Chapter 3

Cleanups and Cleanup Technology

CONTENTS

Boxes

Figures

Talks

Chapter 3
Cleanups and Cleanup Technology

What is a permanently effective treatment technology? The Superfund Administration and Reauthorization Act of 1986 (SARA) strongly supports its development, demonstration, and use for site cleanup, but the statute does not say exactly what "permanent," "effective," or "treatment" mean. The resulting ambiguity for Superfund has fueled public criticism of specific cleanups and clashes between statutory requirements and implementation. Some flexibility is necessary for the people trying to find cleanup solutions to complex sites. The challenge is finding an approach which follows statutory requirements and preferences, uses the latest understanding of science and engineering, and also allows enough flexibility for front-line people to solve tough problems.

OTA's analysis of site cleanup in this chapter focus on how well technology is evaluated and selected to solve contamination problems and to meet cleanup objectives. Ten key issues are identified and discussed.

This chapter is **not** a treatise on Superfund procedures and cleanup technologies. While many people want to know details about cleanup technologies, especially newer ones, the technology area is evolving rapidly and detailed descriptions of specific technologies are quickly out-of-date. [1] Also, the objectivity and reliability of available information cannot be guaranteed because so much of it comes from technology developers themselves. Moreover, engineering specifications have limited value to policymakers charged with making the Superfund program work more effectively and efficiently.

OTA's analysis is meant to provide a background for the discussion of policy options to improve Superfund implementation. Accordingly, general scientific and engineering principles and trends are set out, in somewhat of a tutorial style, which should be of particular use to the non-specialist in cleanup science and technology. Given the paucity of exact information, examples of site decisions also play an important role in OTA's analysis.

10 KEY ISSUES

Issue 1: Is there now available a full range of proven, safe, and cost-effective cleanup technologies so that land disposal and containment can be largely avoided?

In large measure, the answer is yes, Perhaps the best proof is the current smorgasbord of treatment technologies for different kinds of Superfund sites from hundreds of technology vendors. But land disposal and containment are still needed and particular treatment technologies accomplish different things.

Nor can cost-effectiveness be separated from cleanup objectives. That is, no cleanup technology is intrinsically cheap or exorbitantly expensive. The range of cleanup applications is very broad, and cost-effectiveness depends on what the cleanup need is, including what the contamination and site conditions are. Claims that a technology is intrinsically cost-effective are misleading. Yet, some technologies commonly used for generic applications earn the engineering label "proven." Assessment of the availability of treatment alternatives to land disposal, therefore, is linked to general cleanup goals (e.g., permanence, cost-effectiveness), specific site cleanup objectives (e.g., levels of residual contamination for specific contaminants to attain risk reduction objectives, compliance with regulatory standards), and an understanding of different generic cleanup applications.

Because not all treatments are the same, the general availability of all treatment technologies that are lumped together can be misleading. Some treatments are preferred over others, and if some cleanup problems have no good treatment solutions (e.g., very large municipal landfills).

The mere label of "treatment' for a technology can be misleading. The government has not established a clear hierarchy of preferred treatments and preferred environmental outcomes. One possible

[1] In its 1985 report *Superfund Strategy*, OTA listed specific technology vendors with some discussion of their new technologies. To a large degree, the information quickly became outdated; it was also unintentionally unfair to firms not listed. At this time, there is no convenient single source of the latest information on new cleanup technologies.

20–01 1 0 – 89 – 4 : QL 3

hierarchy is given in box l-F, chapter 1. Treatment technologies, such as thermal destruction (incineration) and biological treatment, which actually destroy or detoxify hazardous substances, and technologies that recover contaminants for reuse are the most desirable; OTA concludes that such treatments offer permanent remedies. EPA has said that permanent remedy "has not been strictly defined. "[2]

Permanence is at one end of the performance spectrum for treatment technologies. At the other end, for example, are simple treatments that extract water from a sludge type of waste, reducing volume but leaving the hazardous substances in their original chemical form and quantity. For environmental protection, treatment that permanently renders hazardous substances harmless is most preferred. The reason is simple. To the extent that the treatment is maximally effective, there are no uncertainties: the source of hazard is removed, not merely reduced, separated, or contained. Permanent treatment provides maximum risk reduction, especially if it can be done for all of a site's contaminants. Russell E. Train, former EPA Administrator, stated the importance of permanent cleanups: ''Haunting Superfund is the nightmare of spending millions to clean up a site, then discovering the cleanup is far from permanent. '

Some treatments, however, only reduce mobility, such as chemical fixation, stabilization, and solidification; these also generally increase volume. Some are only separation technologies (e.g., soil washing, solvent extraction from soils, carbon adsorption, and precipitation of contaminants in groundwater) which may reduce volume but actually produce a more concentrated hazardous waste that must be treated or landfilled. Some separation technologies can (and often do) release hazardous materials directly into the environment (e.g., air stripping of contaminated water, soil aeration, and extraction of volatile chemicals from soil) unless contaminants are collected and some form of destruction technology is also used.[4]

Treatment and Permanence-To begin with, the word ''treatment is not especially informative technically. At best, treatment as applied to hazardous waste problems has come to mean anything other than land disposal of hazardous waste. By itself, treatment does not convey what happens to the hazardous waste. In particular, treatment does not imply a permanent transformation of hazardous material to harmless material.

Cleanup permanence may also be seen as a form of pollution prevention. A permanent treatment technology removes the source of future pollution. Other types of treatment leave hazardous material as an uncertain threat, which may require action later. In contrast to primary pollution prevention for industrial hazardous waste generation, cleanups start out with hazardous waste already created. It is only through destruction or recovery that source reduction can be applied to cleanup; this application might be called secondary pollution prevention.

Theoretically, every hazardous substance and contaminated material can be permanently treated to render it irreversibly harmless. Engineering, economics, and the ability to apply such technology to all site contaminants are another matter. Organic hazardous substances can be destroyed by supplying enough energy to break chemical bonds, such as through incineration or biological activity, and through chemical reactions, such as dechlorination, ultraviolet photolysis, wet air oxidation, and supercritical water oxidation. Materials containing toxic metals can be treated to recover the metals, converting them back into their original commercially valuable form. Even some organic hazardous substances can be recovered and sold commercially; recovery of oil from refinery waste sludges and contaminated soils is commercially available

[2] Response to question, in *Preliminary Findings of OTA Report on Superfund*, Committee Report on Hearing before the Subcommittee on Investigations and Oversight, Committee on Public Works and Transportation, U.S. House of Representatives, Apr. 20, 1988, p. 273.

[3] Russell E. Train, ' 'Big Questions Facing the Cleanup, " *EPA Journal*, January/February 1987.

[4] Increasingly, separation technology is used in conjunction with a destruction technology, but little attention may be given to the environmental release of contaminants from the. separation technology. For example, air stripping of contaminated groundwater may be used prior to biological treatment in a reactor; a case study which described a groundwater cleanup of such a combination provided no information on the relative contribution of the air stripping to cleanup versus actual destruction of organic contaminants by microbes. Robert Sanford and Donald Smallbeck, ''Startup of a Physical/Biological Treatment Plant to Treat Groundwater Contaminated With Chlorinated Hydrocarbons and Soluble Organics, " proceedings of Haztech International Conference, St. Louis, MO, August 1987.

through various solvent extraction processes, Acidic or alkaline wastes can be chemically neutralized. Asbestos can be classified. Therefore, in terms of scientific principles, destruction, recovery, or some form of chemical conversion are treatment approaches that produce **permanent** cleanups. In assessing commercial availability of alternative treatment technologies, therefore, it is useful to fist distinguish between those that offer permanence, in a scientific sense, and those that do not. Not all treatment technologies can meet environmental goals.

Reducing the volume or mobility of hazardous substances offers some environmental benefits relative to the goals of controlling the release of hazardous material into the environment and minimizing exposures to hazardous substances. Such treatment technologies may play an important role prior to using a permanent treatment technology. But, in themselves, reducing volume and mobility (or reducing exposure by encapsulating a toxic substance) does not produce the kind of **certain** environmental benefit that destruction or recovery do (even with less than perfect performance) because the source of chemical hazard remains.

Current EPA thinking on the various outcomes of cleanup approaches is different from OTA thinking. For example, under the heading of ''program principles/expectations, at a technical information forum for Superfund personnel, EPA said:[5]

- ''Protwtion can be achieved by the destruction or immobilization of waste through treatment or by preventing exposure through engineering and institutional controls. " (Although engineering and institutional controls must be used at times, this statement can be interpreted to mean that a Record of Decision (ROD) could consider land disposal and deed restrictions as comparable to incineration.)
- "Expect most remedies will involve a combination of treatment and containment technologies. " (Although this statement is true to a large degree and there is a role for containment technologies, this statement does not tell front-line personnel that treatment is to be maximized and containment minimized; see the discussion below on extent of permanence and different types of cleanup actions.)
- ''Highly toxic, highly mobile waste (waste that can be contained reliably with engineering controls, e.g., containment, capping) generally will not need treatment. ' (The problem is the limited information on and in the interpretation of what is highly toxic and highly mobile; the interpretation suggests to personnel a rationale for not selecting treatment.)

Is it useful to think of degrees of permanence? No, not for what a particular technology accomplishes. Superfund implementation, thus far, has shown that it is important to keep the distinction between permanence and volume or mobility reduction clear. Otherwise, too many treatments are credited with permanence. **However, EPA has favored use of the degree of permanence concept and this practice has been important in providing the flexibility—which OTA considers being excessive—to equate different cleanup alternatives as equally satisfying the goal of obtaining permanent remedies.** For example, former Assistant Administrator J. Winston Porter said: ". ., There are degrees of permanence, . . . Certainly digging everything up and burning it is about as permanent as you can get. On the other hand, if you take just putting a cap over it and walking away, that's about as least permanent as you can get. Then there is a gradation. . . . Certainly things like solidification, I would say, is not as permanent in the sense as some destruction techniques. . . . When we put a cap on or when we put monitoring wells in or we do in situ (in-place) solidification or various other things, we do it with the understanding that we hope that will work permanently, not in geologic time . . . but for some finite time period we expect that to work. '

In OTA's view, working for a finite time may mean months or years. What varies is not the degree of permanence but the degree of environmental protection provided by the treatment or containment technology. Indeed, even land disposal and contain-

[5]U.S. Environmental Protection Agency, materials distributed at EPA's Technical Information Forum, Arlington, VA, Feb. 22-23, 1989.

[6]Response to question, in *Preliminary Findings of OTA Report on Superfund*, op. cit., footnote 2, pp. 189, 191.

ment have sometimes been described as giving a degree of permanence.[7]

A related issue is the extent of use of a permanent technology at a site. It is not always possible to apply permanent treatment technology to all of a site's contaminants. When more than one technology is used for a cleanup, including technologies and methods other than destruction and recovery, only part of a site's contamination may receive permanent treatment. Therefore, if at all possible, the percent of hazardous site material rendered harmless through destruction or recovery should be calculated to describe the **extent** that permanent treatment technology is used. Maximizing the extent of such use to satisfy statutory preferences and requirements is the goal.

Three Limiting Principles for Permanent Treat- mets--Unless proven inapplicable, there are three fundamental limits to any destruction or recovery technology. First, no destruction or recovery technology can work on all conceivable hazardous substances. For example, incineration does not destroy toxic metals, and biological treatment is very chemical-specific. This limitation implies the need for effective pollution controls to deal with untreated substances.

Second, no process is 100 percent efficient. Incomplete destruction or recovery must be carefully examined and measured. EPA currently requires an efficiency of 99.99 percent for incineration (and even more for polychlorinated biphenyls (PCBs). If this requirement was applied to other treatment technologies, few would currently pass muster. This deficiency too implies the need for effective pollution controls to deal with untreated material. The deficiency also implies the need to set acceptable levels of residual un-destroyed or un-recovered contaminants at a site on the basis of insignificant health or environmental effects.

Third, a treatment may produce new hazardous substances as byproducts of chemical reactions. Testing for toxic byproducts takes special effort. While the problem is well known for incineration, it is an often neglected issue for other technologies, such as biological treatment. Also, a treatment process may use chemicals which themselves pose some problem, such as additives to make in situ biological or chemical fixation work effectively.

Conclusions—The market for cleanup technologies is rapidly changing, Over the past several years many new technology companies have entered the marketplace. Technology availability has increased, but evaluating different technologies has gotten more difficult. Increasingly, the competition will not be between containment/land disposal and treatment but among different generic treatment technologies-especially permanent ones—and among different options within generic categories. Although permanence is a key goal of final remedial actions, cleanup technologies which do not offer permanence have an important role to play in emergency responses, attempts to recontrol sites, and interim remedial actions. But there it is important not to blur the distinction between technologies which offer permanence and those which do not.

Issue 2: Is the Superfund system using proven cleanup treatment technologies-preferably permanent ones-where and when they are applicable and feasible?

Types *of Cleanup--This* question cannot be fairly answered unless it is understood that there are four types of cleanup actions. First, there is **emergency action,** for which any type of fast response necessary to reduce the immediate danger is appropriate. There is no requirement to choose treatment technology and, indeed, there would rarely be time to pursue treatment.

Second, there is what is now called **removal action.** Both emergency and removal actions can be taken on any site, without the requirement of the site being selected for the National Priorities List (NPL). Originally, removal action was supposed to deal

[7] A critique of an EPA study by a contractor working for responsible parties at a site: ".. · The FS [feasibility study] incorrectly eliminates from detailed consideration those alternatives, such as capping with groundwater renovation, which permanently reduce the mobility and volume of hazardous substances and which arc more cost-effective than the alternatives considered by EPA. (''Review Comments on the Re-Solve Site, Dartmouth, Massachusetts, Draft Feasibility Study and U.S. EPA Preferred Alternative, ' ERT Company, August 1987,) No mention of reducing toxicity is made. According to the contractor, leaving hazardous materials in the ground is a permanent remedy. It should be understood that EPA and its contractors have made similar arguments in their work. The Re-Solve site decision is one of the cases cited by OTA in its 1988 report as an example of Superfund at its best because of the treatment cleanup technology selected (i.e., dechlorination).

with imminent threats of release or exposure and was done relatively quickly and simply, prior to the remedial cleanup, often by removing hazardous material to a landfill. The amounts of such materials can be larger than the amounts treated subsequently during a remedial cleanup. Data from EPA indicates that less than 10 percent of removal actions used some kind of treatment technology (about half of these used destruction technology);[8] the vast majority of removals--over 90 percent—used land disposal and engineering or institutional controls.

But over time some removal actions have come to look like major cleanups, sometimes using treatment technology. Indeed, SARA increased the time and spending limits for removals. A number of multimillion-dollar removals examined by OTA are no different than major cleanups. For the period of fiscal year 1987 and about half of fiscal year 1988, EPA said that there were 22 removals for which it waived the 12-month/$2 million limit of SARA; the average cost for those removals was just over $4 million.[9] However, such multimillion-dollar removals are outside the stringent cleanup standards of SARA which apply to remedial cleanups,

Third, there is an **interim remedial action,** now called by EPA an operable unit, which is a partial remedial cleanup, in terms of part of a site or fraction of contamination targeted. Unlike the previous two categories, interim remedial action requires major site investigation and a feasibility study of cleanup options. Also, EPA issues a Record of Decision which describes the selected remedy and cleanup objectives.

Fourth, there is a **final remedial cleanup** which, as with an interim effort, requires major site study and a ROD and is covered by the stringent cleanup standards of SARA; that is, in these two remedial categories there is a clear statutory preference for using permanent treatment technology. A final remedial cleanup would set the conditions necessary for delisting a site from the NPL.

The Record on Technology Use—First, it is important to recognize that, contrary to some popular beliefs, SARA does not require EPA to select permanent solutions and alternative treatment technologies but only to give them **preference and to use** them "to the maximum extent practicable. " The statutory requirements are vague and permit many different interpretations. There is no government guidance to remove the ambiguities and inconsistencies. Considerable progress toward using more treatment technology has been made, but all too often it is not used. This was a major lesson from OTA's case studies, many of which either used no permanent treatment technology or no other type of treatment technology, or selected unproven and untested treatment technologies (see box 3-A for a summary from the 1988 report).

Second, there are many technical application and implementation issues for any generic cleanup technology; see box 3-B for an overview of such issues for incineration, and see table 3-1 for a summary comparison of the many types and sources of mobile and transportable incinerators available today. Over the past few years, there has been a substantial expansion, nationwide, of the mobile/transportable incinerator business. This competitive market has brought down prices. The key difference between mobile and transportable is that transportable units require significant effort to dismantle, set up, and move while mobile units do not. See boxes 3-C, 3-D, and 3-E for overviews of application and implementation issues for biological treatment, separation, and chemical fixation technologies.

All of these application and implementation issues illustrate the complexity of remedy selection. Despite increasing experience with cleanups and the introduction of more treatment options, the cleanup workforce has found remedy selection to be more complicated. The need for narrowing down cleanup alternatives as early as possible without, however, foreclosing on important options has become greater, But narrowing down requires in-depth experience and insight about generic types of sites and recent technology developments and experiences, so that truly infeasible or impractical cleanup alternatives can be eliminated while retaining important options.

[8] U.S. Environmental Protection Agency, op. cit., footnote 5, The figure of less than 10 percent for treatment compares to just under 70 percent fOr remedial actions in fiscal year 1988, but the data for removals is cumulative, covering all actions since the beginning of the program; the comparable cumulative figure for remedial actions would be much lower than 70 percent, but significantly higher than 10 percent.

[9] Response t. question, in *Preliminary Findings of OTA Report on Superfund*, op. cit., footnote 2, p. 200.

Table 3-l-Comparison of Mobile/Transportable Incineration Technologies

	Rotary kiln	Infrared furnace	Circulating bed	Electric pyrolysis	Plasma arc torch
Operating Temperature	1,200-1,800"F primary chamber	600-1,900'F primary chamber	1,500*F	3,000-3,200 °F	Over 10,OOO"F plasma plume
Residence Time					
solids	Up to several hours	10-180 minutes	About 30 minutes	Variable from minutes to hours	500 milliseconds, plasma plume
Gases	1-2 seconds	2 seconds	2 seconds	2 seconds	
Waste Form	solid, sludges, liquid	Solids, sludges, liquid adaptable	solids, sludges, liquids	solids, sludges, liquids	Liquids, certain liquified sludges
Estimated Throughput	1-5 tons/hour (mobile) 5-20tons/hour (transportable)	80-210 tons/day (tpd)	4 tons/hour	5-10 tpd, pilot 100 tpd, proposed Commercial	2.5-3 gallons/minute; 1 (on/hour
Energy Recovery	Yes, for some units	No	Yes		No
Estimated Cost	$100-$500/ton	$150-$200/ton	$100-$400/ton	$300-$400/ton, pilot (preliminary)	$800-$2,000/ton (preliminary)
Availability	Commercial	Commercial	Commercial	Pilot. Commercial in 1 year	Commercial unit in final testing; available by mid-1989
Movability	Mobile Transportable	Mobile	Transportable	Mobile	Mobile
Startup Time	24 hours (mobile) 4-6 Week (transportable)	1-2 weeks	3 weeks, not including site preparation	l-2 weeks, proposed commercial	1 week
Vendors	(Mobile) M & S Systems, Broad Brook, CT; ENSCO Environmental Services, Little Rock, AR; Thermal Dynamics, Mt. Kisco, NY; Vesta Technology, Ft. Lauderdale, FL; Roy F. Weston, West Chester, PA; Incinerex, Houston, TX; (Transportable) ChemicalWasteManagement, Oak Brook, IL; ENSCO Environmental Services, Little Rock, AR; Envirite Field Services, Atlanta, GA; InternationalTechndogy Corp., Torrance, CA	Environmental Treatment &Technologiescorp., Findlay, OH; Reidel Environmental Services, Portland, OR; Westinghouse Environmental Services, Pittsburgh, PA	Ogden Environmental services, San Diego, CA	Westinghouse Environmental Services, Pittsburgh, PA	Westinghouse Environment Services, Pittsburgh, PA

SOURCE: Adapted from B. Rey de Castro, "Six Burn Technologies Roll Onto Sites," *Waste* Age, February 1989; and Paul N Cheremisinoff, "Mobile, Transportable and Package Treatment Systems," *Pollution Engineering*, April 1989.

Box 3-A—10 Case Study Sites With Capsule Findings

Case Study 1
Chemical Control **Corp.,** Elizabeth, New Jersey
EPA Region 2; NPL rank 223 out of 770
Estimated cost: $7.4 million

Unproven solidification (f. hemical fixation) technology was selected to treat in situ highly contaminated subsurface soil, which previous removal actions had left below the watertable and covered up with gravel. No treatability study was used. The cost of incinerat ion was overestimated. The cleanup will leave untreated contamination onsite.

Case Study 2
Compass Industries, Tulsa County, Oklahoma
EPA Region 6; NPL rank: 483/770
Est imated cost $12 million

Capping (containment) of waste was chosen over incinerat ion. Capping was called a cost-effective, permanent clean-up even though it does not provide permanent protection comparable to incinerat ion. No commitment was made to treat contaminated groundwater.

Case Study 3
Conservation Chemical Co., Kansas City, Missouri
EPA Region 7; NPL rank pending
Est imated cost $21 million

Capping of the site and a hydraulic containment system to pump and treat some contaminated ground water were chosen over excavating and treating contaminated soil and buried wastes, which was recommended in an EPA study and by the State. Water treatment cannot remove all the (Iii't'rsc contaminants at the site. The ROD said that no estimate could be made for the durat ion of the cleanup.

Case Study 4
Crystal City Airport, Crystal City, Texas
EPA Region 6; NPL #639/770
Estimated cost: $1.6 million

Excavation of contaminated soils and wastes (which were buried in a previous removal action) and their disposal in an unl ined landfill with a cap over it were selected over incineration. No treatability study supported the conclusion that the selected remedy is permanent on the basis of the adsorption of diverse contain inants to site soil. Major failure modes for the landfill were not examined.

Case Study 5
Industrial Excess Landfill, Uniontown, Ohio
EPA Region 5; NPL #164/770
Estimated cost: $2 million

Providing alternate water to houses that have or are likely to have contaminated wells was a satisfactory interim remedial action. However, actions to address the source of contaminant ion and to stop and treat contain inated groundwater are long overdue.

Case Study 6
Pristine, Inc., Reading, Ohio
EPA Region 5; NPL #531/770
Estimated cost: $22 million

In situ vitrification was developed originally for radioact ive soils, but its use for chemical}. contam i nated sites is still unproven. In situ vitrification was selected - wit bout treatability test results—chiefly because its estimated cost was about half that of onsite incineration. But the estimated cost for incineration is probably high by a factor of z. Incineration offers more certainty and probably would cost no more than the chosen remedy. Ground water will be pumped and treated by air stripping and carbon adsorption.

Case Study 7
Renora, Inc., Edison Township, New Jersey
EPA Region 2: NPL #378/770
Estimated cost: $1.4 million

The selected remedy makes use of of fsite land filling for soils contaminated with PCBs. Also, biological treatment was selected for soils contaminated with diverse organ ic compounds and toxic metals and for contain inated groundwater, but no treatabil it y study supported its selection.

Case Study 8
Sand Springs Petrochemical Complex
Tulsa County, Oklahoma
EPA Region 6; NPL #761/770
Estimated cost: $45 million

EPA originally said that solidification technology was ineffective for the high organic content wastes and that onsite incineration was effective. EPA then reversed itself and selected solidification for most of the cleanup, which the responsible party had claimed effective based on its treatability study. Incineration is to be used if solidification technology is not successfully demonstrated or fails after sol id i fied material is I and filled on the floodplain site, but criteria for failure are unspecified.

Case Study 9
Schmalz Dump Site, Harrison, Wisconsin
EPA Region 5; NPL #190/770
Estimated cost: $800,000

A simple compacted earth cover over the soil contaminated with lead and chromium was selected. Sol idification/stabilization treatment was rejected, although this was a textbook example of appropriate use of the technology. Voluntary well abandonment and monitoring was chosen over pumping and treat ing contaminated grou ndwater.

Case Study 10
Tacoma Tar Pits, Tacoma, Washington
EPA Region 10; NPL #347/770
Estimated cost: $3.4 million

No treatability study results supported the select ion of chemical stabilization. Significant amnu nts of u ntreated contaminants as well as the treated materials will be left onsite. The effectiveness of the treatment is uncerta in. Incinerat ion was said to offer no better protection and was rejected because of its higher cost.

SOURCE: U.S. Congress, Office of Technology Assessment, Are We Cleaning *Up? 10 Superfund Case Studies*, OTA-ITE-362 (Washington, DC: US. Government Printing Office, June 19ss), p. 9.

Box 3-Key Issues for Onsite *Incineration*

Extra Cost Variables-Wastes or soils with: 1) high water content or large inert objects (e.g., buried automobiles, large rocks), 2) high levels of corrosive chemicals (e.g., chlorine), or 3).high levels of toxic metals require costly materials handling, special construction, or additional pollution control technology, respectively. Materials with low heat value (low organic content) require more external fuel or energy, increasing costs. Such needs do not eliminate the intrinsic advantage of incineration: the ability to destroy organic hazardous substances.

Unit Costs==Unit costs for mobile incineration depend on volume of treated treated becasue there is significant economy of scale. Smaller cleanups are proportionately higher in cost because of high mobilization"on, set up, and testing costs. For very high volumes, unit cost is substantially lower, but total site cleanup cost remains relatively high (e.g., for a large landfill).

Environtmental Risk--General concerns about environmental risks of incineration (e.g., air pollution, no standards for toxic air emissions) can increase costs (e.g., permits, tests) and public opposition which itself results in incereased costs and delay because more data and assurances of safety must be provided.

Imcinerator Market-An inCreasing diversity of mobile incinerators, differing in: 1) size, design, and type of heating (e.g., rotary kiln, infrared, fluidized bed, plasma-arc); and 2) the degree of past experience and proven reliability, requires more analysis prior to selection of remedy and causes greater variables in estimated costs.

SOURCE: Office of Technology Assessment, 1989.

EPA's data for source control RODS (excluding no further action and groundwater cleanup decisions) for fiscal years 1987 and 1988 indicates:

- **use of land disposal/containment in 52 percent of RODS in fiscal year 1987, down to 26 percent in fiscal year 1988;**
- destruction treatment (incineration and biological) in 21 percent in fiscal year 1987, which improved to 30 percent in fiscal year 1988; and
- separation technology in 7 percent in fiscal year 1987, which increased to 21 percent in fiscal year 1988;
- various types of chemical fixation or stabilization techniques in 13 percent in fiscal year 1987, which increased to 17 percent in fiscal year 1988.

Note that some **RODS used more than one technology and that some technologies were not categorized. Separation technologies were not necessarily followed by destruction.**[10]

In understanding the selection of treatment technologies, it is necessary to take into account cost, site conditions (e.g., hydrogeology, climate, geochemistry), Complexity and widely varying levels of contamination, and other factors that may rule out technology that otherwise appears technically feasible from a more scientific perspective. But nearly always there is more than one technically feasible treatment option and increasingly the options are for onsite treatment in mobile or transportable equipment or, to a lesser extent, for in situ application to undisturbed soil or groundwater. Onsite treatment offers the advantage of eliminating the costs and risks of transporting hazardous materials and, increasingly, the high costs and limited availability of some waste treatment technologies at commercial facilities. Moreover, different treatment technologies can be combined or even used in conjunction with land disposal/containment approaches; for example, only hot spots of contamination may be excavated and treated when there are truly enormous amounts of buried materials.

Different forms of a generic technology may vary so much in terms of equipment, cost, mechanism of hazard reduction, environmental safety, and other factors that Feasibility Studies and selections of cleanup technology may have to go beyond generic categories. This situation is definitely the case for forms of thermal and biological destruction that vary greatly. Serious problems result because greater expertise and analysis is required, which can lead to longer and more costly studies.

[10] U.S. Enviworm.wntal Protection Agency, "Solid and Hazardous Waste Report for Fiscal Years 1987 and 1988," and informal corrections provided to OTA.

Box 3--Key *Issues for Biological* Treatment

Lack Of Field Experience--The enormous promise of biological treatment, as a destruction technology for organic hazardous subtances and for the conversion or recovery of some toxic metals, is impeded by the lack of documented field experience in meeting stringent (low residual contaminant level) cleanup standards. This problem is exacerbated by aggressive marketing by an increasing number of vendors with little, if any, experience. Much vendor experience has been for confidential clients, which limits detailed public information.

Chemical Specificity-Biological effectiveness is chemical-specific, meaning that sites with diverse contaminants are difficult and require more testing, verification, and process monitoring. Even variations of a type of chemical can be very significant; e.g., PCB molecules with higher numbers of chlorine ions are difficult to degrade.

Sustaining Performance--Very low and very high contaminant concentrations pose problems for sustaining biological performance. Hazardous material is both a food source and at high concentrations, potentially, a poison to microbes, depending on many factors in addition to concentration.

In Situ Problems--In situ application (i.e., leaving wastes where they are) is more difficult than using above-ground engineered equipment (i.e., bringing wastes to the *biological process)* because: 1) degree and speed of effectiveness depend on controlling critical variables such as oxygen and nutrients to sustain biological activity, 2) natural soil or aquifer conditions can inhibit effectiveness (i.e., bacteria may not be able to reach contaminants because of low permeability subsurface soil or slow moving groundwater), and 3) variations in contaminant concentrations and unexpected contamination can drastically reduce effectiveness which is difficult to detect.

Correlations of Effectiveness--Varying degrees and rates of effectiveness have not been well correlated with various waste and site characteristics. This limits learning about technology and extrapolation of results to other sites.

Uncertain Choices--A very high level of R&D is underway and substantial new or different approaches introduce uncertainty into applicability and remedy evaluation; e.g., aerobic v. anaerobic bacteria fungi v. bacteria natumily occurring site bacteria v. proprietary microbes and genetically engineered bacteria; i.e., acceptance or rejection of the generic approach requires an increasing amount of treatability testing and analysis of specific techniques, requiring more cost and time prior to critical remedy selection decisions. This problem is exacerbated by a generally low level of microbiological literacy in the cleanup workforce, especially those who examine and select cleanup remedies.

Costs-Although there is, theoretically, an intrinsic economic advantage for biological treatment (particularly with thermal destruction technologies), because of low capital, energy, and materials costs, claims of comparative cost advantages for biological cleanups discount offsetting factors, including: high testing costs, the need for using other technologies before or after biological treatment high contingency costs to account for encountering upset conditions (sudden occurrences which cause treatment systems to crash-i.e., stop performing according to specifications), sometimes long processing *times, and similar costs* for competing generic technologies (even though they might not be permanent treatment technologies) or combinations of technologies, such as low-cost separation technology followed by incineration.

Proof of Destruction Above Ground-Above-ground processing may suggest contaminant destruction which actually is contaminant transfer to the air or water. Data to substantiate contaminant destruction is often lacking, and this issue is complicated by the use of other treatment technologies (e.g., air stripping of groundwater) in a site cleanup.

Toxic Byproducts--There is very little information on production of toxic byproducts.

Process Controls--Process controls may not reflect detailed determination of failure points; i.e., combinations of loading and engineering control parameters that cause biological treatment systems to exhibit sudden effluent deterioration and failure.

Biodegradability-Lists of chemicals that say whether or not they are biodegradable reflect scientific knowledge more than engineering information and field experience.

SOURCE: Office of Technology Assessment, 19s9.

Box 3-D--Key *Issues for* Separation Technologies[1,2]

Identifying Contaminants--The disposition of the separated contaminant (s) requires precise identification. Sometimes a contaminant is released into the air or disposed of in a landfill, although it is always feasible to destroy organic material through Some form of incineration or to recover toxic metals.

Concentration Levels--The effectiveness and efficiency of many techniques are sensitive to the concentration of contaminants; some techniques work cost-effectively within certain concentration ranges.

Many Contaminants Need Extra Treatment—When many diverse contaminants are present, any single technology is unlikely to be fully effective on all of them. Use of several technologies can meet stringent cleanup objectives but adds significant new costs, whose avoidance may compromise Cleanup objectives. Detailed treatability testing of site materials and onsite demonstration of system are critical.

In Situ Effectiveness--For in situ techniques, soil conditions, depth of contamination, and water can drastically reduce effectiveness. Complex site conditions increase costs substantially and increase the need to show, in site demonstration, that the technology works.

[1] Separation technologies include:

- Vacuum extraction and air or steam stripping of volatile organic chemicals from soil (in situ);
- Low temperature volatilization from soil (in situ or in process equipment);
- soil flushing or washing (in situ or in process equipment);
- Solvent extraction of soils (in process equipment);
- Ak9Uippiq , carbon adsorption, precipitation, ion exchange, or freeze crystallization of contaminants in water (in process equipment).

[2] Whether a separation technology an be used for contaminant recovery (offering a permanent remedy) depends al its ability to produce P - ~ suitable far commercial use. In combination with destruction or recovery technology, separation technology can offer a permanent remedy.

SOURCE: Office of Technology Assessment, 1989.

***Use of Land Disposal and Containment--No* one** should jump to the conclusion that land disposal/containment options are no longer being selected, or that they will not be selected in the future. Although there are some kinds of sites for which containment remains an appropriate action, the issue is whether to call such actions permanent remedial cleanups. There are still sites where treatment technologies are ruled out, sometimes in a preliminary screening of alternatives and sometimes on the basis of poor information and evaluation, as **OTA's case studies** have shown.[11] In many cases, containment/land disposal options are being used unnecessarily. There is more experience in rejecting treatment technologies than in selecting them. Here are (in no special order) 23 generic explanations for rejection of treatment technology, which **OTA has found are often used singly or in combination** in studies for Superfund sites:

1. Land disposal or containment provide comparable environmental protection.
2. There is too little hazardous material to justify treatment.
3. There is too much hazardous material to treat cost-effectively.
4. Treatment technology provides unnecessary risk reduction at excessive cost.
5. Excavating material would pose unacceptable short-term risks because, for example, of volatile chemicals or explosive materials.
6. There is no treatment technology with enough reliability and implementability to use.
7. The treatment technology used elsewhere will not work for this site, because of its uniqueness.
8. Future land use restrictions are sufficient and the waste can be left in the ground.
9. Natural dilution of contaminated water will be enough.
10. No one is using the contaminated groundwater.
11. An alternative source of water has already been provided.
12. If treatment was used, the clean material would only get re-contaminated because of other sources of contamination.
13. Information on the true extent of contamination and risk exposure is still incomplete and more studies are necessary.

[11] U.S. Congress, Office of Technology Assessment, *Are We Cleaning Up? 10 Superfund Case Studies*, OTA-ITE-362 (Washington, DC: U.S. Government Printing Office, June 1988).

14. No test results show that the technology works for this site's problem.
15. The costs of the treatment technology cannot be estimated.
16. The local community does not want uncertain, innovative treatment technology to be used.
17. If incineration is selected, some commercial operation will begin after cleanup and other people's wastes will be treated on-site.
18. Regulatory permits cannot be obtained expeditiously.
19. The residues of the treatment are hazardous and will have to be disposed of at a permitted hazardous facility at great cost.
20. The law does not say that treatment technology must be selected, only that it be examined and given preference.
21. The technology will not treat all the contaminants at the site.
22. If the technology is used, then some other treatment technology will also have to be used afterwards for residues.
23. Natural treatment will take place through, for example, biodegradation, adsorption to soil, or release to the environment.

o f course, sometimes such explanations for rejection are valid. But when this is so it is necessary to give a well-documented technical case or logical analysis rather than mere assertion. Moreover, many times an obstacle could be effectively overcome if a decisionmaker has the will to do so. For example, poor information can be corrected and tests can be conducted.

Last, there is the emerging issue of how newly developing land disposal restrictions for hazardous waste under the Resource Conservation and Recovery Act (RCRA) affect Superfund cleanup decisions in response to the SARA statutory requirement to comply with current government regulatory standards. Briefly, EPA's current guidance to people implementing Superfund suggests several ways to justify using land disposal by evading land disposal restrictions, particularly treatment requirements: [12]

- The cleanup waste must be placed, but placement does not include: waste capped in place, waste consolidated within a cleanup unit, waste treated in situ, waste processed within the unit to improve its structural stability for closure or for movement of equipment over the area.
- The cleanup waste may not be a RCRA hazardous waste and is not sufficiently similar to a known RCRA waste.
- The cleanup waste may not be restricted in a regulatory sense.

Box 3-E—Key Issues for Chemical Fixation

Permanency-Although there are increasing claims of permanency for new and advanced forms of **fixation, there is very little** scientific evidence to verify **irreversible molecular change for organic contaminants or chemical bonding for toxic metal atoms. Any such evidence cannot be extrapolated from one contaminant to another. Solidification (forming a hard solid) does not necessarily mean that the material is resistant to leaching-out of contaminants.**

Contaminant Compatibility-There is too little recognition that using the technology for sites with diverse contaminants requires extensive fine-**tuning of formulations. Incompatible contaminants can reduce effectiveness substantially.**

Long-Term Effectiveness-Long-term effectiveness cannot be proven experimentally (unless permanency is demonstrated) and modeling has inherent uncertainties. For example, changing environmental conditions (e.g., acidity, chemistry, temperature) might cause increased **leachability of contaminants from solidified/treated material.**

Air Releases--Processing and mixing of materials can release volatile contaminants into the air.

Volume Increase—Often, there is a large volume increase which may complicate onsite disposal.

Dangers of Private Formulas-An increasing number of vendors offer proprietary formulations, leaving users with significant uncertainties, such as questions about worker health and safety, toxic byproducts, and patent infringement.

SOURCE: **Office** of **Technology Assessment**, 1989.

[12] U.S. Environmental Protection Agency, op. cit., footnote 5.

. If treatment standards cannot be met: apply for a no-migration petition; apply for a case-by-case extension; apply for an equivalent treatment method petition; delist the waste; or apply for treatability variance through rulemaking or administrative permission, particularly for soil and debris cleanup wastes.

It seems, therefore, that expectations that the RCRA land disposal restrictions might promote more use of treatment technology in cleanups should be tempered by the many ways such requirements may be circumvented. For example, many cleanups consist of capping waste in place or consolidating site wastes within a cleanup site.

New Technologies--Though more sites **are** using permanent cleanup technologies, new technologies still face difficulties. It may seem to some people that progress is being made because, for example, rotary kiln incineration and not land disposal is chosen for a cleanup. However, some other permanent technology, such as a newer form of thermal destruction or a type of biological treatment, might offer cost, environmental, or technical advantages but has not even been considered and evaluated. Although nearly everyone working within the Superfund system understands the congressional intent to shift to permanently effective cleanup technologies and acknowledges the public's support of that policy, numerous factors account for its slow and uneven implementation.[13]

One recent survey concluded, "The array of technological tools available for treatment of hazardous waste streams and site remediation continues to grow at an ever faster pace . . . In fact, technological advance is in many ways outpacing the rate at which treatment choices made by regulatory agencies can be put into action. . . . The regulatory push toward permanent solutions that can be accomplished onsite and that avoid present and future risk liability is likely to spawn many more new technologies of varying applicability. ' '[14]

A study by Tufts University concluded that ". . . there are elements which result in a bias against the use of innovative treatment technologies. . . Limited data on cost and operational history has resulted in screening out innovative technologies early in the evaluation process. Because of the liability for damages resulting from failure of the technologies, contractors, potentially responsible parties, and government alike are reluctant to recommend the use of innovative technologies that have not been fully demonstrated to remedy hazardous waste problems. "[15]

The frustration of technology developers is widespread. This is what one developer said at a congressional hearing: ''The Remedial Division, the group which should be performing cleanups as dictated by the principles of SARA, appears so wedded to A&E (architecture and engineering) firms for their Records of Decision that it appears virtually impossible to get a new technology accepted in any reasonable time."[16] EPA has made progress in overcoming obstacles to using treatment alternatives to land disposal and has recently clarified its policy objectives,[17] but use of new treatment technologies still faces major obstacles (see following issues).

There is a significant lag not only between research and development and demonstration but also between successful demonstration--considered here as enough onsite work with site materials to establish technical effectiveness and reliability—and full-scale application. This lag tends to push the expanding national cleanup effort toward older technologies rather than toward the risk and uncertainty—but the chance for bigger payoff--of newer technologies. Furthermore, the public may have little patience with delays in Superfund cleanups. In other words, insecurities inside the Superfund system and pressures from outside cause the adoption of newer

13See OTA's 1988 report and following issues.

14Jim Bishop, "Treatment Technologies,'' *Hazmat World*, June 1989.

15Center for Environmental Management, Tufts University, "The Use of Innovative Treatment Technologies at Superfund Sites, " *Environment.d Impact Assessment* Review, vol. 8, 1988, pp. 181-191.

16Paul S. McGough, statement made at hearing, Subcommittee on Transportation, Tourism, and Hazardous Materials, Committee on Energy and Commerce, U.S. House of Representatives, Hoboken, NJ, Dec. 7, 1987.

17U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response memorandum, ''Advmcing the Use of Treatment Technologies for Superfund Remedies," OSWER Directive No. 9355.0-26, Feb. 21, 1989.

technologies to be slow even as the need for them is increasing,

Information transfer and communication are key problems too. For both the general public and members of the Superfund workforce, it is difficult to cope with the flood of scientific and technological data and details, which is increasing at a rapid rate as more vendors enter the market. But technology development and selection of new technologies are crucial to making Superfund work more effectively and efficiently.

***The SpeciaI Case of Pump and Treat for* Groundwater-Cleaning** up contaminated groundwater increasingly means using the pump-and-treat approach, which means that contaminated groundwater is pumped up to the surface and treated in some manner. The treated water may then be pumped back into the ground (through injection wells), sent to a municipal water treatment plant for further treatment, or discharged to a river. The increasing use of pump and treat is in response to the public demand for cleanup of contaminated groundwater. However, over the past few years, there has been increasing discussion in the technical community (particularly from EPA's Robert S, Kerr Laboratory, Ada, Oklahoma) of the uncertainty and probably ineffectiveness of pump and treat. Some key thinking and findings on this issue are excerpted below:

- '' [U]nless the hydrology and contaminant characteristics at the site are adequately understood, the perceived success of pump-and-treat technology can be misleading. A failure to understand the processes controlling contaminant transport can result in extremely long pumping periods and consequently, costly and inefficient remediation." [18]
- ''Using current site investigation and remediation technologies, it is not possible to locate all significant contamination, nor can anyone accurately predict contaminant movement, fate, exposure, effects, or remedial technology performance. [19]
- "[T]here are two principal phenomena of subsurface contaminant movement that limit the effectiveness of pump-and-treat remediation. One is the hydrologic effects of subsurface heterogeneity. In the real world, ground water flows through preferential pathways; that is, through zones of higher permeability . . . The practical effect on pump-and-treat remediations is that it may take much longer to flush out or exchange the water in zones of finer grained materials than is estimated from traditional mathematical models that average flow rates over the thickness of the aquifer. The result is the long tailing effect on (contaminant) recovery curves. . , This effect increases with the age of the contamination because of more time for the pollutants to diffuse into the finer grained subsurface materials.

  "The second phenomenon concerns the chemical and physical forces that retard the movement of contaminants in relation to water movement. Most contaminants sorb onto and into aquifer materials and 'partition' between the solid and liquid phases, Many common contaminants also have a vapor phase in the subsurface. . . . [T]he amount of contaminants in each of these phases is a function of the characteristics of the subsurface material and the chemical properties of the contaminant. If only samples of groundwater are used to estimate the amount of contaminants to be removed by pumping, that amount will often be greatly underestimated because, in general, most of the contamination will be associated with the solid phase. Slow contaminant transfer from geologic material to water, where it can be extracted by pumping, is further exacerbated when immiscible fluids are present."[20]
- "An analysis of the mechanisms that control separate phase migration and dissolution reveals that groundwater extraction as a cleanup

[18]Clinton W. Hall, ''practical Limits to Pump-and-Treat Technology for Aquifer Remediation,' *Hazardous Materials Technical Center Newsletter,* July *1988.*

[19]William A. Wallace and David *R.* Lincoln, ''How Scientists Make Decisions About Groundwater and Soil Remediation,' presented at National Research Council Colloquium *Remediating Ground Water and Soil Contamination: Are Science, Policy, and Public Perception Compatible?*

[20]Clinton W. Hall (Director of EPA's Robert S. Kerr Environmental Research Laboratory), letter to OTA, Sept. 6, 1988.

technology is very inefficient-Petroleum hydrocarbon and organic solvent liquids are trapped within porous media as ganglia and lenses due to air-liquid and water-liquid interracial surface tensions.[21] Water table fluctuations, either regionally or locally, can emplace lighter-than-water liquids below the water table as lenses. Under conditions encountered in aquifers, these ganglia and lenses cannot be mobilized by groundwater extraction. . . . The time required for separate phase contaminant dissolution into groundwater is on the order of decades and produces a dilute waste stream that is expensive to treat. The low boiling points of these liquids indicate that steam injection could mobilize the trapped contaminant phase. A series of experiments has demonstrated the inadequacy of groundwater pumping and the feasibility of steam injection for complete recovery of separate phase liquid contaminants. '[22]

- ''Depending upon the nature of the subsurface terrain and the composition of the contaminants present, remediation may be relatively easy or virtually impossible. . . . [T]here needs to be a recognition that there are many existing sites of contamination that, if not entirely beyond our ability for rectification in an environmentally satisfactory way, may at least require many years to remediate, may involve enormous sums of money, and may create other environmental and social problems that may be equal to or greater than that posed by the contamination itself. Because of the great diversity of the problem sites, setting criteria and priorities for cleanup is not a simple task. An easy solution is not likely to be found. Even the effectiveness of proposed solutions is often quite uncertain because of the many unknowns inherent in site characterization and the absence of proven technologies for remediation. ' '[23]
- "New models have been developed that are potentially sophisticated enough to deal with almost any geologic or hydrologic setting. The problem now lies in our continuing inability to collect sufficient subsurface information to use in the models. Because of the nature of the subsurface, the uncertainties can never be resolved with today's investigation technology.

  " . . . [T]he hazardous waste engineer might reasonably want to know in which direction a plume of dense, pure-phase TCE (trichloroethylene) might flow along the base of an aquifer and whether or not it would be possible to follow it to a low point and extract it through a well.

  " . . . [T]he answer to the hazardous waste engineer's question is just not obtainable, and, therefore, the pure-phase TCE can neither be located, if it exists at all, nor extracted during the cleanup.

  "There is not now, nor will there soon be, quantitative guidance or standards to go by in designing hazardous waste site investigations. (Best judgment) will occasionally result in *errors:* unnecessary samples will be taken; data of the wrong quality will be collected and will have to be collected again; and other errors will occur."[24]
- ''For NAPLs (non-aqueous phase liquids) such as benzene and other petroleum products, which tend to float on groundwater, there have been successes in pumping a significant fraction of the NAPL to the surface. Yet for others

[21] The issue of whether contaminants sink or float in groundwater is very important. In general, petroleum-based materials are lighter than water, and chlorinated chemicals are heavier than water. Volubility in water also determines the physical state of contaminants in groundwater. Dense chlorinated solvents, for example, are not very soluble in water either; therefore, they will tend to sink in aquifers until stopped by the solid aquifer material, and then they may spread laterally. Over time, more of the contaminant may dissolve in the groundwater, particularly if the water is moving, exposing cleaner water to the contaminant. Lighter-than-water contaminants float on the surface of underground water. Essentially pure, discrete forms of insoluble liquid contaminants in an aquifer are just like above ground or subsurface soil sources of contamination, which enter the groundwater because of vertical downward motion, perhaps with the help of water entering the site and moving into the aquifer.

[22] James R. Hunt et al., "Organic Solvents and Petroleum Hydrocarbons in the Subsurface: Transport and Cleanup," University of California, Berkeley, *Sanitary Engineering and Environmental Health Research Laboratory Report No. 86-11,* August 1986. Note that steam injection faces many of the same problems as pump and treat and it has not yet reached commercial availability.

[23] Perry L. McCarty, "Scientific Limits to Remediation of Contaminated Soils and Ground Water, " presented at National Research Council Colloquium, *Remediating Ground Water and Soil Contamination: Are Science, Policy, and Public Perception Compatible?* April 1989.

[24] Hazardous Waste Action Coalition, American Consulting Engineers Council, *The Hazardous Waste Practice—Technical and Legal Environment 1988,* 1989.

more dense than water (e.g., chlorinated solvents, creosote, and PCB-rich oils), very little success has been achieved in even locating the subsurface NAPL sources, let alone removing them.

. . . [E]ven after exceptionally detailed site investigations are conducted, it is normally not possible to predict reliably where these (dense) NAPL pools are, Not knowing the size and location of (dense) NAPL pools and zones of residual (dense) NAPL makes it impossible to predict how long a pump-and-treat program must operate in order to clean the aquifer.

''The mass of NAPL at or below the water table is not known with sufficient detail at most sites to make reliable predictions of the time necessary for cleanup by pump-and-treat programs. In general, it is appropriate to view such approaches as remediation **in perpetuity** [emphasis added]. "[25] (In contrast to this view about NAPLs, EPA's view seems overly optimistic. *6)

- "Complex groundwater flow patterns present great technical challenges in terms of characterization and manipulation (management) of the associated contaminant transport pathways. . . . One result is that certain parts of the aquifer are flushed quite well and others are remediated relatively poorly. Another result is that those previously uncontaminated portions of the aquifer that form the peripheral bounds of the contaminant plume may become contaminated by the operation of an extraction well that is located too close to the plume boundary, because the flowline pattern extends downgradient of the well. The latter is not a trivial situation that can be avoided without repercussions by simply locating the extraction well far enough inside the plume boundary so that its flowline pattern does not extend beyond the downgradient edge of the plume, because doing so results in very poor cleansing of the aquifer between the location of the extraction well and the downgradient plume boundary.

  "It is not possible to determine precisely where the various flowlines generated by a pump-and-treat operation are located, unless detailed field evaluations are made during remediation. Consequently, there is a need for more data to be generated during the remediation (esp., inside the boundaries of the contamination plume) than were generated during the entire RI/FS process at a site, and for interpretations of those data to require much more sophisticated tools. '[27]
- "Originally, we were confident long-term groundwater remediation (i.e., pump-and-treat) could be accomplished in approximately 20 years. Now, with our present knowledge and experience, many professionals suggest these actions may take much longer, in some cases up to 100 years. , . . Is it cost-effective to continually remediate ground water or should we accept wellhead (point-of-use) treatment and rely on natural attenuation for the aquifer? If we do, then what will be the long- and short-term impacts on surface water and the environment? '[28]
- "Complex fate and transport mechanisms of contaminated ground water often make it difficult to predict accurately the performance of ground water remedial action, . . . To illustrate this principle, figure 3-1 presents three possible situations that may occur after several years of a groundwater response action. In the first scenario (case A), the target concentration will be reached within the desired time period. In the second scenario (case B), the target concentra-

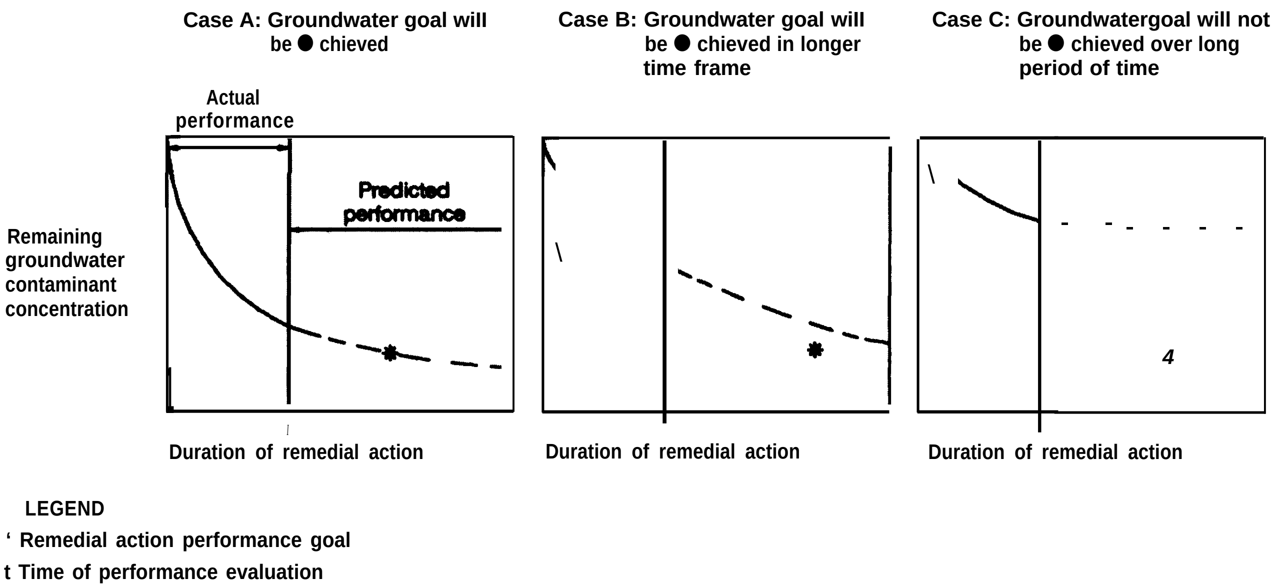
[25]Douglas M. Mackay and John A. Cherry, "Groundwater Contamination: Pump-and-Treat Remediation, ' *Environmental Science and Technology*, vol. 23, No. 6, 1989.

[26]U.S. Environmental Protection Agency, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*, December 1988. EPA's view is: ''The presence of dense non-aqueous phase liquids (DNAPLs) also may affect the extent to which contaminants can be removed from the ground water; points of accumulation are difficult to Identify, and, unless the well screen is located in the non-aqueous liquid phase, the contaminant will only be extracted slowly as it dissolves into the groundwater. '

[27]Joseph F. Keely, ' 'Performance Evaluations of Pump-And-Treat Remediations,'' draft of EPA Superfund Groundwater Issue Paper. See following discussion on the observational method.

[28]Stephen R. Wassersug and Christopher J. Corbett, ' 'Policy Aspects of Current Practices and Applications,'' presented at National Research Council Colloquium *Remediating Ground Water and Soil Contamination Are Science, Policy, and Public Perception Compatible?* April 1989.

figure 3-1-Possible Restoration Scenarios When Evaluating Performance Data



SOURCE: National Research Council, *Hazardous Waste Site* Management: *Water Quality Issues*, report on a Colloquim sponsored by t he Water Science and Technology Board (Washington, DC: National Academy Press, 1988).

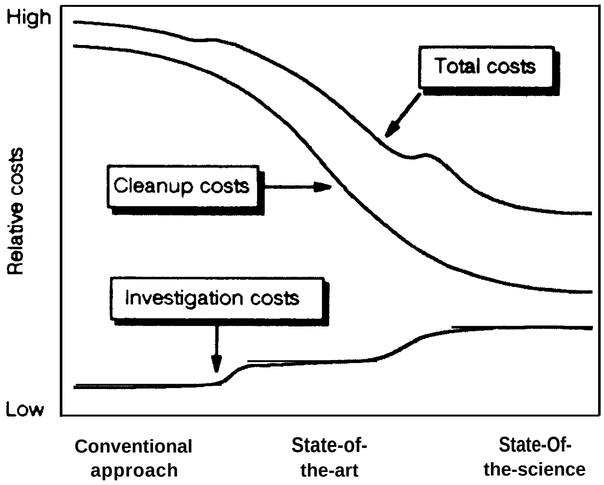
tion will be reached somewhat later than the desired time period. In the final scenario (case C), the target concentration will not be reached in a foreseeable time period. "[29] (This is an idealized portrayal wherein contaminant concentration declines continuously to an apparently irreducible level. In actual fact, contaminant rebound may occur after pumping is stopped and then started again because of diffusion of contaminants within spatially variable sediments, hydrodynamic isolation, sorption-desorption, and liquid-liquid partitioning. The main problem, however, is that case C seems to be a far more likely situation than originally thought.)

- ''There seems to be widespread overconfidence among those not directly" involved in groundwater quality research regarding the ability to predict transport and fate of contaminants in the subsurface.

"Additional effort devoted to site-specific characterizations of natural process parameters, rather than relying almost exclusively on chemical analyses of groundwater samples, can significantly improve the quality and cost-effectiveness of the remedial actions at such sites. . . . [S]ome investment in specialized equipment and personnel will be needed to make the transition to more sophisticated approaches, but those investments will be more than paid back in reduced cleanup costs (see figure 3-2). The maximum return on increased investments is expected for the state-of-the-art approach and will diminish as the state-of-the-science approach is reached (see table *3-2)* because highly specialized equipment and personnel are not widely available. It is vitally important this philosophy be considered because the probable benefits in lowered total

[29] Edwin F. Barth III et al., ''Establishing and Meeting Ground Water Protection Goals in the Superfund Program,'' *Hazardous* Wrote *Site Management: Water* Quality Issues (Washington, DC: National Academy Press, 1988),

Figure 3-2--Concaptuallzatlon of the Trade-offs Between Investigation and Cleanup Coats as a Function of the Sophistication of Site Characterizatlon Efforts



SOURCE: *Journal WPCF*, vol. S6, No. 5, May 1966,

costs, health risks, and time can be substantial."[30]

OTA's main conclusions from its assessment of pump-and-treat technology are:

1. **Superfund implementation (i.e., Records of Decision) currently conveys a sense of certainty about groundwater contamination and cleanup that is inconsistent with the above kinds of insights.** Some private sector practitioners also convey a different viewpoint; a recent article said this about pump-and-treat: **"This method is effective** with most, if not all, types of contaminants. Remediation time, while protracted, is predictable. "[31] This kind of general optimism misleads the public. Both duration and potential to achieve cleanup objectives are highly uncertain with the prevalent pump and treat method, especially for complicated sites. Little attention seems to have been paid to addressing multiple sources of aquifer contamination, which really adds complexity to groundwater cleanup. Other than non-point contributions to contamination (e.g., pesticide runoff), individual aquifers may face contamination from multiple Superfund sites. An EPA study of 877 sites found 12 aquifers threatened by three or more sites,[32] yet few Superfund cleanups seem to be integrated with other ones. All things considered, the current large commitment of money to pump-and-treat groundwater cleanups may be largely misdirected **with current practices.** Except for the simplest contaminated groundwater, current technology and practice do not offer a reliable cost-effective solution. The latest thinking about groundwater cleanup by **EPA's** Superfund office does not convey the generally negative view about pump and treat consistently found in the technical community .33 Moreover, inevitably, the public will learn what the technical specialists know. Indeed, Superfund's technical assistance grants virtually assure this. One of the frost reports from this program illustrates how this public knowledge will probably influence EPA cleanup decisions, as summarized in box 3-F.

2, **Because of the difficulty in cleaning up groundwater, much more attention should be given to identifying and removing the source of groundwater contamination.** In the past, the size and complexity of buried waste and soil contamination have sometimes lead to groundwater cleanup starting without any source elimination. While capping such a site has the merit of minimizing water infiltration, it does not preclude continued movement of contaminants into the groundwater,

30Joseph F. Keely et al., "Evolving Concepts of Subsurface Contaminant Transport,' *Journal of the Water Pollution* **Control** *Federation, vol. 58, No. 6, May 1986.* As an example of improved practice, see Steven M. Gorelick, "Reliable Remediation of Contaminated Aquifers," in *United States Geological* Survey Yearbook *Fiscal Year 1988, 1989.* The new methodology described are techniques that use combined simulation-management models; these join computer simulation techniques, for predicting subsurface contaminant migration, with advanced mathematical and statistical methods, for determining alternative and economical designs for remediation. Thousands of simulations for each site are necessary to assess and design reliable cleanups.

31Gary J. Ziegler, ''Remediation Through Groundwater Recovery and Treatment, " *Pollution Engineering,* July 1989.

32U.S. Environmental Protection Agency, ''Extent of the Hazardous Release Problem and Future Funding Needs—CERCLA Section 301(a)(1)(C) study, *' December 1984.

33U.S. Environmental Protection Agency, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites,* December 1988. Months earlier, a former senior Superfund manager published an article which discussed "a recent analysis by EPA's own Office of Research and Development' that revealed the problems discussed here with pump and treat. Gene A. Lucero, "Son of Superfund—Can the Program Meet Expectations," *The* Environmental *Forum,* March/April 1988.

Table 3-2-Site Characterization

Conventional approach	State-of-the-art approach	State-of-the science approach
Actions typically token	***Recommended actions***	**Idealizes *approach***
Install a few dozen shallow monitoring wells	Install depth-specific well clusters	Assume state-of-the-art approach as starting point
Sample and analyze numerous times for 129+ pollutants	Sample and analyze for 129+ pollutants initially	Conduct tracer-tests and borehole geophysical surveys
Define geology primarily by driller's log and cuttings	Analyze selected contaminants in subsequent samplings	Determine percent organic carbon, exchange capacity, and other other properties of solids
Evaluate hydrology with water level maps only	Define geology by extensive coring/split-spoon samples	Measure redox potential, pH, dissolved oxygen, and other properties of fluids
Possibly obtain soil and core samples (chemical extractions)	Evaluate hydrology with well clusters and geohydraulic tests	Evaluate sorption-desorption behavior using select cores
	Perform limited tests on solids (grain size, clay contents)	Identify bacteria and assess potential for biotransformation
	Conduct limited geophysial surveys (resistivity soundings)	
Benefits	***Beneflts***	***Benefits***
Rapid screening of problem	Conceptual understanding of problem more complete	Thorough conceptual understanding of problem obtained
Moderate costs involved	Better prospect for optimization of remedial actions	Full optimization of remedial actions possible
Field and lab techniques standardized	Predictability of remediation effectiveness increased	Predictability of remediation *effectiveness* maximized
Data analysis relatively straightforward	Cleanup costs lowered, estimates improved	Cleanup costs lowered significantly, estimates reliable
Tentative identification of remedial options possible	Verification of compliance more soundly based	Verification of compliance assured
Shortcomings	***Shortcomings***	***Shortcomings***
True extent of problem often misunderstood	Characterization costs somewhat higher	Characterization costs significantly higher
Selected remedial alternative may not be appropriate	Detailed understanding of problem still difficult	Few previous field applications of advanced theories
Optimization of remedial actions not possible	Full optimization of remedial actions not likely	Field and laboratory techniques not yet standardized
Cleanup costs unpredictable and excassive	Field tests may create secondary problems	Availability of specialized equipment low
Verification of compliance uncertain and difficult	Demand for specialists increased	Demand for specialists dramatically increased

SOURCE: Joseph F. Keely et al., "Evolving Concepts of Subsurface Contaminant Transport," *Journal WPCF*, vol. 5S, No. 5, May 1966.

resulting from subsurface groundwater flow through the site's contamination or possibly the sinking of dense liquids. Nor is the long-term effectiveness of caps assured; many current Superfund cleanups put new caps on older ones which evidently were not effective. (The intrinsic problems of pump and treat should be borne in mind for soil cleanup based on flushing, because the same subsurface problems pertain.)

3. **Making pump and treat more predictable and effective requires improved practices which will tax the current workforce and may increase costs substantially.** Still, development of improved pump-and-treat practices is important. However, more strategic thinking and economic analysis should go to two other primary options:

a. Point-of-use treatment: "Serious consideration should be given to point-of-use treatment for contaminated groundwater rather than attempting to reverse the random movement of organic molecules at tremendous pumping and treatment expense. The pumping and treatment of billions of gallons of groundwater to recover a few pounds of spilled solvent requires serious rethinking. Technology development should focus on how to economically and consistently surpass low part-per-billion treat-

Box3-F--How a TecbnicalAssistance Grant[1] Analysis Concluded That a Pump-And-Treat Approach Did Not Offer a Reliable Cleanup of Groundwater

The following excerpts illustrate how an understanding of the limits of pump and treat can affect a community's perception of a remedy proposed by EPA, in this case one largely based on site containment and pump and treat. The community and its technical advisers, of course, wanted the groundwater cleaned up. But their insights into the limits of pump and treat led them to other alternatives, including obtaining the kind and quantity of information necessary to make pump and treat work effectively and giving higher priority to effective source control of the contaminants in the landfill (through identification of hot spots for excavation and treatment, for example). This particular experience also illustrates how the U.S. Geological Survey can perform analyses of use to Superfund site investigations and selection of remedies; their work was not integrated into EPA's efforts.

". . . [T]here are too few wells, particularly to the south and west of the landfill, to define the full extent of the contaminant plume or to understand the complex pattern of groundwater flow. The U.S. Geological Survey has reached the same conclusion. Furthermore, the EPA used inappropriately low flow rates to estimate the area of the potentially contaminated groundwater.

"... [A] groundwater punp and-treatment system based on ERA's current understanding of flow may be grossly inadequate to prevent the continued offsite contamination of groundwater. If potent NAPL [non-aqueous phase liquid] pools are present they may be drawn into the extraction wells and overwhelm the treatment system designed for much lower contaminant levels. Another possibility is that lowering the groundwater under the landfill (resulting from groundwater extraction) may actually dislodge NAPLs and thus aggravate groundwater contamination problems.

"An evaluation of the site remedy selected by EPA in the Feasibility Study is not possible at this time because the database defined by the RI is insufficient to evaluate the effect or the efficacy of the proposed pump-and-treat system.

".,. the USGS report prepared for ATSDR (Agency for Toxic Substances and Disease Registry) evaluated the hydraulic characteristics of the flow system over an area encompassing 4 square miles. This large-scale view allowed them to place the IEL site in a proper regional context and led to conclusions which are at odds with those reached by EPA.

"The approaches selected do little, if anything, to remove or even stabilize the potentially large amounts of toxins in the landfill. This is exactly what one would expect since they based the selection of the proposed remedies on a lack of data on what is in the landfill. "

(It should be noted that EPA's Proposed Plan for the site (December 1988) offers no information on risk or risk reduction or any specific information on the objectives of the groundwater cleanup. Nor does it say anything about the limits to or uncertainty of pump and treat. The Feasibility Study for the site speaks of meeting MCLs and preventing a lifetime cancer risk of from 1 in 10,000 to 1 in 10 million (i.e., the broadest risk range used by EPA), but gives no specifics.)

[1]Technical Assistance Grants were established by Congress m SARA to assist communities in obtaining help from independent technical experts.

SOURCE: "Comments on EPA's Preferred Remedial Alternative for the Industrial Excess Landfill Superfund Site in Uniontown, Ohio," prepared for The Concerned Citizens of Lake Township by The Clam Water Fund, Disposal Safety be., and The HampshireResearch Institute, May 31, 19s9.

ment levels with a margin of safety required for potable water supplies. "[34]

b. Other aquifer cleanup methods: **There is a clear** need for a focused R&D effort to find more reliable groundwater cleanup methods, including site investigation techniques. Some form of enhanced in situ biological treatment is particularly desirable, but other approaches, such as injection of steam or surfactants, also need more support. The in situ biological approach is probably the most important option and it is currently receiving much attention

[34]Douglas C. Downey, ' 'Applying New Technologies: A Scientific Perspective, ' presented at National Research Council Colloquium, *Remediating Ground Water and Soil Contamination: Are Science, Policy, and Public Perception Compatible?* April 1989.

and some use. But the advice of two groundwater experts should be heeded: "Laboratory studies and small-scale field prototype trials are likely to yield overoptimistic expectations for the application and efficiency of these (new) technologies. ' '[35]

Another important view is: "In situ biodegration is frequently among the remediation options recommended for soil and groundwater decontamination. . . . Our experience has shown that a 250-milliliter flask has little or nothing in common with the contaminated subsurface and its response to nutrient and hydrogen peroxide (oxygen) additions. Permeability problems and rapid decomposition of hydrogen peroxide have both been documented in the field with little warning from laboratory experiments. While microbiologists have proven the principles of biodegradation in the laboratory, engineers are having less success achieving a uniform reaction in heterogeneous aquifers. "[36] An independent review of experiences with biological groundwater cleanups came to generally negative conclusions about their proven effectiveness, including: "While seeding of an acclimated or mutant microbial population holds a great deal of potential . . . results from previous attempts have not proven it to be responsible for the removal of contaminants. Further work needs to be done to demonstrate that seeding microbes is a viable technique for the restoration of contaminated aquifers. "3[7] One of the more detailed case studies for a Superfund site concluded". . . the large volume of ground water that has flowed through *the* contaminated zone has failed to produce appreciable removal of the sorbed contamination. . IB]iodegradative processes were a major means of dissolved contaminant removal [emphasis added].' **A** study of anaerobic biodegradation of groundwater at a Superfund site confirmed that trichloroethene resulted in the production of vinyl chloride as a toxic byproduct.[39]

4. **Cleanups using pump and treat may be stopped because data on pumped groundwater indicates that contaminant concentration has reached a stable low level, but in fact subsequent testing (or testing in different locations) might show that contaminant levels have increased or rebounded.** Original cleanup objectives should not be foregone (or changed to whatever the technology has been able to deliver) until there is convincing evidence that equilibrium has been achieved (case C in figure 3-1) and that no other cleanup options exist. Current **EPA** thinking on this issue is to favor a "flexible decision process" that includes using performance information to change the cleanup objectives.[40]

Moreover, there is some indirect indication that EPA is already adjusting its cleanup objectives for sites to reflect, in some way, the problems with pump and treat. For example, the cleanup level for carcinogens in groundwater at the Seymour Recycling site (which was assessed to pose a relatively high aggregate risk of **4** in 10,000) is an aggregate risk of 1 in 100,000 in addition to meeting individual MCLs (maximum contamination levels under the Safe Drinking Water Act), One of the reasons given to justify this cleanup level (which is less stringent than the more typical 1 in 1 million risk level) was "low levels of contaminants will continue to migrate when the extraction system is terminated. "[41] In other words, the more typical, more stringent cleanup level would be difficult to attain.

5. There is a distinct possibility that, for some sites, natural attenuation, including biodegradation, of contamination within the aquifer might produce essentially the same cleanup results as lengthy and costly pump and treat. Research on biodegradation is ongoing and some results are very positive, but it is not yet a reliable cleanup alternative. Indeed, a recent study of a site for which natural attenuation

[35] Mackay and Cherry, op. cit., footnote 25, 1989.

[36] Downey, op. cit., footnote 34.

[37] L.W. Canter and R.C. Knox, *Ground* Waler *Pollution Control* (Chelsea, MI: Lewis Publishers, 1986).

[38] Robert Doyle and Michael Piotrowski, "In-situ Bioremediation at a Superfund Site," *The Second Annual Hazardous Materials Management Conference/Central*, proceedings of conference March 1989, Tower Conference Management Co., Glen Ellyn, IL.

[39] Lyle R. Silka and Douglas A. Wallen, "Observed Rates of Biotransformation of Chlorinated Aliphatics in Groundwater,'' *Superfund* '88, proceedings of November 1988 conference, Hazardous Materials Research Institute, Silver Spring, MD.

[40] U.S. Environmental Protection Agency, op. cit., footnote 33.

[41] EPA, ''Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, ' December 1988.

was selected concluded that site conditions favorable to natural attenuation ''are not going to be found at a large number of sites, due primarily to complex hydrogeologic conditions and significant exposure potentials. '[42] Augmentation of natural biodegradation by supplying dissolved oxygen, for example, has possibilities, but success depends on a variety of factors, such as the soil permeability and groundwater flow rates being high enough.

6. It should be understood that there are appropriate uses of pumping groundwater to contain the movement of a plume of contamination and to treat relatively simple, well understood aquifers and relatively simple and well identified types of contamination. Indeed, beginning pump and treat very early at a site may be important as a recontrol measure. Improved practices are needed to make these applications more cost-effective. However, pumping contaminated groundwater and reinfecting it upgradient in order to prevent plume migration and contamination from entering a sensitive area (e.g., a withdrawal well for a municipal water supply, a river) is also uncertain. For example, one modeling study showed that the effect of pumping and injection was "to reduce the total amount of contaminant entering the river at the onset of the operation and to spread contaminant flow into the river at later times. ' '[43] The point is that the method reduced the average concentration of the contaminant entering the river over many years, but eventually all the contamination reached the river.

Comments on the Observational Method-The Hazardous Waste Action Coalition, a trade association of hazardous waste technical consulting firms, has endorsed what it calls the observational method as appropriate for hazardous waste site investigation, assessment, and remediation design and implementation.[44] In addition to hypothesized environmental benefits from improved recognition and resolution of the inevitable uncertainty about a site's contamination, reduction of contractor liability is a goal in adopting the observational method. The observational method seems to be especially relevant to the problems of groundwater contamination discussed above, The method is based on the correct belief that no amount of site study can eliminate all uncertainties about the site's problem(s) and the effectiveness of the selected remedy (ies). However, after examining the main points of the observational method, OTA concludes that in addition to its potential benefits there are significant implementation issues and problems, as discussed below under the five key contributions defined by the coalition. After this discussion, two alternatives or supplements to the observational method are presented.

1. "*The site remediation design is based on the most probable site conditions. '* Remediation design follows the formal government decision on cleanup objectives and remedy selection. Remedy design is currently based on the best understanding of the site's contamination and conditions. Therefore, this contribution does not say anything different than current and necessary practice. The implication that current practice presumes complete and certain understanding of a site's cleanup problems and natural conditions might have been true for some people early in the cleanup business; but most people are now skeptical about obtaining site information in the Remedial Investigation which is the last word. The need is only to obtain enough good information to select a cleanup strategy, the details of which will be worked out in the design phase.

2. "*Reasonable deviations from these conditions are formally identified and accounted for.* This approach seems beneficial. Presumably, the formal remedy design, performed by an engineering consulting firm, would identify potential deviations concerning site contamination and natural conditions which might arise from new information about the site. But there are typically a lot of possibilities which could be identified. This approach, therefore, might add significant new costs to the design part of the process. There is a potential for unnecessary

[42] Richard L. Hebert et al., "Case Study of Factors Favoring Natural Attenuation as the Preferred Alternative for Aquifer Restoration, " *Superfund* '88, proceedings of conference November 1988, Hazardous Materials Control Research Institute, Silver Spring, MD.

[43] R.W. Nelson, ''The Need t. Update Groundwater Pollution Control Strategies—A Technical Basis and Historical Perspective, ' Proceedings of the International Conference on Advances in Groundwater Hydrology, Tampa, FL, November 1988.

[44] The Bead of Directors of the Hazardous Wrote Action Coalition of the American Consulting Engineers Council endorsed the observational method on Mar. 16, 1989, and the coalition's members currently advocate this approach in publications, testimony, and presentations. The coalition's firms represent most of the major Superfund contractors.

contractor work. Moreover, presumably a really first-rate Remedial Investigation and Feasibility Study would do this under current practice, according to the degree of understanding about the uncertainty of the site's contamination and conditions.

3. *"Parameters are identified for further observation in order to detect deviations.'* Another part of the design study would presumably design continuing site investigation efforts to verify whether the remedy is working and whether previously identified potential deviations are occurring. There is a potential for continuing site investigation after a ROD and as part of remedy implementation. In current practice, most experts recognize that during remedy implementation new site information may arise, especially because information is obtained on the remedy's performance. But this situation is different than a directed effort to obtain new information about the site which might alter the selected remedy, except that an interim action (operable unit) already implies that key decisions have not yet been made about some part of the site. Remedial investigations now can proceed while an interim action is being implemented.

4. *"Contingency plans for each deviation are incorporated into the remediation design."* The design study report would also presumably present detailed contingency plans (akin to a feasibility study) if such deviations became documented. However, contingency planning means that changes in the originally selected remedy might be made. OTA has expressed concerns about remedies changing after a ROD is issued, when public participation is minimal. Significant new information about a site after a ROD is now recognized as a possibility, and there is a procedure to amend a ROD or issue a new one without compromising public participation and accountability.

5. *"Post-remedial monitoring is established as an essential component of hazardous waste site remediation.* There is potential for more monitoring to replace action and closure to a cleanup. The law currently requires such monitoring if hazardous waste remains onsite, and EPA normally requires significant monitoring when there is potential groundwater contamination or when impermanent remedies are used.

Overall, the observational method changes the process of study and cleanup. This method may have technical benefits, but it also might complicate public accountability of the critical cleanup decisions for a site, although its proponents say it would improve communication and accountability. By focusing on uncertainties, the method may also produce increased uncertainty about remedy implementation, and health-based cleanup objectives may be transformed into technology performance ones (especially when pump and treat is used). As intended, contractor liability might be reduced because the cleanup process would become tentative and be maintained longer, and produce increased information to reduce the possibility that a selected remedy is ineffective; this last point is clearly a benefit. But considerably more contractor work might be created and there would be more reliance on the engineering judgments of contractor staff and the responses to them by either the government (for fund-financed cleanups) or responsible party (for settlements which give the responsible party implementation authority). Indeed, the people who have devised the observation method said "The party responsible for operating the remedial action will have to have the judgment required to determine if a deviation has occurred and which response to take. . . . In cases where more than one response is possible to a deviation, considerable judgment may be required to select the most appropriate response.'[45] To some degree, EPA appears to have accepted the observational method.[46]

Two alternatives or supplements to the observational method are: 1) improving the technical methods and practices used in site assessment and cleanup design to reduce and better understand uncertainties about a site, and 2) changing the kinds of cleanup decisions made to reduce the negative impacts of imperfect information on decisions. First, as discussed in the previous groundwater section,

[45] Stuart M. Brown et al., *Application of the Observational Method to Remediation of Hazardous Waste Sites* (Bellevue, WA: CH2MHill, April 1989).

[46] For example, in its guidance for groundwater cleanup, EPA said: "Data to reduce the uncertainty of important variables should be collected throughout the remedial selection [presumably pre-ROD], design, and construction phases to refine and modify the remedy." U.S. Environmental Protection Agency, op. cit., footnote 33.

shifting from the conventional to the state-of-the-art approach for site investigation (table 3-2 and figure 3-2) offers environmental and cost benefits. This shift recognizes the problem that the engineering community, to a large extent, is not using the best available techniques for site investigation. Although better techniques (e.g., the simulation-management model developed at the U.S. Geological Survey) require more skilled personnel, may take more time, and cost more money, they ultimately lead to more cost-effective cleanups, greater reliability, and fewer failures. In fact, even now there are wide differences in the capabilities and practices of firms working on groundwater cleanup. With the observational method, conventional techniques may remain dominant and change slowly as the more conservative, analysis-intensive process attempts to reduce errors and failures.

Second, key cleanup decisions can change to reflect an improved understanding of the complexity of site investigation and cleanup. The options include: 1) stressing the distinction between actions necessary because of current risks and actions that can be postponed because of uncertain, future risks; 2) emphasizing different types of remedial actions over time (i.e., emergency, recontrol, interim remedial, and final permanent); 3) refraining from calling a remedy complete and permanent when impermanent technologies or highly uncertain ones (e.g., pump and treat for groundwater) are used; and 4) avoiding making critical cleanup decisions after the ROD unless there is full public participation and accountability. For groundwater cleanup, for example, the alternative would be making a different decision about the groundwater cleanup, including: continuing the site investigation before committing to pump and treat or postponing cleanup if no significant current risk exists, trying a different cleanup method (e.g., in situ bioreclamation), or implementing a recontrol approach based on plume containment but not aquifer restoration. With the observational method, the increased use of pump and treat would probably continue and changes in the original cleanup objectives might be unknown to communities and other interested parties who are not directly implementing the cleanup (see following discussions of landfill cleanup decisions).

Issue 3: Is the current enforcement emphasis on obtaining settlements with responsible parties affecting remedy selection?

After examining nearly all fiscal year 1988 RODS, summary statistics on them, and studying some RODS in detail, OTA arrived at a number of findings about how settlements with responsible parties influence selection of cleanup technologies and standards, and about other major issues .47 The most important findings for the settlement impact issue are summarized first:

- Cleanup standards, the extent of cleanup, the permanency of cleanup, and the selection of cleanup technology are often compromised in formal or informal negotiations to obtain settlements with responsible parties. What responsible parties are willing to pay, together with the flexibility inherent in the current system, can lead to less stringent cleanups. Indeed, a former administrator of EPA said, "We do not believe it is wise to select a remedy that cannot be implemented because of . . . unwillingness of the responsible parties to agree to a settlement. '[48] Of course, when responsible parties are successful in obtaining remedies they believe more cost-effective, they correctly main-

[47] The detailed discussion under Issue 3 of RODs from fiscal year 1988 supplements OTA's 1988 case study report, *Are We Cleaning Up? 10 Superfund Care Studies* which examined fiscal year 1987 RODS. A number of observations in the discussion here pertain to general issues concerning Superfund implementation, such as conflicts between statutory requirements and cleanup decisions.

[48] Prepared testimony of Lee M. Thomas, in *Preliminary Findings of OTA Report on Superfund*, Committee Report on Hearing before the Subcommittee on Investigations and Oversight, Committee on Public Works and Transportation, U.S. House of Representatives, Apr. 20, 1988, p. 99. At the hearing, EPA's former Assistant Administrator J. Winston Porter aJso testified, "Let me tell you the worst result in Superfund, and that is if I get in a bind where the State won't pay the 10 percent—that means we can't move ahead with the fund-nor will potential responsible parties (PRPs) agree to do it,'' p. 189. Also, in EpA's removal program ''regional offices must aggressively pursue cleanup by the potentially responsible part (PRP) before initiating any Fund-financed removal action. " (Karen Burgan et al., ' 'Setting Removal Program Priorities, " *Superfund '88*, proceedings of November 1988 conference, Hazardous Materials Research Institute, Silver Spring, MD. Legally, EPA may not be able to perform a fund-financed remedial action without State agreement to pay the matching 10 percent, and if responsible parties will not settle and if EPA does not wam to delay cleanup until successful legal enforcement action, then again action becomes contingent on State agreement to pay the 10 percent. One way out of this dependency on State cooperation might be for EPA to take a removal or, as discussed in this report, a recontrol action which would not require State agreement.

tain that the government has affirmed their adequacy to protect health and environment.[49]

- The decisions for 12 sites discussed below, for which the desire for settlement is probably important may save responsible parties about $400 million, compared to estimated costs of more stringent remedies in the sites' RODS or in matched-site RODS. Roughly, that seems to represent about a 50-percent saving overall. In fiscal year 1988, OTA estimates that there may have been 50 to 70 decisions affected by the desire for and pursuit of settlement.[50] Through the decisions documented in these RODS, responsible parties may eventually save many hundreds of millions of dollars, perhaps as much as $1 billion. If all these settlements lead to permanent, complete cleanups, the savings are laudable. But will in fact those cost-saving remedies work effectively in the long term? Only time, effective environmental site monitoring, and effective government oversight will provide conclusive answers. But science, common sense, and experience suggest that, eventually, major follow-up cleanups may be necessary. And if some of these cleanups prove ineffective, then damage to public health and the environment may result.
- Cleanup standards, such as the acceptable level of residual soil contamination at a site after cleanup, are sometimes substantially less stringent at sites where decisions seem influenced by the government's desire to obtain a voluntary settlement with responsible parties—compared to sites where settlement is not an issue. These differences cannot be explained technically, for example on the basis of major differences in site conditions. While current risk assessment methods can easily lead to different results for the same conditions (because many somewhat arbitrary assumptions have to be made, and because it is not always clear just what data should be used), sometimes higher levels of residual contamination (less cleanup) result from using high levels of acceptable risk.
- When sites are in EPA's enforcement program and when responsible parties perform the critical Remedial Investigation and Feasibility Study (RIFS),[51] cleanup actions are much more likely to use land disposal and containment techniques rather than waste destruction technologies. For fiscal year 1988 RODS, 78 percent of RODS using waste destruction technologies were in the fund program, and 75 percent of the RODS using containment/land disposal were enforcement RODS. Some Superfund cleanup waste is still being sent to commercial landfills. And EPA's statistics on use of treatment cleanup technologies may present an overoptimistic picture, because many of the treatments do not destroy toxic material and sometimes deal with a very small portion of site contamination.
- In enforcement cases, low-cost cleanups that facilitate settlement are sometimes based on relatively speculative or unproven treatment (but not destruction) technologies.[52] They are tested for their effectiveness on site materials **after the** government has selected them and during Remedial Design, which is much less visible to the public than the pre-ROD activities. Assurances that consent decrees provide for the contingency of ineffective test results are not entirely satisfactory. Who will interpret the post-ROD test results? How much more time will be added to the already lengthy site cleanup process if another remedy has to be selected? Moreover, an important issue is whether specific cleanup standards committed to by the government in the ROD may be changed years later to accept the limited accomplishments of the selected technology. That is, health-based cleanup objectives may be replaced by technology performance standards, especially for groundwater cleanup. The way to promote use of innovative technologies is

[49]Responsible parties are not always successful in obtaining the remedies they want; see discussion in ch. 1 about Superfund syndrome and relative roles of communities and responsible parties.

[50]We arrived at this estimate by assuming that at least two-thirds of the RODs designated as enforcement (half the total) involved settlement and that perhaps as much as one-third of the RODs designated as fund might involve settlement.

[51]For some enforcement RODs, EPA does the RIFS, usually because responsible parties have declined the opportunity to perform the RIFS.

[52]This situation was revealed in OTA's 1988 case studies; see especially the case study for the Sands Spring site in Oklahoma.

through pre-ROD treatability studies which provide a basis for confidence in the technology selection for a particular site.

. For about the last 2 years, EPA has used a framework for evaluating cleanup alternatives (and the one in EPA's proposed National Contingency Plan) that permits virtually any kind of decision to be rationalized. This excessive flexibility affects settlements with responsible parties. EPA uses cost-benefit analysis of alternative cleanup approaches, in which the level of environmental protection is a variable. EPA's instruction to personnel implementing Superfund is, ''Make final determination of which alternatives provide overall effectiveness **proportionate to costs "**[53] [emphasis added]. But the statute requires a cost-effectiveness technique, which first sets specific environmental objectives of a cleanup and **then** finds ways to minimize costs. Alternatives that offer far less certain and effective protection of health and environment are sometimes given the same ratings as better techniques, making it appear that cleanup goals have not been compromised.

Research-OTA examined summary statistics on remedy selection provided by EPA for RODS classified either as enforcement or fund. In addition, OTA examined pairs of sites in three generic categories (wood preserving, PCB contamination, and lead battery); that is, sets very similarly contaminated sites whose RODS were issued in fiscal year 1988, one or more sites involving settlement, and one or more which did not. Sites were chosen solely on the basis of finding matches in the nature of site contamination and on the basis that there were no site condition variables that could explain substantially different cleanup decisions, Nine cases are discussed below.

Third, OTA examined all the fiscal year 1988 RODS in Region 5 for which containment/land disposal was selected. All these sites were landfills of various types. Five were enforcement RODS and three were fund RODS, but one of the latter said that EPA was negotiating with responsible parties for remedy implementation.

***Statistical* Patterns--From** EPA's summary statistics, we conclude that there is a substantial difference in cleanup technology for sites in the enforcement program compared to sites in the fund program. For example, in fiscal year 1988, the enforcement program selected land disposal or containment actions in 42 percent of its source control (these exclude groundwater action RODS), compared to only 12 percent for the fimd-fma.need program. Between fiscal years 1987 and 1988, the fund program substantially decreased its use of land disposal from 44 to 12 percent, but the enforcement program showed a smaller decrease from 64 to 42 percent. There has been wide agreement for some time that land disposal and containment are not permanent remedies, are bound to fail eventually, and pose uncertain long-term costs and threats to health and environment, Indeed, many of EPA's RODS that have rejected land disposal and containment cite these reasons for doing so. Moreover, the law expresses a particular policy against sending hazardous waste from Superfund cleanup sites to offsite landfills. In the past 2 years, 83 percent of the remedial action cases using offsite landfills were in the enforcement program.

Conversely, in fiscal year 1988, the enforcement program selected those kinds of treatment technologies (chiefly incineration and biological treatment) that permanently destroy toxic waste in 14 percent of its source control RODS; the fund program selected permanent treatment in 44 percent of its source control RODS. Between fiscal years 1987 and 1988, the fund program substantially increased its use of destruction technology from 26 to 44 percent, but the enforcement program's usage remained constant at 14 percent. The law explicitly expresses a preference for permanent treatment remedies over land disposal and containment.[54] Sometimes, treatment technology, for example at a very large landfill or mining waste site, could be rejected by invoking the statute's fund-balancing provisions for fund-financed cleanups; in such cases there may be no

[53]U.S. Environmental Protection Agency, op. cit., footnote 5.

[54]Treatment technologies that only reduce volume or mobility of hazardous waste do not guarantee permanence, but they are also preferred over land disposal and containment. SARA does not explicitly favor destruction technologies over other forms of treatment. EPA has not provided a technical interpretation of permanence the way OTA has.

other choice with current technology but a much less costly containment approach. But the nine examples given below are not such cases.

EPA's data on remedy costs shows that enforcement costs are less likely to be at the high range (above $20 million) and more likely to be at the low range (below $5 million) as compared to fund decisions. In fiscal year 1988, only 7 percent of enforcement costs were above $20 million but 16 percent of fund decisions were; also, 51 percent of enforcement costs were below $5 million, while 64 percent, of fund decisions were in this range. One plausible explanation is that, to encourage settlements, the enforcement effort selects containment remedies for source control (and possibly justifies taking no action for groundwater contamination) for relatively large sites in order to arrive at a cost acceptable to responsible parties. However, in order to balance this bias for using containment, relative to the need to be responsive to the statutory preference for treatment-based remedies which assure permanence, the enforcement effort selects treatment-based remedies for smaller sites. Because of smaller volumes of hazardous waste for treatment, the costs remain low enough to facilitate settlement.

For fund program RODS, having proportionately more remedies with costs at the low and high ends, a plausible explanation is that containment is more likely to be used for relatively smaller, simple sites and destruction technology for larger, more complex sites. In other words, this interpretation suggests that responsible parties for smaller sites pay more for cleanup than the government spends for similar sites, and responsible parties for larger sites pay less for cleanup than the government spends for similar sites.

Nine Cases

Four Wood Preserving Sites

These four Superfund sites have similar histories and similar contamination. The contamination is principally from the use of creosote, which consists of many toxic chemicals, including a number of known carcinogens.

The first site is the Brown Wood Preserving site in Florida, an enforcement program site. The Brown site may be the clearest example we have found of the environmental consequences where settlement is the goal. Responsible parties contracted for the RIFS. The ROD did not use EPA's required nine criteria for evaluating remedial alternatives. Most of the hazardous material from this site was sent to the Nation's largest hazardous waste landfill in Emelle, Alabama, in a removal action several months before the ROD was signed in April 1988. (Landfilling was rejected in the three other wood preserving site examples.) A total of 16,500 tons of the site's most contaminated sludge and soil was sent offsite. Ten thousand tons of less contaminated soil was left onsite for biological treatment which, however, had not yet been proven effective for the whole range of chemicals at this kind of cleanup.[55] A background document for the Brown site reveals that 840 tons of the carcinogenic chemicals (in the soil) were landfilled offsite and 50 tons were left onsite for biological treatment; that is, **94 percent of the carcinogenic contaminants were landfilled offsite.**[56] **The** cleanup level for contaminants was 100 parts per million (ppm) carcinogenic chemicals in the soil. (With exactly the same exposure route of soil ingestion for residents and acceptable risk of 1 in 1 million excess cancer deaths, the corresponding value for the Southern Maryland site in Maryland, discussed below, was 2.2 ppm, and for the L.A. Clarke & Son site in Virginia, discussed below, 0.08 ppm.) The ROD said that cleanup standards had been changed from the original risk assessment but did not say what the changes were.

In its explanation for the removal action, EPA's ROD said that it "contributed to the acceleration of the site along the Superfund enforcement process track. The ROD also said that the responsible parties "have been very cooperative in furthering

[55] A recent technical paper on biological treatment noted some problems with the kinds of chemicals found at sites contaminated by creosote. First, the rate of degradation of larger polyaromatic hydrocarbons decreases with increasing molecule size and decreasing volubility. Second, if the creosote is present as small droplets within pores of soil, the degradation process will be inhibited. Gaylen R. Brubaker, "Screening Criteria for In situ Bioreclamation of Contaminated Aquifers, " *The Second Annual Hazardous Materials Management Conference/Central,* proceedings, Tower Conference Management Co., Glen Ellyn, IL, March 1989.

[56] This cleanup illustrates how important it is to have data that can be used to identify the contribution of different technologies to the *overall* cleanup. For example, EPA credits this site with using biological treatment, even though it addressed only 6 percent of the contamination,

the cleanup of the site. ” The timing of the removal was significant. At a public meeting in October 1987, an EPA official explained that the RCRA land disposal bans imposed by Congress were going to make it impossible to landfill the site’s toxic material and that he ‘‘was told by Headquarters within the last couple of days that virtually all this type of waste will eventually have to be incinerated onsite or offsite. The type of land disposal whereby excavation and removal were accomplished will be a thing of the past. Therefore, the government cooperated in circumventing the congressional intent to prohibit land disposal of certain toxic materials.

The remedy approved by EPA was estimated in the ROD to cost $2.4 million (apparently $1.9 million for the landfilling and $0.5 million for the biological treatment), while the use of onsite mobile incineration was estimated to cost $5.4 million. EPA’s analysis of cleanup alternatives acknowledged that onsite incineration would provide greater environmental protection, was more consistent with statutory requirements, and would take significantly less time to fully implement than the remedy selected. There was no explicit acknowledgment of the inconsistency between the selected remedy and statutory requirements and preferences.

Second, consider the June 1988 ROD for the Southern Maryland Wood Treating site in Maryland, a fund program site, EPA selected onsite mobile incineration for treating over 100,000 cubic yards of contaminated materials at an estimated cost of $38 million, including groundwater cleanup. There is no apparent viable responsible party to settle with. An early attempt by the responsible party at using biological cleanup at the site had failed. The ROD specifically rejected the use of a hazardous waste landfill at $23 million and biological treatment at $31 million; for landfilling, the ROD said that potential leaks and leachate migration made “the permanence of this option . . . dependent upon the expected life of the landfill, ” and for biological treatment it said that it had ‘‘a higher risk of remedy failure than thermal treatment. ” In contrast to the Brown site in Florida, the Southern Maryland ROD presented extensive data on contamination, risks, and cleanup standards. The key cleanup objective selected was 1 ppm carcinogenic chemicals in subsurface soil necessary to protect groundwater—i.e., 1 percent of the 100 ppm standard for the Florida site. (In both cases the risk level was said to be 1 in 1 million excess cancer deaths.) The cleanup standard for surface soil was 2,2 ppm.

At a third site, an enforcement ROD was issued for the Brodenck Wood Products Co. site in Colorado. Most of the RIFS work has been done by responsible party contractors. A small amount of surface impoundment material (4,000 cubic yards of sludge and oil) will be incinerated onsite. Except for visibly contaminated soils beneath surface impoundments, the ROD commits to using onsite incineration only if the volume of soil is less than 2,500 cubic yards. If, as is likely, the volume is greater than 2,500 cubic yards-and it may be as much as 30,700 cubic yards-the material will be stored onsite for further study and, it appears, may not be incinerated, There is no technical or environmental reason why the larger amount of contaminated soil could not be incinerated, except that it would of course cost more—an estimated $11 million for the larger amount of incineration, instead of $1 million for either the small amount of incineration or the stockpiling.

The Brodenck ROD presents no actual cleanup standard for soils beneath impoundments, other than the somewhat subjective identification of **visible** contamination. Soils can be quite contaminated without being visibly contaminated. The more routine ROD requirement is a specific level of residual contamination above which soil would have to be excavated and remediated. Moreover, data in the ROD suggests that soil beneath the impoundments may be contaminated with dioxins, because relatively high levels were found in some impoundment sludges. This situation argues for using onsite incineration, sooner rather than later. (The presence of dioxins was also a factor in the decision for using incineration at the Southern Maryland site; dioxin contamination at wood preserving sites is likely when, in addition to creosote, pentachlorophenol was used, as was the case for the Brodenck site.)

A fourth wood preserving site—the L.A. Clarke & Son site in Virginia—illustrates a general problem facing analyses of Superfund implementation. Some site RODS that EPA classifies as a fund program may, nevertheless, reflect the consequences of a preference for and pursuit of voluntary settlement, a process that often begins **before the** ROD is issued. The L.A. Clarke & Son site is a sister site of the Southern Maryland Wood Treating site discussed earlier. Both sites are in EPA Region 3, L.A. Clarke & Son operated both facilities, and the estimated volume of contaminated material was nearly the same for both sites (the volume of material requiring cleanup at the L.A. Clarke & Son site was said to be 119,000 cubic yards). But the ROD for the Virginia site selected a combination of soil flushing, biological treatment (i.e., a combination of in situ bioreclamation, biotreatment in tanks, and land farming), and landfilling of an unspecified amounts of material which are not effectively treated by the in situ flushing and biological treatment.[57] The selected remedy would have to be proved effective by extensive post-ROD testing. (Biological treatment was selected in two of these examples [Broderick and L.A. Clarke& Son] and rejected in the other two [Brown and Southern Maryland], and its effectiveness for this cleanup is uncertain.[58]) The site's contamination is complex, including a layer of dense creosote that lies on top of a clay layer beneath an upper aquifer, which raises serious concerns about the selected remedy's ability to be effective. The flushing component would probably generate hazardous waste for land disposal.

Moreover, the L.A. Clarke & Son site ROD selected an acceptable concentration for soil for a standard group of carcinogenic chemicals of 10.3 ppm for protection of groundwater (corresponding to a risk level of 1 in 100,000 excess cancer deaths and 10 times higher than corresponding figure for the Southern Maryland site). Onsite incineration was not evaluated as a cleanup alternative and no explanation was given, but an offsite incineration option was estimated to cost $76 million. Cleanup of contaminated groundwater was deferred to a later ROD. The estimated cost for the L.A. Clarke& Son site cleanup was about half that for the Southern Maryland site, a difference of about $20 million. EPA has indicated that if a cleanup goal of 1 in 1 million risk had been used "the only feasible remedy would have been incineration, "[59] A few months after **EPA** issued the ROD, based on its own RIFS, a complete settlement was reached with a responsible party for implementation of the selected remedy; the ROD had identified the responsible party and said that negotiation with it was intended, and the responsible party had submitted extensive comments to EPA on its RIFS and proposed remedy. The ROD provides strong indication that the desire to allow the industrial facility to keep operating was a significant factor in remedy selection. To implement incineration, it would be necessary to remove the site's buildings because of the extensive contamination below them. The ROD noted that "many residents are skeptical of the treatment technology proposed in the preferred alternative and are unhappy with the length of time projected for the cleanup (the longest of the alternatives).' The desire of some residents to shut down the facility was also noted.

The L.A. Clarke & Son site decision is actually more indicative of environmental compromise and less protective than it first appears. The safe soil cleanup level was determined to be 0.08 ppm for ingestion (compared to 2.2 ppm for the Southern Maryland site), but the ROD used the figure for soil of 10.3 ppm for protection of groundwater based on a lower risk level of 1 in 100,000 instead of 1 in 1 million (compared to 1 ppm for the Maryland site). To justify replacing the 0.08 ppm figure for surface soil with a cleanup objective over 100 times higher, the ROD said, "To achieve surface soil levels protective of direct contact exposure, the site will be

[57] Nothing specified in the ROD precludes a major amount of the site's contaminated materials from being landfilled.

[58] OTA examined the results of a preliminary feasibility study on the potential for indigenous microbes to destroy the site's polynuclear aromatic hydrocarbons reported to EPA's RIFS contractor for this site in October 1986. There were 51 laboratory results for percent destruction of four chemicals in soil and surface water samples from different locations. Only 29 percent of the results were vety successful (i.e., 96 to 99 percent reduction of contaminants), nearly half of the results were zero or close to zero percent reduction, and the other 20 percent were partially successful but not sufficient for effective cleanup. The results are particularly important because they indicate a potential problem for achieving effective in situ bioreclamation selected for subsurface soils. But a report which designed a formal treatability study, issued in March 1987 by an EPA contractor, described those initial results as finding that "indigenous microbes were capable of degrading" the four chemicals tested. Apparently the 8-month $70,400 treatability study was not conducted prior to completion of the RIFS and ROD about a year later.

[59] In an undated internal EPA Region 3 memo provided to OTA. The memo also refers to a cost of incineration of $125 million which does not agree with the ROD, and says that the soil volume needing treatment was twice as much as at the Maryland site, which also does not agree with ROD information.

covered with 1.5 feet of seeded topsoil. This move is not standard EPA practice, especially as no institutional controls on future land use were imposed by the ROD for this containment solution. Indeed, the industrial facility is still active. In other words, cleanup costs were also reduced by replacing some biological treatment with crude capping; that is, soil cover and not an engineered hazardous waste landfill cap.

Three PCB Sites

Technologically, the cleanup of PCB contamination illustrates the availability of competing permanent treatment techniques, mostly incineration and to a lesser degree chemical dechlorination and biological treatment. The enforcement ROD for the MGM Brakes site in California, however, selected offsite landfilling of over 10,000 cubic yards of contaminated soils. The cleanup standard for soil of 10 ppm PCBs was for a risk level of 1 in 100,000 excess cancer deaths and not the more typical 1 in 1 million risk level. The estimated cost of the selected remedy is $5.3 million.

A previous Feasibility Study had selected onsite incineration at a cost of $8.4 million, but in response to public opposition EPA issued a revised FS and changed the remedy to offsite landfilling. The MGM Brakes site is still a major operating industrial facility and is a prime employer in the community. This fact may explain why, according to the ROD, community opposition focused on ''the economic and health risks' of onsite incineration. The ROD noted that there was no public opposition to the selected remedy of offsite Iandfilling. (Landfilling was rejected in the next two PCB cleanup examples.[m])

The ROD for MGM Brakes noted that some testing of PCB dechlorination technology, which EPA has selected elsewhere for a Superfund PCB cleanup, had been done in 1987, but the ROD said that 'it was deemed impractical due to the nature of site soils' and because of "process control problems. " However, the ROD did not support this interpretation with specific technical data. Chemical fixation, which EPA has used elsewhere for a Superfund PCB cleanup, was rejected in part because it would not destroy the PCBs and would not offer a permanent solution (consistent with OTA's views on permanence), and also because treated materials would have to be landfilled which would require institutional controls such as deed and land use restrictions, The ROD said that ''EPA also does not have well-developed administrative capabilities to oversee and enforce institutional controls,"[61] But the selected remedy of offsite landfilling also has the disadvantages of impermanence and uncertainty,

But the most significant issue is the cleanup's apparent violation of the statutory requirement to comply with applicable or relevant and appropriate regulatory requirements. Regulations promulgated under the Toxic Substances Control Act (40 CFR 761.60) require that PCBs in concentrations greater than 500 ppm must be disposed of by incineration. The MGM Brakes ROD said, Soil sampling results showed a significant percentage of samples with PCBs in excess of (milligrams per kilogram) 1,000 mg/kg (1,000 ppm). ' The ROD referred only to a regulatory requirement that concentrations over 50 ppm be incinerated or disposed of in an approved landfill, Actually, the regulations speak of the range between 50 and 500 ppm for the option of land disposal or incineration.

Next, consider the fund program ROD for the LaSalle Electrical Utilities site in Illinois, The fiscal year 1988 ROD selected onsite incineration at a cost of $28.6 million for 23,600 cubic yards of soil and sediment. There is no viable responsible party to settle with. The cleanup standard is 5 ppm down to one foot and 10 ppm beneath one foot of soil; the ROD said that a soil concentration of 0.03 to 3 ppm of PCBs corresponds to a risk of 1 in 100,000 excess cancer deaths (indicating a relatively high residual

60However, landfilling of PCB cleanup waste has been practiced elsewhere; for example, the cleanup of the Geneva Industries site in Texas is based on sending 47,000 tons of PCB-contaminated soil to the commercial hazardous waste landfill in Emelle, Alabama.

61This statement is particularly significant because many Superfund RODS rely on institutional controls as part Of the selected remedy. It also is a good example of regional autonomy, because EPA headquarters has not expressed this view and probably would not as policy or guidance because ıt frequently endorses institutional controls.

risk for the cleanup levels selected).[62] The least costly option of landfilling at about $3.5 million was rejected because of the "difficulty in assuring the long-term integrity of hazardous waste landfills. " The options of biological treatment and dechlorination were rejected initially on the basis of uncertain effectiveness and implementation times. A 1986 ROD for the LaSalle site had selected onsite incineration for contaminated soils in a residential area offsite. The 1988 ROD noted that costs for the earlier selected incineration cleanup, started in early 1988, had been 45 percent less than the original estimate ($15 million instead of $27 million) because of 'the current competitive atmosphere in the thermal destruction business. "[63]

Another fiscal year 1988 ROD labeled as fund program (like the L.A. Clarke site in Virginia) was that for the French Limited site in Texas, for which PCBs are a major contaminant in about 150,000 cubic yards of sludges, sediments, and soils. However, responsible parties have been very active at the site; they conducted a multimillion-dollar technology demonstration for in situ biological treatment and have produced a supplemental Remedial Investigation, which EPA said it used. Indeed, EPA overturned its original selection of incineration and selected in situ biological treatment in its ROD. (Biological treatment was not selected in the above two PCB site examples.) The estimated cost for the selected biological remedy was $47 million as compared to the ROD's estimated $120 million for the rejected onsite incineration option; the biological alternative was the second lowest cost treatment option (a containment option at $42 million was rejected). A few months after EPA issued the ROD a complete settlement was reached with responsible parties for implementation of the selected remedy.[64]

The French Limited cleanup standard was 23 ppm for PCBs which the ROD said corresponds to a risk of 1 in 100,000 excess cancer deaths. (This is a relatively high risk and a high level for PCB cleanup, which in the previous two PCB examples was 5 to 10 ppm,) The site study conducted by the responsible parties, as noted by EPA in its ROD, found that PCBs were not reduced to below the relatively high allowable PCB level of 23 ppm, and that some secondary chemical fixation treatment would be necessary. The ROD acknowledged that the pilot study had presented "no data . . . to show what portion of the decrease is specifically attributable to degradation. In other words, some of the apparent decrease in measured PCB contamination levels might not have resulted from molecular destruction by microbes but may have resulted from a transfer of PCBs to another medium, such as air or water. The current scientific literature on biological treatment of PCBs does not show that all PCB molecules (higher chlorine types) can be destroyed biologically to low residual levels.[65] A professional paper by people working for the responsible parties which described the remedy selection made no mention of the issue of PCB destruction.[66]

Moreover, the French Limited ROD also noted that "some degradation of the water quality in the upper aquifer did occur during the pilot study. ' Furthermore, "Recovery and treatment of the shallow aquifer is necessary to control any groundwater degradation which may occur during implementation

[62] In other words, it seems that a trade-off was made, increasing the risk to reduce the amount of soil requiring incineration; however, the 5 and 10 ppm levels for PCBs are typical of many PCB cleanups. The risk assessment may have been overly conservative or a mistake may have been made (see discussion on risk assessment in ch. 1).

[63] This observation supports OTA's conclusion that competition among generic cleanup technologies and within classes of technologies has reduced unit cleanup costs, preventing permanent remedies from becoming exorbitant, as some people feared would happen as a result of SARA.

[64] The estimated cost for incineration seems hi@; using the unit cost from the LaSalle cleanup would suggest a cost of $90 million and a still lower cost is likely-perhaps $60 million—because of the much larger (six times) volume of material at French Limited and there are significant economy-of-scale effects for incineration.

[65] The effectiveness of biological treatment of soil contaminated with PCBs remains a controversial issue and there is a large literature on the subject. (see EPA, *Technology Screening Guide for Treatment of CERCLA Soils and Sludges*, September 1988; and S. Niaki, "Treatment Technologies for PCB-Contaminated Soils," conference proceedings Haztech International, St. Louis, Missouri, August 1987) EPA concluded that with more than 5 chlorines per molecule bacterial degradation was not readily observed. (EPA, *Microbial Decomposition of Chlorinated Aromatic Compounds*, September 1986.) Some commercial vendors of biological cleanup technology say that they are effective on PCB-contaminated soil, but little detailed data are available. professor John Waid of La Trobe University in Australia has informed OTA of promising results of a field test in the United States using his method, based on white rot fungus and landfarming techniques, to destroy PCBs in soil.

[66] Richard L. Sloan et al., 'The French, Ltd. Project: A Case study, *Superfund '88*, proceedings of conference November 1988, Hazardous Materials Research Institute, Silver Spring, MD.

of the biotreatment remedy. " Based on our extensive study of RODS, such uncertainty about effectiveness and implementation problems would typically rule out an alternative. However, the ROD's evaluation of alternatives gave the selected remedy the same ratings for effectiveness and irnplementability as incineration, But the ROD acknowledged that incineration 'offers destruction of all of the contaminants to levels below the health-based criteria' whereas biological treatment would require stabilization for PCBs and that the stabilization would not destroy the PCBs. Chemical fixation had been evaluated and rejected in the MGM Brakes site ROD, which said that it ''would not provide a permanent solution for the site. " For most of the many commercially available forms of chemical fixation, effectiveness on PCBs is unproven.[67]

Two Battery Recycling Facilities

Lead is the principal contaminant of concern at two very similar battery recycling facility Superfund sites. Unlike organic contaminants (e.g., creosote and PCBs) discussed earlier, toxic metals cannot be destroyed by treatment technology; however, the statutory goal of recycling when it is feasible is the key issue for metals. It is through recovery and then recycling of toxic metals that a truly permanent remedy can be obtained. At both sites presented here, the chief problems are battery casings and contaminated soil, both surface and subsurface.

The enforcement ROD for the Gould site in Oregon selected a cleanup standard for surface soils of 1,000 ppm of lead; the standard for subsurface soil and the unrecyclable materials was the failure of EPA's EP Toxicity test. Twenty-nine-thousand cubic yards of contaminated soils will be treated by chemical stabilization and backfilled onsite. (OTA notes that the estimated volume appears to be based on the responsible party RIFS which used a 3,000 ppm level for lead [which EPA apparently rejected] and, therefore, underestimates the volume based on the selected standard of 1,000 ppm.) It was estimated that about 25 percent of the lead in the casings would be recycled, plus some other materials. Contaminated unrecyclable battery casing materials, from a total of 81,000 cubic yards of casings, will be sent to an offsite hazardous waste landfill. Estimated cost for the selected remedy at the Gould site is $21 million, but this figure does not count any income from sale of recycled material.

The fund program ROD for the United Scrap Lead site in Ohio selected a cleanup standard for 45,000 cubic yards of surface soils of 500 ppm of lead-one-half of the value for the Gould site—and the failure of EPA's EP Toxicity test for subsurface soils (unestimated volume, but could be two to three times surface volume) and 55,000 cubic yards of residual battery casing materials, Contaminated soils and battery casings will be treated using a chemical process developed by the Bureau of Mines, and the safe residuals of treatment will be replaced onsite. This treatment process uses fluosilicic acid to remove and purify lead for recycling. Similar to technology currently used in the mining industry, the process was evaluated in laboratory treatabilily tests and was found to successfully reduce lead content of soils and battery casings below the cleanup standards. Further tests and a pilot study will be conducted as part of the design phase to optimize the process. For the United Scrap site, the ROD noted that "the 500 ppm level was chosen in order to assure protectiveness. It is also the level chosen at other CERCLA sites nearby . . . Soils contaminated with lead at or above 500 ppm level represent a health threat. " Consistent with OTA's perspective on permanence, the ROD also said that

[67] The selection of chemical fixation for the Pepper's Steel & Alloys site in Florida was an unusual decision. In addition to PCB contamination, the site also had very high levels of toxic metals which posed a problem for incineration. The site decision was based on test work and analysis by the responsible party which developed and now sells the chemical fixation technology. A full settlement was reached for this site. Significant uncertainty about long-term effectiveness remains. Indeed, about one month before the ROD was signed, EPA's expert on chemical fixation in its Office of Research and Development said, ''The subject report [responsible party's] does not provide conclusive evidence that soil from the waste site can be treated to provide a solid that will be harmless to the environment. The waste would appear to be capable of leaching unacceptably high levels of lead into a highly used aquifer system. " A few weeks earlier, a professor at Louisiana State University submitted a report as a consultant to EPA's contractor; the report raised a number of issues about the limits of the testing done by the responsible party. After the responsible party began the cleanup, EPA said: ''Solidification/stabilization costs less than the other alternatives. It is also more likely to perform as expected. . An extensive testing program was conducted by EPA and Florida Power & Light to make sure that the stabilized and solidified materials would meet the goal of isolating the waste from the environment over an extended period of time. " About 2 1/2 years after the ROD and before the remedy was complete, an EPA Region 4 memo on the cleanup said, ' 'Time will tell if the remedy meets our expectations. . . . Universally accepted tests to characterize either short- or long-term performance did not and still do not exist.

''since the contaminants are removed and recycled, the possibility of future actions is eliminated. " The estimated cost for the selected remedy is $27 million, which accounts for sale of recycled material.

These two RODS illustrate:

- A surface soil cleanup standard for lead at the enforcement site half as stringent as that selected for the fund program site; this difference cannot be explained on the basis of fundamentally different exposure or risk factors. The consensus in the technical literature is that a cleanup level of 1,000 ppm for lead in surface soil could pose a significant health threat to children who might come into contact with such soil.[68]
- A selected remedy at the enforcement site which, in part, uses a treatment technology (stabilization) for soil that does not recover lead, whereas the treatment technology at the fund program site does. Institutional controls for the enforcement site are an important part of the remedy because lead will remain onsite. The ROD for the fund program site, which rejected chemical stabilization, said, "Since contaminants are contained rather than removed, the possibility for future remedial actions at the (cleanup) site or at the offsite landfill site will remain. " This position agrees with OTA's concerns about the uncertainties and impermanence of chemical fixation, compared to recovery of metal.
- The recovery of lead from casings at the enforcement site relies on a less effective mechanical separation technique (a grinding and physical separation operation); the one at the fund program site uses a chemical technique, which is likely to remove more of the lead, producing, therefore, a permanent remedy. Therefore, for the enforcement site, significant quantities of hazardous material will be sent offsite for landfilling, but for the fund program site safe treatment residuals will be backfilled onsite.
- It is difficult to compare costs for the two sites. About 80 percent of the cost for the enforcement site is operation and maintenance (mostly for offsite landfilling); the cost for the fund program site consists almost entirely of capital costs for the more sophisticated chemical recovery treatment facility (10 times more capital cost than for the enforcement ROD cleanup); the cost also accounts for revenue of about $4 million from selling recovered metal. Still, if the enforcement ROD had used the cleanup standard of the fund program ROD and its cleanup technology, then it might have cost perhaps as much as another $10 million.[69]

Eight Landfills

Sites at which wastes were buried initially vary greatly, some were used only for industrial wastes but many were municipal or mixed waste landfills. But there are also significant similarities from a cleanup perspective. For example, the cleanup of landfills nearly always is based on leaving the wastes buried, capping them, and, if necessary, addressing groundwater contamination, which is very common around such sites. The assumption is nearly always that the volume of buried waste is too large to consider excavation and treatment; little attention is normally given to identifying hot-spots of contamination amenable to excavation. In many cases these sites already have caps on them, but they

[68] At a major Superfund site in Michigan (Rose Township), the cleanup standard for lead in soil was 70 ppm, which is quite low for lead and illustrates the benefit of having uniform cleanup standards for common contaminants in soil, which for lead would probably be higher than 70 ppm. This site cleanup was also a settlement with originally stringent cleanup objectives. However, subsequently, as asked for by the responsi le parties, a portion of the incineration was replaced with less expensive soil flushing for volatile organic chemicals, and EPA's usual cleanup standard was dropped, with a new one to be determined by the responsible parties during post-ROD work. This suggests that a technology performance standard might replace a health-based one. The Natural Resources Defense Council testified that "The Rose Township reversal is a sobering reminder of the power wielded by PRPs, and of the *numerous means* by which a protective remedy can be undermined. Donald S. Strait and Jacqueline M. Warren, testimony before Senate Subcommittee on Superfund, Ocean and Water Protection, June 15, 1989. The reduction of cleanup cost issue was described recently: '''It was strictly a money thing, ' said Kevin Adler, the EPA's project manager. The maximum the companies would pay voluntarily was $14 million; any more and they'd take the EPA to court. Newsweek, July 24, 1989 The situation at the Rose Township site also illustrates the potential significance of distinguishing between current and future risk (see discussion in ch. 1 of policy option 1) because much of the justification for cleanup was baaed on speculative future risks. This appears to weaken EPA's position in obtaining stringent cleanups by responsible parties.

[69] Actually, the estimated capital cost for the Bureau of Mines treatment plant was probably overstated because the equipment could be used at other Superfund sites and the capital costs distributed over several cleanup projects.

have not prevented the need for further action which, ironically, is often to use another cap.

Instead of matching a small number of similar sites, as in the previous sections, all the fiscal year 1988 RODS in Region 5 for which containment/land disposal was selected were examined to determine if there were effects from settlements with responsible parties. Summary findings are given in box 3-G Three of the eight RODS were labeled by EPA as fund and five were designated enforcement. That is, 62 percent of the containment/land disposal RODS were enforcement, compared to a national average of 71 percent. Region 5 is a large but representative EPA region.

The general conclusion is that enforcement containment RODS had significantly more issues related to effects from settlements or the conduct of RIFSs by responsible parties. Issues include the reduction of cleanup costs by: selecting simpler caps, consistent with municipal instead of hazardous waste landfill regulations; rejecting the use of incineration for small amounts of hazardous material (with costs similar to typical cleanup costs) or for large amounts (with costs which are high-perhaps $50 million to $100 million-but not necessarily infeasible);[70] avoiding or minimizing groundwater cleanup.

The total costs of the five enforcement RODS and the one fund ROD which EPA said it was negotiating with responsible parties (Belvidere) is $44.2 million compared to costs which might have totaled $283.6 million if more stringent cleanups considered in the RODS had been selected.

Conclusions

There is nothing intrinsically wrong with EPA's desire to maximize settlements which reduce the need for fund-financed remedies. OTA's research shows that EPA's emphasis on using negotiated settlements as its chief enforcement tool, however, is linked to EPA's ability to reduce cleanup costs to levels attractive to responsible parties by compromising environmental objectives. However, there is nothing illegal about this, because there is currently a lot of flexibility in statute and EPA's implementation of it to allow different kinds of remedies and levels of protection for similar sites. This conclusion suggests the need for routine EPA examination of remedy selection and cleanup objectives in RODS and, perhaps, a policy about enforcement which assures consistent levels of environmental protection, regardless of whether a cleanup is fund-financed or responsible party-financed.

But it is also important to note that there are examples of responsible parties showing great interest in performing first-rate cleanups, sometimes more consistent with statutory provisions than EPA's selected remedies. For example, at the Tyson's Superfund site in Pennsylvania the responsible party did its own technology demonstration and convinced EPA to change its ROD, replacing major offsite landfilling with onsite vacuum extraction and destruction of volatile organic chemicals, if further testing confirms its effectiveness.

OTA's analysis also shows that technical work in Superfund looks better when enforcement site decisions, in which non-technical considerations strongly affect outcomes, are separated from fund site decisions.

EPA spends hundreds of millions of dollars on its Technical Enforcement Support contractors. A major job for them is oversight of responsible party contractor work and supplemental work at enforcement sites. But this extensive EPA contractor activity is not preventing EPA decisions that sometimes compromise environmental protection. Given this and the increasing rate of settlements, the key question is: Will future government oversight, from the same system, reveal whether or not settlement cleanups performed by responsible parties are com-

[70] It is conventional wisdom that for large landfills it is economically infeasible to employ expensive cleanup technologies, such as incineration. But there has been no attention by EPA or others to exactly what level of cleanup cost is unacceptable or prohibitive. The statute gives EPA a way to reject very expensive *fund-financed* cleanups; it is called fund-balancing, which means that when costs for a cleanup get so high as to seriously reduce the government capability to address other Superfund sites, the expensive cleanup can be rejected on economic grounds, even though it might be the best environmental solution for the site. EPA, however, rarely invokes the fund-balancing provision when it rejects high cost alternatives for fund-finance cleanups. How much money is too much for a site? At enforcement sites where responsible parties-which for landfills often include local government---could pay a high cleanup cost, should high cost alternatives be dismissed automatically? The issue of whether the lower cost containment remedies being selected are permanent is also important, and whether settlements and consent decrees hold responsible parties liable for future major secondary cleanup *actions*

Box 3-G--Summarie s of Eight FY88 Region 5 Decisions Selecting Containment/Land Disposal

Belvidere Municipall No. 1 Landfill, Belvidere, Illinois: fund ROD, EPA did RIFS.

The ROD did not give specific groundwater cleanup levels, but extensive details from the site's risk assessment were given. The cap selected is consistent with that required for a hazardous waste landfill, even though the limited amount of hazardous waste was disposed before 1980. ((Men, EPA defends using a solid (municipal) waste landfill cap when there is documentation that hazardous waste disposal was prior to 1980.) The ROD rejected an incineration option for 790,(X)0 cubic yards at a cost of $127.6 million [which is low but realistic in today's market] chiefly because it was "so much more costly. " No fired-balancing argument was given, Environmental benefits for the indneration option were not given. The selected remedy's estimated cost was $7.9 million. The ROD said that EPA was negotiating with responsible parties to implement the ROD.

Kummer Sanitary Landflll, Northern Township, Minnesota: fund ROD, State did RIPS.

The ROD rejected a hazardous waste landfill cap, but justified it correctly on the basis of no documented disposal of hazardous waste and an estimate of the small increased protection over using the State's required municipal landfill cap, which is stringent. Incineration of the 1.3 million cubic yards in the landfill was eliminated early on because of short-term problems and "excessive cost" and because it was "cost-prohibitive." No explicit use of the fund-balancing provision was made. The selected remedy's estimated cost was $6.9 million to $12.5 million. A 1985 ROD had selected an alternative water supply: a future ROD will address groundwater cleanup. The case for deferring a decision on groundwater cleanup was well discussed

Oak Grove Sanitary Landfill Site, Oak Grove Township, Minnesota: fired ROD, State did RIFS.

The ROD acknowledged documented disposal of hazardous waste, but rejected using a hazardous waste landfill cap because only about 0.1 percent of the 2.5 million cubic yards of landfilled waste is hazardous was* and it is dispersed throughout the landfill. Using the hazardous waste cap had an estimated cost of $7.4 million to $14.6 million compared to the selected remedy's estimated cost of $5.1 million to $10.7 million. Incineration was eliminated early on because of cost and short-term risks. The deferral of the decision on groundwater cleanup was well presented

Cashocton City Landfill, Coshocton, Ohio: enforcement ROD, EPA did RIFS.

The originally proposed remedy (at $17.5 million) was changed because of comments by responsible parties primarily a lower cost option (at $8.9 million) was selected. Cost was reduced by eliminating a leachate treatment system and a system to vent landfill gases, but these were to be considered in the design of the remedy. Although groundwater contamination on and signficant risks were documented in the ROD, no groundwater cleanup was selected; monitoring was selected instead. Even though there was documentation that 6.4 million pounds of hazardous waste were disposed in the landfill, a cap for a municipal and not a hazardous waste landfill (as was proposed initially) was selected. The ROD acknowledged that the responsible parties want an even less stringent cap and that waivers are possible later. The ROD contained candid discussions of the desire by the responsible parties to minimize immolate costs, even though EPA thinks that they risk higher long-term costs due to eventual cleanup needs. But clearly EPA gave the responsible parties what they wanted. From the ROD: "The PRPs' proposal suggests a remedy which is less costly, initially, but which could be substantially more expensive should the monitoring system detect changed conditions... . The PRPs. . . have expressed a preference for a less comprehensive (and less costly) initial containment option, with the understanding that should said initial action not be sufficient, the ensuing remedy could be more costly. While it may not be appropriate for the federal government to 'gamble' in this way, if financially viable private entities agree to undertake the remedy and are willing to enter into an enforceable court order by which they would be obligated to quickly act in response to changed the government maybe willing to consider a remedy by which the PRPs explicitly assume such a risk." How well this arrangement does not jeopardize public health and environment depends on effective EPA oversight of post-ROD activities and fast responses by responsible parties should they be necessary.

Republic Steel Quarry Site, Elyria, Ohio: enforcement ROD, EPA did RIFS.

The decision not to pursue groundwater and sediment cleanup was well supported. The ROD gave good details from the site's risk assessment. However, the ROD selected offsite Iandfilling for 100 cubic yards of contaminated soil at an estimated cost of $63,2(M). The alternative to use offsite incineration at an estimated cost of $279,700 was rejected because of its higher cost.

Mason **County Landfill, Mason County, Michigan: enforcement** ROD, EPA did RIFS.

To its credit the ROD selected **a cap consistent with a hazardous waste landfill because industrial slurry and** sludge wastes had been disposed there (prior to 1978). The ROD gave good details on the site's risk assessment results and the case for deferring a decision on groundwater cleanup was well presented. An alternative of using chemical fixation for excavated material at a cost of $43 million was rejected on sound technical grounds. Incineration for the relatively small landfill (140,000 cubic yards) was rejected without detailed examination, but its cost might be about $50 million. The selected remedy's estimated cost was $2.8 million.

Allied **Chemical/Ironton Coke Site,** Ironton, Ohio: enforcement ROD, responsible parties did RIFS.

Cleanup levels for groundwater cleanup were given in the ROD. However, numerous statements indicate that the pump and treat method is not likely to reach those levels, will be stopped when "technical unfeasibility is demonstrated" during cleanup, and a formal waiver from regulatory requirements for contaminant concentrations will then be implemented. The ROD had few details from the site's risk assessment. Options to excavate most and all of the site's hazardous materials and incinerate them were seriously examined. But they were rejected because the overall environmental protection was not rated higher than capping the landfill, and because of high costs ($92.2 million and $218 million). The ROD acknowledged the difficulty of the selected remedy being effective for the layer of dense non-aqueous contaminants which have settled at the bottom of the site. The higher cost incineration option which would treat all 456,000 cubic yards of site hazardous material was actually overestimated in cost by close to $100 million, based on current costs for onsite incineration. The ROD referred to the high cost incineration option as "cost prohibitive" and offering advantages "not commensurate with the costs. " To its credit, the ROD selected a hazardous waste landfill cap; hazardous waste disposal had stopped in 1977. The estimated cost of the selected remedy, which also includes **a slurry wall around the disposal area was $13.1** million. The ROD included a discussion about comments from the Department of Interior: "DOI asserted that the major advantage of the selected remedy is cost, and without reviewing the cost assumptions, asserted that future operation and maintenance of the preferred alternative will meet or exceed the cost of the most expensive alternative [incineration of all site hazardous material]. DOI also raised concern about the source of money for continued long-term operation and maintenance, and the future environmental consequences if long-term operation and maintenance% is not conducted. "

Waste Disposal Engineering, Andover, Minnesota: enforcement ROD, responsible parties did RIFS.

The ROD lacked details from the site's risk assessment and specific cleanup objectives for the groundwater cleanup. Optimism about the pump and treat groundwater cleanup was contradicted by other ROD statements: "The extraction system will effectively intercept all [emphasis added] contaminated ground water migrating from the Site in the Upper Sand aquifer and currently entering Coon Creek. . . . The extraction system will be active indefinitely, and will greatly reduce, if not eliminate, any loadings to Coon Creek, . ." Serious attention was given to excavating and incinerating a confirmed hot-spot called the Pit. But it was not selected, even though only 5,500 cubic yards was estimated to cost $6.3 million. The argument was that only 10 percent of the site hazardous waste was in the Pit. But this position is undermined by many statements in the ROD which refer to the Pit as the "major," **"dominant," and "most serious" source of groundwater contamination. There is no mention of the benefit of permanently removing such a major confirmed source of groundwater** contamination. Moreover, the cost for the incineration is overestimated by about 100 percent and the issue of 'severe safety risks' from excavation seems overstated because a test excavation in 1986 did not result in safety problems. To its credit, the ROD selected a hazardous waste landfill cap, even though disposal had stopped in 1974. The selected remedy's estimated cost was $11.4 million, which includes a slurry wall around the Pit and pumping from within it.

SOURCE: Office of **Technology Assessment**, 19S9: **based** on **examination** of EPA RODS.

parable environmentally to fund-financed cleanups and SARA's stringent cleanup requirements?

The issue that seems important for future Superfund implementation is: Is there a better way to get responsible parties to pay for cleanups without compromising environmental goals? After all, SAM'S cleanup requirements do **not** distinguish between enforcement and fund-financed cleanups. EPA could maintain uniformly high environmental standards for all Superfund cleanups and make cleanup decisions independent of who pays for cleanup. EPA could use the tough enforcement tools given to it by statute to get those responsible for creating Superfund sites to pay for environmentally effective cleanups that are consistent with statute and congressional intent. The more EPA uses strong enforcement tools, the stronger its position in reaching voluntary settlements which do not require compromising environmental goals. However, it should be noted that responsible parties believe that settlement cleanups **are** effective environmentally and satisfy statutory requirements. Indeed, there generally is enough flexibility or ambiguity in key statutory requirements to permit some widely different interpretations. Moreover, EPA's implementation has already included so many different types of cleanups for essentially the same types of sites that responsible parties can easily point to the least stringent cleanups as precedents for cleanups providing effective environmental protection. (See several policy options in ch. 1)

Finally, OTA's findings on effects of settlements should also be examined with regard to other cleanup programs into which potential Superfund sites may be deferred, especially programs in which responsible parties routinely select and implement cleanups (e.g., EPA's corrective action program within its RCRA hazardous waste regulatory program, the leaking underground storage tank program, and many State cleanup programs). Such cleanup programs include many more sites than in Superfund and influence Superfund in several ways *(see* ch. **4).**

Issue 4: Are analyses and selections of cleanup technologies inconsistent and, if so, does it matter?

OTA's 1988 case studies have documented substantial cleanup inconsistencies among and within the 10 EPA Regions and EPA headquarters. The inconsistencies are for critical decisions about cleanup objectives and remedy selection. The situation can be credited to excessive regional autonomy—there literally are 11 different EPA and Superfund programs.

An environmentalist's 1987 analysis of 10 post-SARA RODS is consistent with OTA's case studies:

> Our review of the 10 RODS reveals a disorganized, confused bureaucracy making seat-of-the-pants, poorly documented decisions that fail to protect public health and violate the law. Seven years into the program, we have not progressed beyond ad hoc and inconsistent process that was the hallmark of Superfund's grim first few years. [The] Superfund program . . . continues to make bad and inconsistent cleanups the rule and the reality. The inconsistent approaches *taken* in the 10 RODS underscore the urgent need for the agency to develop specific national policies for its regional offices to use in making such decisions.[71]

A rarely addressed consequence of inconsistent decisions was also noted:

> In short, the agency's erratic, inconsistent approach to cleanup standards today could compromise the fiscal integrity of the fund years into the future.[72]

A study by Washington State University and Battelle's Pacific Northwest Laboratory on improving site study methodologies said:

> Although EPA has provided general guidance for conducting an RI, EA (endangerment assessment), and FS, detailed procedures are not readily available to implement these guidelines; as such, analyses tend to be inconsistent from site to site, and the quality and quantity of documentation varies.[73]

Another recent observation was that:

71 A.B. Early, testimony before the Senate Subcommittee on Superfund and Environmental Oversight, June 25, 1987.

72 Ibid.

73 Kenneth E. Hartz and Gene Wilson, '"~As and RAAS Methodologies as Integrated Into the RI/EA/FS Process," *Superfund* '88, proceedings of conference November 1988, Hazardous Materials Research Institute, Silver Spring, MD.

> The ROD process, occurring in ten EPA regions as well as at headquarters, results in wildly inconsistent remedies and sometimes conflicting rationales,[74]

Why is there so much inconsistency? Different information is used. For example, the unit cost of a technology such as mobile incineration may vary by 100 percent or more (see OTA's 1988 case studies). The problem is caused, in large part, by having many different contractors working on sites for 10 EPA regions that are responsible for selecting remedies. At the Pristine site in Ohio, incineration was rejected because it w as estimated to cost twice as much as the selected remedy (in situ vitrification). In fact, its cost was overestimated by a factor of 2, according to detailed incineration costs contained in two feasibility studies on other sites by the same contractor, but at a different regional office of the contractor.

Different technical criteria and different structures for analysis are used in feasibility studies and RODS. Some RODS have analyses that really do help a reader understand why the remedy selected is better than the others. But, more often, the analyses can be used to justify any remedy selection because either they are superficial and qualitative, or they are lengthy and redundant with no sharp distinctions. A State official summed up his view of EPA's method to evaluate cleanup alternatives and select a remedy:

> Sometimes it seems that "guidance" is followed so faithfully that common sense is neglected. Flexibility is a crucial missing component when remedial alternatives are developed and evaluated, but it is overutilized in actual remedy selection. In our view it is best to consider a wide, variable range of alternatives and allow the best one to emerge. Instead, EPA does a rigid evaluation of generic remedies, only to be confronted with a choice between several square solutions for a round problem. At that point flexibility is too late.[75]

Variable interpretation of SARA's provisions on remedy selection is also important in understanding the presence of inconsistent Superfund implementation. EPA has tacitly encouraged subjective, variable, and inconsistent interpretations of statutory language. No attempt has been made to clarify the meaning of terms such as treatment, permanence, reduction in toxicity, cost-effectiveness, and future failure modes. Nor has there been any attempt to establish hierarchies for types of treatment technologies and their outcomes. The current use of nine different criteria-apparently with equal importance and no hierarchy-to evaluate cleanup alternatives does not help to make clearly understood, sharp distinctions. Regions and specific remedial project managers emphasize whatever criteria they choose to.

Some of the nine criteria could have been simple requirements to be met by a selected remedy rather than criteria for which alternatives have different levels of performance (e.g., compliance with regulatory standards, long-term effectiveness, community reaction, State support). Also, the overlapping and ambiguity of some of the environmental criteria (e.g., short-term effectiveness, reduction of toxicity, mobility or volume, implementability, overall protection of human health and the environment) fosters an analysis that can be made to support any decision.

The inclusion of cost (but not cost-effectiveness) has also facilitated ruling out alternatives early in the screening process and in combination with the flexibility of the preceding environmental criteria facilitates a cost-benefit kind of analysis. All of this is compounded by the lack of detailed analysis, including references to the technical literature, scientific principles, and actual data. In its place is qualitative assertion and cost-benefit reasoning.

As OTA's case studies have documented, use of any treatment technology and, in some cases, even use of land disposal or containment are interpreted as meeting SARA's requirements and preferences concerning the examination and selection of remedial cleanup technologies. Confirmation of this OTA conclusion comes from a study of fiscal year 1987 RODS which concluded, "The degree to which selected alternatives are cost-effective cannot be determined based on the limited discussions and

---

74 Roger J. Marzulla, ''Superfund 199 1: How Insurance Companies Can Help Clean Up the Nation Hazardous Waste, paper presented to Insurance Information Institute, Washington, DC, June 13, 1989.

75 Michael J. Burkhart, Director of New Mexico's Environmental Improvement Division, letter to OTA, July 5, 1988.

rationales provided in the documents reviewed."[76] This conclusion is all the more significant because the study also concluded that:

> . . . cost was the most significant factor in the selection of remedial alternatives in the decisions reviewed. Thirty-four percent of RODS reviewed selected either no action or the least costly alternative other than no action; 8 percent selected the most costly alternative evaluated. In 40 percent of RODS, more protective alternatives not selected cost at least an additional $10 million; some of these remedies cost an additional $100 million or more. . . . [C]ost appeared to play a more significant role in the selection of remedial alternatives than did risk.[77]

This work supports our previously discussed finding concerning money saved by responsible parties as a result of settlement-impacted RODS, and the conclusion that cost-effectiveness has given way to cost-benefit thinking which leads to selection of low-cost remedies and rejection of higher cost remedies which, however, offer higher levels of environmental protection. In other words, **not using the statutorily required cost-effectiveness form of decisionmaking has lead to inconsistent cleanup decisions in Superfund.**

In addition to the case studies, a few more examples from RODS illustrate the diversity of ways to comply with the statutory requirements:

- For the Powersville Landfill site in Georgia, the selected remedy consists of capping the landfill, grading of the surface, groundwater monitoring, providing alternate drinking water, and restricting the site deed. The 1987 ROD said: ''This remedy satisfies the preference for a treatment that reduces toxicity, mobility, or volume as a principal element. . . . [T]he remedy utilizes permanent treatment technologies to the maximum extent practicable. ”
- For the NW 58th Street Landfill in Florida, the selected remedy closes the landfill in accordance with regulatory requirements, including leachate control and probably capping, groundwater monitoring, and providing municipal water to some private well users. The 1987 ROD said: “The statutory preference for treatment is not satisfied because treatment was found to be impracticable due to the magnitude of waste to be treated (estimated 27 million cubic yards). ’ Treatment of contaminated groundwater was rejected because the contamination is too widespread; a 1985 ROD selected air stripping at the water treatment plants, The ROD also noted that: “The present worth estimate of the cost of excavation alone is $439 million, Since this is two orders of magnitude higher than the other alternatives that would provide comparable protection, this alternative is rejected on the basis of cost [emphasis added], ” But if treatment offers better protection, then the selected remedy does not offer comparable protection and is not cost-effective. The fund-balancing provision of the statute, which provides a way to avoid spending so much at any one site that cleanups at other sites would be jeopardized, could have been used, but was not, to justify rejection of excavation and treatment.
- For the Tri-City Oil Conservationist Corp. site in Florida, the selected remedy was no further action. The 1987 ROD said: “The statutory preference for treatment is not satisfied because treatment was found to be impracticable. Treatments which reduce toxicity, mobility, or volume of wastes would not have been cost-effective at this site because of the small volume (850 cubic yards) of wastes present. The ROD also said “. . . the remedy utilizes permanent treatment technologies to the maximum extent practicable given the small volume of contaminated materials. ” In fact, the 850 cubic yards had been removed and landfilled in 1985 and, therefore, the volume present that the ROD actually addressed was zero.
- For the Vega Alta Public Supply Wells site in Puerto Rico, the selected groundwater remedy was treatment of some well waters and shutdown of some others with connections to another source of water. The 1987 ROD said: ''The statutory preference for treatment, while not fully satisfied in that the sources still need to be considered, is partially addressed in that

[76] Carolyn B. Doty and Curtis C. Travis, ''The Superfund Remedial Action Decision Process' draft, Oak Ridge Nationat Laboratory, undated, received by OTA in May 1989. The study was done for EPA and did not analyze the effect of responsible parties on cleanup decisions.

[77] Ibid.

the groundwater treatment system reduces the toxicity and volume of contaminants.

- For the Presque Isle site in Pennsylvania, the selected remedy was no further action, The 1987 ROD said: "This remedy satisfies the preference for treatment that reduces toxicity, mobility, or volume as a principal element. Finally, it is determined that this remedy utilizes permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable. " All the deep well-injected wastes will be left onsite.

EPA has examined the presence and cause of inconsistent Superfund implementation with regard to risk assessments, an important part of the RIFS process that leads to setting cleanup goals which cleanup technologies must then meet. Some of the EPA report's findings substantiate an organization and management structure that also explains inconsistent technology analysis and selection like this:

- "The current guidance, Regional review, and HQ oversight systems will not necessarily detect or prevent inconsistencies. "
- "Guidance cannot ensure consistency. Unresolved technical and policy issues and the continuing need for judgment leave room for differences to emerge. "
- " . . . [N]o one group. , . has a broad view of all risk assessments, limiting HQ's ability to identify inconsistencies between sites or Regions."
- ' 'Regions, intent on their own work, know little about the actions of other Regions.
- "... [N]o one really knows the extent of inconsistency. As the number of assessments grows, it becomes increasingly likely that some significant inconsistencies will go undetected. '[78]

The report omits the possibility that non-EPA activities might elucidate the presence and significance of inconsistent Superfund implementation, including congressional oversight, studies by public interest groups, and news media coverage. Instead, staying within its own perspective and system, EPA concluded that no major new actions were necessary but that existing activities could be strengthened. OTA does not concur. The level of inconsistent Superfund implementation is so high that it is reasonable to seek new ways to remedy the situation.

A more recent study of fiscal year 1987 RODS also found many problems in the processes leading up to RODs.[79]

Summary--Inconsistency is not necessarily bad. But similar Superfund sites and cleanup problems have received different cleanups with different, uncertain, and sometimes relatively low levels of environmental protection. Variable environmental protection is the central problem with inconsistent Superfund implementation. Counter to statutory requirements and preference, non-treatment, impermanent remedies based on land disposal, containment of wastes, or wait-and-see monitoring are often selected. ROD selections of untested and uncertain treatment technologies also occur. Particular treatment technologies have become favorites of some EPA Regions and are ignored by others. Moreover, as said earlier, some treatments do not destroy or detoxify site contaminants and cart crowd out more effective treatments, which may be more costly. Inconsistency makes the marketplace very difficult for technology developers, creating major uncertainties that have little to do with the merits of the technologies.

Issue 5: Are there incentives built into the Superfund program for making broad use of improved cleanup technologies?

There are nearly none.

SARA does, of course, provide a basic national policy framework that favors improved treatment technologies, and public opinion helps, But this policy can be responded to superficially, ignored, and misinterpreted. There are far more penalties than rewards for going with new solutions over older ones, even though the older ones may not offer reliable, permanent long-term protection.

All those who bear costs generally see treatment alternatives as more expensive in the near term than conventional containment/land disposal and monitoring options. Those who pay include responsible

[78] U S Environmental Protection Agency, Evaluation of the Preparation Of Risk Assessments for Enforcement Activities,'' September 1987.
[79] Doty and Travis, op. cit., footnote 76,

parties, States, and EPA. EPA also is driven by a desire to distribute funds over as many sites as possible and by its interest in facilitating agreements with responsible parties so that they pay for cleanup. Responsible parties may worry about the long-term uncertainty and liability of newer cleanup techniques. Engineering consulting companies worry a great deal about liability for ineffective work or work that is judged later by different standards. Inevitably, engineers see less risk with favoring use of 'standard' off-the-shelf technologies. Few people want to be the first to use a new technology on a major scale. The view of professional consulting engineers is this:

> Engineers incorporating unproven technologies in their designs are gambling with their clients' money. If the gamble backfires, the engineering firm could be held liable. Thus, engineers are not like] y to often make use of unproven technologies in remedial designs. This results in an impasse: engineers do not want to use unproven technologies, but technologies cannot reach commercial status unless they are used.[80]

Within government, there are also bureaucratic pressures on people to finish reports and RODS, pressure that goes against what could be a more lengthy and costly examination of alternative treatment technologies.

There is an important exception regarding incentives. Some responsible parties have been very aggressive in examining and selecting newer treatment technologies, chiefly because they see a reduction in cost over some other alternate-often another older, more expensive treatment technology. Moreover, responsible parties want to minimize their future liabilities and, therefore, sometimes work very hard to have a permanent remedy selected. Indeed, some EPA decisions to use land disposal have been changed because of responsible party work that demonstrated the effectiveness of treatment technology; this happened at the Tyson's site in Pennsylvania.

Last, an important disincentive built into the current system is the need to obtain a regulatory delisting of the residue of a treatment operation if the material is to go offsite after treatment. The RCRA regulatory program has considerable inefficiencies. If delistings cannot be obtained quickly, then the cost of using a treatment technology escalates, because the residue is automatically considered hazardous unless found otherwise through the delisting process. This situation means that the residue must go to a permitted hazardous waste facility or that one must be built onsite, instead of a lower cost solid waste one or just backfilling the material into the site. Uncertainty about delisting and high cost of residue management can block adoption of effective treatment technology.

issue 6: Will using permanently effective cleanup technologies mean that cleanup costs will skyrocket?

No one seriously believes that American society can afford Superfund cleanups at **any** cost, regardless of who is paying for the cleanup. But discussions on cost and, eventually, where the money comes from, and liability issues have obscured some basic points about technology which, after all, is the tool with which cleanups are accomplished, The same is true about discussions of cleanup standards and goals that ignore the means of meeting expectations.

Better cleanup technology is not the enemy of cost reduction. In the long-term, permanently effective technologies avoid uncertain and possibly high future repeated cleanup costs. Certainly in the long-term and probably in the short-term, technological innovation and development will reduce costs as well as increase technical effectiveness to meet stringent cleanup goals. These gains are clearly happening for some cleanup technologies already. Competition among more vendors and more available treatment capacity is also helping to reduce costs. In several areas, such as thermal destruction and removal of volatile organic chemicals from contaminated soil, unit cleanup costs for permanent remedies have decreased in the past few years.

Combinations of newer technologies at complex sites can also reduce total long-term costs, particularly use of separation technologies to reduce the use of more expensive destruction technology such as

[80]Hazardous Waste Action Coalition, American Consulting Engineers Council, *The Hazardous Waste Practice-Technical and Legal Environment 1988.1989,*

incineration, For example, a variety of in situ techniques can remove volatile organic chemicals from soil which can then be burned, thus avoiding the high cost of excavating the contaminated soil and burning a largely inert, uncontaminated mass.

More reliable comparative data on costs of different permanent and containment/land disposal technologies are needed. In particular, it is critical that actual cleanup costs be collected, analyzed, and disseminated to compare with data from vendors and with estimated costs in feasibility studies. One preliminary study of 30 completed Superfund cleanups found that cost estimates tend to be less than actual costs at all stages of the projects (i.e., feasibility study, ROD, design, and contract procurement). The study noted, ''Even at late project stages the estimates do not 'hone in' accurately on actual costs. ' '[81]

OTA's 1988 case studies show an average cost of $20 million for a cleanup considered consistent with SARA and $10 million for one which can be questioned, but some of these costs are only for parts of a site's total cleanup.

On the one hand, EPA said: ''More permanent remedies are not necessarily slower or more expensive remedies. ' '[82] But EPA's Assistant Administrator J. Winston Porter had said earlier: ' 'There's probably not enough money in the world to clean up all the sites permanently. "[83]

OTA has examined EPA's official figures for estimating the average cost of a remedial cleanup in its regulatory impact analyses, as published in the Federal Register. In 1984 and 1986, EPA said a remedial cleanup would cost $7.2 million in 1984 dollars. In 1987 and 1988, the figure was adjusted upward to $8.6 million, but only to reflect the earlier cost in 1986 dollars (no real change). In 1989, the figure became $13.5 million in 1988 dollars, the first real increase since 1984 and **after SARA.** (Interestingly, the net present value of operation and maintenance over 30 years at a 10 percent discount rate remained exactly the same at $3.77 million in 1984, 1986, and 1988 dollars, If these calculations are not mistaken, then such costs are decreasing in real terms.)[84] More recently, EPA said that the average construction cost per site is $25 million, which with study and administrative costs might total $30 million. In other words, EPA's data indicates that some increase in remedial cleanup costs has been foreseen because of the more stringent requirements in SARA, but not what would be described as skyrocketing costs. However citing an average cleanup cost is not especially instructive, because costs vary enormously (from several hundred thousand dollars to the $50 million to $100 million range) and because a number of site actions may be taken over some years at a particular site.

However, there has been a lot of rhetoric about skyrocketing cleanup costs. A view from the responsible party community is: '', . . SARA includes a strong bias in favor of permanent remedies and onsite remedies and requires that applicable or relevant and appropriate State and Federal standards be applied. , . . SARA has created a cleanup process with great potential for inflating costs. EPA has estimated that the cleanup requirements in SARA would drive the cost of a Superfund cleanup from its present average of about $8 million-$9 million per site to between $25 million and $30 million per site. '[85] The major cause of the shift in cleanup costs has been the shift away from impermanent remedies based on containment and landfilling. Indeed, a study for the Chemical Manufacturers Association estimated high post-SARA costs of over $60 million for using incineration, This compared to $27 million for using incineration for hot spots and onsite containment which was called modified permanence.[86] However, the scenario based on *using*

[81] Independent Project Analysis, Inc., ''Better Cost and Schedule Estimates for Hazardous Waste Cleanup," background package, Great Falls, VA, January 1989.

[82] *EPA Journal*, 13(1), January/February 1987.

[83] *Environment Reporter Current Developments*, Sept. 26, 1986, p. 778.

[84] These figures are *from* the following Federal *Register notices:* Sept. 21, 1984; June 10, 1986; Jan. *22,* 1987; June 24, 1988; Mar. *31, 1989.*

[85] T.M. Hellman and D.A. Hawkins, in H&@&~ Wrote *Site Management: Water Quality Issues* (Washington, DC: National Academy Press, 1988), pp. 98-119.

[86] Susan Fullerton et al., ''Impact Analysis of SARA on the CERCLA Remediation Program, ' *Superfund* '88, proceedings of November 1988 conference, Hazardous Materials Research Institute, Silver Spring, MD.

incineration pervasively for Superfund cleanups overstated costs for achieving permanent remedies, because incineration is more expensive than some other technical approaches, unit costs for incineration have decreased, and it would not be used for very large landfills.

Sites with large amounts of landfilled material definitely pose a particularly difficult problem for using excavation-treatment approaches. Consider a volume of 1 million to 10 million cubic yards. There may be hundreds of sites in this range, typically old municipal and industrial landfllls whose leachate is hazardous. Though the actual amount of hazardous substances in the landfill may be very small, they are distributed within a large mass. At a low cost of $200 per cubic yard, the cleanup cost would range from $200 million to $2 billion-both costs are beyond the routine capabilities of Superfund for fund-financed cleanups. It is not a question of cost-effectiveness, because containment does not offer comparable protection to treatment. Large landfills illustrate an appropriate use of the fund-balancing provision of Superfund. That is, cleanup at too many other sites might be blocked because of enormous individual site cleanup costs. But the containment remedy should not be called permanent. Very low cost in situ permanent treatments or clever ways of identifying hot spots of contamination for excavation and treatment are needed. Otherwise, traditional containment approaches will prevail.

Another major problem is that decisions are made with unreliable cost estimates. As one insightful analysis concluded: "It is difficult enough to estimate costs at this early (screening) stage of the feasibility study when 'old' technologies are involved; it is hardly prudent to try to estimate the costs of innovative technologies before a much more detailed analysis (not to mention extensive pilot testing) is performed. "[87] OTA's case studies have revealed major under-and over-estimates of cost. While it is generally recognized that a desire to minimize cleanup costs might be influencing decisions, it is another matter that estimated cleanup costs can easily be manipulated to create the appearance of too high a cost for a treatment alternative (that allows cost-effectiveness to rule it out) or too low a cost (that makes it appear that cost is not the main reason for rejecting it).

Finally, there will be increasing debate over how **much contaminated material** will be treated in a cleanup and to what levels of residual contamination. The shift to treatment technologies is being compromised by limiting the extent of treatment in order to reduce costs while still getting credit for using treatment. Some cleanups may use treatment for very small fractions of site-contaminated materials. A good example of this issue is a study done by two national environmental organizations for a community group concerned about the selection of remedy for a Superfund site in New Hampshire. The report concluded:

> The community-based plan would provide permanent treatment for a much greater volume of soil, would destroy nearly all PCB's and would clean up groundwater to a cancer-risk level that is 100 times lower than EPA's cleanup, Equally important, the community-backed alternative is cost-effective. . . . [A]ll of the above benefits can be achieved for a total cost that is less than 13 percent higher than EPA's substandard cleanup. The new Superfund clearly indicates that such increases are warranted where they bring about large benefits.[88]

Note that the remedy selected by EPA **did** include incineration.

Another example is the complaint for the Bayou Bonfouca site in Louisiana:

> Although the remedy selected by the agency involves the excavation and incineration of some contaminated sludges, 20,000 cubic yards of contaminated soil will be left onsite and covered with a cap to keep out rainfall. The entire area is characterized by standing water and saturated surface soil,[89]

Issue 7: Are research and development producing a steady stream of more cost-effective cleanup technologies?

[87] D. Truitt and J. Caldwell, ' 'Evaluation of Innovative Waste Treatment Technologies, '' Waste Management Conference-Focus on the West, Colorado State University, June 1987.

[88] H. Cole et al., *'The Ottari and Goss/Great Lakes Container Corporation Cleanup Decision: A Bad Precedent for the New Superfund, " National Campaign Against Toxic Hazards and Clean Water Action, June 1987.

[89] Early, op. cit., footnote 71'

The answer is yes. The cleanup market is enormous and private sector funds so available, because of the perceived volume of business, that extensive R&D is constantly producing new and improved cleanup technologies. Government spending and university activities have also increased, some with the help of SARA programs. The activity in separation and biological treatment technologies is particularly intensive and productive.

Of particular importance is the rapid emergence of in situ cleanup technologies; these have the advantage of eliminating the need to excavate contaminated soil or to extract groundwater, which add expense, and sometimes cause concern over site worker safety (for soil) or releases of contaminants into the environment (for soil and groundwater). Moreover, testing and demonstration of cleanup technologies at cleanup sites are taking place at an increasingly rapid pace because of actions by responsible parties, EPA Regional offices, States, and the formal SITE program (discussed below) established by Congress. Still, this technical activity is not necessarily reflected by program decisions and commitments at actual sites.

The main problem continues to be a "clogged pipeline. " That is, R&D efforts are driven by continued optimism about the number of cleanups, the availability of government cleanup funds, and the availability of venture capital. But the cleanup market rarely meets the expectations of technology developers. Enormous amounts of money can be spent in ways that do not create business for companies selling newer cleanup technologies. Paradoxically, the rapid growth of Superfund and the public pressures on the government to produce more cleanups as fast as possible do not necessarily promote the adoption of **newer, innovative** cleanup technologies. Already one company with anew form of thermal destruction, which had received a lot of attention and had passed several site demonstrations successfully, has gone bankrupt. Some biological treatment companies have failed. Moreover, the competition is constantly increasing so that available business and opportunities for site demonstration are being distributed over more technology companies. Small market share can limit company success and continuing technology development.

Government agencies themselves that spend lots of time and resources developing a technology may interfere with fair competition among other, privately developed technologies. For example, EPA developed its own mobile incinerator and gave it preferential treatment, publicity, and work over privately developed mobile incinerators, But the EPA incinerator offered no significant technological advance. Indeed, EPA's interest in incineration has dwarfed its interest in biotechnology, although the agency has tried to offset this imbalance in the past year. New York State with some EPA assistance has spent substantial time developing a plasma thermal destruction unit without the same level of success of some private enterprises. Such government activities make sense to the extent that private industry is not already doing similar development and if they do not remove comparable testing, demonstration, and application opportunities from private technology developers. In the cleanup area, there is some basis for believing that direct financial development of cleanup technology by government agencies has not been adequately justified. Nor is there any evidence that the government efforts have been cost-effective.

The EPA SITE Program—in 1985 and 1986, Congress had discussed the need for a joint government industry effort to aid the introduction of innovative technologies into the Superfund program during its initial authorization period, and later Congress created the SITE program in SARA. Thus far, the SITE program has had mixed results. A few corporate participants in the program commented on it recently:[90]

- "Those hoping involvement in SITE will turn quick profits in the short-term may be disappointed. " (Carl Brassow, Soliditech, a subsidiary of United Resource Recovery.)
- "[SITE was] very slow moving." (Mark Zwecker, American Combustion Inc.)
- "The analytical expense that the EPA went to was close to $1 million. We could have cleaned up the entire site for less than half that amount." (James Malot, Terra Vac Inc.)

A recent survey of the program found that:

[90] *Environmental Business Journal*, May 1989.

> Nearly one-third of the interviewed company officials (28 technology developers) claimed that the contractors hired by EPA to sample, test, and analyze data were unsatisfactory.. . . Some industry representatives felt the contractors were slow, inexperienced, and generated irrelevant data. . . . One official commented that contractors continue to analyze and re-analyze the same data, making more money for themselves and taking away dollars from both industry and EPA,[91]

In this same study, of the five technology companies that had completed their demonstrations, four had problems with EPA's contractors that prompted the study to note, "Future demonstrations may be hindered unless the contracting system is improved in the future. "

An issue that merits more attention is the degree to which participating technology developers in SITE are sometimes making public statements to advance their commercial interests, despite the lack of SITE results to back up those claims. Moreover, sometimes EPA officials seem to be cooperating in such efforts. For example, a report by EPA's Inspector General documented several instances where publications spoke about a successful test within SITE "despite a lack of successful operations. ' '[92] Indeed, EPA's published results on the B.E.S.T. process,[93] which portray test results as successful, are in disagreement with the results of the Inspector General's office. A broader issue, therefore, is whether there is an inclination within the SITE program to emphasize positive findings and to discount negative results. Similarly, for an incineration technology, the Inspector General's report said that "PCBs and particulate (mainly lead) were released into the air and thousands of gallons of wastewater containing lead were sent to the local wastewater treatment plant. " But EPA's SITE program said, '[Lead] remained in the ash and was not transferred to the scrubber water or emitted to the atmosphere."% The SITE program literature does not explicitly point out that the test results show that the stringent requirements of the Toxic Substances Control Act for PCB destruction were not met.

In an article in a technical magazine, the president of a participating company said, ''The EPA's Paul DePercin, project manager for the HAZCON SITE field evaluation, stated the test '. , , was an unqualified success in stabilization of heavy metals and PCBs in the presence of 25 percent by weight of oils and grease. "[95] In fact, some months later, EPA's Demonstration Bulletin in March 1989 said that volatile organics were primarily released to the environment during processing, and that test data showed that base neutral/acid extractable organics were higher in the treated samples than the untreated ones. No data to support effective stabilization of PCBs was obtained. The only clear positive result was the lack of toxic metals in leachate for treated materials. But this result is what is expected of commercially available chemical fixation technologies. To its credit, the SITE program also publishes Application Analysis Reports which give a broader and more interpretive presentation of a demonstrated technology; the one for the HAZCON technology (almost 2 years after the site demonstration) said: "Data shows immobilization of organics in a few instances but not in most. . , . It can be concluded that immobilization of volatile and semivolatile organics does not usually occur. '[96] While this official EPA work does not rule out the technology for Superfund cleanups involving organics, EPA definitely shifts the burden of proving effectiveness to detailed site-specific treatability and demonstration tests.

In the June 1989 issue of *Chemical Engineering Progress,* Gee-Con said in an advertisement: "Deep Soil Mixing and its sister technique, Shallow Soil

[91] J. Calarese et al., ''An Evaluation of the EPA SITE Demonstration Program, ' Worcester Polytechnic Institute, Washington, DC, Project Center, December 1988.

[92] Inspector General, U.S. Environmental Protection Agency, ''Review of Region 4's Management of Significant Superfund Removal Actions,' Sept. 26, 1988.

[93] U.S. Environmental Protection Agency, Project Summary, "Evaluation of the B. E.S.T. (TM) Solvent Extraction Sludge Treatment Technology Twenty-Four-Hour Test, " November 1988.

[94] U.S. Environmental Protection Agency, demonstration bulletin, "Elw~c Infrared Incineration, ' April 1989.

[95] Ray Funderburk, "EPA's SITE Test of Solidification," *Pollution Engineering,* December 1988.

[96] U.S. Environmental protection Agency, ''HAZCON Solidification Process, Douglassville, Pennsylvania, " April 1989.

Mixing, have been proven effective in the U.S. EPA's Superfund Innovative Technology Evaluation (Sites) program at Hialeah, FL, where PCB-contaminated soil was stabilized in place. ' But at that time no report had been issued by EPA on the demonstration.

A critical concern about the SITE program is that it has never focused on truly innovative technologies, ones that would make major breakthroughs in particularly difficult cleanup applications and ones for which prior R&D has justified field demonstration. Some of the technologies in EPA's SITE program are variations of well-known, commercial technologies and have been demonstrated several times already or have even been used for an actual cleanup. It appears that the SITE program has become a public relations opportunity for companies. OTA's examination of the 30 technologies and firms in the SITE[97] program indicates that at least 21 technologies have been commercially available for some time, used in cleanups, and cannot be interpreted to be innovations. Four other technologies are variations of existing, commercially used technology. An EPA spinoff program is the Emerging Technologies Program to develop "cutting-edge technologies. The goal is to prepare technologies for demonstration; direct financial assistance is available to support R&D. Of the seven technologies in the program, two are known commercial technologies,

One company has told OTA: "Three years ago the Terra Vac process was being labeled as 'unproven' technology even though the process was initially developed over six years ago at a Superfund site. Terra Vac's independent application of the technology at more than 60 sites across the country has done more to promote the technology than the reams of data collected during the demonstration and still awaiting final evaluation. Instead of paying (Terra Vac) for worthwhile services rendered while partially cleaning up a Superfund site during a demonstration, EPA paid five times as much for a subcontractor (who is one of our competitors and now offering **our** technology to clients) to learn the process from Terra Vac. "[98]

To some extent, the SITE demonstration program looks redundant or like a formality that EPA imposes on technology companies, and it may be impeding development and adoption of truly innovative technology. In most cases thus far, several years or many months have passed before the results of demonstrations have been completely analyzed and presented to the public. Meanwhile, some companies can complete actual cleanups and may have enough data to convince others that the technology merits adoption. Waiting for ''proof' from a SITE demonstration may only maintain the stigma of being ''unproven' and ''innovative. An added complexity, in the case of thermal destruction technologies, is that some companies have also carried out test burns at sites in order to meet various government requirements, The results of these are just as important as those from formal demonstrations.

Issue 8: Are the rules clear on what constitutes proof of cleanup effectiveness for new technologies?

The answer is no. There seems to be much disagreement on how to prove that newer cleanup technologies work. Inconsistent cleanup technology selections are being made because there is no clear, generally accepted understanding of what amount and type of information are reasonable proof of effectiveness and reliability. Moreover, the engineering side of technology selection can obscure fundamental environmental protection goals, with the result being the rejection of environmentally more effective cleanup technologies.

The key problem is how to bridge the gap between technology selection decisions and laboratory results or very limited use of a newer technology. The problem is compounded by rapidly changing and increasing data and experience as well as by increasing numbers of companies and individuals implementing Superfund.

There are at least three types of inquiry where actual Superfund site materials are tested; in order of

[97] U.S. Environmental Protection Agency, ' 'The Superfund Innovation Technology Evaluation Program-Progress and Accomplishments Fiscal Year 1988,;; March 1989.

[98] James Malot, President of Terra Vac, personal communication, spring 1989.

increasing cost they are: treatability studies, pilot studies, and site demonstrations.

Non-site materials (prepared to simulate actual site waste) are generally used in laboratory experiments carried out as part of R&D programs or by technology developers. In these cases, the materials are typically very simple chemically compared to complex mixtures of contaminants at many Superfund sites. The unavoidable risk is that field tests may not be successful even though laboratory tests were. This risk is greatest for in situ techniques where actual site conditions and not just the chemical nature of the contaminants are important.

Overall, it is not clear to everyone implementing Superfund just how these various types of tests differ or what has to be done to satisfy EPA in reaching a conclusion, which itself is currently informal, that a given new technology can be considered as proven for some types of Superfund cleanups.

Treatability Studies--Increasing attention is being given to treatability studies in which actual site materials and newer treatment technologies are evaluated in offsite laboratory facilities. Treatability refers to the ability of treatment to work effectively on site hazardous material. Relatively few treatability studies are currently being done before RODS; an EPA survey of fiscal year 1988 RODS found that only 4 of 50 source control RODS examined discussed treatability studies.[99] A key issue is when such studies are done; another is with what technologies they are done. OTA's 1988 case studies showed that treatability testing of technologies was often delayed until the post-ROD Design Phase, which is not subject to much public scrutiny. It is difficult to accept the legitimacy of selecting a remedy **before tests** show that the selected remedy can work unless, of course, the technology has been widely used on similar problems successfully. For example, a pre-ROD test of commonly used forms of incineration is probably unnecessary for most cleanups. Yet, if tests are delayed, then negative post-ROD test results also mean major delays because it is necessary to go back to the study stage; such a delay happened at the Conservation Chemical Co. site in Missouri, and at the Re-Solve site in Massachusetts. Clean Sites, Inc., has described two of its sites. At one, a post-ROD treatability study will "likely indicate that the selected remedy will not be effective' and delay is likely. At the other site, the treatability study is being conducted 3 years after completion of the feasibility study.[100]

Considering its historic lack of confidence in Superfund, the public is likely to be suspicious of exactly how post-ROD test results will be verified and what criteria will be used to conclude that the test results are positive enough to proceed with the remedy's implementation. This suspicion is particularly true for remedies implemented by responsible parties. The danger is that cleanup objectives can shift from health-based to technology performance.

If the basic purpose of treatability testing is to provide data on the feasibility of a cleanup technology for site materials, then it must be done during the RIFS and before the ROD. Otherwise, it is possible to rule out or select technologies without enough credible technical data to support the ROD analysis and decision. For post-ROD treatability tests with negative results, there are incentives and pressures to avoid re-opening the ROD, carrying out another feasibility study, and possibly performing another treatability test.

On the other hand, if the purpose of the test is to get more detailed data to implement the Design Phase, then it could be done at the beginning of the stage. A pilot study definitely fits into this legitimate need to obtain refined engineering data for reliable design of the cleanup.

Selection of technologies and test laboratories is another issue. Based on their technical expertise, innovative technology developers (and not Superfund contractors) should perform treatability studies. Their self-interests requires detailed documentation of results and careful review by government and independent experts. Another problem is fairness in ensuring that all interested and qualified parties have equal access to laboratory results. Very often only one treatment technology or company has the advantage of a treatability test. Remedy selection and establishing of site cleanup objectives may be

[99] *Superfund Report,* July 5, 1989.

[100] Clean Sites, Inc., *Making Superfund Work,* January 1989.

biased in favor of a particular technology within a generic class.

Engineering consulting firms that perform Remedial Investigation and Feasibility Studies are not necessarily expert enough about new cleanup technologies to conduct treatability studies. There may be a conflict of interest if treatability testing is done by companies that also perform RIFSs or by responsible parties, both of which may have a financial interest in certain technologies remedy selection. The point is not to legally prohibit such practices, but to raise the conflict-of-interest issue. EPA has a responsibility to ensure fairness in order to ensure that the most effective cleanup solutions are found.

Another issue is: Is the technology considered proven from a scientific perspective? If so, is its appropriateness for a specific site to be demonstrated through a treatability study? In most cases the answer should be yes. If the range and levels of site contaminants are different from a previous demonstration, it is necessary to perform a treatability study.

Alternatively, can an innovative technology that has not been tested very much at the laboratory stage nor considered proven by EPA be adopted for use on the basis of a positive treatability test result? Unless the answer to this question is yes, doing treatability studies (which increase as more new technologies enter the picture) as part of the RIFS process may be a waste of considerable money because they can be expensive, from tens to hundreds of thousands of dollars. But, on the other hand, allowing a treatability study to be sufficient for remedy selection shortcuts the R&D process. Such a shortcut is likely to sidestep obtaining data on the more subtle aspects of performance, including production of toxic byproducts and the dependence of effectiveness on contaminant concentration.

Pilot Studies-A valid reason for a site pilot study or small-scale test (including incinerator test bums) is that laboratory results cannot take into account actual site conditions. For example, even treatability studies on site materials do not necessarily encompass site climatic, hydrological, or biological conditions. Nor do they address materials handling problems found in the field. Pilot studies are essential for evaluating in situ techniques such as soil washing or flushing, biological treatment, chemical stabilization, vitrification, and extraction of volatile chemicals. It is unlikely that a treatability study would provide a sufficient technical database for full-scale use of an in situ treatment technology, and this deficiency is often true for relatively conventional above-ground technologies that treat contaminated groundwater, for example. Another technical problem is highly variable concentrations of contaminants which are not likely to be properly assessed in offsite treatability studies.

Often the issue of scale-up is also pertinent; that is, either an onsite or offsite pilot study (which may also be called a treatability study) is needed to examine feasibility on a larger scale than can be done in laboratory tests. Trying to determine the relationship between scale of use (e.g., volume) of waste and cost is, however, difficult and expensive. Some pilot studies, however, could probably be extensive enough to accomplish smaller cleanups, because the concept of scale-up does not have its traditional engineering significance for cleanups. There is no standard size or type of cleanup. For example, quantities of contaminated soil to be cleaned can range from hundreds of tons to hundreds of thousands of tons at a site, and volumes of contaminated surface and ground waters vary greatly. Sometimes, a small unit or several small modular units or combinations of smaller units of different technologies may be quite feasible for a cleanup. Moreover, there is some flexibility for cleanup duration because imminent dangers rarely exist by the time a remedial cleanup is done. Many recent pilot studies have been nearly complete cleanups of relatively small sites. For example, a 3-month pilot study of in situ bioreclamation, based on supplying nutrients and oxygen to the aquifer to promote degradation of gasoline by indigenous organisms, cleaned up 90 percent of the groundwater contamination. The study noted that it would have taken conventional pump and treat 7 years to achieve such a result.[101]

Site Demonstrations-There is probably nothing more convincing to skeptics than the successful

[101]Edward A. Radecki et al., "Enhanced Natural Degradation of a Shallow Hydrocarbon Contaminated Aquifer,' in proceedings of Haztech International Conference, St. Louis, MO, August 1987.

results of a technology demonstration that successfully cleans up part or all of an actual site. This reaction is especially true for in situ techniques. Still, there are many uncertainties yet to address. Site contaminants and conditions vary substantially, and one or more successful demonstrations may not be adequate to select the technology at a significantly different site. Who has conducted the demonstration and the accuracy and reliability of the data are also important factors. Many times technology developers speak of their successful demonstrations at cleanup sites, often without EPA or any government agency being formally revolved. EPA and others may not recognize those tests as acceptable demonstrations, for good reason. In a great many cases, the technology company and the site owner make very little technical data available to substantiate their claims.

General Comments-Frustration on the part of technology developers and controversy about the selection of cost-effective permanent technologies are explained by insufficient rules for the burden of proof that EPA requires before newer technologies can be selected. Equally important is the poor dissemination of information to an increasingly large number of people and organizations implementing Superfund and other cleanup programs.

Moreover, there is evidence of inconsistency about remedy selection in the history of the Superfund program (see OTA's 1988 case study report) which sends confusing signals to technology companies and raises the issue of fairness. While some technology companies are being made to jump numerous high hurdles, others are being treated quite deferentially. Other than government personnel, people in the engineering consulting firms that work for government and industry as well as for responsible parties can help technology companies substantially if they choose to do so. An enthusiastic supporter of a technology can get treatability or other tests done and can even build a case for ROD selection without test data. Conversely, consultants can also easily kill a cleanup alternative without any detailed data.

Although the frequently heard complaint is that new technologies cannot get tested or used at Superfund sites, in fact many treatment technologies are being selected without any significant technical data to support the decision. For example, an extensive study by EPA's Inspector General for two removal actions said:

> Region 4 funded commercial testing and development of two hazardous waste treatment prototypes: SHIRCO's infrared incinerator and Resources Conservation Company's Basic Extraction Sludge Treatment (BEST) unit. To fund the tests, the Region sidestepped several internal controls; such as permitting, delisting, and contracting regulations. Region 4's selection of the two technologies was speculative and unsupported by scientific or engineering fact. Nevertheless, both prototypes were used to conduct full-scale operations at removal sites prior to evidence that the manufacturer's performance claims were true.[102]

Several examples were also given in OTA's 1988 case studies, including the Chemical Control site in New Jersey and the Sand Springs site in Oklahoma. We have two other examples to add.

At the Lipari Landfill site in New Jersey, for example, a positive treatability study for biotreatment was ignored, but a cleanup approach based on soil flushing was adopted for the site cleanup even though the technique had never been documented to be successful at a similar site. The long duration of soil flushing was a major point noted by a number of parties unhappy with the selection of soil flushing at Lipari. A major factor of concern was the diverse types of contaminants at Lipari, some of which were shown to be difficult to remove by water flushing. For several PCB-contaminated sites in Indiana a novel incineration approach based on burning both municipal solid waste and site-contaminated materials was selected. But it had not been tested or used elsewhere. In both cases, there has been considerable community opposition to the selected remedy because of the lack of convincing data on technology feasibility.

Finally, the situation is made even more complex and ambiguous because there is no evidence that information from various types of testing done by many different parties involved in the national cleanup effort, inside and outside of the Superfund program, comes together in some central way for

[102] Inspector General, op. cit., footnote 92.

analysis and transfer. Testing protocols are absent and there may be redundancy and technical inconsistencies among treatability testing, pilot studies, and demonstrations on the same technologies. While EPA has made progress in addressing this problem, there is now no effective Federal effort to provide independent professional review and expeditious distribution of validated information nationwide.

Issue 9: Is poor information affecting the use of better cleanup technologies?

The latest technical information on generic and specific cleanup technologies, their costs, and their performance and implementation at sites does not travel far. Similarly, the considerable experience from private, State, RCRA corrective action, and non-EPA Federal agency studies and cleanups may go untapped, along with the expanding reservoir of cleanup-related R&D, including university work. Theoretically, much of this activity could have a positive impact on Superfund, including making it more efficient and effective.

A particularly striking example of poor communication about cleanup technology with EPA happened for the Crystal City site in Texas (one of the case studies in OTA's 1988 report and a cleanup decision that has been criticized by the local community, State and national environmental groups, and Members of Congress). In defense of EPA's selected remedy which was based on land disposal, the Region 6 Administrator testified that "No technology was found that could effectively remove (arsenic) from the soils. . . . Arsenic, a principle pollutant of concern at this site, cannot be effectively removed from the solids by alternate treatment technologies. ''[103] In a ROD that was signed at the same time that the Crystal City ROD was signed in September 1987, "on-site flushing of soil with an acidic water solution to remove arsenic was selected for the Palmetto Wood Preserving Site in South Carolina. A month before the Crystal City ROD, EPA had formally acknowledged in regulations for the RCRA program that chemical fixation was proven, available technology for waste with arsenic; and the ROD for the French Limited site in the same State and region (and signed by the Regional Administrator a month before the testimony on Crystal City) also acknowledged the applicability of chemical fixation for arsenic.

Some poor information transfer is unavoidable because of the rapid rate of growth and in change. But most of the problem is probably due to insufficiently focused EPA activities, arising from the highly decentralized, fragmented nature of the Superfund program and-just as importantly-the whole national cleanup effort. OTA has examined a number of documents that EPA uses in its technology transfer activities. Often only a superficial level of information is being reported. A person would still have to expend considerable time and energy to obtain the detail necessary for a good technology evaluation. A remedial project manager with little experience and a heavy workload is not likely to be able to do this research. In other cases, highly detailed voluminous studies are prepared at considerable expense, but hardly anyone seems to be using these documents (from EPA's Office of Research and Development) because it would take so much time to use them effectively. They are meant for researchers and experts, not practitioners at the frontline of Superfund.

Some part of the problem of poor information may also result from insufficient attention to the problem by contractors. OTA agrees with the perspective of a technology developer: "The REMS and ARCS contractors (types of contracts for the remedial program) are at best six months behind on individual technology development programs, and more frequently 18-to-30 months. " The developer, therefore, believes that bringing technology developers into the RIFS process through the conduct of treatability studies ''is a way for EPA to effectively help the technology transfer from the developers to their contractors. '[104]

Another problem is the generally inexperienced and, therefore, cautious workforce. There is a preponderance of civil engineers and hydrologists working in the cleanup, but these people are likely

[103] Robert E. Layton, testimony at hearings before the House Subcommittee on Environment, Energy, and Natural Resources, Apr. 11, 1988.

[104] James A. Heist et al., ''Remediation and Treatment of RCRA Hazardous Wastes by Freeze Crystallization, " presented at EPA's Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International, June 1989.

20-011 0 - 89 - 5 : QL 3

to lack the expertise and experience necessary to understand many new forms of cleanup technologies based, for example, on complex chemical engineering or biological treatment. Moreover, the rapid expansion of cleanup technologies has resulted in increasingly exotic and sophisticated technologies which only a few people implementing Superfund understand. A judgment that a newer technology is proven, reliable, and applicable-or unproven, unreliable, and inapplicable-may depend on the limited and recent experiences of the contractor company (or really, individuals within the company) instead of the accumulated experiences of all parties within the national cleanup system, within and outside of Superfund.

Technology loyalty, instead of an open mind, can also be a problem when organizations other than technology developers exercise it. First, as Superfund contractors have diversified, some of them have a stake in the adoption of a particular technology that they own. For example, at least one contractor owns an incinerator, several have developed techniques to physically remove volatile organic chemicals from contaminated soil, and one's parent company sells raw materials to a technology vendor. This problem is compounded by the fact that sometimes the identity of the company performing a Superfund study is not revealed. The more one looks carefully, the more one finds Superfund contractors, their parent companies, or their subsidiaries involved with the ownership of cleanup equipment and technology.

Technology companies themselves are a problem because of the limited information they provide. They sometimes may not make necessary information available because they cannot afford to get it or do not want to get it. The waste treatment industry has long been frustrated with the slow adoption of treatment technologies. While the treatment industry fosters the appropriate use of newer treatment technologies, it sometimes contributes to premature selections and inappropriate use as discussed in OTA's 1988 case studies. It is just as unwise to select an untested and unproven technology as it is to reject a risky, innovative one with real promise to solve a difficult problem. Both actions can lead to an ineffective cleanup that wastes money, increases environmental risks, and creates a worse cleanup problem for the future.

Limited information from technology companies is an especially important problem for emerging biotechnologies. People knowledgeable about this area said,

> Past attempts at bioremediation have failed to establish conclusively biodegradation of chlorinated aromatic compounds in large-scale systems and have not yielded information useful for other systems, even those similarly designed. . . . Failure to consider testing and evaluation of bioremedial processes can lead to a credibility crisis. Left on its own, the race to market environmental biotechnology within the entrepreneurial private sector may not only prevent the effective technical development of this technology, but may also lead to market failure. The inability to analyze and correct failures and to enhance successes leads to a perception of unreliability and a major erosion of confidence. 105

Technology companies may sometimes want to keep information confidential or may have to, in the case of cleanups on sites unknown to government officials. Technology companies may also be worried about giving information to RIFS contractors which may compete against them for field work or which may have a competing technology.

The overselling of a technology is a real problem. Providing detailed available data often is in conflict with marketing efforts because the data reveals the limits of the testing or application to date. Oversell is especially prevalent because usually few contaminants have been worked on successfully relative to the enormous variety of contaminants found at Superfund sites. Too many technology developers extrapolate successful test results to other chemicals or site conditions without a valid theoretical basis for doing so. They ignore or underestimate the importance of technology specificity. For example, biological treatment which works for one chemical may not work for others present at a site; site conditions such as the soil chemistry and porosity may require significant changes in the design of a bioreactor or the materials that are added to assure effective microbial destruction.

105 Tennessee Valley Authority, Center for Environmental Biotechnical Applications (University of Tennessee); and EPA, "A Proposal for the Development and Application of PCB Bioremediation Technology for the Texas Eastern Sites," September 1988.

One more factor is the often confused need for Federal and State regulatory permits for onsite cleanup activities (there is no uncertainty about the need for using permitted offsite waste treatment or disposal facilities, although their regulatory compliance status remains an issue). A need for permits increases information requirements significantly. Debate persists on the need for permits for onsite work—by law, none are needed for work on Superfund sites—but sometimes States have exercised their prerogative to require State environmental permits under their existing regulatory programs. The problem is that many cleanup technologies are not now regulated by existing programs, especially hazardous waste programs. If no specific regulatory standards exist, it can be difficult to get agencies to issue permits. Another issue is the need to get permits for mobile equipment, with technology companies and other parties wanting to reduce the complexity, costs, and delays associated with permitting.

Issue 10: Is experience leading to easier, faster, and less expensive analyses and decisions on cleanup technologies?

Just the opposite appears the case. Even though some individuals may be moving up a learning curve, the **program** does not appear to be gaining substantial efficiency. There are three key problems,

First, not many people see past the conventional wisdom that every cleanup site is unique, with the implication that every site decision must be on a case-by-case basis. Although there is as much truth to this as there is that every person is unique, sites can be grouped by important commonalities of site conditions and problems. Overly stressing the uniqueness of every site does not necessarily make the system worse as it expands, but it does hinder a global view. It also promotes unnecessary site studies, which add more cost and delay than providing truly useful information. Belief in site uniqueness stands in the way of using cleanup objectives and technologies selected at similar sites, because site differences currently obscure site similarities.

Another part of this problem is that there has been reluctance by EPA staff to admit and openly communicate the failures of cleanups at sites, even though this could substantially affect other decisions. OTA's examination of RODS indicates that most failures are for containment and land disposal approaches and, less frequently, simple forms of treatment such as chemical stabilization. There often seems to be an attitude that maybe the technology can be made to work at other sites or that other EPA regions have the right to make their own decisions and mistakes. Moreover, public criticism of Superfund makes it difficult for EPA officials to acknowledge cleanup failures.

Each site study and decision has the potential for being made in isolation. To the extent this is true, then the more sites and cleanup technology options, the worse the situation. Indeed, there are so few central management controls imposed on the program that it is difficult to see Superfund as learning and maturing from its own experiences, and less so from other cleanup programs. Instead, disparate working elements of the program act independently, too free of central oversight and control which would help the elements learn from each other's positive and negative experiences.

Second, the increasing numbers of generic and specific cleanup technologies outpace the transformation of information into wisdom, They increase the amount of information ideally obtained in the RIFS and place difficult demands on the workforce. Considerable information on exact site and contaminant conditions is necessary to rule out or to defend the selection of particular technologies. There are fundamentally different constraints to different generic technologies, such as thermal v. biological treatment. Increasing numbers of technologies also means that increasing combinations of them can be assembled, at least theoretically, to clean up complex sites.

Technology specificity, where effectiveness varies for different hazardous substances, takes on more importance as the range of cleanup technologies expands, because for many of them no theoretical or scientific case can be made for non-specificity. Although specificity has been a problem even for containment techniques (e.g., effect of some chemicals on slurry wall permeability), it is less relevant for older incineration techniques. Generally, technology specificity has not been adequately dealt with. In fact, the frequent practice of using short lists of indicator contaminants, instead of the full array of chemicals present at a site, to reduce the RIFS workload conflicts with evaluating and using diverse permanent cleanup technologies. Indicator contaminants might make sense for simplifying risk assessment. But physical and chemical properties that affect cleanup technology feasibility may vary substantially from health effects.

Specificity can be a problem with treatability studies because they too may rely on indicator chemicals to evaluate a technology's performance. The ultimate risk is the use of cleanup technology thought to be generally proven effective and found to be applicable through a site treatability study but that, nevertheless, does not work effectively on the full range and often wildly fluctuating concentrations of contaminants at a complex site.

Moreover, analyses and decisions themselves are coming under more scrutiny. The increasing numbers of technology companies mean that more parties want their technologies fairly and carefully considered in cleanup decisions. Technical assistance grants to communities are supposed to help the affected public make sure that the best technologies are used. Grants may also provide another opportunity for technology developers to enter the system. Responsible parties want to free themselves of future liabilities and to cut unnecessary costs. They can introduce new cleanup alternatives into the process. All of these concerns mean that the time and cost of "defensible' RIFSs and RODs are likely to escalate--competing with full-scale cleanups themselves-and thus the introduction and adoption of newer technologies may suffer. Increased overhead costs due to more extensive studies--often several hundred thousand dollars-at a large number of sites might offset cost savings from using improved technologies at a much smaller number of sites. Delays alone can be sufficient to stymie technology companies at a critical point in their development. A way to address this problem is to use the most experienced and expert people, with certain types of sites or technologies, to screen alternatives and reduce the number of alternatives studied.

Third, the general level of inexperience in technical and management areas of the national cleanup workforce in government and industry is a major problem on its own. The rapid expansion of activity coupled with a steady stream of new technologies requires major efforts to prevent delays and poor work. As the role of contractors has grown, it uses government programs as breeding grounds for its workforce. The constant shift of people from government to the private sector, because of substantially higher salaries and probably better working conditions and potential for promotion, **keeps the government workforce inexperienced. This** makes effective government oversight and management of contractor activities difficult, if not impossible. One observer recently summed up the current contractor system as being ''wasteful, disorganized and inefficient."[106] On top of this, there is also a high degree of mobility of the most experienced people among contractors as contractors compete to maintain or increase market share or business volume. Some of those with the most technical expertise go into management.

The result is a national cleanup workforce which is expanding rapidly, which is in constant motion, with few people having institutional memories or loyalties, for whom information transfer and education through working with experienced people is minimal, with no substantial improvement in average level of experience, and where labor costs are increasing. These problems will not cease without effective organization and management controls and clear and explicit policies.

[106]Roger J. Marzulla, ''Superfund 1991: How Insurance Companies Can Help Clean Up The Nation's Hazardous Waste,' paper presented to Insurance Information Institute, Washington, DC, June 13, 1989. Also see U.S. Congress, Office of Technology Assessment, *Assessing Constructor Use* in *Superfund*, OTA-BP-ITE-51 (Washington, DC: U.S. Government Printing Office, January 1989).