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RISK ASSESSMENT AND REMEDIAL TECHNOLOGY EFFECTIVENESS AT SUPERFUND SITES

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ABSTRACT

Although the protection of public health is one of the primary goals of the Superfund program, the program's success in achieving risk reduction has been difficult to determine thus far. However, evidence to date suggests that risk reduction is not being effectively integrated into the remedial action decision process in spite of the change of program philosophy since the passage of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and the advances made in the field of risk assessment in recent years. Defining risk, using risk assessment as a priority-setting tool, and defining risk reduction within the confines of both the current state of technology and the resources available with which to address risk are essential components of the decision process. Although risk assessments are conducted at Superfund sites, risk assessment has not been used effectively as a priority-setting tool. Many decisions to remediate are made where no current exposure exists and potential risk is not well-defined. At the same time, the majority of remedial alternatives are selected without evidence of their effectiveness in meeting health-based cleanup goals, even at sites which pose a threat to human health. Recent analyses of the effectiveness of treatment remedies suggest that treating contaminated media to health-based cleanup goals is considerably more difficult than originally expected. Thus, Superfund policy-making should focus on determining when health-based cleanup goals are necessary and when attaining such standards is feasible.

INTRODUCTION

A number of issues have been raised regarding the effectiveness of the Superfund program during its first decade of implementation. Although the original emphasis of the program was on short-term remedies, the Superfund Amendments and Reauthorization Act of 1986 (SARA) established more stringent expectations for the program both in terms of the pace of the program and the types of remedies selected. The central requirements are that remedial alternatives be "protective of public health and the environment" and "significantly and permanently" reduce the toxicity, mobility, or volume of contaminants. The mandate also requires that potential risk be considered in the decision-making process. Legislation, however, has not provided easy solutions to the historical hazardous waste problem. Terms such as *protective*, *permanent*, and *potential risk* have not been clearly defined by either Congress or the EPA, and the program appears to suffer from a basic inconsistency between what society wants and what technology can provide.

The degree of public health risk reduction achieved as a result of the Superfund program has been difficult to determine thus far. However, several indicators of effectiveness can be examined. Reducing public health risk involves not only defining risk, but it also involves using risk assessment as a priority-setting tool and defining risk reduction within the confines of the current state of technology and the resources available with which to address risk. Recent analyses of Records of Decision (RODs)[1,2] and subsequent analysis of remedial action implementation suggest that the current system is not effectively integrating risk reduction into the decision process. Many decisions to remediate have been made at sites where no current exposure exists and potential risk is not well-defined. Remediation to health-based standards has been selected for almost all NPL sites without a systematic framework for using risk assessment as a priority-setting tool. At the same time, the majority of remedial alternatives have been selected without evidence of their effectiveness in meeting health-based cleanup standards, even at sites which pose an urgent threat to human health.

Not only are incomplete or inadequate rationales for selection provided in the RODs, but some of the treatment remedies currently being implemented do not appear to be providing cost-effective solutions to the Superfund problem. Retrospective evaluations of the pump and treat remedy for contaminated ground water indicate that aquifer restoration to health-based standards is not achievable within a reasonable time frame given the current state of technology. Moreover, few source treatment technologies other than incineration have been successfully implemented at Superfund sites thus far. This central weakness in the basic framework of the Superfund program has resulted in the spending of millions of dollars with little to show for it in the way of permanent remediation of hazardous waste sites.

RISK ASSESSMENT AND THE DECISION PROCESS

Although the Superfund remedial action decision process is a complex process that involves a variety of technical, political, and economic considerations, the primary goal of site remediation is the protection of public health. Therefore, assessment of the presence and magnitude of public health risks under baseline (no-action) conditions is a key element of the decision-making process. Travis and Doty found that risk assessment is indeed a central element of the Superfund decision process.[1,2] A quantitative baseline risk assessment had been conducted for at least one medium for 72 percent of sites where a remediation decision had been made. Thus, the central question is not *whether* risk assessment is being used at Superfund sites, but *how* it is being used.

Risk assessment is the cornerstone of EPA's current decision-making process. However, it plays a limited role in defining cleanup priorities. Although only 11.5 percent of sites on the NPL involve actual or potential current human exposure,[3] 88% of all sites reviewed by Doty and Travis[1,2] were remediated. Seventy percent of all these sites have current risk levels in the 10^{-4} to 10^{-7} range, the same range that the EPA targets as acceptable after remediation (Figure 1). Although estimates of future risks are often high, these estimates are based on hypothetical exposure scenarios. Furthermore, little correlation exists between risk levels and decisions to remediate. All sites with contaminated soils remaining on-site were remediated, regardless of risk levels or the likelihood of migration to ground water. Risk ranges for contaminated ground water were essentially identical for sites that were remediated and those that were not. Remediation decisions appear to be driven more by cost, EPA policy, compliance with state and federal environmental regulations, and professional judgment than by current or future risk levels.

RISK REDUCTION AND REMEDIAL ALTERNATIVE SELECTION

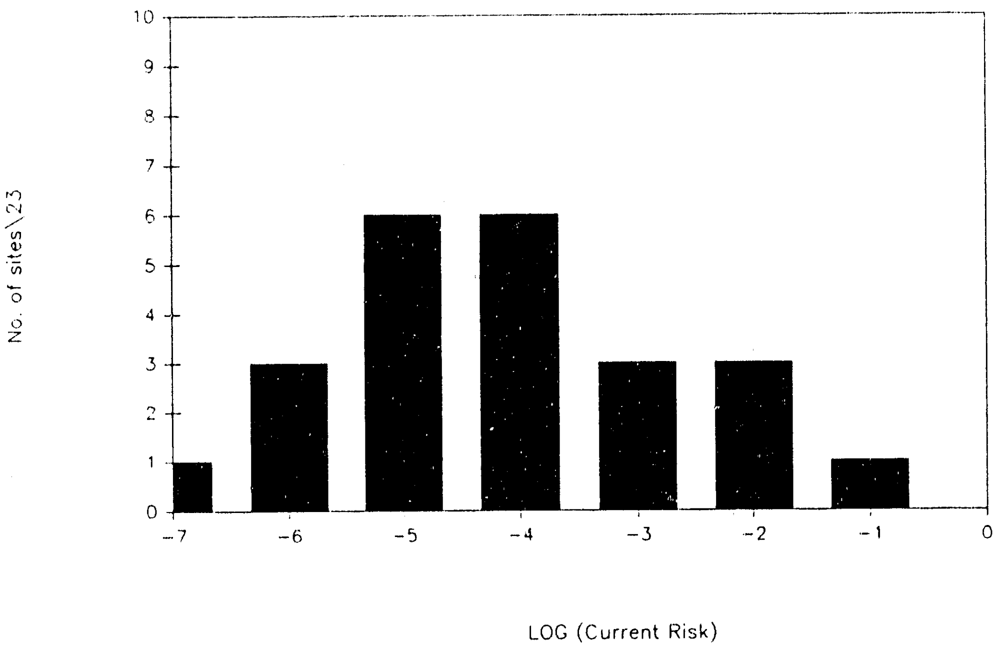
The selection of effective remedial alternatives is an essential element of risk reduction. Risk reduction can be achieved at hazardous waste sites in two primary ways: by containing or isolating the waste to prevent human contact or by reducing the toxicity, volume, or mobility of the contaminants through treatment. Containment remedies, although they may provide short-term risk reduction, are not permanent solutions. Treatment remedies may, in theory, provide permanent risk reduction; however, treatment does not necessarily constitute a permanent remedy. The treatment process may involve the transfer of contamination to another media or may not result in the reduction of concentrations to health-based levels.

SARA's preference for the selection of permanent remedies has resulted in the selection of more treatment remedies over the past few years. However, setting health-based cleanup goals and selecting treatment alternatives have essentially been two disparate components of the decision-making process. During fiscal year 1987, although 58% of source RODs selected treatment for at least a portion of the site, only 19% selected remedies that utilize a proven treatment technology to the maximum extent practicable. The effectiveness of the remaining treatment technologies was uncertain. Sixty-eight percent of all sites for which final source and/or ground water remedial components were selected required additional studies to confirm the extent of contamination, the effectiveness of the technology, or its applicability under the site conditions.[1,2] Thus, the lack of established treatment technologies has resulted in the turning of Superfund sites into field laboratories.

GROUND WATER RESTORATION AND THE DECISION PROCESS

Remedial action decisions addressing ground water contamination through fiscal year 1985 primarily consisted of containment of the contaminant plume or provision of an interim drinking water supply. Only 14% of the decisions addressed aquifer restoration. The average cleanup time predicted in these decisions was one to five years, although the cleanup times were subject to extension because toxicological data were lacking for many of the priority pollutants and thus, cleanup standards were often not available.[4] The feasibility of aquifer restoration using ground water pumping and treating was assumed based on limited theoretical, laboratory, and field studies.

The number of decisions selecting aquifer restoration as a remedial objective increased during fiscal year 1986, and approximately 68% of remedial action decisions addressing ground water contamination during fiscal year 1987 involved aquifer restoration.[1] Quantitative cleanup goals were established for all of these sites based on applicable or relevant and appropriate requirements (ARARs) or health-based goals derived from site-specific risk assessments. This trend reflects not only the change in program philosophy and the progress made in the field of risk assessment, but it also illustrates the prevailing view among environmentalists and Superfund managers that ground water contamination can be cleaned up through ground water pumping. Although more quantitative toxicological data were available, thus facilitating the



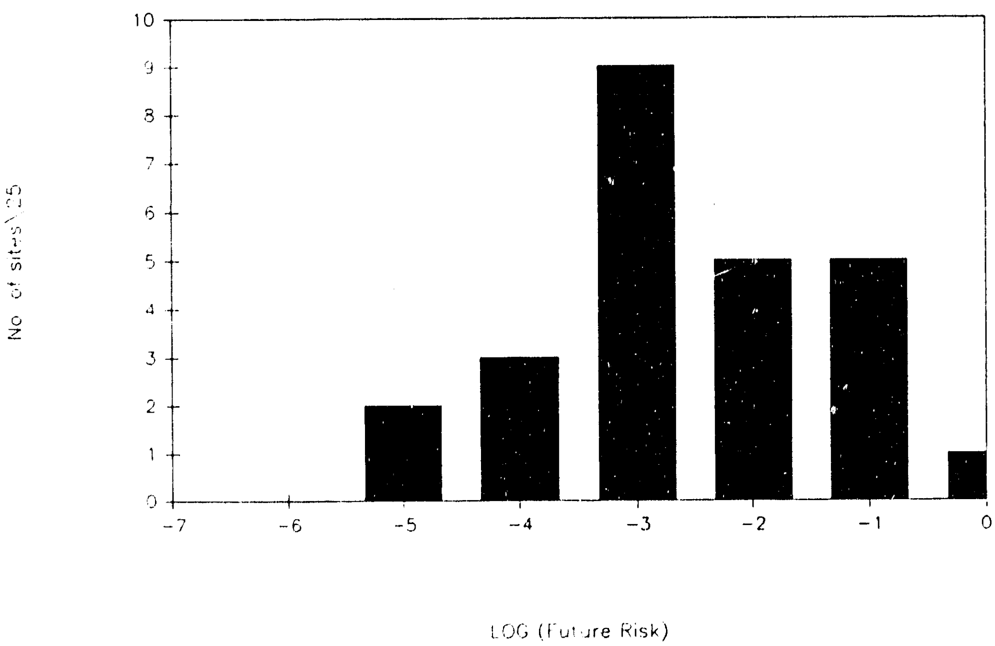


Figure 1. Total Baseline Cancer Risks for Decisions to Remediate

establishment of health-based cleanup goals for ground water, the effectiveness of the pump and treat remedy was no more certain than it was in earlier decisions.

In the 1987 decisions, rationales for predicting the effectiveness of pumping and treating to restore aquifers to the cleanup levels established in the RODs were not well-supported, even at sites where actual exposure to contaminated ground water existed and final remedies were selected. The predicted effectiveness of this method was questionable at these sites for one or more of the following reasons:

1. Effectiveness and permanence of the source remedy selected was uncertain.

2. Extent of ground water contamination had not been confirmed, and additional studies were needed.

3. Contributing sources of contamination had not been determined or fully characterized.

4. Further studies were needed to determine applicability of technology to site conditions.

5. Hydrogeological uncertainties were associated with pumping and treating.

EFFECTIVENESS OF PUMPING AND TREATING FOR AQUIFER RESTORATION

Recent studies suggest that aquifers cannot be restored to drinking water standards through pumping and treating. Leading ground water scientists have predicted that continuous pumping for as long as 100 to 200 years may be needed in order to lower concentrations by a factor of 100, assuming the ideal conditions of a totally dissolved contamination in a homogeneous aquifer.[5-7] Aquifer restoration is less reliable at sites involving non-aqueous phase liquids (NAPLs) that either float on top of the water table or sink to the bottom of the aquifer. At best, even if eventual restoration is conceivable, it is impossible to predict how long pumping and treating will take to restore an aquifer.[5] In spite of this observation, aquifer restoration is the remedial objective at approximately 93 percent of the sites which are known to involve NAPLs.[8] The director of EPA's ground water research laboratory in Ada, Oklahoma has pointed out that restoration could take thousands of years for water-insoluble constituents such as jet fuel.[6]

Seventy-six percent of Superfund pump and treat decisions involve trichloroethylene (TCE), the organic contaminant that most frequently drives decisions to remediate. The mean TCE concentration at Superfund sites is 850 ppb,[1] and the Maximum Contaminant Level (MCL) for TCE is 5 ppb. Thus, greater than 99% of the mass of TCE must be removed in order to meet drinking water standards at the average Superfund site. Since TCE is denser than water, the likelihood of extensive dense NAPLs (DNAPLs) at these sites is great, and thus far, little success has been achieved in locating DNAPLs, much less extracting them. When large pools of dense NAPLs are present at the bottom of an aquifer, meeting drinking water standards is unachievable at any cost.[9]

Direct experience in pumping contaminated aquifers over the past 10 years illustrates this problem. A recent EPA study involving 19 sites where pumping and treating had been ongoing for up to 10 years concluded that although significant mass removal of contaminants had been achieved, there had been little success in reducing concentrations to the target levels.[8] The typical experience is an initial drop in concentrations by a factor of two to ten, followed by a leveling out with no further decline. When the pumps are turned off, concentrations rise again.

Ground water at the IBM Dayton hazardous waste site in New Jersey was contaminated with approximately 400 gallons of VOCs, primarily 1,1,1-trichloroethane (TCA) and tetrachloroethylene (PCE), with maximum ground water concentrations ranging from 9,590 ppb for TCA to 6,132 ppb for PCE.[8] Pumping with an average onsite extraction rate of 330 gpm between 1978 and 1984 lowered VOC concentrations to below 100 ppb. However, subsequent to shutdown of the operation in 1984, PCE concentrations rose to 12,558 ppb in 1988. Pumping was resumed in 1989, but the remedial objective was changed from restoration to containment. Thus, despite extensive ground water pumping, this site is no closer to remediation than it was 12 years ago.

The objective of the pump and treat operation at the Savannah River Plant in South Carolina has also been changed from restoration to containment and mass reduction. Permeable and impermeable layers were contaminated with up to 464,000 gallons of solvents. No significant reduction in the size of the plume has been observed after 5 years of pumping. Although concentrations have been reduced by as much as 96% in some wells, this reduction still results in concentrations of 10,000 ppb.[8,10]

SOURCE TREATMENT TECHNOLOGIES

Although no cleanup standards currently exist for contaminated soils at Superfund sites, the National Contingency Plan (NCP),[11] EPA's primary Superfund policy directive, specifies that remedies should achieve reductions of at least 90 to 99 percent in the concentration or mobility of contaminants. However, it also states that treatment technologies must achieve site-specific cleanup levels which may be more or less than these guidelines. Fifty-one percent of 1987 RODs established quantitative cleanup goals for contaminated soils based on site-specific risk assessments.[1] Although remediating contaminated soils to health-based levels is not always feasible or necessary, the effectiveness of treatment technologies in meeting health-based cleanup goals is still an area of uncertainty.

We compiled results of bench-scale, pilot-scale, and full-scale operations for TCE for a group of soil treatment technologies.[10,12] We also compiled the initial soil concentrations and cleanup goals for TCE for a group of RODs signed between 1985 and 1989.[10] Based on these concentrations, we compared the removal efficiency required to meet soil cleanup levels at the average Superfund site to the removal efficiencies for the treatment technologies evaluated. The results are presented in Table 1. Although TCE data are not available for all currently used treatment technologies, the examples illustrate that few current technologies can meet health-based cleanup goals. Uncertainty can exist, even for technologies the EPA considers to be demonstrated effective technologies for halogenated aliphatic compounds.

DISCUSSION

The present decision-making process reflects an ambiguous approach to addressing risk. Many sites are being cleaned up where no actual human exposure exists and potential public health risk is unlikely. Thus, minimization of the extent of environmental contamination per se seems to play a larger role in the selection of remedial alternatives than does protection of human health. The degree of risk reduction associated with the remedial alternatives considered is rarely evaluated quantitatively, thereby undermining cost-effectiveness discussions. Because the remedial alternatives selected often lack effectiveness and permanence, protectiveness of public health and the environment cannot be expected, even in cases where current human exposure to contamination does exist.

Table 1. Soil Removal Efficiencies for TCE

Immobilization	Low Temp. Thermal		Incineration	Requirement to Achieve Goal	
76%[a]	96%[a]	96%[b]	99.86%[b]	99.67%[c]	99.99%[d]

a ORNL study
b EPA study
c Based on mean of initial concentrations
d Based on maximum initial concentration

RECOMMENDATIONS

To meet the challenge of effectively remediating Superfund sites, we recommend that EPA make a serious commitment to its renewed "worst sites first" policy, balancing a clear definition of worst sites with attainable expectations for addressing these sites. Therefore, Superfund policy-making should focus on the fundamental areas of determining: (1) when health-based cleanup goals are necessary, and (2) when attaining such goals is feasible.

Priorities in the Decision-Making Process

Goals and priorities need to be more clearly defined in the Superfund decision-making process. More emphasis needs to be placed on: (1) immediately identifying and remediating sites that pose a clear and present risk to human health; (2) defining the role of future risk based on hypothetical exposure in the decision-making process; (3) making the extensiveness and effectiveness of remediation correspond with the degree of current and/or future risk; and (4) establishing realistic goals given the state of technology, acknowledging that aquifer restoration is currently not technically feasible and recognizing that attempting to restore the environment to a pristine state is not always necessary.

Effectiveness and Permanence of Remedies

More attention needs to be directed toward determining the effectiveness of remedial alternatives selected. First, quantitative assessments of the degree of risk reduction associated with remedial alternatives should be conducted. Second, EPA needs to accelerate efforts in the areas of both field research and theoretical studies to demonstrate the effectiveness of classes of treatment alternatives under various field conditions. Environmental variables (i.e., soil type, pH, microbial content) should be identified that can be used to predict the effectiveness of a remedial alternative under a given set of environmental conditions. Without such information, EPA will continue to select alternatives for which effectiveness is uncertain.

More emphasis needs to be placed on the selection of permanent remedies where implementation of such remedies is technically feasible, particularly for source control. Since restoring ground water to a condition compatible with health-based standards is difficult, if not impossible, remedial efforts should focus on developing and implementing permanent cost-effective source remedies.

REFERENCES

1. Doty, C. B. and C. C. Travis. "The Superfund Remedial Action Decision Process: A Review of 50 Records of Decision," Journal of the Air and Waste Management Association, 39(12): 1535-1543 (1989).

2. Travis, C. C. and C. B. Doty. "Superfund: A Program Without Priorities," Environ. Sci. Technol. 23(11):1333-1334 (1989).

3. Agency for Toxic Substances and Disease Registry. ATSDR Biennial Report to Congress: Volume 2. U. S. Department of Health and Human Services, Public Health Service, Atlanta, GA, 1988.

4. Haiges, Lisa and Robert Knox. "Groundwater Cleanup at Selected Superfund Sites," Proceedings of the Superfund '87 Conference. Hazardous Material Control Research Institute, 1987.

5. Mackay, D. M. and J.A. Cherry. "Groundwater Contamination: Pump-and-Treat Remediation," Environ. Sci. Technol. (23):630-636 (1989).

6. Hall, C. W. "Practical Limits to Pump and Treat Technology for Aquifer Remediation" in Groundwater Quality Protection Pre-Conference Workshop Proceedings, Water Pollution Control Federation, 1988.

7. Mackay, D. M. "Characterization of the Distribution and Behavior of Contaminants in the Subsurface," in Proceedings of the National Research Council Water Science and Technology Board Colloquium, 1989.

8. Environmental Protection Agency, Evaluation of Groundwater Extraction Remedies, Office of Solid Waste and Emergency Response, EPA/540/0289/054, 1989.

9. Freeze, R. A. and J. A. Cherry. "What Has Gone Wrong?" Groundwater 23(4):458-464 (1989).

10. Office of Risk Analysis. Unpublished draft database. Effectiveness of Treatment Technologies at NPL Sites. Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1990.

11. 40 CFR Part 300. National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule, Vol. 55, No. 46, March 18, 1990.

12. Environmental Protection Agency. Summary of Treatment Technology Effectiveness for Contaminated Soil. Office of Emergency and Remedial Response. Washington, DC (1989).

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