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Paying for permanence: an economic analysis of EPA's cleanup decisions at Superfund sites

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We analyze EPA's cleanup decisions at over 100 Superfund sites and examine whether and how EPA trades off the cost against the permanence of cleanup. EPA's decisions reveal both a preference for permanent solutions and an aversion to cost. For example, EPA prefers incinerating soils to isolating and containing them in place, but not at any price. At larger sites EPA appears willing to accept additional costs of as much as $40 million to incinerate. With regard to environmental equity, we find little evidence that EPA's cost-permanence tradeoff is affected by socioeconomic characteristics in the communities surrounding sites.

1. Introduction

■ In the United States there is currently a heated debate about the amount that should be spent to clean up hazardous waste sites. Businesses, complaining that the cost of cleanups will put them at a competitive disadvantage, have argued that the current system for cleaning up such sites should be reformed. Experts in risk assessment have argued that many of these sites pose only a small threat to human health and the environment. Indeed, expert rankings of environmental problems (USEPA, 1987) place toxic waste sites sixteenth in a list of 31 environmental problems. By contrast, the lay public has ranked toxic waste sites as the number-one environmental problem in the United States, ahead of nuclear accidents, pesticide residues, and the destruction of the ozone layer (Clymer, 1989).

The controversy over hazardous waste sites has in large part been caused by the high cost of cleaning them up. A recent study estimates the average cost of cleanup at

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$27 million per site (USEPA, 1990). If there are indeed 10,000 such sites, the total cost of cleaning them up ($270 billion)—spread over 20 years—would double expenditures on hazardous waste disposal.

What drives the cost of cleanup is how permanently a site is cleaned up. A typical hazardous waste site consists of contaminated surface area (e.g., contaminated soil, a pond into which waste was deposited) and contaminated ground water. At most sites, imminent danger of exposure to contaminants can usually be removed at low cost. Contaminated soil can be fenced off or capped, and an alternate water supply can be provided if ground water is used for drinking. What raises the cost of cleanup is the decision to clean up the site for future generations—for instance, to incinerate contaminated soil or to pump and treat an aquifer for 30 years to contain a plume of pollution.

Under the Comprehensive Emergency Response, Compensation and Liability Act (CERCLA), the U.S. Environmental Protection Agency (EPA) is responsible for deciding how permanent the cleanup at a hazardous waste site will be, at least at those sites deemed serious enough to be placed on the National Priorities List (NPL).[1] In choosing how to address contaminated soils, EPA must determine (1) the size of the contaminated area needing remediation and (2) what remedial technology should be applied. The first of these decisions must protect the health of persons currently living near the site regardless of cost.[2] By contrast, in the second stage of decision making, EPA is directed to trade off permanence against cost.

In this article we study the second stage of decision making. By examining EPA's choice of cleanup option at 110 Superfund sites, (1) we can test whether these decisions reveal a systematic tradeoff between permanence and cost and (2) we are able to infer the value that the agency has implicitly attached to more permanent cleanup options, such as incineration of contaminated soil, versus less permanent options, such as capping of soil. Our purpose in doing so is to examine whether EPA's decisions conform to its mandate to balance cost against permanence and to raise the question, "Is the value that EPA implicitly places on more permanent cleanups the same value society would place on them?"

Our article is thus in the spirit of the growing literature on the revealed preferences of a government bureaucracy (McFadden, 1975, 1976; Thomas, 1988; Weingast and Moran, 1985). As in Van Houtven and Cropper (1996), we ask whether EPA has balanced the costs of environmental protection against the benefits, and we attempt to infer the magnitude of the benefits ascribed to environmental protection (Cropper et al., 1992).

In addition to estimating the value attached by EPA to more permanent cleanups, we wish to see what factors influence the choice of cleanup technology. It is, for example, reasonable that more permanent cleanups would be selected at sites in more densely populated areas, or that soil would be cleaned up more permanently if ground water contamination were a threat. Has this, in fact, been the case?

Finally, we wish to shed some light on an issue that has received much attention in the last several years, but little careful study—the issue of environmental equity. Environmental and other advocacy groups have charged that minorities and the poor suffer disproportionately from the effects of pollution (United Church of Christ, 1987). In the case of hazardous waste cleanups it has been charged (Lavelle and Coyle, 1992) that EPA selects less permanent cleanups in areas that have a high percentage of poor and/or minority residents. These allegations are, however, based on simple correlations

[1] EPA has developed a Hazard Ranking System (HRS) to assess risks at hazardous waste sites. Sites that receive a sufficiently high HRS score are put on the National Priorities List.

[2] It is generally assumed that the risk of an adverse health outcome is directly proportional to the concentration of the pollutant in the soil. The larger the volume of soil addressed, the lower this risk. EPA's guidance states that enough soil must be remediated to reduce risk of death to no more than 1 in 10,000.

between variables that fail to hold other factors constant. We wish to see whether, holding other factors constant, EPA has in fact selected less permanent cleanups in areas that have a high percentage of minority residents or low median household incomes.

To examine these issues we have gathered data on the decisions to clean up 110 Superfund sites. We focus on two types of sites: (1) all wood-preserving sites, where contamination with creosote, a hazardous substance commonly used to treat and preserve wood, is present and (2) selected sites with PCB (polychlorinated biphenyl) contamination in excess of 10 parts per million. We have used the data to model the decision to clean up contaminated soils at these sites.[3] In Section 2 we provide a brief description of the Superfund program and of the data we collected. Section 3 presents a discrete-choice model of the cleanup decision. Section 4 contains empirical results, and Section 5 summarizes our conclusions.

2. A description of the decisions studied

■ **An overview of the Superfund cleanup process.** The decisions we have studied were made under CERCLA, popularly known as the Superfund law. The law requires EPA to maintain a database of hazardous waste sites[4] and to investigate each site to determine the seriousness of its waste problems. If required, the site goes through a formal hazard-ranking process. This evaluates the site's potential to inflict damage through three pathways: ground water, surface water, and air. Sites are scored on the basis of a Hazard Ranking System (HRS), with each site receiving a score between 0 and 100. If the score exceeds 28.5, the site is put on the National Priorities List.[5]

All sites on the NPL are subject to a Remedial Investigation and Feasibility Study (RI/FS). The Remedial Investigation characterizes the wastes at the site and assesses the risks it poses to human health and the environment. In the Feasibility Study, remedial alternatives (cleanup options) are developed and screened. This is the stage at which the costs for the different cleanup options are estimated. These estimates are typically produced by independent contractors and are based on engineering cost models. After the RI/FS, EPA issues a Record of Decision (ROD), which describes and justifies the cleanup option selected by the regional EPA administrator. This is followed by cleanup of the site, after which it is eligible for deletion from the NPL.

At a typical Superfund site, the Feasibility Study must address two pollution problems: ground water contamination and surface contamination—contaminated soils or sludge or contaminated ponds. The usual method of treating contaminated ground water is to pump and treat it. The treated water is either reinjected into the aquifer or discharged into a river or stream.[6] Since the choice of cleanup strategy for ground water varies little from one site to another, we focus on the decision to remediate contaminated soils.

There are two parts to the decision to clean up contaminated soils at Superfund sites: the decision on how large an area to clean up, and the choice of what technology to use.

The first decision—the size of the contaminated area needing remediation—affects current health risks to residents near the site. Typically this decision is stated in terms

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[3] The article is thus distinct from the work of Barnett (1985) and Hird (1990), who have examined the size of EPA allocations at Superfund sites, but not remedy selection.

[4] The database, called CERCLIS (Comprehensive Environmental Response, Compensation and Liability Information Service), currently contains over 33,000 sites.

[5] At the end of fiscal year 1992 there were over 1,200 sites on the NPL.

[6] In some cases the use of an alternative water supply may be chosen instead of a pump-and-treat strategy.

of the concentration of contaminants above which all soil is excavated and/or capped. These concentrations are then mapped into a lifetime risk of death from exposure to hazardous substances at the site. In effect, by determining how much current risk will be reduced, this stage determines the amount of soil to be addressed.

In this article we focus on the second stage of cleanup, namely the choice of cleanup technology. This choice determines the permanence of cleanup. In deciding which technology to employ to clean up the site, EPA has three fundamental options: capping the soil, treating the soil onsite (*in situ* treatment), or excavating the soil. Excavated soil can either be put in a landfill (usually after treatment) or treated more thoroughly. For example, soil containing organic waste can be incinerated. The choice of technology is, essentially, a decision about the permanence of cleanup. The least permanent cleanup is not to excavate soil at all, but to cap it. The cleanup, in this case, will last only as long as the life of the cap. A more permanent solution is to excavate soil and put it in an approved landfill. This prevents exposure via ground water (and other routes) as long as the landfill liner remains intact. An even more permanent solution (assuming pollutants are organic) is to incinerate the soil.

The guidelines for EPA action are expressed in general terms in the Superfund legislation (CERCLA and the Superfund Amendments and Reauthorization Act (SARA)) and are set out more formally in the National Contingency Plan (NCP).[7] In selecting target concentrations of pollutants, EPA's choice is restricted in two ways: the concentrations must comply with state and federal environmental standards, and the risk of death that they imply cannot exceed 1 in 10,000. In selecting which technology to use, however, EPA is allowed to balance the cost of cleanup against four other cleanup goals: (1) permanence; (2) reduction of toxicity, mobility, or volume of waste through treatment; (3) short-term effectiveness; and (4) implementability. The preference for treatment is, for all practical purposes, a reiteration of the preference for permanence. The third and fourth goals refer to safety and feasibility during the cleanup process itself.

Although a preference for more permanent remedies is clearly articulated, it is no easy task to measure the benefits of permanence. Conceptually, the benefits of an entirely permanent remedy could be defined as the discounted future costs that are avoided, i.e., the costs of maintaining and renewing less permanent solutions in perpetuity. In practice, this is difficult because, beyond calculating standard operation and maintenance costs for each remedy (for at most thirty years), EPA rarely addresses future cleanup costs in the RODs. We discuss this issue in more detail below.

We believe that the following treatment of permanence is more in line with EPA's decision-making framework. We assume that all remedies considered at a site result in the same reduction in current health risks; however, remedies differ in how long they are expected to last—their expected time to failure—and in the level of future risk that will result if they do fail. From this perspective a more permanent remedy is one that is expected to last longer and that will result in a lower future risk. By this definition, capping is less permanent than putting contaminated soil in a landfill, which in turn is less permanent than incinerating the soil.

□ **The scope of the study.** To study cleanup decisions, we were limited to those sites on the National Priorities List for which Records of Decision—the document describing the cleanup strategy chosen by EPA—had been signed. Of the 945 sites for which RODs had been signed as of the end of fiscal year 1991, we selected 110: 32

[7] 55 *Federal Register* 8721 (March 8, 1990).

wood-preserving sites and 78 sites with PCB contamination.[8] There are a total of 127 RODs for the 110 sites, since a single site may have more than one operable unit, a portion of the site that is treated separately for purposes of cleanup.

Wood-preserving sites are wood-treatment facilities where pentachlorophenol (PCP) or creosote was used to pressure-treat wood to prevent it from rotting. Soils at these sites are contaminated with polyaromatic hydrocarbons (PAHs)—a constituent of creosote—which are considered a probable human carcinogen. The PCB sites in the sample include landfills, former manufacturing facilities, and other sites where PCBs—also considered probable human carcinogens—are found.[9]

These sites were selected for two reasons. Because their principal contaminants are carcinogenic, estimates of health risks from each site are more likely to be available than for sites whose pollutants are not carcinogenic. Second, because both sets of sites contain organic pollutants, they have similar technological options available for cleanup.

For each site (more accurately, for each operable unit), we gathered data from the ROD on the set of cleanup alternatives considered and on the characteristics of the site. For each cleanup option considered, we would like to know the cost of the option and the permanence of the option. Data are available on the cost of each option, but the ROD does not report the permanence of each option; however, we have developed a scheme to characterize permanence. It is described below.

□ **A classification scheme for cleanup options.** Our classification of cleanup options is based on two aspects of each alternative: whether it involves excavation of contaminated soil, and whether it involves treatment of the contaminated soil. In addition, we distinguish whether remedies that entail excavation are conducted onsite or offsite. Combining these choices yields a total of six categories of remedial alternatives: (1) onsite treatment of soil that has been excavated (onsite treatment); (2) offsite treatment of soil that has been excavated (offsite treatment); (3) disposal of excavated but untreated soil in a landfill on the site (onsite landfill); (4) disposal of excavated but untreated soil in a landfill off the site (offsite landfill); (5) onsite treatment of soil that has not been excavated (*in situ* treatment);[10] (6) containment of soil that has been neither excavated nor treated (containment).

The six categories are pictured in Figure 1. Table 1 lists, for wood-preserving and PCB sites, the number of times each category was considered and selected, and the unit cost of cleanup options within each category at wood-preserving sites.[11] Of the six categories, onsite and offsite treatment correspond to the most permanent cleanups. According to the 1986 amendments to the Superfund law (the SARA amendments), EPA is supposed to show a preference for treatment, as opposed to nontreatment, alternatives. We have also distinguished whether disposal and/or treatment of excavated soil occurred on- or offsite because of the controversy surrounding offsite cleanups. Offsite cleanups are often favored by persons living near a Superfund site, since they are perceived as a permanent solution to the problem. The SARA amendments, however, indicate a preference for onsite remedies. We wish to see whether EPA has, in fact, exhibited such a preference.

[8] The 32 wood-preserving sites include all such sites for which RODs had been signed as of fiscal year 1991. The 78 sites with PCB contamination were selected from those sites with PCB contamination in excess of 10 parts per million for which RODs had been signed as of fiscal year 1991.

[9] PCBs are a group of toxic chemicals that, before they were banned in 1979, were used in electrical transformers, hydraulic fluids, adhesives, and caulking compounds. They are extremely persistent in the environment because they are stable, nonreactive, and highly heat resistant.

[10] This includes flushing of soil to remove contaminants and bioremediation—the use of bacteria to neutralize toxic substances.

[11] All six categories may not be considered at a site, whereas some, such as onsite treatment, may be considered more than once.

FIGURE 1

REMEDIAL ALTERNATIVES FOR SOIL CONTAMINATION

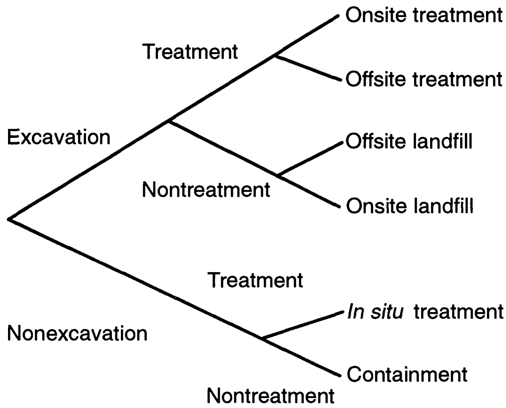

Table 1 illustrates the magnitude of the permanence-cost tradeoff facing environmental officials. At wood-preserving sites, the average cost of the least permanent options—containment and onsite landfill—is approximately one order of magnitude smaller than the average cost of onsite treatment.[12] Nevertheless, onsite treatment was the most preferred of the six cleanup categories: It was selected 73% of the time at wood-preserving sites and 62% of the time at PCB sites. For this reason, onsite treatment has been further broken down into three categories: incineration, innovative treatment, and solidification/stabilization.

□ **Variables that may influence the cleanup decision.** In addition to gathering data on cleanup options, we assembled data on variables that might influence the choice of cleanup option at a site. These are listed in Table 2, together with summary statistics. The variables fall into three categories: characteristics of the site (baseline risk, HRS score, size of the site, and where it is located); characteristics of the population living near the site (percent of the population that is nonwhite, median income of the population); and two miscellaneous variables, the year in which the ROD was signed and Fund Lead.

Since EPA sometimes sets priorities on the basis of baseline risks, we have gathered data on baseline risks at each site. The baseline risk associated with each site measures the lifetime risk of cancer to the "maximally exposed individual" from all exposure pathways, assuming that nothing is done to clean up the site.[13] This may be disaggregated into two categories, risk attributable to direct contact with contaminated soil and risk attributable to exposure to contaminated ground water.

Two features of baseline risk are worth noting. First, the risk of cancer at the sites studied comes primarily from contaminated ground water, rather than from direct contact with contaminated soil. Second, because the exposure scenarios used by EPA include many upper bound assumptions, the magnitude of the lifetime cancer risks is, in many cases, remarkably high (Hamilton and Viscusi, 1994).[14]

[12] Costs for PCB sites are not included in Table 1 for reasons that are explained in the discussion of remedy selection at PCB sites.

[13] The "maximally exposed individual" may be a child who ingests contaminated soils, a person working at a still-active site, or a resident living within the boundaries of the site.

[14] EPA's "Risk Assessment Guidance for Superfund" directs assessors to sum the risks from all carcinogenic substances at a site. When this is done for maximum plausible risk scenarios for each substance, the probability of cancer can exceed one!

TABLE 1 Cleanup Options Considered and Selected

	Wood-Preserving Sites					PCB Sites		
	Mean Cost Per Unit[a] ($/cubic yard)	Total ($ million)	*N*	Mean Volume (cubic yards)	Standard Deviation of Volume	*N*	Mean Volume (cubic yards)	Standard Deviation of Volume
Remedial Options Considered								
Excavation Alternatives								
Onsite Landfill	144.23	6.11	16	36,052.81	28,753.70	29	45,876.90	59,593.38
Offsite Landfill	618.77	7.89	15	18,135.59	14,691.63	50	77,057.76	224,228.58
Offsite Treatment	1,428.00	45.50	19	38,351.00	37,896.00	33	26,235.42	61,114.91
Onsite Treatment	350.00	13.10	85	44,881.00	48,097.00	156	55,555.42	141,736.00
Onsite Incineration	555.00	22.00	29	40,639.00	38,508.00	67	53,577.00	110,364.00
Onsite Innovative	252.00	9.70	45	42,826.00	38,281.00	58	44,535.00	50,326.00
Onsite S/S[b]		3.90	11	20,038.00	21,282.00	31	80,450.00	267,022.00
Nonexcavation Alternatives								
In Situ Treatment	231.98	11.27	12	42,261.79	38,312.15	11	45,810.00	38,003.00
Containment	78.66	3.54	23	46,549.02	46,355.46	36	128,850.00	282,599.31
TOTAL	429.85	14.20	170	41,535.80	43,030.34	315	63,042.04	167,760.00
Remedial Options Selected								
Excavation Alternatives								
Onsite Landfill	67.18	3.35	2	34,875.00	15,379.57	6	42,050	69,323.93
Offsite Landfill	763.41	4.79	3	14,651.48	20,117.84	13	9,078.85	10,110.06
Offsite Treatment	655.00	17.50	1	26,733.00	—	4	533.75	445.9517
Onsite Treatment	329.00	10.90	29	36,529.00	45,624.00	54	32,905.33	31,982
Onsite Incineration	486.00	21.20	8	39,627.00	34,610.00	22	34,298	33,103
Onsite Innovative	267.00	8.00	16	32,127.00	33,628.00	18	32,295	30,903
Onsite S/S[b]	279.00	3.70	5	11,924.00	6,598.00	14	31,501	33,841
Nonexcavation Alternatives								
In Situ Treatment	141.79	7.65	2	66,150.00	62,013.26	1	149,000	—
Containment	31.49	.38	3	35,733.33	42,287.27	9	421,222.2	467,159.98
TOTAL	325.27	9.29	40	36,855.52	42,920.10	87	69,992.5	189,503

[a] The cost figures refer to wood-preserving sites only and are in 1987 prices.
[b] S/S = stabilization/solidification.

Although baseline risk is the formal measure of hazards posed by the site before cleanup, it is possible that the agency is also influenced by the HRS score, a measure of the relative risk posed by a site but not a quantitative estimate of risk. It would be ironic if cleanup decisions were influenced by HRS score—a quick-and-dirty estimate of the hazards posed by a site—but not by more careful (and expensive) estimates of baseline risk.[15]

[15] Throughout our analysis we use a modified version of the HRS score that combines the surface and

TABLE 2 Variables That May Influence the Choice of Remedial Action

	Wood-Preserving Sites		
Variable	*N*	Mean	Standard Deviation
Baseline current soil risk[a]	33	.019	.043
Baseline future groundwater risk[a]	19	.36	.603
Baseline future soil risk[a]	20	.0380	.062
Recalculated HRS score	40	45.255	10.532
Volume of contamination (cubic yards)	40	36,856	42,920
Urban setting dummy variable	40	.125	.335
Percent minority population	40	19.85	17.878
Median household income (1989 $)	40	27,493	11,874
Per-capita income (1989 $)	40	12,814	5,837.5
Year ROD signed	40	88.325	1.608
Fund-Lead dummy variable	40	.325	.474

[a] Excess lifetime cancer risk, plausible maximum case.

The size of a site may also influence the nature of the cleanup chosen. While the main influence of size should be felt through cost (large sites, being more expensive to clean up, may receive less permanent cleanups), it is possible that size—measured here by the volume of contaminated soil at the site—may exert an independent effect. In particular, if short-term risks associated with cleanup are proportional to the volume of soil excavated, excavation may be less likely to be chosen the larger the site. Location of a site in an urban area (a proxy for population density) may exert a similar effect.

The three population characteristics—percent minority, median income, and per-capita income—are included to test the hypothesis that EPA selects less permanent cleanups at sites in poor and/or minority areas. Both variables are measured for the zip code in which the site is located and are based on 1990 Census data.

The year in which the ROD was signed may exert an influence on the type of cleanup chosen if EPA is sensitive to the 1986 amendments to CERCLA (the SARA amendments). As noted above, these call for EPA to give preference to treatment options and to onsite disposal of waste.

The final variable in Table 2, "Fund-Lead," indicates who was in charge of conducting the Risk Investigation and Feasibility Study at the site. Although the regional EPA administrator is ultimately responsible for selecting a cleanup strategy for a site, the RI/FS that precedes the choice of cleanup strategy may be conducted either by the EPA (at a "Fund-Lead" site) or by the parties responsible for cleaning up the site (the "potentially responsible parties") at a PRP-lead site. It is sometimes thought that the party responsible for the site investigation can influence the menu of alternatives considered for cleanup and, hence, the cleanup option selected at the site.

ground water components of the score, but eliminates the air score. It is often the case that the air score is not computed for a site if the ground water and/or surface water scores are sufficient to put the site over the threshold for inclusion on the NPL. It is, unfortunately, impossible to distinguish the case of a zero air score from cases where the air score was never computed, so we eliminate it from consideration.

TABLE 2 ***Extended***

Wood-Preserving Sites		PCB Sites				
Minimum	Maximum	*N*	Mean	Standard Deviation	Minimum	Maximum
0	.14	55	.007	.020	0	.12
2.4E−06	1.6	34	.208	.591	1E−05	3.4
1E−05	.17	30	.010	.044	7E−06	.24
18.61	71.46	87	50.33	13.94	8.85	74.30
84.15	2E+05	87	69,993	189,503	5	1,509,000
0	1	87	.195	.399	0	1
.516	69.04	87	14.1	23.3	0	93.5
12,210	74,620	87	30,349	11,709	8,991	64,641
5,496	42,100	87	13,316	4,139	6,782	28,865
85	91	87	87.99	2.03	83	91
0	1	87	.609	.491	0	1

3. A model of the choice of cleanup option

■ At a typical Superfund site, from three to twelve cleanup options may be considered in the Feasibility Study, from which the regional EPA administrator must select one. We assume that this decision is made to maximize the net benefits of cleanup, broadly defined. The net benefits of cleanup option i are a function of the risk reduction it achieves, other benefits associated with it, and its cost. In this section we formally model this decision.

We measure the risk-reduction benefits of a cleanup option by the present discounted value of the stream of lives saved by the option. Let P be the size of the exposed population near the site. The annual reduction in risk of death achieved per exposed person is the product of baseline risk, R^0, and the percentage reduction in baseline risk achieved by the cleanup. We assume that all options reduce risk by the same percent, δ, in the near term.[16] The options differ, however, in how long this risk reduction will last and in how large risk becomes after the remedy fails.

Let T_i be the time to failure of remedy i.[17] We assume that T_i is uncertain and, for simplicity, treat it as having a negative exponential probability density function; i.e., $f(T_i) = \lambda_i \exp(-\lambda_i)$. This implies that the mean life of remedy i is $1/\lambda_i$. After T_i, annual lives saved by the remedy fall from $PR^0\delta$ to $PR^0\gamma_i$, where γ_i is the percent reduction in baseline risk achieved after the landfill liner fails or the cap cracks., The expected number of future lives saved, discounted to the present at rate r, are

$$B_i = PR^0/(r + \lambda_i)[\delta + \gamma_i\lambda_i/r]. \tag{1}$$

The first term in (1), $\delta PR^0/(r + \lambda_i)$, is the present value of expected lives saved before the remedy fails. The second term is the present value of lives saved after the remedy

[16] EPA's guidance states that the agency may consider only those remedies that reduce risk of death from the site to 1 in 10,000 or less.

[17] T is the life of the cap when soil is capped, or the life of the liner of a landfill. For incineration, $T = \infty$.

fails. Expression (1) is increasing in the expected life of the remedy, $1/\lambda_i$, provided $\gamma_i < \delta$. In general, we shall characterize a remedy as less permanent the shorter its expected life and the smaller the reduction in future risk that it achieves.

Implicit in this representation of the benefits of nonpermanent remedies is the assumption that no additional remedial action is taken at the time of failure or that future remedial actions will not be able to reduce risks to the same extent as current ones. If, by contrast, one assumes that a less permanent remedy can simply be repeated at the time of failure, and will yield the same amount of protection, then all remedial alternatives will provide equivalent risk-reduction benefits. The only difference between a permanent remedy and a series of less permanent remedies in this case is the present discounted value of their costs.

In practice, however, it is often not possible to institute a remedy at time T that brings one back to the initial risk level. In the case of a cap, for example, it is natural to think of T as being the time when the cap cracks and to assume that the cap will be replaced by a new one. If, however, the contaminants in the soil below the cap might leach into ground water, then T is really the time at which this begins to happen. (When the leaching occurs, the cap no longer yields the same protection as, for example, incineration of the contaminants in the soil.) Once leaching has occurred, there may be nothing that can be done to remedy the situation. A similar story could be told about the failure of a landfill liner, if the contents of the landfill begin to contaminate an aquifer. Because of these complications, we have chosen to model the benefit of more permanent options as described above.

Benefits may, however, depend on factors other than risk reduction. Residents living near a site may, for example, derive psychic satisfaction from the fact that waste disposal occurs offsite rather than onsite. Let n_i denote the present value of other benefits associated with cleanup option i. Then the net benefits of cleanup option i (compared to doing nothing) are given by

$$NB_i = \alpha_1(\mathbf{Z})PR^0/(r + \lambda_i)[\delta + \gamma_i\lambda_i/r] + \alpha_2(\mathbf{Z})n_i - \alpha_3(\mathbf{Z})C_i, \tag{2}$$

where C_i is the present discounted value of the cost of cleanup option i[18] and α_1 and α_2 are weights attached to life-saving and other benefits, respectively. These weights may, in fact, depend on a vector $\mathbf{Z}$ of characteristics of the population living near the site. If, for example, as alleged by Lavelle and Coyle (1992), EPA has a preference for less permanent cleanups in areas with a significant minority population, then α_1 will depend on this characteristic. We also allow, via $\alpha_3(\mathbf{Z})$, for the possibility that costs are weighted differently (carry a different disutility to the agency) depending on where the money is spent.

Unfortunately, many of the components of net benefits are unobservable, such as the per-capita risk reduction, $R^0\gamma_i$, and other benefits, n_i. The average life of the remedy is also not reported. What one does observe is the categorization of remedies described in Section 2 and the total cost of the remedy, C_i. This implies that the net benefits of remedy i at site j must be approximated by

$$NB_{ij} = \mathbf{DT}_{ij} + \mathbf{FT}_{ij}{*}\mathbf{Z}_j + bC_{ij} + \mathbf{B}C_{ij}{*}\mathbf{Z}_j + e_{ij}, \tag{3}$$

where e_{ij} represents unobserved components of net benefits. We assume that the $\{e_{ij}\}$ are independently and identically distributed for all i with a Type 1 Extreme Value Distribution so that the choice of cleanup option is described by a multinomial logit

[18] As in equation (1), remedial actions beyond T_i, the time of failure, are not explicitly included. In other words, only costs of the initial remedy are included in C_i.

model. $\mathbf{T}_{ij}$ is a vector of technology dummies (described in Section 2) that characterize remedy i at site j.[19] A comparison of (2) and (3) reveals that the coefficient of each technology dummy captures the permanence of the remedy (γ_i and λ_i) as well as the value of other benefits associated with the remedy.[20]

If the coefficient of C_{ij} is significant and negative, and the coefficient of the onsite treatment dummy is significant and positive, then EPA has indeed balanced cost against permanence in its selection of cleanup option. In this case, one can compute the rate at which EPA was willing to substitute cost for permanence to determine an implicit willingness to pay (or have polluters pay) for increased permanence. Formally, one can ask how much costs may be increased while changing the cleanup option from containment to onsite treatment, and keep net benefits constant. Let C_0 represent the cost of containing waste at a site, d_0 the coefficient of the containment dummy, and d_1 the coefficient of the onsite treatment dummy. W_1, the most EPA would pay for onsite treatment, is defined implicitly by $d_0 + b\ Cost_0 = d_1 + bW_1$, in the simple case in which $\mathbf{F} = \mathbf{B} = 0$.

One final point: In categorizing a remedial alternative according to the scheme presented in Figure 1, we must face the fact that a cleanup option may involve the use of a combination of technologies. It may, for example, call for capping a relatively benign portion of a site while excavating and incinerating the most contaminated soil. In the case of wood-preserving sites, we handle this by categorizing the remedial alterative according to the primary technology used, i.e., the one applied to the majority of contaminated soil at the operable unit, and then including a dummy variable to indicate that a secondary treatment was applied to the rest of the unit. At PCB sites, the part of the site receiving primary treatment is the only part of the site studied, hence each remedial alternative corresponds to a unique category in Figure 1.

4. The choice of technology at Superfund sites

■ Separate equations were estimated to explain the remedial alternative selected at wood-preserving sites and at PCB sites. In examining these results we focus on three questions: (1) Did costs matter to EPA in its choice of cleanup option? That is, was the agency more likely to select an inexpensive cleanup than an expensive one, other things equal? (2) Did EPA show a preference for more permanent cleanups, and, if so, how much was it willing to pay for them? (3) Did EPA's propensity to select one option rather than another vary with site characteristics?

□ **The choice of technology at wood-preserving sites.** Table 3 presents the model for wood-preserving sites. Two results stand out. First, in most specifications, EPA is less likely to choose a cleanup option the more costly it is. Costs do matter in determining which technology to use in cleaning up a wood-preserving site. Second, EPA has demonstrated a clear preference for onsite excavation and treatment at wood-preserving sites.

Both results appear clearly in the first three columns of Table 3, which explain the choice of cleanup option solely as a function of cost and of the technology dummies. In these and all other columns for wood-preserving sites, it is the logarithm of the cost of the remedial action that enters the equation, implying that marginal disutility of cost

[19] In the estimating equation, at most five of the categories in Section 2 can be used, since a constant term is included in the equation. The omitted category is the nonexcavation (capping) option.

[20] For the logit model to yield meaningful results, it must be the case that the set of remedial alternatives and the cost of each alternative be exogenous to the decision maker (the regional EPA administrator). We believe this is the case. The set of alternatives and their costs are determined by independent contractors, based on engineering calculations. Cost estimates for a given type of cleanup (e.g., incineration) vary across sites because of a site's topography, its size, and factor prices.

TABLE 3 Choice of Remedial Action to Wood-Preserving Sites

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Log cost (1987 $)	−.909	−.694	−.699	−.755	−.825	−.633
	(−2.50)	(−2.39)	(−2.43)	(−2.48)	(−2.56)	(−2.13)
Onsite landfill	.749	.536	.537	−3.853	2.495	.951
	(.68)	(.51)	(.51)	(−.59)	(1.22)	(.26)
Offsite Landfill	1.701	1.291				
	(1.32)	(1.08)	**1.244**	**−.852**	**−.946**	**3.382**
Offsite treatment	1.627	1.133	**(1.09)**	**(−.15)**	**(−.48)**	**(.84)**
	(1.05)	(.77)				
Onsite excavation		**2.290**	**2.301**	**3.55**	**2.348**	**5.085**
and treatment		**(2.48)**	**(2.50)**	**(.89)**	**(1.51)**	**(1.55)**
Incineration	3.126					
	(2.48)					
Solidification/ stabilization	2.523					
	(2.20)					
Innovative treatment	2.419					
	(2.44)					
In situ treatment	1.306	1.088	1.096	2.325	.579	6.527
	(1.08)	(.93)	(.94)	(.45)	(.28)	(1.46)
Secondary treatment	1.551	1.380	1.389	−3.169	−.465	1.888
	(2.11)	(1.97)	(1.99)	(−.72)	(−.38)	(.70)
Onsite landfill * HRS[a]				.082		
				(.68)		
Offsite remedies * HRS				.047		
				(.41)		
Onsite excavation and treatment * HRS				−.026		
				(−.33)		
In Situ treatment * HRS				−.027		
				(−.25)		
Secondary treatment HRS				.09		
				(1.02)		
Onsite landfill * % minority					−.32	
					(−.97)	
Offsite remedies * % minority					.128	
					(1.48)	
Onsite excavation and treatment * % minority					.009	
					(.13)	
In situ treatment * % minority					.037	
					(.47)	
Secondary treatment % minority					.101	
					(1.85)	
Onsite landfill * per-capita income						−2.4E−05
						(−.11)
Offsite remedies * per-capita income						−.00015
						(−.58)
Onsite excavation and treatment * per-capita income						−.00021
						(−.98)
In situ treatment * per-capita income						−.0005
						(−1.2)
Secondary treatment per-capita income						−4.2E−05
						(−.18)
Log likelihood	**−43.56**	**−44.12**	**−44.12**	**−42.72**	**−39.49**	**−42.95**

Note: t-ratios in parentheses; coefficients in boldface represent aggregated categories.
[a] HRS = Hazard Ranking System score (air scores not included).

decreases with its magnitude. In general, this reflects a greater willingness to spend a dollar at larger rather than smaller sites, although interactions between the volume of contaminated waste and cost were insignificant. In all columns in the table, the logarithm of cost is significant and negative, indicating that the higher the cost of a cleanup option, the less likely it is to be chosen. In column 2, of the five technology dummies described above (containment is the omitted category), only onsite excavation and treatment is statistically significant. This implies that EPA was willing to pay significantly more for onsite excavation and treatment, the most permanent technology, as compared to capping; however, it was willing to pay no more for the other four categories in Figure 1 than for capping.

Columns 1 and 3 of the table present, respectively, a more detailed and a less detailed characterization of cleanup options. Column 1 disaggregates onsite excavation and treatment into three categories: incineration, solidification, and innovative treatment. While each of the three categories is statistically significant—EPA is willing to pay a premium for any one of them relative to capping—their coefficients are not significantly different from one another. A comparison of columns 2 and 3 likewise indicates that the coefficients for the two offsite options are not significantly different from one another.

The remainder of the table interacts site characteristics with log cost and with the technology dummies. Secondary treatment (the use of more than one treatment technology) is more likely to be used the higher the percent of minority residents near the site. We emphasize, however, that there is no evidence in Table 3 that EPA selected less permanent remedies in areas with a large minority population or in low-income areas. All interactions between the permanence dummies and either race or income are insignificant.

One of the implications of Table 3 and of alternate specifications not reported in the table is that the weight attached to cost and to the technology dummies seems to vary little with site characteristics: EPA's propensity to choose one cleanup option over another was consistent across sites. In particular, it was unaffected by whether the site was located in an urban area, by baseline risk, or by risk of ground water contamination.[21] Interactions between the technology dummies and a variable equal to one after the SARA amendments were also insignificant: There is no evidence that EPA was more likely to select onsite treatment options after the SARA amendments than before.

The value of more permanent cleanup options. Since costs and permanence are both statistically significant in explaining the cleanup option chosen, one can compute the rate at which EPA was willing to substitute cost for permanence to determine an implicit willingness to pay (or have polluters pay) for increased permanence. Formally, one can ask how much costs can be increased while changing the cleanup option from containment to onsite excavation and treatment, and keep net benefits constant.

Column 1 of Table 3 implies that, at a site where capping would cost $400,000 (1987 dollars), EPA would be willing to spend an additional $11.4 million (standard error = $11.89 million) to incinerate the soil. Its willingness to pay for onsite innovative treatment or stabilization (over the cost of capping) is about half as much: $5.03 million for innovative treatment (standard error = $5.67 million) and $5.68 million for stabilization (standard error = $7.38).

It is important to emphasize what these implicit valuations measure. The $11.4 million value attached to incineration is not simply the difference in cost between onsite incineration and capping at sites where incineration was chosen. Indeed, this cost difference, $21.2 million minus $.4 million (see Table 1), is greater than the valuation

[21] These variables were dropped from the specification in both the wood-preserving and PCB site analysis. Particularly for wood-preserving sites, we have limited degrees of freedom, and in any case we could not reject the joint hypothesis that their coefficients were all zero at conventional levels of significance.

implied by Table 3. What Table 3 reflects is that EPA sometimes chose not to incinerate soil, even when it was relatively inexpensive to do so. This lowers the implicit valuation of the option below average cost at sites where it was chosen.

□ **The choice of technology at PCB sites.** The way we collected and analyzed data for PCB sites differed in certain respects from the approach used for wood-preserving sites. This was due largely to the fact that PCB sites tend to be less homogeneous than wood-preserving sites, both in terms of the type and volume of contamination present and in terms of the remedies considered. When PCBs are present at a site, they inevitably become the focus of remedial action, but frequently other areas of contamination must be addressed simultaneously. When, as a result, cleanup options contain multiple components, they are inherently more difficult to characterize. The approach we used at the PCB sites was (1) to restrict our analysis to those options considered in a ROD that differed from the selected option only in the way the major area of PCB contamination was addressed and (2) to characterize each of these options based on the dimension of the remedy that did vary. The technology dummy variables and the volume variable used in the analysis of PCB sites refer to the component of the remedy that pertains only to PCB contamination.

By contrast, the cost variable refers to the total cost of the remedial option (includes all components). Disaggregating and allocating costs to the specific components of an option was often infeasible, given the information in the RODs. With a multinomial logit model, however, only differences in the values of explanatory variables (between the selected option and the other options) matter for estimation; therefore, the components that are common to all options in a ROD do not affect estimation of the model—the portion of total cost attributable to a common component drops out in the logit analysis.

One important implication of using total costs as described above is that the common component of cost cannot be differenced away at PCB sites when the logarithm of cost is used in the multinomial logit estimation (as is done for wood-preserving sites in Table 3). To capture a declining marginal disutility of cost that would otherwise be implied by using log cost, we interacted cost with volume and tested whether the marginal disutility of cost is lower at larger sites. Using a spline, we found that the marginal disutility of cost decreases with (log) volume up to 15,000 cubic yards (above 15,000 cubic yards, this interaction term is not significant and is dropped).

Table 4 presents models of the choice of cleanup option at PCB sites. At PCB sites, costs clearly play a role in the selection of cleanup technology: in all columns of Table 4, more expensive technologies are less likely to be selected, other things equal. By interacting costs with the volume of waste at the site (using a spline function) in specifications 2–7, it is apparent that the marginal disutility attached to cost is less at larger sites (up to 15,000 cubic yards) than at smaller sites. Costs in general tend to rise with the amount of contaminated material, and EPA appears to be less averse to additional costs at larger sites. If the benefits of site remediation increase with the volume of contaminated material present, this is a desirable outcome. However, a larger volume of contaminated soil at a site does not necessarily mean that it is more of a threat.

Table 4 also suggests that EPA is willing to pay more for more permanent cleanups at PCB sites. Of all the categories in Figure 1, onsite treatment (in practice, onsite incineration) is clearly the most valuable—its coefficient exceeds that of the other technology dummies in all columns.[22] In fact, column 1 implies that EPA was willing

[22] This is clearly true by inspection of columns 1 and 2. In columns 3 through 7 it is also true if one evaluates the coefficients of the technology dummies at different volumes of waste.

to pay $33.5 million (1987 dollars and standard error of $7.51 million) more for onsite treatment than it was willing to pay to contain the waste or treat it *in situ.*[23]

Offsite treatment (in practice, offsite incineration) was nearly as valuable as onsite treatment. It is the second most preferred technology in all columns in the table, and commands a value in column 1 of $22.3 million (standard error = $9.52 million), relative to nonexcavation cleanups. The fact that offsite treatment is somewhat less valuable than onsite treatment reflects the fact that it was chosen less often than onsite treatment, which accords with the spirit of the SARA amendments.

It is not surprising that EPA is willing to pay more for the two treatment alternatives than for other cleanups: excavation and treatment (usually incineration) of contaminated soil is the most permanent method of disposing of PCBs. What is, perhaps, surprising is that disposing of waste in an offsite landfill—a less permanent alternative—is valued about as highly as offsite incineration. The value of an offsite landfill (relative to nonexcavation) is $25.3 million (standard error = $7.72 million) in column 1—approximately the same value as offsite treatment. Indeed, the hypothesis that the two cleanup options have identical coefficients (compare columns 3 and 4) cannot be rejected. A plausible explanation for this is that EPA's preferences reflect those of local residents, who view all cleanups that remove waste from the site as equally permanent.

Offsite landfills are clearly valued more highly than onsite landfills. The latter category is valued no more highly than nonexcavation cleanups in columns 1 and 2.

The effect of site characteristics on choice of technology. In columns 3 through 7 the values attached to treatment and to offsite disposal are allowed to vary with the volume of waste at the site.[24] In all cases the value attached to treatment or to a landfill decreases with the size of the site. A possible rationale for this finding is that at large sites, excavation of soil will expose more people to short-term hazards than at small sites. Cleanup options involving excavation are therefore less attractive at large sites than at small sites. This suggests that, as it is supposed to do, EPA is balancing not only permanence and cost, but short-term effectiveness as well.

When volume of waste is interacted with the technology dummies, onsite treatment still remains the most preferred of the six cleanup technologies at all waste volumes in the sample. Offsite disposal (there is no difference in the value attached to offsite landfills versus offsite treatment) is the second most preferred option at sites of 50,000 cubic yards or less.

With the exception of volume, the choice of cleanup option at PCB sites is relatively unaffected by site characteristics (see columns 5–7). In particular, the allegation that EPA has selected less permanent cleanups in poor and/or minority areas is not supported by our results. Interactions of median income (not reported), per-capita income and percent minority with the technology dummies (see columns 6 and 7) are insignificant at conventional levels. The only interaction term that is marginally significant is the product of per-capita income and the offsite dummy. This suggests a preference for offsite treatment in neighborhoods with higher per-capita incomes.

Neither the urban dummy variable nor the Fund-Lead dummy variable were significant in any specification of the model. The only other variable that is significant at a .10 level when interacted with the technology dummies is HRS score: EPA was more likely to choose onsite treatment at a site the higher its HRS score. This result may be consistent with conventional economic theory. If more permanent cleanups result in

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[23] The excluded category in Table 4 is nonexcavation cleanups, which include both containment of waste and *in situ* treatment. The two categories were combined because *in situ* treatment is rarely considered at PCB sites.

[24] Interactions of the volume of contaminated waste with technology dummies were also tried in the model for wood-preserving sites; however, these interaction terms were never significant.

TABLE 4 Choice of Remedial Action at PCB Sites

Variable	(1)	(2)	(3)	(4)	Variable
Cost	−.083	−4.074	−3.492	−3.482	Cost
(millions 1987 $)	(−3.729)	(−3.088)	(−2.177)	(−2.599)	
Cost *		.415	.357	.356	Cost *
LVOL1[a]		(3.030)	(2.139)	(2.549)	LVOL1
Offsite	2.101	2.079	32.711		Offsite
landfill	(2.764)	(2.747)	(2.546)	**32.881**	
				(2.565)	
Offsite	1.852	2.992	35.759		
treatment	(1.952)	(2.757)	(2.698)		
Onsite	.889	.508	26.537	26.434	Onsite
landfill	(1.224)	(.684)	(2.024)	(2.012)	landfill
Onsite	2.784	3.052	25.238	25.087	Onsite
treatment	(3.933)	(4.292)	(2.024)	(2.012)	treatment
Offsite landfill			−2.981		
* log volume			(−2.513)		
				−3.004	Offsite
Offsite treatment			−3.397	**(−2.538)**	* log volume
* log volume			(−2.630)		
Onsite landfill			−2.430	−2.420	Onsite landfill
* log volume			(−2.007)	(−2.002)	* log volume
Onsite treatment			−2.064	−2.046	Onsite treatment
* log volume			(−1.816)	(−1.801)	* log volume
					Offsite
					* HRS[b]
					Onsite landfill
					* HRS
					Onsite treatment
					* HRS
Log likelihood	**−79.15**	**−71.63**	**−62.88**	**−63.51**	

Note: t-ratios in parentheses; coefficients and t-values in boldface represent aggregated categories.
[a] LVOL1 = min{log(volume), log(15,000)}, volume is in cubic yards.
[b] Hazard Ranking System score (air route score not included).

greater reductions in health risks,[25] this result implies that greater risk reductions are being selected at sites with higher baseline risks—a result consistent with the value of life literature (Jones-Lee, 1974).

The value of more permanent cleanups. Because Table 4 indicates that EPA is willing to pay more for more permanent cleanups, it is interesting to see exactly how large these valuations are. Figure 2 shows the value attached to different cleanup options by size of site, based on column 2 of Table 4. At a 10,000 cubic yard site, EPA would be willing to pay $12.1 million (1987 dollars and standard error of $3.22 million) to treat waste onsite rather than contain it. For sites with 15,000 or more yards of contaminated waste, however, this figure jumps to $36.5 million (standard error = $7.86

[25] When quantitative risks were included in the model, they were never significant; however, because these risk values were not available for many sites, we cannot draw any strong conclusions from this result.

TABLE 4 ***Extended***

(5)	Variable	(6)	Variable	(7)
−3.443 (−2.598)		−4.281 (−2.598)		−3.395 (−2.505)
.351 (2.494)		.439 (2.560)		.347 (2.454)
40.339 (2.601)		30.574 (−2.363)		37.402 (1.956)
34.424 (2.139)		27.622 (2.032)		36.932 (1.824)
30.983 (2.072)		22.974 (1.825)		31.492 (1.687)
−3.884 (−2.613)		−2.797 (−2.365)		−3.927 (−2.110)
−3.334 (−2.153)		−2.533 (−2.040)		−3.573 (−1.850)
−2.905 (−2.017)		−1.875 (−1.653)		−3.021 (−1.660)
.054 (.913)	Offsite * % minority population	2.651 (.345)	Offsite * per-capita income (1989 $)	.451 (1.735)
.046 (.753)	Onsite landfill * % minority population	−7.057 (−.697)	Onsite landfill * per-capita income	.163 (.563)
.082 (1.753)	Onsite treatment * % minority population	3.162 (.422)	Onsite treatment * per-capita income	.348 (1.427)
−61.47		**−61.86**		**−61.34**

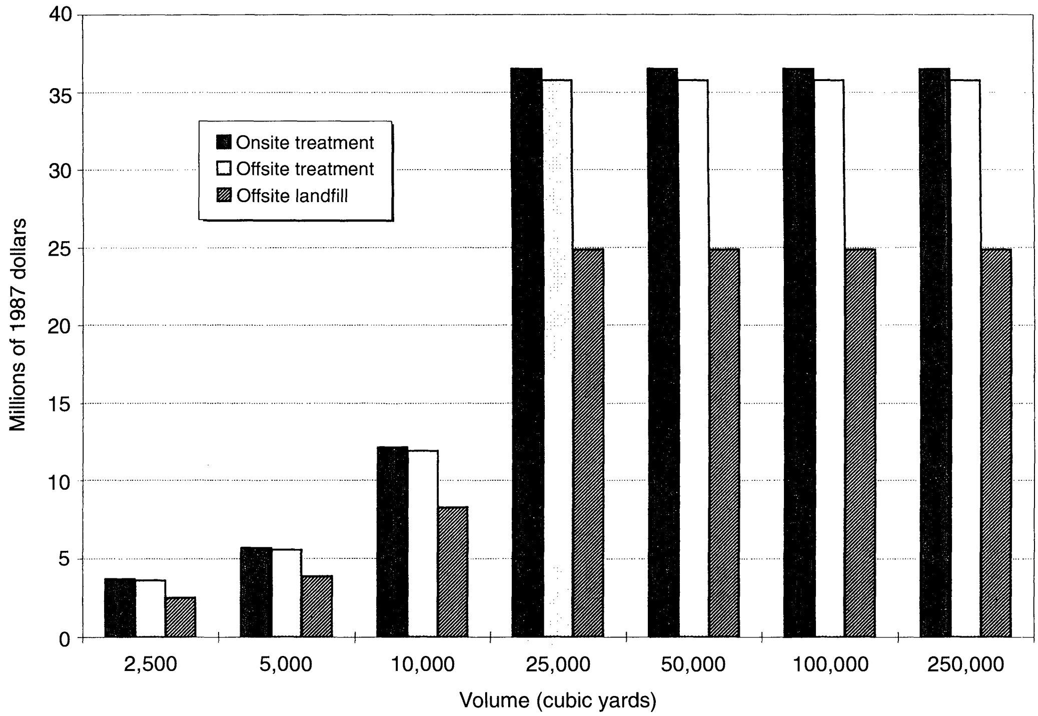
million).[26] The values attached to offsite treatment (compared to containment) are almost as large: $11.9 million (standard error = $4.03 million) for sites of 10,000 cubic yards and $35.8 million (standard error = $11.29 million) for sites in excess of 15,000 cubic yards.

Offsite disposal of excavated soil is also valued positively by the agency—indeed, the value of transporting waste offsite rather than containing it onsite is $8.25 million (standard error = $3.13 million) at a site of 10,000 cubic yards and $24.8 million (standard error = $7.73 million) at a site containing 25,000 cubic yards of waste. This implies that the agency implicitly valued offsite landfilling of waste more than onsite landfilling (whose coefficient is not significantly different from zero), an interesting result in view of the preference of the SARA amendments for onsite disposal. The more important question that Figure 2 raises, however, is whether the implicit valuations

[26] Recall that the interaction of cost with log(volume 1) implies that the effect of volume stops at volumes of 15,000 cubic yards. That is, the disutility attached to cost at sites of 15,001 cubic yards is the same as the disutility at sites of 50,000 cubic yards.

FIGURE 2

IMPLICIT VALUATION OF REMEDIAL OPTIONS WITH RESPECT TO NONEXCAVATION OPTION



of more permanent cleanups agree with amounts that society would be willing to pay for these cleanups.

5. Conclusions

■ The answer to the question, "How does EPA select cleanup options at Superfund sites?" has several parts. First, at the sites we studied, the agency did consider cost in determining how permanently to clean up a site. Other things equal, EPA was less likely to select a remedial alternative the more expensive it was. At PCB sites, however, this aversion to cost decreased as the size of the site increased.

Second, the agency was willing to pay more for excavation and treatment of waste—the most permanent cleanup option—than it was willing to pay to contain (e.g., cap) the waste. Landfilling of waste—a less permanent alternative than treatment—was valued more highly than capping at PCB sites, but not at wood-preserving sites. As far as the choice between offsite and onsite disposal is concerned, the agency was willing to pay more at PCB sites (but not at wood-preserving sites) to dispose of waste offsite rather than onsite, in spite of the preference the agency is supposed to give to onsite disposal.

In many ways, the most interesting result of the study is a negative one: Despite allegations to the contrary, there is little indication that EPA has a preference for less permanent remedies in areas with a sizable minority population (as measured by percent of the population that is nonwhite) or in poor areas (as measured by median household income). Neither variable had a significant effect on the permanence of the remedy chosen, although there was a marginally significant tendency for offsite remedies to be chosen more often in areas with higher per-capita incomes.

The lack of significance of race and median income in explaining cleanup decisions is mirrored by other site characteristics: Few variables are significantly related to the choice of cleanup option. The exception to this rule is the hazard ranking score of the site. At PCB sites, the agency was willing to spend more and had a preference for more permanent remedies at sites with higher HRS scores. These results agree with Hird (1990), who found that sites on the NPL with high HRS scores had RODs signed sooner than sites with low HRS scores. Moreover, more money was likely to be allocated to a site the higher its HRS score.

While most of the results reported here suggest that EPA has been fulfilling its mission in selecting Superfund cleanups, at least one aspect of the results is disquieting. The value attached to more permanent cleanup options, such as onsite excavation and treatment of waste, is remarkably high, although the benefits of permanence are still uncertain. The premium that the agency is willing to pay for onsite incineration of waste (over and above the cost of capping it) is $12 million (1987 dollars) at small (10,000 cubic yard) sites and up to $40 million at large (25,000 cubic yard) sites.

What remains to be ascertained is whether the benefits of more permanent cleanups—such as those achieved by the incineration of contaminated soil—are worth the amount the agency is willing to pay for them. If one could assume that less permanent remedies such as capping could be renewed periodically before any decrease in protectiveness occurs, then each remedy could be viewed as equally protective and compared solely in terms of its future stream of costs. In this case, a one-time cost for a permanent remedy could be compared to an infinite stream of periodic costs for less permanent remedies, and our estimated implicit valuations would reveal an implicit discount rate as well. Even with conservative assumptions about the relative costs and the expected life of a less permanent remedy, EPA's implicit discount rate would have to be very small to justify what it appears to be willing to pay for the more permanent remedies.[27] However, as we have argued in the discussion of the theoretical model, it is unlikely that this type of assumption will adequately represent the nature of the cost-permanence tradeoff. More appears to be at stake here. With this in mind and in view of the size of the resources devoted to Superfund cleanups, research to determine the actual value of more permanent cleanups deserves the very highest priority.

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[27] Assuming a $400,000 capping cost to be renewed every 15 years and a one-time $5 million cost for incineration, EPA's discount rate would have to be less than approximately .5% to justify the incineration option.

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