QUANTIFYING THE CERCLA PROCESS: USE OF DECISION SUPPORT MODELING TO IMPROVE TECHNOLOGY SELECTION FOR AN ACTUAL MIXED WASTE SITE

R. K. Farnsworth, G.E. McDannel, J. G. Richardson
Idaho National Engineering and Environmental Laboratory

ABSTRACT

This paper describes a technology evaluation process that was used to evaluate various remediation technology options for mixed radioactive and hazardous wastes that are present in four subsurface "V-tanks" at the Idaho National Engineering and Environmental Laboratory (INEEL). The process used a Decision Support Model that was specifically designed to support the technology evaluation process, in accordance with Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) guidelines. Use of a Decision Support Model had never been formally included before in CERCLA technology evaluation decisions conducted at the INEEL. The model significantly improved technology selection by quantifying the basis for the final decision.

The subsurface tank wastes evaluated by this process are aqueous sludge sediments and non-aqueous-phase liquids that were produced at the INEEL between the 1950s and 1980s. They contain a variety of inorganic, organic, and radioactive contaminants, such as mercury, cadmium, various chlorinated solvents, polychlorinated biphenyl, Cs^{137}, Sr^{90} and plutonium. A 1999 Record of Decision (ROD) is currently in place supporting off-Site treatment of this waste. The off-Site facility capable of treating the waste is no longer available, however. The technology selection process described here was part of a ROD amendment effort aimed at recommending new on-Site technology alternatives for the V-tank wastes.

The process evaluated seven potential remediation technologies. They include two batch vitrification systems, three thermal desorption systems, and two chemical oxidation/stabilization systems. Each technology option was initially designed to meet CERCLA threshold criteria associated with Overall Protection of Human Health and the Environment, and Compliance with Applicable or Relevant and Appropriate Requirements (ARARs). The technology options were then evaluated in accordance with CERCLA balancing criteria related to Implementability, Short-Term Effectiveness, Reduction of Toxicity Mobility & Volume (TMV), Cost, and Long-Term Effectiveness, using the Decision Support Model.

The report includes information on setup of the model, which broke the balancing criteria into smaller sub-criteria, and assigned value functions and weighting factors to each sub-criteria. The assigning of weighting factors was as defined by the Agencies (i.e., the U.S Department of Energy-Idaho Operations Office [DOE-ID], Region 10 of the U.S. Environmental Protection Agency [EPA], and the Idaho State Department of Environmental Quality [IDEQ]). Technology experts within the INEEL then provided performance data useful in assigning relative "values" to each sub-criteria, for each of the seven technology options. The sub-criteria "values" were multiplied by their respective weighting factors, with the weighted "values" added together to produce an "overall value" for each technology option. These "overall" values were then compared against each other, to aid in the final technology selection process.

Results of the technology evaluation identified *Ex Situ Chemical Oxidation/Stabilization* (ES-CO/S) as the preferred option for remediating the V-tank waste. Even though the "overall value" distinctions between the various technology options were somewhat less than desired, the quantified decision produced by the Decision Support Model was sufficient to accelerate Federal and State Agency acceptance of *ES-CO/S* as the preferred technology option. Use of the Decision Support Model also improved presentation of the technology evaluation process to the public.

Use of such a Decision Support Model is recommended for other CERCLA decisions within the DOE complex or public sector, particularly complex waste sites. However, a number of modifications could be made to the Decision Support Model to improve final technology selection. These proposed modifications are discussed in this paper.

INTRODUCTION

The Test Area North (TAN) V-tanks at the INEEL involve three 38,000-L (10,000-gal) tanks (V-1, V-2 and V-3) and one 1500-L (400-gal) subsurface tank (V-9). All four subsurface tanks were installed in the early 1950s and were used for about 30 years in a system that collected and treated radioactive liquid waste from TAN operations, beginning with the Aircraft Nuclear Propulsion Program in the 1950s and early 1960s. Wastes were piped from the adjacent research facilities into Tank V-9, where some of the solids were removed. The remaining wastes were then routed into one or more of the larger tanks (V-1, V-2, and V-3). Remediation of the subsurface tank contents is required because of the non-compliant single-shell nature of the V-tanks (per Resource Conservation Recovery Act [RCRA] guidelines) and the presence of known spills in the area. Based on recent volume determinations, it is estimated that a total volume of 45,100 L (11,900 gal) of aqueous sludge sediments and non-aqueous phase liquids are present in these four tanks. The sludges within each tank contain F001-listed chlorinated solvents, mercury, cadmium, poly-chlorinated biphenyls (PCBs), Cs^{137}, Sr^{90}, plutonium, and other radionuclides.

The original technology selected for remediation of the V-tanks involved pumping out the tank contents, separating the sediments from the liquids, and transporting the sediments to an off-Site location where they were to be thermally processed. The thermally processed wastes would then be either returned to the INEEL, for disposal at the INEEL CERCLA Disposal Facility (ICDF), or shipped to an approved off-Site repository, such as the Waste Isolation Pilot Plant (WIPP). Details of this process are contained in the Final Record of Decision for Test Area North [1], and the Comprehensive Remedial Design/Remedial Action Work Plan for the Test Area North, Waste Area Group 1, Operable Unit 1-10, Group 2 Sites [2].

According to the 2001 Work Plan [2], the estimated cost for implementing the original remedy was nearly four times that of the original cost estimate identified in the 1999 ROD [1], eliminating its identified cost advantage over other potential remediation technologies that had been considered. In addition, shortly after the Work Plan was completed, the only off-Site facility capable of processing this waste stopped offering the thermal treatment that was called for by the ROD.

For these reasons, a decision was made to amend the portion of the TAN ROD associated with remediation of the V-tanks. The ROD amendment was to focus on potentially applicable on-Site technologies that had been demonstrated and were commercially viable. In addition, as part of the ROD amendment process, it was decided to pursue a technology evaluation process that was more quantifiable than was used in the past. The primary reason for quantifying the technology evaluation was to provide an improved basis for the technology selection that would (hopefully) accelerate Agency and public acceptance of the recommended technology. Quantifying the technology selection process was also expected to reduce the perception of bias, associated with final technology selection, by establishing a technical basis for the decision that was made. The primary component associated with the technology evaluation quantification was the Decision Support Model that was chosen for this evaluation.

INITIAL TECHNOLOGY SCREENING

The initial technology screening was focused on identifying those technologies that have either been demonstrated on similar applications, or are commercially viable. The purpose of this constraint was to eliminate a repeat of the 1999 ROD [1], in which the original technology identified for V-tank remediation was selected under the assumption that it would be commercially viable prior to initiating the

V-tank remediation (which didn't occur). By requiring this of all potential technologies, the chance of another ROD amendment process in the future was minimized.

A summary of the initial technical screening was detailed in the Technical Evaluation Scope of Work for the V-tank remediation effort [3]. The initial technical screening considered information from previous technology studies and evaluations [4,5,6,7] before settling on three technology types that were considered the most mature and potentially applicable for V-tank waste remediation, namely:

- Vitrification,
- Thermal Desorption, and
- Chemical Oxidation/Stabilization.

The three technology types were then broken down into alternative applications, with vitrification and chemical oxidation/ stabilization considered for both in situ and ex situ (on-Site) applications, and on-Site thermal desorption broken down into three different levels of secondary waste processing (on-Site, off-Site, and a hybrid of on- and off-Site processing).

Technical experts within the INEEL were then asked to provide pre-conceptual designs supporting each of the seven technology alternatives, in a manner that met the CERCLA threshold criteria of Overall Protection of Human Health and the Environment, and Compliance with ARARs. In particular, the technology alternatives had to be designed in a manner that provided viable options for on- or off-Site disposal, while operating in a safe manner that would not impact either the public or the worker. Meeting CERCLA threshold criteria is a mandatory requirement for the technology alternatives to be considered further. Once designed, the technology alternatives were compared and contrasted against each other, using the Decision Support Model. The pre-conceptual design effort proceeded concurrently with setup of the Decision Support Model used to evaluate each technology. Details of the pre-conceptual designs for each technology alternative are shown in the Pre-Conceptual Design Report for the V-tank Alternatives [8].

DESCRIPTION OF EVALUATED TECHNOLOGIES

As identified, a total of seven technology alternatives were considered. A brief description of each technology alternative is presented below:

The *In Situ Vitrification* (*ISV*) process involves glassification of the V-tank waste within some or all of the subsurface V-tanks. The *ISV* process destroys or removes organic contaminants in situ, while dissolving all non-volatile inorganic contaminants and radionuclides in a vitreous mass with a product durability (upon hardening) similar to that of basalt or obsidian. Semi-volatile inorganic contaminants and residual organic contaminants are transported to a metallic hood over the melt that channels the contaminants to a regulated off-gas system. The proposed *ISV* application for the TAN V-tanks involves planar-ISV processing from the sides of the V-tanks inward, rather than from the top down. This eliminates safety concerns over melt expulsions that have impacted conventional *ISV* processes. Battelle Pacific Northwest Laboratory patented the initial form of *ISV* in 1983. AMEC Earth and Environmental, Inc., currently control commercial rights to *ISV* (as well as all rights to planar-*ISV*).

Ex Situ Vitrification (*ESV*) produces glassified waste forms that are similar in durability to those produced via *ISV*, while destroying nearly all organic contaminants in the waste, and collecting semi-volatile inorganic and residual organic contaminants in an off-gas system. The primary difference between *ISV* and *ESV* is that *ESV* is performed outside of the tanks, in smaller containers (such as roll-off boxes). The ex situ nature of *ESV* requires less soil processing than *ISV,* but with slightly more complexity, due to the need for increased shielding requirements.

The *Thermal Desorption on-Site* (*TD on-Site*) processing option allows for on-Site ex situ processing of the V-tank wastes in small batches. Thermal desorption allows for volatile organics and semi-volatile inorganics to be volatilized away from the waste sediments, without the high temperatures needed to glassify the waste. Soil will need to be mixed with the V-tank wastes prior to *TD on-Site* processing, in order to improve implementability. During *TD on-Site* processing, all thermally desorbed contaminants will either be destroyed (via an in-line thermal oxidizer) or captured. The radioactive residue produced by *TD on-Site* will then be disposed of at the ICDF, in either a stabilized or non-stabilized form (depending on whether or not it meets Land Disposal Requirements).

The Thermal Desorption option involving on- and off-Site processing of the secondary waste (*TD on/off-Site*) is similar to the *TD on-Site* processing option. The only difference between this option and *TD on-Site* is that the secondary organic wastes produced during thermal desorption are collected in activated carbon filters and sent off-Site for processing, rather than processed on-Site. The primary wastes residues associated with this option will also be disposed of in either a stabilized or non-stabilized form (depending on regulatory requirements).

The *Thermal Desorption off-Site* (*TD off-Site*) processing option differs from the *TD on/off-Site* option in that the residue from the thermal desorption operation will be shipped off-Site, for eventual stabilization and disposal. Thermal desorption processing will still be performed on-Site. In addition, the *TD off-Site* processing option will not involve the addition of soil materials that are generally recommended for improving operation of the thermal desorption system. Therefore, there is a potential for substantially less residual waste form with this option.

The *In Situ Chemical Oxidation/Stabilization* (*IS-CO/S*) process involves placing chemically oxidizing (or reducing) chemicals into one (or more) of the V-tanks (depending on tank consolidation efforts). The chemical oxidizers will be designed to destroy all organic contaminants that are present in the wastes to below regulatory levels. The chemical oxidation process may require heat and or pH control, within the tank, in order to be effective. In the event of any volatilization during chemical oxidation, a simple off-gas system will be used to recycle the contaminants back to the tank and/or capture any residual contaminants that are not recycled. Following in situ chemical oxidation, the oxidized wastes will be mixed with stabilization agents to solidify the wastes and meet applicable regulatory requirements and waste acceptance criteria. The solidified wastes will then be deposited in the ICDF.

Ex Situ Chemical Oxidation/Stabilization Process (*ES-CO/S*) is similar to *IS-CO/S*, except that the chemical oxidation process will be conducted ex situ, in small (350-700 L) batches. The ex situ nature of *ES-CO/S* will require more shielding than *IS-CO/S*, but is expected to be easier to control mixing, heat and pH. In addition, the ex situ nature of *ES-COS* allows for the chemical oxidation to be conducted in a more chemically resistant process tank.

MODEL DESCRIPTION

The Decision Support Model used for the technology evaluation was modified from a screening model that had been previously implemented in Analytica™, an interactive object-oriented programming environment developed by Carnegie-Melon University, and currently supported by Lumina Technologies, Inc. The objective of the Design Support Model was to incorporate CERCLA-based measures into an automated assessment system that would provide a quantifiable basis for CERCLA-based technology evaluations.

The model provides a mathematical representation of the effects of different technology applications to a site by first identifying a number of sub-criteria needed to evaluate each technology. Each sub-criterion is then assigned a value function, which provides a scale relating the range of performance measures associated with each sub-criterion to an assigned “value” for that sub-criterion. An example of such a value function is shown in Figure 1, which shows the assigned “values” associated with the waste form’s estimated transuranic concentration, following treatment. As shown in the figure, the assigned “value” associated with a particular performance measure need not necessarily be linear. Rather, the assigned “value” is developed based on the relative importance of the range of potential performance measure inputs under consideration.

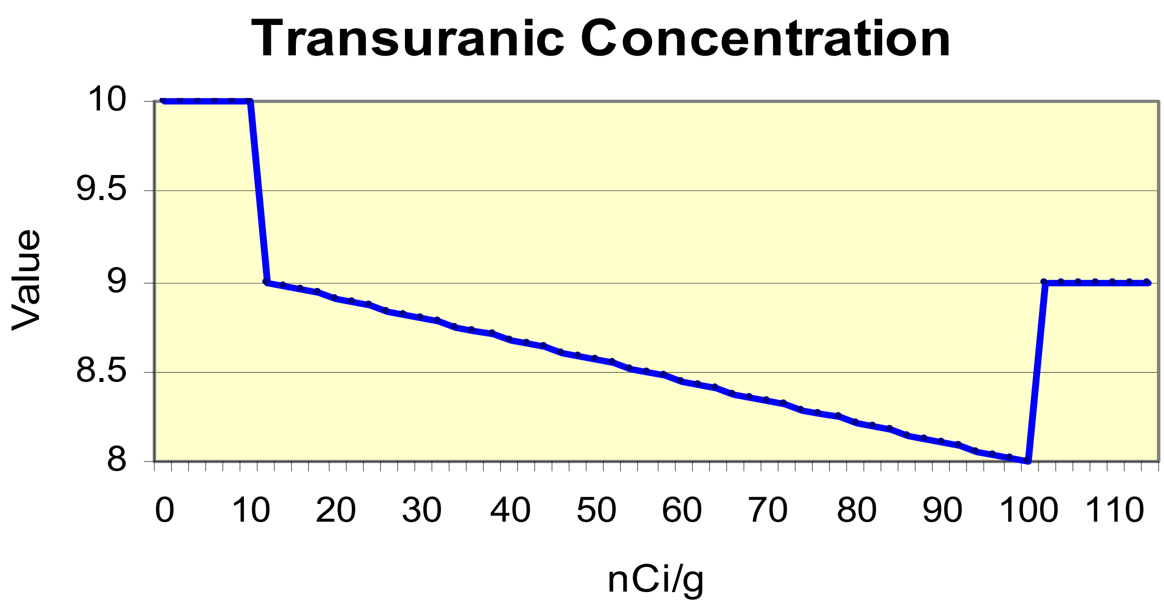

Fig. 1 Assigned value function for transuranic concentration in the resulting waste form

Referring to Figure 1 (for example), it was felt that technologies with transuranic waste form concentrations less than 10 nCi/g should be assigned values of “10”, since their resulting waste forms could be disposed of at the ICDF. A value of “9” was to be assigned to technologies with transuranic waste form concentrations above 100 nCi/g, since their waste forms would have to be disposed of at WIPP. Between 10 and 100 nCi/g, however, ultimate waste disposition was more tenuous, resulting in assigned values between “8” and “9” (depending on concentration) for each prospective technology.

Similar value functions, relating performance measures to assigned values, were developed for each of the sub-criteria associated with the CERCLA remediation decision. Each value function also had a quantified weighting factor assigned to it, representing the relative importance of the value function in the overall technology evaluation process.

Upon developing the necessary value functions, and assigning weighting factors to each value function, the Decision Support model could be used to quantitatively evaluate the relative strengths and weaknesses for each prospective remediation technoloigy under consideration. This was done by evaluating the expected performance of each technology against the value functions that had been developed for the model. The model allows for the technology performance and site attribute data to either expressed deterministically (as a single end-value) or as a probability distribution (using a 10,000-point Monte Carlo calculation). Using the inputs for each weighted value function, the model is used to calculate an "overall value" for each evaluated technology, according to the following equation:

$$Value_{overall} = \sum (Value_i * Weight_i), \qquad \text{(Eq. 1)}$$

where:

$Value_i$ = specific value given to each sub-criteria,
$Weight_i$ = weighting factor for each sub-criteria, and
$Value_{overall}$ = calculated "overall value" for a specific remediation technology.

The "overall values" for each evaluated technology can then be compared and contrasted, to assist in the final technology decision.

MODEL DEVELOPMENT

Details of the Model Development Effort can be found in the V-Tank Model Design Report [9]. The initial model development consisted of identifying sub-criteria to assist in the technology evaluation, along with value functions for each identified sub-criteria. This was done by modifying CERCLA based measures that had been originally developed in 1992 [10], updated and first applied to INEEL technical alternatives in 1997 [11], and then expanded into a state variable model as described in *INEEL Subsurface Disposal Area CERCLA-Based Technology Screening Model* [12]. The original sub-criteria/value function identification had been developed around CERCLA balancing criteria (i.e., Implementability, Short-Term Effectiveness, Long-Term Effectiveness, Cost, and Reduction of Toxicity Mobility & Volume [TMV]) for generic CERCLA-based technology evaluations. The modification was needed to specifically apply the generic sub-criteria (and associated value functions) to the V-tank remediation effort.

Finalizing the modified evaluation sub-criteria was a collaborative effort between representatives of the various Federal and State Agencies associated with the final remediation decision (i.e., DOE-ID, EPA Region 10, and IDEQ). The sub-criteria finalization was performed with minimal technical input from the various technology experts within the INEEL. This was appropriate, since the Agencies were ultimately responsible for the final decision on which technology alternative should be used. On the basis of meetings held in 2002, the Agencies selected 30 evaluation sub-criteria.

Twenty-seven of the 30 evaluation sub-criteria were specifically applicable to the five CERCLA balancing criteria that needed to be considered in the technology evaluation process, with seven sub-criteria applied to Implementability, six applied to Short-Term Effectiveness, two applied to Long-Term Effectiveness, eleven applied to Reduction of TMV, and one applied to Cost. The other three sub-criteria included in the evaluation are associated with the technology alternatives' potential applicability to other INEEL CERCLA waste streams. This included a number of waste tanks at TAN that containing solidified wastes, a small INEEL tank containing similar waste materials, and Investigation Derived Waste associated with the V-Tank Remedial Investigation. Although the additional sub-criteria are outside of the classical CERCLA evaluation criteria, it was felt that they could be used to assist in the final technology selection process, provided their weighted values were small, relative to the resulting total weight for the five CERCLA balancing criteria.

Following identification of the sub-criteria, efforts were made to define appropriate value functions for each sub-criteria, as well as the weighting factors that would be applied towards each value function. The assignation of value functions for each sub-criteria was initially developed by CERCLA evaluation experts at the INEEL, then modified and concurred with by the Agencies involved in the decision making process. The assigning of weighting factors for each value function was also the responsibility of the Agencies, with the each Agency providing equal input to the final weighting factor for each value function. For instance, if one Agency had cost at 30%, and the other two Agencies had it at 5%, the overall weighting factor associated with cost would be 13%.

In most of the defined value functions, the defined scale was a simple straight-line curve. Some value functions, however, were combinations of two evaluations, while other value functions involved either non-straight-line curves or step changes. All value function scales were also concurred with by the Agencies.

A summary of the 30 evaluation sub-criteria, along with their weighting factors, is shown in Table I. Included in the table are the cumulative weighting factors associated with each CERCLA balancing criteria, as well as the cumulative weighting factor for the non-CERCLA criteria. As shown in Table I, the cumulative weighting factors associated with each CERCLA balancing criteria (from 8% to 33%) were larger than that assigned for the non-CERCLA criteria of technology applicability to other waste streams (4%).

ASSIGNING TECHNOLOGY INPUTS

Once the model value functions and weighting factors were established, meetings were held with the INEEL technical experts associated with the pre-conceptual designs of each remediation technology alternative. The purpose of the meetings was to provide inputs to the value functions for each of the technology alternatives under consideration. In many cases, this was relatively straight forward, based on the results of the pre-conceptual designs. In some cases, however, the application to a particular value function was more complicated. To assist in the interpretations, representatives from the model development meetings were included in the meetings, as well as regulatory experts and potential users. During the meetings, the technical experts were allowed to contrast and compare their assigned values with those from other technology alternatives, to remove the potential for bias. In the end, the final assigned values for each technology alternative had to be agreed upon by a consensus of persons present at the meetings.

Details associated with the resulting sub-criteria values for each technology alternative (as well as further breakdown on the value function scales and weighting factors) are provided in the Technology Evaluation Report for the V-Tanks [13].

Table I Weighting factors for criteria & sub-criteria associated with the v-tank technology evaluation

Criteria	Sub-Criteria	Weight
Implementability		**33%**
	Technology Maturity	4.6%
	Technology Complexity	4.6%
	Recovery Potential	2.0%
	Ability to Monitor	2.0%
	Administrative Feasibility	6.6%
	Access to Treatment, Storage & Disposal Facilities	9.2%
	Availability of Technical Specialists & Equipment	4.0%
Short-Term Effectiveness		**25%**
	Time to Remediate	5.6%
	Time to Complete Record of Decision	9.5%
	Shipments Out of INEEL	3.8%
	Worker Hazard Potential	3.8%
	Impact to Animals	1.15%
	Impact to Plants	1.15%
Reduction of Toxicity, Mobility & Volume (TMV)		**17%**
	Primary Waste Volume	2.7%
	Transuranic Concentration in Waste Form	1.9%
	Resulting Cadmium Leachate Concentration	0.64%
	Resulting Lead Leachate Concenration	0.64%
	Resulting Mercury Leachate Concentration	0.64%
	Trichloroethene Concentration in Waste Form	0.64%
	Polychlorinated Biphenyl Conc. In Waste Form	0.64%
	Bis (2-Ethylhexyl) Phthalate Conc. in Waste Form	0.64%
	Residual Cs-137 Concentration at Waste Site	5.1%
	Irreversibility of Treatment	2.6%
	Secondary Waste Volume	0.9%
Life-Cycle Cost		**13%**
Long-Term Effectiveness & Permanence		**8%**
	Magnitude of Residual Risk	4%
	Adequacy and Reliability of Controls	4%
Application to Other INEEL Waste Streams		**4%**
	Small ARA-16 Tank	1.33%
	Large PM2A Solidified Tanks at TAN	1.33%
	Investigation Derived Waste	1.33%

IDENTIFICATION OF PREFERRED ALTERNATIVE

Once values had been assigned for each technology alternative, the Decision Support Model was used to calculate an “overall value” for each technology alternative. A summary of the resulting overall values for each technology alternative is shown in Table II. Included in the Table are "overall values" for each CERCLA balancing criteria, as well as the non-CERCLA balancing criteria.

Table II Summary scoring results for V-Tank remediation alternatives

Technology Alternative	Implementability	Short-Term Effectiveness	Reduction of TMV	Cost	Long-Term Effectiveness	Other Waste Streams	OVERALL VALUE
ES-CO/S	7.63	7.19	5.70	6.11	10	5.66	**7.12**
TD on-Site	7.54	6.95	6.01	5.59	10	7.66	**7.10**
IS-CO/S	7.11	7.25	5.82	6.07	10	5.66	**6.98**
ISV	6.93	6.33	7.79	4.05	10	9.99	**6.94**
TD on/off-Site	7.63	6.20	5.89	5.61	10	7.66	**6.92**
ESV	6.76	6.31	7.04	4.21	10	9.99	**6.77**
TD off-Site	4.81	4.12	6.19	3.57	10	7.66	**5.26**

As shown in Table II, the technology alternative with the highest calculated "overall value" was *ES-CO/S*, with an overall value (on a 0-10 scale) of 7.12. As a result, it was designated as the preferred alternative for remediating the V-tanks. However, the separation in value between it and the other technology alternatives was not as large as originally hoped for, with four of the other six technology alternatives scoring above 6.9 (7.10 for the runner-up *TD on-Site* technology alternative). Furthermore, only one of the technology alternatives (*TD off-Site*) had an "overall value" (5.26) that was significantly lower than the other technology alternatives under consideration. The similarities in overall value amongst six of the seven technology values supports the contention that any one of these six technology alternatives could do an effective job of remediating the V-tank waste. However, greater value separation could have been created by either eliminating those value functions that scored equally for all technology alternatives, or by providing more relative discriminators in the value functions that were used for the technology evaluation. This is discussed further in the evaluation section of this paper.

A review of the weighted values associated with each technology alternative indicates the relative strengths (and weaknesses) of *ES-CO/S* over the other technology alternatives that were considered. *ES-CO/S* is preferred over the other alternatives because it is a low-temperature operation, using a simplified off-gas treatment system, while generating a stabilized waste form that can be disposed of at the ICDF. Compared to *ISV*, *ES-CO/S* has fewer potential hazards to workers, fewer monitoring concerns, lower costs, and higher system reliability, and less off-gas waste production, which more than offset *ISV's* relative strengths (technology maturity, less primary waste volume, and increased treatment capability for investigation-derived waste). Compared to *ESV*, *ES-CO/S* has fewer potential hazards to workers, lower costs, and higher system reliability. Compared to *TD on/off-Site*, *ES-CO/S* produces a lower volume of off-gas wastes, requires fewer shipments off the INEEL, and presents fewer potential hazards to workers (which more than offsets *TD on/off-Site's* greater administrative feasibility). Compared to *TD on-Site*, *ES-CO/S* poses fewer potential hazards to workers, offers higher system reliability, and produces a lower volume of off-gas wastes. Compared to *TD off-Site*, *ES-CO/S* has fewer potential hazards to workers, uses more readily available disposal facilities, has lower cost, requires fewer shipments off the INEEL, and offers better system reliability. Finally, *ES-CO/S* has equal system reliability with fewer design complexities than *IS-CO/S*.

AGENCY APPROVAL OF PREFERRED ALTERNATIVE

Following its identification, the preferred technology alternative was presented to Agency representatives, along with how the Decision Support Model was used to arrive at this decision. Included in the presentation was a discussion of which value functions were modified to better meet the requirements of the technology alternatives under consideration. As part of the two-day meeting, Agency representative were allowed to manipulate values and weighting factors associated with each technology alternative's value functions, and see the results of their manipulations.

Initial support at the Agency meeting focused on *ISV* as a potential alternative preferred technology for V-tank remediation. This was due to *ISV's* significant advantages in reducing TMV, relative to *ES-CO/S* (see above). However, this was balanced by Agency concerns over the administrative feasibility associated with implementing *ISV* at the INEEL. The meeting adjourned with the Agency representatives agreeing to contact the INEEL within the week, after presenting information from the meeting to their superiors.

At the following conference call, the Agencies agreed to support the INEEL in their determination of *ES-CO/S* as the preferred technology for remediating the V-tanks. Although support continued for *ISV* as an alternative preferred technology, the consensus felt that *ES-CO/S* provided a slightly better "overall value" than *ISV*. Furthermore, based on previous public input, the non-thermal nature of *ES-CO/S* appeared to have greater support than *ISV,* in terms of state and community acceptance (both CERCLA modifying criteria).

From its presentation to Agency representatives, the total time required to obtain Agency concurrence on the preferred remediation technology was less than one week. The entire process associated with developing pre-conceptual designs, evaluating each design, and obtaining Agency concurrence was less than 7 months. These lengths of time were considerably shorter than the time required to obtain past Agency concurrence on similar technology evaluation decisions at the INEEL.

A primary reason for the shorter turnaround on concurrence was due to use of the Decision Support Model, which quantified the combined Agencies' basis for selecting a particular technology for V-tank remediation. Use of the Decision Support Model forced early interaction between the Agencies to come to an agreement as to the relative weights that would be applied to each particular evaluation criteria (as well as the types of criteria that would be used). The early interaction between the Agencies and the INEEL also allowed for better understanding of which criteria was most important, which improved the focus of the pre-conceptual designs for each technology alternative. Finally, use of a Decision Support Model allowed the Agencies to more rapidly evaluate potential changes in the way a technology alternative is considered, or what selection criteria are more important.

PUBLIC INVOLVEMENT

The preferred technology for V-tank remediation (*ES-CO/S*), was presented to the public via a Revised Proposed Plan for the V-tanks [14]. Included in the proposed plan was a discussion of how the Decision Support Model was used to quantify the basis for final selection, as well as the results of the alternative technology evaluations that were performed.

To improve communication, the public was informed early towards the need for an amended ROD for remediating the V-tanks, and how a decision analysis model would be used to assist in the new technical evaluation. Between August 2002 and May 2003, a series of publications and face-to-face (or telephone) meetings offered information and comment opportunities to the public, including stakeholder groups. The publications were initially in the form of reports in *EM Progress* (a periodical discussing Environmental Management activities at the INEEL), and a 2002 Fact Sheet [15] that was distributed to the public.

As part of the Revised Proposed Plan presentation, meetings were held with various stakeholder groups that had shown past interest in the final technology selection for V-tank remediation. In addition, a public meeting was held in Idaho Falls, in which members of the public were presented with the results of the technology evaluation, and allowed chance for written or public comment.

In general, the public responses were favorable to the process that was used to quantify the final technology selection. Most of the critical comments associated with the presentation were related to *ES-CO/S's* less desirable waste form but more desirable non-thermal process (in terms of off-gas concerns) vs. vitrification's more desirable waste form but less desirable thermal process and perceived safety record. Even with these differences of opinion, however, the use of a quantified Decision Support Model strengthened the responses to public questions and concerns, by allowing the response to focus on quantified decision making tools that could be referenced to provide a quantified basis towards why one technology's perceived strength in Reduction of TMV (*ISV and ESV*) are offset by *ES-CO/S's* strengths in Implementability, Short-Term Effectiveness, and Cost.

As a result of the public involvement process, plans are to continue with *ES-CO/S* as the preferred technology for V-tank remediation, pending the results of laboratory-scale studies that are currently underway. The final technology decision will be included in a ROD Amendment that should be finalized by the end of 2003.

CONCLUSIONS AND RECOMMENDATIONS

Due to the unavailability (and increased costs) of the original remediation technology for the TAN V-tanks, a decision was made to pursue a ROD amendment to the V-tank portion of the TAN ROD that considered other on-Site treatment technologies. A Decision Support Model was used to assist in the overall evaluation of technology alternative for V-tank remediation, to quantify the basis for technology selection and (hopefully) accelerate preparation of the ROD amendment. From the initial technology screening, a total of three technology types, vitrification, thermal desorption, and chemical oxidation/stabilization, were carried forward for further process consideration. The technology types were broken down into different in situ, ex situ, and on- or off-Site secondary waste processing applications, resulting in a total of seven technology systems that were to be considered. Pre-conceptual designs were then developed for each technology alternative, with the results applied to a CERCLA-based Decision Support Model that had been pre-engineered with Agency support towards the sub-criteria, value functions and weighting factors associated with the decision making process. The results of this process provided a quantified basis for selection of the preferred technology alternative that greatly accelerated Agency concurrence. Use of a Decision Support Model also helped focus data collection efforts associated with pre-conceptual design., by pre-identifying the parameters needed for evaluating each prospective technology.

Based on the accelerated decision concurrence received from the Agencies, use of such a Decision Support Model is recommended for other CERCLA decisions within the U.S. Department of Energy (DOE) complex or public sector. This is particularly true for other more complex waste sites, where a quantified decision basis could provide an improved means for supporting the final decision that needed to be made, while reducing (or at least quantifying) the inherent bias associated with each final decision.

Use of the Decision Support Model identified a number of potentially problematic concerns associated with its use, however. As a result, a number of potential modifications have been identified for either the

Decision Support Model or the decision-making process itself, when using Decision Support Modeling. These proposed modifications are discussed below.

The first modification relates to the relatively close "overall value" of six of the seven technology alternatives that were evaluated for potential V-tank remediation. As previously stated, the closeness of these "overall values" can be considered a good indication that any of the six technology alternatives could be used to remediate the process successfully. However, there may be a need for increased discrimination in the quantified CERCLA evaluation process. A simple modification that could be made to the Decision Support Model would be to ignore those value functions that have similar scores for each of the technologies under consideration. In the V-tank technology evaluation, a total of eight of the 30 value functions (totaling 17.8% of the overall evaluation) had equivalent or nearly equivalent assigned values for each technology option (with another 9.5% of the total evaluation only differing between the *TD off-Site* option vs. the other six technology alternatives). Removing these redundancies can increase distinction between competing technology alternatives, by increasing the weighting factors for those value functions that truly matter. Using this modification results in a less robust evaluation, however, since the evaluation only focuses on those criteria that differ between the evaluated technologies.

Another method to increase distinction between competing technologies is to shrink the scale range for each value function, so that a 0-10 scale represents the true range of technologies under evaluation, rather than a range that was pre-set (in our case), before the pre-conceptual designs could be finalized. In the V-tank technology evaluation, for instance, the minimum output value for a value function was less than half the output value in only 12 of the 30 value functions. Increasing the range of output values for each value function across the entire 0-10 scale would serve to increase the distinction between the various technologies under evaluation.

Shrinking the scale ranges within each value function would need to be accompanied with a new re-evaluation of the weighting factors that had been applied. This is because of the more relative nature of the technical evaluation that is being proposed. In the V-tank technology evaluation, for instance, the original Technology Complexity Scale assumed a difference (in number of components) of 10-100, for each technology under consideration. It was under this original scale that a weighting factor of 4.6% (equivalent to the weighting factor for Technology Maturity) was established. Upon completing the pre-conceptual designs for each technology alternative, however, it was decided that only "major component systems" should be considered, rather than all components. The revised scale associated with Technology Complexity ranged 8-16 "major component systems", rather than the 10-100 components that had been originally designated by the Agencies. At the time, it was assumed that the change in scale from 10-100 components to 8-16 "major component systems" was insufficient to impact the weighting factor associated with Technology Complexity. However, process improvement could be achieved by resubmitting the re-scaled value functions to the Agencies, to verify whether or not they feel that the change in scale would be sufficient to justify a change in weighting factor.

A final potential improvement related to the decision making process involves the gradual improvement in data that is being used to evaluate each technology alternative, over time. In comparing innovative technologies with more established technologies, there is a potential for gross underestimation or over estimation of the innovative technology, due to the lack of knowledge associated with it (relative to established technologies). Although the Decision Support Model attempts to account for this, via a value factor associated with Technology Maturity, there is a possibility that new data associated with the innovative technology may either invalidate its assumed superiority to other technology alternatives, if selected, or its assumed inferiority to the established technology that was selected. Unfortunately, within the DOE complex, this re-evaluation occurs most commonly between the time that the ROD is signed, and the final design is completed (as evidenced by the increased costs associated with the original technology alternative for the V-tanks). A primary reason for this is the long delay period, within the DOE complex, between the time of the ROD and the actual remediation.

A possible way around this would be to delay the ROD until more information is known, regarding the potential technologies under consideration. Under such a condition, continued use of Decision Support Modeling could provide a method for determining when to discontinue research of a particular remediation technology, over that of another, prior to publication of the ROD. An alternative approach would be to prepare more open-ended RODs, involving a number of potential remediation technologies along with a discussion of how the Decision Support Model would be used to select the final remediation technology. Changes to the preferred remediation technology could then be made via an Estimate of Significant Discrepancy (ESD), rather than the more cumbersome ROD amendment. Such a modification may require a major paradigm shift with Agency acceptance and approval, however, since current published guidance for RODs suggest that a change in the specified technology is a "fundamental" change that requires a ROD amendment.

ACKNOWLEDGMENTS

This work was supported by the U.S. Department of Energy, Assistant Secretary for Environmental Management (EM), under DOE Idaho Operations Office Contract DE-AC07-99ID13727. The authors are indebted to Eric Miller, Mark Elliott, Dale Cresap, and Jenn-Hai Pao for their technical expertise, with regards to thermal desorption and chemical oxidation technologies.

REFERENCES

1 U. S. Department Of Energy, Idaho Operations Office. "Final Record of Decision for Test Area North", DOE/ID-10682, Rev. 0, U.S. Department of Energy, Idaho Falls, ID (1999).

2 U. S. Department Of Energy, Idaho Operations Office. "Comprehensive Remedial Design/ Remedial Action Work Plan for the Test Area North Waste Area Group 1, Operable Unit 1-10, Group 2 Sites", DOE/ID-10875, Rev. 0, U.S. Department of Energy, Idaho Falls, ID (2001).

3 U. S. Department Of Energy, Idaho Operations Office. "Technology Evaluation Scope of Work for the V-Tanks, TSF-09/18, at Waste Area Group 1, Operable Unit 1-10", DOE/ID-10999, Rev. 0, U.S. Department of Energy, Idaho Falls, ID (2002).

4 S. C. Ashworth. "K-Basin Sludge Polychlorinated Biphenyls Removal Technology Assessment", EDT 624542, HNF-3095, Rev. 0, Cogema Engineering Corporation, Richland Washington (1998).

5 U. S. Department Of Energy. "Report of the Secretary of Energy Advisory Board's Panel on Emerging Technological Alternatives to Incineration", Secretary of Energy Advisory Board, U.S. Department of Energy, Washington, DC (2000).

6 U. S. Department Of Energy, Idaho Operations Office. "Comprehensive Remedial Investigation/ Feasibility Study for the Test Area North Operable Unit 1-10 at the Idaho National Engineering and Environmental Laboratory", DOE/ID-10557, U.S. Department of Energy, Idaho Falls, ID (1997).

7 Environmental Protection Agency. "Section 3 Treatment Perspectives", http://www.frtr.go/matrix2/ section3/sec3_int.html (2002).

8 Idaho National Engineering And Environmental Laboratory. "Pre-Conceptual Designs of Various Alternatives for the V-Tanks", INEEL/EXT-02-01310, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID (2002).

9 J. G. Richardson And A. Chambers. "V-Tanks Decision Support Model Design Report", INEEL/EXT-02-01448, Rev. 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID (2003).

10 J. G. Richardson. "Performance-Based Technology Selection Filter Description Report", EGG-WTD-9989, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID (1992).

11 B. J. Grelk. "A CERCLA-Based Decision Support System for Environmental Remediation Strategy Selection", Air Force Institute of Technology (1997).

12 J. G. Richardson. "INEEL Subsurface Disposal Area CERCLA-Based Technology Screening Model", INEEL/EXT-2000-00158, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID (2000).

13 U. S. Department Of Energy, Idaho Operations Office. "Technology Evaluation Report for the V-Tanks, TSF-09/18, at Waste Area Group 1, Operable Unit 1-10", DOE/ID-11038, Rev. 0, U.S. Department of Energy, Idaho Falls, ID (2003).

14 U. S. Department Of Energy, Idaho Operations Office, Environmental Protection Agency, and Idaho Department Of Environmental Quality . "New Proposed Plan for the V-Tanks Contents (TSF-09 and TSF 18) at Test Area North, Operable Unit 1-10", Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID (AR No. 24783) (2003).

15 Idaho National Engineering And Environmental Laboratory. "New Alternatives Considered for V-Tanks at Waste Area Group 1," Update Fact Sheet, Revision 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho (AR No. 24774) (2002).