problems to eventually place them on the NFL.

As indicated earlier, it is possible only to estimate the number of facilities that might become future NPL sites. On the basis of the analysis in this chapter, OTA believes that a reasonable estimate is that at least half of the approximately 2,000 operating hazardous waste facilities that are or should be subject to RCRA groundwater protection standards will become NPL sites. Many more sites may require cleanup, but they might be cleaned *up* by their *owners* or users.

THE SITE SELECTION PROCESS

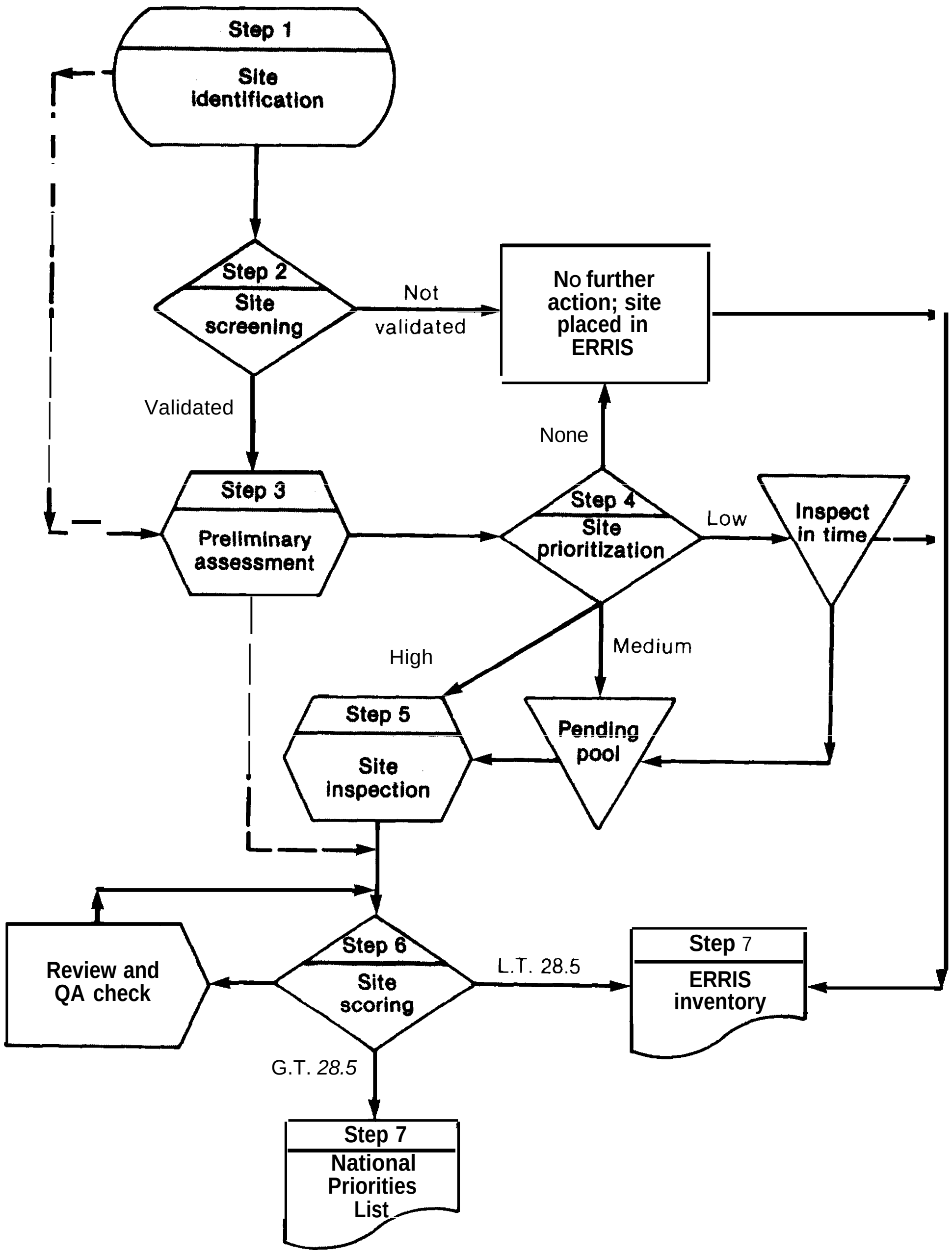
This section describes EPA's current process for selecting sites for the NPL (figure 5-I]. This process was analyzed to ascertain the likelihood that sites that merit cleanup will not be placed on the NPL.

Site Identification

There is a large backlog of about 12,000 sites, that have not y& been evaluated. Efforts to discover sites have slowed. For the most part, States do not have the resources for site identification, and Federal resources are not being supplied. EPA policy is to place highest priority on evaluating already identified sites. Only a few States, including New York, Michigan, and California, have developed programs to identify additional sites, However, even without emphasis on discovering new sites, the national inventory has been growing steadily, to about 19,000 by late 1984.

The argument has been made that the vast majority of the worst sites have been identified. But there are likely to be older, abandoned sites

Figure 5.1 .—Summary Site Scoring Flowchart



SOURCE Office of Technology Assessment

and sites that pose indirect environmental hazards that have not been identified.

Setting Priorities for Sites

As a result of the "desk-top" preliminary assessment (PA) based on known information, priorities for subsequent actions at the site are established. Each site is given a high, medium, low, or no priority ranking. Without priority, a site is retained in EPA's basic site inventory, ERRIS (Emergency and Remedial Response Information System), High-priority sites are immediately inspected; the others wait their turn, Sites with low priority are unlikely to get attention. (Although some States may request inspection of low-priority sites, this does not yet appear to be happening.) Documentation is required only if a low or no priority status is assigned, There are no national EPA guidelines or criteria for setting priorities, The process is subjective, rests on professional judgment, and provides little assurance of consistency among EPA Regions or States. No national data are available on the numbers of sites in the various priority categories. On most occasions, little attempt is made to verify the completeness or accuracy of the information upon which the priority judgment is made.

Although States usually conduct PAs, regional EPA offices, EPA contractors, and Field Investigation Teams (FIT), also conduct them. The States are supposed to perform this task to a greater extent in the future. For fiscal year 1985, EPA has budgeted $1,800 per PA for State work. An example of the type of guidance provided by some Regions is given in figure 5-2 for EPA Region 5. The guidance is minimal. In addition, as a practical matter, sites that do not affect a large population are less likely to receive a high priority, even though they may present serious hazards,

Figure 5-2.— Region 5 Prioritization Criteria

High priority for inspection	**1. Known hazardous waste onsite. and 2. Known contamination of surface, water, groundwater, or air, or Potential to affect large population**
Medium priority for inspection	1. Known or suspected hazardous waste onsite. and 2. Potential to contaminate surface water, groundwater or air, or Potential to affect any population.
Low priority for inspection (pending)	1. Known or suspected hazardous waste onsite, and No potential to contaminate surface water, groundwater, or air, and No potential to affect any population. 2. Site has been or is being evaluated and State is taking action. 3. No known hazardous waste onsite, but the potential exists.
No further action	1. No hazardous waste onsite. 2. Site has been cleaned up. or 3. Hazardous material onsite, but handled correctly. Complete documentation needed to justify

SOURCE Office of Technology Assessment

Site Inspections

Most site inspections (SIs) are conducted by EPA FIT contractors with the purpose of obtaining data to evaluate and score the site to determine its eligibility for placement on the NPL. SIs involve considerable field work, often with limited sampling and analysis. For fiscal year 1985, EPA has budgeted $16,800 per SI for State work. The order in which sites are inspected does not necessarily reflect the priorities assigned in the earlier step. Instead, inspection schedules take into account geographic distribution and other logistical factors. Within the same region, the completeness of the information entered into the S1 form varies considerably according to who conducted the inspection, prior known facts about the site, suspected hazards, and other factors. The lack of detailed guidance can lead to data voids or inaccuracies that can have an important effect on site scoring.

Site Scoring

Sites are scored by an established procedure called the Hazard Ranking System (HIM), which can be regarded as a crude hazard or risk assessment. An initial scoring is conducted by the State, the region, or the FIT. There are reviews at the EPA regional and headquarters levels, with EPA headquarters assigning the final score. All the facts provided in the file are assumed correct. The cutoff score of' 28.5 was chosen to provide an original NPL of 400 sites, the minimum required by statute. *EPA* has re*tained this cutoff for administrative convenience and consistency over time, even though there is no technical justification for believing that sites with lower scores do not merit cleanup.* Sites designated by States as their highest priority site are exampted from the cutoff. As of September 1984, only seven sites with scores less than 28.5 were on the NPL.

The H KS methodology has been criticized elsewhere, and the major problems 11'ill be summarized only briefly here.[100] The final score is a composite of' three migration route scores for groundwater, surface water, and air. some of the major problems with the H RS are:

- There is a very strong bias toward human health effects, with little chance of a site getting a high score if there are primarily environmental hazards or threats.
- For huma11 health effect S, there is a St1'01)~ bias in faker of high affected populations.

[100] See [*Vork shop on Se* '/(' [*tion of I* /(//,1 *rdous* 11'*aste' Sites for Supe*'1 "/[/1)(/ /'/) /lo//l L/, U.S Senate Committee on Appropriations, March 1982.

- For the air route there must be documentation (e.g., laboratory data) of' a release, but there is no such requirement for the water routes.
- Scoring for toxicity/persistence may be based on a site contaminant, which is not necessarily one with a known or potential release.
- A site with a very high score for one migration route but zero or very low scores for the other two routes can get a relatively low total score, while a site with moderate scores for all three routes might get a higher score; in other words, averaging the route scores creates a bias against a site with one particularly important hazard.
- Only the quantity and not the distribution of waste is considered, even though similar quantities over markedly different areas pose different threats.

Variability Among EPA Regions

Table 5-16 presents data, arranged by EPA Region, on a number of aspects of the site selection process. No matter what statistic is examined, there is considerable variability among the Regions. Some examples are:

- The percent Of ERRIS sites that have become NPL sites varies from 1.1 percent (Region 7) to 5.3 percent (Region 2],
- The percent of the national ERRIS inve-tory by Region varies from 3 percent (Region 8) to 20 percent (Region 5).
- The percent of the national NPL by Region varies from 3 percent (Regions 7 and 8) to 26 percent (Region 5).
- Several Regions have a high fraction of' NPL sites compared to ERRIS sites (Regions 1, 2, 3, and 5). Two Regions have much smaller fractions of the NPL sites compared to ERRIS sites (Regions 6 and 7).
- For fiscal year 1985, plans to perform PAs as a fraction of the Regional ERRIS number varies from 4 percent (Region 6) to 38 percent (Region 8).
- For fiscal year 1985, plans to perform SIs as a fraction of the Regional ERRIS number varies from 1 percent (Regions 5 and 7) to **7** percent (Region 10).

Table 5-16.—Site Selection Variability Among EPA Regions

Region	ERRIS Number	ERRIS % NPL	% of national total ERRIS	% of national total NPL	FY 85 Preliminary Assessments (PAs) Number	(%, ERRIS)	$(000)	FY 85 Site Investigations (SIs) Number	(% ERRIS)	$(000)	FY 85 PA/SI Total $(000)	% Total
1	937	4.8	5	8	240	(26)	432	55	(6)	921	1,353	7
2	2,313	5.3	12	23	NA	NA	NA	NA	NA	NA	1,775	10
3	1,741	3.4	9	11	NA		NA	NA	NA	NA	1,820	10
4	3,423	19	18	12	1,135	(33)	2,043	190	(6)	3,183	5,226	28
5	3,689	38	20	26	1,295	(35)	2,331	25	(1)	419	2,750	15
6	2,289	1.3	12	5	100	(4)	100	100	(4)	4	1.869	10
7	1.318	11	7	3	290	(22)	522	10	(1)	168	690	4
8	576	31	3	3	220	(38)	396	15	(3)	251	647	3
9	1,388	19	7	5	NA	NA	NA	NA	NA	NA	805	4
10	878	2.4	5	4	260	(30)	468	65	(7)	1,088	1.556	8

SOURCE Office of Technology Assessment using data from various EPA documents

- Regions 4 and 10 appear to have planned for a large PA/SI effort for fiscal year 1985 as compared to their fraction of the national ERRIS sites. Conversely, Regions 5, 7, and 9 have relatively small efforts compared to their fraction of the national ERRIS sites.

Data on variations in total and component HRS data for EPA Regions and the Nation are given in table 5-17. While the variation among total scores for the regions is not great, there are considerable variations for the component scores. This suggests problems in the Hazard Ranking System.

In particular, for most regions the air route scores are very low, with the notable exceptions of Regions 1 and 6 which have relatively high scores with high correlations of those scores with the total scores. To ascertain the extent and significance of the national variability in air scores, a more detailed analysis was done; the results are given in table 5-18.

In examining the number of sites with a nonzero air score, it is seen that Regions 4, 5, and 9 have relatively low fractions. For all Regions, 20 percent of the NPL sites received nonzero air scores, but without Regions 4, 5, and 9 that fraction increases to 29 percent. Of more importance is the number of sites with an air score for which placement on the NPL is crucially dependent on that air score (those sites that would have a total HRS score below 28.5 without their air scores). Consider the fraction of crucial sites relative to the number of NPL sites. Without Regions 4, 5, and 9, nine percent of NPL sites depend on their air scores for NPL status, compared to 6 percent for all Regions.

Table 5-17.—Summary Statistics on Hazard Ranking Scores

EPA Region	Number NPL sites	Mean total	Mean GW	R GW-total	Mean SW	R SW-total	Mean A	R A-total
1	45	466	67,3	0.557	207	0.433	169	0.570
2	122	449	627	0.468	203	0443	139	0390
3	59	403	492	0.525	195	0475	207	0299
4	66	42,9	68,5	0.777	16.0	0173	228	0012
5	137	425	68,6	0.710	129	0272	379	0232
6	29	435	59,0	0557	190	0.120	249	0539
7	14	385	52.7	0748	193	0,431	118	0179
8	18	459	61 1	0722	390	0652	8.78	0270
9	28	392	515	0.578	202	0.368	642	0007
10	21	409	525	0.443	137	0.282	19.3	0335
All	539	425	593	0712	201	0.435	129	0.055

Total total score
GW groundwater score
SW surface water score
A air score
R correlation coefficient between route score and total score

SOURCE Office of Technology Assessment

Table 5-18.—Analysis of NPL Sites With Air Route HRS Scores

Region	Number of NPL sites	Sites with-air scores: Number/percent of NPL sites	Sites with-air scores: N-umber/percent crucial for listing[a]	Crucial sites, percent of NPL sites
1	45	'1 2/27	3/25	7
2	122	30/25	9/30	7
3	59	22/37	9/41	15
4	67	3/5	0/0	0
5	141	11/8	2/18	1
6	30	13/43	2/15	7
7	14	4/29	1/25	7
8	18	3/17	0/0	0
9	29	3/10	2/67	7
10	21	7/33	3/43	14
Total	546	108/20	31/29	6
Without regions 4,5,9	309	91/29	27/30	9

[a]A site has a crucial air score if its total HRS score without the air score would be below 285 the cutoff for Placement on the NPL

SOURCE US Environmental Protection Agency, NPL dated September 1983

If the 9 percent is applied to the NPL sites of Regions 4, 5, and 9 (and accounting for the four crucial sites), then there is an indication that 17 sites may have been missed due to the procedures followed in these three Regions. This discrepancy could increase if more attention is given to Subtitle D landfills, which often pose problems of methane generation.

Although the groundwater route clearly has the highest scores and the highest correlation with total scores in table 5-I7, here too there is considerable variation among the regions.

Most of the variations are difficult to explain other than through administrative, procedural, or policy variations among the Regions and States. The one exception is probably for Regions 1, 2, 3, and 5 (and to a lesser extent for Region 4), for which an argument could be made that these locations have a substantially greater number of uncontrolled sites resulting from earlier periods and higher densities of industrial activities as compared to the rest of the Nation.

Estimate of Future NPL

Many sites may not be making it through the site selection system, Available statistical data support this view.

Table 5-19 gives the results of a 1983 survey of States conducted by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), States were asked to identify the number of sites that might require cleanup and the number of sites needing a cleanup response. This table also gives the number of sites in EPA's ERRIS inventory and on the NPL (as of August 1984), These data reveal marked differences between the estimates made by States and EPA data for the total population of uncontrolled sites, even though the totals appear similar, about 18,000 for each. It appears that some States believe there are many more sites than EPA estimates, and in other cases the reverse appears the case. Only a few States have estimates within about 10 percent of the ERRIS data. If the highest figures are used for each State, then the universe of uncontrolled sites appears to be about 24,000.

The responding States estimate about 8,000 sites will require cleanup. That is, the States foresee the need for a large NPL. According to the States, about 40 percent of all uncontrolled sites will need cleanup. But less than 5 percent of current ERRIS sites have been placed on the NPL, and EPA's projection of about 2,000 NPL sites out of a total ERRIS of 20,000 amounts to a 10 percent placement for the NPL. The problem of estimating the future size of the NPL is further shown by the considerable variation among the State estimates. Seventeen States believe that 50 percent or more of sites will need cleanup and 13 States believe that 10 percent or less will require cleanup.

Table 5-19.—ERRIS/NPL v. State Officials Views on Site Cleanup Requirements

	ASTSWMO data			ERRIS/NPL data		
	Total sites	Response needed	Percent	Total ERRIS	Total NPL	Percent
Region I:						
Maine	—	—	—	78	5	6
Vermont	12	6	50	22	2	9
New Hampshire	95	50	52	74	10	14
Massachusetts	350	53	15	455	16	4
Connecticut	200	200	100	230	6	3
Rhode Island	—	—	—	78	6	8
Subtotal	657	309	47	937	45	5
Region II:						
New York	750	200	27	1,132	29	3
New Jersey	1,500	800	53	1,041	85	8
Puerto Rico	—	—	—	139	8	6
Virgin Islands	1	0	0	1	0	0
Subtotal	2,251	1,000	44	2,313	122	5
Region III						
Pennsylvania	1,200	600	50	1,008	39	4
Maryland	100	11	11	166	3	2
Delaware	80	8	10	69	9	13
Virginia	275	15	6	280	4	1
West Virginia	200	—	—	213	4	2
District of Columbia	3	0	0	5	0	0
Subtotal	1,858	634	34	1741	59	3
Region IV:						
North Carolina	—	—	—	646	3	<1
South Carolina	30	30	100	203	9	4
Georgia	300	150	50	589	5	1
Florida	237	90	38	373	28	8
Alabama	400	100	25	402	7	2
Mississippi	250	25	10	272	1	<1
Tennessee	650	500	77	622	6	1
Kentucky	150	75	50	316	7	2
Subtotal	2,017	'970	48	3.423	66	2
Region V:						
Ohio	40	40	100	855	22	3
Indiana	200	200	100	696	17	2
Michigan	1,200	700	58	779	48	6
Illinois	550	100	18	896	11	1
Wisconsin	750	500	67	241	20	8
Minnesota	125	90	72	222	23	10
Subtotal	2,865	1,630	57	3,689	141	4
Region VI:						
Arkansas	300	20	7	248	6	2
Louisiana	—	—	—	319	5	2
Oklahoma	50	15	30	449	4	1
Texas	1,300	150	12	1,109	10	1
New Mexico	200	100	50	164	4	2
Subtotal	1,850	285	15	2,289	29	1
Region VII:						
Iowa	—	—	—	280	3	1
Missouri	100	65	65	604	7	1
Kansas	150	100	67	260	4	2
Nebraska	150	15	10	174	0	0
Subtotal	400	180	45	1,318	14	1
Region VIII:						
North Dakota	15	0	0	31	1	3
South Dakota	50	2	4	38	1	3
Wyoming	—	—		74	1	1

Table 5-19.—ERRIS/NPL v. State Officials Views on Site Cleanup Requirements—Continued

	ASTSWMO data			ERRIS/NPL data		
	Total sites	Response needed	Percent	Total ERRIS	Total NPL	Percent
Montana	79	20	25	81	5	6
Colorado	20	8	40	242	9	4
Utah	—	—	—	110	1	1
Subtotal	164	30	18	576	18	3
Region IX:						
Arizona	200	50	25	225	6	3
Nevada	150	15	10	118	0	0
California	4,750	2,000	42	955	19	2
Hawaii	50	5	10	77	0	0
Guam	—	—	—	13	1	8
Subtotal	5,150	2,070	40	1,388	26	2
Region X:						
Idaho	—	8	—	114	4	4
Oregon	45	8	18	167	3	2
Washington	500	—	0	501	14	3
Alaska	10	2	20	96	0	0
Subtotal	555	18	3	878	21	2
Totals	17,767	7,126	40	18,552	541	3

SOURCE Office of Technology Assessment

It is not possible for OTA to calculate exactly how much the current site selection process might underestimate future NPL sites. But an estimate can be made. First, it should be noted that the results of the ASTSWMO survey and the ERRIS data do not include most Subtitle D solid waste facilities nor Subtitle Chazardous waste facilities examined in the two previous sections of this chapter. Thus, the Following estimates do not include those categories.

Three main parameters can be examined to make an estimate. First, the size of the ERRIS inventory can vary. As shown in table 5-20, OTA has considered a low and high case, with the low case representing EPA's current estimate of 22,000 sites, and the high case assuming an inventory of 32,000 sites. The high case assumes that the steady increase in ERRIS over the past 2 years, amounting to several thousand sites, will continue. If site discovery and identification is given renewed emphasis, an inventory of 32,000 appears possible within 5 to 10 years,

The fraction of sites that receive a site investigation after the preliminary assessment has been 28 percent. The fraction of sites that have received a site investigation and have been scored, and which then have been placed on the NPL, has also been 28 percent. If it is assumed that the inconsistencies discussed above were corrected, including removal of the arbitrary 28.5 cutoff score and that environmental problems were recognized, then both of these fractions could increase significantly. OTA has, therefore, used two additional fractions of 35 and 45 percent for each of these step-downs. Note that in 1982 and 1983 the fractions of sites investigated that were placed on the NPL were 42 and 38 percent, respectively, Also, in a study of 11 civilian agencies with uncontrolled sites (excluding the Department of Defense) it was found that 39 percent of sites which had received preliminary assessments had completed site investigations, with more SIs possible.[101] These higher fractions also recognize that if the site selection system were improved, the sites that have been eliminated from the NPL could be reevaluated and contribute to the NPL,

The range of step-down fractions for the two levels of ERRIS in table 5-20 yield a wide range

[101] U.S. General Accounting Office, *Status of Civilian Federal Agencies' Efforts To Address Hazardous Waste Problems On Their Lands*, RCED-84-188 (Gaithersburg, MD: U.S. General Accounting Office, Sept. 28, 1984).

Table 5.20.– Range of Estimates for Future Size of the NPL

Estimated future ERRIS sites -	PAs completed =	PAs to complete -	Site investigations to complete		- Additional sites for NPL		+ Current NPL =	Estimated future NPL
22,000 (low)	6,859	15,141	4,239	*(280/o)*	1,187	(28%)	538	1,725
					1,484	(35%)	538	2,022
					1,908	(45%)	538	2,446
			5,299	*(35%)*	1,484	(28%)	538	2,022
					1,855	(35%)	538	2,393
					2,385	(45%)	538	2,923
			6.813	(45%)	1,908	(28%)	538	2,446
					2,385	(35%)	538	2,923
					3,066	(45%)	538	3,604
32,000 (high)	*6,859*	25,141	7,039	*(280/o)*	1,971	(28%)	538	2,509
					2,464	(35%)	538	3,002
					3,168	(45%)	538	3,706
			8,799	(35%)	2,464	(28%)	538	3,002
					3,080	(35%)	538	3,618
					3,960	(45%)	538	4,498
			11,313	(45%)	3,168	(28%)	538	3,706
					3,960	(35%)	538	4,498
					5,091	(45%)	538	5.629

NOTE: PA Preliminary assessment

SOURCE Off Ice of Technology Assessment

for a future NPL based on an improved site selection process. In comparison to EPA's prejection of about 2,000 sites on the NPL, OTA projects an additional 1,000 to 3,000 sites. OTA believes that with an improved site selection process an additional 2,000 sites might be recognized as requiring cleanup.

SUMMARY ESTIMATION

On the basis of the information in this chapter, OTA concludes that the number of uncontrolled waste sites that may merit cleanup and placement on the NPL will be markedly greater than EPA's current estimates. There are some basic benefits to be derived from a site selection system that maximizes *early* identification. With early identification, better decisions can be made about priorities and the allocation of resources for cleanups. There will be less chance that the worst sites will be neglected.

As discussed in chapter 3, setting national priorities requires as complete a picture as possible of total cleanup needs facing the Superfund program. It is not now possible to understand whether it makes sense, environmentally and economically, to let 50 percent of the NPL sites go unattended, while at the same time some 30 percent are receiving remedial cleanup, and another 20 percent receive attention of some sort. Placement on the NPL establishes eligibility for cleanup, and there is some indication that a site's score establishes priority for determining whether it receives an initial response, a remedial cleanup, or studies to select a cleanup option.

OTA finds that the contribution from solid waste facilities to an expanded NPL could easily be 5,000 sites, and perhaps more, The contribution from operating hazardous waste facilities could to be 1,000 sites. Improving the site selection process could add another 2,000 sites. Therefore, together with the 2,000 sites, which would result from current *procedures* and policies and which OTA agrees merit cleanup, the *total NPL could reach 10,000 sites*.

The largest uncertainty is for the contribution from solid waste facilities, both open and closed. Assuming that only 5,000 sites from this category might require cleanup is conservative; it could be two to three times greater.

The 10,000 figure is consistent with the results of the survey of State officials; they estimated a need for about 8,000 cleanups. But it is unlikely that the estimates of State officials included many solid waste facilities.[102] It should also be noted that State officials also concluded that the more than 10,000 sites that were not put into the highest priority category still had "the potential to threaten public health and the environment."

Finally, consider EPA's recent analysis of future Superfund needs.[103] It concluded that "the current inventory of sites and anticipated new additions will produce an NPL of 1,500 to 2,500 sites over the next several years." Although EPA discussed a number of potential sources of additional NPL sites, including some that OTA did not, the major factors that lead to their lower projection include:

- EPA did not consider surface impoundments, even though: a) according to their data such sites are the single largest source of NPL sites, about one-third, and b) the surface impoundment problem is acknowledged in EPA's Ground-water Protection Strategy. In OTA's analysis, 340,000 such facilities were considered.
- EPA did not consider closed as well as open industrial landfills. OTA estimated that there were twice as many closed as open ones (150,000 sites).
- No basis was provided for concluding that there were only twice as many closed municipal landfills as open ones. OTA used data for several States to develop an estimate of three times as many closed as open facilities (42,000 such sites).
- EPA did not account for the more stringent 1984 amendments to RCRA for hazardous waste facilities that could lead to more failures of companies. Nor was there any reference to EPA's problems with groundwater protection standards, which could lead to the creation of uncontrolled sites. EPA's Interim Status Ground-Water Monitoring Implementation Study substantiates this problem. OTA estimated that 1,000 hazardous waste facilites could become NPL sites; EPA's estimate was about half this figure.
- EPA gave limited consideration to the site selection process and changes in it that could result in more ERRIS sites, with more of them becoming NPL sites. Nevertheless, there is some indication that EPA believes that an improved site selection process (without further site identification) could add an additional 1,670 to 2,170 sites to the NPL. OTA's estimate from further site identification and improved site selection was 2,000 additional sites.

EPA has said that a full examination of the problem of future sites could lead to a situation where the funding needed "would overwhelm" the Superfund program. But OTA's point is that by acknowledging the full extent of future needs, rather than underestimating them, effective planning can prevent a crisis.

[102] This view is supported by the basic similarity in the States' estimates of total number of uncontrolled sites to the number in ERRIS, and their dissimilarity from the numbers of solid waste facilities. (ERRIS does contain some solid waste facilities, something over 2,000 sites according to EPA; but this is a small fraction of the total universe of Subtitle D facilities.)

[103] U.S. Environment] Protection Agency, "Extent of the Hazardous Release Problem and Future Funding Needs, CERCLA Section 301(a)(l)(C) Study" (Washington, DC: Office of Solid Waste and Emergency Response, December 1984),

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Cleanup Technologies

INTRODUCTION

In the Superfund program so far cleanup of uncontrolled sites has generally meant that hazardous wastes are confined on the site or disposed of elsewhere. Containment strategies have been adapted from construction engineering techniques and little thought given to the development and application of innovative technologies to deal with the unique problems encountered. With increasing evidence that containment is not effective in the long term and may result in the need to repeat site remedial action at the same site or on the same waste and as the dimensions of groundwater problems at these sites become clearer, technologies which aim at *destroying* the toxic component of hazardous wastes are now being developed by the private sector, However, the adoption of new treatment technologies by the Superfund program faces institutional, regulatory, and financial barriers.

This chapter is divided into four sections. The first section is an overview of the problems encountered at Superfund sites and an introduction to the applicable technologies. Next, the barriers to the adoption of improved technology are discussed. In the third section, conventional and innovative technical options are summarized and analyses of the effectiveness and applicability of both types is provided. The final section reviews the current status of Federal, State, and private sector support for Superfund technology research, development, and demonstration (RD&D).

THE PROBLEM

The selection of the preferred technology or set of technologies for cleanup at a Superfund site depends on the characteristics of the site, the composition and distribution of hazardous materials, the technical characteristics of the technologies, the costs of the technologies, the nature of the selection process mandated by regulation, and other institutional factors. Ultimately, the selection of technologies for remedial action is accomplished by examining the cost effectiveness of a technology or a set o 1' technologies vis-a-vis the alter natives.[1]

The feasibility' of any given technology for a site cleanup is decided early i n the decision process. Once a Superfund site has been identified and remedial action proceeds, current practices call for the following basic steps:

1. problem definition (Remedial Investigation);
2. selection of alternatives (Feasibility Study);
3. engineering design;
4. construction;
5. startup, trouble shooting, and cleanup: and
6. long-term operation and maintenance, if necessary,

A Remedial Investigation (RI) and Feasibility Study (FS) are required for all Superfund financed and enforcement-lead remedial actions. The RI focuses on data collection and site characterization; the FS on data analysis and evaluation. Despite the dependence of the FS on results from the RI, EPA conducts the two concurrently rather than sequentially.

[1] A discussion of cost effectiveness and institutional factors that affect the decision process appears in the following section, "Barriers to the Adoption of Improved Technology."

Site Conditions and Wastes

As part of its data collection, the RI catalogs the site's conditions and its wastes, Site factors that affect technology applicability include its geologic, topographic, hydrologic, and meteorologic characteristics. Waste characteristics pertain to the chemical and physical state of the waste and to the media where it is found. Hazardous wastes may have been placed in "surface impoundments, " such as settling ponds or lagoons that can contain liquid wastes and sediments; may be found in drums; and/or may have been landfilled (buried). Other Superfund sites have been created by the application of pesticides (e.g., dioxin) to large land areas. Contaminated environmental media at Superfund sites include air, soils, water (surface or groundwater), and biota.

While there is an extraordinary degree of variability among uncontrolled sites, most wastes found at sites can be broken down into five distinct classes for consideration of applicable technologies:

- slightly contaminated solids and soils,
- contaminated groundwater,
- concentrated liquid wastes,
- concentrated organic sludges and solids, and
- concentrated inorganic sludges and solids.

Organic materials of concern are hydrocarbons (compounds of carbon and hydrogen) or compounds containing carbon, hydrogen, and other elements, The latter include solvents, PCBs, pesticides (e.g., dioxin and DDT), and halogenated compounds (primarily those with chlorine). Inorganic materials of primary concern include heavy metals (e.g., cadmium, chromium, mercury, copper, zinc), cyanide, ammonia, and nitrates.[2] Because mixed wastes, plus variable concentrations of wastes, must be dealt with, Superfund cleanup technologies must operate in a different environment than those processes that treat the more consistent waste streams generated at industrial plants.

Technology Evaluation

As the FS evaluates alternative remedial actions, various types of technologies are introduced as possible solutions to site problems. After an initial screening of technologies, obviously infeasible or inappropriate alternatives are eliminated, The remaining technologies are then subjected to complete technical, cost, institution, public health, and environmental analyses to provide a "cost-effectiveness" evaluation. The cost-effectiveness measure attempts to weigh the costs of various options versus the effectiveness of the cleanup achieved. This evaluation limits the number of technologies suitable for consideration and forms the basis of an engineering design study for the cleanup procedure. However, without cleanup goals, alternatives cannot be properly evaluated. This leads to cost-benefit analysis where both effectiveness and cost vary. It is possible, therefore, to choose a relatively low-cost option whose level of effectiveness may equate to some arbitrary level of protection.

The basic generic technological approaches at any Superfund site are:

1. *in situ treatment* of soils or groundwater containing hazardous waste;
2. *excavation* of the hazardous waste solids, liquids, and/or sludges *for disposal, storage, or treatment* offsite (removals) or onsite; and
3. *pathway control* through encapsulation and/or containment, or by ground or surface water diversion, a

Nontechnical alternatives to cleanup that also are relevant to site (risk) management include mitigating exposures by providing an

[2] A recent EPA study shows that, of the 2 5 most frequent substances found at Superfund sites, 11 are chlorinated solvents, 7 are heavy metals, 5 are aromatic solvents, and 1 is cyanide. (Reported in the Hazardous Materials Control Research Institute's *Focus* newsletter, February 1985.)

[3] Trade-offs occur when hazardous wastes are transported off-site. While transportation adds a cost that can be substantial, for low volumes of a particular hazardous waste it may be less expensive to treat in regionally located facilities. Transportation off site adds a health and environmental risk. Onsite treatment may be restricted due to the availability and cost of necessary infrastructure, such as power and water sources.

alternate water supply, restricting land use, and evacuating people.

Remedial technologies are often broken down into two broad categories: containment *and treatment.* Table 6-1 compares containment and treatment technologies, both conventional and innovative, in terms of their effectiveness, reliability, environmental media affected by their use, least compatible waste, and estimated cost. The primary functions of containment technologies are: 1) to arrest or prevent the movement of contaminants from a source (e. g., overflow of a holding pond); 2) to limit the extent of already contaminated groundwater plume or soil mass; or 3) to immobilize the contaminants to prevent or reduce exposure to humans or the environment, The functions of treatment technologies are: 1) to detoxify contaminants by changing or destroying the chemical characteristic(s) that render them hazardous, or 2) to separate those hazardous materials from the environmental media that serve as routes of exposure.

Since containment technologies do not render harmless that which is the *source* of the problem, Superfund sites subjected to containment may have to be monitored indefinitely, or at least for as long as containment is used, to assure continual protection. Landfills under Subtitle C of the Resource Conservation and Recovery Act (RCRA) are containment technologies. Treatment processes, while they have been shown to destroy extremely high percentages of hazardous constituents, inevitably produce a residue that must be dealt with. Processes such as incineration, for instance, produce ash that may or may not be considered a hazardous waste and air emissions that may have to be controlled, Physical separation techniques produce an output stream that retains the hazardous properties of the original waste, frequently in a more concentrated, manageable form. These residues require proper disposal (and perhaps additional treatment) to achieve overall objectives. If the subsequent treatment and disposal are not properly managed, the original hazards may be shifted to other environmental media or locations and to new exposed populations. Such a shift is always the case when hazardous wastes are simply removed from Superfund sites for containment (land disposal) elsewhere.

Both containment and treatment technologies range greatly in potential applicability and expected effectiveness. *Most containment technologies depend primarily on site factors.* On the other hand, *most treatment technologies are dependent on waste properties,* both in terms of class (organic or inorganic) and also physical state. In general, containment systems have low capital costs but long-term operating and maintenance (O&M) costs which can be substantial if measured over their lifetime. The reverse is generally true for treatment technologies: high capital costs with short-term O&M costs. The result is that if *all* costs are accounted for over the long term, then treatment technologies can offer lower overall costs, Offsite application of either type of technology adds cost to cleanup activity and introduces risks from the transportation of hazardous wastes.

Containment systems generally fall into four types. The first, based on hydrologic principles, uses wells and pumping to control the outward flow from, or the potential contact of groundwater with, a source of contamination. Alternatively, some sort of physical barrier, such as a grout curtain or slurry wall, can be installed to prevent groundwater from moving into or out of the contaminated mass of soil or aquifer. The third type comprises conventional interception and drainage systems. The fourth set of technologies isolates the wastes in containers or highly impermeable matrices. These techniques are often employed in combination to increase effectiveness,

Treatment technologies employ many types of processes. *Organic* chemicals can be broken down by biological, chemical, or thermal methods, or toxic organics can be separated from nontoxic materials by physical methods. Detoxification of *inorganic* species, such as arsenic or cadmium, is more difficult. Toxicity often resides in the element itself. Treatment technologies act on inorganic species by immobilization and separation, or in a few cases,

Table 6-1.—Generic Technology Comparison

	Containment	Treatment			
	Landfills and impoundments	Conventional incineration	Emerging thermal/chemical destruction	Physical/chemical separation methods	Biotechnology
Effectiveness: How well it contains or destroys hazardous characteristics	Low for volatiles, questionable for liquids; based on field tests, preliminary use data	High, based on field tests, except little data on specific constituents	Very high. commercial-scale tests	High, based on conventional uses	High, when combined with pre/post treatment
Reliability issues	Siting, construction and operation Uncertainties: long-term cover, liner life less than life of toxic waste	Long experience with design Monitoring uncertainties with respect to high degree of DRE, surrogate measures, PICs, incinerability	Limited experience Residues, PICs Mobile units; on-site treatment avoids hauling risks Operational simplicity	None, due to long experience	Completeness of in situ process
Environmental media most affected by use of technology	Surface and ground water	Air	Air	Depends on waste management	None likely; except groundwater, if in situ
Least compatible waste[a]	Linear reactive; highly toxic, mobile, persistent, and bioaccumulative	Highly toxic and refractory organics, high heavy metals concentration	Metals	Possibly none. Each process highly waste specific	Mixtures
costs: (low, medium, high)	L – M	M — H	M – H	L — M	L – M

[a]Waste for which this method may be less effective for reducing exposure relative to other technologies Wastes listed do not necessarily denote common usage

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by converting the element to a nontoxic or less toxic compound. As with toxic treatment residues, unless a separated material can be recycled for reuse, landfilling will be the ultimate means of disposal.

Unless a Superfund site is found to contain a single source of a hazardous waste and in a single form, a combination of technologies will most likely have to be applied. A number of containment techniques are often combined—for instance, groundwater barriers with pumping and treatment of leachate. Treatment technologies may have to be applied in combination to permanently destroy hazardous wastes, or with some form of containment to prevent the contamination from spreading during the period required for treatment. In the Superfund program, the choice of technologies has been primarily containment methods applied on a site or off'. In a 1984 study that evaluated 395 Superfund sites,[4] destruction technology (incineration) was employed for 1 percent of the sites. The balance of responses were combinations of onsite containment technologies or offsite removals of the hazardous wastes.

[4]U.S. Environmental Protection Agency, *Summary Report: Remedial Response at Hazardous Waste Sites,* EPA-54012 -84-O02a (Cincinnati, OH: Office of Research and Development, March 1984).

BARRIERS TO THE ADOPTION OF IMPROVED TECHNOLOGY

The selection of technology rests on a cost-effectiveness measure previously discussed. To be among the alternatives whose cost and effectiveness are evaluated, a technology must be known to the contractors who prepare the FS and it must have been judged viable through research, development, and demonstration (RD&D). Once included in the evaluation process, a technology must be treated equitably relative to other technologies. But the current Superfund selection system inhibits the development and consideration of innovative technologies for permanent remedies in a number of ways. These barriers can be broken down into four categories:[5]

- policy and market uncertainties,
- RD&D financing,
- institutional practices and regulatory impacts, and
- a status quo/existing tech nology bias.

[5]As developed by a workshop held by OTA in Washington, DC, in November 1984 entitled "The U-se of Innovative Technologies for Superfund Remedial Action. " Attending were representatives of technology developers, State agencies, an EPA Superfund contractor, and industrial firms who conduct voluntary cleanups.

Policy Uncertainties Create Market Uncertainties

Superfund, along with the Federal-State RCRA program, industrial generators of hazardous wastes, and the current commercial waste management industry, determine the market for hazardous waste treatment technology. The market is driven by regulations imposed by the Federal Government under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), RCRA, and the Toxic Substances Control Act (TSCA) and those imposed by individual States. Regulations determine which materials are classified as hazardous wastes, whether and the extent to which such materials must be controlled, and how they are controlled. Technologies evolve because of and based on these regulations, Institutional practice has determined how the market views innovative, developmental technologies. They must compete with the dominant, historically used solutions (land disposal and incineration techniques).

Continuing to view Superfund as a short-term program results in weak market support for long-term development of innovative technology. Uncertainties over the ultimate size and type of the Superfund program (how many sites undergo remedial action, the level of cleanup desired, the type of solutions selected) create market uncertainties. Technology developed to treat newly generated hazardous wastes may be inadequate and/or inappropriate for cleanups.

According to the president of one technology firm, the Superfund program is full of uncertainties, elusive, going through a shakedown process, a market characterized as one of "indeterminate clients."[6] Such uncertainties affect the availability of funds to conduct R&D programs and corporate decisions to enter the market or continue involvement with technology development. Another view expressed is that there may be no clear market for treatment options until the destruction of hazardous wastes is the *prime* Superfund goal.[7]

Uncertainties also result from technology marching ahead of the regulatory process. The only standards available to judge Superfund technologies are those for incineration and land disposal. Without regulation or guidance for other technologies, there are no operating standards to incorporate into the design of a new technology. Thus, there is no clear-cut, objective way to judge the effectiveness of new technologies, or to compare them with the traditional technologies. For biotechnology, rules for the release of genetically engineered organisms are not yet set. How much effort should a private firm risk developing an in situ biological process for destroying hazardous wastes when the technology may be regulated out of use? Another unknown that industry faces are patent rules for both microorganisms and the process technology necessary to use the bugs.

The continuing lack of cleanup standards for Superfund sites, a definition of "how clean is clean," gives the impression that new cleanup technologies are not necessary to safeguard public health and the environment. Technology development that does push ahead suffers from uncertainties over whether levels eventually will be set too high to meet or too low to justify the cost of the process.

Access to RD&D Financing

Without adequate R&D and demonstration funding, no technology will reach the stage where it can demonstrate an acceptable level of reliability and effectiveness under field conditions. This critical and expensive demonstration period is preceded by laboratory and pilot stages that often must be funded without guarantee that a commercial product will result.

The degree of market uncertainty will determine when and at what levels the private sector will support the RD&D process. The private sector funds RD&D either by committing internal funds (primarily in the case of large firms) or through the use of venture capital and limited partnerships (in the case of entrepreneurial firms) but they will do so only on a limited basis and only if a clear, sustainable market for the end results can be identified. One large firm, J. M. Huber Corp., has spent $6 million so far in RD&D of its Advanced Electric Reactor. Now, at the point of committing additional funds to attempt to commercialize their technology, several criteria must be met, including an appropriate market size for their product, an estimate about when that market will be available, and a sense that the risks of entering the market are manageable. Another, small firm sought funding for 9 months before it secured $2 million to produce a demonstration unit. Part of the necessary money came from several foreign firms seeking treatment technologies because they are subject to regulations prohibiting landfilling of hazardous wastes.

Ultimately, it is up to the public to decide how much it is willing to pay for the best possible cleanup of hazardous wastes. Support for RD&D of innovative technologies offers a real possibility to lower those costs. Direct support by the Federal Government, however, has been very limited, in terms of level of funding, ac-

[6]Lowell Bowie, president of RoTech Inc., OTA Workshop, November 1984.
[7]Michael Modell, president of MODAR Inc., OTA Workshop, November 1984.

cess to funds, or relevant programs. B State funding is, for the most part, constrained by budgets that must consider immediate cleanup costs before engaging in long-term R&D funding, Some market risk could be mitigated by indirect support, such as tax incentives.

Institutional Practices and Regulatory Impacts

It is often difficult to separate institutional practices and regulatory impacts. In terms of Superfund technology, these factors combine to increase the financial burden on technology firms seeking operating permits and increase the uncertainties over permitting for testing purposes. Testing standards are not available and valid testing materials are difficult to acquire. A bottleneck exists, make recognized testing standards unavailable and access to testing materials from sites difficult, and create a bottleneck under RCRA hazardous waste delisting procedures. The problems culminate when a technology is at the stage of actually demonstrating its effectiveness. They can raise the cost of (or bar) such demonstrations and result in inconsistencies in the information available on new technologies. There is no established procedure for collecting and disseminating the information that is generated.

Authentication

Permitting requirements under the RCRA program for processes in the RD&D stages are expensive and time-consuming. Procedural duplication between Federal and State agencies and differences between the various States, and even between EPA Regions, multiply time and expenses. A 1- to 2-year processing period is not uncommon and one firm has calculated that it has spent $1 million so far in permitting procedures.

Because landfill and incineration technologies are defined under RCRA, these technologies are given de facto established technology status even though not much data has been collected about their performance as Superfund technologies. On the other hand, new technologies are required to present recognized testing results to demonstrate comparable reliability and effectiveness. A *protocol,* a detailed, technology and application specific testing procedure, must be followed. Protocols, however, by their very nature are not available for innovative technologies, and cannot be written without first acquiring testing information. The following examples of what two different firms had to undergo in order to *prove* their technology illustrate these points.

A permit for a 3-month demonstration project was applied for by MODAR Inc., a small R&D firm, through Region 2 of the Environmental Protection Agency (EPA) in August 1983. Permission was finally granted by October 1984, over a year later. Two parallel permitting processes were necessary, one under RCRA and the other under TSCA since one of the wastes that MODAR intended to test was PCBs. (RCRA permits protect against adverse affects of hazardous wastes; TSCA regulates specific wastes.) Under RCRA law at the time, there was no provision for R&D permitting as opposed to operations permitting unless the system classified as an incinerator. MODAR's unit is not an incinerator, but they had to convince EPA of that fact. Eventually it was classified as a "new chemical physical process" for which tests would be needed to develop a protocol. In this instance, EPA decided that the 3-month demonstration testing would be considered the required tests and gave MODAR a release to conduct those tests. For TSCA purposes, MODAR developed a set of tests for their unit equivalent to those established for incineration and was given a permit. Meanwhile, the State of New York conducted its own investigation and issued a permit after EPA did so. The end result is a permit/release valid for 3 months demonstration testing at one site in New York, Testing anywhere else, or beyond the 3-month period, will require MODAR to apply for a new permit.[9]

[8]See the discussion of RD&D support for technology in the last section of this chapter.

[9]Michael Model], personal communication, December 1984,

Lopat Enterprises has produced a sealant or encapsulant which they state is applicable to PCB contaminated structures, After trying unsuccessful y on their own to reach someone within EPA who could make a decision about evaluating the sealant, they secured assistance from congressional staff in setting up meetings with appropriate EPA officials, The writing of a protocol was agreed on but testing did not occur due to EPA's lack of funds, Lopat, meanwhile, was testing their product at their own expense. They were told, however, that running tests on their own in a recognized laboratory would not be valid because the government had to run parallel tests. At one point, when EPA was well aware that Lopat's process was a chemical one, they provided a protocol covering processes that incinerate PCBs.[10]

Often no response is forthcoming. Deluged with requests for authentification of many black box processes, EPA is forced, in the absence of established procedures and adequate staff, to essentially ignore the information it receives regardless of the possible merit of a technology. One particular incident involved the participation of the Mayor of Verona, Missouri, who repeatedly asked the regional EPA office, EPA in Washington, and the State agency for a hearing on a chemical process designed to detoxify dioxin-contaminated soils, The Mayor saw it as a possible alternative to expensive and controversial incineration techniques which were being imposed on her community. Over a period of months, meetings were agreed to and then canceled. No action was ever taken.[11]

Testing Material

Testing that will result in applicable and valid data requires the use of *real* material rather than synthetically produced wastes. Material can be supplied from the outflow of an industrial process or can be samples from Superfund sites, Firms encounter costly delays and other problems in the acquisition and transport of such material that can strain their resources. Transporting relatively small quantities of hazardous waste requires the transportation system and receiver to follow the same rules and procedures as those for regular hazardous waste shipments. Under these circumstances it can be difficult to locate an experienced carrier who is willing to handle an LTC (less than carload) shipment. If the material is acquired, the receiver becomes subject to uncertain liabilities.

Regulations

This section about policy uncertainties has shown how the lack of regulations or uncertainty about new regulations can negatively affect technology development. Existing regulations also affect technology adoption because of: 1) duplication in permitting requirements between Federal, State, and local agencies; 2) differences between various States and EPA regions and; 3) the preemption of sister regulations, such as those covering landfill and incineration practices under RCRA.

Simply figuring out which regulations apply in any given case can be frustrating. Experts attending an OTA workshop in November 1984 could not agree among themselves, even after extended discussion, about the applicability of various regulations. In fact, the only agreement they reached was that sorting out conflicting regulations and determining applicability were a major problem for technology developers who are trying to demonstrate their processes. There appears to be no one place to consult to obtain definitive information,

One option available under Superfund remedial actions is to use mobile or transportable treatment systems, but the regulatory climate does not yet support this option. Under RCRA, once a permit is granted it only covers the operation of a treatment technology on a particular substance at a particular site. Moving the system requires engaging once more in the permit process, The *availability of class rather than site permits would alleviate a considerable burden on treatment technologies.*

[10] U.S. Congress, House of Representatives, Committee on Small Business, hearings Oct. 27, 1983. From the statement of Louis Flax, president of Lopat Enterprises Inc., p. 49.
[11] Jane Johnson, Mayor of Verona, MO, personal communication, September 1984.

Any residue from a hazardous waste treatment process is considered hazardous waste itself unless the residue receives a delisting, i.e., is removed from regulation. This is one of the most important steps in determining the acceptability of a new process as it can provide information about the completeness of the destruction and assure that no new hazardous products are created. Under current EPA practices, however, delisting is a costly and lengthy procedure which can take over a year. Two components appear to adversely affect the procedure: 1) lack of sufficient EPA staffing, and 2) the analytical burden on the technology developer to provide a negative finding (i.e., that the residue is in no way hazardous).

The Status Quo/Existing Technology Bias Syndrome

Both the regulations under the National Contingency Plan (NCP) that deal with remedial action (Section **300.68** of CFR **40)** and EPA's "Guidance on the Preparation of Feasibility Studies" encourage a bias toward containment and, to a lesser extent, incineration technologies. It is against these so-called established technologies that all others are measured, even though the presumption that such technologies have proven their effectiveness for cleanups generally is not correct. A predilection for short-term costing and a reluctance to reach beyond comfortable, traditional technology favors the status quo.

For instance, the user of the Feasibility Guide is advised to adhere to the guidance document in order to guard against legal challenges to enforcement actions,[12] Since established technologies are emphasized, innovative ideas seem to be viewed as detrimental to the overall process of remedial action. In another example, in the first step of the FS the Guide advises that "technologies which are unreliable, offer inferior performance, or are not *demonstrated* (emphasis added) processes should be eliminated from further consideration."[13] No provisions are offered for obtaining recognized information that may constitute *demonstration,*

The lack of demonstration data prevents a new technology from being considered in the RI/FS process and ultimately used for remedial action. Both the high cost of demonstration projects and the lack of EPA procedures and support for the evaluation of technologies are obstacles that a new technology must overcome to be adopted. (See the section, "Support of Cleanup Technology RD&D, " in this chapter.)

The primary criterion for selecting technologies at cleanup sites, as reflected in the NCP and in most equivalent State documents, is cost effectiveness; that is, the "lowest cost alternative that is technologically feasible and reliable and which effectively mitigates and minimized damage to and provides adequate protection of public health, welfare, or the environmerit, ' '[14] In the Federal decisionmaking process, this criterion is qualified by the fund-balancing provisions of the NCP. These provisions require that prospective costs at a given site be balanced against the overall needs for all sites to be cleaned up. In essence, even the most cost-effective alternative at a site may be ruled out if the total cost is out of line with needs at other sites.

The *effectiveness* portion of the cost-effectiveness criterion is based on technical factors (performance, reliability, implementability), public health (level of cleanup/isolation achievable, reduction of impacts], institutional factors (permitting requirements, community impacts), and environmental factors (beneficial and adverse effects] factors.[15] *Costs* considered include capital costs, operation and maintenance costs, and/or a present value calculation combining both capital and O&M costs.[16]

If these factors and their components are not uniformly applied to both containment and treatment technologies, the options will not be judged fairly. Containment technologies, for instance, despite increasing evidence to the contrary, are considered to be more reliable than

[12] U.S. Environmental Protection Agency, "Guidance on the Preparation of Feasibility Studies," final draft, Nov 15, 1983, pp 1-6

[13] Ibid , pp 2-12

[14] Ibid., p i\,

[15] Ibid, chapter 8.

[16] Ibid.

treatment technologies. Moreover, permitting requirements for treatment technologies tend to be more burdensome than for containment technologies.

The cost elements applied to containment versus treatment are quite different. For treatment systems, estimates are generally quite straightforward, Project life is usually short; a few years is common. Assuming proper design and that the system will operate as projected, all the cost elements can be estimated quite accurately. (Decommissioning costs have been less consistently included and are more difficult to estimate,) No long-term costs are involved because the project is expected to end with an acceptable level of residual contamination.

The situation for containment is quite different. Since the hazards remain in place indefinitely, any future costs associated with maintaining the original level of protection, such as monitoring, major repairs, and future cleanups, should be included. When removal for redisposal is considered and only the immediate costs for commercial land disposal are included in the cost projection, the analysis is not realistic, O&M costs for onsite containment, moreover, are usually considered only for a relatively short time, often 20 to 30 years. Since no long-term performance data is available for containment systems for hazardous waste applications, O&M uncertainties are likely to be high. Discounting or computing the costs on a present value basis, with conventional discount rates (currently around 10 percent), effectively ignores costs beyond a 30-year period, even though many contained hazardous wastes are likely to remain toxic and will need to be controlled well beyond that period.

One factor that has influenced the choice of technology is related to the cost-sharing provisions of CERCLA. For State and Federal lead sites, the Federal Government generally pays 90 percent of the capital costs and costs for the first year's operation. Subsequent O&M costs, on the other hand, are entirely the State's responsibility. The consequences are fairly straightforward: the Federal Government favors technologies with low capital costs and States argue for low and/or short-term O&M costs,

National cleanup goals do not exist to compare and evaluate technology performance, Without cleanup standards, choices must be made as to what environmental standards apply (if any) to any given situation, If, for instance, effluent limitations rather than water quality standards are chosen for a groundwater treatment system, capital and O&M costs can change. This will alter the apparent cost-effectiveness of the solution and its potential for selection, If RCRA or equivalent State permits are deemed to be required for operations at cleanup sites, technologies considered difficult to permit will be discriminated against, as obtaining a permit adds time, cost, and uncertainty to the process.

The budget process in most States creates a bias against alternatives that have costs spread out over a number of years. Most States can only budget year-by-year and many have no authority to operate cleanup projects through trust funds or bond proceeds.

EPA and most State agencies rely heavily on contractors to carry out the RI/FS process, Because of public and political concerns, there is tremendous pressure to move through the site study phases quickly. The time pressures can inhibit thoughtful and careful examination of all alternatives. This is of particular significance now because few sites have yet moved beyond the study phase. Consulting firms are conservative, concerned about liability, and are under considerable pressure to produce sound and reliable solutions and to control their costs. These conditions have made it hard for innovative or developing technologies to receive serious consideration thus far in the Superfund program,

THE TECHNICAL OPTIONS

Technical solutions to the problems of Superfund sites are either long-term containment systems or relatively expeditious treatment remedies. These technologies are discussed in some detail in the following sections on conventional containment and treatment. A review of emerging innovative treatment methods follows. Another option is presented first: techniques for temporary storage. These are most appropriate for use in initial responses to reduce immediate threats to public health and the environment under a two-part Superfund strategy.

Temporary Storage

Increasing attention is being given to the above ground storage of cleanup wastes (see chapters 1, 2, and 3). A variety of technologies exist to carry out storage safely and cost effectively. There are three approaches: 1) when amounts are small, containerization as used in transportation and traditional chemical storage; 2) when amounts are large, bulk storage in tanks, vaults, and other structures; and 3) when amounts are large, new forms of above ground encapsulation technology. The first two options are likely to be combined at some Superfund sites.

In general, it should be possible to safely store cleanup wastes for anywhere from 5 to 20 years, When onsite storage is difficult because of limited space or unsuitable geologic or climatic conditions (e.g., earthquake fault zones or flood plains), offsite storage can be considered. It may be necessary to examine the possibility of building regional storage facilities to deal with Superfund wastes. Most importantly, above ground storage offers the intrinsic advantage, compared to traditional burial and land disposal, of ready accessibility and relatively easy visual inspection to detect leakage and damage to containers and structures, Moreover, many types of instruments and monitoring devices are available to provide safeguards, including those to deal with the chance of fire and explosion.

Recent advances in materials have improved containers. High-strength, corrosion-resistant materials are now readily available for the most hazardous materials; often these containers can be cleaned and reused. Containers can be placed in various types of structures to reduce the effect of weather, For example, they can be stacked on concrete slabs in shelters with roofs but not necessarily walls. Containers, such as drums, can also be encapsulated with polyethylene to mitigate the effects of leakage. If the amount of cleanup waste is relatively small, use of containers and onsite storage is feasible.

Tanks, vaults, and more complete buildings are also used for conventional storage in the chemical and petroleum industries. This is attractive for bulk materials that are not highly hazardous or corrosive, and materials that can be moved easily in large amounts, such as liquids and soil. If the amounts of cleanup waste are very large, it may be too costly to store onsite, and a regional storage facility may be needed.

A recent proposal in Minnesota combines containers and bulk storage and illustrates what might be conceived of for regional storage facilities for Superfund wastes. The concept was developed for "long-term monitorable and retrievable storage facility for hazardous wastes . , . The facility was designed to store 22,000 drums in a container building and 185,000 gallons in bulk-liquid tanks each year. Assuming an operating life of ten years, the facility would require an area of 60 acres. "[17] The study dealt with every conceivable type of environmental safeguard and was probably over designed, resulting in relatively high costs, particularly for construction of buildings to house drums. The initial investment was estimated at $10.6 million; annual O&M costs varied from $1 million to $2 million over the lifetime of the

[17] C. I. Lough, et al., "Above Ground Storage of Hazardous Waste, " *Management of Uncontrolled Hazardous Waste Sites* (Silver Spring, MD: Hazardous Materials Control Research Institute, 1982).

facility. More recent work, such as in Missouri, has focused on the use of less costly structures while affording environmental protection.

There have also been several recent proposals for new types of above ground storage aimed especially at the hazardous waste market, In one of these, wastes are chemically treated to solidify and stabilize them; they are then formed into an onsite mound on top of various engineered materials, The mound is covered to prevent water intrusion, Again, various safeguards are used to collect and monitor water. The author notes that the method "provides easy access for future manipulation of the waste for resource recovery and new treatment technology."[18] It is also claimed that exhumation and solidification rates of about 1,000 to 3,000 tons per day are possible. Some cost data are provided that indicate savings over more traditional offsite removal and redisposal. One project involving PCB sludge was estimated to cost $70 to $80 per cubic yard to evaluate and execute. O&M costs to monitor groundwater were not provided,

A case has also been made for what is called an above ground "hillfill" that provides ease of collecting leachate and protection against contaminating groundwater.[19] Most of the problems with conventional landfills are reduced or eliminated by this approach, which still allows removal of the wastes later for treatment.

Conventional Technologies[20]

Since *containment* methods have been the technology of choice for Superfund remedial action, they constitute the bulk of applicable conventional technologies. Existing methods of *treatment,* such as incineration, are also conventional in the sense that forms of the techniques have been used in many industries for many years and are relatively easy to adapt to Superfund problems. These conventional containment and treatment technologies are examined below. Containment technologies use construction engineering techniques that have long records of successful use *in that application*. However, because relatively few remedial actions have actually taken place and because no long-term record of performance at Superfund sites exists, there is little data available to support the view that containment technologies are reliable or proven for use with hazardous wastes, In fact, the evidence appears to be pointing in the opposite direction (see chapter 5). Existing treatment technologies, so far limited in use for Superfund cleanups, constitute the basis for most emerging technologies.

Table 6-2 compares the estimated costs of applying a number of conventional technologies at Superfund sites.

Conventional Containment

Hazardous waste—regardless of whether disposed of in the ground, in barrels or drums, in impoundments, or in landfills—eventually leaks to some extent. The threat that this leakage (or migration) presents is related to the level of contamination (exposure) at points of concern. Migration primarily occurs when ground or surface water or air comes in contact with the hazardous waste. Thus the objective of containment is to seal the hazardous waste as well as possible and reduce the possibility of an inflow of migration media or outflow of contamination. In addition, any leachate formed by contact of the hazardous waste with water must be collected and treated, This system of control requires that a number of technologies be combined to produce the lowest possible probability of failure.

The following is a summary of these containment technology components, how they are used and function. Their applicability depends almost entirely on site factors (e.g., topography, erosion potential, surface and groundwater water flow patterns, and expected rainfall) and is primarily independent of waste specific fac-

[18] L. Graybill, "Evolution of Practical On Site Above Ground Closures," *Management of Uncontrolled Hazardous Waste Sites* (Silver Spring, MD: Hazardous Materials Control Research Institute, 1983).

[19] K. W. Brown and D.C. Anderson, "The Case for Aboveground Landfills," *Pollution Engineering*, November 1983.

[20] This section is based primarily on A. D. Little, "Evaluation of Available Cleanup Technologies for Uncontrolled Waste Sites," contractor report prepared for the Office of Technology Assessment November 1984.

Table 6-2.—Estimated Costs of Conventional Technologies

	Capital costs: based on a hypothetical site[a]	Operation and maintenance costs
Containment t:		
Ground water barriers.		
Slurry walls	$250.000	
Grout curtain	$1,25 million	
Piling . , ...	$800,000	
Vibrated beam	$250,000	
	2,400 ft long, 20 ft deep barrier	
G roundwater pumping	$55,000 to $65,000	Due to the lack of operational experience using these technologies at remedial sites, there is little data available on which to base estimates of operation and maintenance costs.
	18 PVC well points, 15 ft apart Pumped at 25 gpm with 18 pumps 1,250 ft piping, wellheads to treatment	
Subsurface drains	$15,000 to $20,000	Operation and maintenance costs for containment technologies include site costs such as: 1) the running of any necessary equipment (i.e., pumps); 2) site monitoring (particularly for groundwater migration); 3) inspection of the systems; and 4) any necessary repairs and possible replacement.
	200 ft long drain, 20 ft deep using 12" PVC pipe; backfilled with 5 ft clay	
Runon/runoff controls	$1,000	Repairs and replacement constitute the most expensive items. Several years after construction, repairs might cost 50 percent of the original cost; replacement, over 100 percent (due to inflation and worsening conditions).
	500 ft dike, up slope	
Surface seals/caps:		
Materials available onsite	$32,000	Uncertain: depends on life of system relative to lifetime of toxic wastes.
Using off site materials	$150,000	
Synthetic cap (top layer) sub-base materials available onsite	**$50,000**	
	Cap over source area consisting of sand (6 in), clay (**2** ft), sand/gravel (1 ft), and top soil/vegetation (2 ft)	
Onsite treatment:		
Solidification and stabilization	**$5,000** to $10,000	
	60 cubic yards of sludge in lagoon excavated and mixed with kiln dust; then replaced	

Groundwater treatment;	Based on treating 450 gallons per minute	Costs per year[b]	Costs per 1,000 gallons treated[b]
Biological treatment			
activated sludge	$3.1 million	$940,000	$4.14
Chemical treatment			
neutralization and precipitation	**$650,000**	**$233,000**	**$1.03**
Physical treatment			
carbon absorption . , .	$7.5 million	$3.8 million	$16.75'
ion exchange . . .	$2.25 million	$1.2 million	$5.13
air stripping . . .	$360.000	$153,000[d]	$0.67[d]

NOTES

[a] This example site is 200 ft by 200 ft and has three sources of contamination — a drum recycling area, a metals recovery operation, and a lagoon filled with sludge (4 ft . 20 ft , 20 ft) As a result of leakage and spills from these sources, groundwater has been contaminated with organic solvents and heavy metals A 200 ft wide plume of contamination extends 81X ft of fsite, and is only 2,500 ft from a nearby well field The water table is 5 ft below the ground surface Bedrock is sound and unfractured and begins 20 ft below the site Groundwater travels at O 001 cm/second, and a groundwater treatment rate 450 gpm is expected

[b] Both O&M and capital recovery costs are included O&M costs are incurred Until treatment has been completed

[c] Carbon regeneration not included

[d] vapor treatment not included

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tors. Table 6-3 presents the advantages, disadvantages, and limitations of their use.

Groundwater Barriers.—Groundwater barriers are designed to prevent the offsite migration of contaminated groundwater by physically restricting horizontal groundwater flow. Groundwater barriers have become one of the principal options to contain plumes of contamination at cleanup sites threatening aquifers, They can be used alone, but often are employed in combination with capping or groundwater pumping, All methods, except block displacement, are derived from general construction practices. Experience under conditions at cleanup sites, however, is as yet limited, and little data are available to show the long-term effects of wastes in contact with the barrier. Considerable research evidence for adverse impact of wastes on barrier materials does exist.[21]

Except for the block displacement technique, barriers must be keyed in or attached to a low-permeability layer, such as bedrock or clay, beneath the site that will restrict vertical or downward migration of contaminants. Barriers, then, are limited to sites where bedrock is not extensively fractured or is not too far below the surface, The extent of fracture in bedrock is difficult to predict,

None of these techniques provides a completely impermeable barrier, even if constructed ideally. Rather, they reduce groundwater flow through the contained region to on the order of 10-* centimeters per second (77 gallons of groundwater per year would pass through a barrier 10 feet deep by 100 feet long), Thus, an anciliary pumping or drainage system is used to contain the leakage or dewater the zone near the barrier. Caps over the site are used to reduce the amount of water that can enter the contained area. Such systems must function indefinitely or as long as a medium for movement of the contaminant is present.

The major types of groundwater barriers are:

- *Slurry walls:* fixed underground physical barriers formed by pumping slurry (e.g., a cement-bentonite mixture) into a trench and either allowing the slurry to set or backfilling with a suitable engineered material, Use of a vibrating beam technique, a relatively new procedure, avoids the need to dig a trench prior to filling with slurry.
- *Grout curtains:* fixed underground physical barriers formed by injecting a grout (either particulate such as portland cement or chemical such as sodium silicate) into the ground through well points.
- *Pilings:* fixed underground physical barriers constructed by driving webbed sections of sheet piling (typically steel) into the ground. Each section is connected with interlocking socket or bowl and ball joints that fill with fine-medium grain soil particles. This serves as a seal to restrict groundwater flow through the barrier.
- Block *displacement* allows for the placing of a fixed underground physical barrier beneath a large mass of earth, This developmental technique was field tested by EPA in 1982.[22] Unexpected geologic details of the site interfered with accomplishment of the barrier placement according to the design plan.

Groundwater Pumping.—Groundwater pumping involves the use of a series of wells to remove groundwater for treatment or to contain a plume. Techniques are well developed, depend on standard technology, and offer high design flexibility (number of wells, location, depth, and pumping rate) to meet a wide variety of site-specific requirements. Uncertainties with groundwater information and modeling, especially in complicated flow regimes and for deep well systems, mean that the effectiveness of the system must be verified in the field. Modifications that might be required can reduce the cost effectiveness of the system. (See chapter 5 for

[21]See, for instance, "Barrier-Leachate Compatibility: Permeability of Cement/Asphalt Emulsions and Contaminant Resistant Bentonite/Soil Mixtures to Organic Solvents" by David C. Anderson, Alicia Gill, and Wayne Grawley. Paper presented at 5th National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, DC, November 1984 (Silver Spring, MD: Hazardous Materials Control Research Institute, 1984).

[22]Ronald D, Hill, U.S. Environmental Protection Agency, "Promising Site Cleanup Technology, " paper presented at *Superfund Update: Cleanup Lessions Learned*, Schaumburg, IL, Oct. 11-12, 1983.

Table 6-3.—Containment Technologies—Summary

Advantages	Disadvantages	Limitations
Groundwater barriers:		
• *Slurry wall*		
Most versatile, best understood barrier technology. Can be inexpensive compared to other barrier techniques. Low O&M	Requires excavation. Requires site area to mix backfill. Difficult to verify continuity of slurry or backfill. Difficult to key to bedrock.	Must tie to impervious zone. Not 100°/0 impermeable. Long-term effects of some chemicals on permeability uncertain.
. *Grout curtain*,.		
Minimal site disturbance, No excavation required, Low O&M.	Chemicals in the grout may cause site safety or environmental problems. Difficult to verify continuity of wall. Limited applicability. Expensive compared to other barriers. Difficult to key to bedrock.	Less than 20°/0 soil can pass No. 200 sieve. Must tie to impervious zone. Not 100°/0 impermeable. Long-term effects of some chemicals on permeability uncertain,
• *Vibrated beam*		
Special slurries improve chemical compatibility. No excavation required, Low O&M.	Very sensitive to construction quality. Difficult to verify continuity of wall. Difficult to key to bedrock. Relatively new technology.	No obstructions in soil. Must tie to impervious zone Access for large crane needed. Not 100°/0 impermeable. Long-term effects of chemicals on permeability uncertain.
• *Sheet pile*		
No excavation required Low O&M.	Expensive. Difficult to key to bedrock. Continuity of wall at joints difficult to verify.	Soils must be loosely packed, Limited to about 50 ft. Must tie to impervious zone. Not 100°/0 impermeable. Some chemicals may attack piling material.
• *Block displacement t*		
No underlying impervious zone needed,	Technology under development. Continuity is difficult to verify.	Site conditions must conform to complex design requirements.
Groundwater pumping:		
• *Well points*		
Proven and well understood, Can function for very long periods. High design flexibility, High reliability, Useful in many situations. Effectiveness can be verified	Design may require expensive modeling. Long-term O&M required. Performance sensitive to design. Collected liquid must be treated or disposed of.	Useful up to 10 meters. Will not affect contaminants in unsaturated zone or contaminants that do not flow. Site conditions may complicate use and performance.
. *Deep we// systems*		
Same as well points.	Same **as well** points	Same as well points; except useful to any depth.
Subsurface drains:		
Proven and well understood, Low O&M. Superior to wells under certain conditions. Less sensitive to design than wells. Conceptually simple.	Less flexibility than wells. Susceptible to clogging. Excavation required. Collected liquid must be treated or disposed of.	Difficult to install beneath waste site. More cost effective in shallow applications.
Runon/runoff controls:		
Proven and well understood, Inexpensive. Effectiveness desirable. Only conceptual design required.	Periodic inspection and maintenance required.	May not be able to handle abnormal storms.
Surface seal/caps:		
Inexpensive compared to excavation and removal. May be used as an interim measure where surface infiltration is a problem,	Periodic inspection and maintenance required.	Difficult for very large sites, or if obstructions are present. Subject to potential failure without proper design, installation, and maintenance.

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Table 6-3.—Containment Technologies—Summary -Continued

Advantages	Disadvantages	Limitations
Solidification and stabilization:		
Improves containment performance.	**Extensive testing may be required.**	**Long-term integrity uncertain.**
High short-term effectiveness possible.	**Many** processes developmental.	Not useful for many organics.
Waste material (e.g., fly ash, kiln dust) can be used as pozzolan.		
Encapsulation:		
Improves effectiveness of land disposal.	Developmental.	Long-term integrity uncertain.
		Requires solidification of bulk wastes.

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a discussion of problems related to understanding groundwater and containment movement.)

As soon as a pumping system is shut down, groundwater flow patterns are likely to return to their pre-pumping condition. Therefore, *pumping systems have to be operated for long periods of time* unless *the source of contamination is eliminated or degraded through treatment.* If, during this time, other wells are used to draw water from the same groundwater system, flow patterns may change.

Subsurface Drains .—Subsurface drains can be installed to collect leachate as well as lower the water table for site dewaterin. They are built by placing tile or perforated pipe in a trench, surrounding it with gravel (or similar material), and backfilling with topsoil or clay.

The use of subsurface drains is a very old technology, well proven in applications other than for hazardous waste environments. While overall costs will vary depending on site-specific conditions, the drains are relatively inexpensive to install and have low O&M costs.

Drains are not as versatile as wells and are more sensitive to design errors. They compete with wells where soils are heterogeneous or exhibit low hydraulic conductivity, or where the plume of contamination is very large. They may be preferred to wells where there is a contaminant layer floating on the groundwater or where the contaminants are viscous.

placing drains in highly contaminated soils can require special construction techniques. They are susceptible to clogging and their performance can be affected by variations in groundwater flow and level, important problems, considering the long lifetimes of many hazardous substances.

Runon/Runoff Controls.—Surface water control technologies are designed to prevent contaminated surface water from leaving a site and uncontaminated water from entering a contaminated area. They are almost always employed in conjunction with other technologies (e. g., surface seals or excavation and removal), Conventional and inexpensive techniques include dikes, terraces, channels, chutes, downpipes, grading, and revegetation. Contaminated runoff, if it occurs, requires treatment prior to discharge.

Surface Seals/Caps.—Surface seals are low-permeability barriers placed over a site to reduce surface water infiltration, prevent contact with contaminated materials, and control fugitive emissions (gases and odors) at cleanup sites. Various materials are used including soils and clays; mixtures (e. g., asphalt and concrete, soil and cement); and polymeric membranes. Soil and vegetation generally cover these materials.

Surface seals are versatile and can be designed for most sites, although they may be difficult to install at large sites, sites with surface obstructions, sites with extremely irregular topography, or sites with inadequate subbase stability, which leads to subsidence or settling. They require very careful installation, as well as continued inspection and maintenance to ensure their integrity over time. Vents may be required to prevent gas buildup from cracking the cap. Over the long term, there are concerns about increased permeability resulting from puncturing by roots, animals, and activities on the surface. Under some conditions, contact with waste or leachate also causes problems.

Solidification and Stabilization.—Solidification, sta-bilization, and chemical fixation technologies reduce the potential for leachate production by binding waste in a solid matrix via a physical and/or chemical process. Wastes are mixed with a binding agent and subsequently cured to a solid form. The stabilized waste then usually is capped, contained, or land disposed to prevent contact with water,

Applicability of the technique is affected by both waste and site characteristics, Prime candidates for fixation by state-of-the-art processes are inorganic materials in aqueous solution or suspension and those containing large amounts of heavy metals or inorganic solids. Organic wastes and waste streams containing organic constituents (one of the major problems at Superfund sites) are less amenable to fixation. Site-specific factors determine the feasibility of mixing the waste with a fixative, and whether the mixing can occur in situ or after excavation of the waste. In some cases significant volume increases raise problems for onsite use,

While in situ and onsite solidification and stabilization technologies offer promise in decreasing leaching at cleanup sites (in combination with caps and barriers), reliability over time is uncertain due to the lack of monitoring data. Questions remain as to the long-term integrity of the resultant matrices. Freeze-thaw cycles can cause cracking in the wastes above the frost line. For in situ use, nonuniform conditions at a site and operational difficulties can create pockets of incomplete immobilization,

Encapsulation .—Encapsulation is a process where wastes are enclosed in a stable water-resistant material. The process may be applied to wastes in containers or to wastes that have been bound into a matrix of sufficient strength to hold together while the covering is applied. Once encapsulated, wastes must be placed in a landfill.

As long as the covering is intact, the potential for leaking is very low. However, no data are available on the long-term stability and integrity of the covering materials.

Conventional Treatment

Treatment technologies can be broken down into four major types: physical, chemical, biological, and thermal. All tend to be waste-specific, some more so than others. This section explains each type in general and looks at specific conventional treatment technologies. Table 6-4 summarizes these technologies and their advantages and disadvantages.

Few have been applied at Superfund sites. Largely, these technologies are standard processes that are used to treat industrial hazardous waste streams and might be adaptable to Superfund wastes, perhaps using specially constructed onsite facilities, The complexities and variability of wastes at Superfund sites as compared to the outflow of a given industrial process, however, may reduce the applicability and efficiency of most of these techniques. Thus, multiple treatment may be necessary.

Physical Treatment.—Physical treatment processes do not destroy contaminants. They change the hazardous constituents to a more convenient form through concentration and/or phase change. Ideally two output streams are produced. One is a concentrated volume of hazardous material that must undergo additional treatment or be placed in a landfill and the second is a nonhazardous liquid or solid material.

Physical treatment systems are used widely for conventional wastewater treatment, and methods are available to treat many types of wastes over a wide range of conditions. Nevertheless, the combinations of wastes found at cleanup sites may limit the degree of separation that can be achieved.

Some of the more widely used processes include carbon adsorption, flocculation, sedimentation, filtration, flotation, stripping, ion exchange, and reverse osmosis. Many are used in combination with other treatment processes. Some of the systems that remove inorganic

Table 6-4.—Treatment Technologies—Summary

Advantages	Disadvantages	Limitations
DESTRUCTION/DETOXIFICATION PROCESSES:		
Biological treatment:		
● *Conventional*		
Applicable to many organic waste streams. High total organic removal. Inexpensive. Well understood and widely used in other applications.	May produce a hazardous sludge which must be managed. May require pre-treatment prior to discharge.	Micro-organisms sensitive to oxygen levels, temperature, toxic loading, inlet flow. Some organic contaminants are difficult to treat. Flow and composition variations can reduce efficiency. Aeration difficult to depths > 2 ft.
• *In-situ biodegradation*		
Destroys waste in place.	Limited experience. Extensive testing may be required. Containment also required.	Many common organic species not easily biodegraded. Needs proper combination of wastes and hydrogeological characteristics. Obtaining proper mix of contaminants, organisms, and nutrients. Organisms may plug pores.
Chemical treatment:		
● *Wet air oxidation*		
Good for wastes too dilute for incineration or too concentrated or toxic for biological treatment.	Oxidation not as complete as thermal oxidation or incineration. May produce new hazardous species. Extensive testing is required. High capital investment. High level of operator skills required. May require post-treatment.	Poor destruction of chlorinated organics. Moderate efficiencies of destruction (40-90 "/0),
● *Chlorination for cyanide*		
Essentially complete destruction. Well understood and widely used in other applications.	Specialized for cyanide.	Interfering waste constituents may limit applicability or effectiveness.
● *Ozonation*		
Can destroy refractory organics. Liquids, solids, mixes can be treated.	Oxidation not as complete as thermal oxidation or incineration. May produce new hazardous species. Extensive testing is required. High capital investment; high O&M.	Not well understood.
. *Reduction for chromium*		
High destruction. Well understood and widely used in other applications.	Specialized for chromium.	Interfering waste constituents may limit applicability or effectiveness.
Ž*Permeable treatment beds*		
Limited excavation required. Inexpensive,	Developmental. Periodic replacement of treatment media required. Spent treatment medium must be disposed of.	Best for shallow plumes. Many reactants treat a limited family of wastes. Effectiveness influenced by groundwater flow variations.
● *Chemical injection*		
Excavation not required. No pumping required.	Developmental. Extensive testing required.	Best for **shallow plumes.** Need fairly homogeneous waste composition.
incineration:		
● *Conventional incineration*		
Destroys organic wastes (99.99 + "/0).	Disposal of residue required. Test burn may be required. Skilled operators required. Expensive.	

Table 6-4.—Treatment Technologies—Summary -Continued

Advantages	Disadvantages	Limitations
• *Onsite*		
Destroys organic wastes (99.99 + %). Transportation of wastes not required.	Disposal of residue required. Onsite feedstock preparation required. Test burn may be required, Skilled operators required. Expensive.	Mobile units have low feed rate.
• *Thermal oxidation for gases*		
Proven technology. High destruction efficiencies. Applicable to most organic streams.	May require auxiliary fuel. O&M cost can be high.	
SEPARATION/TRANSFER PROCESSES:		
Chemical:		
• *Neutralization/precipitation*		
Wide range or applications. Well understood and widely used in other applications. Inexpensive.	Hazardous sludge produced.	Completing agents reduce effectiveness.
• */on exchange*		
Can recover metals at high efficiency.	Generates sludge for disposal. Pre-treatment to remove suspended solids may be required. Expensive.	Resin fouling. Removes some constituents but not others.
Physical treatment:		
. *Carbon absorption for aqueous streams*		
Well understood and demonstrated. Applicable to many organics that do not respond to biological treatment. High degree of flexibility in operation and design. High degree of effectiveness.	Regeneration or disposal of spent carbon required. Pre-treatment may be required for suspended solids, oil, grease. High O&M cost.	Many inorganic, some organics are poorly absorbed.
. *Carbon absorption for gases*		
Widely used, well understood. High removal efficiencies.	High capital and O&M costs.	More effective for low molecular weight, polar species. Disposal or regeneration of spent carbon required.
. *Flocculation, sedimentation and filtration*		
Low cost. Well understood.	Generates sludge for disposal.	
. *Stripping*		
Well understood and demonstrated.	Air controls may be required.	Applicable only to relatively volatile organic contaminants.
• *Flotation*		
Well understood and demonstrated. Inexpensive.	Generates sludge for disposal.	—
. *Reverse osmosis*		
High removal potential.	Generates sludge for disposal. Pre-treatment to remove suspended solids or adjust pH may be required. Expensive.	Variability in waste flow and composition effects performance.

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will produce a sludge or solid (e.g., heavy metals) that must be sent to a landfill for disposal. Reverse osmosis and ion exchange produce a dilute aqueous stream containing the toxic substances that have been removed. Stripping transfers volatile compounds to a gas stream where they may be destroyed by thermal oxidation, treated by other techniques, or emitted into the atmosphere. These systems range in cost from quite low (sedimentation, filtration) to quite high (ion exchange, reverse osmosis). Operating costs for carbon adsorption are generally high and depend on the concentration of the contaminant stream.

Under *carbon adsorption* waste streams are passed through beds of activated carbon particles, Organic compounds and some inorganic species in the waste stream become bound to the surface of the particles and can subsequently be removed along with the carbon adsorbent, But treatment and disposal of spent adsorbent poses a significant secondary problem. The adsorbent can be regenerated, in which case the contaminants and carbon are separated and the contaminants must undergo subsequent treatment, or the adsorbent including contaminants must be destroyed or landfilled.

Carbon adsorption is a highly effective, well demonstrated technique for removing organic compounds, and to a lesser degree metals, from aqueous waste streams. It is a widely used technique for removing organic contaminants from gas streams. It also can treat many organic species that do not respond well to biological treatment. Streams with high organic concentrations can be treated but the cost may become excessive due to high carbon use and other O&M costs. In such cases, combining carbon adsorption as a finishing step with a cheaper process such as biological treatment may be more cost effective. Pre-treatment stages may be needed to remove suspended solids, oil, and grease, all of which would rapidly plug and deactivate the carbon bed.

Flocculation, sedimentation, and filtration are used to remove suspended solids from a waste stream. Flocculation is a process in which small particles are brought together in larger aggregates. The larger particles can then be filtered out of the waste stream. Sedimentation removes suspended solids by permitting the particles to settle to the bottom of a vessel through the action of gravity. Filtration separates the solids from the liquids by forcing the fluid through a porous medium. Filtration can also be used to dewater sludges.

Stripping removes volatile contaminants from an aqueous waste stream by passing air or steam through the wastes, Contaminants are transferred to the air stream, or, in the case of the steam process, to a distillate.

Dissolved air flotation removes insoluble hazardous components present as suspended fine particles or globules of oils and greases from an aqueous phase. After being saturated with air at high pressure and being removed to tanks under atmospheric pressure, bubbles form in the aqueous mixture, The bubbles containing the fine particles and globules rise to the surface and can be skimmed off.

In *ion exchange,* unwanted ionic species, principally inorganic, are exchanged with innocuous ions on a resin. The process results in a sludge that requires management.

Reverse osmosis removes contaminants from aqueous wastes by passing the waste streams at high pressure (usually in the range of 200 to 400 psi) past a semipermeable membrane. Clean water passes out through the membrane, leaving behind a concentrated waste stream for further treatment, Typical membranes are impermeable to most inorganic species and some organic compounds,

Chemical Treatment.—In chemical treatment, hazardous constituents are altered by chemical reactions, In the process, hazardous constituents may be either destroyed or the resultant product or products may still be hazardous, although in a more convenient form for further processing or disposal. Since chemical reactions involve specific reactants under specific conditions, these processes are usually used when only one substance is involved (or a few substances similar in chemical character).

When chemical treatment is applied to a mixed composition waste, there can be problems because the treatment chemical might be consumed by side reactions, the intended chemical reactions might be blocked by impurity interference, or unexpected end products might add new hazards.[23]

Neutralization and precipitation are widely used in industry to remove inorganic and some organic compounds from aqueous streams. They are important options for separating out heavy metals in hazardous wastes, Neutralization may be used alone or in combination with other techniques. Precipitation is always used with follow-up steps to remove the insoluble matter produced. Both are often used as parts of larger treatment programs. Neutralization adjusts the pH of acidic or basic liquid wastes, soils, or other contaminated materials. It may be used alone to reduce the corrosivity of wastes or to adjust the pH to a range where metals are immobilized (remain in insoluble form). Precipitation is used, often in combination with neutralization, to reduce the concentration of metals, and in rarer cases organics such as phthalates, to low levels in an aqueous stream. The major problem with both processes is that they create hazardous sludges that must be subsequently disposed of in a secure manner.

Other chemical processes can be used to treat contaminated hazardous liquids. Both wet air oxidation and chemical oxidation can be applied to broad families of organic wastes. Other processes apply to specific waste types. While there has been little or no experience with these technologies at Superfund sites, all have been used at regulated hazardous waste treatment facilities or in conventional industrial waste treatment, The variable nature of contaminant streams at cleanup sites may limit performance relative to conventional applications.

Wet air oxidation involves a combustion reaction occurring in the liquid phase through addition of air or oxygen at high pressure (greater than 350 psi) and elevated temperature (greater than 1700 C]. The products of the reaction are steam, N_2, CO_2 and an oxidized liquid stream. In *chemical oxidation,* an oxidant (e.g., ozone, perchloric acid, or permanganate) is mixed with the waste and reacts with those oxidizable species present. Neither process breaks down organic molecules as completely as thermal destruction or incineration, and new hazardous species may be produced in the process of destroying those in the wastes. Both require extensive testing to determine their efficiency and the properties of their effluents. Both are expensive to operate and require major capital investments,

Toxic hexavalent chromium ion (Cr VI) can be reduced to the less toxic trivalent chromium ion (Cr 111) by adding a reducing agent under highly acidic conditions. The reduction process is followed by Cr III removal through precipitation as the insoluble hydroxide. *Alkaline chlorination* is used to remove cyanide from alkaline cyanide-containing waste by oxidation in stages,

Biological Treatment.—Biological treatment uses micro-organisms to degrade (biodegradation) or remove (bioadsorption) contaminants from a waste stream. It has seen widespread application for many years for treating wastewaters, both hazardous and nonhazardous, in closed systems such as sewage treatment plants. It is a generally inexpensive method of treatment for groundwater, surface water, or impounded liquids containing a low concentration of organics. Although systems can be designed to achieve fairly high levels of overall removal, the effectiveness for specific hazardous organic species can be quite low. For this reason, some sort of post- or pre-treatment, such as carbon adsorption, may be required.

Conventional biological treatment processes include *activated sludge, aerobic stabilization ponds (surface impoundments), rotating biological disks, and trickling filters,* All of these techniques produce a sludge containing the remains of the organisms, unreacted organic matter, and the insoluble inorganic constituents. Metal removal occurs by processes that attach the metal cations to the sludge. *Some* organic compounds, such as PCBs and poly - nuclear aromatic compounds, may become ad-

[23]Jay A. Mackie, et al., "Hazardous-Waste Management: The Alternatives," *Chemical Engineering,* Aug. 6, 1984, p.57.

sorbed to the sludge and exhibit some removal although not by biological activity, The sludge may be considered hazardous and require additional treatment if residual toxic contaminants are present. The performance of biological systems can vary substantially from unit to unit depending on the individual compounds treated. Variations are due to the basic composition of the micro-organisms present, the degree to which the mix has become acclimated to the wastes, the presence of interfering or toxic (to the organisms) contaminants, flow and concentration variations, and other factors.

Biological treatment systems are very sensitive to changes in temperature, oxygen content, and to toxic loading of contaminants. Sensitivity to changes in inlet composition is a particular problem in adapting these techniques for use at cleanup sites. Achieving low enough residual levels of contaminants can be a problem under some conditions.

Biodegradation is discussed in the "Innovative Technologies" section.

Thermal Treatment.—Thermal treatment processes use high temperature as the principal mechanism, either to drive a chemical reaction or to simply break chemical bonds and thus destroy the hazardous nature of a substance. During incineration, the conventional method of thermal treatment, organic materials are burned (i.e., oxidized) at very high temperatures. Common types of incinerators applicable to hazardous wastes include rotary kilns, multiple hearth, fluidized bed, and liquid injection and are discussed below.[24] New forms of *thermal destruction* processes are discussed under "Innovative Technologies. "

The end products of complete incineration depend on the input materials but will generally include CO_2, H_2O, SO_2, NO_x, HCl gases, and ash. Emission control equipment (scrubbers, electrostatic precipitators) for particulate, SO_2, NO_x, and products of incomplete combustion (PICs) are needed to control emission of hazardous air pollutants, Incineration is effective for essentially all organic contaminants, particularly if they are present as liquids. Sludges and contaminated soils require special incinerators, usually rotary kiln types that properly mix the reactants and provide even heat transfer.

Incineration can be employed on or off a Superfund site, Although commercially available techniques could be adapted for onsite incineration, the technology has not been used at cleanup sites. Limited quantities of wastes and contaminated soils have been transported to offsite incinerators, As with the onsite/offsite applications of any technology, trade-offs will occur. Onsite units could be semi-permanent, constructed onsite, or mobile units brought to the site as component units and assembled onsite. Offsite units could be regionally located, permanent facilities that might offer economies of scale. However, they would require that hazardous wastes be transported, an expensive and potentially risky operation. Onsite incinerators require substantial supporting activities, such as electric power, and must be permitted by Federal, State and, often, local governments for each site at which they are used. (See the "Barriers to Adoption of Improved Technology" section in this chapter.)

The secondary effects of incineration include residue disposal, possible exposure to unburned contaminants or toxic products of combustion in the stack gases, scrubber sludge disposal, and scrubber effluent discharge, Removing wastes to an offsite incinerator changes the population affected by exposure to these secondary effects. Incinerating contaminated soil would produce large amounts of residues. Until the issue of *delisting* is handled efficiently, residues would be deemed hazardous and would have to be placed in a RCRA-permitted landfill.

Rotary kilns can handle a wide variety of burnable waste feeds—solids and sludge, as well as free liquids and gases, A rotating cylinder tumbles and uncovers the waste, assuring uniform heat transfer. The cylinders range in size and the kilns operate between temper-

[24] More complete information can be found in U.S. Congress, Office of Technology Assessment, *Technologies and Management Strategies for Hazardous Waste Control, OTA-* M-196 (Washington, DC: U.S. Government Printing Office, March 1983),

atures of approximately 1,5000 and 3,0000 F, depending on the position along the kiln.

Multiple hearth incinerators use a vertical cylinder with multiple horizontal cross-sectional floors or levels where waste cascades from the top floor to the next and so on, steadily moving downward as the wastes are burned, This action provides for long residence times. While such incinerators are able to handle a wide variety of sludges, they are not well suited for most hazardous waste for two reasons, First, they exhibit relatively cold spots wherein complete combustion will not occur producing a very uneven burn, Second, because wastes are introduced relatively close to the top of the furnace, where hot exhaust gases also exit, there is the potential for volatile waste components near the top of the incinerator to escape to the atmosphere without being destroyed.

Fluidized bed combusters are a relatively new design being applied in many areas. They achieve rapid and thorough heat transfer to the injected fuel and waste, and combustion occurs rapidly. Air forced up through a perforated plate maintains a turbulent motion in a bed of very hot inert granules, which provide for direct conduction heat transfer to the injected waste. The bed itself acts as a scrubber for certain gases and particulate. The units tend to be compact and are simple to operate relative to incinerators but have low throughput capacity. Other disadvantages are a limited range of applicable wastes and difficulties in handling the ash and residues. (The "Innovative Technologies" section has information on adaptions of this conventional technique,)

With *liquid injection* incineration, freely flowing wastes are atomized by passage through a carefully designed nozzle. It is important that the droplets are small enough to allow the waste to completely vaporize and go through ail the subsequent stages of combustion while they reside in the high-temperature zones of the incinerator. Injection incinerator designs tend to be waste-specific, especially nozzle design, but can be designed to burn a wide range of pumpable waste.

Groundwater Treatment.—The contamination of groundwater is a common occurrence at Superfund sites and may be the major and most intransigent problem. Treatment often incorporates a combination of the above technologies, is costly, and there is no guarantee that complete renovation of aquifers can ever be accomplished.

While some innovative techniques pursue in situ biological or chemical treatment of groundwater, the current practice is to first contain a plume of contamination to avoid further migration and then pump the contaminated water from the ground and through a treatment facility located onsite. Treated water can be reinjected into the ground to enhance and speed up the flushing of the contaminants from the system or pumped down gradient (i.e., returned to the aquifer or a stream or river).

Some discussion of how technology has been applied at Superfund sites to treat groundwater and its effectiveness can be found in chapter 5. For a more complete discussion of groundwater treatment options, see OTA's report, *Protecting the Nation Groundwater From Contamination*.[25]

Innovative Technologies

Innovative technologies are varied but can be broadly classified into containment and treatment categories. The concentration in this section, however, is on new treatment technologies[26] that offer the possibility to destroy hazardous wastes and eliminate the need to tie up resources in long-term operation and maintenance of containment facilities. Not all innovative treatment technologies destroy contaminants, however. Some improve on physical separation methods and, as such, can provide important pre-treatment steps. Others, such as

[25] U.S. Congress, Office of Technology Assessment, *Protecting the Nation Groundwater From Contamination*, OTA-O-233 (Washington, DC: U.S. Government Printing Office, October 1984),

[26] Most of these technologies are not breakthroughs in basic science but rather are innovative in adopting existing processes for the management of hazardous waste.

vitrification, decompose and entrap hazardous wastes.

The nature of innovation makes it more difficult to classify developing treatment methods as strictly physical, chemical, biological, or thermal processes, In fact, procedures for qualifying new technologies on the basis of preexisting classifications can inhibit their adoption, New methods of analysis will have to be considered to properly evaluate the effectiveness and reliability of innovative technologies,

Because the procedure for testing incineration technologies (the most common conventional destruction technique) has been defined under RCRA and performance standards adopted, the recognized bottom line for any hazardous waste reduction/destruction technology has become the Destruction and Removal Efficiency (DRE)[27] rating. This system forces all technologies to a level of 99.99 percent ("four nines") removal for organic hazardous wastes and 99.9999 ("six nines") for PCBs (regulated under TSCA). The blanket use of this rating ignores the question of whether these degrees of thoroughness are an appropriate level of hazard reduction for the public *and the* environment for *all* hazardous wastes found in *all* media and whether the public ought to pay that cost in all cases, However, until national cleanup goals are established and/or additional ways of measuring technology effectiveness are adopted, DREs will remain the prime criterion for technology evaluation.

Comparing technologies by their DREs must take into account that the type and concentration of the input material can affect the outcome for each technology. Often it will be less expensive to attain desired removal rates by combining techniques that individually offer relatively low removal rates. Other methods of regulating technologies include "design and operation" standards (such as applied to landfill techniques under RCRA) and environmental standards (comparable to National Primary and Secondary Air Quality Standards). With regard to the latter, it should be noted that even *high DREs do not necessarily signify acceptably low levels of toxic air emissions in terms of the quantity released over time.*

Technology Comparisons

Of the many technologies that are now being conceived, researched, and developed, OTA has selected some examples of alternatives to common Superfund practices that appear to offer the potential for improved reliability and cost effectiveness.

Much of the analysis of innovative technologies and their applicability to Superfund must be based on judgement due to a lack of Superfund performance data.[28] Comparisons among the technologies is difficult because of a lack of standardization in the available information. While only one of the technologies presented below has been applied at an uncontrolled site; some have been used to treat industrial hazardous waste streams.

All have undergone a variety of tests, but only a few of the technologies have actually been tested on a Superfund site or on a large scale with Superfund waste (i. e., have been demonstrated), Instead, the material used for testing has ranged from pure hazardous waste compounds to synthetically produced wastes to sample Superfund wastes, in varying concentrations. Testing has been conducted at different levels (e.g., laboratory, bench, and pilot-scale) since the technologies exist at these different levels of development,

[27] The DRE is calculated by the following mass balance formula:

$$DRE = (1 - W_{out}/W_{in}) \times 100 \text{ percent}$$

where:

Win . the mass feed rate of 1 principal organic hazardous constituent (POHC) in the waste stream going into the incinerator.

Wout = the mass emission rate of the same POHC in the exhaust prior to release to the atmosphere.

Incinerators are also regulated by the amount of hydrogen chloride and particulate emitted. See U.S. Congress, Office of Technology Assessment, *Technologies and Management Strategies for Hazardous Waste Control*, OTA-M-196, p. 159 (Washington, DC: U.S. Government Printing Office, March 1983) for more detailed information.

[28] An assumption is often made that such data exists for conventional technologies and that, therefore, their reliability and effectiveness is better known. In fact, conventional technologies are only conventional in the sense that the techniques have been proved in conventional applications; i.e., applications other than Superfund remedial action.

There are no standardized estimates of capital and operating costs for each technology. Costing is often based on the results of tests specific to a certain type and concentration of hazardous waste and is not necessarily transferrable to the treatment of other types and concentration of hazardous wastes. For example, as a waste stream becomes more dilute (i.e., the water content of an aqueous waste stream increases), incineration techniques become increasingly expensive due to the need to raise the water in the waste stream to treatable temperature, Therefore, while a technique maybe technically capable of treating a variety of waste streams, it may be *inefficient* to do so.

Physical, chemical, biological, and thermal treatment processes have been described earlier under "Conventional Technologies. " For innovative technologies, thermal and biological categories require further descriptions.

Thermal Destruction.–High temperatures (800° to 3,0000 F) are used to break down organic compounds into simpler, less or nontoxic forms under either oxidation or pyrolysis. Two important questions to ask are how completely the process will destroy the input hazardous wastes and what products are created out of the destruction of hazardous wastes.

During *incineration,* combustion occurs in the presence of excess oxygen (more oxygen than theoretically needed for a reaction to occur). In general, complete incineration produces water, carbon dioxide, ash, and acids and oxides that depend on the input material. *Pyrolysis* occurs in an oxygen deficient atmosphere, and pyrolysis facilities consist of two stages: a pyrolyzing chamber and a fume incinerator. The latter, which operates at 1,800° to 3,0000 F, combusts the volatilized organics and carbon monoxide produced in the pyrolyzing chamber. This two-stage system avoids the volatilization of inorganic components (i.e., the production of hydrogen chloride, for instance, which can corrode the system) and forms inorganic, including any heavy metals, into an insoluble solid char residue. Thus, the air emissions and residues from incineration and pyrolysis are different and depend on the point at which they are removed from the system or released to the atmosphere. Ash and char residues can contain salts, metals, and traces of other noncombustibles that must be properly handled. Incineration systems must be fitted with devices to control the release of acid gases and particulate. And these collected materials must be treated or landfilled.

No system is perfect or operates at maximum efficiency at all times. Inevitably, PICs are produced along with the expected products. A recent Science Advisory Board report[29] reviewed the environmental impacts of the incineration of liquid hazardous wastes and evaluated the overall adequacy of existing scientific data. Among their findings were:

- the adoption of the concept of destruction efficiencies emphasizes the elimination of several preselected compounds in the waste and does not fully address either partial oxidation or chemical recombination, which may create new toxic compounds in the incineration process;
- research on the performance of incinerators has been conducted only under optimal burn conditions, ignoring upset conditions that occur; and
- the existing analytical data for emissions from hazardous waste incinerators have serious limitations and toxicology information on emissions is inadequate.

While basic research still needs to be conducted on the processes of combustion, the emerging thermal processes offer improvements over traditional means of incineration. Improvements show in the ways they maintain adequate *temperatures* for the required reactions to occur, provide for adequate *turbulence* (mixing) of waste feed and fuel with oxygen for even and complete combustion, and allow for adequate residence *times* in high-temperature zones so that waste materials can volatilize and the gases completely react. In addition, new thermal processes may be superior

29 U.S. Environmental Protection Agency, Science Advisory Board, Environmental Effects, Transport and Fate Committee, "Draft Report on Incineration of Hazardous Liquid Waste," December 1984.

to traditional incineration because of reduced air emissions and improved quality control during processing.

The thermal processes described below may be unique because of their heat transfer mechanism (e. g., fluidized bed, supercritical water). Improvement in the transfer of heat can increase the probability of reaction and decrease the reaction time (and cost) of a process. They also offer different mechanisms for breaking the bonds of compounds. The plasma arc, for instance, uses the bombardment of very high energy free electrons.

Vitrification.–This special form of thermal treatment involves the melting of soil and wastes by passing an intense electric current through the mixture. The high temperature fuses the materials and binds them into a glassy, solid matrix after cooling.

In situ vitrification has been successfully tested in laboratory and pilot-scale tests for soils contaminated with radioactive wastes, but no data is available for applications to hazardous wastes. The process should be compatible with nonvolatile inorganic wastes/soil mixtures in general, but probably not with soils containing organic contaminants. It may not be applicable to saturated soils and is limited by the amount of water present. Little data exist on long-term resistance to leaching.

Vitrification may have limited applications because variable site conditions and the presence of complex mixes of contaminants severely lessen its reliability. If found to be practical, however, it could be used to treat wastes in situ and provide a more permanent containment solution than the use of barriers.

Biodegradation.–These techniques involve the use of naturally occurring or synthetically generated bacteria to break down chemicals via ingestion and respiration. They include either applying the organisms to aerated soils in situ or after excavation and deposition in surface impoundments, ponds, or treatment facilities where the wastes can be mechanically aerated, More recently, several concepts have been developed where the biodegradation occurs within the saturated, contaminated soil/groundwater system. Here, nutrients and oxygen are injected directly into the groundwater. Oxygen is added by pumping air into the ground through well points located below the water table. Some systems rely on indigenous micro-organisms; others inject additional micro-organisms together with nutrients. All pump and recirculate groundwater, since it takes more than one pass to obtain high removal efficiencies.

While biological treatment of wastewater is not a new concept, its application to solid waste and contaminated soils, especially in situ, is.[30] Various natural and chemical processes will affect the efficiency of biotechnology used in open systems. The effectiveness of the technology will be influenced by environmental conditions such as temperature, type of soil, type of naturally occurring micro-organisms, and the amount of air and water within the soil matrix.[31]

A biotechnology system to degrade hazardous waste consists of micro-organisms (selected mutants of natural strains already present in the contaminated matrix or genetically engineered organisms) and a *process technology*. The process technology makes possible the use of the organisms in highly variable, real world conditions, So far, much of the research interest and funding has been directed toward the micro-organisms with only limited funding to develop the technology.[32]

Before *genetically* engineered organisms can be used effectively in Superfund applications, especially in situ, certain problems require solutions :[33]

- Foreign organisms injected into a particular system will likely create problems of

[30]Wastewater treatment facilities are closed systems where the proper environment can be maintained for optimal performance results.

[31]S. W. Pirages, et al., "Biotechnology in Hazardous Waste Management: Major Issues, " paper presented at symposium *Impact of Applied Genetics in Pollutions Control,* University of Notre Dame, May 1982.

[32]Stanley Sojka, Manager, Environmental Technology, Occidental Chemical Corporation, personal communication, December 1984.

[33]M. A. Alexander, '<Ecological Constraints on Genetic Engineering: Genetically Engineered Organisms in the Real World, " paper presented at *Genetic Control of Environmental Pollutants,* University of Washington, Seattle, 1983.

survival for either the indigenous or foreign organisms.

- Laboratory results cannot be directly extrapolated to full scale because of differing conditions under which micro-organisms operate.
- Soil particles present a physical barrier to the movement of micro-organisms as water is required for movement between particles. Lack of proper conditions would give uneven degradation.
- The effect of possible abiotic stresses (e.g., unsuitable temperatures and pH levels) on micro-organisms released into the environment are unknown. Toxic elements within the environment might reduce, or eliminate, a microorganism's ability to degrade chemicals of concern. In addition, possible predators could be a critical factor to the effective use of laboratory-bred organisms,

An additional point is that little work has been done using organisms to treat complex waste mixes.

An advantage to using genetically engineered organisms at a Superfund site is that once the wastes have been degraded, the organisms should die, This is because the carbon source for growth and reproduction of the microorganism has been depleted or is unavailable to the organism.

Illustrations of Innovative Technologies

The following section describes **26** innovative technologies. Using available information, OTA has attempted to discuss: the principles on which each technology is based and the process itself; whether it destroys or contains hazardous waste; the expected products, air emissions and residues; the applicable wastes; economic costs and uncertainties; and the current stage of development and the level of testing, These technologies illustrate the scope of activity underway in cleanup technologies; OTA does not recommend or endorse any of them. Many more innovations are also likely to exist now, and yet more can be expected in the future,

Table 6-5 provides a technical summary of the 26 technologies showing their development stage, an estimate of how well each removes or destroys hazardous wastes, and the relative cost of their use. Table 6-6 summarizes their applicability to Superfund sites and table **6-7** their technical advantages and disadvantages. *A preferred technology would effectively treat a variety of hazardous wastes under a variety of physical conditions, be transportable so as to be useful for onsite treatment, transfer little health or environmental risk through air emissions and residue, and would not require extensive post-treatment facilities.* Many of the technical disadvantages and uncertainties of these emerging technologies might be resolved through demonstration testing.

1. **GARD Division, Catalytic Dehalogenation.—In the** presence of a catalyst, halogenated compounds (organic compounds that include a halogen such as chlorine, bromine, or fluorine) react with hydrogen to form an acid and a hydrocarbon. In this system, organic material is detoxified by reacting with hydrogen to form nontoxic materials.

GARD, a division of Chamberlain Manufacturing, has developed a treatment system using a platinum-based reforming catalyst supported on gamma alumina. The system begins with a storage unit that holds the hazardous waste material. The material is pumped from the tank to a preheater. When it reaches the proper temperature, it is sent to the catalytic reactor where it reacts with hydrogen. For a chlorinated compound, the reaction yields hydrochloric acid and a hydrocarbon. During the processing, most solvents remain intact and can be recovered, After leaving the reactor, the products are cooled and sent to a vapor-liquid separation stage. The dehalogenated hydrocarbon and acid are sent through a scrubber and on to another storage tank.

A second conversion stage can be added to the system as a polishing stage to remove a second halogen if necessary, and a provision for product recycle can be added to the reactor for cases when one pass is insufficient. The second conversion stage could be used to remove oxygen from some materials to enhance their fuel value.

GARD's process is probably best suited for treating liquids with low concentrations of halogenated compounds (e. g., Silvex herbicide), but it is also capable of treating liquids that are pure halogenated compounds and solids (e. g., contaminated soils), Liquid wastes can be treated directly with no pre-

Table 6“5.—Innovative Technology Summary

Company	Project development stage	Removal/ destruction capability	Relative estimated costs	
			Capital	Treatment
Gard	pilot	medium	low	*low*
Zerpol	pilot	?	7	?
Bend Research	pilot	medium	low	*low*
DeVoe-Holbein	pilot	medium	low	low
MODAR	pilot	high	medium	medium-high
Zimpro	full	low-medium	medium	low
Methods Eng.	pilot	?	medium	low
IT Corp.	bench	low-medium	?	medium-high
Huber..	pilot	high	high	medium-high
Thagard ...,	pilot	high	?	7
Pyrolysis	pilot	high	medium	high
Westinghouse.	pilot	high	high	high
Lockheed.	bench	medium-high	?	7
RoTech	pilot	high	medium	low-medium
Midland-Ross	full	?	high	medium
Waste-Tech	pilot	medium	medium	?
GA Tech.	pilot	medium-high	medium	7
Rockwell	pilot	high	medium	high
Sandpiper	pilot	7	medium	medium
Detox	pilot	medium	?	low
GDS	full	medium	low	low
SBR Tech	pilot	medium	7	?
University of Gottingen	research	high	?	7
Battelle Pacific.	pilot		7	low
Lopat-K20	pilot/full	high	low	low
NMT-Fujibeton	pilot/full	high	low	low

NOTES
na not applicable
? = not available
KEYS
Removal/destruction capability (systems not necessarily tested on comparable waste)
Low = less than 90 percent
Medium = 90 to 9999 percent
High – 9999 percent and greater
Capital costs (based on full-scale system where possible)
Low – less than $1 million
Medium - $1 million to $5 million
High = more than $5 million
Treatment costs (not all systems evaluated using same operating costs components)
Low - less than $100/ton or $0.01/gallon
Medium = $100 to $500/ton or $0.01 to $1/gallon
High greater than $500/ton or $1/gallon

SOURCE: Office of Technology Assessment

treatment, except for filtering to catch solids. Solid waste must be dissolved in hydrocarbon solvents first. Since the solvent is unaffected by the process, however, it can be used repeatedly,

A bench-scale single pass reactor has been built for testing. GARD has considered building a pilot-scale system for further testing but is seeking financial assistance (private or public sector) before continuing the research. Test results are available for Silvex and PCBs, With a single pass, Silvex was dechlorinated by nearly **80** percent; with two passes, greater than 99 percent. Dechlorination of 93 percent in a single pass was achieved with material containing approximately **2,000** ppm PCBs, but only 30 percent for material containing slightly more than 17,000 ppm PCBs.

GARD has estimated costs based on the treatment of 1 million gallons of Silvex, assuming a feed rate of 50 gallons per minute. Capital costs would be $110,000 for **a** skid-mounted system and site hook-ups (e. g., electricity). Operating costs would be $99 per 1,000 gallons of Silvex treated and include cost of the hydrogen, pumping power, heating and cooling water without heat recovery, and labor. [GARD is located in Niles, IL; (312) 647-9000.][34]

[34] Each of the 26 technologies is listed by the firm developing the technology and the firm's name for its product. In addition, each firm's location and telephone number are provided so that the reader who wants more information may contact the developer directly.

Table 6-6.—Innovative Technology Applicability to Superfund Sites

Company	In situ[a]	System applicability: Onsite[a]	System applicability: Offsite[a]	System applicability: Mobile(M) Transportable(T) Permanent(P)	Primary waste applicability[b]: Class	Primary waste applicability[b]: Form	Air emissions and/or residues generated[c]	Post-treatment required[d]	Applicable systems standards
GARD	N	Y	Y	M,T	O	L,SL	L	P	P
Zerpol	N	Y	N	T	I	GW,L	L	P	P
Bend Research	N	Y	P	M,T	I	GW,L	S	Y	P,DO
DeVoe-Holbein	N	Y	N	M,T	I	GW,L	S,L	Y	DO,P
MODAR	N	Y	Y	P,T	O	GW,L	L	N	P
Zimpro	N	P	Y	P,T	O	GW,L	L,S	P	P,DO
Methods Egg.	N	P	Y	P	O	GW,L	L	N	P
IT Corp.	N	P	Y	P	O	L	L,A	P	P
Huber	N	Y	Y	T	O	S,L	A	N	P
Thagard	N	Y	Y	T	O	S,SL	A	N	P
Pyrolysis	N	Y	N	M,T	O	L	A,S	N	P
Westinghouse	N	Y	N	M,T	O	L	A,S	N	P
Lockheed	N	P	Y	P	O	L	S	N	P,DO
Ro Tech	N	Y	Y	M,T	O	S,SL,L,S	S	N	P
Midland-Ross	N	P[f]	Y	P,T	O	SL,L	L,S	N,P	DO,P
Waste-Tech.	N	P[f]	Y	P	O	SL,L,S	A	N	P
GA Tech.	N	Y	Y	M,T	O	S,SL,L	S	N	P
Rockwell	N	N	Y	P	O	L,SL	S	N	DO
Sandpiper	N	Y	Y	M,T,P	O	L,S,SL	L	P	P,DO
Detox	Y	Y	N	T	O	GW,S,SL	A,S,L	P	P,DO,E
GDS	P	Y	N	T	O	GW,L	none	N	P,E
SBR Tech.	N	‘t	Y	P,T	O	GW,L	S	P	P
University of Gottingen	P	P	P	T	O	SL,L	?	P	?
Battelle Pacific	Y	P	N	T	O	S,SL	A	N	E(g),DO
Lopat	Y	Y	Y	T	O/I	S,SL,L	S	P	P,E(g)
New Materials	Y	Y	Y	T	O/I	S,SL,L	S	P	P,E(g)

[a]Y = yes N . no P = perhaps with further testing
[b]*Class*
O – organics
I – inorganics
Form
GW – groundwater (dilute aqueous)
S = soils/solids (low concentrated)
L liquids (concentrated)
SL - sludges/solids (concentrated)
Pretreatment pretesting mav be required
C s solid L = liquid A air emissions Shown as dominant form since most processes result in some of each
‘Y yes N no P possibly Post-treatment needs can vary i.e., products depend on treated hazardous waste In general thermal processes do not ’treat heavy metals therefore residues may have to be tested for trace amounts prior to landfill Also products of Incomplete combustion may be hazardous knowledge base is weak
[e]If utilized on Superfund wastes a technology Will probably require regulation Three types are considered p performance (analogous to RCRA Subpart O incinerator regulations e.g 99.99 percent DRE for primary organic hazardous components) DO design/operation (similar to RCRA landfill standards) and E environmental standards (comparable to National Primary and Secondary Air Quality Standards) The most applicable approach is given first
[f]For large sites: i e high volume of waste to b@ treated
[g]For subsequent leaching from a treated area

SOURCE Off Ice of Technology Assessment

Table 6-7.—Innovative Technology Advantages and Disadvantages

Company: Technology	Advantages	Disadvantages/uncertainties
GARD: **Catalytic dehalogenation**	Little pre-treatment for liquids Fuel recovery potential Good portability Conventional equipment	Wastes must be in liquid phase Development at small pilot stage
Zerpol: Zero Technology	Salt recovery possible Highly treated liquid discharges Highly concentrated residues Leads to metals recovery	Has not undergone relevant testing Applicable to concentrated wastestreams Pretesting required to fix wastestream applicability—highly selective applicability y
Bend Research: Coupled transport for sludge reclamation	Potential for metals recovery Requires little ion exchange agent High copper, chromium, zinc applicability	**Only** tested at small scale High exchange membrane costs Sludge requires residue disposal
DeVoe-Holbein: **Metal extraction**	Selective exchange leads easily to **metal recovery** **High metal capture efficiencies**	Clean, dilute liquid wastes required Considerable pre-treatment required
MODAR: Supercritical water oxidation	**High DREs for wide range of organics** **Operates in self-sustained** mode on low organic content wastes Applicable to large volumes of wastes	Requires demonstration testing Relatively high capital costs High pressure/temperatures process[a]
Zirnpro: Wet **air oxidation**	Wide previous experience on variety of nonhazardous wastes Low energy requirement v. incineration	Destruction dependent on residence time Higher capital investment than for incineration Elevated temperature/pressure process[a]
Methods *Eng.:* Submerged reactor	Potential onsite application Operates in self-sustained mode on low-organic content wastes Applicable to large volumes of waste	Requires demonstration testing Relatively high capital costs High pressure/temperature process[a]
IT Corp.: **Catalyzed wet ox id at** ion	Can be operated to produce no aqueous residue Low-volume residue for further disposal	Destruction dependent on rates of oxidation of compound in reactor—longer rates will dominate processing time for waste Elevated temperature/pressure process[a]
Huber: Advanced Electric Reactor	Very high reaction temperatures/absence of oxygen limits unwanted product formation High destruction efficiencies for organics Applicable to large sites Demonstration tested	High energy use
Thagard: Fluid wall reactor	Very high combustion temperatures PIC formation considered low[b] High destruction efficiencies for organics Applicable to large sites	High energy use
Pyrolysis:		
Plasma arc	High operating temperatures result in high organic destruction efficiencies Mobile system possible	Cost estimates incomplete
Westinghouse: **Plasma arc**	High operating temperatures result in high organic destruction efficiencies	**Small-scale testing** to date Cost estimates incomplete
Lockheed.' Microwave plasma	High destruction efficiencies for chlorinated compounds Can process gases and liquids	High degree of pretreatment required Bench-scale tests convince developer to drop project
RoTech: Cascading Rotary Incineration System	Small commercial-scale operation on actual wastes Cascading solids have very high contact with combustibles No afterburner required No refractory maintenance	Testing required on mixed wastes, metals emissions Need pre-treatment for waste size uniformity
Mid/and-Ross: Rotary pyrolytic incineration	Fuel recovery possible Application shown on actual wastes Metals retained on residual char Low or no NO, emissions	Destruction efficiency difficult to assess Not applicable to aqueous wastes Tested on a narrow range of wastes

Table 6“7.—Innovative Technology Advantages and Disadvantages—Continued

Company: Technology	Advantages	Disadvantages/uncertainties
Waste-Tech: Fluidized bed Incineration	Expect metals attenuation in bed Good combustion turbulence and waste contact Capital costs compare to rotary kiln Destruction efficiencies high	Waste character and particle size should be uniform Need further metals emission testing and waste tests
GA Tech: Circulating bed combustor	Higher turbulence than typical fluidized bed Expect metals retention in bed Shown on variety of wastes High destruction efficiencies Little/no gas discharge treatment required Low-temperature operation—expect low NO_x emissions	Need further metals emission testing Waste feed pre-treatment for character/size uniformity required Need fuller testing on mixed wastes
Rockwell: Molten salt incineration	Little air emission of toxics Metals retained in melt Very high destruction efficiency for organics	Works best on low ash content wastes: requires melt-ash removal system Small-scale test thus far
Sandpiper: SEGAS process	Energy recovery possible Compact mobile system	Costs/testing for waste application incomplete
Detox: In situ biological treatment	Tested at actual site on mixed wastes Demonstrated lower costs than some chemical/thermal processes Anaerobic capability Tested in a soil matrix Little pre-treatment	Longer treatment times than chemical/thermal Intermediate compounds not defined
GDS: Biological degradation	Proven cleanup technology	Applicability dependent on site characteristics In situ phase contribution uncertain
SBR Technologies: Sequencing Batch Reactor	Each cycle is monitored by computer system High throughput possible	Production of sludge can reduce efficiency of operation
University of Gotfingen: Biological degradation	Promising research approach	Intermediates are formed Needs process technology
Battelle Pacific: In situ vitrification	No removal costs Very low leachability Application in past to radioactive wastes successful Good control for metals	High energy use Small site applicability For organics—requires off gas treatment High soil moisture increases costs
Lopat: Chemical treatment	Low cost, safe chemical, easy to apply to wastes and contaminated surfaces Effective on organic and inorganic materials	Duration of effectiveness uncertain For soils and wastes other additions such **as** cement, increase volume
New Materials: Chemical treatment	Low cost, **safe** chemical, easy to apply to wastes and contaminated surfaces Effective on organic and inorganic materials Proven technology	Long-term (greater than 10 years) effectiveness uncertain

[a] High temperature h..h..~ ~ systems have inherent risk of process catastrophe Redundant safeguards required
[b] PIC—Product of Incomplete Combustion

SOURCE Off Ice of Technology Assessment

2. **Zerpol Corp., Zero Technology .—This** pollution control system developed for the metals finishing industry is a unique collection of conventional processes. The system recently has been extended to other industries, such as textile manufacturers, chemical manufacturers, petroleum refiners, paper mills, and pharmaceuticals. It could provide a chemical method of removing organics, heavy metals and inorganic, including cyanides, from contaminated groundwater. There is no liquid discharge from the system.

For wastewater from a metal finishing plant, proprietary chemicals sequentially reduce chromates, oxidize cyanides and adjust the pH to 9 to 9.2 (an alkaline solution). The primary objective is to reduce the cyanide levels in the solution and precipitate out heavy metals without the use of flocculating and settling agents. The resultant liquid contains dissolved salts that must eventually be removed by a distillation process. The distilled water is then recycled back through the system.

Residues from the process include heavy metals and a concentrated salt solution that is dried by evaporation, producing a small amount of solids, No test data is available on hazardous waste removal levels, nor is any information regarding capital and operating costs, [Hatfield, PA; (212) 368-0501]

3. **Bend Research, Coupled Transport for Sludge Reclamation**.—This coupled transport system is an adaption of ion exchange technology in which an immobilized, liquid membrane process allows certain metals to be selectively extracted from a solution containing various other metals. This system offers several advantages over other ion exchange processes. It requires only small amounts of agent, thereby lowering costs, and feed pre-treatment, especially the removal of suspended solids, is expected to be minimal.

An inert, microporous support is impregnated with a water-miscible liquid ion exchange resin. (This agent is held in the pore of the support material by capillary forces.) When the membrane contacts an aqueous solution containing metal ions, the membrane exchanges ions of like charge, thereby extracting the metal ions from solution, The process includes acid leaching of sludge as a first step, followed by the exchange in which the metal is deposited on one side of the membrane. An electrolytic extraction of the exchange-concentrated solution is the final step,

Bend has developed three membranes so far, for copper, chromium, and zinc recovery. If the process can be made to work on a wider base of metals, the potential for treating hazardous wastes might be high. As this is a physical separation process, the products are a metal and a sludge residue. Given that the metal is a hazardous waste component of the initial sludge, that product would have to receive further treatment or disposal, if it is not recycled.

The process has received only laboratory-scale testing. In those tests, copper purity in a sample was over 99,9 percent. Future work is required to demonstrate nickel recovery and to increase copper flux in the ion exchange unit, chromium oxidation efficiency, and the number of potentially exchangeable metals.

Costs have been estimated for a plant capable of treating 27,000 grams (60 pounds) per hour of sludge. Post-treatment of the metal residue and sludge disposal is not included. Capital costs would be $118,700 and operating costs, $85,700 per year, with payback within 4 years. At this level of operation, resale of the metal values are said to result in income of $148,000, but this would depend on metal market conditions. [Bend, OR; (503)382-4100]

4. **Devoe-Holbein, Inc., Metal Extraction.—This technology** offers a method to extract metal from relatively clean waste streams using synthetically produced compositions. Ion exchange then regenerates the compounds by separating out the metals. The extraction compositions are patterned after the natural metal extraction capability of living cells.

Each of the 30 compositions developed by Devoe-Holbein extracts a different metal. Both the composition and the extracted metal can be recovered and reused, reducing the cost of the process. The technology might be used either as an independent waste treatment or in conjunction with other processes as a pre-treatment step,

The process is mainly applicable for treating dilute wastes such as those produced by metal finishing operations (i. e., electroplating). It is highly selective of the metal in question. Once metals considered to be hazardous have been extracted, they must be reused or receive further management,

The measure of success for the process is the percent of metal captured from the solution being treated. Synthetic compositions have been shown to capture nearly 100 percent of the metals in both aqueous solutions and industrial wastes in pilot-scale tests: 99.96 percent of copper in solution, 99,91 and 99.98 percent of zinc chloride and zinc phosphate from electroplating rinse solution, 99.99 and 99.97 percent of cobalt and zinc from a petrochemical effluent, Large-scale testing is planned.

Estimated capital and operating costs have been made for a representative plant treating 10 gallons per minute of waste and removing zinc. Capital investment for this relatively small plant would be $15,000. Stated operating costs of $6,100 to $6,600 per year (at 8 hours per day and 220 days per year) work out to less than a penny per gallon of waste, but Devoe-Holbein has not included labor costs. [Quebec, Canada; [514)636-6042]

5. MODAR Inc., Supercritical Water Oxidation.—Supercritical water is used by MODAR to destroy organic materials by oxidation. Above its critical temperature [374° C) and pressure [210 atm or 0.3 g/cm^3), the properties of water are quite different from that of the normal liquid or atmospheric steam. For example, organic substances are completely soluble in water under some supercritical conditions, while salts are almost insoluble under other supercritical conditions. The volubility of organics, coupled with low hydrogen bonding properties in supercritical water, facilitates the destruction of organics and formation of inorganic acids (from the halogens and possible metal elements present), plus carbon dioxide and water. The acids can be precipitated out as salts by adding a base to the feed,

The MODAR system is a multi-stage process. First, the waste in the form of an aqueous solution or a slurry is delivered to the oxidizer inlet, where it is pressurized and heated to supercritical conditions by direct mixing with recycled reactor effluent. Oxygen is then supplied in the form of compressed air and the inlet mixture is a homogeneous phase of air, organics, and supercritical water. The organics are oxidized in a controlled but rapid reaction (residence time of 5 seconds), The effluent is fed to a cyclone where the inorganic salts that are originally present in the feed, or which form in the combustion reactions, precipitate out and are separated from the effluent. The fluid effluent (some of which is recycled through the system as a preheater) is then a mixture of water, nitrogen, and carbon dioxide. Once cooled to subcritical temperature, the mixture forms two phases and enters a high pressure liquid-vapor separator. Practically all of the N_2 and most of the CO_2 leaves with the gas stream; the liquid consists of water, inorganic salts, and an appreciable amount of dissolved CO_2. The liquid is depressurized and fed to a low-pressure separator. The vapor stream is vented. At two points in the system, energy can be generated.

The MODAR process can be applied to organic wastes with a wide range of concentrations; solids must be slurried prior to treatment. Economically, it is currently particularly well suited for aqueous wastes containing 1 to 20 percent weight organics. For lower concentrated wastes, fuel value must be added; for higher concentrations, water.

Originally designed to detoxify industrial aqueous organic waste streams, the firm is now offering the process for use at Superfund sites. A demonstration, skid-mounted pilot-scale system is available for testing.

A continuous flow, bench-scale system with an organic throughput of 1 gallon per day was used to collect the test results. Feed mixtures of various organic hazardous wastes were used, containing from 1 to 20 percent chlorine. Liquid effluents were analyzed for total organic carbon (TOC) and pH. Gaseous effluents were analyzed for low molecular weight hydrocarbons and permanent gases. In general, organic carbon is reduced to less than 1 ppm (DREs of 99,99 to 99.9999 percent); organic chloride DREs are also 99,99 to 99.9999 percent.

The system has low operating costs but relatively high capital costs. Operating costs are kept low because the system recycles its superheated effluent to heat incoming wastes. Consequently, the system requires almost no fuel once operation has begun. The incoming slurry must contain at least 2 percent combustible organic matter to maintain self-sufficiency (compared with a typical incinerator's feed of about 30 percent), Excess heat generated by the system can be used to drive a turbine to generate electricity (an option that might only be feasible for a centrally located plant rather than a transportable system used for Superfund sites).

Disposal costs have been projected by MODAR for a representative plant processing 10 tons of organic waste per day; it would require a capital investment of nearly $5 million with treatment costs of $1.50 per gallon for organic liquid and solid wastes and $0.15 for dilute aqueous wastes. [Natick, MA; (617)655-7741]

6. Zimpro, Wet Air Oxidation.–The basic principles of air oxidation are covered above under "Conventional Treatment Technologies. " The use of water ("wet") as a reaction medium allows for reactions to take place at relatively low temperatures, 175° to 3250 C (347° to 617° F). It also modifies the reaction rates that remove excess heat by evaporation and provides an excellent heat transfer medium. This allows the process to be self-sustaining thermally with relatively low organic feed concentrations (i.e., feeds with low fuel value). The process pressure is usually between 300 and 3,000 psi to prevent excessive evaporation of the liquid phase in the reactor,

Zimpro has been using wet oxidation for the treatment of industrial wastes for over 30 years, and they are now adapting the process for the treatment of hazardous waste, The degree of oxidation achieved (i. e., degree of destruction) depends on temperature and residence time in the reactor and oxidation conditions are waste-specific, Zimpro feels that wet oxidation can be valuable for the treatment of dilute organic hazardous waste streams because it is far more efficient (in terms of energy consumption) than incineration.

Air pollution problems are nearly eliminated because most harmful contaminants produced remain in the aqueous phase and do not burn off as gases. The only gases discharged from the process are spent air and a small amount of carbon dioxide. Any harmful liquids produced may have to be treated.

Bench-scale tests have been conducted with pure hazardous organic compounds and DREs ranged from 2.0 to 99.997 percent. The poorest performers were Kepone (31 percent), Arochlor 1254 (2 and 63 percent), and 1,2, -dichlorobenzene (32 and 69 percent). Otherwise, DREs were at least 82 percent and averaged over 99 percent. Testing and treatment of industrial hazardous waste streams show that most compounds are easily oxidized by the wet air process but that halogenated aromatic compounds (e.g., chlorobenzene and PCBs) are resistant.

The capital investment for wet air oxidation is considerably higher than that for conventional incineration, but there is the potential for lower operating costs. A small plant processing about 4 tons per day would require a capital investment between $1.9 million and $3.0 million, Zimpro expects wet air oxidation to save a great deal in operating costs because power requirement are low. Total operating costs are expected to vary depending on plant capacity; estimates of $30 per ton (at 100 tons processed per day) and $150 per ton (at 10 tons per day) have been made. [Rothschild, WI; (715) 355-3523]

7. Methods Engineering, Inc., Burleson/Kennedy Submerged Reactor.—The Burleson/Kennedy reactor uses a deep well to form a reaction chamber for the combustion of waste in water. The deep well promotes the conditions (pressure and temperature) necessary for supercritical water, which is used as a process medium (see MODAR, above).

The ideal structure for the submerged reactor is an abandoned oil well at least 6,400 feet deep with a cement casing to retard heat loss. Water, pressurized oxygen, and the hazardous waste to be treated must be pumped into the well, The bottom of the well serves as the reaction vessel. An electrical current input near the bottom of the well heats the fluid for the reaction.

Aqueous organic hazardous wastes would be the most appropriate use of this system. The products of the process are carbon dioxide, water, and various soluble and insoluble solid salts, Depending on the input waste, some of the salts may contain heavy metals that will need to be separated out for proper handling.

Information is not available on testing results. Capital and operating costs were estimated in mid-1984. The initial capital outlay would be $1.2 million, and the system is expected to be capable of processing 480 million gallons of wastewater per year at a cost of $0.0014 per gallon, [Angleton, TX; (409)849-7033]

8. IT Corp., Catalyzed Wet Oxidation.—In conventional wet air oxidation, heat and pressure drive the dissolution of oxygen from air and its reaction with dissolved organics in an aqueous solution. In this catalyst system, the transfer of oxygen to the dissolved state is speeded. With enhanced oxygen transfer, it is possible to oxidize organics at lower temperatures (165° to 200° C versus 250° to 3250 C for conventional systems) and at lower pressures. The catalyst consists of bromide, nitrate, and manganese ions in acidic solution.

In its simplest form, the reactor contains a continuously stirred catalyst solution. Air and waste are continuously pumped into the reactor. Products formed that leave the reactor are CO_2, N_2, water vapor, and depending on the input, volatile organics and inorganic solids. Water is condensed and returned to the reactor, if necessary, as are condensable organics. Any inorganic salts or acids that may form have to be removed by treatment (e. g., filtration or distillation) of the catalyst solution in a closed loop stream. The vent gases are low in volume and can, if necessary, be treated by conventional techniques such as adsorption or scrubbing, Nonvolatile organics remain in the reactor until destroyed and there is no aqueous bottoms product.

This system is best suited for the treatment of liquid organics, and bench-scale tests have been conducted by IT Corp. Results show that organic reduction varied depending on the compound tested, temperature, and residence time. Further R&D awaits more funding. The initial research was internally funded by IT, supplemented by EPA funds.

Preliminary treatment costs have been estimated so far and range from $0.12 to $1.04 per pound of compound. Actual costs will vary markedly depending on what compound is sent through the system. Slow destruction rate compounds would cost much more to treat than fast destruction rate compounds. In addition, treatment costs are influenced to a lesser degree by factors such as the air compressor, condenser size, cooling water requirements, neutralization or scrubbing requirements, and catalyst loss. [Knoxville, TN; (615)690-321 1]

9. J.M. Huber Corp., Advanced Electric Reactor.—The Advanced Electric Reactor (AER) rapidly heats materials to temperatures in the range of 4,0000 F (2,2000° C) using intense thermal radiation in the near infrared region. The reactants are isolated from the reactor core walls by means of a gaseous blanket formed by flowing nitrogen radially inward through the porous core walls (thus, its common name of "fluid wall reactor"). Solid waste is introduced at the top of the reactor through a metered screw feeder, and nitrogen is forced through the walls of the reactor.

After leaving the reactor, where pyrolysis occurs at temperatures of about 4,0000 F, the product gas and waste solids pass through two post-reactor treatment zones. The first is an insulated vessel to provide additional high temperature (in excess of 2,000° F) and residence time (5 to 10 seconds), The second is water cooled to reduce the gas temperature to less than 1,000° F prior to downstream particulate cleanup. Solids exiting these zones are collected in a sealed bin. Additional solids in the product gas are removed by a cyclone and routed back to the solids bin, The product gas then enters a bag house for fine particulate removal followed by an aqueous caustic scrubber for chlorine removal. Any residual organics and chlorine are removed by passing the product gas through activated carbon beds just upstream of the emission stack. The organic, particulate, and chlorine-free product gas composed almost entirely of nitrogen is then emitted to the atmosphere through the process stack.

The AER runs entirely on electrical power and requires 800 to 1,200 kWh per ton for treating contaminated soils and 1,500 to 2,000 kWh per ton for the complete dissociation of liquids. Gaseous, liquid, or solid wastes can be treated. Pre-treatment of solids and liquids may be required to ensure that feed particle size is small enough for the reaction to proceed to completion within the residence time, The system is suited for the treatment of low Btu content hazardous materials (i. e., contaminated soils, pure PCBs, and other heavily halogenated hydrocarbons) and extremely hazardous materials [e.g., dioxins and nerve gases).

The principal products of soil-borne PCB destruction using the Huber process are H_2, Cl_2, HCl, elemental carbon, and a granular, free-flowing, solid material. Typical products of incineration, such as carbon monoxide, carbon dioxide, and oxides of nitrogen, are not formed in significant concentrations.

Huber has built and maintains two fully equipped reactors as part of its over $6 million 17 RD&D program. The smaller reactor unit (0.6 pounds per minute of contaminated soil feed capacity) is installed in a covered truck trailer for mobility. It is used for proof-of-concept experiments and onsite demonstrations. The larger, pilot/commercial-scale reactor with a capacity of up to 50 pounds per minute or 10,000 tons per hour is used solely for research purposes. Although the larger unit has been permitted by EPA Region VI to commercially treat PCB-contaminated soils, corporate policy restricts its use to RD&D.

To date, four test programs have been conducted to demonstrate the effectiveness of the AER for treating soils contaminated with hazardous wastes. Tests were conducted in September 1983 on PCBs and certification was received from EPA Region VI in May 1984 under TSCA. A second series of tests were conducted in May 1984 with carbon tetrachloride in applying for a broad RCRA permit (expected in 1985). In October 1984, a test series was initiated on soils spiked with octachlorodibenzo-p-dioxin (a thermodynamically more stable surrogate for the acutely toxic 2,3,7,8 tetrachlorodibenzo-p-dioxin isomer). In November 1984, at Times Beach, Missouri, the mobile reactor was tested on soil contaminated with 2,3,7,8 TCDD and other dioxins.

Results from various test programs have provided typical gas phase DREs of 99.99999+ percent. In all cases, DREs were at least 99.9999 percent. Treated soil concentrations have always been equal or less than 1 ppb of the contaminant in question (PCB, CCl_2, dioxin) and usually nondetectable. Further, no chlorinated products of incomplete pyrolysis have been observed.

Operating costs depend on the size of the waste site and the soil pre-treatment requirements, which could include drying and sizing. For a large site (containing more than 10,000 tons of materials), the cost is estimated to be between $300 and $600 per ton, But costs could be as high as $1,000 per ton. Capital costs to build a large reactor are estimated at $10 million. [Borger, TX; (806)274-6331]

10. Thagard Research, High Temperature Fluid Wall Reactor .—This High Temperature Fluid Wall [HTFW] process is based on the same principles as the Huber's AER. The reactor was orginally developed for the continuous dissociation of methane into carbon fines and hydrogen. To accomplish this, temperatures in excess of 1,700° C (3,0920 F) and a mechanism to prevent precipitate formation on the reactor walls were required. To meet both requirements at the same time, the reacting steam is kept out of physical contact with the reactor wall by means of a gaseous blanket. Energy for the reaction is supplied by carbon resistance heaters that bring the carbon core of the reactor to incandescence. Heat transfer occurs through radiative coupling from the core to the stream.

The destruction process is driven by pyrolysis conditions in the reactor, In addition, some materials (e. g., soils) will vitrify under the high temperatures. The system has a wide application to many hazardous wastes as long as they can be fed into the reactor in a pulverized form. This may require pre-treatment.

Two sets of testing have been done on a pilot-scale unit. Thagard views one set to be correct and the other incorrect due to errors in testing (contamination occurred), DREs for the former test were dichloromethane (99,9999+ percent), carbon tetrachloride (99.9+ percent), dichlorodifluoromethane freon 12 (84.99 percent), trichloroethane (99.99 + percent), and hexachlorobenzene (percentage not reported). In the latter tests, the most significant difference showed in dichloromethane, with much lower DREs,

Extensive cost estimates (capital and operating) prepared by Thagard have compared its treatment process with the cost of landfills. They concluded that if wastes must be moved at least 100 miles at a cost of $65 per ton, the HTFW reactor can be substituted as long as at least 100 tons per day are being processed. [Costa Mesa, CA; (714)556-4470]

11. Pyrolysis Systems, Inc., Plasma Arc Technology.– The principle of plasma pyrolysis involves breaking the bonds between organic constituents. Once the compounds are atomized, they reform into other compounds under controlled conditions that attempt to prevent the formation of hazardous materials.

Waste fluids are injected into a plasma arc zone of a reactor vessel where temperatures ranging from 15,0000 to 50,0000 C exist in a gaseous cloud of charged particles between electrodes. The organic molecules react with the plasma species and are destroyed within microseconds. These elements are subsequently released into another vessel where they recombine into stable forms such as hydrogen gas and methane.

The new compounds created are predictable. Using a computer model, the appropriate operating conditions can also be predicted prior to destruction. Undesirable products can be reduced by altering the character of the feedstock or modifying the operating conditions.

At the product gas outlet from the reaction chamber, water is injected along with liquid caustic soda to quench the product gas, neutralize acidic products, and trap particulate, Saltwater and particulate are pumped and sampled before the discharge is approved.

Product gas, mainly of hydrogen and carbon monoxide, flows to a flare stock where it is electrically ignited and burns between 2,0000 and 3,0000 C. The flare prevents the release of methane gas to the environment, Chlorinated wastes produce a hydrogen byproduct that is converted to salt in a caustic scrubber. An activated carbon filter blocks the release of toxic material in the event of a power failure.

The system has been designed to be mobile. All of the equipment is to be contained in a 45-foot trailer. It includes a 500-kilowatt plasma device located at one end of a stainless steel reaction chamber with a graphite core,

The technology has been developed with financial assistance (up to $1.5 million) from EPA and the State of New York to treat the organic leachate from the Love Canal site. Pilot-scale testing (1 gallon per minute) on organic sludges is to begin in 1985 in Canada. These tests will provide data for the permit to place the unit on the Superfund site in New York for demonstration testing. Previous laboratory-scale tests of askarel fluids with contents up to 58 percent chlorine have produced DREs in excess of 99.9999999 percent. Handling contaminated soils for treatment would involve melting down the inorganic components and gasifying the organic components,

Full-scale operating costs have not been estimated by Pyrolysis Systems yet, Estimates made in 1983 for the prototype model showed operating costs of about $0.30 per pound of waste at a treatment rate of 1 gallon per minute and that capital costs would be $2 million to $2.5 million for a full-scale unit with an input feed of 50 gallons per minute. Labor costs have not been estimated, but it is known that three operators would be required to run the system. [Welland, Ontario, Canada; (416)735-2401]

12. Westinghouse Electric Corp., Plasma Arc Technol-Ogy.—Plasma arc technology has been described above under Pyrolysis Systems, Inc. Westinghouse has been a major developer of the torch systems incorporated in plasma arc furnaces and has developed a bench-scale reactor to test surrogate hazardous waste fluids, The surrogate material chosen for testing was 31 percent by weight hexachlorobenzene in a slurry made up of water (26 percent), alcohol (as an emulsifier), and kerosene (3 I percent). The researcher felt that the results for this surrogate would be similar to those of PCBs, (PCBs were not chosen because EPA approval is required to test with PCBs.] The results demonstrated the ability of the plasma technology to destroy hexachlorobenzene, dibenzofuran, and dibenzodioxin. In three tests the treatment product, analyzed by both a mass spectrometer and a gas chromatography, showed 0.13, 0.3, and 0.5 ppm of hexachlorobenzene. The latter substances were not detected at a 1 ppm resolution,

The company has recently begun an intensive 10-month testing program that they expect will answer any remaining questions about the new technology on a larger scale.

Preliminary cost estimates were made for a fixed plant treating 700,000 gallons of PCB liquids per year (assuming 7,000 hours of operation a year). Capitol cost was set at nearly $5.9 million, with total operating costs for one year at $2.8 million. These costs are now under revision, [Madison, PA; (412) 722-5000]

13. **Lockhead Missles & Space Co., Inc., Microwave Plasma Detoxification.—In** a microwave reactor, a plasma is generated by electrons subjected to microwaves. When used to decompose organic materials, a large number of complex reactions take place. Free radicals and atoms are produced from collisions of free elections with organic molecules. These species then react further to form secondary products.

The reactor effluent consists mainly of carbon dioxide and steam, with minor amounts of chlorine, hydrochloric acid vapors, and nitrogen oxides depending on the molecular structure of the material being destroyed. The hot gaseous plasma effluent is cooled, discharged through a caustic scrubber to remove acid products, and vented to the atmosphere.

Lockheed initiated a research program on applying this process to hazardous waste detoxification in 1975, By 1980 a bench-scale reactor (rated at 15 kilowatts) had been developed to a stage where both gases and volatile liquids could be fed into the system. The feed rate was 10 to 20 pounds per hour, and reaction time was on the order of 10 milliseconds.

Simulated wastes were used for testing the bench-scale reactor. For vinyl bromide, DREs ranged from 99.98 to 99.9998 percent and carbon tetrachloride, 99.72 to 99.94. For tests of aniline, toulene and 1,1,1-trichloroethane, results averaged 99.99 percent.

Lockheed has not compiled cost data for this project, which was primarily funded by outside sources (EPA and a Canadian firm). It seems, however, to be an expensive way of destroying hazardous wastes. In 1980, EPA withdrew funding and Lockheed abandoned the research before any demonstration took place, Technical and political issues also contributed to the project's termination. Included among the technical problems were feed rates too slow to be commercially viable, difficulties in proving DREs of six nines, and corrosion by HCl on the vaccum pump requiring an internal scrubbing system, Politically, Lockheed faced problems in acquiring permission from the local community to test real wastes. [Palo Alto, CA; (415)424-2593]

14. **RoTech Inc. (formerly Pedco), Cascading Rotary Incineration** System .—The RoTech technology is an incinerator whose cylindrical reactor unit rotates at 10 to 20 revolutions per minute (rpm), A conventional rotary kiln incinerator usually rotates at I to 3 rpm. This motion produces a cascading motion of the solids in the reactor (ash, unburned solids, and limestone residue) through the combustion gases, The high turbulence and solids-gas contact results in maximized heat transfer and optimal combustion kinetics.

The intimate contact between solids and gases also provides the opportunity to neutralize acid gases (e.g., HCl) by adding limestone to the combustion zone. The high combustion efficiency and acid gas removal eliminates the need for afterburners and acid scrubbers. Particulate are removed with baghouse filters.

The system includes air preheating and solid reheating by countercurrent flow with combustion gases. Combustion takes place between 1,2000 and 1,500° F (640° and 807° C).

RoTech's system could be applied to a wide range of organic wastes: solids (pre-treated if necessary for size consistency), gases, solid-laden gases, sludges, and liquids. Low heat value wastes (sewage sludge at 1,650 Btu per pound, for instance) can be incinerated without auxiliary fuel.

Combustion gas products include carbon dioxide, oxygen, and water. As mentioned above, acid gases produced from halogen compounds are reacted with limestone to produce salts. These solids, along with inert ash, are periodically removed from the furnace. Additional pollution control needs will be evaluated as testing proceeds,

At present, a pilot or small commercial size unit is operating on industrial and other wastes and has been tested on a sludge/emulsion, an acrylic emulsion, and a chlorinated aromatic waste. The DREs are expected to be high, better than 99.99 percent, but the data are not yet available. The technology is ready for full-scale application, and several units with 100 ton-per-day capacity are under design.

The installed cost for a system at the 35 million Btu per hour capacity level is estimated to be about $2,5 million; a 10 million Btu per hour unit is estimated to cost $1.5 million. Treatment costs are estimated to range from $70 to $150 per ton. [Cincinnati, OH; (513)782-4519]

15. **Midland-Ross Corp., Rotary Pyrolytic Incineration.—** The main objective of this system is to convert waste material from a disposal problem to a gaseous fuel source using pyrolysis. (Pyrolysis produces a product stream that contains a high-energy content by virtue of its hydrocarbon concentration.)

The treatment process begins with dried sludge being deposited onto a preheated, rotating hearth. When the sludge comes into contact with the hearth, its viscosity decreases and the material spreads out in a uniform, thin layer. Due to the absence of air, the material is pyrolyzed on the hearth. Volatile products are exhausted through a flue and the inert char materials that are left, mostly carbon and ash, are removed. The generated gases are combusted in a reactor at approximately 2,800° F in the presence of oxygen.

The prime candidate hazardous wastes for this system are organic sludges. Products of the process are a char and gas effluent from the energy conversion unit. The char is collected to prevent leakage to the atmosphere and must be shipped to a landfill.

Three types of wastes have been tested using this process: API waste, styrene waste, and rubber plant waste. All three are organic wastes containing various metals in amounts ranging from 0.1 to 1,000 ppm. Testing results have not been made available,

Preliminary economic estimates have been made for the processing of API and rubber wastes (styrene waste was not included because of poor test results). The estimates were made for a system that included waste storage, a feed system, the pyrolyzer, fume incinerator, and heat recovery. No costs were included for air pollution control, which could be necessary. The total estimated operating costs for the API waste is $894 per metric ton for a $440,000 system capable of processing 300 metric tons per year. For rubber waste, three systems were considered. At 1,000 metric tons per year, capital costs were estimated at $670,000 and operating costs, $526 per metric ton; at 2,000 metric tons, $920,000 and $296 per metric ton; and at 6,000 metric tons per year, $150 million and $117 per metric ton. [Toledo, OH; (419)537-6242]

16. **Waste-Tech Services, Fluidized Bed Incineration.—** The fluidized bed concept was described earlier under "Conventional Treatment Technologies. " Waste-Tech has extensive experience in such standard systems, having provided 45 commercial fluidized bed incinerators for nonhazardous waste disposal, They are now building two similar incinerators for hazardous waste treatment.

Solids, sludges, slurries, and liquids can all be treated with this system, although it is not very economical to treat liquids with a fluidized bed, Products of the incineration process are flue gases and ash, The contents of both are dependent on the input hazardous waste.

The ash generated is sent through a cyclone to remove particulate matter. Gases are then sent through a scrubber to remove the remainder of the particulate matter, A caustic neutralized wet scrub system can be used to remove HCl from the exhaust gases before release to the atmosphere. All noncombustible, inorganic wastes larger than the bed material are removed from the incinerator by a screening and recycling system. This material and particulate removed from ash and gases would have to be separately treated for any hazardous waste components.

Waste-Tech has tested chemical compounds as well as actual wastes in their pilot incinerator, Included have been fuel oil, carbon tetrachloride, tetrachlorophenol, pentachlorophenol, and phenol at concentrations ranging from 0.5 to 40,8 percent by weight. All of the components tested had DREs of at least 99.99 percent except for tetrachlorophenol (99.97 percent). Waste-Tech claims to have destroyed tetrachlorophenol up to 99.99 percent in subsequent experiments by raising the system temperature. Pilot-scale testing has also shown that DREs are inversely related to the feed rate.

The company estimates capital costs to be between $790,000 and $1.35 million depending on the size of the incinerator required (a site-specific factor). The smallest unit could treat about 2,500 tons of waste per year; the largest, 10,000 tons per year, The estimated operating costs for relatively small units range from $0.18 to $0.21 per pound of treated material, based on non-hazardous waste and include costs for labor, utilities, consumable, depreciation, cost of money, and permitting, [Idaho Falls, ID; (208)522-0850]

17. G. **A. Technologies, Circulating Bed Combustor.—** This circulating bed combustor is designed to be an improvement over conventional fluidized beds (see "Conventional Treatment Technologies"). It operates at higher velocities and with less and finer

sorbents than conventional systems, allowing for a unit that is more compact and easier to feed. The unit also produces lower emissions and an offgas scrubber is not necessary.

The key to the high efficiency (in terms of destructive power) of the circulating bed combustor is high turbulence, a large combustion zone with uniform and relatively low (less than 8500 C, or 1,5620 F) temperatures, and longer residence times.

This technology can destroy all types of halogenated hydrocarbons, including PCBs and other aromatics. It is capable of treating solids, sludges, slurries, and liquids containing such compounds as chlorobenzenes, acetonitrile, carbon tetrachloride, trichloroethane, sodium fluoride, tributyl phosphate, aniline, malathion, sodium silicates, and lead oxide. Wastes , however, must be homogeneous in composition when fed to the combustor.

Due to the relatively low operating temperature of the system, acid gases can be treated with lime scrubbing within the combustor, resulting in the release of lime salts. The low combustor temperatures, coupled with good mixing in the combustor, prevent extensive formation of NO_x.

More than 7,500 hours of testing have been completed using four pilot-scale combustors. The variety of wastes tested have included spent carboneous cathodes from primary metal plants, halogenated hydrocarbon solvents, phosphate bearing wastes from polymer production, and radioactive waste carbon from metals production. All tests showed efficient destruction of hazardous chemicals, low emissions of air pollutants (NO_x levels were 120 ppm or less), high combustion efficiency, and significant volume reduction. DREs exceed 99.99 percent for oily water sludge, chlorinated organic sludge, aluminum potlinings and PC B-contaminated soil. Chemical plant wastes showed DREs of greater than 99.9 percent.

The capital investment for a 25 million Btu per hour sludge incinerator, including a process steam generator, has been estimated at $2 million plus or minus 30 percent. A smaller, 6 million Btu per hour, incinerator is estimated at $1 million to $1.5 million plus or minus 25 percent. Operating costs vary widely depending on the wastes being destroyed. [San Diego, CA; (619)455-3045]

18. Rockwell International, Molten Salt Incineration.— Molten salt incineration is a method of burning organic material while simultaneously scrubbing the objectionable byproducts from the effluent gas stream. Materials to be burned are mixed with air and injected under the surface of a pool of molten sodium carbonate. The melt is maintained at temperatures on the order of 9000 C, causing the hydrocarbons of the organic matter to be immediately oxidized to carbon dioxide and water.

Rockwell's units are capable of being fed either crushed and sized solid material or liquid fuels. The pulverized solids, mixed with air being used for combustion, are injected into a stainless steel reaction vessel. The feed mixture passes through 6 inches of salt (in a bench-scale unit). Periodically, the inorganic materials that build up in the molten salt must be removed so that the bed can retain its ability to absorb acidic gases. Exhaust gases (carbon dioxide and water vapor] can be directed through a scrubber and/or baghouse, if necessary, to remove particulate before being released to the atmosphere.

The ultimate products of the molten salt process are carbon dioxide, water, various inorganic salts, and ash. The ash and any inorganic materials containing metals may be considered hazardous.

Although molten salt technology has been used by several companies to incinerate wastes, only Rockwell's system has been used to incinerate hazardous liquid or solid wastes. The company currently operates three sizes of units: bench-scale (feed rate of 2 pounds per hour), pilot-scale (up to 250 pounds per hour), and a production unit that is operated as a coal gasifier and has not been designed for hazardous wastes.

The bench-scale unit has been tested and shown to effectively destroy organic chemicals and wastes (DREs have exceeded 99.99 percent). No hazardous waste streams have been incinerated in the larger unit but since its bed depth is proportionally larger, it is reasonable to expect that its destruction efficiencies would be at least as great as in the bench-scale unit.

Cost estimates are not available for Rockwell's incineration system. [Conoga Park, CA; [818) 700-4887]

19. A. L. Sandpiper Corp., SEGAS Process.–SEGAS, or Sequential Gasification, converts incinerable solids, sludges, and liquid waste to a medium heat-value fuel gas. The process was developed in the 1970s to convert petroleum into more volatile products. Sandpiper is now testing the system for use on hazardous wastes typical of Superfund sites.

The basis of the SEGAS process is a pressure vessel operating at 1,2270 C [2,241 °F) and 200 psi. The reactants, the wastes, and superheated steam are continuously fed into a proprietary fluid bed reactor. Wastes are thermally decomposed, releasing hydrogen and carbon. The steam reacts with the deposited carbon to form carbon monoxide and additional hydrogen. This mixture of hydrogen and carbon monoxide—synthesis gas—is a fuel gas and basic raw material of the petrochemical industry. Chlorine and sulfur in the waste feed material react with the hydrogen within the reactor to form hydrogen chloride gas or hydrogen sulfide gas and are removed by conventional scrubbing technology. Solid residues will vary depending on the feedstream and scrubbing technology and must be landfilled if not delisted.

The process differs from conventional incineration in that it does not burn the waste and, therefore, no air of combustion is required in the system. The absence of air eliminates the necessity to contain, heat, cool, scrub, and discharge large volumes of nitrogen. The reactor and scrubbing system are substantially smaller than for conventional incineration of comparable waste streams.

Results of testing hazardous wastes are not yet available but Sandpiper claims that extensive testing of the technology has been conducted on a variety of heavy petroleum products and has demonstrated process efficiency. Separate testing of the fluid bed reactor showed high DRE capabilities. Integration of the reactor with the SEGAS process will occur in a 60 gallon per hour demonstration unit expected to be available by June 1985.

Sandpiper has designed a stationary or mobile unit (on a 40-foot trailer) to treat 600 gallons of waste per hour, They have projected capital costs for a stationary unit of $2.3 million and $2.2 million for the mobile unit. Operating costs will vary depending on the specific waste being processed. Sandpiper estimates that it will cost $0.03 per pound to process lower heat value, refractory materials (e.g., heavily chlorinated hydrocarbons). Costs do not include any offset from the sale of synthesis gas. [Columbus, OH; (614)486-0405]

20. **Detox Industries, Inc. (DTI), In Situ Biological Treatment.—This** is an assisted microbiological degradation process for the destruction of organic compounds. It will work either aerobically or anaerobically. In anaerobic conditions, an oxygenating agent is added. Chlorinated organics serve as the carbon source for the organisms and the process is more efficient in destroying toxic compounds if the carbon source is limited to the compounds of interest.

DTI developed its degrading microbe culture by selective adaption of known bacteria in the presence of various concentrations of PCBs. The organisms were conditioned to use PCBs as the sole carbon source. The biodegradation of 14,000 cubic yards of soil contaminated with pentachlorophenol has been completed, and PCBs (Arochlor 1260) have been treated in a 25,000 gallon tank. Treatment applied to several hundred thousand cubic yards of material can be expected to take months to complete.

The first step is to determine the parameters of the material to be treated. Contaminant concentrations, acidity, density, volubility, temperature, oxygen, and moisture content are important variables. Then a design is developed to most effectively stimulate growth and biodegradation. The process uses naturally occurring microbes, but is proprietary. To be effective, proper mixing of and contact between the microbes, waste constituents, and nutrient supply, along with control of environmental factors, must be maintained.

The process has been tested on PCBs and can be designed to be applied in situ to detoxify soils, sludge, lagoon contents, or can be designed to operate as a treatment process on or offsite. Degradation results in carbon dioxide, water, and cell protoplasm (new cells). After degradation is complete, the micro-organisms used in DTI's process die off and the original culture, or mix, of organisms becomes dominant again.

Demonstrations with DTI's process have used concentrations ranging from 46 to 2,000 ppm of PCBs and have achieved destruction efficiencies greater than 99 percent, Further work will fix the efficiencies more accurately and extend the range of chemicals.

Costs are highly site-specific, DTI has estimated that costs will range between $60 and $120 per cubic yard (about 1 ton) of material to be treated, depending on the initial concentration of contaminant and the matrix within which it is contained. [Houston, TX; (713)240-0892]

21. **Groundwater Decontamination Systems, Inc., Biological Degradation .—The GDS system takes** place onsite and aims to eliminate hydrocarbon and halogenated hydrocarbon contaminants from groundwater and soil through accelerated biodegradation by micro-organisms existing in the contaminated soil. It was developed by Biocraft Laboratories in New Jersey as a remedial technique for cleanup of their own property under a consent order and is now being marketed for use at other locations.

It is essentially a flushing and treating operation that must be specifically designed for the characteristics of each site and its contaminants, A pumping system is installed to remove contaminated groundwater from the site, The water is cycled through an activating tank, where the micro-organisms found in the water are enriched with compounds of phosphates and ammonia. From the activating tanks, the water is transferred to settling tanks and the treated water, rich in oxygen, nutrients, and micro-organisms is reinfected into the ground upgradient from the intake system. This permits biodegradation to occur in situ as well as in the tanks, The groundwater and soils are aerated through air injection wells to further increase the rate of biodegradation.

At the original site, groundwater was contaminated by leaking underground storage tanks, The contamination covered a surface area of 360 feet by 90 feet and extended below the surface to a depth of 10 feet. Biodegradation treatment was considered the most cost effective choice when compared with carbon absorption (too expensive) and ozone treatment (too ineffective), Measurements of the effluent indicate that removal of most of the contaminants to the desired level has occurred. Average removal efficiency for the system was greater than 98 percent for isopropyl alcohol, greater than 97 percent for butyl alcohol, greater than 88 percent for acetone, and greater than 64 percent for dimethyl aniline during the first 16 months of operation. In the following 7 months the acetone removal was increased to greater than 97 percent and dimethyl aniline to greater than 93 percent.

GDS claims that conventional methods might have taken 15 to 20 years cleanup time whereas their system will be completed in less than the 5 years originally estimated, and at a lower cost. At the New Jersey site, 12,000 gallons of groundwater are being treated daily at a cost of less than $0.02 per gallon. Total cost of the project has been placed at $859,000 including the original R&D costs of $453,000. [Waldwick, NJ; (201)796-6938]

22. SBR Technologies, Sequencing Batch Reactor.—The Sequencing Batch Reactor (SBR) has been under development by Professor R. L, Irvine of Notre Dame University over the past 15 years. Although initially intended for municipal wastewater treatment, the technology recently has been shown to be applicable to treat contaminated groundwater and hazardous waste leachates.

The SBR has several virtues that overcome the traditional disadvantages of biological treatment. For example, the SBR has been shown to be relatively insensitive to changing feed characteristics, including loading rates. It is not as susceptible to shock loadings; it selects for the proper micro-organism in a mixed population; and it combines all treatment functions in only one tank, a definite economic advantage,

The reactor does in time what traditional biological process technology does in space with sequential tanks. There are five periods in its operation: fill, react, settle, draw, and idle. During fill, wastewater is charged to the reactor, and during react the biological processes started in fill are continued, Aerobic, anoxic, or anaerobic conditions can be created during the fill and react periods. During settle, the micro-organisms are allowed to settle to the bottom of the tank, and during draw the supernatant treated water is removed. Idle is a short time where the reactor is awaiting the next batch of feed. The five time periods can be adjusted for optimum removal efficiencies for varying types of wastes.

Two full-scale demonstration SBR plants exist: one in Indiana treating municipal waste and a 250,000 gallon per day facility at the Cecos site in Niagara Falls treating hazardous waste. The project at Cecos is cofunded under a demonstration contract with the New York State Energy Research and Development Authority and in part by Jet-Tech., manufacturer of SBR's aeration and decant system, A computer controls all phases of the treatment process, Laboratory studies show that the SBR can achieve 70 to 80 percent removal of organic materials and 98 percent removal of phenol, A carbon adsorption system has been added as a secondary treatment method to achieve higher removal levels.

This may be quite a cost-effective approach to the destruction of hazardous leachates, especially when coupled with some form of carbon treatment. Production of biomass or sludge is a potential disadvantage; however, natural decomposition seems to circumvent the need for frequent sludge removal. [Mishawaka, IN; (219)236-5874]

23. **University of Gottingen, West Germany, Biological Degradation of Chlorophenols.—W/est** German researchers have developed several bacterial strains that are capable of degrading chlorophenols. The process has been tested on synthetic sewage containing phenol, acetone, and alkanols plus 4-chlorophenol or a mixture of isomeric chlorophenols. One particular bacterial strain completely degraded the chlorophenols in the synthetic mix. The release of chloride and a low content of dissolved organic carbon in the cell-free effluents indicated total degradation of the organic carbon. During adaptation to high loads of chlorophenols, hybrid strains were detected that were determined to be even more competitive than the original strain for the degradation of chlorophenol.

The research has also shown, however, that the presence of additional organisms capable of degrading the phenol, acetone, and alkanols in the mix caused incomplete degradation of the chlorophenols. Thus, the approach, while considered well defined, is valid only for one organism at a time.

24. Battelle Pacific Northwest Laboratories, In Situ Vitrification.—In situ vitrification classifies contaminated soils in place while the organic waste constituents contained within are pyrolyzed, The gases from the process combust when they rise above the soil and contact the air.

The area to be treated is heated (between 1,100° and 1,600° C) electrically, melting the soil, As the soil is heated, the molten zone grows outward and downward approaching temperatures of 2,0000 C. The high temperatures and long residence times result in essentially complete combustion and destruction of the organic components. An offgas hood is placed over the soil to catch small amounts of hazardous elements, The effluents are directed to an offgas treatment system in a mobile semitrailer. The effectiveness of the gas capture system is not proven,

Cooling takes several months and depends on the size of the mass produced. After cooling, the vitreous mass may be covered with clean fill. The mass is a containment system that could be enhanced by the addition of engineered barriers,

This process was originally designed for radioactive wastes. Tests have been conducted on various metals (e. g., cobalt, cadmium, lead) as well as carbon tetrachloride, tributyl phosphate, bibutyl butylphosphate, wood, plastics, and other organic compounds. Bench- and pilot-scale tests have been conducted on soils contaminated with metals and organic wastes. While organic materials will be destroyed by the process, metals are encapsulated, The cost of the process increases as the liquid content of the waste increases.

All residues are contained within the vitreous mass that remains in the ground. Air emissions are controlled by the offgas system, which includes a scrubber, a water separator and condenser, and particulate air filters,

Battelle has estimated costs and the major variables are soil moisture and cost of electric power. In five different scenarios, costs ranged from $4,60 to $6.30 per cubic foot ($161 to $224 per cubic meter) of soil vitrified, (Soil was vitrified to a depth of 5 meters in each case.) Calculations included site preparation, annual equipment charges, operational costs (labor), and consumable supplies such as electrical power and electrodes. [Richland, WA; (509)375-2927]

25. Lopat Enterprises, K-20 Chemical Treatment.—The patented agent K-20 was developed to seal surfaces against water intrusion. It was found to be a fire retardant and to have the ability to encapsulate a number of toxic chemicals, K-20 is a mixture of potassium silicates and other materials, is said to be safe and nontoxic, can be varied to meet different objectives, and can be used in conjunction with cement and other inorganic agents. Unlike conventional chemical fixation and stabilization products, K-20 appears to be effective on organic as well as inorganic toxic materials,

The product is applied to surfaces after being mixed with a catalyst, Little technical expertise is required to apply it once an effective formulation has been developed for a particular application. The product can penetrate porous materials of any sort to considerable depths.

K-20 has been used commercially to a limited extent on building surfaces contaminated with either PCB or chlordane. In both cases, readings on contaminated surfaces and in the air after application of K-20 have been brought down to the nondetectable level. Lopat Enterprises is pursuing studies to determine exactly how K-20 works on organic toxic chemicals. Questions have been raised about how long the chemical encapsulation will be effective. The company maintains that the base silicates it uses have been used for other purposes for many years and that its product should be effective for at least 50 years. The product has also been used effectively on buildings with asbestos contamination. In this case, microscopic evidence shows that K-20 penetrates deeply and coats asbestos fibers so that they are not friable or suspendable in air,

The company also has laboratory test results on contaminated soil. When mixed with portland cement and soil with a lead content of 200 ppm, K-20 reduced the measured lead level to 0.1 ppm according to EPA's EP Toxicity test. The product was recently tested on dioxin-contaminated soil from Missouri. For a sample of soil containing 174 ppb of dioxin, treatment with K-20 at levels of 5, 10, and 20 percent by weight resulted in a finding of less than 1 ppb, the limit of detection. Proponents say that contaminated soil could easily be treated in situ or in other ways. After treatment, the soil is an inert, friable material.

Research is also planned for introducing K-20 into materials used for below ground barriers for groundwater, such as slurry walls, to reduce attack or penetration by organic toxic chemicals. There is also potential for the product to be used with liquids in uncontrolled surface impoundments to form solid harmless materials.

Although precise cost data is not available, costs appear quite low. Cost depends on how much of the product is necessary, and that depends on a number of factors such as the nature of the contaminated material, the contaminants, and the need for additional agents such as cement. For treatment of contaminated soils, some equipment would be necessary to achieve thorough mixing of K-20 and soil.

The company is a small business that has faced difficulties obtaining funds for RD&D. Thus far all its work has been self-supported. [Wanamassa, NJ; (201)922-6600]

26. New Materials **Technology Corp., Fujibeton Encapsulation.**—Fujibeton is an inorganic polymer that has been shown to chemically bond with and physically encapsulate both inorganic and organic toxic compounds. It has been used in large hazardous waste treatment projects in Japan. The product was developed by Fujimasu Synthetic Chemical Laboratories in Tokyo, and New Materials Technology Corp. is its exclusive manufacturer and distributor in the United States. The technology's supporters claim over 10 years of successful application in Japan.

Fujibeton is an advanced form of cement, [Concrete, which results from the reaction of water, cement, and aggregate is a relatively primitive example of an inorganic polymer.) It is able to improve the bonding properties and cross-linking abilities of silicate macromolecules. The result is to greatly reduce the release of hazardous chemicals from the treated materials. The combination of compounds and the nature of the bonding mechanism of the process are proprietary.

New Materials Technology foresees several applications in the hazardous waste area for their product. For remedial action, its prime use would be to treat and immobilize hazardous wastes in solid, sludge, and liquid forms. Liquid wastes must be first mixed with an absorbent, such as fly ash. The solidified end product can be reduced to a granular form without substantially reducing its effectiveness. Treatment can take place onsite with simple equipment (e. g., a concrete mixer).

An example of a successful application in Japan was the treatment and stabilization of PCB-contaminated sludges and sediments found in the harbor of Takasago West Port, Prior to treatment the sludge contained 450 milligrams per kilograms (mg/kg) of PCB plus 91 mg/kg of lead and 0.02 mg/kg of mercury. Leachable concentrations after treatment were 0,003 milligrams per liter (mg/1) of PCB, 0.01 mg/1 of lead and 0.0005 mg/l of mercury,

Two remedial action projects are planned for 1985 in Japan using Fujibeton. Up to 763,000 cubic yards of contaminated material will be dredged from the bottom of Waka River which has been polluted over a long period of time with *a* whole range of industrial wastes. After treatment, the stabilized material will be used as a landfill for a new industrial site for Sumitomo Heavy Industries. At Lake Biwa, the largest inland lake in Japan, 25.5 million cubic yards of contaminated sediments will be treated in place to improve the water quality to an acceptable drinking level, The lake serves as the main source of water for the Osaka-Kyoto area with a population of 13 million.

Several tests have been conducted on the effect of applying Fujibeton to a variety of hazardous wastes, both organics and metals. In one University of Arizona test, an electroplating sludge was treated; and the resultant material underwent the standard EPA EP Toxicity test. For all metals present, the extractable metal concentrations from the treated/stabilized material were one to two order of magnitude below the maximum allowable. For instance, lead ranging from 360 to 690 ppm was reduced to 0,5 to 0,36 ppm; chromium, from 37 to 100 ppm to 0.8 to 0.35 ppm; and cadmium, from 1.7 to 2,9 ppm to an undetectable level. Similar results occurred when material from a toxic waste dump at Bridgeport, New Jersey, was tested. In addition, in the latter case the organics orginally present were not detectable in leach tests on the treated samples. Comparative leach testing against conventional technologies (cement/soluble silicate and portland cement) have shown Fujibeton to be superior.

There are no capital costs associated with the use of this encapsulation technology, Material costs for the treatment of contaminated soils vary depending on the amount of Fujebiton required (5 to 15 percent) per pound of soil and the overall size of the project. The amount required varies depending on the level and type of contamination, and the unit cost ($0.15 to $0.25 per pound) decreases as the project size increases, For instance, a project treating 50,000 tons of soil and consuming 10 million of pounds of Fujebiton (at 10 percent per pound of soil) would cost from $30 to $50 per ton of soil. The treatment process would consist of three steps: 1] excavation of the soils, 2) mixture with Fujibeton, and 3] cure and subsequent disposal as nonhazardous fill back into the original excavation. [Wichita, KS; (316] 683-8986]

SUPPORT OF CLEANUP TECHNOLOGY RD&D

Introduction

Research and development can lead to better ways of tackling Superfund remedial action problems. Compared to existing cleanup options, R&D can improve the range of applicability, the effectiveness, and the reliability of technology and also reduce costs. Hazardous waste problems at any one Superfund site can range from one to many, and a technology may be *applicable* to only a specific waste and form, A technology is *effective* when it achieves remedial action objectives and is *reliable* if it is effective under operating conditions and has the ability to maintain its effectiveness over the long term.

The design and development of innovative technologies are conducted within the private sector with little assistance from the Federal Government. The Federal Government funds Superfund-related R&D programs in EPA and in the Department of Defense (under its Installation Restoration program). Within EPA the amount of funds for the support of Superfund technologies has been relatively small and narrowly focused. For example, while over 50 percent of EPA's total R&D budget has been spent on contracts and grants during the last 5 years, only a fraction of the total (4 percent in fiscal year 1985) has been dedicated to the Superfund program and only a portion of that to cleanup technologies.[35] Most of the research contracts awarded by EPA under Superfund seem to complement internal activities rather than provide for the influx of new ideas.

In what may prove to be a more relevant link between research and technology, the National Science Foundation (NSF) in October 1984 provided seed money for an Industry/University Cooperative Center in New Jersey that will concentrate on hazardous and toxic waste research.

[35] According to a summary sheet prepared by the Congressional Research Service in October 1984, a total of $307 million was appropriated for R&D at EPA for fiscal year 1985; $202 million is for grants and contracts, $9 million of which is for Superfund.

EPA Technology Research and Development

Because Superfund has been considered a short-term program, EPA has not followed the normal research and development process of concept development, laboratory evaluation, pilot testing, and field demonstration. Instead, the program has been one of:

> . . . technology assessment to determine cost and effectiveness, adaptation of technologies to the uncontrolled waste site problem, field evaluation of technologies that show promise, development of guidance material for the EPA Office of Emergency and Remedial Response (OERR), technical assistance to OERR and EPA Regional Offices.[38]

Short-term thinking and an original interpretation by EPA that CERCLA excluded expenditures for basic research has concentrated activity on applied research, such as adapting existing construction engineering technologies to improve disposal practices and evaluating containment and incineration technologies, This policy, compounded by an initial belief that existing technologies could indeed solve Superfund problems (i.e., innovation was not *required)* has resulted in little if any emphasis on basic research and innovative approaches.

There are some signs that this attitude is beginning to change within the EPA R&D system, but only evidence of a shift in funding levels in the next few years will confirm a real shift in commitment. In 1985, new emphasis will be placed on innovative approaches, such as in situ technologies and onsite treatment.[37] According to a recent report, EPA is now beginning to look at the prevalant wastes found

[36] Ronald D. Hill, U.S. Environmental Protection Agency, "Promising Site Cleanup Technology," paper presented at *Superfund Update: Cleanup Lessons Learned,* Schaumburg, IL, Oct. *11-12, 1983*. Similar statements were made in 1984 at EPA's *Tenth Annual Research Symposium: Land Disposal of Hazardous Waste.*

[37] Ronald Hill, *director,* Land Pollution Control Division, Office of Research and Development, U.S. Environmental Protection Agency, personal communication, Dec. 14, 1984.

at Superfund sites and to attempt to match them with the best treatment technology.[38]

R&D Funding

The total EPA R&D budget during each of the Superfund program's first 5 years is shown in table 6-8, with a comparison of the amounts dedicated to Superfund and Hazardous Waste activities.[39] Over the 5-year period, only about $50 million has been spent on Superfund R&D, a small fraction of the $1.6 billion Superfund program.

The R&D amounts for the Superfund program are modest when compared with the total EPA R&D budget and with what many observers think is required to adequately support the development and assessment of technology to handle Superfund problems.'" The *Superfund R&D budget for fiscal year 1985 represents about 4 percent of the EPA R&D budget, while the Superfund program represents 35 percent of the total EPA Operating Budget request.*[41]

The R&D funds are budgeted under the Office of Research and Development (ORD) and within ORD divided as shown in table 6-9. At most, about half these funds are related to R&D in cleanup technologies. The EPA budget, as shown in table 6-8, also allocates R&D funds under hazardous waste (13 percent of R&D in fiscal year 1985) for RCRA-related activities, Some of this R&D, as well as that conducted under other programs is relevant to Superfund program needs. But only the funds committed under Superfund consider remedial action technology per se and are dedicated to solving Superfund's special problems.

R&D Activities

Superfund and RCRA R&D within ORD were reorganized in late 1984 to more closely link the activities of the two programs. R&D objectives that deal with technology are primarily the concern of the ORD's Office of Environmental Engineering Technology and its Hazardous Waste Engineering Research Laboratory (HWERL), HWERL'sS Land Pollution Control Division (through its Containment Branch and Releases Control Branch) and the Alternate Technologies Division deal with Superfund-related technology investigations. The Containment Branch is responsible for research in the area of remedial action (also for RCRA); the Releases Control Branch for emergency removals. The Alternate Technologies Division now conducts research in incineration, chemical and biological technologies, primarily those applicable under RCRA.

The Releases Control Branch work is divided into three areas. The goal of the *personnel health and safety* program is to develop protective equipment and procedures for personnel working in known or suspected dangerous environments. Efforts under *removal technol-*

Table 6-8.— EPA R&D Budget (millions of dollars)

Fiscal year	Superfund	Hazardous Waste	Overall[a]
1981 ....., ...	4.7	21,9	303.0
1982 ...., .	13,8	29.2	314.6
1983. , ...	6.9	33.4	228.5
1984 [b].	9.0	33.5	250.0
1985 [b].	12.7	40.7	306.0

[a]Includes funds for Superfund and Hazardous Waste plus Air, Water Qual W, Drinking Water, Pesticides Radiation Toxic Substances Energy, Interdisciplinary, and Management categories
[b]Estimated

SOURCE U S Environmental Protection Agency, Off Ice of the Comptroller, Decem be r 1984

[38]Theresa Hitchens, "Public Push for Alternatives to Land Disposal Years Ahead of Research, " *Inside E. P. A.*, Feb. 15, 1985, pp. 12-13.

[39]EPA b...ks down its R&D budget into 11 *media* categories: air, water quality, drinking water, hazardous waste, pesticides, radiation, interdisciplinary, toxics, energy, management, and Superfund. Each of these media are subsequently broken down into various *program elements* and program elements into *objectives*.

'According to an internal EPA memo dated Dec. 3, 1980, from Alvin R. Morris, director, Superfund Task Force, projected Superfund program costs are dependent on the number of NPL sites. Under this scheme, Superfund R&D should total $115.5 million for 1,000 sites, $152.4 million for 1,400,$1893 million for 1,800, and $226.1 million for 2,200 sites. As of late 1984, NPL sites totaled 538. This would argue for a Superfund R&D budget of about $90 million.

[41]U.S. Environmental Protection Agency, *Summary of the 1985 Budget* (Washington, DC: Office of the Comptroller, January 1984).

Table 6-9.—Superfund R&D Budget (millions of dollars)

ORD Office	FY84	FY85	Primary objectives
Environmental Engineering Technology.	3,7	6.3	Control technology, technical support
Monitoring Systems and Quality Assurance	3,7	4.9	Site assessment, quality assurance
Health and Environmental Assessment	1.0	1.3	Site assessment, technical support
Environmental Processes and Effect Research	0.5	0.2	Site assessment
Total[a]	8.9	12,6	

[a]Figures may not add to totals due to rounding

SOURCE U S Environmental Protection Agency, Office of Research & Development, December 1984

ogy center on demonstrating equipment for hazardous spill control. Under this program a mobile incinerator, carbon regenerator, and soils washer equipment are being modified, adapted, and field tested. The *chemical countermeasures* program is concerned with the use of chemicals and other additives that are intentionally introduced into the open environment for the purpose of controlling hazardous contaminants,

The activity of the Containment Branch includes: 1) the survey and assessment of current technologies, 2) field demonstration and verification of techniques, and 3) site design analysis. The first activity is a followup to remedial actions that have occurred, reviewing and evaluating techniques that have been applied at Superfund sites, Techniques identified as having "potential for being cost effective" or those being installed as part of a remedial action are given field testing and evaluation. For example, the block displacement method of isolating hazardous wastes has been field tested and a particular slurry trench installed at a New Hampshire site has been given field evaluation. The third category, which involves the publication of technical handbooks to guide those handling site design analysis, is an outgrowth of the data collected and analyzed in the first two areas of activity.

Specific projects under both branches can be broadly classified as either pertaining to treatment or containment technologies and include:

- *Treatment.* Development of: 1) a mobile soils washing system that can be used to treat excavated soils onsite, 2) mobile and modular incineration systems for field use to destroy hazardous organic substances collected from cleanup operations at spills or at uncontrolled hazardous waste sites, and 3) a trailer-mounted system for the onsite regeneration of spent granular, activated carbon from carbon adsorption systems. In addition, bench-scale testing of a number of leachate treatment processes will be conducted and the Chemical Countermeasures Program mentioned above is underway.
- *Containment.* Evaluation of installed slurry systems and low-permeability covers, pilot-scale tests of injection grouting, assessment of the feasibility of retrofitting membrane liner systems to existing surface impoundments, development of the criteria for evaluating the use of permeable materials as hazardous waste control mechanisms. Development and evaluation of a prototype full-scale process and equipment for encapsulating corroding 55-gallon drums of hazardous waste. The investigation of asphalt encapsulation techniques to improve the leachate quality and act to reduce the hazardous nature of some sludges.

The Alternative Technologies Division now incorporates activities evaluating fixed incineration systems that were ongoing under the previous Industrial Environmental Research Laboratory. The division is funded ($8.8 million in contract funds in fiscal year 1985)[42] from the RCRA R&D budget and consists of two branches: the Thermal Destruction Branch, which will continue with the above incineration program, and a Chemical and Biological Technology Branch. The division's primary emphasis is ap-

[42]Clyde Dial, director, Alternative Technologies Division of the Office of Research and Development, U.S. Environmental Protection Agency, personal communication, Dec. 13, 1984.

plied research on industrial hazardous waste streams although some fundamental research is conducted in such areas as combustion (e. g., minimization of PIC formation) and genetic engineering, Although this division is RCRA-oriented, many of its activities could have applicability to Superfund, The group has cooperated with various States that wish to evaluate innovative technologies. In a project completed with the State of California, EPA paid for the sampling and analysis of molten salt, fluid wall, and wet oxidation processes. *Emphasis on this type of program could help generate standardized data collection to be used for the development of protocols for testing of new technologies.*

Grants and Contracts

One of the major ways that technology transfer occurs between the private sector and EPA is through the grants and contracts awarded by EPA, That portion of the R&D budget totals $201.8 million for fiscal year 1985 (66 percent of the overall R&D budget). The funds are spent under a grants program, a centers program, and by contracts let through the laboratories of ORD. Due to the Small Business Innovative Development Act of 1982[43] at least 1 percent of these funds must be spent to support small business R&D.

The agency's Small Business Innovative Research (SBIR) program was set up within ORD in November 1982. Once a year, it solicits bids on a dozen or so topics considered to be of interest to EPA, Twelve topics were listed in the 1984 offering, a number of which are directly related to Superfund cleanup technology R&D. Included were improved stability of containment mechanisms; organic waste/containment liner compatibility; biotechnology applications for hazardous waste control; advanced thermal, chemical, and physical methods for hazardous waste destruction; methods for soil and aquifer decontamination; and innovative volatile organic compound control methods. To participate, a firm must first apply for a Phase I contract to show the scientific and technical merit and feasibility of its idea. Following successful completion of Phase I, a firm can apply for a Phase II contract to further develop the proposed idea. In the first year of the program (fiscal year 1983), 10 Phase I projects were funded for a total of $248,000. Ten Phase I and five Phase II projects (at about $100,000 each) were funded in fiscal year 1984 at a total cost of $856,000. In fiscal year 1985, the SBIR program expects to spend $1.9 million. Six to eight Phase II projects will be funded at about $150,000 each, along with Phase I projects at about $48,000 each.

The SBIR program is considered by the private sector to be the prime source of financial assistance for R&D in Superfund-related innovative technologies, but it has its drawbacks, First, due to SBIR's once-a-year funding cycle, a firm must wait a full year to obtain follow-on (Phase II) funding. An option that would be more conducive to the private sector business climate would be to allow Phase II funding to proceed directly following the completion and evaluation of a Phase I project. Second, the size of the awards may not be consistent with private sector costs of R&D.

Most of EPA's basic research is funded under its grants program in ORD which has a 1985 budget of $12.2 million, The monies can be used by nonprofit entities only. General guidelines are provided in an annual proposals list covering five program areas: environmental health, environmental biology, environmental engineering, and physical/chemical measurement of air and water. Due to the initial decision by EPA that Superfund monies cannot be expended for basic research, grants are not awarded for research specifically related to Superfund. Undoubtedly some of the research will eventually benefit Superfund but it is difficult to measure how much. (Possibly about 10 percent of the work funded under the environmental engineering category will eventually benefit Superfund.)[44]

[43] Public Law 97-219, July 1982.

[44] Clarise Gaylord, director, Grants Office of the Office of Exploratory Research of the Office of Research and Development, U.S. Environmental Protection Agency, personal communication, December 1984.

The centers program was set up within ORD in 1979 in response to criticisms regarding EPA's concentration on short-term research. EPA developed eight themes needing support in fundamental research, and eight centers based on these themes have now been funded through cooperative agreements at various universities. Each center receives about $500,000 per year from EPA (out of ORD's R&D budget) and is expected to supplement its income from other public and private sector sources. The results of the research conducted by the centers are disseminated through peer review journals and publications.

Three of the centers conduct research that may have a bearing on Superfund needs: the Hazardous Waste Center at Louisiana State University, the Center for Advanced Environmental Control Technology at the University of Illinois at Urbana, and the Industrial Hazardous Waste Elimination Center at the Illinois Institute of Technology in Chicago. Of the three, the Hazardous Waste Center is most germaine to Superfund technology needs. Its research focuses on ultimate disposal and landfill techniques and destruction technology.

At Tufts University in Massachusetts, EPA has funded at the specific request of Congress the Center for Environmental Management, So far, $3 million have been appropriated for the Center; $2 million in the fiscal year 1983 supplemental appropriations bill for EPA and $1 million in the fiscal year 1984 supplemental appropriations. This program is outside of the Centers Program, and its grant money does not come from ORD's R&D budget, This "national research, education, and policy center" is applying a multidisciplinary research approach to link environmental research, technology, and public policy issues.[45] The chairman of EPA's internal Hazardous Waste Committee oversees the Center's research program, and efforts are made both by EPA and the Center to coordinate its research with that ongoing within EPA and with the activities of the centers program.[46]

[45]Anthony Cortese, director, Center for Environmental Management, persona] communication, December 1984.

[46]Mathew Bills, EPA program manager for the Center fOr Environmental Management, personal communication, December 1984,

Of the first $2 million appropriated, six research projects were funded by the Center for $330,000. (The balance of the funds were spent on planning and setting up the Center.) One of these projects, investigating a new method for groundwater monitoring using laser fluorescence fiber optics, is relevant to the Superfund program. A proposal will be made by the Center in 1985 to use the remaining $1 million appropriation to set up a comprehensive research project dealing with an actual Superfund site, An investigation of innovative cleanup techniques and followup assessment of their effectiveness is expected to be part of this project.[47] This prospect has the potential to make a substantial contribution to the Superfund program,

Support for the Private Sector

Outside contracting by the EPA laboratories and program offices could be a source of support for private sector R&D efforts. The established contract procedures, however, apparently inhibit participation because they do not offer a mechanism for handling unsolicited *proposals* from the private sector, Thus, if a firm is seeking financial assistance for R&Don its particular technology, it must be able to mesh its requirements with those established by an EPA Request For Proposal.

From EPA's point of view, funding an unsolicited proposal constitutes single source procurement and EPA is loath to being viewed as supporting any particular firm or technology over another, This appears to be a critical barrier to the adoption of innovative technologies, EPA is the *buyer* of technologies under Superfund; yet if a technology has not been evaluated by them and testing methods declared acceptable, it will be eliminated from consideration during the FS process of evaluating a Superfund site, (The situation may not be much different for cleanups financed in other ways.) Re*moving this barrier will require an active demonstration projects policy on the part of EPA.* Lately, EPA has made attempts to correct this situation and to devise ways to handle the large volume of unsolicited proposals that it receives.

[47]Cortese, personal communication, op. cit.

However, the amounts dedicated have been relatively minor and the decision process is slow,[48]

According to one EPA official,[49] demonstration projects to test commercially developed, new technologies under actual Superfund site conditions are hampered for three basic reasons: 1) EPA's existing R&D funding levels are not sufficient to cover the costs; 2) demonstration projects have required RCRA permits that are not obtainable without testing data the demonstration is intended to provide; so and 3) demonstrations conducted on Superfund sites can run against public sentiment, which wants cleanup activity to proceed quickly.[51]

The Land Pollution Control Division initiated a demonstration program in 1984 ($150,000 was offered for two solicitations), and starting in 1985 it will begin an annual program, In 1985, with a maximum budget of $750,000, three to ten projects will be selected and testing will be conducted to develop protocols. A set of demonstration projects are planned for 1985 and the next 5 years by the Releases Control Branch, They are seeking technologies for use in removal actions where short-term response and mobility are key criteria. The initial year's effort has a maximum budget of $250,000; the following years will be funded at about $400,000 per year. Not all of the monies will necessarily be spent, however. Actual spending levels will be determined by the quality and appropriateness of the solicitations.[52]

The programs will be run on a cost sharing basis with the selected technology firms. Each firm is expected to provide the complete hardware (late pilot or full scale), pay for the operation of tests, and obtain the necessary permits. EPA will help design the testing programs, provide quality assurance and quality control, and offer an independent evaluation of the results. Because of the potential high cost of this program to firms, only those firms with substantial financial resources will be able to participate. Accordingly, these demonstration programs are designed not to provide financial assistance, but to give firms access to appropriate testing materials and to result in recognized testing results that will enable them to market their technology.

In comparison to the above-mentioned funding levels for demonstration projects and indicative of the *real* **costs** involved, EPA is planning to spend approximately $3 million ($2 million from the Superfund budget and $1 million from R&D) in 1985 to run test burns at the Times Beach area in Missouri on its *own* mobile incinerators' Technology firms have told OTA that demonstration costs can range from several hundred thousand to a million dollars for one test burn.

Department of Defense

The Department of Defense has been given the authority to conduct all hazardous waste cleanups on military bases, and the Installation Restoration (IR) program has been set up to parallel EPA's Superfund program, Although the program has been in existence for about 7 years, only in the last 2 years has it received emphasis within DOD.

Under this program, the U.S. Air Force is taking the lead in R&D activity with a $12.1 million budget in fiscal year 1985 (an increase of **$10.8** million over 1984). Included are projects

[48]The Alternate Technology Division, for instance, soli Cited bids for "ideas" in 1983. out of 27 proposals received, 2 projects were selected and funded in the fall of 1984. The total budget for the program is $300,000 for processes considered to be at the demonstration stage. *One* demonstration project can easily cost a firm $500,000 or more.

[49]Hill, personal (communication, op.cit.

[50]Provisions in the RCRA legislation passed by the 98th Congress may reduce this barrier. Under Subtitle B, EPA is authorized to issue special RD&D permits for any hazardous waste treatment facility which proposes to use an innovative and experimental hazardous waste treatment technology or process for which permit standards have not been promulgated. One technology firm commented to OTA that, while they were extremely pleased to see this provision, they were worried that the vagueness of the wording would cause EPA to be extremely cautious in using it.

[51]To avoid this potential problem, two Land Pollution Control Division demonstration projects will proceed in 1985 in cooperation wit h the U. S Air Fore e on Federal la rids. I n Texas a microbial process will be tested on contaminated soils: and i n Wisconsin, EPA's mobile soils washer,

[52]Mary Stinson, EPA project officer, persona] communication, Dec. 13, 1984.

[53][44] EPA to Conduct Dioxin Test Burns in Missouri," *Hazardous Wastes Report,* Jan, 7, 1985.

to develop technologies to clean contaminated groundwater. The U.S. Army will spend $2.7 million in fiscal year 1985 to develop treatment technologies for contaminated soil/sediment, water, and buildings; containment systems; and methods to recover energy and materials from hazardous waste. This program is projected into the 21st century.

National Science Foundation

NSF awarded a 5-year grant of $350,000 in October 1984 to set up the Industry/University Cooperative Research Center for Hazardous and Toxic Waste at the New Jersey Institute of Technology in Newark. In addition to NSF, the Center is sponsored by private industry (a dozen or so companies have paid an annual fee of $30,000 each) and academic institutions. It has also received a grant of $1.2 million from the State of New Jersey.

The goal of the Center is to help bridge the gap between governmental requirements and the needs of industry. Its research goal is to advance the state of engineering management of hazardous and toxic waste. According to its director, the Center has an annual budget of $2 million and has already solicited bids under specific research topics.[54] Included are a number of research projects relevant to Superfund technologies, such as the incineration, biological/chemical, and physical treatment of hazardous wastes. Many of the projects are planned to proceed to the pilot stage.

State Efforts

Efforts by individual States to assist in RD&D for Superfund technology are hampered by a lack of funding and a need to be able to prove that any monies spent are directly applicable to specific State problems. Their first priority is cleanup itself, and often funding for this purpose alone is difficult to appropriate. However, some States do offer support to RD&D and a few examples are presented below.

As the result of a comprehensive study of hazardous waste management in Illinois, in 1984 the State created a Hazardous Waste Center within the Illinois Department of Energy and Resources. It will be supported by the State hazardous waste tax and general revenue funds. The Center, which is to take a broad view of the hazardous waste problem from generation to cleanup needs, will focus on technology-based applied research and technology transfer.[55] The State of Pennsylvania has a similar program,

Missouri has turned part of its Times Beach dioxin-contaminated area into a research facility, The objectives are: 1) to identify those technologies that have potential to detoxify dioxin-contaminated material; and 2) to compare different, successful technologies for their ability to solve the State's extensive problem with dioxin-contaminated soils. Plots of contaminated soils are made available to firms to test their techniques, and some of the infrastructure (e. g., water and power connections) is provided. The cost for leasing a plot is a one-time fee of $16,500 and is meant to cover the cost of the State's sampling and analysis program,

New York has underway a project to assist in the development and demonstration of a plasma arc technology for use at Love Canal to treat organic sludges. The project is now budgeted at $1.5 million and while EPA is contributing to the cost, the State's share is over 50 percent.

Private Sector

As the previous "Innovative Technology" section shows, a wealth of new technology ideas is being generated by the private sector. Two fundamental problems are faced by this group, however, in moving these technologies along the long path toward commercialization: 1) an initial difficulty in obtaining seed money to continue the R&D process beyond the first few tentative steps; and 2) overcoming the barriers to the adoption of these technologies, primarily through the ability to demonstrate their worth, These, and other barriers have been discussed above and in a previous section of this chapter,

[54] John W. Liskowitz, personal communication, Dec. 12, 1984.

[55] James Patterson, Chairman, Pritzker Department of Environmental Engineering, Illinois Institute of Technology, personal communication, Dec. 18, 1984.

Chapter 7
Achieving Quality Cleanups

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Achieving Quality Cleanups

INTRODUCTION

This chapter considers the challenge of assuring timely, environmentally sound, and cost-effective remedial work at Superfund sites. The chapter first identifies several major problems affecting the quality of work at Superfund sites. Second, it examines technical oversight of cleanups. Good *technical oversight is a key to a successful Superfund program*. Finally, because competent, trained technical specialists from many fields are critical to a successful national cleanup program, OTA looks at current and projected needs for technical specialists. Bottlenecks that might slow the program or reduce its effectiveness are discussed.

PERFORMANCE AT SITE CLEANUPS

Based on a broad examination of the Superfund program and on several engineering case studies at NPL sites, OTA has evaluated the performance at site cleanups. The analysis found problems with designing and building long-term, effective measures to control releases of hazardous substances, The three sites studied were: Stringfellow Acid Pits, Glen Avon, California; Seymour Recycling Corp., Seymour, Indiana; and the Sylvester Site, Nashua, New Hampshire, (See chapter 1 for summaries of the case studies.)

OTA looked at the history of remedial response, the extent and quality of the site assessments, and at the evaluation, selection, and construction of remedial measures.[1] These studies show significant problems in the implementation of the Superfund program and a pattern of incomplete and inadequate site assessments. Problems were identified in such key areas as:

- estimates of the amounts of wastes and contaminated materials on site;
- estimates of the costs of remedial alternatives;
- hydrogeological assessments;
- design, installation and operation of groundwater monitoring systems; and
- design and construction of onsite containment systems.

Insufficient coordination among some States, EPA regional offices, and EPA headquarters may have contributed to problems with contractor performance.

Some problems may result from the newness of the Superfund program, But there are indications that if the Superfund program expands, they may grow acute as less qualified and less experienced technical people are employed by

[1]Certain terms describing site cleanup have very specific meanings in the Superfund Program and the stages of remedial activity. **Immediate measures** (also referred to as removals, planned removals, or interim or initial remedial measures) stabilize site conditions and mitigate imminent danger to provide temporary or short-term protection. **Remedial Investigations** or RIs provide an assessment of site conditions and include onsite sampling and data collection. **Feasibility Studies** or FSs evaluate possible response actions for long-term site protection. Separate feasibility studies can be done for different phases of site cleanup. **Remedial Design** studies provide a detailed site remedial action plan and engineering specifications for construction of the selected remedy. **Remedial Construction**, sometimes also referred to as remedial action, includes all construction activities and an initial period of operations and maintenance. Remedial construction can include relocation of residents or provision of a permanent alternate water supply. A site may have more than one remedial construction phase. **Operations and Maintenance** or "O&M" are any onsite activities occurring after construction of the permanent remedy, such as operation of the onsite treatment plant, maintenance of the site cover, and monitoring.

the government and the private sector. Their frequency suggests that they may be endemic to the Superfund program as currently structured and managed. These problems are discussed below, not necessarily in order of importance. Cleanup progress at several Superfund sites is examined to identify areas where the program might be improved.

Nature of Surroundings and Contaminant Transportation

The interaction of wastes with soil, clay, gravel, sand, and bedrock greatly influences the effectiveness of a cleanup. If these interactions are misunderstood or ignored, the control measures selected may be ineffective. Chemicals, particularly complex chemical wastes, can change the properties of soils and clay. For example, clay, which is considered relatively impermeable at 10^{7} cm/see, can increase in permeability by several orders of magnitude in the presence of some contaminants.[2] Some chemicals can migrate faster than water alone through porous materials such as soil and clay.

When chemical wastes are placed into the ground they can migrate and eventually find their way into groundwater. No natural containment is impermeable to chemical transport. Bedrock, often wrongly assumed to be impermeable, may, for example, itself be an aquifer or contain fractures that can act as conduits for chemical transport. Chemicals can also attack and change the porosity and other properties of engineered containment structures such as slurry walls. Eventually, these structures become permeable to the chemical wastes they were designed to contain.

Once chemicals reach the groundwater, a contaminant plume forms. Even if the waste source is removed, a threat remains in the moving plume of contamination which may be 50 or 100 feet below the surface, The transport of chemicals in an aquifer by the contaminant plume is often incorrectly assumed to be similar to the flow of groundwater. The movement of the contaminant plume may in fact be very different from the general groundwater flow, Contaminants in a plume may change the properties of the medium, often adsorb and desorb from the surrounding medium and can interact chemically with each other. Thus, the rates of contaminant transport are complex and differ from that of water in the same medium. For these reasons, the common practice of using groundwater flow maps to describe plume migration can produce misleading results,

Some contaminant flow models exist, but they are not necessarily reliable in predicting the migration of contaminant groundwater plumes under complex hydrogeological conditions, The current practice of relying on homogeneous models, such as Darcy's Law, for predictions in nonhomogeneous, stratified subsurface conditions yields, at best, crude estimates of contaminant movement, Subsurface geology is often nonhomogeneous and contaminant plume behavior may be complex. For example, despite a predominant flow direction for groundwater, a contaminant plume may have multiple paths and directions,

[2] Waste liquids and water carrying contaminants leached from hazardous wastes can percolate through the soil and subsurface and reach groundwater. Typically, contaminants pass through the unsaturate subsurface, the ''zone of aeration or vadose zone, and then to the saturated zone where voids between rock or soil particles are filled with groundwater; this zone that can store and transmit significant quantities of groundwater is called an aquifer. once contaminated, and depending on site conditions, restoration of groundwater to its previous condition can be difficult, if not impossible. Many factors influence groundwater flow and the behavior of contaminants in groundwater. Porosity and permeability control the ability of a material to store and transmit liquids, Porosity, expressed as a percent of the bulk volume of the material, is a measure of void space and how much fluid can be stored in it. See generally David W. Miller, cd., *Waste Disposal Effects on Groundwater: A Comprehensive Survey of the Occurrence and Control of Groundwater Contamination Resulting From Waste Disposal Practices* (Berkeley, CA: Premier Press, 1980), pp. 45-59. This publication is a reproduction of a 1977 publication, *The Report to Congress, Waste Disposal Practices and Their Effects on Groundwater*, U.S. Environmental Protection Agency, office of Water Supply and Office of Solid Waste Management. See also U.S. Congress, Office of Technology Assessment, *Protecting the Nation Groundwater From Contamination, OTA-O-233* [Washington, DC: U.S. Government Printing Office, October 1984) for a more detailed discussion of the nature of ground water contamination and methods for detecting and correcting contamination in the groundwater. in particular, see Volume I, p. 116, for a description of problems and information used in assessing contamination and hydrogeologic conditions. See Volume II, p. 396, app. D for key definitions.

Multiple Studies, Multiple Contractors

OTA's case studies and other analyses of remedial activities at Superfund sites show that frequently a single site will undergo multiple studies and have multiple contractors. Multiple studies at the same site create the potential for delay or inaction without guaranteeing thorough site assessment or effective cleanup plans, Often, these studies produce conflicting or inconsistent results and are of uneven quality. Studies of site conditions may be repeated needlessly; for example, earlier adequate site studies prepared for State or local agencies are sometimes ignored during the Superfund Remedial Investigation and Feasibility Study (RI/FS), In other cases, the scope and direction of later studies and remedial actions have been set by inaccurate or misleading initial studies.

Sometimes poor coordination in the same study can be a problem. OTA's case studies found examples of different sections of the same report using different data and assumptions. Contractors who may not have done quality work in an early phase maybe rehired at a later stage of the study or during the implementation phase.

Some multiple studies at Superfund sites are inevitable because of the highly specialized skills required for cleanups and the sometimes rapidly changing or uncertain site conditions. Because multiple site studies continue to be done, it is especially important that site supervisors: 1) are technically competent and experienced, and z) maintain adequate oversight of site contractors.

How do problems with multiple or repetitive studies arise? After a site begins to have problems or is known to have contaminated groundwater, local officials, perhaps under pressure from local citizens, may commission a study to examine the problem and recommend remedial action. Because ground or surface waters are at risk, the local water district or the health department may become involved and commission studies, in addition to investigations by the State hazardous waste agency. Water districts may have local civil-sanitary engineering consultants who have worked many years for the district. Consequently, in many cases they are awarded the initial study contract. However, even skilled sanitary engineers and hydrologists may not be familiar with the movement or treatment of hazardous wastes. This lack of experience can result in a flawed study despite hard work and good intentions. Common problems include: the effect of chemicals on soil properties usually is not considered; the fact that a contaminant plume can have multiple paths is not reflected in a pumping program if it is predicated solely on the direction of groundwater flow; natural basins and aquifers that are nonhomogeneous and stratified are modeled as constant property homogeneous bodies; the suggested remedies are not appropriate for the variable nature of the buried wastes; groundwater contaminant treatment plants are designed for a steady, predictable influx, which is unlikely; the option of treating the wastes is usually not considered. Other site-specific examples can be found in the case studies.

Early studies may underestimate the magnitude of the problems, yet they often set the tone and direction for future study and action. Opportunities for effective, timely responses to detect or control the spread of contamination may be lost. For example, programs to monitor surface waters, basins, and aquifers will not be implemented if the problem is thought to be localized.

When a site becomes a Superfund site, EPA and its consultants become involved. The National Contingency Plan (NCP) requires that an RI/FS be completed before remedial action begins, and thus, another study starts. In many cases, the RI/FS follows reviews, updates, and critical evaluations by the EPA's zone consultant, so that the RI/FS may represent the third or fourth study of the same site by EPA contractors. The RI/FS contractor maybe more experienced in hazardous waste management than the earlier contractors, but if inexperienced staff are assigned to the work, the final outcome may not be improved.

Two general problems have been encountered with multiple studies: 1) Mistakes or omissions in early site studies are not detected through timely and critical review and propagate through the RI/FS process, contributing to the adoption of ineffective remedies; and 2) good quality early work is ignored in a lockstep "start from scratch" RI/FS approach as studies are needlessly repeated, delaying remedial action. At first glance, the two results may appear contradictory, but they really are different possible consequences of the inherent risks in multiple studies. Minimizing these risks is an important goal for effective oversight of Superfund contractors.

Information and study results obtained by a consultant at a particular site generally are not shared with contractors working at other sites. Consequently, the study phase of the Superfund program suffers from the "reinventing the wheel" syndrome. This is especially true for Feasibility Studies where the same alternative technologies are described and discussed generically for different sites. Even though information is obtained with public funds, consultants tend to take a proprietary view of their work. As an example, the approach to treating contaminated groundwater varies with consultants and may not incorporate field experience gained at other Superfund sites.

Containment Rather Than Treatment

EPA shows a consistent bias toward containing wastes on the site rather than rendering them harmless through treatments such as detoxification, conversion, or destruction. Containment is popular because it is often seen as a cost-effective remedy, For a variety of reasons, confining mixtures of complex chemicals in the ground can, at best, only be temporary. Some of these reasons have already been mentioned. Engineered containment such as grout curtains and slurry cutoff walls can be affected by the chemicals they are designed to contain. A containment material that is highly impermeable to water can become several orders of magnitude more permeable when altered by leachate from chemical wastes. Furthermore, such structures can be difficult to key or seal to bedrock, which may itself be fractured and/or only slightly less permeable than the containment material. Containment structures can only temporarily reduce the inflow of water into the wastes or retard the migration of contaminants from the site.

Because containment provide only temporary and partial control of the spread of contamination, they are sometimes used in combination with groundwater pumping and treatment, At the Sylvester site, a slurry wall and cap with pumping, treatment, and recirculation of contaminated groundwater through the site have been designed to reduce releases of hazardous substances to acceptable levels within a few years. The slurry wall and cap have not reduced water flow from the site as much as projected, An interim pumping program has been started to contain the plume. The water treatment system is not yet complete.

The experience at Sylvester thus far has been limited, and it is not yet possible to evaluate the effectiveness of the remedial containment/treatment strategy there. Waste sites often contain tons of hazardous substances. Removing these contaminants through a water treatment system could take decades. There is also no guarantee that pumping and treating a particular plume are effective in stopping or controlling all of the material leaving the site. These types of remedial actions may not be found in the longer term to be permanent cleanups, except under certain conditions, such as where wastes have been limited to relatively small amounts dissolved in groundwater.

EPA's preference for containment strategies rather than treatment has limited the consideration of other, more reliable alternatives. At many sites, waste treatment is only considered, if at all, as part of an excavation and removal for redisposal alternative. Although removing the wastes eliminates the source of the problem at one place, it almost always means that the problem has been shifted to another 1ocation. Onsite treatment plants for contaminated soil and wastes are rarely considered in detail in an RI/FS even though the proposals and contracted scope of work for these studies call for evaluation of all options. In some cases, technologies exist to detoxify and treat the wastes and materials that are contaminating the groundwater, but they are given little attention in the RI/FS. In other cases, innovative solutions would be required.

There is an important lesson to be learned from the experiences of the Superfund program. In designing and evaluating alternative strategies for cleanup, the cost of failure or impermanence is rarely included (see chapter 3). The selected remedy is often presumed to be totally effective. If, however, the cost of further actions to repair failure is calculated, then an option which is initially more expensive, but more reliable, may prove to be the most cost-effective solution in the long term.

Political Pressures

Political influences rather than technical considerations can control the speed and nature of studies and cleanups at Superfund sites. In many cases, publicity and persistent citizen complaints eventually can force public officials and agencies to take action. Sites located in areas where the residents are politically sophisticated and organized are sometimes given priority over other sites that may pose greater or more immediate threats to health or the environment. Political considerations have at times influenced the timing of resource allocations for cleanups.[3]

In addition to being sensitive to public pressure, officials are sensitive to the types of remedial actions that EPA prefers and is likely to fund. This has a direct bearing on the scope and results of contractor studies. The case studies document several examples of the correlation between the views of the funding agencies and the recommendations of the consultant. Approaches that differ from familiar containment and pumping alternative are given little attention in the RI/FS.

Citizens, individually or in groups, often rely on common sense rather than on technical expertise, yet they can sometimes provide an effective check and balance for the action being considered or implemented at a site. At several sites, citizen suggestions modified the preferred remedial approach (see chapter 8), However, opportunities for effective public involvement in and scrutiny of site assessments and evaluation of remedial alternatives are limited.

[3]See also *Hearings on EPA: Investigation of Superfund and Agency Abuses Before the Subcommittee on Oversight and Investigations of the House Committee on Energy and Commerce*, 98th Cong., 1st sess., 1983 (3 vol.).

Studies Versus Timely Actions

Successful remedial action must be based on an accurate assessment of site conditions, risks to health and the environment, and the technical feasibility and cost effectiveness of alternative remedies. OTA's review disclosed a number of problems with the adequacy, completeness, cost effectiveness, and timeliness of site assessments.

Many of the sites on the NPL have been known for some time and have or are undergoing a series of Federal and State responses. At all three OTA case study sites, remedial investigations and emergency actions were initiated before passage of Superfund legislation. OTA has found that studies of site conditions often were repeated by different State and Federal agencies. In one instance, and perhaps in others, studies were repeated to meet requirements of various emergency and remedial response programs,

EPA has defended its current ad hoc approach by emphasizing that every site is unique. Many sites, however, share common characteristics and, with the experience the Superfund program has gained, it should become possible at many sites to limit extensive site assessments for initial responses and for high-priority remedial measures, Time and money could be saved. For example, 2- to 3-year site assessments may cost many hundreds of thousands of dollars, but result in the selection of a partial remedy costing only $1 million to $3 million or less. Experience to date suggests that there has been overdesign and overemphasis on extensive, high-cost, time-consuming site investigations and feasibility studies for impermanent partial remedies such as temporary containment, removals, and alternate water supplies,

At Stringfellow, remedial action was delayed while several successive groundwater contamination studies and site assessments were performed by local, State, and Federal contractors. Contamination grew and site conditions changed. Over $15 million has been spent at the site so far. A permanent remedy is still under study and its cost could be very high, with the State now estimating **$65** million.

At Seymour, about $4 million has been spent so far in studies and emergency response to achieve a $7 million incomplete, limited surface cleanup by private parties. When further site assessment is completed, some of the “toxic hot spots” that were buried in the partial cleanup area may have to be reexcavated to remove a continuing source of groundwater contamination.

Adequacy of Site Assessments

OTA found a number of technical problems with contractor studies for the three Superfund sites. Poor quality work on groundwater conditions and site hydrology has been the most serious recurrent problem. This underscores the critical need for competent, trained technical specialists in hydrology and related fields to work on Superfund sites that have extensive or complex aquifer contamination.

The initial site investigation of the Seymour Recycling facility had several shortcomings, The extent of offsite contamination from incinerator operations was not investigated. Possible pathways of escape for contaminants offsite through surface runoff, groundwater, and city sewer lines were not adequately investigated, so that the suggested onsite containment and control options may not effectively prevent the spread of contaminants. There were allegations that preliminary groundwater monitoring wells were not installed properly. Some samples taken from these wells were reportedly not usable by EPA’s contractors. One generator-funded contractor study attributed groundwater contamination to improper well installation. OTA was unable to determine whether the monitoring wells were improperly installed. Difficulties with inadequate design, installation, and operation of groundwater monitoring systems are not uncommon at Superfund sites and at interim status RCRA facilities (see chapter 5).

At Sylvester, initial estimates of the degree to which bedrock was fractured now appear to have been low, and the amount of waste deposited at the New Hampshire site might have been significantly underestimated.

The Stringfellow case study found a long history of problems with contractor work on site geology and hydrology, The complexity of the site geology was consistently underestimated with adverse consequences for the effectiveness of the control measures recommended. Until the late 1970s, it was generally assumed that the site lay on impermeable bedrock. Then it was discovered that the granitic and metamorphic bedrocks were highly fractured and jointed and hosted several underground springs that flowed into the site, In **1982** the permeability of the site and down-gradient areas was found to be much greater than originally thought. Earlier indications of the presence of an extensive, rapidly moving plume of contamination had been discounted and wrongly attributed to surface runoff. In 1980, interceptor wells were drilled to control the plume of contaminants. However, the wells were not pumped continuously as required and the plume moved beyond the zone of influence of the wells. Incorrect conclusions about site geology caused two interceptor wells to be misplaced, The wells were set west of the buried drainage channel in the alluvium underlying the canyon and drilling was abandoned when bedrock was not encountered at the projected 100-foot” depth,

Another Stringfellow contractor was unable to analyze depth-specific samples of the plume to determine its extent because its laboratory could not perform the appropriate analysis of total organics. As a result, information showing the three-dimensional extent of the plume and the areas with the highest concentration of contaminants is not available. The expense incurred in designing and executing an elaborate drilling procedure to obtain the data was wasted. This waste might have been avoided if EPA had verified the contractor's laboratory qualifications before awarding the contract and if EPA had required collection of two samples and the use of a backup laboratory.

Optimistic Assumptions

In all three case studies that OTA examined, a tendency towards optimistic assumptions about site conditions and remedial technologies was evident. At Stringfellow, for example, optimism about containment has prevailed despite mounting evidence that the site is fundamentally unsuited for this strategy. At Seymour, removal of a limited amount of soil was deemed adequate, without testing for residual contamination. (Contaminated surface water runoff indicates that significant amounts of contamination remain in the soil at the site.) At Sylvester, the figure adopted for the amount of waste deposited at the site might be a significant underestimate. Finally, the pervasive preference for containment as a key festure of remedial cleanups at Superfund sites is based on an optimistic assumption of doubtful validity about the long-term effectiveness of this technology.

Constraints on Superfund Contractors

Several Superfund contractors have expressed concern over the direction of the program and the structure of the remedial response under the NCP. These engineering firms complain of the lack of clear goals for cleanup design (see chapter 4). Lack of explicit cleanup standards or guidance from EPA makes it difficult for engineering firms to perform their assignments, such as comparing the relative cost effectiveness of remedial alternatives. According to one major Superfund contractor:

> [Engineering practice needs the law to require the use of engineering criteria and standards on which to base the extent and cost effectiveness of a remedial action.[4]

[4]Gary Dunbar, Camp Dresser & McKee, statement in *Hearings on the Implementation of the Superfund Program Before the Subcommittee on Commerce, Transportation and Tourism of the House Committee on Energy and Commerce*, 98th Cong., 1st and 2d sess., 1984. (Hereafter referred to as Hearings on Superfund Implementation.)

A representative of CH2M Hill, one of EPA's major Superfund contractors, testified that the lack of cleanup standards makes evaluating the suitability of alternative treatment and destruction technologies difficult:

> There are a wide variety of existing and promising technologies that might be employed to destroy hazardous contaminants . . . There are few design and performance criteria against which the technologies might be tested. In other words, we *do not have any reliable performance standards or risk assessment methodologies that we can use to determine whether or not a particular technology performs well enough to be applied to a specific site* [emphasis in the original]. It is very difficult to determine whether a particular technology will clean up a site if we have not defined what "clean" means. s

The cost-balancing test for remedial actions also poses difficulties for engineering contractors:

> The practice of "balancing" site-specific engineering issues, such as cleanup criteria, with external factors, such as availability of money and the remedial needs of other sites, hinders effective engineering efforts. We have found that this balancing requirement poses several problems for engineering firms trying to develop and implement an adequate cleanup plan. First, it is difficult to judge the cost-effectiveness of different plans without site-specific standards. Second, it is difficult to determine what a site can be used for after it is "cleaned up" if such standards do not exist. Third, the absence of standards can often delay a response action. Fourth, a remedial action lacking specific standards is not generally trusted by the public.[6]

Some consultants have noted that institutional tensions in the program favor the selection of impermanent remedial alternatives. A representative of the Hazardous Waste Treatment Council made the following observations about problems in the use of the cost-balancing test in the implementation of Superfund:

> The situation can best be described as one which results in the overdesign and evalua-

'William A, Wallace, statement during *Hearings on Superfund Implementation*.

[6]Dunbar, *Hearings on Superfund Implementation, op. cit.*

> tion of short-term cleanups; cleanups which will likely require additional future remedial action.[7]

The current process for assessing remedial alternatives seems to be producing a "least cost" preference for containment approaches using slurry walls and caps—despite the fact that containment is not a permanent solution. Nor are these techniques appropriate for some hydrogeological conditions, According to congressional testimony, construction of a slurry containment wall at $3 million was selected as the remedial alternative at one unnamed NPL site in New England. Further site analysis has determined that a more cost-effective approach would be to install an onsite system to treat, rather than contain, the wastes at an additional cost of $4 million, The treatment option would have initially cost $1 million more than containment, "but in the end would have saved approximately $3 million. "[8]

Another adverse impact of the balancing test, in some opinions, is the trend toward employing remedial options with high operation and maintenance (O&M) costs, e.g., dyking and counterpumping for long periods of time. These options may have low initial construction costs, but have high, and perhaps indeterminable, O&M costs. These are paid by the States rather than the Federal Superfund. In most cases these strategies are not a truly permanent remedy to the threat posed:

> The "balancing test" issue is fundamental in both nature and choice: the fund can either be used to temporarily contain many sites at a lower short-term cost or be used to permanently remove site hazards from posing future threats to health and the environment at a higher short-term cost. It is a most difficult issue, but perhaps the most critical one on which Congress must act.[9]

The artificial segmentation of projects into emergency actions, removal actions, and remedial actions, or into surface and subsurface remedial actions, also poses difficulties. A contractor is asked to look only at part of the problem and can expect to be responsible for that segment only. This limited focus may preclude consideration or design of more comprehensive and effective cleanups. Not taking a comprehensive environmental systems approach to releases has also limited the effectiveness of engineering consultants in designing a remedial alternative appropriate for site conditions. It is very unlikely that a single engineering contractor will work on a site from initial response through completion of remedial construction. This switching of firms for successive phases of one project and without clear cause differs remarkably from what generally occurs in other large engineering projects.

OTA found that contractor assessments of remedial alternatives were very limited in scope. Certain remedial alternatives were excluded from detailed feasibility analysis for cost or policy reasons. This may contribute to the ineffectiveness of some remedial actions. In all three case studies (Stringfellow, Seymour, and Sylvester) the cost effectiveness, long-term reliability, and risk equity of removing wastes from the site and redisposal elsewhere was given little or no analysis in EPA or contractors' documents.

OTA's Seymour case study concluded that government contractors at the site generally performed satisfactorily within the scope of what they were asked to do. However, the report found that limitations on the amount of money available and restrictions on its use (i.e., no offsite material disposal) may have hampered their effectiveness,

At the Stringfellow site, pressures from EPA regional and headquarters officials may have precluded serious consideration of site excavation and removal of the wastes, contaminated soil, and groundwater followed by onsite or offsite waste treatment and/or destruction, Yet, in this case, extremely complex and unfavorable hydrogeological conditions would make any successful containment option difficult if not impossible; removal of the materials from the site might be the only effective option.

[7] *Hearings on Superfund Implementation.*
[8] Ibid.
[9] Richard Fortuna, testimony during *Hearings on Superfund Implementation.*

The Stringfellow fast-track feasibility study completed in 1984 was the basis for selecting an interim remedial action to pretreat contaminated groundwater onsite. The contractor warned of possible problems with this option. Because of the lack of water sample testing, there exist "extremely significant" uncertainties in the quantity of water to be treated, its characteristics, and response to treatment. These uncertainties may cause major revisions to cost estimates and projections of the treatment's effectiveness. The contractor is now proceeding on bench-scale treatability studies that will shed some light on these uncertainties, but EPA appears to have no plans for a pilot facility on the site. Reliance on bench-scale work to adequately resolve uncertainties may be overly optimistic. This interim action appears to be an attempt to respond to public pressure rather than being a thorough engineering solution.

The full site investigation and feasibility study for Stringfellow is now underway and is scheduled to be completed in mid-1985. A review of the contractor's proposal, approved by EPA, indicates that the scope of remedial alternatives to be considered focuses on containment strategies and excludes several important permanent remedies. The feasibility of removal may not be examined and, hence, not considered as a permanent remedy. The option of building an onsite treatment facility for contaminated materials may also not be considered.

EPA's current preference in the Stringfellow RI/FS would leave the contaminated soil and water at the site and control the inflow of groundwater upgradient by hydrofracturing the bedrock, which is an untested and unproven technique for this application. It would also use conventional containment systems. An onsite, permanent water treatment facility would be built to control the hazardous constituents leached from the site into groundwater.

OTA's study found that the proposed RI/FS did not attack the source of the problem: the buried wastes and contaminated soil. Removing the source of contamination is not taken seriously in the proposal. Emphasis is on dealing with the effect rather than the cause of the problems, with consideration given only to containment methods similar to those that have been unsuccessful before at this site of complex geology,

EPA has issued guidance documents to its contractors to help them prepare site assessments that will be used *to* select remedial alternatives. The use of guidance manuals suggests the beginning of some degree of uniformity and consistency in work being done by EPA contractors. The manuals call for extensive policy-related technical judgments by the technical personnel on matters such as the seriousness of site contamination and the relative effectiveness of alternatives. But the technical judgment of contractors is limited in other areas such as the suitability and reliability of particular remedial technologies. The guidance documents do not yet include information to accommodate changes in setting a cleanup standard for remedial alternatives under the proposed NCP revisions. It is thus possible that a significant number of sites moving through the RI/FS and remedial design phases will not be consistent with the new policy. It is not known whether these site assessments will be required to be redone, or if remedial actions will proceed, perhaps with inconsistent and less stringent standards of protection.

Effects of Early Responses on Long-Term Remedies

OTA has found that most emergency responses have worked well where materials were *removed* from the site because of immediate threats. When immediate removal actions consist only of waste containment, which they often do, the site may get worse over time and require repeated removal actions. Actual removals, however, pose questions about the long-term adequacy of redisposal sites and the transfer of risks, The Superfund program management has put little emphasis on inter-site problems.

Onsite emergency responses to contain wastes temporarily and control contamination have not advanced permanent cleanups and in some cases have exacerbated conditions at the site. Often, "cleanup" is used to describe a limited action.

At Stringfellow and Seymour, initial actions have not been effective because contractors misinterpreted site conditions and applied inadequate control measures. Lack of quality supervision in building and designing these controls may also have contributed to their failure, Total cleanup involving removal of wastes, site decontamination, and groundwater treatment was advocated at an early stage, However, because of the cost involved, this prompt remedial action was rejected in favor of partial removal, temporary containment, and further study. Delays let the plume of contaminants spread substantially increasing the amount of contaminated soil and groundwater to be dealt with in later remedial actions at greater expense.

In *1982,* construction was completed on interim abatement measures for the Stringfellow site that were originally proposed in 1977 and approved in 1979. Some contaminated waste liquids and contaminated soils were removed. The site was excavated, bedrock fractures were grouted, kiln dust was mixed with the waste and soil to neutralize it, and the site was covered with a clay cap and regraded. A series of monitoring and interceptor wells were installed to deal with groundwater contamination. Contaminated groundwater is continuing to be pumped from the wells and shipped offsite to RCRA hazardous waste facilities for disposal. The emergency and interim cleanup actions taken to date at Stringfellow have alleviated immediate threats of floods and sudden catastrophic failure of the site impoundment, but they have been largely ineffective in protecting the water supply of the nearby community of Glen Avon from surface and subsurface contamination. Some of the interim control strategy measures exacerbated soil and groundwater contamination.

At the Seymour site the initial response in 1981-82 included: 1) security fencing, spill cleanup and removal, restaging about 45,000 drums, constructing a berm around the drum storage area to retard surface contamination (all typical immediate removal actions); and 2) building a rudimentary surface water pretreatment system consisting of an interception pond and two large concrete pipes filled with activated carbon to treat contaminated surface water runoff before it entered the municipal sanitary sewer system. Some actions prior to the actual surface cleanup were relatively ineffective and may have hindered the cleanup, since the structural integrity of the drums was reduced. At least one contractor study of one site found that the bermed area was a source of soil and water contamination. The impact of the initial response actions on the cost of the surface cleanup, however, was slight.

Design and Construction of Remedial Measures

The effectiveness of a cleanup depends on the remedial alternative selected. An ineffective remedy properly designed and built is still ineffective. However, effectiveness also depends on the quality of design and construction of the chosen alternative.

OTA's Stringfellow case study found several inadequacies in the design and construction of site control measures. Problems in construction of the Stringfellow interim abatement program were not corrected by State and Federal supervisors overseeing construction, For instance, during work at the site, underground springs were observed. The fact that these springs would cause leaching of materials left in the ground does not appear to have caused the site cleanup approach to be reevaluated. Kiln dust was mixed with soil to reduce the acidity of the waste, but its effectiveness could not be determined because no background testing was done on the soil before the addition of the kiln dust. The kiln dust may therefore only have added to the bulk of contaminated material onsite. The clay cap does not appear to have been installed as designed and consequently may be of limited value. Because the construction contractor used local materials instead of imported clay, it is not certain that the site does in fact have a clay cap. Surface water intrusion into the ground was exacerbated because the cover was built concave instead of convex because there was not enough material available to create the proper shape. Instead, drainage ditches were installed near the bottom of the cover. The site was not promptly seeded and rain has eroded the cover.

The Sylvester slurry wall and cap completed in 1982 have not contained the flow of water to the degree predicted. A hydrogeological study is underway to evaluate this problem. Building a slurry wall around the 20-acre site to a relatively unprecedented depth of 100 feet to retard the spread of contamination in unconsolidated glacial material over fractured bedrock was a bold engineering initiative. Because of the unprecedented construction involved, care was exercised in onsite supervision of slurry wall installation, but nonetheless the containment is less effective than predicted. State officials believe that most of the leakage is attributable to highly fractured bedrock. Another cause for leakage may have been construction problems in the installation of the wall, In addition, laboratory studies gave early indications that contaminants in the groundwater could degrade the slurry wall material, increasing its permeability, Based on hydrogeological modeling, State officials reject the possibility of leakage through the wall. The effectiveness of the slurry wall over time is highly dependent on the quality of initial construction and the length of time during which the wall must maintain its integrity. No containment system has been proven effective for long periods of time,

At Sylvester, the cap design and construction may be inadequate for the *long-term* maintenance of a surface seal over the site. Specifications for cap design, such as topsoil thickness, and drainage layer permeability, appear to be less stringent than that recommended for RCRA land disposal facilities.

Implications for Future Superfund Strategy

As seen in the case studies, the cleanup of uncontrolled hazardous waste sites poses many new technical and institutional challenges. The economic and environmental costs of inadequate assessment of site conditions, of delays, and of impermanent remedies can be substantial. Public expectations of progress in site cleanup have been high, but the rate and success of cleanups have been disappointing. Public confidence in a renewed and expanded cleanup program can be improved if lessons are learned from past experiences and incorporated into a long-term strategy for permanent cleanups that effectively protect public health and the environment.

Difficulties can be expected in the implementation of the Superfund remedial action program and in the assessment, design, and construction of remedial measures. There are many reasons why such difficulties will occur. Some circumstances are inherent in the program and cannot be avoided, but they can be anticipated and dealt with through effective contingency plans.

There are significant uncertainties and gaps in knowledge about site conditions, nature of hazards, environmental fate, interaction of substances, and hydrologic characteristics and behavior at sites. As more experience is gained and more research is done, some of these uncertainties will be reduced. But to a large degree, cleanup decisions, early or late, will always be based on incomplete information.

Complex situations at Superfund sites require specialized and sometimes novel or experimental approaches to achieve permanent cleanups. Because of this, the possibility or probability of failure must be given greater consideration in the design and selection of cleanup approaches. The concept of an "Impermanence Factor" used in chapter 3 could be further developed by EPA. Means to measure the performance and efficacy of remedial actions and assess the availability and feasibility of later corrective actions should be given greater attention. Where appropriate, cleanup goals and specifications might provide for an adequate margin of safety because of the risk of failure.

No proven technological solutions exist for many of the conditions present at uncontrolled hazardous waste sites. Despite this, construction projects at remedial sites have been treated as routine public works projects rather than as experimental or demonstration efforts. Technologies that may be proven for some applications are not necessarily proven for dealing with uncontrolled site problems.

For example, some containment strategies being applied to uncontrolled sites, such as slurry walls, were not originally designed to control mobile, highly reactive hazardous substances in soil and groundwater. The long-term effectiveness of these containment under Superfund conditions remains to be demonstrated. Methods must be established to monitor the performance effectiveness of such control measures. Moreover, reliance on groundwater monitoring alone also poses some problems, and so far, the success and effectiveness of this strategy has been poor at RCRA facilities.

How can problems be avoided when there are no specific criteria against which to measure the cost or technical effectiveness of alternatives? The determination of relative effectiveness (more a cost-benefit analysis) is left to the subjective judgment of individual contractors preparing background studies. Nor has any mechanism been established to let us learn from mistakes, so they are not repeated, *An overemphasis on the uniqueness of each uncontrolled site has resulted in very little collection of information for the national program*. Information and technology transfer among contractors, EPA, and States appear minimal. Yet the guidance documents encourage an approach of selecting the alternatives to be analyzed from a list of approved technologies (for the most part containment and land disposal). The suitability of site conditions for alternative technologies is inadequately considered, This is, of course contradictory to the "each site is unique" perspective, but might be the result of attempts to speed program progress and compensate for inexperienced personnel.

The Superfund program as currently structured and administrated seems poorly prepared to assume greater responsibility as the number of NPL sites increases and as many sites progress from site assessment to remedial design and construction. The whole cleanup program seems to assume that sites move smoothly through the process from site investigation to remedial design and construction and that there is little possibility of failure or mistakes, The history of site remedial actions contradicts this assumption. Design and construction of remedial actions are not predictable, routine engineering or construction projects and should not be managed that way. Some aspects of remedial action will always pose great uncertainties, but experience shows that these can be anticipated, The challenge is to build a Superfund program that can accommodate both the controllable and the uncontrollable.

AN EXPANDING PROGRAM'S NEED FOR TECHNICAL OVERSIGHT

Effectiveness of Contractor Oversight

The quality of work at Superfund sites depends largely on effective management of contractors. For cleanups performed by responsible parties, technical oversight by EPA is also needed. Three aspects of cleanup supervision are important: technical direction, oversight, and continuity, Contractors must be given a technically adequate scope of work, performance must be monitored to assure compliance and to allow modification of scope or effort if conditions change, and there must be some continuity of oversight for long-term contracts and multiple contractors at a site. Technical supervisors must have an appreciation of the complex and often unprecedented work they are overseeing. OTA's Stringfellow case study found that the State and Federal people involved with the day-to-day operations were mostly young engineers with relatively little experience in hazardous waste management. Without technically competent and experienced site supervisors, contractors are relied on to assure the quality of their own work. Outside review can also be used, but, as discussed in chapter 8, opportunities for effective technical review of site studies and selected remedies by the public and by potentially responsible parties are limited. The short amount of time available for review and comment and the lack of independent technical assistance for community groups limit the utility of outside review as a quality control measure for Superfund contractor performance.

Assuring continuity in oversight of remedial work appears to be an emerging problem, and there is a very high turnover in agency staff responsible for onsite coordination of contractor activities. OTA has been told by several EPA on scene coordinators (OSC) that they do not expect to be at the site when the evaluation is complete because they expect a reassignment or promotion to a more responsible position in Government or an outside job offer, High turnover rates increase the possibility that work will be repeated needlessly because of the lack of institutional memory. Management of an expanding Superfund cleanup program should therefore anticipate high employee turnover and adopt measures to minimize its impact.

OTA found that multiple contractor studies at a single site frequently yielded conflicting conclusions. Examples from OTA's case studies are summarized in table 7-1. The record does not indicate specifically how government technical site supervisors responded to these inconsistencies or even if they were aware of them. However, at Stringfellow, failure of government or contract personnel to recognize the implications of conflicting conclusions and assumptions in a timely manner may have contributed to the selection or construction of ineffective remedial measures at considerable cost.

To be effective, the remedial response process (particularly at the design and construction stages) must have the capability to be more flexible and responsive to new information or better interpretations about actual site conditions, even if these contradict earlier assumptions. This requires vigilance on the part of the site contractors and the government cleanup supervisors,

A Larger Program

The number of remedial actions under the Superfund program will increase substantially. New sites are being added to the NPL and more and more sites already on the NPL *are moving* from the initial study phase toward remedial design and construction. Cleanup at many of these sites may take years, Responsible parties also are initiating more private cleanups. As the level of activity increases, so will the need for additional qualified and experienced staff at the State and Federal level to design and implement an expanded program, to make judgments on cleanup goals, to support enforcement efforts, and to supervise work by government contractors and responsible parties. To be successful, the program must have adequate, experienced staff to provide sound management and technical oversight.

EPA's current staffing levels appear to be too low to provide effective oversight of the rapidly expanding number of sites requiring remedial action. Moreover, EPA has identified several institutional constraints on its ability to expand its program quickly. EPA has projected that States may take over management of as many as half of the NPL site cleanups. However, many States lack the needed technical and administrative personnel to support Superfund cleanups. Where money is available, States report delays in obtaining qualified technical specialists,

There are several reasons to question whether the Superfund program can effectively man-

Table 7.1.—Four Examples of Inconsistencies in Reported Site Characteristics

Site/location	Factor	Values reported	Contractors	Type work performed	Date reported	Impact
Chem-Dyne, Hamilton, OH	Linear velocity of groundwater	1.71 ft/day	E&E	EPA field invest.	June 1982	Speed of movement of contaminated groundwater underestimated originally. Might have influenced decision on when action needed.
		2.8 ft/day	Weston	Preliminary feasibility investigation	June 1983	
Stringfellow, Glen Avon, CA	Linear velocity of groundwater	0.6 ft/day	Neste, Brudin &. Stone	Regional Water Board study	June 1973	Rapid movement of contamination by groundwater rather than surface water not realized until after failure of containment techniques. Effective remedial action delayed.
		3.5 ft/day	CH2MHill	EPA RI/FS study	April 1984	
	Nature of bedrock	Solid	Neste, Brudin & Stone	Regional Water Board study	June 1973	
		Fractured	James M. Montgomery		December 1979	
Seymour, Seymour, IN	Nature of site subsurface	Permeable	ES&E	Coast Guard study	February 1982	If subsurface is permeable, much contaminated soil left onsite and continued water intrusion causes further groundwater contamination.
		Impermeable	Canonie Environmental Services	Responsible parties study	July 1982	

SOURCE Office of Technology Assessment, based on data in various reports age and oversee even current NPL site cleanups, let alone an expanded number of cleanups,

First, progress to date has been slow. Certainly one reason for this has been the inherent delays in starting a new program, developing procedures, identifying sites, and conducting preliminary site assessments. The Superfund program has also changed policy direction over the relative priority of fund-financed cleanups and enforcement, However, there is reason to suspect that EPA may fall short of meeting its *currently* projected cleanup goals. At the end of fiscal year 1984, EPA reported some form of remedial activity was underway at about 30 percent of NPL sites, however, site remedial *construction* had started at only 50 sites, a relatively small number of the 552 NPL sites, The number of sites where cleanup is considered *complete* or where a permanent long-term remedy is under construction is relatively low, Many remedial actions announced so far are temporary or interim remedial measures that will need further work or nonremedial measures, such as supplying alternate drinking water, intended to remove an immediate threat of exposure to hazardous substance releases. Moreover, as discussed in chapter 1, the adequacy of remedial action at several of the "completed" cleanups is under question.[10]

Detailed information on EPA cleanup activities at Superfund sites is not easily obtained. One of few publicly available summaries tracking Superfund cleanup progress at individual sites is The National Campaign Against Toxic Hazard's recently published "Assessment of Cleanup Progress at Superfund Sites."[11] This report documents the status of remedial activities at 343 NPL sites in 19 States as of mid-1984 based on EPA data and a phone survey of EPA site project officers. (According to the Campaign, detailed information on the remaining 209 sites was not available for study because of problems with EPA's computerized site tracking system.) Table 7-2 shows the *latest* stage of remedial activity for the 343 sites surveyed as of July 1984,

Remedial Investigations and Feasibility Studies were underway or complete at about 44 percent of the sites. These stages are the beginning of the Superfund "pipeline. " However, only 14 percent of the sites in the survey have advanced to remedial design (seven sites) or remedial construction (42 sites]. Responsible party cleanups, rather than fund-financed cleanups, account for about half of the 42 sites where a long-term remedy is being implemented. The report found that some form of

Table 7-2.—Status **of Cleanup Progress, July 1984**
(343 NPL **sites)**

Latest stage of remedial activity[a]	Number of sites at stage	Percent of sites at stage
No site activity[b]	96	28-
Immediate measures only[c]:		
Complete ., ...	27	8
Underway	19	5
Total	46	13%
Remedial Investigation (Rl):		
Rl complete ., ...	5	
R I underway. ., ...	77	23
Total	82	240/o
Feasibility study (FS):		
FS complete ., ., ...	25	7
FS underway	45	13
Total	70	20%
Remedial design (RD)[d]:		
RD complete ... ., .	2	1
RD underway	5	1
Total ., ...	7	2%
Remedial construction (RC)		
RC complete, delisted . . .,	2	1
RC complete	4	1
RC underway	36	10
Total	*42*	12"/0
Grand total	343 sites	100%

[a]Number of NPL sites at this stage of remedial activity in July 1984 This is not the *cumulative* number of sites at which this stage has been completed or initiated
[b]No activity means neither immediate measures nor studies have been started at these sites Studies or response activity *before* the site was li steal on the NPL are not included Some no activity sites have had remedial action master plan (RAMP) studies completed; RAMPs are low cost (about $25,000) summaries of available information on the site RAMPs were recently discontinued
[c]Immediate measures include removals that were taken *after* the site was listed on the NPL Not all NPL sites require immediate measures
[d]Sites proceed to the remedial design stage after selection of an appropriate remedy based on the RI/FS Selection of an appropriate remedy is documented in a Record of Decision (ROD)

SOURCE Office of Technology Assessment from National Campaign Against Toxic Hazards, 'An Assessment of Cleanup Progress at Superfund Sites, " September 1984

[10]See also Richard C. Bird, Jr. and Michael Podhorzer, "Evaluation of the Six National Priorities List Sites Delisted by the Environmental Protection Agency', National Campaign Against Toxic Hazards, Oct. 24, 1984.

[11]Dan na Tulis, Henry S. Cole, and Michael Podhorzer, "An Assessment of Cleanup Progress at Superfund Sites, " National Campaign Against Toxic Hazards, September 1984.

onsite cleanup work, either immediate measures and/or long-term remedial construction, had occurred at 147 of the 343 sites. (Immediate measures at 105 sites; remedial construction underway or complete at 34 sites; eight sites had both immediate measures and remedial construction.) Some sites with immediate measures have progressed to later stages of remedial activity as shown in table 7-2. No onsite cleanup had occurred at 196 of the 343 sites surveyed (57 percent). There were 100 sites with studies only and 96 sites with no remedial activity at all.

Based on EPA records, the Campaign was able to assess the cleanup progress through the end of fiscal year 1984 for all 552 NPL sites (including six delisted sites where cleanup is completed), The group found that there has been no onsite cleanup (either immediate measures or remedial construction) at 332 NPL sites. Some form of remedial action (RI/FS, design, or construction) had begun at 120 sites. There were immediate measures underway at 100 more sites.

The Campaign's study focused on the stage of remedial activity at NPL sites and did not examine what kinds of remedial activities were occurring and whether the remedies would provide effective long-term control of threats to human health and the environment. OTA's own review of EPA Records of Decision (RODS) for remedial actions at NPL sites and the site activities described in the Campaign's report suggests that both the EPA and Campaign figures overstate the progress made in cleaning up Superfund sites. Many of the remedial actions taken do not represent a final or permanent remedy providing for the removal, destruction, or treatment of the wastes and the decontamination and, where feasible, restoration of the site. Such remedial actions require more technical oversight than the early measures that now account for most program activity. (See table 7-3 and the discussion in chapter 2 of this report,) Of 24 RODS reviewed, 10 were for initial remedial measures to deal with immediate problems at the site. Of the 14 remedial actions, six involved complete or partial remedies with additional measures to effectively deal with site releases and contamination still under study. Three remedial actions provided for replacement or treatment of the threatened water supply; three others involved only partial or surface removals with source control measures. Only eight sites had a final or permanent remedial action underway (these eight are in addition to the six sites where EPA says cleanup has been completed). The RODS indicate that completion of remedial construction at many sites will not result in site cleanup or a final remedy, Additional remedial activities at these sites may continue for years or may be required at some later time.

It may take many years for cleanups at current NPL sites to be completed and varying degrees of oversight and activity will be required for the duration of each cleanup. At the same time, more and more sites can be expected to

Table 7.3.—Summary of Remedial Cleanup Approved, 1981 to mid-1984

Cleanup actions approved	Number of decisions a/	Initial remedial actions b/	Remedial actions	Final remedies c/
Removal/offsite disposal with/without source control	14	6	8 d/	5
Off site removal with incineration	1	0	1	1
Alternate water supply provided	3	1	2	0
Alternate water supply and treatment e/	2	1	1	0
Treatment f/	2	1	1	1
Source control and onsite treatment	2	1	1	1
Totals	**24**	10	14	8

a/ Total includes two sites and two RODS each which are combined in the above table
b/ Includes planned removals
c/ Final remedies are remedial actions that are intended as the last action at the site and that, If successful, wi II effectively control releases from the site
d/ Includes three partial remedial actions, e g , surface cleanup, additional remedial measures are still under review
e/ Includes treatment of contaminated drinking water
f/ Includes treatment of contaminated groundwater

SOURCE Of fice of Technology Assessment

enter the system. The RI/FS process can take up to 18 months to complete, remedial designs take 9 to 12 months. The whole pre-construction process can take 3 years once activity has begun and without any other delays. A range of from 2 to 5 years from site investigation to completion of construction. Complex sites, particularly those with extensive groundwater contamination, will require more time to assess, and to design and construct a remedy. Operations, maintenance, and monitoring could continue for 20 to 30 years or more at sites with significant groundwater contamination and cleanup. There will be a continuing long-term need for technical oversight and monitoring at a large number of sites.

The rate at which EPA has been able to obligate and spend Superfund appropriations gives some indication of the agency's ability to handle a greatly expanded program. Only a small percentage of funds obligated for remedial action actually has been spent on construction of long-term remedies. *With two-thirds of Super fund's $1.6 billion obligated, the resources of EPA and State agencies may not be adequate to manage an accelerating rate of cleanup activities, even if only for a 2,000 site NPL.* There appear to be significant delays in moving sites from the study stage to construction. A major portion of the $1.6 billion Superfund appears to have been obligated for initial contractor assessments and administrative expenses, creating the probability that the program will need very large amounts for remedial construction and, hence, oversight in the future.

The Campaign found that for 343 sites surveyed, over $100 million had been obligated for remedial actions out of a total of over $236 million in Superfund obligations in those 19 States. Less than half of the remediaI action obligations were for construction. Of the total monies obligated, $44 million had been paid out (see table 7-4).

The slow rate of cleanup and the small portion of obligated funds spent on remedial construction suggests that EPA and State agencies may not have sufficient resources or personnel to carry out the process efficiently. EPA officials have admitted that the frequent switching of project officers has been a problem in maintaining the momentum of cleanup activities. Retention of experienced, qualified cleanup supervisors was also identified as a problem in OTA's case studies.

Table 7-4.—Superfund Obligations and Expenditures, 19 States, July 1984

State	Number of sites	Remedial" act ions funds obligated	Total fund obligated	Total funds expended
California	19	$25,478,390	$37,867,020	$1,010,047
Connecticut	6		1,369,000	49,965
Florida	29		6,390,828	1,766,279
Illinois	11	0	4,069,291	678,855
Indiana	17	0	3,911,401	307,519
Iowa	3	0	2,187,014	1,075,276
Maine	5	0	1,639,932	90,306
Massachusetts	15	8,121,800	17,415,68	2,241,413
Minnesota	23	0	5,903,543	908,517
New Hampshire	10	10,007,018	13,605,340	4,719,449
New Jersey	85	17,885,809	55,004,130	7,049,176
New York	29	11,702,800	31,173,799	8,373,695
North Carolina	3	2,374,176	2,364,176	2,364,176
Ohio	23	3,191,125	9,787,656	5,394,571
Oregon	3	0	139,000	2,266
Pennsylvania	40	11,440,400	23,575,534	4,110,486
Rhode Island	6	5,043,570	5,766,831	2,373,831
Vermont	2	0	360,000	0
Washington	14	5,000,00	13,820,269	2,346,767
19 State total	343	$100,235,088	$236,350,445	$44,862,594

SOURCE : Natinal Campaign Against Toxic Hazards, An Assessment of Cleanup Progress at Superfund Sites, September 1984 at 14

EPA Staffing Needs

The pace at which Superfund remedial actions are moving through the system suggests that *current* staffing levels are not sufficient to support *current* Superfund activities. This is shown by the lag between the number of sites with RI/FSs and the number of sites where construction is underway and by the percent of obligated remedial action funds that have been spent (see tables 7-2 and 7-4). The problems with effective technical oversight of EPA contractor work revealed in OTA's case studies is another indication that EPA staffing may not be adequate either in the number of technical staff assigned to a site or in the qualifications and experience of those employees.

EPA has greatly expanded the number of employees allocated to the Superfund program. Administrator Ruckelshaus testified that the hiring rate for Superfund is now at the highest level that EPA has ever experienced.[12] EPA's authorized Superfund employment has been increased from 774 workyears in fiscal year 1983 to 1,357 in fiscal year 1985, This staffing level is needed to support currently planned activities for only a moderately increased program, With this staff, EPA estimates that it could support about 115 sites in the RI/FS stage per year, EPA expects that a total of about 200 sites will reach the remedial design and construction stage at the end of fiscal year 1985 (including 68 new designs and 46 new remedial cleanups). About 150 immediate removals are also projected for fiscal year 1985. By the end of fiscal year 1986, some kind of remedial response would have been started at about 400 existing NPL sites. After that, the number of sites in various phases of response would remain fairly constant. EPA has said that there may be an upper limit of about 600 NPL sites that EPA can effectively deal with at any one time. This includes overseeing removals, RI/FSs, and remedial design and construction.[13]

EPA officials are concerned that the agency may not be able to quickly absorb a significantly expanded number of cleanups even if additional funds were made available for more staff. They have identified the following limitations on the agency's capacity to expand:

1. Superfund staff and resources are already expanding at an exceptional rate to manage projects already in the pipeline,
2. The Federal Government's competitive hiring regulations would delay the hiring and housing of additional new employees 6 to 8 months at a minimum;
3, Intensive training would be required before the newly hired staff would be fully effective—at least 2 to 3 months on-the-job training for nontechnical personnel and considerably longer for technical personnel.
4, The private sector support industry for Superfund would not 'be able to expand rapidly enough to allow effective use of a larger work force for several reasons. The analytical laboratory industry, already operating near capacity, is unlikely to increase its capacity for organic sample analysis and high hazard sample analysis at a correspondingly rapid rate. Lead time for procuring additional, highly specialized equipment is up to 6 months. It could take years to find, hire, and train competent technical staff.

Administrator Ruckelshaus argued that too rapid an expansion risked increased potential for fraud, waste, and abuse:

> Too large a program pushed at too rapid a pace could create excessive public expectations that even with the best of management and will could not be met. The result could be—could be—one more case of disillusionment with the ability of Government to protect and serve the public responsibly.[14]

EPA's claimed inability to expand maybe a consequence of its own policies: Moreover, the constraints cited by Mr. Ruckelshaus are pri-

[12] *Hearings on HUD-Independent Agencies Appropriations, 1985-Part 1, Before the Senate Committee on Appropriations,* 98th Cong., 2d sess., 1984, pp. 302.

[13] Lee Thomas, statement before the Environmental Law Institute-American Bar Association Superfund Conference, NOV. 29, 1984.

[14] *Hearings on Superfund Reauthorize tion Before the Subcommittee on Commerce, Transportation and Tourism of' the House Committee on Energy and Commerce,* 98th Cong., 2d sess., 1984, pp. 725-26.

marily short-term constraints of perhaps a year or two, Some of EPA's statements seem to assume that Superfund staffing will not increase much over currently projected levels. This assumption may reflect budget policies more than actual experience or actual need. EPA has been able to accommodate the significant spending and hiring increases in the Superfund program of the last 3 years, albeit with some inefficiencies, The capacity—and, more importantly, the quality—of the private analytical laboratories to accommodate increased need for chemical analysis for cleanups is a matter that merits further investigation.

Another assumption in EPA's projections for only modest additional Superfund expansion seems to be that sites are dealt with expeditiously and will not require further attention after the 2 to 5 years needed to complete remedial construction. This view does not reflect the impermanent nature of many remedial actions or recent experience with cleanups. Perhaps EPA is assuming that the States will be able to take over all oversight of sites with completed remedial construction. If this is so, then State staffing needs will continue to grow, and probably will be largely unmet. Without increases in staffing and resources for Superfund cleanups, it could take decades to dispose of the large number of known sites that are anticipated to require remedial action, The 10,000 site NPL seen possible by OTA (see chapter 5) would clearly require decades under almost any conceivable program,

OTA does not have information on specific EPA personnel needs for an expanded number of remedial actions under Superfund, The long-term nature of cleanup actions suggests that long-range planning for hiring, training, and retaining qualified technical personnel to oversee cleanups is warranted, Existing information provides some indication of the magnitude of future staff needs. EPA estimates that it requires 2,8 staff workyears to complete a Superfund remedial action, ” Given the complexity and long-term nature of many site cleanups, this estimate may be low for both the duration of site activity and the level of management required. One State Superfund agency representative has advised OTA that most sites require a team of several technical specialists from various disciplines over the 2 to 5 years required to oversee site activities from initial investigation to completion of all construction. (This would suggest a modest estimate of from 4 to 10 staff workyears per site.) More complex site cleanups would require a larger team and probably more time. Post-construction operations, maintenance, and monitoring of the site will present a continuing need for oversight.

OTA's review of technical personnel availability later in this chapter estimates that there are about 3,750 technical specialists currently working on Superfund cleanups both inside and outside of government. There were an estimated 1,000 Federal and 700 State staff positions (including administrative and technical jobs) for Superfund and other remedial activities in 1984. Not all of these people are directly involved in site activities and so total Superfund program employment may not have to increase in direct proportion to the growth in cleanup expenditures. Assuming that site personnel currently represent one-half of government positions at most, this ratio would suggest that government employment would have to increase significantly to accommodate an expanding number of cleanups. OTA has estimated that overall demand for technical personnel could grow to about 22,750 specialists in 1990-95 under a moderately expanded level of funding for cleanups.

New State and Federal positions for technical specialists to supervise site cleanups will likely represent a significant share of this increased demand. Even with a significant expansion in State and Federal technical personnel to direct and oversee site cleanups, the Superfund program will still depend to a great degree on private contractors for site assessments, design, and construction of remedial actions for decades.

[15] Donald Lazarchick, ASTSWMO, testimony at *Hearings on Superfund Reauthorization Before the Subcommittee on Commerce, Transportation and Tourism of the House Committee on Energy and Commerce*, 98th Cong., 2d sess., 1984, pp 536.

State Staffing Needs

State agencies have repeatedly testified that they do not have enough qualified and experienced staff available to meet their responsibilities under the *current* program for identifying and ranking sites, consulting with EPA on site activities and enforcement, and in participating as the lead agency at some sites. Although some Federal funds are available to the States, they are limited and almost entirely site specific. States vary in their ability and willingness to provide funding for these activities. Remedial staff and funding are concentrated in a small number of States. Massachusetts, Michigan, California, New York, New Jersey, and Tennessee accounted for over 60 percent of positions in 1983 and 70 percent in 1984. These States have a total of 201 sites. On a national average, nearly 75 percent of the positions are paid for by State monies and about 25 percent are funded by Superfund or other Federal sources. The percentage of Federal funding, however, varies greatly by State.

Reliance on State funding for their own staffs leaves 20 States being able to devote less than 2.5 person years annually to Superfund program work. " EPA is currently projecting that State lead sites will account for about half of Superfund site cleanups. Cleanups may fall short of projections if States do not have enough technical people to provide direction and effective oversight,

The Association of State and Territorial Solid Waste Management Officials (ASTSWMO) has testified that States should receive Federal funding for a number of activities under Superfund including site identification, assessment, and investigation and the development and implementation of State contingency plans. Funds are needed to support enforcement, health studies, equipment, and staff training, These funds are in addition to funds that States might receive as part of a site-specific cooperative agreement.

A survey done by ASTSWMO in December 1983 for EPA's study of State participation in the Superfund program required by Section 301(a)(l)(E) of CERCLA concluded that States would have to increase their total fiscal year 1983 technical staffing levels by 84 percent to reach optimal levels to support the *current* Superfund program (table 7-5). The greatest need is for staff to oversee site cleanups, State technical staff allocated to remedial activities was expected to increase by 65 percent from 1983 to 1984 (from a total of 259 to 428 person years). These aggregate figures do not reflect the differences in individual State staffing levels nor do they differentiate between State-funded cleanups and Superfund actions.

The ASTSWMO survey also identified the types of technical specialists needed by the States. The most critical technical staffing needs were engineers, hydrologists, and chemists (table 7-5).

Among the constraints identified by the States in quickly obtaining additional technical personnel to support remedial activities were limitations on hiring under State civil service regulations, problems with the institutional stability of the programs such as hiring freezes and noncompetitive salaries, Another constraint on expanding State activities are delays in obtaining private contractors for site studies, remedial design, and construction due to competitive bidding and contract review procedures under State procurement regulations.

[16]Lazarchick, op. cit., pp. 530.

Table 7-5.—Current and Optimal Technical Staffing Levels (Annual totals for respondent states in person years) (41 States)

	Number of current staff	Number of optimal staff	Number of additional staff needed (optimal – current)	Percentage increase needed
Civil engineer	15.9	29.0	13.1	82
Sanitary engineer	86.6	165.1	78.5	91
Environmental engineer	35.7	96.6	60.9	171
Chemist	42.0	108.0	66.0	157
Biologist	46.7	55.7	9.0	19
Public health specialist	46.3	63.6	15,3	33
Geologist/hydrologist	47,0	119.5	72,5	154
Soil scientist	14,6	31.1	16.5	113
Other				
Agricultural engineer	0.5	0.3	–0.2	–40
Chemical engineer	3.1	4,3	1.2	39
Environmental field officer/scientist technician	27.2	42.9	15.7	58
Field inspectors	5.0	5.0	0.0	0.0
Investigator	0	1.0	1.0	—
Industrial hygienist	0.8	1.5	0.7	88
Pharmacist	1,0	1.0	0.0	0.0
Specialists (radiation solid waste, environmental enforcement, environmental, pollution control, resource control, emergency response, water quality)	119,2	177.0	57.8	48
Toxicologist	0.0	0.5	0.5	—
Zoologist	1.0	5.0	4.0	400
Totals	492.7	907.1	414,5	88 [a]

[a]Percentage Increase of total current technical staff needed to achieve total optimal technical staff

SOURCE ASTSWMO survey US Environmental Protection Agency State Participation in the Superfund Program CERCLA Section 301(a)(1)(E) Study final report December 1984

AVAILABILITY OF QUALIFIED TECHNICAL PERSONNEL FOR SUPERFUND CLEANUPS

An Overview of Findings

Cleanup of uncontrolled hazardous waste sites requires a concerted multidisciplinary approach. The situations often involve great uncertainty over the amounts, types, and behavior of the wastes and the appropriateness, feasibility, and effectiveness of various technical remedial options. Because of the relatively short history of a large-scale commitment to cleaning up hazardous waste sites, there is not yet a large cadre of experienced professionals in this area. As the number and complexity of public and private cleanup efforts continue to increase, demand for qualified technical personnel will grow. Because the availability of technical specialists could become a short- and long-term constraint on a greatly expanded cleanup effort, OTA conducted a study of the expected demand and supply of professionals in the required technical specialties.

Little work has been done in this area. Statistics on current and future personnel needs and on the pool of potentially available trained technical professionals for waste cleanup are not readily available. Thus, OTA had to assemble information on the available pool of technical specialists, on the enrollment and training capabilities of educational institutions, and on expected levels of future demand for technical specialists under significantly expanded public and private cleanups. Estimates of future demand were based on current Superfund staffing needs, contractor surveys and assumptions about future funding levels, and extrapolations for demand in 5 to 15 years. Several technical specialties that appear to be critical at various stages of Superfund cleanups were identified.

For a significantly expanded Superfund program, OTA's analysis concludes:

- It is probable that substantial increases in technical personnel needs will accompany expansion of Superfund. These jobs will be in Federal and State governments, in private sector consulting firms, and in the internal environmental management groups of private corporations active in cleanups. The overall number of new positions to be created is somewhat small when compared to employment in the national economy as a whole. However, this increase is several times more than the nuber of new graduates in some fields currently produced by institutions of higher education,
- Significant personnel bottlenecks could develop in the Superfund program. By bottleneck OTA means a condition where employees would not have the optimum training, background, or experience for the work required, and consequently the quality of responses and cleanups could suffer, Even moderate increases in the numbers of Superfund cleanups during the next decade and a shift to more permanent cleanups could lead to shortages of qualified technical specialists.
- With few exceptions, the present educational programs and manpower pools can supply adequate numbers of basically *qualified* scientists and engineers.
- There will be difficulty in developing adequate numbers of *experienced* professionals for the next decade at least, and yet the development of such a cadre of qualified supervisory professionals appears to be the key to the successful implementation of Superfund.
- There could be some shortages of technical specialists particularly in the critical fields of hydrology, " geological engineering, and toxicology. The increase could strain the capabilities of existing institutions over the short term. Over a longer period it appears that an adequate supply of technically trained people would become available as more students are attracted to these specialties and new graduates enter the job market, Technical specialists in related fields can also be expected to shift to remedial work at uncontrolled sites. In some instances these professionals may require some retraining assistance.

Based on OTA's conclusions that a large Superfund program will be needed for several decades to come, serious consideration could be given to Federal support of training programs in critical technical specialties such as geology, hydrology, risk assessment, and toxicology to meet expected sharp increases in demand.

A range of options is available to promote technical training for hazardous waste cleanups. Among these options are:

- expanding graduate research and training in fields relevant to hazardous waste cleanups;
- encouraging development of specialized short courses to assist current hazardous

[17] The terms ground water hydrologist and **hydrogeologist** are often used synonymously in this report. Many geologists and professionals in the field of ground water hydrology refer to themselves simply as hydrologists. Some may associate hydrology with surface waters only. Hydrology as a science deals with both surface and subsurface waters. In this chapter hydrologist refers to both surface water and ground water h~'orologists. **Hydrogeologist** refers to a technical specialist i n the field nf hydrogeology, a subspecialty of hydrology dealing with subsurface? waters and related geologic conditions. Assessment of complex subsurface conditions at uncontrolled waste sites with extensive groundwater contamination will frequently require the special skills of a hydrogeologist.

waste profess ionals and those entering the field; and

- promoting the establishment of regional technical centers or "centers of excellence" to provide research, professional training, and graduate education.

Technical Specialists for Cleanup of Uncontrolled Sites

Estimates of the size of the effort required to clean up many of the known uncontrolled hazardous waste sites span a wide range (see chapters 3 and 5). There is general agreement among State and Federal authorities, however, that the cleanup could eventually involve many thousands of sites, will extend over many decades, and that contamination of surface and groundwater is a common problem.

Proposals to expand the cleanup effort raise the possibility of creating shortages of qualified technical professionals, Without such trained specialists, cleanups are unlikely to be performed well or cost effectively. Since little information was available, a personnel needs survey was conducted of practicing professionals in government agencies, Superfund contractors, and engineering firms to estimate the numbers of people required, their specialties, and the desired levels of training and experience.

The survey requested information on the importance and levels of skills for 30 specialties for four phases of cleanup actions—site investigation, emergency response, surface cleanups, and subsurface cleanups. (Note that site investigation and emergency response include all short-term investigations and site stabilization; surface and subsurface cleanups include all longer term "permanent solutions.") The specialties were identified from previous studies and a review of skills needed at 28 sites undergoing EPA remedial response. The respondents were asked to indicate their optimal staff training and experience requirements for cleanup work, rather than the training and experience levels of current employees. The optimal staff requirements were used because many contractor and government personnel now working on Superfund cleanups were not trained for these jobs and had little previous experience in dealing with uncontrolled waste sites. Analysis of survey results showed 18 specialties were deemed very important or important for at least one of these cleanup phases. A strong demand for experienced professionals in these fields is evident now. (See table 7-6 for a list of specialties.) The majority of respondents indicated that a master's degree and 3 to 5 years training were the desired qualifications for almost all technical specialties (figure 7-I). The second choice is for entry level people with a bachelor's degree and limited experience. A doctorate was not deemed necessary for most cases and specialties, except for toxicology,

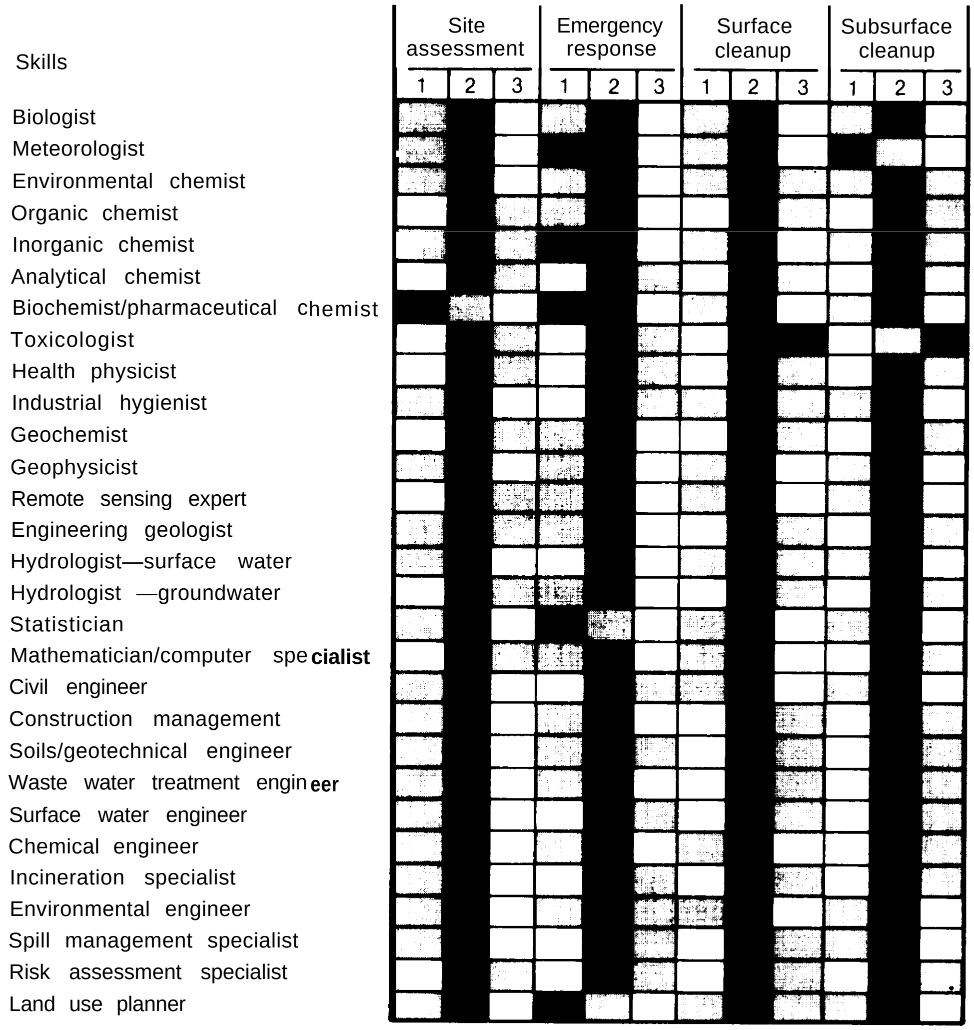
The survey confirmed general trends shown in earlier surveys and the case studies. Several disciplines were found to be most important

Table 7.6.—Technical Specialties for Cleanup of Uncontrolled Hazardous Waste Sites: Personnel Skill s Survey-Importance of Technical Skills For All Site Activities

Rank	Speciality
1	Hydrologist —groundwater
2	Toxicologist
3	Environmental chemist
4	Analytical chemist
5	Hydrologist—surface water
6	Civil engineer
7	Soils/geotechnical engineer
8	Environmental engineer
9	Engineering geologist
10	Organic chemist
11	Risk assessment specialist
12	Chemical engineer
13	Construction management
14	Industrial hygienist
15	Geochemist
16	Inorganic chemist
17	Spill management specialist
18	Waste water treatment engineer
19	Health physicist
20	Mathematician/computer specialist
21	Surface water engineer
22	Remote sensing expert
23	Geophysicist
24	Biologist
25	Incineration specialist
26	Statistician
27	Meterorologist
28	Biochemist/pharmaceutical chemist
29	Land use planner

SOURCE A Keith Turner, Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov. 30 1984

Figure 7-1 .— Desired Levels of Experience or Education for Technical Specialists



– High
– Middle
– Low

1. Entry level
   Bachelors or O-2 years experience
2. Intermediate level
   Masters degree and 1-2 years or, 3-5 years experience
3. Advanced Level
   PhD or 5 + years experience

SOURCE A Keith Turner, "Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste sites, " final report, Nov. 30, 1984

for Superfund activities and are likely to see an increase in job opportunities. These are: 1) hydrologists, both groundwater and surface water; 2) geologists; 3) civil engineers, especially in the disciplines of soils/geotechnical engineering, construction management, and wastewater engineering; 4) certain classes of chemists and chemical engineers; 5) toxicologists; 6) industrial hygienists (and to a lesser extent health physicists); and 7) specialists in risk assessment and spill management. (See table 7-7, table 7-8, and figure 7-2.) Other specialties do not appear to be affected to the same degree.

Table 7-7.—Technical Personnel Needs for Uncontrolled Hazardous Waste Sites: Personnel Skills Survey—Importance of Technical Skills by Cleanup Category

Skill	Cleanup category: Site assessment	Emergency response	Surface cleanup	Subsurface cleanup	Total
Biologist	283	155	204	108	750
Meterologist	166	170	174	71	581
Environmental chemist	381	276	344	331	1332
Organic chemist	331	274	297	297	1199
Inorganic chemist	301	235	269	266	1071
Analytical chemist	365	298	336	332	1331
Piochemist/pharmaceutical chemist	145	105	119	107	476
Toxicologist	387	354	316	313	1370
Health physicist	233	230	213	195	871
Industrial hygienist	271	337	293	240	1141
Geochemist	366	157	205	359	1077
Geophysicist	277	108	139	248	772
Remote sensing expert	255	162	186	171	774
Engineering geologist	378	219	283	357	1237
Hydrologist—surface water	392	269	398	238	1297
Hydrologist—groundwater	452	265	261	500	1478
Statistician	189	92	166	172	619
Mathematician/computer specialist	241	124	196	310	871
Civil engineer	311	260	377	348	1296
Construction management	167	210	400	371	1148
Soils/Geotechnical engineer	324	199	369	379	1271
Waste water treatment engineer	182	162	280	314	938
Surface water engineer	191	156	285	188	820
Chemical engineer	280	266	313	331	1190
Incineration specialist	124	101	234	155	624
Environmental engineer	331	280	339	316	1266
Spill management specialist	185	447	227	162	1021
Risk assessment specialist	299	333	277	290	1199
Land use planner	122	49	96	96	363

NOTE This table based on 60 responses
The maximum possible score for each category is 600
The maximum possible total score is 2400

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov. 30 1984

Table 7-8.—The Top Skills by Cleanup Category

Skill category	Site assessment	Emergency response cleanup	Surface and subsurface
Very Important skill (rank ordered)	1) Hydrologist—groundwater 2) Toxicologist 3) Hydrologist—surface water 4) Environmental chemist 5) Engineering geologist	l) Spill manager 2) Toxicologist 3) Industrial hygienist	1) Hydrologist—groundwater 2) Construction manager 3) Civil engineer 4) Soils engineer 5) Engineering geologist 6) Hydrologist—surface water
Important skills (not ranked)	a) Biologist b) Organic chemist c) Analytical chemist d) Geochemist e) Civil engineer f) Soils engineer g) Environmental engineer h) Risk assessment specialist	a) Organic chemist b) Analytical chemist c) Hydrologist d) Civil engineer e) Chemical engineer f) Environmental engineer g) Risk assessment specialist	a) Environmental chemist b) Analytical chemist c) Toxicologist d) Waste water treatment engineer e) Chemical engineer f) Environmental engineer

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov. 30 1984

Figure 7-2.—Classification of Importance of the Various Technical Specialties for Hazardous Waste Cleanup Actions

Skills	Site assessment	Emergency response	Surface cleanup	Subsurface cleanup
Biologist				
Meteorologist				
Environmental chemist	■			
Organic chemist				
Inorganic chemist				
Analytical chemist				
Biochemist/pharmaceutical chemist				
Toxicologist	■	■		
Health physicist				
Industrial hygienist		■		
Geochemist				■
Geophysicist				
Remote sensing expert				
Engineering geologist	■			■
Hydrologist—surface water	■		■	
Hydrologist —groundwater	■			■
Statistician				
Mathematician/computer specialist				
Civil engineer		■	■	■
Construction management			■	■
Soils/geotechnical engineer			■	■
Waste water treatment engineer				
Surface water engineer				
Chemical engineer				
Incineration specialist				
Environmental engineer				
Spill management specialist		■		
Risk assessment specialist				
Land use planner				

■ Very important skill
□ Important skill
□ Optional skill

SOURCE A Keith Turner, ‘Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report, Nov. 30, 1984

Overall, *hydrology seems to be the most critical specialty*. This is because of the frequency of water contamination problems encountered at sites, For instance, the EPA reports that 75 percent of the NPL sites showed groundwater contamination and about 50 percent showed surface water contamination, With increasing attention being given to protecting groundwater resources, the demand for hydrologists will increase not only for waste site cleanups, but for design and monitoring of RCRA facilities and for groundwater protection programs.

The importance of qualified specialists for monitoring systems to determine the effectiveness of Superfund cleanups and to prevent future groundwater contamination at active hazardous waste facilities cannot be overstated. Groundwater consultant David W. Miller pointed this out in congressional testimony in 1982:

> The process of obtaining the data for predicting groundwater conditions, interpreting the information and making accurate decisions to implement compliance monitoring is a scientific endeavor. It can only be carried out in a confident manner by well trained groundwater technicians. There is presently a severe shortage of trained groundwater scientists in the public and private sector, and it is doubtful that there is sufficient talent available to work on more than a relatively small percentage of the existing sites that would fall under the compliance monitoring aspects of the new hazardous waste regulations.[18]

A report of the House Committee on Government Operations reviewing the development of a national groundwater protection strategy also noted the possibility of shortages of competent technical personnel:

> The Committee concludes that as the Groundwater Protection Strategy moves from the planning and strategy development phase into the implementation phase, there will be a significant increase in the need for well-trained professional groundwater specialists if the strategy is to succeed. The Committee, therefore, recommends that EPA and the Department of the Interior act in concert to assess the future and take such steps as are necessary to prevent any shortfall.[19]

Estimating the Pool of Available Professionals

Estimates of the current number of technical specialists in the work force and their probable future numbers were developed from data on enrollment trends, the awarding of technical degrees, and from membership in professional and scientific societies. Enrollment and degree figures tend to overstate the potential availability of trained graduates because not all students find work in their academic fields. Membership data, however, would tend to yield conservative estimates of available manpower because not all practitioners are members.

Performance issues aside, current staffing needs are being met for the most part. This is partly attributable to the slowdown in the minerals, petroleum, and construction industries which has reduced the demand for geologists, hydrologists, and civil engineers. Future staffing problems are likely to depend on general economic conditions as well as Federal funding for cleanup programs. The future levels of Federal funding for cleanup activities will greatly affect the overall levels of effort, even though not all activities will be funded from Federal sources. EPA Superfund monies currently fund about half of all cleanup activity. Other cleanup actions are being funded by other Federal agencies, such as the Departments of Defense and Energy, and by the States. Responsible parties in the private sector also pay for a substantial share of cleanups. It seems likely that cleanups paid for with non-Superfund money will continue to play a significant role in the demand for trained technical personnel. The perception of the importance of cleanup actions in the Nation's priorities will affect the future funding levels by these other sources; this perception will be largely shaped by the levels of funding authorized under Superfund.

Estimates of Future Demand

Using a range of what are believed to be reasonable projections of future funding needs, (see tables 7-9, 7-10, and 7-11), the demand for cleanup professionals was estimated using historically observed ratios of funds to technical personnel (table 7-12). About 3,750 professionals are estimated to be involved in current cleanup activities nationwide. It will undoubtedly take many decades to complete the clean-

[18] David W. Miller, *Hearings Before the House Subcommittee on Natural Resources, Agricultural Research and Environment of the House Committee on Science and Technology*, 97th Cong., 1 St sess. Nov. 30, 1982.

[19] U.S. Congress, *Groundwater Protection: The Quest for a National Policy*, Report of the House Committee on Government Operations, 98th Cong., 2nd sess., October 1984, p. 17.

Table 7-9.—Current and Projected Funding Levels Allocated to Type of Cleanup Activity (billions of dollars)

	Funding Levels[a]					
	1980-85		1985-90		1990-95	
Type of activity	Five-year total	Average annual expenditure	Five-year total	Average annual expenditure	Five-year total	Average annual expenditure
Long-term cleanups	$0.75	$0,15	$5.0	$1.0	$10.0	$2.0
Short-term cleanups	$1.0	$0.2	$2,75	$0.55	$5.5	$1,1
Emergency responses	$0.25	$0.05	$0.25	$0.05	$0.25	$0.05
Site investigations	$1.0	$0.2	$2.5	$0.5	$5.0	$1.0
Totals	$3.0	$0.6	$10.5	$2.1	$21.0	$4,2

[a]All dollar values are in billions and reflect midrange estimates Dollar values are constant 1984 dollars

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov 30, 1984

Table 7-10.—Current and Projected Funding Levels for the Cleanup of Uncontrolled Hazardous Waste Sites (billions of dollars)

Funding levels[a]	1980-85	1985-90	1990-95
Current	$3.0	—	—
Projected:			
Low		$7.6	$19.0
Midrange		$10.5	$21.0
High		$14.4	$25.6

[a]Includes Superfund, other Federal (e g., DOD, DOE). State-funded programs, and private industry

SOURCE A Keith Turner, "Potential for Future Shortages of Technical Personnet for a National Cleanup of Hazardous Waste Sites, " contractor report prepared for the Off Ice of Technology Assessment, Nov. 30, 1984

up of uncontrolled hazardous waste sites. The projections cover two 5-year increments 1985-1990 and 1990-1995. In making these projections it was assumed likely that after an initial steep increase in funding levels, the number of cleanups, and the number of required technical specialists, the program would reach a plateau or steady state and activity would continue at a similar level for several more decades.

With national spending to clean up uncontrolled hazardous waste sites at approximately $4 billion annually, the demand *for cleanup professionals* will *rise to about six times current levels, to about 22,750 professionals in 1995, and remain stable at this higher level for several decades as the cleanup actions are continued.* This growth will not affect all specialties equally. As discussed in the following section, for most specialties, such growth can be accommodated by the present work force and the educational system, *but additional emphasis on training in toxicology, hydrology, and engineering geology will be necessary to prevent shortages* in these areas, *There will be an unavoidable shortage of experienced technical*

Table 7-11 .—Current and Projected Manpower Levels Allocated to Type of Cleanup Activity

		Funding levels[a]					
		1980-85		1984-90		1990-95	
Type of activity	Ratio[b]	Average annual funding	Number of FTEs	Average annual funding	Number of FTEs	Average annual funding	Number of FTEs
Long-term cleanups	1:300,000	$0.15	500	$1.0	3,500	$2.0	7,000
Short-term cleanups	1:200,000	0.2	1,000	0.55	2,750	1.1	5,500
Emergency response	1:200,000	0.05	250	0.05	250	0.05	250
Site investigation	1:100,000	0.2	2,000	0.5	5,000	1.0	10,000
Totals		$0.6		$2.1	11.500	4.2	22.750
Average ratios[b]		1:160,000		1:182,600		1 : 184,600	

[a]All funding levels are in billions and reflect midrange estimate
[b]Ratios are in 1FTE/funding dollars (FTE - full time equivalent)

SOURCE. A Keith Turner, "Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites, " cent ractor report prepared for the Off Ice of Technology Assessment, Nov 30, 1984

Table 7-12.—Current and Projected Manpower Demand for 18 Critical Skills[a]

Skills	Numbers of people (FTEs)		
	1980-85	1985-90	1990-95
1. Hydrologist —groundwater	363	1,138	2,263
2. Hydrologist—surface water	333	1,013	2,013
3. Toxicologist	330	963	1,900
4. Civil engineer	283	938	1,863
5. Soils/geotechnical engineer	270	925	1,850
6. Environmental engineer	208	626	1,238
7. Construction manager	150	625	1,250
8. Engineering geologist	280	900	1,800
9. Geochemist	140	350	700
10. Environmental chemist	278	851	1,688
11. Analytical chemist	263	806	1,593
12. Organic chemist	135	315	615
13. Chemical engineer	88	326	638
14. Industrial hygienist	25	25	25
15. Risk assessment specialist	120	270	520
16. Waste water engineer	75	313	625
17. Biologist	100	250	500
18 Spill manager	38	38	38
Total	3,479	10,672	21,119

[a]Includes the top 18 of 29 technical specialists accounting for over 90 percent of total demand for cleanup specialists

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov 30 1984

specialists in all disciplines due to the rapid growth projected for these activities. Additional shortages of personnel may occur if the economy improves and causes increased demands and competition for trained personnel in science and engineering.

Analysis of Demand Projections

The numbers of professionals needed for each 5-year time period are estimated in table 7-12. In the periods following 1995, employment levels in each of these categories is expected to stabilize as the hazardous waste cleanup activities at various uncontrolled sites are expected to continue at a steady level. The number of professionals projected in table 7-12 are comparable to previous estimates by the National Water Well Association (NWWA) and ASTSWMO for the demands for hydrologists and State employees. NWWA estimated the demand for hydrologists would double, to about 10,000 by 1990, but hydrologists work in many fields in addition to hazardous waste cleanups. The ASTSWMO estimated State employment related to hazardous waste activities should rise to 1,000 fairly quickly, and this seems in line with these projections. In general, *these different projections show that the employment rate over the next decade will rise to about six times current levels.* While such an increase sounds very dramatic, the numbers must be looked at in comparison with the total numbers of people in these specialties. It then becomes apparent that these demands will affect the various specialties unevenly.

Toxicologists, hydrologists, engineering geologists, and geotechnical engineers are going to be affected by the demands placed on them by hazardous waste cleanup activities. Current trends suggest that about half the present toxicologists could be involved in cleanup actions, and that over 2%-times the current number of practicing toxicologists could be needed by 1995. Obviously there is room for growth in this specialty. Similarly, over 10 percent of current hydrologists and engineering geologists are now involved in cleanup actions, and this could rise to over two-thirds of the current total number of such professionals by 1995, if growth does not occur.

The civil engineering profession as a whole will not be affected because a large number of civil engineers graduate annually. Within some disciplines, such as geotechnical engineering, construction management, and wastewater engineering, however, some changes will be required.

Increased opportunities for environmental chemists are evident. This is also true, to a lesser extent, for analytical chemists, and to an even smaller extent for organic chemists. There appears to be increased demand for risk assessment specialists, although the total demand is small and will remain relatively small (perhaps 500 people).

By contrast, the changes in demand for geochemists, industrial hygienists, biologists, chemical engineers, and the other remaining critical skills do not seem likely to pose undue strains on the present populations in these fields.

Of equal or greater concern to the number of technical specialists available is their *quality* and experience. The personnel needs survey indicated a strong preference for experienced middle managers, people with masters degrees and/or 3 to 5 years of experience. The demand for experience is going to be a major problem. The projected rate of growth over the decade, coupled with the relatively small base of experienced persons on which to build, will cause a continuing shortage of fully qualified, experienced specialists in almost all the critical skills. The impact of this shortage can be mitigated, at least in part, with specialized training courses, and in part, by careful personnel management policies, but the shortages cannot be fully overcome by these measures, Nevertheless, suggestions for increased training opportunities are made later in this chapter as one of the most effective methods for dealing with this problem.

Other Factors

Other factors affecting the future availability of technical specialists for hazardous waste cleanups should also be noted. Survey respondents noted problems already with employee burnout due to job stress and heavy workloads. This appears true both in the administrative agencies and in technical and administrative jobs with contractors and consultants.

EPA's system of awarding major contracts for the Superfund program may create some problems in providing a stable technical work force. Because it cannot be guaranteed that contracts will be renewed, large consulting firms are hesitant to invest in developing skills of employees who may have to be let go. Long-term employment commitments for technical specialists may be limited. In submitting contract proposals, many firms rely on the qualifications of persons not yet employed or under contract to them. Once the contract is awarded, the team will be assembled. Some professionals may be offered as staff by several different firms competing for the same contract. If a major contract is not renewed, experienced site assessment and remedial design teams may break up and disperse.

Shortages at State or Federal agencies caused by hiring freezes or noncompetitive pay-scales could greatly hamper the cleanup programs. A recent ASTSWMO study (1983) explored these issues at the State agencies and found them to be important.[20]

Increased use of technicians and less qualified professionals in field and site investigators hinges on the availability of experienced professionals to manage these teams. This underscores the importance of augmenting the supply of experienced professionals,

The survey also found that training in health and safety procedures for all current and future onsite employees will be required. Although the market is likely to respond to the demand for expansion of such courses and training facilities without government help, there may be some need for government assistance in quality control and monitoring.

Encouraging Technical Training for Hazardous Waste Cleanups

OTA's analysis concluded that the greatest need is for *experienced* scientists and engineers. There do not appear to be major problems in providing basic technical training to enough people, Methods for gaining practical experience rapidly are essential. Although nothing can fully substitute for years of on-the-job experience in the field, several alternatives can help.

The personnel needs survey asked questions about ways to gain experience. The results are shown in table 7-13. There were differences in preferences among respondents, The EPA, Superfund contractors, and industry respondents favored intensive retraining/refresher courses, while State agencies and other consulting firms favored masters level graduate training.

[20]The ASTSWMO report is published as: U.S. Environmental Protection Agency, "State Participation in the Superfund Program, CERCLA Section 301(a)(l)(E) Study" (Washington, DC: Office of Solid Waste and Emergency Response, December 1984).

Table 7-1 3.—Preferences for Training

Respondent/training method	Choice ranking 1st	2d	3d	4th
EPA:				
0 Undergraduate training ., . . .	0....4.	..9	. .	
Graduate (MS) Training	2	5	5	1
Retraining/refresher courses .	9	3	1	0
On job training	2	5	3	3
State Superfund agencies:				
Undergraduate training	2	2	2	6
Graduate (MS) training	4	3	4	1
Retraining/refresher courses	3	5	3	1
On job training	3	2	3	4
Superfund contractors:				
Undergraduate training	1	0	2	7
Graduate (MS) training	2	2	4	2
Retraining/refresher courses	4	3	2	1
On job training	3	5	2	0
Private consultants:				
Undergraduate training .	0	1	0	7
Graduate (MS) training	4	2	2	0
Retraining/refresher courses	2	2	2	2
On job training	1	3	4	0
Industry:				
Undergraduate training	0	0	0	5
Graduate (MS) training .	1	3	1	0
Retraining/refresher courses	3	2	0	0
On job training	1	1	3	0
Academic:				
Undergraduate training ., ...	0	0	0	2
Graduate (MS) training	1	1	0	0
Retraining/refresher courses	1	1	0	0
On job training	0	0	2	0

SOURCE A Keith Turner, Potential for Future Shortages of Technical Person nel for a National Cleanup of Hazardous Waste Sites final report Nov. 30, 1984

Each method has advantages and disadvantages. The intensive courses, if properly prepared, can significantly upgrade skills in a short time. Graduate training is slower, usually more expensive, but offers a greater depth and breadth of study. It also allows for the continued development of improved methods through research programs.

Accordingly, a strategy combining the two methods appears beneficial:

1. develop additional intensive short course programs for training and retraining and for maintaining skills; and
2. expand graduate research and training programs.

A number of short courses and programs are currently offered by universities, professional societies, and private firms. Their quality is not uniform. In addition, there are limited sources of public information available, beyond that offered by the EPA.

A selected number of regional technical centers might be established to assist in the following:

- offer short courses on topics of interest to hazardous waste professionals, including health and safety training;
- develop graduate programs for hazardous waste cleanup skills within existing academic disciplines;
- conduct research on technical problems at cleanups;
- enhance the current EPA technical guidelines literature with other guidelines, technical memoranda, and reports aimed at the public, local and regional planning officials, and others; and
- serve as regional public information clearinghouses to assist the public, businesses, and State and local governments on hazardous waste issues, much as the existing State Water Resource Research Centers and Agricultural Extension Stations have assisted their clients in the past.

Such regional centers should be explicitly identified and funded for these activities. The cost would be a small fraction of the total cleanup budget and could be a solid investment in the overall program efficiency.

Sources. The following OTA working papers were used in the preparation of this chapter:

1. George J. Trezak, "A Case Study of the Sylvester Superfund Site, " February 1985;
2. ERM-Midwest, Inc., "Case Study: Seymour Recycling Corporation, Seymour, Indiana," March 1984;
3. George J. Trezak, "Engineering Case Study of the Stringfellow Superfund Site, " August 1984; and
4. A. Keith Turner, "Potential for Future Shortages of Technical Personnel for National Cleanup of uncontrolled Hazardous Waste Sites," NOV. 30, 1984.

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Chapter 8

Public Participation and Public Confidence in the Superfund Program

Contents

Chapter 8

Public Participation and Public Confidence in the Superfund Program

SUMMARY

Public confidence in the Superfund program is vital to its success, The Superfund program, however, contains few formal opportunities for public participation in decisionmaking. In this chapter, the term "public" includes local residents, community groups, businesses, organizations such as environmental groups, and business and trade associations. "Public" also generally includes potentially responsible parties; however, discussion of their specific involvement in cleanups, negotiation of settlements, and liability issues is beyond the scope of this chapter.

Public participation does not necessarily slow the implementation of Superfund cleanups. While public participation adds steps to the process, which take time, it also adds public support. Public support can help a cleanup progress smoothly and effectively, while shortcutting public review in the hope of speeding cleanups can have unintended adverse effects. Public review of the adequacy of site assessments and other contractor work is a check on the quality of work and the effectiveness of remedial activities, and public scrutiny of agency performance can help management of the Superfund program.

The Environmental Protection Agency's (EPA) information dissemination programs have received mixed reviews. Although some programs have drawn praise for keeping people informed, *information dissemination itself offers only a one-way communication that does not substitute for active participation in decisionmaking.* If cleanup strategies are developed behind closed doors, the public will feel disenfranchised and suspicious, eroding public confidence in the Superfund program.

The principal opportunity for public involvement in Superfund cleanups occurs late in the decisionmaking process after a proposed cleanup strategy has been identified. Even though the Remedial Investigation/Feasibility Study (RI/FS) process may have lasted for several years and remedial design and construction of an approved remedy may take several more years, the time allowed for review and comment may only be several weeks. Effective participation is frequently hindered because the public may lack the expertise needed to analyze complex environmental, public health, and technological issues. EPA, with rare exception, does not provide funds for citizens to hire technical advisers.

The limited opportunity for public involvement in decisionmaking to develop specific cleanup plans and the inability of public groups to obtain costly technical advice can affect the type of cleanups that are undertaken at Superfund sites. For example, local residents who do not understand complex remedial technologies or who are not involved in the development of cleanup plans can be less likely than their more technically oriented counterparts to: a) support more permanent cleanup strategies based on onsite treatment or decontamination of hazardous wastes, and b) understand if such permanent cleanups are not yet available. Lack of technical expertise can also result in some viable cleanup strategies that might be acceptable to the local population being prematurely rejected or not considered by EPA.

The pollution problems and community concerns at every Superfund site are substantial, Furthermore, the problems of assigning responsibility among large numbers of former

waste disposers are unparalleled. The complexity and variety of Superfund issues complicates attempts to modify the program to increase public participation, Opening the doors to public participation in negotiations and enforcement actions, granting new access to the courts for the public to seek redress of grievances, and even increasing public access to data collected in the course of Superfund activities are all confronted by some often equally compelling counterarguments,

That public participation in the Superfund program could be improved is clear. How to go about making the improvements is not nearly so obvious, and there currently is no clear consensus, even among groups in the public sector, on precisely how it should be accomplished.[1]

[1] See the "National Contingency Plan" section below for a description of how EPA's recent proposed changes to the NCP would add ress concerns about public participation.

INTRODUCTION

"The Superfund community relations program encourages two-way communication between communities affected by releases of hazardous substances and agencies responsible for cleanup actions . . . An effective community relations program must be an integral part of every Superfund action."[2] These words, amid other EPA policy statements, attest to the perceived importance of public participation in Superfund decisionmaking and establish an EPA objective to promote public involvement in the Superfund program,

This chapter compares that EPA objective with how public participation actually works in the Superfund program. It discusses the provisions for, and constraints on, public participation during the development of the national Superfund program and during the implementation of cleanup programs at individual Superfund sites. The chapter examines the public's efforts to become involved in Superfund decisionmaking, both through avenues provided by the program and through other pathways. It also assesses how participation has shaped overall public confidence in the Superfund program, confidence that has been shaken in recent years by the slow pace of program implementation at many sites and previously during the period when allegations of program mismanagement by top officials within EPA were being made. Finally, the chapter compares public participation in the Superfund program with other environmental programs, most notably with the hazardous waste permitting process of the Resource Conservation and Recovery Act (RCRA).

For the purpose of this chapter, the term "public" refers broadly to anyone who is not working as an employee or under contract to a government agency directly responsible for implementing the Superfund program. Thus, the public includes citizens living near Superfund sites, businesses, local governments, organizations such as environmental groups, professional and trade associations, and potentially responsible parties (PRPs). PRPs can be made to clean up sites or to reimburse the government for fund-financed cleanups. PRPs share with the public many of the same concerns about the availability of information and opportunities to participate in decisionmaking about remedial activities. PRPs, however, can be held liable for the costs of cleanup and in some cases for punitive damages. This liability exposure creates additional complications for PRP participation that do not apply to other groups. PRPs are or may soon be involved in adversarial proceedings with the EPA. Litigation strategies may influence the governments' willingness to share information with PRPs. Litigation considerations may also limit the PRP's willingness to work with other members of the public.

[2] U.S. Environmental Protection Agency, "Community Relations in Superfund: A Handbook," Interim Version (Washington, DC: September 1983), p. 1 Introduction. Hereafter referred to as the Community Relations Handbook,

PUBLIC PARTICIPATION PROVISIONS UNDER CERCLA

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) has, compared to other key environmental laws enacted since 1970, few requirements for, or references to, public participation in decisionmaking. The only guaranteed opportunities for public involvement occur as a result of Federal agency rulemaking proceedings mandated by CERCLA. The Act contains 11 rulemaking requirements.[3] Under the Administrative Procedures Act, rulemaking would normally include a public comment period on the proposed regulations. CERCLA requires that the following be accomplished through rulemaking:

- Designating hazardous substances and establishing reportable quantities of hazardous substances (Section 102).
- Establishing information reporting requirements (Section 103).
- Defining emergency procurement powers (Section 104).
- Revising the National Contingency Plan (Section 105). (There are several requirements for rulemaking in this section.)
- Evaluating a program of optional private post-closure liability insurance for hazardous waste facilities (Section 107).
- Determining financial responsibility for vehicles (Section 108),
- Assigning money-spending powers to government officials (Section 11 1).
- Giving notice to potential injured parties (Section 111).
- Establishing procedures for filing claims (Section 112)

Section 113 of CERCLA discusses access to the courts by parties that disagree with EPA actions. Subsection (a) permits the public to seek judicial review of any Federal regulation promulgated under the Act in the U.S. Circuit Court of Appeals in Washington, D.C. Additionally, subsection (b) provides that " . . . the United States district courts shall have exclusive original jurisdiction over all controversies arising under this Act . . . ," but it is silent on who has standing to bring suit regarding what types of controversies. These are the only statements in CERCLA concerning the rights of the public to initiate or participate in legal actions related to Superfund activities.

Absent from CERCLA are provisions allowing "citizen suits" to be brought against the government or a private party, such as a potentially responsible party, thought to be acting in violation of the law. Citizen suits are explicitly permitted under most other major environmental protection laws including the Clean Air Act (Section 304), the Clean Water Act (Section 505), the Endangered Species Act (Section 11g), and the Toxic Substances Control Act (Section 20).[4] Moreover, CERCLA does not define procedures by which the public may petition EPA to promulgate new regulations under the Act. Citizen petition provisions are contained in the Toxic Substances Control Act (Section 21) and the Resource Conservation and Recovery Act (Section 7004).[5] Finally, CERCLA does not guarantee that the public may intervene in Superfund negotiation or enforcement actions involving potentially responsible parties,[6] and several courts have ruled that community groups may not join Superfund lawsuits as intervening parties.[7] These limitations in CERCLA may have resulted from concerns about delays in the cleanup process and about problems associated with getting PRPs to fund cleanups if the public were more directly involved.

CERCLA contains instructions to guide the EPA as it develops the Superfund program,

[3] Fred Anderson, *Negotiation and Informal Agency Action. The Case of Superfund*. Report to the Administrative Conference of the U.S., May 25, 1984.

[4] Jeri Bidinger, " Hazardous Waste Cleanup in Wyoming: Legal Tools Available to the Private (citizen, " *Land and Water Law Review*, 1984.

[5] Natural Resources Defense Council, Memorandum from Jane Bloom to the Superfund Reauthorization Coalition, Jan 3, 1983. pp. 9-11,

[6] Ibid., p. 1

[7] Randy Mott, letter to Karen Larsen, office of Technology Assessment, Nov. 30, 1984. Hereafter referred to as the Mott letter.

but, with one exception, these instructions make no reference to public involvement. For example, CERCLA requires that the Attorney General be consulted prior to the issuance of "guidelines for using the imminent hazard, enforcement, and emergency response authorities" (Section 106(c)), but does not require public review of those guidelines. Similarly, Section 105(8)(B) requires that "each State shall establish . . . priorities for remedial action," but it does not order the States to allow public involvement during that process, nor does it insist on public participation during EPA reviews of State nominations.

The one exception, Section **105(4),** requires that the revised National Contingency Plan examine the "appropriate roles and responsibilities for the Federal, State, and local governments and for interstate and *nongovernmental entities* in effectuating the plan" (emphasis added). While the public is not mentioned specifically, it could arguably be considered a subset of nongovernmental entities. No guidance is offered about how the "appropriate roles" might be determined.

CERCLA was drafted during an era when for the first time many abandoned hazardous waste sites were discovered to be leaking substances that could endanger public health. News of "toxic timebombs" such as Love Canal, New York, appeared in the press routinely. These announcements, coupled with the apparent inability of the government or private parties to take quick action to protect the health of people living near the sites, heightened public fears and created an emotionally charged atmosphere. In that environment, Congress enacted a law to facilitate a rapid response by the Federal Government to what many thought was a national emergency.

The law seems to reflect a belief that this is a problem best handed to the experts. The extent of pollution and the public health threats it causes at many uncontrolled hazardous waste sites is poorly understood. The selection of appropriate cleanup technologies often requires sophisticated engineering and scientific judgments. The assignment of liability to parties that caused environmental problems involves difficult legal issues. The two themes of promoting quick action and domination of decisionmaking by EPA and technical experts acting on behalf of a frightened public are reflected in CERCLA and guide the development and implementation of the Superfund program.

THE NATIONAL CONTINGENCY PLAN

CERCLA ordered the EPA to develop a framework for the Superfund program in the form of Federal regulations incorporated into the National Contingency Plan (NCP), first developed under the Clean Water Act,

Public participation during the NCP revision process took two forms—litigation and formal public comments on proposed regulations. Litigation resulted because the EPA missed the June 9, 1981 statutory deadline for promulgating revisions to the NCP. The Environmental Defense Fund (EDF) then sued in the U.S. Circuit Court of Appeals in Washington, D. C., seeking a court order forcing EPA to propose NCP revisions.[8] The suit was later combined with a similar action by the State of New Jersey.[9] On February **12, 1982, the court ruled in favor of the plaintiffs and ordered** the EPA to complete NCP revisions by May 13, 1982.[10] The deadline was extended for 15 days by the court on March 18, 1982, to provide additional time for public comment on the proposed rules

[8] U.S. Court of Appeals, District of Columbia Circuit, Civil Action $81-2083,

[9] U. S. Court of Appeals, District of Columbia Circuit, Civil Action #81-2269.

[10] Decision published in the *Environmental Law Reporter* at 12 ELR 20376-20378, April 1982.

(which was *expanded* from 30 to 45 days).[11] The final regulations were promulgated on July 16, 1982.[12]

During the 45-day comment period, EPA received 146 written statements from the public, government agencies, and industry that included over 1,000 pages of text.[13] The preamble to the final regulations notes that the regulations were modified in response to comments. However, with one except ion, EPA rejected every recommendation to expand public participation procedures outlined in the draft NCP. The preamble noted four major themes contained in comments related to public participation:[14]

- there should be stronger advocacy of public participation in the NCP;
- the draft NCP placed too much authority in the hands of the lead agency and the National Response Team;
- some procedure should be established to help the public understand what cleanup actions were being taken; and
- the NCP should include specific public participation requirements.

Consequently, EPA added a provision requiring that government personnel "be sensitive to local community concerns (in accordance with applicable guidance)" when assessing the need for, planning, or undertaking Superfund-financed actions.[15] However, EPA did not include the guidance as part of the regulations, nor did it define any specific public participation requirements,

With regard to other comments related to public involvement in the Superfund program, EPA rejected a request that the Hazard Ranking System (HRS) be expanded to include consideration of nontechnical factors—including community interests—when used to assess the severity of a site's environmental problems. EPA reasoned that the appropriate place to consider community interests was during the development of cleanup strategies, well after the site ranking.[16] However, sites not receiving a high hazard ranking are not considered for remedial cleanup actions.

Also relevant to the "community interest" issue is that the HRS scoring criteria does consider population density near sites. That criterion can create a bias in favor of adding NPL sites in populated regions in comparison to equally hazardous sites in sparsely populated regions. To the extent that densely populated regions are likely to have high levels of community interest compared to rural areas, adding a specific ''communit}' interest criterion to the HRS could exacerbate that bias.

EPA also rejected a recommendation that meetings of the National Response Team be open to the public by saying that ''such a provision is not appropriate in this Plan, since some meetings may be public and others may require executive session."[17] Finally, recommendations that private parties be allowed to suggest to EPA that particular On-Scene Coordinators (OSCs) of Superfund actions be replaced were also denied. EPA continued to limit such suggestions to the Regional Response Teams—which contain no members from the public-reasoning that "it is inappropriate to encourage such requests in the Plan, especially since the OSC will often be involved in situations where private parties have failed to clean up properly. "[18]

The final NCP is similar to CERCLA itself in its lack of specificity with regard to required public involvement in Superfund activities. It is perhaps notable that the word "public" does not appear anywhere in the introductory Section 300.3 which defines the scope of the entire NCP.

In addition to the requirements, cited above, for "sensitivity to local community concerns" when studying cleanup options and for public comments on proposed additions to the NPL, the following NCP sections address public participation issues:

- "Federal agencies should coordinate planning and response action with affected

[11] Modification published in the *Environmental Law Reporter* at 12 ELR 20401, May 1982.
[12] 47 Federal Register 31180-31220.
[13] 47 Federal Register 31180.
[14] 47 Federal Register 31198.
[15] 40 CFR 300.61(c)(3).
[16] 47 Federal Register 31181.
[17] 47 Federal Register 31197.
[18] 47 Federal Register 31197.

State and local government and private citizens" (40 CFR 300.22(b).

- "Industry groups, academic organizations, and others are encouraged to commit resources for response operations" (40 CFR 300.25(a)).
- "It is particularly important to use valuable technical and scientific information generated by the nongovernment local community along with those from Federal and State government to assist the OSC in devising strategies where effective standard techniques are unavailable" (40 CFR 300.25(b)).
- "Federal local contingency plans should establish procedures to allow for well-organized, worthwhile, and safe use of volunteers" (40 CFR 300.25(c)),
- "The USCG (U.S. Coast Guard) Public Information Assist Team (PIAT) and the EPA Public Affairs Assist Team (PAAT) may help the OSCs and regional or district offices meet the demands for public information and participation during major responses. Requests for these teams may be made through the (National Response Center)" (40 CFR 300.34(f)).

The promulgation of the final revised NCP precipitated a second legal challenge by EDF and the State of New Jersey.[19] The plaintiffs argued that the NCP did not contain the necessary information in sufficient detail to comply with CERCLA,[20] Negotiations between EPA and the plaintiffs resulted in a consent decree signed on January 16, 1984.[21] In the agreement, EPA promised to propose further revisions to the NCP to address six major issues, one of which was public participation, Specifically EPA agreed to the following:

> EPA will propose amendments to the NCP to (a) require development of Community Relations Plans for all Funded-financed response measures, (b) require public review of the Feasibility Studies for all Fund-financed response measures, and (c) provide comparable public participation for private-party response measures undertaken pursuant to enforcement actions.[22]

EPA released a second draft version of possible regulatory language to the plaintiffs in September 1984. The draft requires community relations plans at every Superfund site and orders a 21-day public comment period on all feasibility studies.[23] These actions have to date been EPA policy, but they have not been regulatory requirements. Also, the draft contains language that would permit public participation in enforcement actions, but only when EPA determines that public participation will be "useful to further the cause of settlement. " EDF has taken issue with that condition by responding to EPA as follows:

> This requirement ignores the fact that the central purpose of public participation is not to facilitate settlements but rather to deal effectively with the concerns of the surrounding community , . . If public representatives are willing to comply with the other conditions, including small numbers, technical and legal expertise, and a pledge of confidentiality, they should be permitted to participate in the negotiations.[24]

It is important to note that many people disagree, at least in part, with EDF's position on public involvement in all stages of enforcement actions. One lawyer believes, for example, that "public participation in enforcement cases is a potential necessity, but public access to settlement discussions would have a potentially disastrous effect on voluntary cleanup. We have generally conducted all our negotiations in the open, but this is the exception, not the rule and, even then, on some issues privacy is critical. "[25] A paper on Superfund negotiations written for the Administrative Conference of the United States cites discussions involving the allocation of cleanup costs among private parties or involving analysis of the amount, tox-

[19] U.S. Court of Appeals, District of Columbia Circuit, Civil Actions #82-2234 and #82-2238.

[20] Bob Percival, Environ mental Defense Fund (E D F), personal communication, Oct. 9, 1984.

[21] Copy of the Settlement Agreement obtained from EDF.

[22] Ibid., p. 2,

[23] "Comments of the Environmental Defense Fund on the Sept. 10, 1984, Draft Revisions to the National Contingency Plan, " Oct. 1, 1984, p. 8. Mailed from EDF's Washington, DC, office to EPA.

241 bid., p. 8.

[25] Mott letter, op. Cit.

icity, longevity, and condition of the wastes deposited by individual parties as examples of issues that might require privacy.[26]

EPA Proposed Changes to NCP

On January 28, 1985, EPA announced its proposed changes to the NCP.[27] A number of important changes have been proposed concerning public participation. However, the proposal undergoes public comment for 60 days and it is not now possible for OTA to know how the proposal may be changed in response to public comments or how the new NCP will be implemented. Nevertheless, the proposed changes significantly address concerns about public participation.

A new section to Subpart C on Organization entitled Public Information is proposed. This sets up the mechanism to "address public information at a response, " The purpose is to ensure "that all appropriate public and private interests are kept informed and their concerns considered throughout a response, "

A new section to Subpart F on Hazardous Substance Response entitled Community Relations is proposed. The Preamble notes that: "The purpose of the community relations program is to provide communities with accurate information about problems posed by releases of hazardous substances, and give local officials and citizens the opportunity to comment on the technical solutions to the site problems. " A formal community relations plan is required for all removal actions and all remedial actions, including enforcement actions, but not for "short term or urgent removal actions or urgent enforcement actions. " Moreover, the formal plan is to be "based on discussions with citizens in the community" and "should be reviewed by the public, " The plan "should be developed and implementation begun prior to field activities" for remedial actions, including enforcement actions. A "responsible party may develop and implement specific parts of the community relations plan with lead agency oversight ." Furthermore:

> . . . the minimum public comment period allowed for review of feasibility studies for remedial actions at NPL. releases shall be 21 calendar days. The comment period is to be held prior to final selection of the reined} and allows for effective community and responsible party input into the decision making process. The public may also have the opportunity to comment during the development of the feasibility study. This will provide the public with advanced warning as to possible remedial alternatives.

Records of decision would be required to have a responsiveness summary "addressing the major issues raised by the community. "

Lastly, with regard to the interactions between the lead agency and PRPs, there could be meetings with "a limited number of representatives of the public, where these representatives have adequate legal and technical capability and can provide appropriate assurances concerning any confidential information that may arise during the discussions, if in the judgment of the lead Agency such meetings may facilitate resolution of issues involving the appropriate remedy at the site. "

Note that the remainder of this chapter examines and discusses the current Superfund program, even though some of the above changes might address the issues and concerns that now exist.

[26] Anderson, op. cit., p. 97.
[27] The revisions are published at 5[) Federal Register 5861, Feb. 12, 1985

THE EPA COMMUNITY RELATIONS PROGRAM

The Community Relations Program defines public participation procedures that agency staff should follow as a matter of policy, rather than law or regulation. The document that currently explains the program is a September 1983 report entitled "Community Relations in

Superfund: A Handbook," It describes in detail public participation activities that EPA staff should conduct during the development and implementation of cleanup efforts at Superfund sites. (The specifics of how the program is operated are discussed later in this chapter,)

Despite the length of the handbook—over 100 pages—and its degree of detail, there are some notable limitations to the program it defines. First, the document is an "interim version" and is incomplete. For example, an entire chapter concerning public participation in enforcement actions is missing. EPA has drafted several versions of the chapter, but none have been adopted.[28] Secondly, the program applies only to cleanup activities at NPL sites. It does not include procedures to promote public participation during the review of proposed regulations or policy or during the hazard ranking or site selection processes, Thirdly, the program focuses on public participation activities by EPA employees, it does not establish legally enforceable minimal requirements for public involvement at Superfund sites. As explained above, EPA has agreed to promulgate new regulations requiring Community Relations Plans, but implementing the program is currently discretionary.

Finally, the handbook is designed to help EPA officials develop community relations programs, not to help the public participate in them, Indeed, the handbook specifically cautions that it:

> ... does not serve as a public participation manual, In the past, several public participation manuals have been prepared for EPA, particularly in the water program. Readers that need detailed guidance on public participation techniques . . . should consult these manuals.[29]

The Superfund program differs considerably from other EPA programs. The task of explaining public participation procedures to the public has fallen to citizen groups involved in Superfund issues. For example, the Environmental Defense Fund has published a public participation manual entitled *Dumpsite Cleanups: A Citizen Guide to the Superfund Program*.[30]

[28] Margaret Randall, Deputy Director of the Office of Public Affairs EPA Region II and Lillian Johnson, Superfund Community Relations Coordinator EPA Region 11, personal communications, Oct. 24, 1984. Hereafter referred to as the EPA Region II interview.

[29] Community Relations Handbook, op. cit., p. 1-4.

[30] Environmental Defense Fund, *Dumpsite Cleanups: A Citizen's Guide to the Superfund Program*, Washington, DC, 1983. Hereafter referred to as Dumpsite Cleanups.

THE SUPERFUND PROGRAM IN ACTION

The actual implementation of the Superfund program can be divided into two phases. The first involves identifying potential sites for Superfund cleanup and ranking those sites according to the severity of the environmental and human health risks they present. The second phase involves selecting and conducting cleanup programs at uncontrolled sites, including emergency and remedial cleanup actions, EPA provides opportunities for public participation in each of these phases, as discussed later.

The National Priorities List

With the exception of some short-term emergency actions, cleanup of a hazardous waste site as part of the Superfund program is not undertaken unless the site is on the National Priorities List (NPL), which is revised periodically. A site cannot become part of the NPL unless it has been identified as a potential NPL candidate and the severity of its pollution problems have been evaluated.

While EPA states the purpose of the NPL merely "as an informational tool for use by EPA in identifying sites that appear to present a significant risk to public health or the environment,"[31] appearance of a site on the NPL has other implications. For example, listing can provide State leverage to pressure EPA for cleanup funds or offer citizens groups information with which to pressure EPA, States, and responsible parties to take actions. Also, publication of the list and the press coverage that accompanies it provide a way for the public to learn about the Nation's hazardous waste problems and track the progress of the Superfund program, On the other hand, NPL listing can have some potential adverse consequences. For example, appearance of a site on the NPL can heighten community fears beyond what is warranted by the health risks posed by the site, and it can cause negative economic consequences such as reducing local property values. Thus, for a number of reasons many citizen groups are keenly interested in the selection process and are anxious to participate in it.

About 19,000 uncontrolled sites have been identified in the United States and EPA estimates that the list might ultimately reach 22,000.[32] Many sites were identified by their present or past operators as required under Section 103 of CERCLA. Site identification is an ongoing process, however, and there are two official pathways by which the public can bring potential Superfund candidates to EPA's attention. First, CERCLA and the NCP require the National Response Center in Washington, D. C., to record site identifications phoned in by the public and to report this information to the On Scene Coordinator for Superfund activities in the appropriate region, In addition, EPA headquarters and each EPA Region maintain Superfund "hot-line" numbers that people can use to identify hazardous waste sites.[33]

Once a site has been identified, its pollution problems are evaluated. The first two steps in this process involve the collection of information during a preliminary assessment and a site inspection (see chapter 5), While there are no formal opportunities for public comment during these procedures, the EPA Community Relations Handbook suggests that EPA "establish contact by phone with State and local officials and with key citizens" during the preliminary assessments* Furthermore, "community relations activities during a site inspection should focus on informing the community of site inspection activities and the likely schedule of future events."[35]

The public now has no formal way to influence which sites are selected for preliminary assessments and site inspections or when those evaluations are conducted. In the words of Margaret Randall, Deputy Director of the Office of Public Affairs at EPA Region 11, "EPA decides when the (evaluation process) kicks in."[38] One community group in Greenup, Illinois, has gone as far as holding public demonstrations at a potential Superfund site to

[31] 49 Federal Register 40320, Oct. 15, 1984.
[32] Dennis Melamed, "Superfund: From Site Selection to Cleanup," *Environmental and Energy Study Conference Guide* (Washington, DC: July 11, 1984), p. 1. Hereafter referred to as EESC Guide.

[33] EPA Region III Interview, op. cit,
[34] Community Relations Hand book, " op. c i t., p. 3-2.
[35] 1 bid., p. 3-2.
[36] EPA Regio 11 III nterview, op. cit.

pressure EPA into beginning a preliminary assessment. 37

If the site inspection uncovers potential or actual discharges of hazardous substances, the HRS is used to evaluate and "score" its pollution problems. The development of the HRS itself included some public participation. Public comment was solicited on an HRS model proposed by EPA in a Federal Register notice along with the draft NCP on March 12, 1982.[38] EPA received extensive comments on the HRS and modified it in several ways prior to adopting a final version on July 16, 1982.[39]

The development of the HRS also involved an unusual effort by the Senate Appropriations Subcommittee on HUD—Independent Agencies to sponsor a workshop on the topic attended by representatives from industry, government, and one environmental organization. The 2-day workshop, convened on March 19 and 20, 1982, in the midst of the public comment period on the draft NCP and HRS, was moderated by a professional mediator, and a written record of portions of the proceedings was later published .40 While the information and opinions discussed at the workshop were not entered into the public comment record for the draft HRS, EPA officials were present and the meetings provided an avenue for public participation in the HRS decisionmaking process.

There are no opportunities for public participation during the application of the HRS to sites after the site inspection. Moreover, there are no public participation provisions during the reviews performed subsequently by the States and the EPA. HRS scores and the worksheets produced during the evaluations are not made public either by States or the EPA unless and until the EPA publishes a list of sites proposed for inclusion on the NPL. EPA treats information on sites that are not added to the NPL as privileged and it is not available to the public.

Once proposed additions to the NPL have been published in the Federal Register, a 30-day public comment begins. At the beginning of the comment period, EPA releases ranking worksheets and other background information, but only for sites named for the NPL. Comments were received on about 50 percent of the sites named to the first proposed NPL list. About 90 percent of the comments came from potentially responsible parties and changes were made in the rankings for about 2 percent of the sites based on information provided in the public comments.[41] During the most recent proposed NPL listing, completed in September 1984, EPA received 128 comments. Fifty of the 133 proposed sites were the focus of 112 comments. Only 16 comments addressed sites not included on the proposed list.[42]

In short, the public is completely excluded from the draft NPL selection process itself, and then is provided information only about proposed NPL candidates to assist them in preparing comments. Although many people are concerned that sites with severe toxic pollution problems might be omitted from the NPL (see chapter 5), *the current decisionmaking process does not offer them an opportunity to examine why sites were rejected.*

Thus, the current process does not generate public confidence that sites not named to the NPL list have been justifiably omitted. As a result, some experts believe that "every site picked is bad, but not every bad site is picked."[43] Others, such as PRPs, believe that the NPL selection process overscores as many sites as it underscores. q'

Several groups have attempted to obtain information about sites not proposed to the NPL,

[37] Robert Ginsburg, Citizens for a Better Environment, personal communication, Oct. 8, 1984.

[38] 47 Federal Register 10975, Mar. 12, 1982.

[39] 47 Federal Register 31186-31191, July 16, 1982.

[40] Sam Gusman, Senior Associate of the Conservation Foundation, personal communication, Oct. 5, 1984. The written record of the workshop appears as *Workshop on Selection of Hazardous Waste Sites for Superfund Fundings. Sponsored by the Subcommittee of Department of Housing and Urban Development-Independent Agencies of the Committee on Appropriations, U.S. Senate*, Mar. 19-20, 1982 (Washington DC: U.S. Government Printing office, 1982). Hereafter referred to as the Workshop Record.

[41] ESC Guide, op. cit., p. 4.

[42] "Background Information: National Priorities List Update #l, September 1984," obtained from EPA Region II.

[43] Linda Greer, Environmental Defense Fund, personal communication, Oct. 8, 1984.

44 Mott letter, op. cit.

or to influence which sites are placed on the list. For example, prior to the publication of the first NPL candidate list, a law firm filed a Freedom of Information Act request seeking data about the sites submitted by the States. The request was refused. The firm had better luck at the State level. According to an attorney at the firm, "we had input into the 115 list solely because we went to States and found the candidates they were submitting and (somehow) managed to whip in data and information in the process. "[45]

The staff of a public interest organization in Ohio had a completely different experience. They attempted to obtain information from the State environmental agency about a site that had been evaluated, but their request was denied. The information was obtained from EPA, however, not as part of EPA policy, but unofficially from a sympathetic agency employee. [46]

Bonnie Exner, representing the Colorado Citizen Action Network, was involved in a review of a ranking process at the Lowry Landfill site near Denver that resulted in a reevaluated score 20 points higher than originally calculated. Several years ago during a controversy over the permitting of an operating hazardous waste facility at Lowry, the Governor formed the Lowry Landfill Monitoring Committee, an advisory group that included local citizens and representatives of EPA, the State health department, local government, and a waste disposal company, After a 300-acre " area within the much larger landfill site was evaluated as part of the Superfund program, the local citizens decided to perform their own HRS scoring. When the citizens' score turned out to be much higher than the official evaluation, they "forced the issue, " in Exner's words, and the higher score was ultimately submitted by the State to EPA as part of its NPL nomination.[47]

As a final example, a citizens group in California, Concerned Neighbors in Action, used lobbying and a threatened press conference to expose conditions at the Stringfellow Acid Pits to influence the State selection process, The Stringfellow site did not receive the highest ranking of all sites evaluated in the State during the initial site selection process. But, as one analyst has summarized, the citizens group:

> . . . was very active in lobbying for the passage of the State's Superfund law. Prior to announcing passage of the law, the State was leaning toward selecting the McColl dumpsite in Fullerton as the highest priority site. The citizens prevailed, claiming that if McColl was selected and money was not allocated for Stringfellow, a press conference would be held . . . [48]

The State ultimately chose Stringfellow as the highest priority site; McColl was not placed on the Interim Priority List, but was placed on the 1982 NPL. However, a new California ranking process has changed the entire situation.

Fund-Financed Removals and Remedial Responses

Removal Actions

Removal programs are categorized according to the length of time involved in the cleanup. Varying levels of community relations activities accompany the different types of removal programs. For removals estimated to last fewer than 5 days, the Community Relations Handbook instructs EPA staff to be ready to respond to requests for information from the media, to provide information to government officials to help them to answer questions from their constituents, and to explain the removal program directly to the public.[49]

If a removal is expected to last between 5 and 45 days, regional EPA staff must prepare a Community Relations Profile that must be approved by EPA headquarters prior to the undertaking of the removal program. The profile should explain the public participation pro-

[45] Workshop record, op. cit., p. 81.

[46] Steven Lester, Citizen's Clearinghouse for Hazardous Wastes, Inc., personal communication, Oct. 11, 1984.

[47] Bonnie Exner, Colorado Citizen Action Network, personal communication, Oct. 18, 1984.

[48] George J. Trezek, "Engineering Case Study of the Stringfellow Superfund Site," contractor report prepared for the Office of Technology Assessment, August 1984, p. 50.

[49] Community Relations Handbook, op. cit., p. 2-1.

visions EPA expects to conduct during the removal, Recommended activities include designating a single EPA contact person, publicizing the phone number of the contact, providing information to government officials, holding a press conference if there is sufficient interest, establishing a repository for documents explaining the removal, and meeting periodically with small groups of local officials and interested citizens. so

For removals lasting between 45 days and 6 months, regional EPA staff must prepare a Community Relations Plan as part of the Action Memorandum or Draft Cooperative Agreement that must be approved by EPA headquarters. Recommended public participation activities during these lengthier removal actions include briefings and periodic progress reports for officials and interested citizens, public meetings and workshops, site tours, and news releases describing developments at the site. After completing the removal, regional EPA staff must submit a "responsiveness summary" to EPA headquarters describing what community relations activities were actually conducted.[51]

All community relations efforts at removals have a common focus on providing information. No activities permit the public to participate in decisionmaking about what type of removal program should be implemented or how it should be implemented. Indeed, none of the 18 suggested "community relations techniques" described in the Community Relations Handbook for use during Superfund site activity involve public participation at the points when cleanup decisions are actually made.[52] All the techniques involve information dissemination, tours, or citizen group meetings where no cleanup decisions are made,

Moreover, the Community Relations Handbook instructs EPA staff to fit their activities to respond to the degree of public interest or concern. The higher the level of interest, the more extensive the community relations program. There is a certain logic to this guideline, but it places citizens groups in an awkward position, as described by Lois Gibbs, Director of the Citizens Clearinghouse for Hazardous Wastes:

> The message this policy sends out is "organize and raise hell and you'll have input—sit back, behave yourselves and you'll be ignored. " The very nature of this policy is to force people into an adversarial role. Once a relationship begins poorly, it is difficult, if not impossible, to build trust.[53]

Because rural or low-income areas often have fewer resources and organizations compared to more densely populated or middle-class areas, this could produce a bias against providing extensive community relations programs for some areas.

Remedial Actions

All remedial actions must include at least one formal opportunity for public participation, Remedial responses must be undertaken whenever cleanup of a Superfund site cannot be accomplished within the 6-month time limit set in CERCLA. The key steps in remedial actions include an in-depth investigation of the site (the remedial investigation), the development of several cleanup plans and the selection of a preferred alternative (called the feasibility study), the final approval of a cleanup program, and the execution of the cleanup.

The Community Relations Handbook explains public participation activities that may or must occur during remedial actions.[54] Those activities must be explained in an approved Community Relations Plan prepared by regional EPA staff after meetings with local officials and citizens to assess community concerns and the technical complexity of the site's pollution problems. During the remedial investigation and the drafting of the feasibility study, the objectives of community relations activities are to distribute information and to elicit citizen

[50] Ibid., pp. 2-3.
[51] Ibid,, pp. 2-7.
[52] Ibid., pp. 4-1 through 4-33.

[53] Lois Gibbs, "Why Government and Industry Have Failed at Public Participation at Superfund Sites," undated reprint, p. 192.
[54] Community Relations Handbook, op. cit., pp. 3-1 through 3-13,

views. The recommended techniques again focus on small or informal meetings, news releases, tours, briefings, and progress reports.

It is only *after* the publication of the feasibility study and the delineation of a preferred cleanup strategy that the public is given a formal opportunity to comment to decisionmakers on the development of a remedial action. EPA requires that a public comment period of at least 3 weeks must follow the release of a feasibility study; EPA may extend the comment period upon request, and it frequently does so.

After selecting a final remedial design and while the remedial action is occurring, EPA continues the same sorts of information dissemination activities that characterize the earlier phases of the program. In addition, EPA community relations staff is instructed during the cleanup implementation phase to "make sure local residents understand that cleanup of the site may not resolve all problems . . . Meetings with small groups of citizens and officials , . . may again be the most effective communications technique during this stage of the response action."[55] When a remedial action is completed, regional EPA staff must submit a report to headquarters describing and evaluating the overall community relations effort.

Two general criticisms of the public participation program for Fund-financed cleanups are frequently stated by citizens groups active at Superfund sites. The first is that the public is not given the opportunity to influence decisionmaking early in the process while cleanup strategies are being selected. The second criticism is that the program does not address the lack of technical expertise on the part of citizens groups that hampers constructive public participation. The second issue seems to be the most difficult one to resolve, as it involves funding needs.

On the issue of opportunities to participate in decision making, for example, the EDF Dumpsites *Cleanup* citizen guide concludes that: "Unfortunately, EPA has not supported the notion of active citizen involvement in the dumpsite cleanup program."[56] Steven Lester of the Citizen's Clearing House for Hazardous Wastes, Inc., is another critic. He terms the community relations program "public relations, not community relations. " He complains that the EPA generally does only what it is required to do by law and as a result the community relations program is ''almost nonexistent for us as far as public involve merit." Finally, he adds that he knows of "one hundred groups dealing with the process. They are all frustrated, "[57]

Bonnie Exner summarizes her 5-year experience at the Lowry Landfill site as follows: ''All your questions (about public participation) have one answer. Citizens don't have much of a chance. "[58]

For more than 4 years, Exner has been researching innovative technologies that might be used successfully to treat the hazardous wastes at the Lowry site, including gas collection, venting and burning, and carbon filtration. She has personally met with representatives from 17 companies and has tried repeatedly, without success, to interest the EPA, which is preparing the feasibility study, in several cleanup options. So far, she says, the EPA regional Superfund manager supervising the Lowry site has "fought the idea of bringing in outside technologies. He calls them magic black boxes. " EPA counters by asserting that the new technologies will not work or that they would take too long to be licensed for use at Lowry.[59]

The adequacy of EPA community relations plans in achieving their primary purpose of providing information has also drawn criticism from community groups. Exner, for example, terms EPA's information dissemination program helpful, but complains that "90 percent of the time EPA will not volunteer information EPA doesn't want citizens to understand. They

[55] Ibid., pp. 3-11.

[56] Dumpsite Cleanups, op. cit., p. 53.

[57] Steven Lester, Citizens Clearinghouse for Hazardous Wastes, Inc., personal communication, Nov. 7, 1984.

[58] Exner, op. cit.

[59] Ibid.

stymie them with technical terms. " Citizens then shy away from becoming involved because they "are afraid to look stupid. " Lois Gibbs points out that "public meetings have often proved to be unproductive, uninformative, and, at times, completely out of control . . . Too often, information is presented to communities in either technical jargon or so simplified as to be insulting."[60]

The history of public participation at the Seymour, Indiana, Superfund site provides some evidence to support such criticisms. Only one public meeting was held prior to initiation of cleanup activities, during which public input was not sought. The EPA promised to provide the public with periodic progress reports, but none were published. The local Chamber of Commerce was frequently briefed, but those meetings were closed to the public. Overall, the Mayor of Seymour concluded that the EPA's public participation program was of little value.[61] Are these examples solely representative of a few "alarmed citizens"? There seems to be rather widespread agreement with these early experiences of the Superfund program by PRPs and government.

Turning to the second criticism, many citizens groups do not employ and cannot afford to hire people knowledgeable about the technical and scientific issues related to Superfund cleanup proposals. Steven Lester, who has worked with dozens of community groups at Superfund sites, believes "the biggest problem in the Superfund process is that local people don't have the expertise to make comments that will help EPA. "[62] Lois Gibbs writes that: "One of the most significant gaps in the past and present public participation is the lack of funds to provide a way for citizens to hire their own experts to review a proposed plan . . . Without these professionals, a real public participation program will never exist. "[63]

EPA, with rare exception, does not provide money to community groups to hire technical experts. One citizen group that has received EPA funds is the Concerned Neighbors in Action located near the Stringfellow site in southern California.[64] Indeed, it is not clear whether CERCLA or current EPA policy authorizes the funding of citizens groups, Officials at EPA Region II believe that such actions are not permitted by EPA policy. "There is no mechanism for that, " says the region's Deputy Director of the Office of Public Affairs.[65]

The Superfund Community Relations Coordinator at Region II, Lillian Johnson, argues, however, that EPA community relations activities bring technical experts and concerned citizens together throughout the development of cleanup programs, Moreover, in addition to public meetings and briefings, Region 11 frequently convenes 2-day "availability meetings" at Superfund sites where technical experts, such as Superfund project managers, contractors on feasibility studies, and attorneys are available to talk with the public on an informal and pro bono basis.[66]

In fact, despite the shortcomings in Superfund's public participation program cited by citizens groups, many local groups have successfully involved themselves in cleanup decisionmaking processes, particularly while reviewing feasibility studies. For example, one group in New Jersey hired an economist who demonstrated that a cleanup option that included removal of drums of toxic pollutants was more cost effective than the "preferred" alternative of monitoring for groundwater contamination; EPA subsequently selected this as the removal option.[67]

At a harbor Superfund site in New Bedford, Massachusetts, a citizens group called LIFE developed a remedial program that was not considered among the five alternatives in the feasibility study. Four of the five alternatives involve dredging PCB-contaminated sediments

m~ ibbs,op.c it., p. :193.

[61]ERM-Midwest, Inc., "Case Study: Seymour Recycling Corp., Seymour, Indiana, " contractor report prepared for the Office of Technology Assessment, Mar. 5,1984, pp. 4-12 to 4-13.

[62]Lester, Oct. 11, 1984, op. (: It.

[63]Gibbs, op. c it,

[64]Lester, Oct, 11, 1984, op. c it.

[65]EPA Region III nterview, op. cit

[66]Ibid.

[67]Ibid.

and disposing the sediments in various locations. LIFE's plan, coined the "pineapple upside down cake' alternative, involves covering layers of contaminated sediments with clean sediments now lying beneath the harbor; no dredging is involved. EPA is now studying this plan.[68]

At a site in Bruin Lagoon, Pennsylvania, technical comments submitted by EDF and the Citizens Clearinghouse for Hazardous Waste provided leverage for a community group called PURE-West to argue for changes in the preferred alternative. EPA made two additions to the alternative based on those comments, The first provided passive groundwater control to divert groundwater away from the lagoon by building a barrier upgradient from it. This would lower the water table and lessen the migration of toxic substances through the groundwater. The second change added monitoring procedures to test the structural integrity of a dike built to hold back contaminated sludges.[69]

Lowell Fair Share, a community group in Massachusetts, has also used technical comments as a leveraging tool. At the Silresim site, the group successfully pressured the State to investigate the possible seepage of contaminated groundwater into the basements of nearby homes. The group feared that this seepage occurred and that the liquids, once in the basements, evaporated to produce air pollution in the homes, In-house air pollution in the home has been confirmed as a result of the investigations.[70]

Although few citizen groups have the money to hire experts, many groups have been able to obtain some low-cost or pro bono professional assistance. For example, the Colorado Citizens Against Lowry Landfill and the Ecumenical Task Force in Niagara Falls, New York, have been represented by lawyers in legal actions related to Superfund cleanups.[71] Also, national environmental organizations with in-house technical expertise such as Citizens for a Better Environment have commented on feasibility} studies on behalf of local citizen groups.[72]

In some cases, money to hire experts has been obtained from sources outside the community, despite EPA's policy not to fund citizen group activities. For example, The New York State Love Canal Task Force once hired a technical adviser for the Love Canal Home-Owner's Association.[73] In Baltimore, the State of Maryland once hired an expert selected by a local community group to comment on cleanup programs at the Monument St. Landfill.[74] Similarly, the Virginia Environmental Endowment has made grants to several community groups to bolster their expertise on technical issues at Superfund sites.[75]

Enforcement and Other Legal Action

In addition to Fund-financed cleanups, the Superfund program also encompasses cleanups paid for and executed by the parties responsible for generating or managing hazardous materials found at uncontrolled sites. These cleanups are the result of enforcement actions that involve negotiations or legal actions between EPA and potentially responsible parties. The specifics of the cleanup programs that result are contained in voluntary agreements, administrative orders, consent decrees, or court orders.

In fiscal year 1981, 13 settlements were reached between EPA and responsible parties. The number jumped to 28 in the next year, to 36 in fiscal year 1983, and to 46 during the first 8 months of fiscal year 1984.[78] Ultimately, more Superfund cleanups may result from settlements and enforcement actions than from Fund-financed programs. In fact, to date EPA has negotiated more cleanup plans with private parties than it has undertaken on its own or forced on private parties through court or-

[68] Lester, Nov 7, 1984, op. cit.

[69] Ibid.

[70] Ibid.

[71] Gardner, op. cit. Also Bill Butler, Eco-funding, personal communication, Oct. 24, 1984.

[72] Ginsburg, op. cit.

[73] Lester, op. cit.

[74] Lester, Oct. 11, 1984, op. cit.

[75] Butler, op. cit.

[76] EESC Guide, op. cit.

ders.[77] Still other cleanups are performed without public or government awareness or scrutiny. Thus, public participation in cleanups not financed by Superfund is also an issue of major concern to citizen groups.

Neither CERCLA, the NCP, nor the Community Relations Handbook currently provide for public participation during negotiations or enforcement actions. Several citizens groups—including the Ecumenical Task Force that worked at several Superfund sites near Niagara Falls[78]—have attempted without success to convince a court to grant them status to intervene in legal actions involving Superfund sites. Other groups, including one working at a Superfund site in St. Louis, Michigan,[79] and another working in Kingston, New Hampshire,[80] have tried to gain a seat at the negotiating table, also without success.

The current EPA policy is to exclude the public from all negotiation sessions, but to provide periodic information about the progress of negotiations.[81] In addition to the periodic updates, at least one EPA office, Region II, arranges meetings between the public and parties in the negotiations and publishes notices of when negotiating sessions will take place and what issues are on the agenda.[82] EPA policy could change as a result of regulations adopted in accordance with the consent decree, described earlier in this chapter, between EDF and EPA or when the agency publishes an enforcement chapter to be added to the Community Relations Handbook.

Successful negotiations result in "requisite remedial technology agreements, " while legal actions incorporate cleanup strategies in administrative or court orders. as Department of Justice regulations provide that court orders may be published in the Federal Register for public comment. Comments are submitted to the Department of Justice.[84] As a matter of policy EPA also publishes administrative orders and voluntary agreements and provides a 30-day comment period.[85]

In whatever form they appear, cleanup strategies resulting from negotiations or legal actions are the equivalent of the preferred strategy contained in the feasibility studies for Fund-financed projects. A key difference for negotiation or enforcement actions, however, is that alternative cleanup strategies are not examined and presented for public comment.

What happens when citizens are faced with a cleanup strategy not to their liking or when they are upset at not being part of decisionmaking? Citizens are prevented from using several of the most common legal strategies employed in environmental law because CERCLA does not have a "citizen suit" provision granting legal standing in enforcement actions and the right to petition EPA for redress of grievances, Despite the limitations on opportunities for legal actions by the public under CERCLA, other laws implicitly provide some legal options for the public to challenge Superfund decisions,

For example, citizen suit provisions in RCRA or the Clean Water Act can, in some instances, be invoked at Superfund sites, but there are restrictions on their use. The citizen suit provision in the original version of RCRA was limited to operating hazardous waste sites. EPA has in the past used "the imminent hazard provision" of RCRA to support legal action at an abandoned site, but only EPA can use this provision.[86] Congress reauthorized RCRA in 1984 and the new version broadens the scope of citizen suits. Even so, citizen suits still cannot be initiated at Superfund sites if the EPA is actively engaged in a cleanup action or is preparing a feasibility study, if a court ordered cleanup program exists, or if the EPA is diligently prosecuting potentially responsible parties.[87]

77 Anderson, op. cit., p. 2.
78 Butler, op. cit.
79 Anderson, op. cit., p. 97.
80 Lester, Nov. 7, 1984, op. cit.
81 Anderson, op. cit., p. 2.
82 EPA Region II Interview, op. cit.
83 Ibid
84 Dumpsite Cleanups, op. cit., p. 100.
85 Anderson, op. cit., p. 98; and Dumpsite Cleanups, op. cit., p. 101.
86 Bidinger, op. cit., p. 400.
87 Linda Greer, letter to Karen Larsen, Office of Technology Assessment, Nov. 30, 1984.

Similarly, legal actions under the Clean Water Act are restricted to instances of surface water pollution. Also, while the citizen suit provisions of other environmental laws apply to "any person, " the Clean Water Act applies to ''any citizen." The law defines citizen as "a person or persons having an interest which is or may be adversely affected. " This means that plaintiffs under the Clean Water Act must show how they are personally affected by events at Superfund sites.[88]

The National Environmental Policy Act (NE PA) also potentially offers the public a legal means to challenge Superfund programs. For example, Section 102(c) of NEPA requires, among other things, that environmental impact statements be prepared for "all major actions significantly affecting the quality of the human environment. " This requirement exists unless Congress has specifically exempted a Federal action from NEPA or if the government follows procedures or prepares a document that serve as a "functional equivalent" of an impact statement. CERCLA does not contain a NEPA exemption, but the EPA asserts that feasibility studies and the like are, in fact, functional equivalents of NEPA statements.[89] This assertion, however, is subject to other legal interpretations. To date, no organization has successfully challenged a Superfund cleanup program on the basis of insufficient compliance with NEPA.[90]

Another possible strategy, available to some potentially responsible parties and affected citizens, is to challenge some Superfund decisions on constitutional grounds. Such challenges would allege a denial of the plaintiffs constitutional "due process" right to be heard before adverse actions are taken affecting them. Due process is addressed in many laws, including the Administrative Procedures Act which allows the public to challenge Federal agency actions that allegedly: exceed the scope of the agency's powers; are arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law; or were completed without adhering to necessary procedural requirements.[91] A potentially responsible party could, for example, invoke the Administrate\'e Procedures Act to challenge a Fund-financed cleanup plan, the cost of which it might ultimately be forced to pay. Alternatively, a dissatisfied citizens group could claim that a cleanup program was so bad as to be inconsistent with the NCP. Case law for denial of due process in the Superfund program appears absent.

Finally, citizens can attempt to sue in State court if State hazardous waste laws contain citizen suit provisions. Few States have enacted Superfund laws on their own, however. Citizens can also sue under common law. Tort actions based on State strict liability, nuisance, negligence, or trespass claims could apply to pollution issues at Superfund sites.[92] Federal common law actions are preempted by environmental legislation, however. Plaintiffs in State tort actions face difficult burden of proof obligations. Also, most tort actions have a short statute of limitations period during which suits must be filed.[93]

[88] Ibid., p. 398.

[89] Anderson, op. cit., p. 22.

[90] Ibid., p. 40.

[91] "Plaintiffs Memorandum in Support of Motion for Preliminary Injunction," *Long Pine Steering Committee, et al. v. EPA*, U.S. District Court, NJ, Civil Action 484-A51 3-D, p. 36.

[92] Ibid., p. 103.

[93] Bidinger, op. cit., pp. 413-417.

PUBLIC PARTICIPATION UNDER CERCLA VERSUS RCRA

Comparing Superfund's public participation provisions with those provided by CERCLA's legislative cousin, RCRA, can give insight into the extent and adequacy of the public participation opportunities.

RCRA specifically requires or permits public involvement in Federal or State hazardous waste management programs that are denied to the public or not mentioned in CERCLA. As mentioned, for example, RCRA contains a citizen suit provision (Section 7002) not contained in CERCLA. RCRA also permits “any person” to petition the EPA to request the promulgation of new hazardous waste regulations (Section 7004(a)). No petition powers are enumerated in CERCLA.

Perhaps most importantly, RCRA contains in Section 7004(b)” specific instruction for public participation. The law reads:

> Public participation in the development, revision, implementation, and enforcement of any regulation, guideline, information, or program under this chapter shall be provided for, encouraged, and assisted by the Administrator and the States. The Administrator, in cooperation with the States, shall develop and publish guidelines for public participation in such processes,

Other RCRA provisions require a public comment period and public hearings to review operating permits issued under the Act (Section 7004(2)). State programs must include public participation provisions if the States are to receive EPA authorization to implement their hazard waste management programs.

Rulemaking under RCRA, as under CERCLA, requires public notice and comment periods. There is a difference, however, because RCRA requires more extensive rulemakings of greater complexity than does CERCLA. Like CERCLA, RCRA permits the public to seek judicial review of regulations and, in addition, it offers judicial review of petitions.

In short, the hazardous waste management program defined in RCRA requires and permits far more public participation than does CERCLA. Specific public participation objectives and requirements lacking in CERCLA are given in RCRA. The public has more opportunity to become involved in the shaping of the RCRA program because of its detailed rulemaking requirements. Public participation at hearings must be allowed during the permitting process—which is the backbone of the implementation phase of RCRA. And the public, with some limitations, is guaranteed access to the courts for judicial review of the RCRA program or its implementation. The applicability of RCRA public participation requirements to Superfund remedial actions (that might otherwise require a RCRA permit) is not clear. EPA has said at various times that Superfund actions will adhere to substantive RCRA requirements, If EPA considers public participation and review to be procedural rather than substantive, public involvement rights under RCRA may be curtailed at Superfund sites.

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