BWID SYSTEM DESIGN STUDY*

M.C. O'Brien, M.J. Rudin, J.L. Morrison, and J.G. Richardson
INEL

ABSTRACT

The mission of the Buried Waste Integrated Demonstration (BWID) System Design Study is to identify and evaluate technology process options for the cradle-to-grave remediation of Transuranic (TRU)-Contaminated Waste Pits and Trenches buried at the Idaho National Engineering Laboratory (INEL). Emphasis is placed upon evaluating system configuration options and associated functional and operational requirements for retrieving and treating the buried wastes. A Performance-Based Technology Selection Filter was developed to evaluate the identified remediation systems and their enabling technologies based upon system requirements and quantification of technical Comprehensive Environmental Response, Compensation, and Liability (CERCLA) balancing criteria. Remediation systems will also be evaluated with respect to regulatory and institutional acceptance and cost-effectiveness.

INTRODUCTION

The mission of the Buried Waste Integrated Demonstration (BWID) System Design Study is to identify and evaluate systems for the cradle-to-grave remediation of Transuranic (TRU)-Contaminated Waste Pits and Trenches located within the Subsurface Disposal Area (SDA) of the Idaho National Engineering Laboratory (INEL). A Performance-Based Technology Selection Filter (PBTSF) was developed to evaluate the identified remediation systems and their enabling technologies based upon system requirements and quantification of technical Comprehensive Environmental Response, Compensation, and Liability (CERCLA) balancing criteria. There are three distinct objectives of the Study:

1. Direct U.S Department of Energy (DOE) resources to develop technically sound and cost-effective systems for the complete remediation of DOE buried waste sites.
2. Guide the selection and technical justification for the development and demonstration of technologies within the BWID Program.
3. Identify system technology gaps and define quantitative performance requirements for systems associated with the remediation of DOE Complex buried wastes.

BWID will use the results of the Systems Design Study in conjunction with identified DOE Complex buried waste needs to develop a long-term strategy for improving buried waste remediation capabilities throughout the DOE system.

SYSTEM REQUIREMENTS

System requirements are defined in the BWID System Design Study as a set of top-level constraints which guide the development and selection of viable remediation systems from a population of candidate system options. System requirements, as defined in the Study, are not the same as functional and operational requirements (F&OR) associated with each of the steps within a particular system. The overall performance of a remediation system is restricted by requirements such as waste/site characteristics (1), waste acceptance criteria (WAC) (2,3), applicable or relevant and appropriate requirements (ARARs), and programmatic requirements defined by BWID, DOE, Environmental Protection Agency (EPA), and the State of Idaho (4).

System requirements are limited in this Study to those requirements that significantly affect the viability of a specific system. Proposed system requirements have been generated from a combination of technical and regulatory sources and are divided into three categories: (a) Programmatic Requirements, (b) Input Requirements, and (c) Output Requirements. Actual requirements are listed in an EG&G Idaho, Inc. draft report entitled, Performance-Based Technology Selection Filter Preliminary Description Report (5).

CONFIGURATION OPTIONS

A configuration option is defined as a top-level block diagram of a cradle-to-grave remediation system whose overall performance is specified by system requirements. An earlier report (6) identified and pre-screened a number of possible BWID retrieval and treatment configuration options per criteria set forth in DOE Order 4700.1, Project Management Systems. The report recommended the following three configuration options for future evaluation: retrieve/ex situ thermal treatment, retrieve/chemical oxidation and solidification, and in situ vitrification/retrieval. The BWID System Design Study will initially focus on performing a more rigorous evaluation of the retrieve/ex situ thermal treatment and retrieve/chemical oxidation and solidification configuration options.

Each block within a configuration option performs a function and thereby is referred to as a "functional subelement." Specific F&ORs will be identified for each functional subelement within the retrieve/ex situ thermal treatment and retrieve/ex situ chemical oxidation and solidification configuration options. F&ORs will direct the insertion of specific technologies into each functional subelement resulting in the formulation of a technology process option. A technology process option is a CERCLA term used to describe a configuration option with specific technologies or requirements defined for all functional subelements.

* Work supported by the U.S. Department of Energy, Office of Environmental Restoration and Waste Management, under DOE Idaho Field Office, Contract DE-AC07-76IDO1570.

PERFORMANCE-BASED TECHNOLOGY SELECTION FILTER

The BWID Performance-Based Technology Selection Filter (PBTSF) is a tool within the BWID Systems Design Study which represents a formal methodology for selecting and rating technology process options. The PBTSF uses two components during its application. One component screens candidate technology process options against previously defined system requirements. The second component is the execution of trade-off studies rating technology process options against performance measures, to allow direct comparison between and among various systems and their constituent technologies.

The formal methodology used for trade-off studies is unique. It is based on screening and evaluation criteria that must be applied during the CERCLA Remedial Investigation/Feasibility Study (RI/FS) process. These criteria have been reduced to a series of formulas that generate numerical scores indicating how well a technology process option performs by each of the criteria. The scores are then summed up in a weighted average to generate an overall score for the option. The inputs to the formulas are various system technical performance characteristics, of the process option, such as throughput and efficiency, and certain other institutional performance characteristics such as technical risk and effective benefit.

Details Of The Tradeoff Study Function

Federal Regulation 40CFR300.430 requires that the CERCLA RI/FS process follow a formal series of steps for consideration of alternative remediation approaches. The primary objective of the feasibility study is "to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to a decision-maker and an appropriate remedy selected." Federal Regulation 40CFR300.430 presents nine criteria for evaluation of alternatives, and three criteria for development and screening of remedial alternatives.

Several documents have been published providing users guidance for applying the CERCLA criteria. A report entitled Guidance on Feasibility Studies Under CERCLA EPA/540G-85/003 (7) provides instruction on evaluating technology process options. The report identifies seven criteria to consider while evaluating technology process options, such as effectiveness, useful life, operation and maintenance (O&M), demonstrated performance, time, constructability, and safety. The report also provides a narrative on factors contributing to each criteria. Twenty-six contributing factors were identified, and formulas were developed that reflect the text or implied meaning of each of the various sections of the narrative.

The contributing factors have been regrouped in a more recent version of the same document entitled Guidance on Feasibility Studies Under CERCLA EPA/540/G-89/004 (8) under the criteria: effectiveness, implementability, and cost. These categories correspond to the "development and screening of alternatives" criteria as discussed in 40CFR300.430. Formulas used in the trade-off study are collated in this manner. The following outline lists the three general categories and their associated contributing factors:

EFFECTIVENESS

- Volume Reduction
- Waste Generation
- Compliance to ARAR's
- Flexibility of Design
- Reconfigurability
- Robustness
- Expected Lifetime
- Availability
- Throughput
- Effective Benefit
- Environmental/Public Health

IMPLEMENTABILITY

- Technical Risk
- Safety Risk
- Demonstrability
- Site Conditions
- Conditions External to the Site - Permits
- Off-Site Disposal
- Complexity of Operations - Automation
- Complexity of Operations - Training
- Time to Demonstrate
- Implementation Risk

COST

- Life Cycle Cost.

Scoring And Formulas

Each formula consists of two parts, a driver and a normalizing function. The numerical product of the driver and the normalizing function is the score generated by each formula. All scores vary between zero and one, with zero being defined as least desirable and one as most desirable. Each driver was chosen to be an intuitively meaningful indicator of the process being measured. For example, one of the formulas used to measure EFFECTIVENESS is "Volume Reduction." Its driver is the ratio of the volume of waste remediated by the process to the total volume retrieved.

Most drivers range in value between zero and one without normalization. Some do not range between zero and one, or do so with the reverse sense (e.g., one corresponds to "least desirable"). In such cases, the driver is normalized so that the final result is consistent with all the other measurements. The final value or "figure-of-merit" for a general category (effectiveness, implementability, or cost) is determined by averaging all scores that contribute to it. It is possible to give different weights to each of the contributing factors to reflect relative levels of importance to the selection process. If necessary, different weighting factors can be applied to each of the contributing formulas.

An overall score for the entire technology process option is calculated by averaging the three figures of merit for effectiveness, implementability and cost. If desired, different weights can be applied to each of the three categories.

Note that CERCLA does not address the relative weighting of the parts that make up each category, nor does it address the relative weights of the categories to each other. The

PBTSF is implemented using a computer program which will allow all the relative weightings to be set by the Filter user.

Performance Data Input

The technology performance measure data input to the trade-off study is supplied by manufacturers, proposers, or lessons learned from other demonstrations. This may be performance measure data at the subsystem or system level. If at the subsystem level, the data must be "rolled-up" to generate system level performance indicators. In the case where a technology is undemonstrated, the data will be estimated using one or more formalized Department of Defense Logistics, Supportability, and Availability (LSA) techniques. BWID Core Planning Group (CPG) and Technical Support Group (TSG) members will review the performance measures and may request additional information. All input data, actual or estimated, will be documented for further reference.

A formal methodology for performance data roll-up is currently under investigation. The roll-up methodology is expected to depend on both the performance measure and the system configuration being considered. For example the volume reduction of a technology process option may be simply a serial combination of functional subelements and can be obtained by multiplying the volume reduction driver (volume out/volume in) of each subelement. The result would be the system value for V_o/V_i. However, some technology process options have functional subelements running in parallel to others, and the above method would not reflect the true system performance.

Filter Operation

Figure 1 illustrates the sequence of steps followed in the PBTSF to rate competing technology process options and generate specific technology development requirements. Initially, generic configuration options are developed which provide a description of a remediation system at a functional subelement level. Many possible technology process options may reflect the same configuration option, and differ only in performance characteristics of certain subelements. An example might be a melting and incineration configuration option analyzed with several different metal shredders. While each technology process option would have the same block diagram, their end-to-end performance characteristics will reflect each specific shredder technology. The BWID CPG prescreens candidate configuration options and selects those options that are obviously practical from a scientific/engineering standpoint and warrant future consideration. Reasons for rejecting particular configuration options are documented for future reference.

Specific technologies or performance requirements are defined for each functional subelement within a configuration option to develop technology process options. BWID TSGs are consulted to provide and screen technology lists that are considered for each functional subelement.

Technology process options are formally assessed to determine if they meet system requirements. The results of applying the systems requirements matrix will indicate explicitly which technology process options are or are not meeting system requirements and why. Those systems that do meet requirements are then addressed by the trade-off study function. The output of the trade-off study function is a score (also called a rating) which indicates how well the technology process option rates against the CERCLA based formulas discussed above.

Technology process options that do not meet functional requirements are examined to determine where performance must be improved or, more specifically, what performance aspects of various functional subelements must be improved. An example might be a technical process candidate generating a waste form that cannot meet output requirements. Performance requirements are then defined at the subelement level such that system requirements can be met. Note that there may be one or more subelements that are responsible for a technology process option not meeting requirements. Thus, performance requirements may be identified for more than one subelement within a technology process option. These gaps, defined by performance requirements, may be filled by existing technologies that were not initially considered, or postulated innovative technologies. This process is called identification of technology gaps.

Postulated innovative technologies, as defined by their performance parameters, are inserted into technology process options which do not meet system requirements, and the option is then reevaluated against the requirements matrix. If the technology process option meets all system requirements, it is then scored via trade-off studies, and it's overall performance compared to scores of other technology process options. A score lower than other existing systems indicates that the postulated innovative technology will not benefit the process, and that new and higher performance requirements must be met to fill the technology gap.

This process can iterate until a technology process option with a postulated technology generates a high system score. The assumed technology performance parameters then become requirements for technology development. Note, again, that technology requirements are directly related to the score the technology process option must attain in order to compare favorably with existing technology process options that require little, if any, further development.

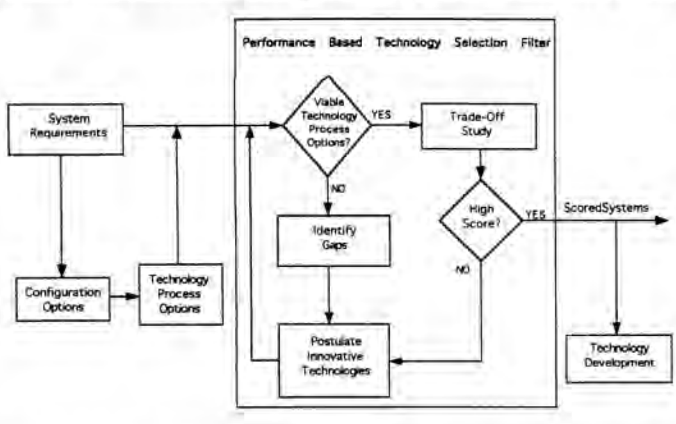

Fig. 1. BWID performance-based technology selection filter methodology.

SUMMARY AND CONCLUSION

The BWID PBTSF is a systems tool whose purpose is to provide a framework and formal methodology for selecting and rating technology process options and their enabling technologies. It also provides a closed-form approach to identify technology gaps and the requirements to fill those gaps.

There are five primary attributes of the BWID System Design Study. These are:

1. Technology process options and their enabling technologies are rated and selected based on performance measures (e.g., not value-judgement based).
2. Selection and ratings are based solely on regulatory and technical requirements, and are auditable and traceable.
3. Rating and selection is performed on complete technology process options.
4. Performance measures that direct technology development are expressively defined.
5. Methodology is applicable to other remediation system analyses.

LIST OF REFERENCES

1. D.A. ARRENHOLZ and J.L. KNIGHT, "A Brief Analysis and Description of Transuranic Wastes in the Subsurface Disposal Area of the Radioactive Waste Management Complex at INEL", EGG-WTD-9438 Rev. 1, Idaho National Engineering Laboratory 1991.
2. "INEL Low-Level Radioactive Waste Acceptance Criteria," DOE/ID-10112, Rev. 4, Idaho National Engineering Laboratory, October 1991.
3. "INEL Transuranic Waste Acceptance Criteria," DOE/ID-10074, Rev. 1991, Idaho National Engineering Laboratory, May 1991.
4. "Federal Facility Agreement and Consent Order," ADN: 1088-06- 29-120, Idaho National Engineering Laboratory, 1991.
5. M.C. O'BRIEN, J.L. MORRISON, M.J. RUDIN, and J.G. RICHARDSON, "Performance-Based Technology Selection Filter Preliminary Description Report," EG&G-WTD-9899 Rev. 0, Idaho National Engineering Laboratory, November 1991.
6. J.L. MAYBERRY, F. FEIZOLLAHI, J.C. SIGNORE, and W.J. QUAPP, "Preliminary Systems Design Study Assessment Report," EGG-WTD- 9594, Idaho National Engineering Laboratory, November 1991.
7. "Guidance on Feasibility Studies Under CERCLA," U.S. Environmental Protection Agency, EPA/540/G-85/003, 1985.
8. "Guidance on Feasibility Studies Under CERCLA," U.S. Environmental Protection Agency, EPA/540/G-89/004, 1989.