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*Robert H. Abrams**

The Comprehensive Environmental Response, Cleanup, and Liability Act (CERCLA, a.k.a. "Superfund")[1] has earned its share of criticism, most volubly for the expense and unfairness of its cost allocation scheme,[2] but also for its remedy selection process.[3] In deciding how to remediate sites, CERCLA employs a lengthy formal process that, on average, takes over eight years from site awareness to the selection of a remedy.[4] Less damningly, perhaps, only the last fifty-eight months of that time elapses after the site is scored as one serious enough to be placed on the National Priorities List as a site eligible to re-

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1. 42 U.S.C. §§ 9601-9675 (1988).

2. *See, e.g.*, Jerry L. Anderson, *The Hazardous Waste Land*, 13 VA. ENVTL. L.J. 1, 40 (1993); John C. Butler III et al., *Allocating Superfund Costs: Cleaning Up the Controversy*, 23 Envtl. L. Rep. (Envtl. L. Inst.) 10,133 (Mar. 1993); William W. Balcke, Note, *Superfund Settlements: The Failed Promise of the 1986 Amendments*, 74 VA. L. REV. 123 (1988).

3. *See, e.g.*, Hearings Before the Subcomm. on Superfund, Recycling, and Solid Waste Management of the Senate Comm. on Environmental and Public Works, 103d Cong., 1st Sess. (1993) (Statement of Carol Browner, EPA Administrator), *reprinted in* 7 Toxics L. Rep. (BNA) 1510 (May 19, 1993); Anderson, *supra* note 2 at 43-47; Jacqueline A. MacDonald & Michael C. Kavanaugh, *Superfund: The Cleanup Standard Debate*, Policy & Planning 55 (Feb. 1995).

4. JEAN PAUL ACTON, UNDERSTANDING SUPERFUND: A PROGRESS REPORT 16 (Rand Corporation Institute for Civil Justice, 1989). That same study indicates that the actual cleanup process averages an additional forty-three months in length. *Id.*

ceive Superfund money for its remediation.[5] The remedy selection process, wholly apart from performing the remedy, can cost millions of dollars, especially at more complex sites.[6]

Congress is aware of the delay and expense that are inherent in the current remedy selection process. Although there has not been a massive frontal assault on remedy selection inefficiency, there are attempts to improve efficiency in this area. The first of these efforts involves reducing or simplifying the substantive requirements that a remedy must meet in order to comport with the law. A second effort, more directly at issue here, seeks to change the means by which remedies are to be selected at some sites.[7] Proposed amendments to CERCLA that failed to be enacted in 1994 are likely to be reintroduced in the current congressional session. Popular wisdom has it that the amendment package died a political death or because of a lack of consensus on other Superfund reform issues.[8]

Beyond changing cleanup standards, however, the legislation also would establish, without a great deal of elaboration, a

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5. *Id.*

6. The average cost of the remedy selection process (including sites where no action is the chosen option) is on the order of $1.3 million. *See* Environmental Protection Agency, Final Rule: National Priorities List for Uncontrolled Hazardous Waste Sites, 55 Fed. Reg. 35,502, 35,511 (1990) (to be codified at 40 C.F.R. pt. 300. The cost estimates used there are based on 1988 data and the EPA acknowledges, "there is wide variation in [RI/FS] costs for individual sites, depending on the amount, type, and extent of contamination." *Id.*

7. *See* S. 1834, 103d Cong., 2d Sess. §§ 501-503 (1994); *see also* H.R. 3800, 103d Cong., 2d Sess. (1994).

8. One theory suggests that the Republicans, as the election season drew near, allowed the proposal to languish in order to deny the Democrats a legislative accomplishment that could be used in campaigning. Senator Dole, for example, was quoted as saying to the United States Chamber of Commerce at an August 15, 1994 meeting, "Why this year?" *White House Meetings Continue on Financing of Superfund Reform Legislation: Caucus Set*, 9 Toxics L. Rep. (BNA) 310 (Aug. 17, 1994); *see also, Superfund Reform: Republicans Withhold Support for Bill Despite Committee Changes, Aides Say*, 9 Toxics L. Rep. (BNA) 250 (Aug. 3, 1994). A second theory points toward the intra-insurance industry rift that grew up between large insurance companies and smaller insurance companies in relation to funding the Environmental Insurance Resolution Fund. *See Superfund: 30 Insurers Would Bear Brunt of Costs for CERCLA Reform, Standard & Poor's Says*, 25 Env't Rep. (BNA) 860 (Sept. 9, 1994); *Superfund Reform: Administration Offers Funding Revision, Seeks to Broaden Support for CERCLA Bill*, 9 Toxics L. Rep. 448 (BNA) (Sept. 21, 1994). A third theory cites the applicability of Davis-Bacon Act wage rates to mixed-funding cleanups as the stumbling block. *See Superfund Reform: Public Works Panel Approves House Bill; One Committee Left Before Floor Action*, 9 Toxics L. Rep. (BNA) 249 (Aug. 3, 1994).

program entitled, "Generic Remedies." The provision proposes to amend current section 121(b) of CERCLA to include a new subsection as follows:

> (4) Generic Remedies.
>
> In order to streamline the remedy selection process, and to facilitate rapid voluntary action, the President shall establish, taking into account the factors enumerated in subsection (b)(3)(A),[9] cost-effective generic remedies for categories of facilities, and expedited procedures that include community involvement for selecting generic remedies at an individual facility. To be eligible for selection at a facility, a generic remedy shall be protective of human health and the environment at that facility. When appropriate, the President may select a generic remedy without considering alternative remedies.

In urging this action, Congress is building on a small, but significant, initiative in this area. The Environmental Protection Agency (EPA) already has a presumptive remedies program. This program has established remedial presumptions for a narrow array of sites.[10] The generic remedies program could, in theory, replace the cumbersome conventional remedy selection process that is currently the norm. What is less clear is how generic remedies should be identified and validated.

The archival methodology for remedy selection and associated empirical research described in the remainder of this article explores the basis for selecting generic remedies. Their paradigm is markedly different from that associated with conventional remedy selection, an engineering dominated process. This work is undertaken in the belief that the generic remedy selection process will, *if the data supports its broad application*, be a valuable addition to the Superfund process and capable of wider use. To establish generic remedies as viable, the data (in es-

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9. The current remedy selection criteria are described *infra* notes 11-34 and accompanying text. Section 503 of S. 1834 proposes that criteria for remedy selection include two threshold criteria: adequately health and environment protective, and meeting a use-based degree of cleanup mandated by the new amendatory § 501. Under § 501 account is also to be taken of effectiveness, long-term reliability, risk to all involved, acceptability of the remedy to affected parties, and cost.

10. This topic is discussed more fully, *infra* at notes 36-44 and accompanying text.

sence a careful study of past remedy selection decisions) can be used to identify patterns that link a series of site and contamination characteristics to the remedy that is selected with a sufficient degree of regularity such that much of the conventional underlying engineering study can be omitted without compromising remedial effectiveness while saving considerable amounts of both time and money.

I. SELECTING A REMEDY, SUPERFUND STYLE

For both good reasons and bad, EPA's present remedy selection process under Superfund is cumbersome and drawn out.[11] Its principal stages follow a logical progression from awareness of the site's existence to making a preliminary assessment (PA) of the hazards it displays, and, on that basis, comparing it to other sites employing a hazard ranking system (HRS) in order to set cleanup priorities and eligibility for federal funding.[12] The next stage, which is the principal focus of this article, is the linked remedial investigation and feasibility study (RI/FS) process that then serves as the underpinning for the remedy selection. The results of this process are then memorialized in the Record of Decision (ROD). Thereafter, the remedy is implemented through the intertwined remedial design-remedial action (RD/RA) phase. Here, the specifics of how the chosen remedy will be implemented are designed in detail (RD) and performed (RA) with modifications as required by the ever-increasing knowledge of site conditions that comes from actual measurements and experience gained in doing the work.

The RI/FS and ROD methodology has its roots in both CERCLA[13] and its administrative articulation by EPA in the

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11. The good reasons are recounted in the text, the bad reasons are linked to the unfortunate handling of Superfund cleanups during the law's infancy that included the misdeeds of the Reagan Administration EPA. To prevent future episodes of misadministration of CERCLA, both the Superfund Amendments and Reauthorization Act of 1986, Pub. L. 99-499, and the revised National Contingency Plan (NCP) insisted on more formalized steps and criteria in the remedial decisionmaking process. *See, e.g.*, Joel A. Mintz, *Agencies, Congress, and Regulatory Enforcement: A Review of EPA Hazardous Waste Enforcement Effort, 1970-1987*, 18 ENVTL. L. 683, 715-43 (1988).

12. This portion of the remedy selection process takes an average of 43 months. *See*, ACTON, *supra* note 4, at 16.

13. *See, e.g.*, 42 U.S.C. §§ 9616(d), 9620(e) (1988).

drafting of the National Contingency Plan (NCP).[14] As part of CERCLA's initial enactment in 1980, Congress required EPA to conduct a notice and comment rulemaking to "revise and republish" the NCP,[15] which was already in existence as a plan for responding to oil spills under the Clean Water Act.[16] This expansion of the NCP enlarged the scope of its coverage to "include a section of the plan to be known as the national hazardous substance response plan which shall establish procedures and standards for responding to releases of hazardous substances, pollutants, and contaminants."[17] When Congress enacted the Superfund Amendments and Reauthorization Act of 1986 (SARA),[18] it added greater direction to the remedy selection process,[19] requiring EPA to revise the NCP "to provide procedures and standards for remedial action undertaken pursuant to this chapter which are consistent with amendments made by the Superfund Amendments and Reauthorization Act of 1986 relating to the selection of remedial action."[20] The key objectives Congress laid out included a new concern for cost effective, long-term remedies.[21]

EPA, duly instructed by Congress, substantially revised the NCP.[22] While the 1990 amendments to the NCP announced the mandated shift in remedy selection criteria, they built upon the RI/FS and ROD procedural substructure that was already in place.[23] As one commentator describes that process, "[d]uring the RI, the nature and extent of the threat posed by the contamination is studied; concurrently, alternative approaches are developed as part of the FS for responding to and managing the site problem."[24] As part of the RI/FS stage, a

14. *See* Federal Water Pollution Control Act, 33 U.S.C. § 1321(C) (1988 & Supp. V 1993).

15. 42 U.S.C. § 9605 (1988 & Supp. V 1993).

16. *See* 33 U.S.C. § 1321(c) (1988 & Supp. V 1993).

17. 42 U.S.C. § 9605(a) (1988 & Supp. V 1993). The parts of the NCP added in response to this congressional directive initially appeared at 40 C.F.R. §§ 300.61-.71 (1982).

18. Pub. L. No. 99-499, 100 Stat. 1613 (1986).

19. 42 U.S.C. § 9605 (1988 & Supp. V 1993).

20. *Id.*

21. *See* 42 U.S.C. § 9621.

22. National Oil & Hazardous Substances Pollution Contingency Plan, 40 C.F.R. pt. 300 [hereinafter NCP].

23. *See supra* note 14.

24. Lawrence E. Starfield, *The 1990 National Contingency Plan—More Detail and*

preliminary site remediation goal is set and alternative cleanup strategies capable of attaining the goal are evaluated.[25] The alternatives are screened in a preliminary fashion to eliminate those that are extreme or impractical, either because they will not attain the goal, cannot be implemented, or are "grossly excessive" in cost.[26]

What goes largely unspoken in the discussion is the fact that the RI/FS process, as currently practiced, employs what might be labeled "A Standard Engineering Approach."[27] This approach, at a minimum, includes (1) a site model, (2) that is subsequently calibrated so that, (3) remedial alternatives can be modeled and evaluated. Modeling a Superfund site is itself a multi-stage process that usually begins with data acquisition, site discretization, plume definition, and importantly, computer simulation.

The basic thrust of these efforts is to delineate what contaminants are present, precisely how much they have dispersed in the environment, and then, by reflecting that data in a computer model of inputs and outputs, predict the effects of various forms of treatment. No matter how simple sounding this may be, the process is both time consuming and expensive. A well chosen set (usually a grid) of soil borings and/or test wells must be dug. The resultant soil and groundwater samples must be analyzed for the presence and concentration of contaminants. Tests that gauge the transmissivity of the soil must be performed, etc. Then all of that data must be translated into a computer model that can be tested by performing small scale experiments to insure that the model is accurately predicting system response to induced phenomena, such as measuring changes in the contaminant plume in response to pumping at a specified rate from a certain depth and location. Only after the model has been calibrated can the remedial alternatives be evaluated. Even that evaluation stage requires additional small

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More Structure, But Still a Balancing Act, 20 Envtl. L. Rep. (Envtl. L. Inst.) 10,222, 10,228-29 (1990).

25. NCP § 300.430(e)(2).

26. NCP § 300.430(e)(7).

27. This is not intended to be a term of art, but rather a rough description of a methodology that will be compared with an alternative "Archival Approach" methodology.

scale field testing of the model to obtain trial and error improvements which can be used to optimize the benefits of the various treatment trains[28] that might be proposed.

Once the RI/FS has identified a series of viable cleanup alternatives, those alternatives are subjected to a nine-factor analysis. The factors are (1) health protectiveness, (2) compliance with relevant laws and standards, (3) long-term effectiveness and permanence, (4) reduction of toxicity, mobility or volume through treatment, (5) short-term effectiveness, (6) implementability, (7) cost, (8) state acceptance, and (9) community acceptance.[29] The analysis is constrained by treating the first two factors as "threshold" criteria that must be met, the next five as "balancing" criteria that weigh trade-offs among remedies, and the final two as "modifying" criteria that allow for adjustments in the selection process to accommodate the political realities in selecting among otherwise viable alternatives.[30]

After the multi-factor analysis is completed, EPA issues its tentative decision for notice and comment. Shortly thereafter, EPA makes its final remedy selection and memorializes it in a ROD that serves as a guide, but not a blueprint, for the subsequent cleanup.[31] Work then commences on the Remedial Design and Remedial Action (RD/RA). In this stage the details of how the selected remedy will actually be performed are drawn up (the RD). Not surprisingly, when the engineers get involved in the nitty-gritty of the design process, they often develop new data about the site and its contamination characteristics that require them to alter their plans and conduct the remedial action somewhat differently than had originally been planned. Should those differences "significantly alter" the remedy selected in the ROD, the agency implementing the cleanup must issue an explanation of significant differences (ESD).[32] If the

28. One of the key pieces of knowledge that Superfund experience has provided is the recognition that complicated contamination sites (as opposed to, for example, single contaminant, single affected medium sites) involve a series of remedial steps in their cleanup, often taken in sequence, giving rise to the image of a "treatment train."

29. NCP § 300.430(e)(9).

30. *Id.* § 300.430(f)(1)(I)(A)-(C).

31. *Id.* § 300.430(f)(5).

32. 42 U.S.C. § 9617(c) (1988); NCP § 300.435(c)(2)(I).

changes "fundamentally alter" the remedy selected by the ROD, for example, if incineration were substituted for containment, a ROD amendment is proposed and offered for public comment.[33]

Perhaps intuitively, the reason for these post-ROD modifications during the RD/RA process relates to the fact that actual implementation increases the knowledge base regarding the site, its characteristics, and the contamination problems being remediated. This, in turn, leads to fine-tuning of the cleanup. What is less evident, but important for those not as familiar with how cleanups really work, is the fact that this aspect of the NCP implementation of the ESD provision "is based in large part on the recognition that design and implementation will, *in almost all cases*, result in some refinements or modifications of the selected remedy."[34] Stated differently, there is almost always tinkering with the selected remedy due to the improved engineering knowledge that is obtained at the implementation stage. More simply, the selected remedies are re-engineered to fit the realities as they become ever better understood during the course of the remedial action itself.

II. Selecting a Remedy, Archival Style

For present purposes, the salient point to be made about the standard engineering approach is that it is time consuming and expensive. That point is meant less as a criticism than as an objective observation. If at some sites a different, yet equally effective, methodology could be substituted that is both quicker and less expensive, the remedy selection process would be markedly improved.

Reflecting on one and a half decades of Superfund cleanup experience opens one promising avenue for truncating the remedy selection process. EPA itself has observed that there are recurrent contamination patterns which, after being subjected to the full RI/FS process, result in the same remedy being selected

33. NCP § 300.435(c)(2)(ii); *see* Starfield, *supra* note 24, at 10,247.

34. Starfield, *supra* note 24, at 10,247 (emphasis added). Mr. Starfield, although speaking for himself and not EPA, describes himself at the article's outset as the EPA "attorney principally responsible for legal issues in the National Contingency Plan's 1990 revisions." *Id.* at 10,225.

in virtually all instances. For those types of contaminant patterns, EPA has established a small program of presumptive remedies. At such sites, EPA will presume that the remedy to be selected is the one that has proven effective in remediating similar sites in the past.

In essence, this is what might be described as an archival approach. By consulting the collected records of past RI/FSs, RODs, and RD/RAs, EPA has recognized that particular remedies have a sufficiently strong correlation with a pattern of underlying contamination characteristics that it is no longer necessary to expend resources to conduct a full RI/FS. Rather than "engineering" the site, presumptive remedies look to archives of past remedy selections for making the initial determination of what should be done.

EPA's experience with the archival approach is of recent origin and of limited extent. In June, 1993, the agency announced several administrative Superfund initiatives, including a presumptive remedies program.[35] Since that time, EPA, acting through its Office of Solid Waste and Emergency Response (OSWER), has released an overall guide to the presumptive remedy initiative[36] and presumptive remedy guidance for Superfund sites with volatile organic compounds in soils[37] and municipal landfill sites.[38] A draft guidance is in place for wood treatment sites[39] and a fourth guidance for presumptive remedies for contaminated groundwater is in the works, but its promulgation has been delayed.[40] As an example, in its wood

35. *See Superfund: Improvements in Remedy Selection Process Focus on Three Areas, EPA Official Tells Panel,* 24 Env't Rep. (BNA) 340 (June 25, 1993).

36. OFFICE OF SOLID WASTE & EMERGENCY RESP., ENVTL. PROTECTION AGENCY, DIRECTIVE 9355.0-47FS, PRESUMPTIVE REMEDIES: POLICY AND PROCEDURES (Sept. 1993).

37. OFFICE OF SOLID WASTE & EMERGENCY RESP., ENVTL. PROTECTION AGENCY, DIRECTIVE 9355.0-48FS, PRESUMPTIVE REMEDIES: SITE CHARACTERIZATION AND TECHNOLOGY SELECTION FOR CERLCA SITES WITH VOLATILE ORGANIC COMPOUNDS IN SOILS (Sept. 1993).

38. OFFICE OF SOLID WASTE & EMERGENCY RESP., ENVTL. PROTECTION AGENCY, DIRECTIVE 9355.0-49FS, PRESUMPTIVE REMEDY FOR MUNICIPAL LANDFILL SITES (Sept. 1993).

39. *See Superfund: Presumptive Remedial Technologies Outlined in Draft Guidance for Wood Treatment Sites,* 25 Env't Rep. (BNA) 1553 (Dec. 9, 1994) [hereinafter *Presumptive Remedial Technologies*].

40. *See, Superfund: Pump-and-Treat Not Listed in Draft Guide as Presumptive*

treatment draft guidance, OSWER designates incineration, thermal desorption, bioremediation, and immobilization as the presumptive technologies to be used.[41] More specifically, EPA found that wood treatment sites characteristically presented pentachlorophenol, creosote, chromated copper arsenate and non-aqueous phase liquids as the contaminants of concern.[42] In graphic form the guidance establishes the following presumptions:

CONTAMINANT(S)	AFFECTED MEDIUM	REMEDIAL TECHNOLOGY
organic (including creosote) pentachlorophenol	soil, sediments, and sludges	incineration thermal desorption bioremediation with capping and institutional controls
organic (including creosote) pentachlorophenol	groundwater	remedies that will be outlined in the forthcoming groundwater presumptive remedies guidance
chromate copper arsenate	soil, sediments, and sludges	immobilization

The guidance also compares the differing treatments and their pluses and minuses and a "detailed decision tree" that will lead site managers to selecting the appropriate remedy.[43]

Ground Water Cleanup Remedy, 25 Env't Rep. (BNA) 1447 (Nov. 25, 1994).

41. *Presumptive Remedial Technologies*, *supra* note 39, at 1553.

42. *Id.*

43. See *Superfund: Improvements in Remedy Selection Process Focus on Three Areas, EPA Official Tells Panel*, 24 Env't Rep. (BNA) 340 (June 25, 1993) (quoting Robert Sussman, EPA deputy administrator's testimony delivered June 23, 1993 to the House Energy and Commerce Committee's Transportation and Hazardous Materials Subcommittee).

For example, the guidance goes on to review the efficiencies of the various treatments and suggests that cost factors and problems with community acceptance make incineration best suited for treating "hot spots." Thermal desorption will not meet the most stringent cleanup goals and produces residuals that require treatment or disposal. Bioremediation is not sufficiently field proven in meeting cleanup goals and will need capping and institutional controls to sufficiently limit future exposures.[44]

The presumptive remedy program, as employed thus far, operates only at relatively simple sites, that is, sites dominated by a single type of waste stream. There is no inherent reason why presumptive remedies cannot be an effective tool at sites exhibiting more complex contamination scenarios. The critical issue in that extension is one that can be empirically verified: is there a sufficient degree of consistency of remedy selection that can be based on a relatively simple assessment of site contamination and other salient site characteristics?

Methodologically, it is important to understand how an archival system would operate and to contrast that process with the previously described engineering approach that undergirds the typical RI/FS process today. Not surprisingly, the archival approach is far simpler and less time consuming. In essence, the archival method requires only three steps: (1) identify the contaminants and the affected media; (2) characterize the site; and (3) select the remedy by searching the archival records to "look up" what has been done in similar situations.

Potential cleanup sites are designated as such precisely because hazardous substances have been released into the environment at the site to a degree that poses an unacceptable danger to human health and the environment. In describing the contamination it is vital to note what contaminants are present and what environmental media are affected. As a common sense matter, these two factors are going to have a powerful influence on remedy selection.

Potential cleanup sites exist in a context. They may be part of a residential area or of an industrial area. They may have a

44. *Presumptive Remedial Technologies*, *supra* note 39, at 1553.

deep or shallow groundwater table, etc. Many people may live in proximity to a site, or the site may be in a remote area. Although it is less clear than with contamination characteristics, these and other site characteristics have the potential to influence remedy selection.

The role of site characteristics in remedy selection can best be seen by recalling that risk reduction (to an acceptable level) is the ultimate goal of all cleanups. The risks to be reduced are, in part, a function of the number of people exposed and the pathways by which those people will become exposed. Albeit indirectly in some cases, these aspects of exposure fall into the categories of information that are covered by site characterization.

As a point of comparison, site characteristics play a far more prominent role in the "engineered" remedy selection process. These characteristics are taken into account as part of the individualized, site-by-site RI/FS-ROD process. In an archival system, where a major part of the goal is to limit the extent of site-specific, fact-specific engineering in the remedy selection process,[45] these characteristics also have to be taken into account, but in a radically different way. In essence, the site characteristics, along with the contamination characteristics, determine which parts of the archival record are relevant precedents that can inform the present decision. In more technical terms, the site characteristics along with the contaminant characteristics (contaminants present and the media they affect) are independent variables that are to be correlated with the dependent variables, the technologies that make up the remedial treatment train to be selected by the process.

It should be evident that the archival method may not work for all sites. There are likely to be some combinations of contamination and site characteristics for which analysis of the data reveals that there are no strongly correlated remedial choices. Likewise, there may be other combinations that display strong correlations with remedy, but for which there is an insufficient amount of archival data to permit confidence. These two limitations of the archival method suggest a more general

45. It is worth noting that site specific engineering issues are not eliminated by the archival method; they play their normal role in the RD/RA process.

point: sound employment of the archival method relies on appropriate judgments regarding the needed strength of correlation and the size of the relevant portion of the archival base.

III. Creating an Archival System[46]

Perhaps oddly, there does not seem to be a functional system of archival data regarding Superfund sites and the remedies selected. EPA publishes all RODs and several commercial services then collect, republish, and, at times, abstract the contents of the RODS.[47] Experience in working with EPA's RODs has proven the difficulty of extracting the needed information for building an archive capable of supporting remedy selection decisions.

The difficulty in compiling good records begins with such fundamental items as contaminant identification. While all of the RODs religiously list contaminants found at the site being described, quantitative measures of the concentration of the contaminant are seldom reported. The most plausible inference to be drawn from such a report is that the concentration present is one requiring remedial attention; otherwise the contaminant would not be mentioned. Even so, there are instances of RODs mentioning contaminants as to which no discernable action was to be taken based on the remedial actions selected for the site. This necessitates either additional inquiry into the rationale for inaction, or a presumption that the contaminant, though present, was not a matter of concern.

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46. As will be evident, the research experience described in this section relates to work that is presently in progress. The work is still sufficiently preliminary that it is not availing to cite specific examples of the difficulties that have been encountered. Suffice it to say, the problems will have to be addressed as the project moves toward its conclusion.

47. At this juncture, thanks and other acknowledgments are in order. Dr. Miller and I are greatly indebted to West Publishing Corporation for allowing us and our research assistants free access to Westlaw and the numerous relevant databases available there. We are also in debt to Morgan, Lewis & Bochius, publishers of RODSCAN, a CD-ROM version of all of the RODs. They have provided for our use two copies of their product, which can be searched electronically. Finally, a special thank you is due to Mark Bennett, President of Environmental Data Resources, Inc., who met with us in the early stages of our efforts to canvas and discuss how we might best assemble the data that would meet our needs.

A second level problem arises in associating various remedial technologies with the contaminant-media combinations. The RODs are not uniformly informative on this score. Most of the RODs that have been studied thus far do not link a particular treatment with a particular contaminant of a particular medium. To supply this linkage has required interpretation by engineers trained in site remediation. This lack of linkage is not a major obstacle, but serves to make the data less accessible to a non-expert and increases the time and expense of data compilation. It also introduces a possibility of erroneous interpretation of the data.

A third level problem arises in relation to identifying treatment trains, rather than treatment collections. At many sites where an active remedy is pursued, the remedy involves the use of several treatments that address the same contaminant or contaminant family. As noted before, the RODs seldom articulate the linkage of treatment and contaminant, and they are even more indefinite about sequencing of treatment efforts. Again, engineering knowledge can supply the likely sequence, but there is also the problem of hot spots, small areas of far higher contaminant concentrations that demand a more aggressive treatment regime. To whatever extent the RODs do not differentiate between treatments which are "hot spot only" and those which are part of trains being applied to the larger areas of the sites, it is possible to overestimate the degree of treatment that is being applied to the site's larger areas of contamination. Here too, engineering judgment can be used. If a site covers many, many acres and soil incineration is one of several remedies, it is reasonable to surmise that only highly contaminated soils are the subject of incineration, while less contaminated soils are being dealt with by less costly means.

Once the data is gathered, the analysis seeks to link site and contaminant-media characteristics as correlates of remedy. The basic tool here is statistical analysis that treats the former as independent variables and the latter as the dependent variables. Having so many variables, however, requires a sizeable data set to be able to generate a high degree of confidence in any correlations that may be found. Even if there is a large enough data set, the interpretation and use of the data calls for judgment. How strong a correlation and what degree of confidence are required to support remedy selection based on archive alone? These types of judgments are commonly referred to as "decision protocols."[48]

The standards that ought to be required may not need to be as high as might be expected. Even though the act of remedy selection makes a commitment to a course of action, that commitment is made with a minimum of resource investment, very little of which is irretrievably lost if later in the process the choice of remedy has to be reconsidered. Consider here that the archival remedy is selected without extensive investment at the site. Presumably, the impetus to reconsideration of remedy would be site-specific data about the contamination and its extent that comes to light in the RD/RA process. In many ways, this sort of remedy revision would be analogous to what already happens when the RD/RA uncovers site-specific data that is inconsistent with the engineered remedy that had been chosen.

After the decision protocols are in place, archival remedy selection becomes a rather routine matter. Once a site has been identified as contaminated and a preliminary assessment has been undertaken, the archive is consulted to see if there is a sufficiently validated (by the decision protocols) remedy associated with the site, contaminant, and affected media characteristics. If there is, the selection process is complete. If there is not, a remedy must be selected in the more traditional "engineering" way.

It may be helpful to amplify what is meant by site, contaminant, and affected media characteristics. The latter two categories are more self-evident. These categories include, for example, BTEX[49] in groundwater and chromium in soils. The third series of site characteristics are more varied. They might include the proximity of human population, current (or intended) land use and whether the aquifer is used as a drinking water source. It should be clear that these site characteristics affect the logic of remedy selection, because they impact on the likely exposure pathways and, therefore, on the risk that is associated with a site.

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48. In the instant research effort, to date the data gathering being undertaken is not sufficiently complete to have reached this Rubicon.

49. Benzene, toluene, ethylene, and xylene.

This same insight helps to explain the initial efforts that Dr. Miller and I are making in data analysis. We have defined four levels of inquiry. The first (Level 0) is simply frequency analysis for contaminants. The contaminants of greatest interest are those that appear at the greatest number of sites. This is an efficient approach to decide where to direct our initial attention. The next level (Level 1) looks at the correlation of contaminant and remedy. For example, we consider how frequently capping is used at a site where arsenic is present. Level 2 looks at remedy as a dual function of contaminant and affected medium. Almost *a fortiori* the correlations should be stronger than at Level 1, because some remedies for a contaminant in one medium are inappropriate for that same contaminant in another medium.

As a hypothesis, Level 2 will, in most cases, provide what could be an end point for the analysis. Most remedial treatment technologies are medium and contaminant family appropriate. Air stripping, for example, is a groundwater appropriate treatment that will remove substances that volatilize. It cannot be used with soils and it does not remove, for example, metals. Despite the above hypothesis, a Level 3 inquiry is being made that starts with favorable Level 2 correlations and inquires whether any additional independent variables strengthen the correlation. For example, add the site characteristic that the groundwater is used for drinking water or the size of the human population in a certain degree of areal proximity to a lead contaminated soil site or that the groundwater feeds surface water. It is axiomatic that in some cases, Level 3 analysis will show increasingly strong correlations when additional variables are added, while there will be indifference or declining correlations when other variables are added. In essence, this additional information establishes which additional variables are important in the remedy selection and takes them into account.

The value of Level 3 type analysis (or something similar to it) is likely to be compounded if the cleanup standards mandated by CERCLA are changed to be more future land-use sensitive or if the cleanup is being undertaken in response to some other law or impetus.[50] Changes in cleanup standards herald

50. Proposed changes in remedy selection criteria were discussed, *supra* at notes

what might be described as a different endpoint for cleanups. Previously obtained archival knowledge is, to some extent, superceded because it was predicated on satisfaction of a different set of cleanup criteria. The Level 3 factors, however, in some cases represent a reasonable proxy for some of the variance that will be introduced by a change in cleanup standards. High population in proximity to a site, for example, may indicate that the site is probably in or near a residential area and requires a greater reduction in contaminant concentrations than would a remote site. If the groundwater supports public water supply, the degree of cleanup demanded will be sensitive to that use of the resource in virtually any imaginable cleanup standards regime.

The Level 3 analysis also suggests how the archival method can be "updated" to survive changes in cleanup standards. Moving the cleanup target necessarily undermines the present value of the precise set of correlations revealed by the data archive; the set of correlations was obtained with reference to the particular set of cleanup goals. However, the archival data set can be "rehabilitated" by adding observations about what cleanup levels are actually achieved at the sites by the various remedial steps and by using Level 3 type inquiries to add variables about cleanup parameters rather than site characteristics. Site characteristics can then be used as a fourth level inquiry, again fine tuning what has already been established by the previous analysis.

IV. THE CHALLENGES AND LIMITATIONS OF USING ARCHIVAL DATA

Use of the archival method offers the possibility of major savings of both expense and time in site remediation. As such, it should be viewed as a valuable tool in the effort to combat existing environmental contamination. As with all tools, however, the archival method has its strengths and weaknesses, situations for which it is well adapted and situations for which other tools are preferable. Thus, even while seeming to champion the methodology, it is vital to understand its limitations.

35-44 and accompanying text.

There are three that come to the fore, involving data collection and analysis, the use of statistical correlations to embody "judgment," and how to account for innovation in a system that is essentially backward looking.

As trite as it may be, the maxim, "garbage in, garbage out" applies with full force to the archival method of remedy selection. If the examples of past contamination and remedy selection are improperly recorded in the archive, it is patent that predictions based upon that data will be unfounded. If the concern were accuracy alone, however, proven, simple devices like dual coding[51] could insure a high degree of accuracy. As it turns out, given the way in which available site data are maintained, coding of the research described herein has involved a degree of judgment and familiarity with site remediation technologies. The records that are available are not sufficiently consistent. For example, contaminants are mentioned as being present at a site, but none of the remedial technologies seem to address that contaminant.[52] Likewise, only some of the RODs specify what particular remedial technologies were used to address which specific contaminant-media combinations.[53] In the end, the need for interpretation and judgment in the preliminary act of archiving the data makes the archival enterprise far harder to mount and open to unintended inaccuracy.

As noted in passing in the initial description of the archival method, decision protocols must be established before the method can be of any use. Here too, judgment plays a major role. How many similar prior sites are enough to use as a predicate for remedy selection at similar sites? How strong must the correlation be before it reliably indicates that the remedy select-

51. This involves having two persons independently extract and enter the data for each site and then compare for discrepancies. To insure objectivity, blind coding (having the coders unaware of the nature of the research) can be used. In the research undertaken to date, a significant amount of dual coding has been used, none of it blind.

52. For this situation, after reading whole RODs in several cases, Dr. Miller and I formed the opinion that those contaminants were found to be present at the site but in concentrations and amounts not requiring any action. Accordingly, we treated them as not present for the purposes of determining what treatments correlate with actionable levels of that same contaminant.

53. For this situation Dr. Miller and I relied on her expertise in the remediation field to link remedies with the contaminant-media combinations.

ed by the archival method is likely to be a wise choice in the real world? Plainly these questions require informed professional judgment for their resolution, and it is easier to know wrong answers than to assess whether any particular combination of association and confidence level will optimize the efficiency gains that can be obtained with the archival method.

Finally, the archival method systematically underselects new technologies and makes provision for innovation only as an add-on. For example, consider a technology that was not considered sufficiently proven in 1990, a decade after Superfund cleanups began. An example might be *in situ* vitrification for certain chlorinated materials in soil. In a study of all remedies selected from 1980 to the present at sites for which *in situ* vitrification might well have been chosen, it may be under represented as the remedy selected, because it was not a viable choice for much of that period. In the more technical workings of the archival method, *in situ* vitrification will not have a sufficiently strong correlation with its appropriate site and contamination characteristics to be "selected" by the operative decision protocols. Brand new technologies fare even worse in an archival system. By virtue of their novelty, new technologies are totally unrepresented in the universe of possible remedial selections.

There are means by which to overcome this blind spot in the archival method. If the technology is one whose acceptance changed during the study period, it is appropriate to adjust the decision protocols to take this change into account. In effect, the selection can be revisited using a more limited data set that corresponds to the time frame during which the remedy enjoyed acceptance. Wholly new technologies, much like current practice, must earn a try based on their potential as proven in testing. It is important to note that new technologies do not fare well in the traditional remedy selection process because of their lack of proven effectiveness. They therefore have become the subject of the Superfund Innovative Technology Evaluation (SITE) Program[54] mandated by SARA. This special accommodation remains crucial in an archival system.

54. *See* OFFICE OF SOLID WASTE & EMERGENCY RESP., ENVTL. PROTECTION AGENCY, DIRECTIVE 9380.0-17FS, FURTHERING THE USE OF INNOVATIVE TREATMENT TECHNOLOGIES IN SUPERFUND AND OTHER EPA WASTE-RELATED PROGRAMS (Aug. 1991).

V. CONCLUSION

The case for using archival remedy selection extensively is not yet a strong one. As recounted above, obtaining a good data set is difficult, characterizing treatment trains with sufficient particularity is a potential stumbling block, and establishing appropriate decision protocols calls for careful judgment. Additionally, archival systems tend to stifle innovation, a concern in a field where encouraging technological advance is also a strong consideration. Even when these obstacles are overcome, the value of archival remedy selection resists accurate quantification at the present time. Three principal uncertainties compromise firm conclusions at this time.

◦ Until an adequate data set is developed, it is impossible to say how many types of site-contamination scenarios are apt candidates for archival remedy selection. It may be that there are not enough clear patterns of remedial action that emerge from the data to allow broad use of archival remedy selection.

◦ The time and monetary savings that are gained in the RI/FS phase of cleanups will be reduced if it proves to be significantly more time consuming and costlier to complete the RD/RA phase at a site that was not the subject of an "engineered" RI/FS. Here, keep in mind that the traditional RI/FS adds to the underlying PA that was used for HRS purposes and this information is used as the starting point for the RD/RA.

◦ Changing remedial goals and remedy selection criteria will require revision of the archive to maintain its relevance in the new setting. This may not be as easy to do as the earlier text suggested, and the politics of cleanup legislation could result in "changing the target" on repeated occasions.

All of the indications are not on the negative side of the ledger. Some items that resist precise quantification seem to suggest that the use of archival remedy selection will be availing and valuable. These too can be listed.

◦ Intuitively, the approach seems promising—similar patterns of contamination seem likely to be appropriately addressed by similar remedial actions.

◦ Even if many of the site-specific engineering costs are not eliminated, the multi-year time savings of truncating the selection process remain likely to be realized. The data gathering of the RI/FS phase probably can be integrated into the RD/RA process rather than standing as a wholly separate time commitment in the remedial process.

• The benefits of the archival method will extend beyond the CERCLA context in which it is being developed.[55] The archival method can serve as "decision support"[56] for engineers preparing to plan cleanups that are not being undertaken with reference to NCP standards. There are literally thousands of these sites nationwide.

Stated most simply, the present uncertainty in evaluating the benefits to be gained through a full blown archival remedy selection program is not sufficient to dampen enthusiasm for undertaking the relatively circumscribed research needed to support such a program. At worst, the research will demonstrate that archival remedy selection cannot be practiced on a wide scale, an insight that itself will inform future cleanup reform strategies. At best, hazardous substance cleanups will happen faster and at a significantly lower cost.

55. The principal contrast developed thus far is between present Superfund remedy selection and archival remedy selection. Implicitly, this comparison suggests that only Superfund sites will be the subject of archival remedy selection and full-blown Superfund remedy selection is not frequently practiced. There are at present only 1296 sites on the National Priorities List (NPL) at which the Superfund process as outlined in the NCP must be followed *in extensio*. This, however, understates the compulsion to use the full-blown NCP process. Private parties at NPL and non-NPL sites seeking cost recovery under § 107 or contribution under § 113 must prove as an element of their claim that the costs they incurred were consistent with the NCP. 42 U.S.C. §§ 9607, 9613(f) (1988). Thus, if the archival method were to be incorporated in the NCP there is substantial room for cost and time savings at private cleanup sites.

56. This is the new term for "expert systems" guidance in areas of high complexity.