INSIGHTS GAINED FROM EVALUATIONS OF ALTERNATIVES FOR THE TREATMENT OF INEL LOW-LEVEL WASTE AND LOW-LEVEL MIXED WASTE*

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ABSTRACT

This paper presents the insights gained from the studies to evaluate treatment alternatives for Idaho National Engineering Laboratory low-level waste and low-level mixed waste. Some of the insights relate to the advantages and disadvantages from one treatment alternative relative to another. The other insights relate to the process of analysis itself.

INTRODUCTION

Background

Department of Energy (DOE) facilities generate significant quantities of various types of waste. The two types of waste considered here are low-level waste (LLW) and low-level mixed waste (LLMW), the latter containing both radioactive and chemically hazardous components.

At the DOE's Idaho National Engineering Laboratory (INEL), part of the LLW has been treated in the Waste Experimental Reduction Facility (WERF) since the early 1980s. WERF has been instrumental in reducing the volume of LLW to be disposed of, thereby extending the limited remaining life of the current INEL LLW disposal facility. WERF has also treated very limited amounts of characteristic LLMW.

As is typically the case with other DOE sites (1), several factors have brought about the need for advanced treatment of INEL LLW and LLMW. First, WERF was built in a decommissioned reactor facility dating from the late 1950s. The facility has hardware and operational deficiencies. WERF is currently shut down for about 2 years to correct the operational and some of the hardware deficiencies. The LLW that formerly would have been treated in WERF is accumulating in storage. Second, WERF is scheduled for closure about the year 2000. Third, there are increasing driving forces to treat more of the LLW. Fourth and most important, current waste-treatment capability at the INEL is not adequate to meet the Land Disposal Restrictions (LDRs) promulgated by the EPA. INEL LLMW is being stored awaiting the development of treatment capability. The generation of mixed waste without available treatment is considered a de facto violation of the LDR storage prohibition. The storage of mixed waste without available treatment is also considered a violation of the LDR storage prohibition. All these factors have led to the need to develop improved treatment capability for INEL LLW and LLMW.

A project has been established to develop the necessary waste-treatment capability for INEL LLW and LLMW. Project studies conducted to date include characterization of such waste streams generated at the INEL (2) and evaluation of waste treatment alternatives (3). Candidate treatment technologies have also been identified (4).

Purpose

The purpose of this paper is to highlight the insights gained from the studies to evaluate treatment alternatives for INEL LLW and LLMW. The insights were gained from a) the results of the analyses and b) the process of performing the analyses.

Several DOE sites face similar challenges in determining their waste-treatment needs and developing capabilities to meet those needs. The similarity of INEL waste with corresponding types of waste at the various DOE sites may make these insights of worth to analogous studies at other sites.

THE ALTERNATIVES STUDY

Background

The insights gained came primarily from the alternatives study (3) cited earlier. The objective of the study was to identify and evaluate, on a preliminary and overview basis, the alternatives for treating INEL LLW and LLMW. The results of the study were intended to provide useful information on which to base a decision on whether to proceed with the conceptual design of a proposed new facility, the Mixed and Low-level Waste Treatment Facility (MLLWTF).

Detailed, engineering-level evaluations of the alternatives were outside the scope of the study. The evaluations were performed using data available at the time of analysis and are subject to change. Figure 1 illustrates the sequence and logic for activities that constituted the study.

Waste Streams and Required Waste Products

To enable development and comparison of alternatives, the given waste inputs and the required product characteristics were evaluated if known, or assumed if unknown. Waste streams considered included those generated by ongoing operations, those generated by the Decontamination and Decommissioning (D&D) Program, and those generated by environmental remedial actions. Because the alternatives evaluated in the study would begin operations about the year 2000 or soon thereafter, the waste streams had to be considered relative to that time period.

Waste streams currently generated by INEL facilities had been characterized (2). No reliable projections are available of waste from ongoing INEL operations in the post-2000 time

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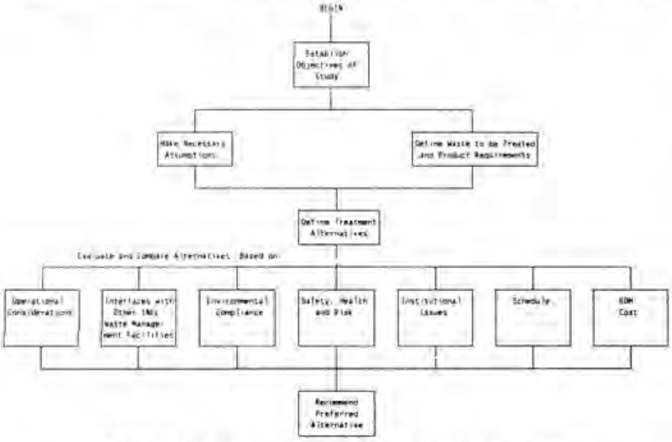

Fig. 1. Logic flowchart for alternatives study.

period. Therefore, an assumption was made that the future waste from ongoing operations will not change from the current waste.

No comprehensive projections were available of the waste to be generated by the D&D Program and INEL remedial actions. Based on guidance from remedial action managers, no waste to be generated by INEL remedial actions is assumed to require treatment in the INEL LLW and LLMW treatment facilities in the time period covered in the study (2003–2028). The waste to be generated will have been dispositioned before the treatment facilities evaluated begin operations.

The volumes and characteristics of the D&D Program waste streams were estimated based on information provided by those working in the Program and on engineering judgement. A major increase in INEL D&D activities is expected about the time that the treatment alternative would begin operations (2003).

The total waste stream volume (ongoing waste plus D&D waste projected for the time period of this study) was 8,042 m^3/yr (4,266 + 3,776). The total LLW volume is 7,517.3 m^3/yr (4,183.3 + 3,334), and the LLMW volume is 524.7 m^3/yr (82.7 + 442). The categorization scheme is shown in Fig. 2. No alpha-contaminated LLW was addressed because another treatment project was addressing such waste.

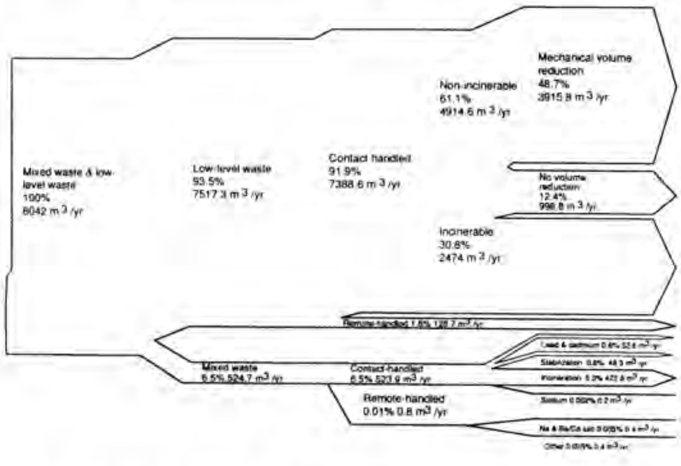

Fig. 2. Distribution of waste from ongoing operations and from the expanded *D&D* Program.

Assumptions and Uncertainties

Many items of information necessary to evaluate the alternative were not available. For example, the treatment processes that will be used in the MLLWTF have not been selected yet by the engineering and design team. Therefore, numerous assumptions were made about the missing items of information.

Several of the assumptions made are not only uncertain, but are also important enough to potentially affect the conclusions of the study. For this reason, "key uncertainties," which could change between now and the date of facility startup (about 2003), were identified.

Treatment Alternatives

Several conceptual alternatives for treating INEL mixed waste and LLW were formulated for evaluation and comparison. The alternatives form a relatively complete set of reasonable, upper-level options. Table I lists the alternatives evaluated in this study. It is noted that the Process Experimental Pilot Plant (PREPP) is a deactivated INEL facility constructed to demonstrate treatment of transuranic (TRU) waste. PREPP is currently being maintained in stand-by condition. The Idaho Waste Processing Facility (IWPF) is a proposed facility for production-scale treatment of INEL alpha-contaminated waste, whether the waste is TRU waste or alpha LLW.

TABLE I
Treatment Alternatives Evaluated

Alternative 1	Construct and operate the MLLWTF (both maximum and minimum treatment options)
Alternative 2	Modify and operate WERF
Alternative 3	Modify and operate PREPP
Alternative 4	Generator treatment
Alternative 5	Offsite treatment
Alternative 6	Treat LLW and LLMW in IWPF
Alternative 7	Combinations of alternatives
	WERF and Offsite treatment
	WERF and IWPF
	Generators and Offsite treatment
	Generators and IWPF
Alternative 8	No action

Evaluations

Seven areas were selected for evaluating the suitability of the alternatives on a preliminary overview basis. The areas of evaluation included operability, environmental compliance, safety, institutional issues, compatibility with other waste management facilities, schedule, and rough order-of-magnitude (ROM) life-cycle cost.

In addition to discussing the performance of each alternative in the areas listed above, the performance was specifically evaluated against lists of "musts" and "wants."

The list of "musts" comprised the mandatory criteria for recommendation of a treatment alternative. To be considered viable, an alternative had to comply with every listed "must." The mandatory "must" criteria for recommendation of a treatment alternative were as follows: 1) comply with all environmental and waste management regulatory requirements, 2) present acceptable risk to the workers, the public, and the environment; 3) perform all required treatment of LLMW and LLW generated at the INEL, over a period of 25 years; 4) all waste forms that are produced must be acceptable for disposal at the proposed Mixed and Low-level Waste Disposal Facility (MLLWDF); 5) have acceptable development risk, as measured by a requirement to use only proven technology; 6) present no potential major conflicts with the missions or operations of other existing or planned INEL waste management facilities; and 7) present no insurmountable institutional problems.

The "wants" represent criteria that affect the recommendation of an alternative, but are not strict requirements. Each alternative was scored on each "want." Each "want" was assigned an importance weight. For each alternative, the scores on the various "wants" were multiplied by the importance weights of the respective "wants," then summed.

Analysis of Results

The WERF, generator treatment, and no-action alternatives failed the first, third, and fourth, "must" criteria. The no-action alternative also failed the seventh "must" criterion. Therefore, these three alternatives were not considered viable treatment options.

Table II summarizes the "wants," importance weights (in parentheses), and weighted scores. The top-scoring viable treatment alternatives were the 1) MLLWTF maximum treatment, 2) MLLWTF minimum treatment, and 3) IWPF.

The study identified other considerations important to selecting an alternative, considerations that are not quantifiable. Among the considerations are a) will the treatment of LLW be required only if cost effective or if needed to enable the disposal facility to meet its performance criteria, or will treatment be required in all cases to reduce volume and increase stability, b) the waste volume projections from the expanded D&D activities are uncertain and the large volume of contaminated debris drives the need for treatment technologies (i.e., rotary kiln incineration) otherwise not needed, c) there is no assurance that several of the waste treatment facilities addressed in the study (offsite treatment of mixed waste, IWPF, etc.) will exist.

INSIGHTS GAINED FROM THE STUDY

The results of the alternatives study range from the expected through the surprising. As used here, an insight is a result or conclusion that is either new or, in some cases, surprising in that it is contradictory to what was expected. The insights discussed here are those felt to have potential application outside the INEL. Insights gained from the results, as well as from the approach used to perform the study, are discussed.

Insights from the Results of the Analysis

Insights gained from the results were primarily in the areas of

1. Risk analysis
2. Waste stream characterization
3. Life-cycle cost estimation
4. Cost of offsite treatment
5. Cost of volume reduction
6. Inadequacy of Best Demonstrated Available Technologies (BDATs) for some mixed waste
7. Length of schedule.

The desire to minimize risk to workers, the public, and the environment is more dominant than expected in the selection of a treatment alternative. Risk was given the highest subjective importance weighing of five, so it was expected that it would contribute more heavily than any other individual "want." However, it was not expected that it would contribute more than all the other "wants" combined. To see this more clearly, note that the overall scores for viable alternatives show a spread of 40 points out of a possible 170 (Table II). If the risk "want" is deleted, the overall scores show only an 11-point spread out of a possible 120.

The risk "want" had three significant parts that contributed to the total score: 1) the risk associated with disposal of waste, 2) the risk associated with shipping waste, and 3) the risk associated with operation of the treatment facility. All three of these risk elements were estimated based on safety-engineering judgement and not on a detailed evaluation. This is, as mentioned below, the nature of the preconceptual approach, but it does indicate that efforts to better define each of the risks are key to reducing the uncertainty of the relative rankings. One particular improvement would be to perform a site-specific performance assessment for the proposed MLLWDF. The results could then be used to evaluate the risk/benefit associated with additional treatment to stabilize the waste, to determine if the benefit is as significant as it was judged to be in the alternatives study.

Another area in which a better understanding is key to the selection of alternatives is characterization of the waste to be treated. This in itself was not an insight; however, the large effect of the expanded D&D Program waste on the selected alternative was not foreseen. In the study it is assumed that D&D operations will produce a large volume of heterogenous, non-combustible LLMW. The hazardous portion of the LLMW will require treatment using incineration. Thus, the alternative must include an incineration system to handle the D&D waste.

For this study, the result of treating the assumed D&D waste was that alternatives using only stationary-hearth controlled-air incineration were not deemed to be capable of treating all the waste and thus did not meet the "must" to treat all waste. Obviously, if the D&D waste did not produce the assumed stream, then the controlled-air options would potentially become viable, perhaps even desirable. The insight gained is that the wastes produced by D&D operations need to be better defined before a final alternative can be selected.

It was not known how the ranking of items on a cost basis might change if a life-cycle cost estimate were performed instead of a front-end cost estimate. A front-end cost estimate is one that includes the initial project costs through startup. The life-cycle costs include all costs through the final D&D of the facility. It was found that the ranking based on life-cycle costs differed from that based only on the front-end costs.

It was not known whether treatment offsite would be economically competitive. From a life-cycle cost standpoint,

TABLE II
Summary of Performance of Alternative Against "Wants"

Alternative	Wants								
	Minimize risk to workers, the public, and the environment. [5]	Minimize noncompliance with safety-related criteria of DOE Order 6430.1A**	Minimize problems in operability, reliability, and maintainability. [3]	Minimize use of technologies proven only under nonradiological conditions or only by the vendor. [3]	Minimize the schedule for beginning radioactive operations. [2]	Minimize the life-cycle cost.	Minimize potential interface problems with other INEL waste management facilities. [1]	Minimize potential institutional problems. [1]	Sum
MLLWTF (maximum treatment)	50	**	15	18	14	12	9	9	127
MLLWTF (minimum treatment)	35	**	24	18	14	10	7	8	116
*Modify WERF	15	**	12	27	18	12	10	5	99
Modify PREPP	30	**	6	18	16	12	9	10	101
*Generator treatment	15	**	24	30	18	14	7	6	113
Offsite	20	**	15	18	14	14	6	7	94
IWPF	35	**	12	18	12	20	7	8	112
WERF/offsite	15	**	9	24	14	10	9	6	87
WERF/IWPF	30	**	6	24	12	12	9	7	100
Generator/offsite	20	**	15	18	14	12	7	6	92
Generator/IWPF	35	**	12	18	12	14	7	7	105
*No action	10	**	30	30	20	16	6	0	112

[ ] = Importance weight.
* Alternatives that failed a "must" and are not considered viable.
** Performance on this "want" is also a factor in the performance on the "want" related to risk. To avoid double counting of compliance with safety-related criteria, the scoring on this "want" is deleted.

the cost of the evaluated offsite-treatment alternative is lower than that for most of the other options. The evaluated offsite-treatment alternative is a minimum-treatment option; that is, it does not result in maximum volume reduction of waste. For offsite treatment resulting in maximum volume reduction, the life-cycle costs would be essentially identical to the other maximum-treatment options.

It was erroneously expected that the alternative with treatment onsite for volume reduction would have a higher life-cycle cost than the alternative with predominantly direct disposal. Even when incremental disposal costs are used (i.e., only the additional cost associated with the additional waste disposed and not the apportioned "sunk costs" are considered) the maximum treatment option is slightly less expensive than the minimum treatment option. In other words, for the easily treated LLW, it saves money to reduce the volume of the waste using incineration and size reduction/compaction equipment.

It was found that some of the BDATs identified in the Resource Conservation and Recovery Act (RCRA) have a questionable basis. In other words, the selection of some BDATs was not made on strong technical grounds, and treatment using the BDATs may result in the disposal of a waste that might cause a health hazard. The two INEL waste streams that fit this category are mercury and lead. The BDAT for lead is encapsulation, which may adequately deal with the relatively short-term radioactivity problem, but does not effectively deal with the long-term problem associated with the lead itself. Eventually, the encapsulation will break down and the lead will be exposed to the environment of the waste disposal site.

Another questionable BDAT is that for mercury. The BDAT is amalgamation. Amalgamation does result in a more stable form of mercury, but perhaps a form that is not very stable overall. It is anticipated that a significantly better form could be achieved.

The final insight gained is related to schedule. It was found that it takes 10 to 14 years to take an INEL project from preconceptual studies to the beginning of operations. The long schedule is a result of the meshing of funding cycles, formal design procedures, National Environmental Policy Act (NEPA) documentation, and permitting requirements. While these elements have been present for years, many additional requirements have been added, especially in the area of permitting, resulting in a recent extension of 4 to 5 years for most major projects.

Insights about the Approach

The approach used to perform the alternatives study is thought to be useful and applicable to those who perform similar studies. The insights gained are related to the timing of the study and to the framework used to perform the study.

When performing an overview alternatives study, the needed information is seldom complete and is sometimes not even available. As a result, many assumptions must be made based on available information and engineering judgment. The earlier in the life of the project that the alternatives are evaluated, the larger the number of unknowns and the greater the uncertainty. The alternatives study discussed in this paper was performed in the preconceptual stage of the project. As a result, many assumptions were required and the result is uncertain. It is possible that the recommended alternatives will be discarded at a later date.

While recognizing that the uncertainty is large, it is felt that the early performance of the study was extremely beneficial. The assumptions required and the questions raised point to areas where further information is needed. More important, the study provides a framework for gauging the effect of (sensitivity to) changes in the assumptions, which in turn helps to prioritize the search for additional information. Since an exhaustive, detailed evaluation is seldom practical, this prioritization is extremely helpful.

As examples, it was pointed out by the study that more information on the characteristics of D&D waste was needed to choose an alternative and that more information on relative risk was needed to rank alternatives.

"Musts" and "wants" make an effective framework for alternatives studies. The approach ultimately provides a ranking of alternatives but the process of developing the rankings is just as valuable. The process, if performed thoughtfully, results in identifying important considerations in making a final selection and points to areas where uncertainty is large and additional information is required.

The user of the "musts/wants" approach should consider the numerical results very carefully. The numerical results are not arbitrary and should be used to guide the selection of the best alternatives. However, the numerical results are subjective. Uncertainty is introduced by the unknowns and assumptions made in order to perform the evaluation. As a result, it may be difficult to differentiate between the top alternatives, or perhaps any of the alternatives, if the rankings are numerically close and the uncertainty high. If this is the case, then more work has to be done to narrow the uncertainty. There is also the possibility that the inability to differentiate means that all of the alternatives are reasonable.

Often, not all the important considerations are included in the numerical evaluation. This can occur because the necessary information to evaluate a certain item was completely unknown or unavailable. The upshot of these warnings is not that the approach is irrevocably flawed, but rather that the results should always be carefully considered, with an eye toward unknowns and bias. The evaluator should always remain flexible, prepared to reconsider the scoring if new information indicates that a change is necessary.

The approach reported here has provided useful insights to be considered as the decision-making process unfolds for providing improved treatment capability for INEL LLW and LLMW.

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