SUMMARY AND ANALYSIS

Introduction

Are we cleaning up the mess or messing up the cleanup? In the eighth year of Superfund, this central question is still being asked. These 10 case studies illustrate how the Environmental Protection Agency (EPA) is implementing the Superfund Amendments and Reauthorization Act (SARA) of 1986. OTA has examined a great many more sites and believes these case studies are representative of what is happening nationwide in the Superfund program.

This report examines two fundamental questions about using technology to cleanup toxic waste sites. ***First,*** is the Superfund program consistently selecting permanently effective treatment technologies which, according to SARA, are preferable because they reduce "toxicity, mobility, or volume" of hazardous wastes? The answer OTA finds is that it is not.

Second, are land disposal and containment, both impermanent technologies, still being frequently used? The answer we find is yes. Future cleanups are likely for the wastes left in the ground or shipped to landfills.

The Superfund program promised a lot. People's expectations have been high, perhaps too high for such a new, complicated, large-scale effort. Frustration often makes it difficult to see real Superfund accomplishments. Since its inception at the end of 1980, Superfund has received a great deal of money, over $5 billion so far, to clean up the Nation's worst toxic waste sites. But OTA'S research, analysis, and case studies support the view shared by most observers—including people in affected communities and people in industry paying for cleanups—that Superfund remains largely ineffective and inefficient. Technical evidence confirms that, all too frequently, Superfund is not working environmentally the way the law directs it to. This finding challenges all those concerned about human health and the environment to discover what is wrong and fix it. Whether Superfund will work cost-effectively over the long term depends on how cleanup technologies are evaluated, matched to cleanup goals, selected, and implemented and how permanent the cleanups will be. People want ***their*** cleanups—the ones they live near or pay for—to last. Improving public confidence in Superfund can be approached from different directions, including the one taken in this report: making better decisions about cleanup technology.

Too much flexibility and lack of central management control are working against an effective, efficient Superfund program. EPA Regions, contractor companies, and workers have substantial autonomy. In principle, flexibility can lead to benefits. But the case studies show the Superfund program as a loose assembly of disparate working parts; it is a system of divided responsibilities and dispersed operations. There is no assurance of consistently high quality studies, decisions, and field work or of active information transfer. The need for cleanups, the newness of the technological challenge, and the growth of Superfund mask the inexperience and mobility of the work force. Program managers have not offset inexperience in technical areas and management with tight management controls and intensive educational programs for government and contractor workers. Oversimplified "bean counting" of results instead of evaluations of what those results mean technically and what they accomplish environmentally provides too little incentive for quality work. The current decentralized system also does not assure higher levels of ***program*** efficiency over time, even though some workers and offices may become much more effective and efficient.

A widespread belief among Superfund workers is that "every site is unique." There is a kernel of truth to this belief. Yet uniqueness has been carried to an extreme and has blocked understanding of common site characteristics, common cleanup problems, common solutions, and common experiences with site studies and decisions. Identifying these commonalities is necessary to understanding how Superfund is being implemented nationally and understanding how to improve the program. At the beginning, when only a few cleanups were addressed, sites looked very different from each other. Now, with hundreds of cleanups examined, it is easier to see the commonalities and to benefit from the experiences to date. The case studies discuss similar experiences at various Superfund sites and help illustrate the link between identifying commonalities and achieving consistent cleanups.

Cleanup costs are major issues in the case studies. In site cleanup decisions, many people in government and industry want to keep costs as low as possible. Hence, there is a tradeoff between environmental protection goals (How clean is clean?) and the cost of the remedy selected (Is it cost-effective?). There is also a tradeoff between effective cleanup at *some* sites versus no action at others. These tradeoffs are getting more difficult as more and more sites requiring cleanup are identified. SARA's *preference* for permanently effective treatment technologies—not a requirement that they always be used—makes these tradeoffs even harder; it also places more importance on the accuracy of cost estimates and on evaluations of the permanency of different cleanup technologies. By understanding the capabilities of different cleanup technologies, it is easier to understand how compromises between cost and environmental performance can lead either to "gold plated" or "band-aid" cleanups.

The Importance of the Record of Decision

A crucial step in the complex process of moving a site from discovery to remediation (see box 1) is the ROD's *technology selection.*[1] Cleanup technology determines whether contamination will be eliminated or reduced to a safe level and environmental protection achieved, as well as determining cleanup cost. Technology selection is the primary focus of this OTA report. But the ROD decision is not everything. Just as a map is not the territory, a ROD is not the cleanup. Future analysis of the environmental results of cleanups is necessary to see how the ROD strategic plan is implemented. Because cleanups have been fully implemented at so few sites and the data are so sparse, this study does not fully examine actual cleanup effectiveness and consistency with ROD goals. But the case studies examine the entire history of the sites. And for some of the sites discussed here, the technologies selected have failed or early work to clean up immediate threats has made matters worse for final cleanup.

By examining RODS in detail, the functioning of Superfund comes into focus because everything that was done before the ROD must be considered and everything to come later must be anticipated. Analysis of RODS offers enormous educational value to improve Superfund implementation because they represent the critical junction between extensive studies and expensive remedial cleanups. Cleanup costs vary widely, from several hundred thousand dollars to tens of millions of dollars. To put cleanup costs in perspective, consider the simple concept of acreage. Data on 15 of the cleanups reviewed in this study indicate that total cleanup costs can reach $500,000 to $1 million per acre,

The Usefulness of Case Studies

In Superfund, case studies are particularly important because, even after *8* years, cleanup technology is a new and fast-changing field and the work force is relatively young and inexperienced. Recent college graduates are often put in charge of multimillion-dollar projects at EPA. These people have had no direct experience and no coursework on cleanup, and they have almost no one to learn from, as turnover is high. People in contractor firms also lack experience. Research papers and technical manuals have significant limitations too. They are quickly outdated, are

[1] EPA has said "The Record of Decision ., , is the centerpiece of the administrative record against which the Agency's decisionmaking maybe judged by the courts." [U.S. Environmental Protection Agency, "Interim Guidance on Superfund Selection of Remedy," Dec. 24, 1986.]

Box 1.-How Does Superfund Operate?

The Superfund system is complex. Sites are identified and enter an inventory because they may require a cleanup. At this point, or at any time, a site may receive a ***Removal Action*** because of emergency conditions that require fast action or because the site could get a lot worse before a remedial cleanup could be implemented. (Most of SARA's requirements for remedial cleanups do not apply to removal actions, even though removal actions can cost several million dollars and resemble a cleanup.) In the pre-remedial process, sites receive a ***Preliminary Assessment*** (PA); some then go forward to a ***Site Inspection*** (S1), with some of those sites scored by the ***Hazard Ranking System*** (HRS). If the score is high enough, the site is placed on the ***National Priorities List*** (NPL) and becomes eligible for a remedial cleanup paid for by the government, if necessary, or by responsible parties identified as having contributed to creating the uncontrolled toxic waste site. Under current procedures, only about 10 percent of sites which enter the system are likely to be placed on the NPL. Some States have their own lists of sites which require cleanup; these often contain sites not on the NPL.

NPL sites receive a ***Remedial Investigation and Feasibility Study*** (RIFS) to define contamination and environmental problems and to evaluate cleanup alternatives. The public is given an opportunity to comment on the RIFS and EPA's preferred cleanup alternative. Then, EPA issues a ***Record of Decision*** (ROD) which says what remedy the government has chosen and the reasons for doing so; the decision may be that no cleanup is necessary. A ROD may only deal with part of a site's cleanup and several RODS may be necessary for a site. The ROD also contains a summary of EPA's responses to public comments. EPA chooses the cleanup goals and technology in the ROD. In actual fact a number of actions involving different technologies are likely to be chosen for any but the simplest sites. The ROD is like a contract in which the government makes a commitment to actions which will render the site safe. If responsible parties agree to clean up the site, they sign a negotiated consent decree with the government; this stipulates the exact details of how the responsible parties will proceed. If the cleanup uses Superfund money, the State must agree to pay 10 percent of the cleanup cost.

In the post-ROD process, the site receives a ***Remedial Design*** (RD) study to provide details on how the chosen remedy will be engineered and constructed. The whole process ends with the ***Reme-dia]Action*** (RA), the actual implementation of the selected remedy. Many cleanups include long-term monitoring to determine whether the cleanup is effective and if more cleanup is necessary. A ROD may be reopened and amended because of new information discovered or difficulties encountered during the design and remedial action. When a cleanup is deemed complete and effective, the site can be delisted by EPA from the NPL.

too theoretical, assume substantial technical knowledge, are either too detailed or too general, and may be biased to boot. Attending conferences where new cleanup technologies are discussed in detail is difficult because of heavy workloads and limited funds. Moreover, helping to inform the public is also critical, especially because SARA increases the participation of communities in the program through technical assistance grants. These grants have not been available, however; EPA only began accepting applications in April 1988.

The case studies examine the decisionmakingprocess, the quality of the ***information*** used in it, and how well the decision and its technical support are ***communicated*** by EPA to the public. Unlike "bean counting" statistics, which give quantitative program results for a large number of sites, case studies show how the complex Superfund system really functions and illustrate the ***quality-of*** its environmental performance. Case studies cannot totally describe the extensive site studies (the RIFSS) which pre-

[3]For example, at EPA's annual research symposium in May 1988 dealing-with treatment of hazardous waste only nine EPA staff people who may be implementing Superfund (i.e., not in the Office of Research and Development) were registered out of a total of over 700 people.

cede the ROD. Nor can they go behind the scenes to investigate all the reasons for decisions. But the ROD and its supporting RIFS are intended to stand alone in making the government's case for the selected remedy and are the primary information sources in the 10 case studies.

This report does not aim to prove whether a technology is good or bad, or whether a decision is unequivocally right or wrong. Cleaning up toxic waste sites is fraught with technical uncertainties and surprises which cannot be eliminated entirely. The issue of quality of RODS is not a black or white situations Each one will have good and bad points. Any cleanup technology can be used effectively for some applications, and every complex cleanup decision has strong and weak points. There is no problem finding important, correct statements in case study RODS. Indeed, this report often uses statements from one case study RIFS or ROD to illustrate inconsistency or to underscore a point about a problem in another ROD, Generally speaking, the decisions made in these 10 case studies are questionable because, for example:

- If different and readily available technical information had been used, the decision would have changed significantly,
- The range of cleanup alternatives was too narrow.
- The analysis was not comprehensive and was not fair to different technologies.
- The study work was not internally consistent.
- Mistakes were made in calculations and estimates.
- Critical assumptions were false.
- Conclusions were stated without analysis and documentation.

On a broader scale, other questions are important: Are government policies and EPA's organization getting in the way of solid, defensible technical work? Is the timing of key pieces of work, such as testing technologies, poor? Looking across sites, are there trends for problems in Superfund technology selection?

The last question is especially important. It is crucial not to look narrowly at single sites but across sites. This is key to central, national oversight of Super fund. While individual case studies can address technical soundness in a specific ROD, all of them together show how consistent the program is nationwide in understanding the advantages and disadvantages of cleanup technologies and in responding to the statutory requirements on cleanup technology selection. As does other information, RODS show that Superfund is being implemented in a highly decentralized manner. There is inconsistency in ROD format and presentation of information, examination of cleanup alternatives, and technology selections. In itself, this is not necessarily bad, but it does mean that central management oversight and controls by EPA are necessary to avoid inconsistency leading to confusion, unnecessary costs and, for some sites, ineffective cleanup. Lack of consistency among hundreds and, eventually, thousands of sites is not an academic issue. Harm to human health and the environment, loss of public confidence in government, and wasting money are what's at stake.

The following case studies also show how a site moves through the Superfund system. General perceptions about delays are documented. Rarely has so much information been assembled on individual sites, possible here because EPA has provided OTA with several databases. RODS do not contain such comprehensive information, which itself is an important observation. On the other hand, there are many areas of interest which are not covered in these case studies. Documents on a Superfund site can fill file drawers. There are many legal and procedural aspects of Superfund; these case studies focus on technical areas and issues. While legal and liability issues get enormous attention, environmental protection is the reason for

[3]An experienced attorney advises responsible parties: "Legal issues, scientific and technical findings, plus the all-important policy component all affect EPA decisions, Nowhere is this more clearly shown than in the context of a **Superfund** Record of Decision . . . the statute calls on EPA to make decisions based on which remedy is cost effective or which 'adequately' protects public health. Applying these terms entails a degree of subjective judgment," [P.H. Hailer, ***Hazardous Materials***, January/February 1988,]

Superfund and ultimately it is technology which must get the cleanup job done.

Superfund's Better Side

A small fraction of RODS meet SARA's requirements. Six recent well-done RODS are briefly summarized below. While not perfect, each ROD sets a good remedial action plan, each selects what is likely to be a permanently effective treatment technology, and each provides adequate data and discussion to justify the technology choice. These six RODS contrast sharply with the 10 case studies which are the focus of this report.

Cooper Road Dump, Voorhees Township, New Jersey

EPA Region 2; NPL #473/7704–The ROD of 9/30/87 decided to take no further action at the site. A detailed technical case, based on substantial site sampling, supported the conclusion that previous removal actions at the site had 1eft it permanently clean. The only question this ROD raises is why the site scored so high on the HRS and wound upon the NPL. In hindsight, Cooper Road Dump illustrates a "false positive," a site that went through the Superfund system unnecessarily. Indeed, in a survey of EPA Regional staff, this site was included on a list of "sites on NPL that should not be."[5] No significant Federal or State money was spent to prove that no cleanup was necessary; the responsible party paid for the work.

Davis Liquid Waste Site, Smithfield, Rhode Island

EPA Region 1; NPL #216/770; estimated cost, $28 million.—The ROD of 9/29/87 selected a comprehensive remedial action plan. The plan included: 1) onsite thermal destruction of 25,000 cubic yards of excavated raw waste and contaminated soil with greater than 2 parts per million (ppm) of volatile organic chemicals; 2) placement of incineration ash and pollution control residues that are found toxic through testing in an onsite RCRA hazardous waste landfill; 3] provision of alternative water for affected offsite residents; and 4) restoration of groundwater by onsite treatment using air stripping and carbon adsorption.

The supporting Feasibility Study (FS) was a textbook example of careful analysis, which included alternative technologies and citations of experiences at other cleanup sites. Most striking was the early elimination of nontreatment options, such as landfilling the hazardous waste, because, as stated in the FS, they "do not provide for any treatment of contamination. " The analysis also reviewed costs for substantial pilot treatability studies during the post-ROD design phase (the RD) as well as acceptable cancer risk levels as cleanup goals. However, a I in 100,000 cancer risk level was used rather than the 1 in 1 million level more frequently used. Another, and probably related, reason why this ROD is not perfect is that some untreated hazardous material will be landfilled onsite instead of being treated. The higher risk level seems to have been a.compromise made to reduce cleanup costs. Also, the delay of the treatability testing until after the ROD is undesirable; although for this site there was more information available to justify the technology selection than in some of the case studies.

The Davis remedial plan used an excellent interpretation of cost-effectiveness for making technology choices: "an alternative which has a similar public health and environmental benefit to other alternatives can be screened out due to costs that are higher in order(s)-of-magnitude, '[6]

Love Canal, City of Niagara Fails, New York

EPA Region *2; NPL#142/770;* **estimated cost, about $30 mifllon.—The** ROD of 10/26/87 altered an earlier

[4] Ranking on National Priorities List and total number of ranked sites as of July 1987.

[5] U.S. Environmental Protection Agency, unreleased contractor report written by CH2MHill, November 1986.

[6] Compare this to EPA's guidance which lacks the concept of comparable environmental protection: "[cost-effectiveness] requires ensuring that the results of a particular alternative cannot be achieved by less costly methods. This implies that for any specific site there may be more than one cost-effective remedy, with each remedy varying in its environmental and public health results." [U.S. Environmental Protection Agency, "Interim Guidance on Superfund Selection of Remedy," Dec. 24, 1986.]

decision at Love Canal to use onsite land disposal for dioxin contaminated sewer and creek sediments. Now, a mobile thermal destruction unit will be used onsite to destroy and remove dioxin with an efficiency of 99.9999 percent. The cost for treatment will be twice that for land disposal, but the ROD selected thermal destruction on the basis of its ability to meet statutory requirements by eliminating toxicity and mobility. In addition, several site demonstrations elsewhere had successfully destroyed dioxin-contaminated soil with mobile thermal destruction units. EPA responded to extensive community comments against landfilling the contaminated material onsite and also decided not to attempt to separate materials with less than 1 part per billion dioxin (EPA's cutoff for acceptable contamination) because of uncertain reliability in doing so.

Operating Industries, Inc., Monterey Park, California

EPA Region 9; NPL #71/770; estimated cost: $4.8 million.—The ROD of 11/16/87 concerned an interim remedial action required to manage contaminated Ieachate at the site, which had a long, complex cleanup history. The ROD selected an onsite Ieachate treatment system with several proven technical steps that can reduce a diverse set of organic and inorganic contaminants to levels low enough to permit discharge to a local water treatment plant. The key steps will be gravity separation, coagulant addition, dissolved air flotation, filtration, air stripping with vapor phase carbon adsorption, and liquid phase granular activated carbon adsorption.

The analysis of alternatives was first rate. Two constraints were applied that ruled out more innovative approaches. First, the action had to be implemented easily and rapidly. Second, it had to be able to cope with major fluctuations in the composition of the leachate. Thus, some technologies that would actually destroy organic contaminants, such as plasma arc thermal destruction and wet air oxidation, both followed by stabilization of solid residues containing toxic metals, were not considered because they would probably face delays because of State regulatory requirements and possibly public concerns. The disadvantage of the selected remedy is that the technologies used rely almost entirely on separation. Therefore, significant amounts of concentrated hazardous residues will have to be moved offsite for disposal or treatment.

There was some laboratory testing of site leachate during the FS. Also, the process leading up to the ROD was rigorous, including an extended public comment period with an unusual opportunity for local citizens to review a draft ROD. (Normally, the public gets a very brief statement of EPA's preferred remedy to review.) Although there was keen community interest, little of it dealt with the selection of technology, but rather with the specific location on which the leachate treatment facility would be built.

he-Solve, Inc., North Dartmouth, Massachusetts

EPA Region 1; NPL#206/770; Mimated cost, $19.9 million.—The ROD issued on 9/24/87 is one of the most technically detailed and complete RODS reviewed for this study. A previous cleanup based on an earlier ROD was stopped when four additional hot spots of contamination were found. The newly selected remedy consisted of: 1) the source control phase of onsite treatment of 25,500 cubic yards of excavated PCB contaminated soils and sediments in a mobile dechlorination facility (volatile organic compounds will also be reduced); and 2) aquifer restoration by pumping, repeated flushing, and treatment involving air stripping and carbon adsorption, particularly for volatile organic compounds. The site will be evaluated every five years because some hazardous substances will remain there; curiously, there are no land use restrictions.

While dechlorination was considered an innovative technology, its selection was based on positive pilot test results on an actual Superfund site with similar contamination and climatic conditions.r (Other work by EPA shows the approach effective in getting residual levels

The technology is sold by six vendors according to U.S. Environmental Protection Agency, "A Compendium of Technologies Used In The Treatment of Hazardous Wastes," September 1987, of PCBS in soils down below 1 ppm.)[8] Additional pilot study results will be obtained onsite prior to use, and if dechlorination is unsuccessful, the ROD specified that onsite incineration will be used instead. Similar treatability and pilot tests will be performed for the groundwater cleanup phase prior to full-scale use,

Cleanup goals at Re-Solve were based on risk analysis on the basis of possible residential use of the site. A 1 in 100,000 excess (over background) cancer risk level was chosen for the soil and groundwater cleanup instead of the more common 1 in 1 million level. Accordingly, PCBS in the soil will be reduced to 25 ppm, which is a higher concentration than goals set at other sites.[9] For example, 20 ppm was chosen at the Ottari and Goss/Great Lakes Container Corp. site in New Hampshire; 5 ppm, at the Renora site in New Jersey; 1 ppm, at the Tacoma Tar Pits site in Washington; and 1 ppm, at the Liquid Disposal site in Michigan (where a 1 in 1 million risk was used). A recent EPA document refers to cleanup to "the desired background levels (1 to 5ppm) or less."[10] In addition, an assessment by EPA's Office of Health and Environmental Assessment concluded that a range from 1 to 6 ppm PCBS in soil is equivalent to 1 in 100,000 cancer risk.[11] The Re-Solve ROD, therefore, illustrates the compromise between level of cleanup and acceptance of cost by the government and responsible parties. The FS noted that "the voIume of PCB contaminated soils increases exponentially as the cleanup levels become more protective." While the final decision may be disputed by some people, particularly on the issue of residual PCB level, the decisionmaking process is clear and there is public accountability.

[8] A. Kernel et al., "Field Experience With the KPEG Reagent," paper presented at EPA's *Fourteenth Annual Research Symposium,"* May 1988.

[9] The PCB concentration level corresponding to the 1 in 100,000 risk level is 30 ppm, but EPA decided that the uncertainty of the approach allowed them to use 25 ppm as being representative of that risk level. The PCB level for the 1 in 1 million risk level was 3 ppm. Also, it was estimated that onsite groundwater may contain 10 to 15 ppb PCB after cleanup, which is far in excess of 0.08 ppb, the health-based cleanup level for a 1 in 100,000 cancer risk for PCBs.

[10] U.S. Environmental Protection Agency, "Report on Decontamination of PCB-Bearing Sediments," January 1988,

[11] As reported by EPA in its ROD for the Liquid Disposal Site in Michigan, Sept. 30, 1987.

Seymour Recycling Corp., Seymour, indiana

EPA Region 5; NPL #57/770; ostimateid cost, $18 million.—The ROD issued on 9/30/87 was the second one for the site. The selected remedy has several key components: 1) a full-scale vapor extraction system to reduce the substantial presence of volatile organic compounds; 2) the extraction and treatment of contaminated groundwater at and beyond the site boundaries; 3) the application of nutrients to remaining contaminated soil to stimulate biodegradation; 4) the installation of a multimedia cap to restrict direct contact and limit water intrusion; 5) deed and access restrictions; and 6) a detailed monitoring program and technical criteria to detect failure and to plan future action if necessary.

A good technical analysis supported the selection of this remedy over alternatives such as incineration and in situ soil washing. Incineration would have cost $37 million and in situ soil washing would have cost $17 million, while the chosen plan will cost $18 million. But technical impediments—the large size of the site (14 acres), the large quantity of contaminated materials (about 100,000 cubic yards), and the dangers of excavating soil with large amounts of volatile compounds—not ***cost,*** were the reasons for rejecting alternatives that may have provided more substantial treatment and detoxification. In addition, the groundwater treatment is estimated to take from 28 to 42 years, but there is no faster alternative available. Of some concern is that treatability studies were not done before the ROD. But the extraction technology is well proven and the final Seymour implementation plan is well thought out.

Summary of Trends From 10 Case Studies

As a rule, RODS are fraught with problems. The 10 case studies, chosen out of over 100 RODS reviewed, illustrate in concrete ways some disturbing trends among these problems —trends that compromise the ultimate protection of human health and the environment (see box 2 for capsule findings). These trends are summarized below.

Evaluation and Selection of Permanent Treatment Technologies

Many good, permanently effective waste treatment technologies are on the market but, too often, are not fully examined, or are not selected for use. A ROD may simply opt not to treat a site at all but rather to bury waste in a landfill or to cap the hazardous area, both impermanent options. A site's having too little or too much contaminated material is often cited as a reason for not choosing a permanent treatment technology. Too little material and too much material both mean high cost for treatment relative to costs for nontreatment alternatives, but cost alone should not guide decisions.

Describing a cleanup technology as a "treatment" can be misleading. SARA sees a treatment as a technology "that, in whole or in part, will result in a permanent and significant decrease in the toxicity, mobility, or volume" of hazardous materials "to the maximum extent practicable," but SARA's "treatment" allows much interpretation. Furthermore, EPA has not established a hierarchy of preferred results and types of treatment.

Not all treatments accomplish the same things. For example, thermal destruction and some biological and chemical treatment can irreversibly destroy or detoxify nearly all of some toxic substances and therefore reduce their mobility and volume. But a number of physical and chemical treatments can separate organic and inorganic materials and release the hazardous material collected and concentrated to the environment (e.g., air stripping) or place it in a landfill (e.g., carbon adsorption, precipitation, soil washing, solvent extraction). The preferred use of separation technology uses treatment to destroy the hazardous material collected.

Chemical fixation, stabilization, and solidification treatments usually only reduce mobility, particularly for toxic metals, (but usually increase volume) and they nearly always leave some uncertainty about long-term effectiveness because laboratory tests can neither fully duplicate field conditions over long periods nor establish what actually is happening to the contaminants.[12] EPA has said that "There is, at present, no set protocol for evaluating the efficacy of stabilization technologies."[13] The use of stabilization technologies for high levels of organic contamination is particularly unproven.[14] A recent EPA review of stabilization technology said:

> Although S/S [solidification/stabilization] technologies have been used for more than 20 years, there exists little information on long-term physical durability and chemical stability of the S/S mass when placed in the ground .., . Generally, S/S technology is recognized effective for inorganic waste, while organic wastes have the potential to cause problems . . . . The long term effects of organics on S/S performance are important, however, little research has been performed. . . . the capability of the technology to perform satisfactorily over long periods of time has yet to be determined ... , uncontrolled air emissions are a potential problem to workers and the environment.[15]

These EPA views are inconsistent with current EPA decisions that choose stabilization and call them permanent remedies.

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[12] The attractiveness of stabilization type technologies is oftened expressed in noncost terms, such as: "Long term effectiveness of incineration, stabilization, and solidification are comparable." [ARCO Petroleum Products Co., "Critique of Sand Springs Operable Unit Feasibility Study," Aug. 31, 1987.)

[13] L. Weitzman, L.E. Hamel, and E. Barth, "Evaluation of Solidification/Stabilization As A Best Demonstrated Available Technology," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.

[14] For example, a recent EPA study found "large losses of organics during the mixing process" [L. Weitzman et al., op. cit.]. Another EPA study showed that stabilization was not competitive with thermal and chemical treatment technologies and soil washing for organic contamination [R.C. Thurnau and M.P. Esposito, "TCLP As A Measure of Treatment Effectiveness: Results of TCLP Work Completed on Different Treatment Technologies for CERCLA Soils," paper presented at EPA's *Fourteenth Annual Research Symposium,* May 1988]. A demonstration of a stabilization technology under EPA auspices concluded that "for the organics, the leachate concentrations were approximately equal for the treated and untreated soils" [P.R. de Percin and S. Sawyer, "SITE Demonstration of Hazcon Solidification/Stabilization Process," paper presented at EPA's *Fourteenth Annual Research Symposium,* May 1988].

[15] C.C. Wiles and H.K. Howard, "U.S. EPA Research in Solidification/Stabilization of Waste Material," paper presented at EPA's *Fourteenth Annual Research Symposium,* May 1988.

Box 2.-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 (chemical fixation) technology was selected to treat in situ highly contaminated subsurface soil, which previous removal actions had left below the water table and covered up with gravel. No treatability study was used. The cost of incineration was overestimated. The cleanup will leave untreated contamination onsite.

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

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

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

Capping of the site and a hydraulic containment system to pump and treat some contaminated groundwater 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 diverse contaminants at the site. The ROD said that no estimate could be made for the duration of the cleanup.

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

Excavation of contaminated soils and wastes (which were buried in a previous removal action) and their disposal in an unlined 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 contaminants 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 contamination and to stop and treat contaminated 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 radioactive soils, but its use for chemically contaminated sites is still unproven. In situ vitrification was selected—without treatability test results-chiefiy because its estimated cost was about half that of onsite incineration. But the estimated cost for incineration is probably high by a factor of 2. incineration offers more certainty and probably would cost no more than the chosen remedy. Groundwater will be pumped and treated by air stripping and carbon adsorption.

Case Study 7
Renora, Inc., Edison Township, New Jersey
EPA Region 2; NPL #3781770
Estimated cost: $1.4 million

The selected remedy makes use of offsite landfilling for soils contaminated with PCBS. Also, biological treatment was selected for soils contaminated with diverse organic compounds and toxic metals and for contaminated groundwater, but no treatability 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 on site 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 he used if solidification technology is not successfully demonstrated or fails after solidified material is landfilled on the floodplain site, but criteria for failure are unspecified.

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

A simple compacted earth cover over the soil contaminated with lead and chromium was selected. Solidification/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 treating contaminated groundwater.

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

NO treatabilty study results supported the selection of chemical stabilization. Significant amounts of untreated contaminants as well as the treated materials will be left onsite. The effectiveness of the treatment is uncertain. Incineration was said to offer no better protection and was rejected because of its higher cost.

Moreover, a cleanup may consist of many different operations in which treatment may be only a small part. Removal actions may send hazardous waste to landfills, perhaps much more than may be treated subsequently. Or action may be taken on contaminated soil but not on contaminated groundwater or vice versa. Too many RODS assume that any use of any technology is a treatment that meets the letter and spirit of the statutory requirement. General Superfund statistics on treatment can be misleading because they do not distinguish among different technologies used at a site for different amounts of material.

There is no clear line between sufficient and insufficient technical and economic data for selecting among cleanup technologies. A ROD may choose an unproven or inappropriate technology or both with the claim that it is a permanent remedy, or a ROD may eliminate a technology because it remains untried on a large scale. It is not uncommon to have a multimillion-dollar cleanup decision made without any technical data to support it, either from the technical literature or from tests done on site material.

Information used to compare treatment technologies is often inaccurate and incomplete. Poor information compromises the RIFS, the selection of remedy, and public support of certain remedies. Alternative treatment technologies that are practical are sometimes ignored or not chosen. Costs for innovative technologies may be unreliable, either too low or too high. Good or bad experiences at other sites are not studied. An example is the failure, discovered in 1985, of chemical stabilization treatment at the Conservation Chemical Co. site after only a few years of use; nevertheless, RODS are selecting chemical stabilization for similar problems more than ever before.

Contractors may quote a wide range for direct costs per unit of material treated for any given treatment technology. For example, quoted unit costs of onsite incineration ranged from a low of $186 per cubic yard for Seymour Recycling to $730 per cubic yard at Pristine for the same amount of treated material; both sites are in the same EPA Region. 2 Le unit cost quoted for mobile, onsite incineration in the Chemical Control case in New Jersey and at the Pristine case in Ohio (where the technology was rejected) was twice the unit cost used at the Davis Liquid Waste site in Massachusetts (where the technology was selected). At the Chemical Control site, both $500 and $750 per cubic yard unit costs were quoted for two cleanup alternatives using the same onsite incineration. In both cases, the material burned was essentially the same and the type of incineration technology was the same (the difference in the options was where the residuals were disposed).

Such variations make it hard to establish a technology's cost-effectiveness—or lack of it—relative to other technologies. Even when a contractor uses the same burden rate (see below) among ROD cleanup alternatives, inaccurate unit costs can distort the comparative analysis. For example, with Pristine, if direct cost had been $186 per cubic yard instead of $730 (with the same 83 percent burden), the total cost for incineration would have been $15 million, not $51 million; Pristine had rejected incineration and selected in situ vitrification for $22 million. If total estimated costs have any effect on post-ROD activities, then actual cleanup costs for clients—and profits to contractors—may vary substantially and some may be much greater than they could be.

Contractors estimate cleanup costs by adding to direct costs substantially different levels of indirect cost (burden or markup). In the Pristine case, the burden—various contingencies, construction services, and design costs—amounted to 83 percent of direct costs, while for Davis and Re-Solve, involving the same RIFS contractor, the burden was 35 percent; the Davis and Re-Solve indirect costs explicitly included pilot study work, while the costs for Pristine did not. For Seymour Recycling, the burden was 60 percent; for Chemical Control, 56 percent; and for Crystal City, 29 percent. The range in burden rates over different sites and across and within contractors illustrates an important management problem in Superfund.

RODS cannot always depend on the results of tests done for other sites. Treatability studies refer to tests on site material and are supposed to bridge the gap between general information about the technology and the more specific information needed for technology selection in the ROD. Results of treatability studies on one site, particularly for innovative technologies, do not necessarily mean that a given treatment will work or not work for some other waste site, unless the conditions are nearly identical or the technology's performance is not waste specific. The problem is that some technologies are very waste specific, and it is impossible to accurately extrapolate positive test results from one waste to another, especially because Superfund sites often have very complex, site-specifc wastes. Incineration of organic contaminants is nonspecific, whereas biological treatment is quite waste specific. Onsite treatment technologies (in which the waste is brought to the technology) perform more predictably than in situ technologies (in which the technology is brought to the waste) because the latter's effectiveness depends on site conditions, such as chemical, physical, and biological properties of the soil. These can vary widely from site to site.

When they are done, most treatability studies are not done early enough. It is critical that they be done during the RIFS ***before*** the ROD, but most are done during the design phase ***after*** the ROD. Treatability studies will improve the RIFS by providing technical data to support the ROD's analysis of cleanup alternatives and to ensure that the ROD'S cleanup choice is effective and satisfies statutory requirements. However, EPA now often speeds up RODS, apparently to meet fiscal year goals; thus treatability tests during the RIFS are sacrificed. This sacrifice can backfire. Negative test results after the ROD would indicate the wrong technology choice and the waste of a lot of time and money. Worse, altering a ROD at this point, even for good reasons, may meet some resistance. Finally, when responsible parties or technology companies conduct these tests, EPA may need to assure their objectivity by independently verifying the results.

Some RODS choose technologies that are in EPA's Superfund Innovative Technology Evaluation (SITE) program, an indication that a technology has not yet been proven. For example, the Chemical Control ROD chose a new type of in situ stabilization, the Pristine ROD chose in situ vitrification, and the Sand Springs ROD chose a stabilization technique in the S&E program. If, as EPA says, the SITE program exists to obtain "sound engineering and cost data" and to "resolve issues standing in the way of actual full-scale application, " then how can such ROD selections be justified? If they are justifiable, are the SITE demonstrations really necessary?

The chemical character and complexity of site contaminants and how they affect the use of some technologies do not get enough attention. A few indicator compounds, used to represent all site contaminants for risk assessment, may be inappropriate for technology evaluation because physical and chemical properties may differ from the way health effects vary. The result can be a poor technology choice. Also, site sampling may be insufficient to detect hot spots of contamination that would facilitate using limited treatment to cut cleanup costs. In addition, groundwater monitoring may not be reliable.

Impermanent Technologies

When wastes are left in the ground or in groundwater or are redisposed in a landfill, a ROD may claim that the remedy is permanent when, in fact, it is not. Permanence may be claimed even when technical factors suggest a high probability of failure, that is, of release of hazardous substances, and of another cleanup. In such cases, the ROD would be more credible if it acknowledged the remedy as impermanent and defended it on its own merits relative to truly permanent ahernatives. Moreover, an impermanent remedy and a false sense of security could lead! for example, to land use that would only complicate future cleanup and pose unacceptable risks.

Contrary to the law, containment/land disposal decisions seldom analyze the risk of future failure, damages, and further cleanup. While some RODS claim that containment/land disposal techniques are proven and reliable technologies with no implementation problems, there is evidence to the contrary. For example, the RCRA clay cap being installed at the Winthrop Landfill Superfund site in Maine failed in September 1987 before its construction was completed. The ROD of November 1985 said the technology was proven, routinely used, and posed no construction difficulties. There had been no analysis of potential failure; under the original Superfund statute-the Comprehensive Emergency Response and Liability Act of 1980 —such analysis was not required. Under SARA it now is.

Sometimes a **ROD** does not commit to a definite outcome even though it appears to have selected a technology. Contingencies, uncertainties, and multiple future options do not assure the public that there will be a permanent remedy and that it will be fully implemented in a timely and effective way. Often, the ROD does not provide specific technical criteria for subsequent decisions, such as for groundwater cleanup or land use, nor are there necessarily assurances of independent validation of data and effective EPA oversight of activities by responsible parties and contractors. Specific groundwater monitoring requirements are particularly important because recent EPA research has found that "low sampling frequency coupled with the generally smaller sampling networks suggest that efforts to characterize groundwater contamination at [Superfund] sites may be inadequate.

Impermanent remedies, which provide less protection than permanent ones and do not assuredly meet cleanup goals, are often selected purely because they are cheaper in the short run; in the long run they are very likely to be more expensive. Regarding cost-effectiveness, when two or more cleanup options offer the same level of environmental protection and can meet established cleanup goals (from risk assessment or existing regulatory standards), everyone will agree that the lowest cost option should be chosen. Impermanent technologies are not cost-effective remedies and do not satisfy SARA, therefore, when permanent technologies are practical. The average estimated cost of the cleanups in the six good RODS noted earlier was $20 million. In contrast, the average estimated cost of not-so-good cleanups in the 10 case studies below was $12 million. (In the 10 case studies, the average for the five treatment remedies is $16 million and the average for the nontreatment remedies is $7.5 million.) It is true that a permanent cleanup based on treatment technology is likely to require a larger initial outlay than an impermanent cleanup based on land disposal. Even a modest cost difference can mean a lot added up over thousands of sites.

EPA is less responsive to community concerns about a remedy being impermanent than to interests which favor a lower cost impermanent remedy. Thus community concerns about impermanence are not very likely to lead to a more expensive cleanup technology. There are many incentives for various parties to keep cleanup costs low by using onsite containment/land disposal or even some relatively inexpensive forms of treatment, such as stabilization and separation technologies. These parties include potentially responsible parties (PRPs) that may have to pay for the cleanup, States that have to provide 10 percent of the cost (unless PRPs pay), and EPA which wants to distribute available funds as broadly as possible and which wants to obtain settlement agreements with PRPs to reduce calls on Superfund money.

In selecting cheap, impermanent remedies, claims of comparable estimated costs may hide the truth that low cost was the key deciding factor. Getting accurate costs to compare cleanup alternatives is crucial. Overestimates or underestimates may be used to justify a choice or a rejection. For example, at the Conservation Chemical Co. site in Missouri, where a settlement with PRPs was involved, an EPA contractor and the State recommended one remedy (rejected) which was said to cost $24 million over another remedy (selected) which cost $21 million. But available EPA data suggest that the rejected remedy would actually cost from $40 million to $150 million.

[18] R.H. Plumb, Jr., "A Comparison of Ground Water Monitoring Date From CERCLA and RCRA Sites," *Ground Water Monitoring Research,* fall 1987, pp. 94-100.

Program Efficiency

EPA pushes most RODS to completion by the end of the fiscal year and this kind of bureaucratic pressure can lead to poor cleanup decisions. To meet deadlines, EPA may reemphasize public comments that would otherwise lead to reevaluation of facts and technologies; EPA may make a hasty, technically unsupported decision as it did at the Sand Springs site in Oklahoma. Typically, there is less than one month between the end of the public comment period and the issuance of the ROD. (See table 1 for summary data from the 10 case studies on times to reach certain stages in the cleanup process.) The RIFS may also suffer from hurried review by EPA because of pressure to issue a ROD by the end of the fiscal year or quarter.

The pm-remedial process has received little attention even though sites can be releasing hazardous substances into the environment and, during the time they are unexamined and unattended, get worse. The time from site identification through placement on the NPL is about 3 years for the case studies (and often much longer for other sites examined by OTA).

The time between a site's placement on the NPL and the start of the RIFS varies greatly, averaging about 16 months. Nationwide, there is no apparent relationship to the site's HRS score; a high score does not necessarily speed cleanup (e.g., three sites with similar high HRS scores waited 39, 15, and 3 months). For sites within an EPA Region, however, the HRS score does seem to matter; this time the waiting period decreased with decreasing score or hazard level (e.g., in Region 6, the HRS scorehime to RIFS start were 47/39, 32/12, and 29/-3).[17] That is, the more hazardous the site according to the HRS, the longer it takes to start the RIFS on the site. This seems opposite to what might be desirable; but in Region 6, the French Limited site ROD said that "The position (rank) of a site on the [National Priorities] list is inconsequential."

The **RIFS** process, from start of the studies through issuance of the ROD, takes from 2 to 3 years. Within this time, early decisions to eliminate some technology alternatives and perform treatability studies for others could be, but usually are not, made. Studying more technologies than necessary increases the time and cost of the RIFS, makes it more difficult to decide to do treatability testing on the most viable tech-

[17] The last score/time is an example of a site for which the RIFS was started 3 months *prior* to the site's placement on the NPL.

Table I.-Times for Sites To Reach Points in the Superfund Process[a]

	Average	Range
From entry into Superfund inventory until:		
Preliminary Assessment completion	18 months	1-45
Site Inspection completion	21 months	1-44
Placement on National Priorities List	36 months	4-75
Start of RIFS	44 months	20-68
Completion of RIFS	75 months	47-103
Signing of ROD	81 months	50-104
Completion of ROD remedy (ESTIMATED)	10 years	6-20
Between Preliminary Assessment completion until:		
Site Inspection	14 months	O-39
Placement on NPL	32 months	3-73
Start of RIFS	42 months	13-68
Between placement on NPL and start of RIFS	16 months	–3-39
Duration of RIFS:		
Studies	32 months	21-38
Total period (studies through ROD)	34 months	24-39
Between signing of ROD and ROD estimate of completion of remedial action	38 months	20-120
Duration of public comment period.	33 days	24-44
Time between end of public comment period and signing of ROD.	34 days	15-122

[a] Based on the 10 case studies in this OTA special report.

nologies, and sometimes contributes to poor RODS.

After the ROD, actual cleanup action, including remedial design, takes 2 to 3 years, Sometimes there are repeated RODS and new actions on different parts of the cleanup (called operable units) and sometimes on the same part of the cleanup.

The entire process from site identification through final (estimated) remedial cleanup can frequently take about 10 years. Unexpected findings sometimes complicate the process. For example, remedial cleanup stopped at the Conservation Chemical site in Missouri and at the Re-Solve site in Massachusetts when new information about the sites' contamination showed a need for more studies, another ROD, and new cleanup strategies. Some risks to health and environment are likely during such long regrouping periods. Contaminants are likely to migrate from areas of high to low concentration, increasing the extent and complexity of cleanup, particularly for groundwater.

Risk Management and Cleanup Goals

There are often problems with how risks are assessed and how cleanup goals are met. Different levels of risk maybe used and very different cleanup technologies may be said to be comparable, because EPA allows a broad range from 1 in 10,000 to 1 in 10 million excess lifetime cancer risk.la Sometimes compromises are made to reduce cleanup cost by allowing a higher risk than the 1 in I million cancer risk commonly used in Superfund. A cleanup can be deemed complete even though significant contamination remains onsite or migrates offsite. Regarding cleanup goals, a cleanup technology can be justified in superficial ways. Hazards (the source of the risk) may not be eliminated through permanent technologies but exposures to the hazard—i.e., the risk—may be reduced through impermanent actions, such as capping a site, or institutional controls, such as deed restrictions that have uncertain future implementation.

RODS do not consider cumulative exposures and risks from multiple sources of similar hazardous substances. Cleanup levels may look acceptable on a site basis but might not when two or more Superfund sites are close together. An example is the two Superfund sites in Oklahoma on opposite sides of the Arkansas River; neither ROD evaluates risks from the other site. Environmental risks seem to take a back seat to bureaucratic definitions of Superfund sites and to constraints imposed by seeking funds from responsible parties.

The risks of transporting hazardous materials offsite for land disposal or even treatment are not considered. Furthermore, SARA's requirements to use permanent treatment technologies are not applied by EPA to waste sent offsite. The ROD can say that the cleanup will be permanent, even though the site was originally a land disposal facility, and the wastes are slated for a landfill that itself might become a Superfund site. Moving hazardous waste from one hole in the ground to another is the nonsolution that was behind SARA's preference for permanent cleanup. For the purpose of many Superfund cleanups, EPA's assumption seems to be that hazardous waste sent to a regulated landfill will never fail and require cleanup even though there is widespread agreement, even within EPA, that landfill technology will ultimately fail. There are also many widely recognized uncertainties about regulatory compliance and future corrective action.

Most RODS seem uncertain about or do not address future land and water use in judging whether a selected remedy will be safe and permanent. In some cases, there is a lot of interest in reusing the land for productive purposes. For example, at the Schmalz site in Wisconsin, where contaminated soil is to remain in place, the ROD makes no land use restrictions. Any remedy that leaves hazardous waste in place or caps it suggests the need for explicit attention to future land and perhaps groundwater use.

[18]**Cancer** risk assessment is not the only way cleanup goals **are** established. Current regulatory standards for acceptable levels of contaminants are also used, but these are not available for many contaminants. When risk assessment is used, probable, worst case, or other levels of risk are calculated. Sometimes **pre-**cleanup risks are also calculated.

The Record of Decision Document

The technical content and quality of RODS varies substantially across and within EPA Regions. Supporting RIFSS generally lack citations to the technical literature, important data, and discussions of actual experiences, good and bad, at sites that have used the technologies under consideration. Multimillion-dollar decisions are often made without any significant technical data to support them. A ROD may drop or choose a cleanup technology with little or no discussion or justification.

Probable causes for the meager level of technical detail are: enormous public pressure to clean up sites sooner; attempts to compensate for delays; bureaucratic pressures to produce RODS faster; poor contractor performance; lack of central, national oversight; and some attempts to carry out activities after the ROD when there is less public scrutiny. Conflicts of interest also may be a problem. Does the RIFS contractor own a cleanup technology or will it or some affiliated company stand to profit if a particular cleanup technology is selected? Is the RIFS contractor also a responsible party at the site? Does a responsible party own the cleanup technology selected for the cleanup?

EPA Regions are not using a standard format for RODS. Lack of uniformity makes RODS difficult to analyze and compare for oversight and quality control purposes. Of particular importance is the way alternative cleanups are evaluated. Different criteria are used.[19] Sometimes the evaluation focuses on each alternative separately with very little comparison. When comparative analysis is used, it often is superficial and qualitative or semi-quantitative with only rankings for alternatives.

Even for a technical expert, the basis for a cleanup decision is often hard to understand; the public has an even greater problem. RODS often lack much key information, such as test data, other nearby sources of contamination, earlier actions, or even an earlier ROD. In hindsight, earlier actions are frequently ineffective from a longer term perspective and often make subsequent attempts to permanently clean sites more costly and difficult. At the Crystal City site in Texas, for example, a previous action buried hazardous materials which must now be excavated and re-buried onsite in a final cleanup. The ROD offers an opportunity—not yet used—to evaluate past site actions and to learn from them.

Sometimes **a remedy and its implementation constitute a research or demonstration project because there is no treatability** study data or the technology isn't proven for the site. But the cleanup is not publicly presented as experimental or highly uncertain. While the technology selected may, in some cases, make sense, the public may ultimately think it unfair of the government to hide the uncertainty and risk. Moreover, making the claim that a permanent remedy has been selected is questionable if the technology is experimental.

[19] A July 1987 directive from EPA's Assistant Administrator for Solid Waste and Emergency Response outlined nine "key criteria which should be considered in evaluating and comparing alternatives." An earlier directive contained essentially the same evaluation criteria, although they were not presented as clearly. [U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, directives 9355.0-21 (July 24, 1987] and 9355.0-19 (Dec. 24, 1986)].