THE EVOLUTION OF A METHODOLOGY FOR SELECTING TREATMENT TECHNOLOGIES FOR LOW-LEVEL MIXED WASTES AT THE ROCKY FLATS PLANT

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ABSTRACT

In response to the compliance requirements of the Federal Facility Compliance Agreement, Docket No. RCRA (3008) VIII-89-251, the U.S. Department of Energy Rocky Flats Office and EG&G Rocky Flats, Inc. have developed a methodology for choosing primary treatment technologies for its Low-Level Mixed (LLM) wastes. Several factors have contributed to the complexity of technology selection at Rocky Flats Plant (RFP), including the lack of detailed waste characterization data, lack of a formalized selection process for evaluating the proposed treatment technologies under consideration, and intense public scrutiny that the selection process is expected to generate.

The basis of the RFP Technology Evaluation Framework is a straightforward multicriteria scoring equation in which technical analysts, non-technical analysts, and members of the general public assign scores to questions ranging from the technology's potential technical effectiveness in treating the particular waste stream to the public's confidence in the selected technology. Weights are assigned to the criteria, and an overall composite score is generated for each technology by adding the weighted criterion scores. The criterion scores are enhanced by requirements for extensive written comments on the scoring rationale and an assessment of the quality of data used to arrive at the score.

The primary lessons learned during three trial technology evaluations include 1) detailed evaluation of every LLM waste generated or stored at RFP versus every applicable technology under consideration at RFP would be too time consuming and costly to be feasible, 2) bias in the evaluations must be mitigated while maintaining continuity in the evaluation process, and 3) results of the evaluation process and analysis must be communicated to all stakeholders in a format easily understood by audiences of varying technical expertise and interest.

Lessons learned during trial runs influenced the evolution of the TEF. Changes to the methodology included reducing the number of waste streams to be evaluated, modifying the scoring methodology to reduce bias, and adding post-evaluation analysis of the data. The TEF is presently being implemented at RFP for all treatability groups and treatment systems proposed under the Comprehensive Treatment and Management Plan.

DRIVERS FOR DEVELOPING A TECHNOLOGY SELECTION METHODOLOGY

Regulatory Background and Land Disposal Regulations

Radioactive mixed wastes are wastes that contain a radioactive component subject to regulation under the Atomic Energy Act (AEA) and a hazardous waste component subject to regulation under the Resource Conservation and Recovery Act (RCRA). Mixed wastes are currently generated, treated, and stored at Rocky Flats Plant (RFP) and are subject to federal and state statutory and regulatory requirements. The U.S. Department of Energy (DOE) has responsibility for enforcing the requirements of the AEA, and the U.S. Environmental Protection Agency (EPA), Region VIII and the Colorado Department of Health (CDH) have the authority for enforcing the requirements of RCRA at RFP.

In 1976, Congress passed Public Law 94-580, otherwise referred to as RCRA. RCRA has since been amended by the Hazardous and Solid Waste Amendments of 1984 (HSWA). Under HSWA, the EPA was assigned the task of promulgating regulations to prohibit the land disposal of untreated hazardous waste. In 1986, EPA initiated its promulgation of regulations regarding land disposal of hazardous waste. This body of regulation is commonly referred to as the Land Disposal Restriction (LDR) regulations. In addition to defining specific standards for the treatment of hazardous waste prior to disposal, the LDR regulations prohibit indefinite storage of wastes subject to the LDR regulations (LDR wastes), unless such storage is for the purpose of accumulating sufficient quantities to effect proper treatment, disposal, or recovery. The basic premise of the LDR regulations was to develop specific treatment standards for the treatment of hazardous waste so that it could be effectively and responsibly disposed, while at the same time being protective of human health and safety and preserving the environment.

As a result of the promulgation of the LDR regulations and due to the unique nature of mixed wastes, DOE notified EPA in 1989 that RFP was storing mixed wastes that were subject to the LDR regulations. DOE indicated that such storage might not be solely for the purpose of accumulating sufficient quantities necessary to facilitate proper recovery, treatment, or disposal, as the methods and technologies did not exist. Following this notification, DOE, EPA, and CDH entered into a series of Federal Facility Compliance Agreements (FFCA I and FFCA II) to establish a mechanism for DOE to achieve compliance with the storage prohibition language. Under FFCA II, RFP was required to develop plans and schedules for developing capabilities to treat mixed waste to meet the LDR regulation treatment standards.

The Comprehensive Treatment and Management Plan (CTMP) was submitted to EPA on June 9, 1992, to fulfill a compliance requirement under FFCA II. The CTMP

proposed primary and secondary milestones for which DOE is held accountable, based upon associated schedules for the development and implementation of treatment or management technologies to achieve compliance with LDR requirements for hazardous waste and the hazardous waste components of mixed wastes. The CTMP proposed treatment technologies grouped in various combinations resulting in six CTMP low-level mixed (LLM) waste treatment systems.

Federal Facility Compliance Act of 1992 Impacts at Rocky Flats Plant

As a result of a recognized lack of treatment capability and capacity on a national basis for treating mixed waste, the LDR issues are not unique to RFP. Many DOE facilities were in similar positions of not being able to meet the LDR regulation treatment standards. In October 1992, the Federal Facility Compliance Act (FFC Act) was signed into law by President Bush. The FFC Act, among other things, modified Section 6001 of RCRA to indicate that the United States (i.e., federal agencies) waives sovereign immunity for violations of RCRA, HSWA, existing permits, agreements, and compliance orders entered pursuant to RCRA.

A specific provision of the FFC Act recognizes that federal agencies (e.g., DOE) that manage mixed waste cannot immediately comply with the storage prohibition contained within the LDR regulations. As such, the waiver of sovereign immunity is not effective until 1995 for violations of the LDR storage prohibition for these agencies. This extension is valid only if these agencies manage their mixed waste appropriately in accordance with all other applicable regulations and comply with the additional terms of the FFC Act. Additional terms applicable to the DOE include preparation of a National Inventory Report (which includes a national treatment capacity and technology inventory) and a Plan for Developing Treatment Capacities and Technologies Report. DOE is currently pursuing the preparation of these documents, with the latter submittal occurring in three phases now known as the Site Treatment Plans. Although RFP is still following the commitments made in the CTMP in 1992, this document will soon be superseded by the Site Treatment Plans being prepared under the terms of the FFC Act. A Conceptual Site Treatment Plan was prepared and submitted in October 1993. A Draft Site Treatment Plan is currently under development for submittal in August 1994. Ultimately, a Final Proposed Site Treatment Plan will be prepared and submitted in February 1995. This "Final Proposed" plan will contain modified schedules and commitments for developing mixed waste treatment technologies and capacities.

DEVELOPMENT OF INITIAL TECHNOLOGY SELECTION METHODOLOGY

To evaluate and choose the proper technologies for treating mixed waste, a variety of technical and non-technical factors must be considered. Upon complete evaluation of the multitude of factors, one must eventually choose a technology that has the capability to reduce the mobility and minimize the toxicity of the hazardous constituents present within the waste. In an ideal world, it would be possible to develop an infinite number of technologies tailored to each specific hazardous constituent. In practicality, where multiple priorities compete for each dollar allocated to DOE, it becomes apparent that technically effective technologies are available at acceptable costs that can deal with the problems presented by mixed waste treatment requirements. The question then becomes how to choose an appropriate technology to achieve one's goals while acting in a fiscally responsible manner as a guardian of taxpayer dollars. To answer this question, RFP began developing a methodology to provide a systematic analysis evaluation for choosing the correct solution (i.e., mixed waste treatment technology) to an identified problem (i.e., mixed waste requiring treatment). This methodology is referred to as the Technology Evaluation Framework (TEF). The objectives of the TEF include the following:

- develop a technique for evaluation of treatment technologies for mixed waste
- select technologies based on sound judgment in an efficient, cost-effective manner
- eliminate unnecessary/impractical waste treatment methods
- provide formal documentation of the selection process
- provide a mechanism for accommodating public concerns in the decision process

The evolution of the TEF methodology, as described below, will 1) provide RFP with a structured framework to ensure that technology development funds are being spent on the correct technologies; 2) aid in ensuring that decisions regarding the treatment of mixed waste are defensible under scrutiny by the public, local regulators and Congress; and 3) aid in increasing the likelihood of the successful implementation of future treatment systems thereby resolving the mixed waste treatment dilemma.

The basis of the RFP Technology Evaluation Framework is a straightforward multicriteria scoring equation in which technical analysts, non-technical analysts, and members of the general public assign scores to questions ranging from the technology's potential technical effectiveness in treating the particular waste stream to the public's confidence in the selected technology.

Several sources supplied information that helped guide the development of the methodology: survey of decision analysis and risk analysis literature was performed; the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) methodology for technology selection was studied; and other technology selection methodologies within the DOE complex were examined.

Current decision and risk analysis theory emphasizes the importance of decision traceability. Without a formal decision making process, a multitude of factors, many of them subjective, may enter into expert decision making (1). The TEF ensures technology decision traceability and minimizes the cognitive bias of decision makers by formally documenting peer analysis using consistent problem breakdown. The TEF documentation generated during the formal decision making process makes the technology selection process transparent to those who wish to scrutinize the decisions made. Several features of the TEF help minimize analysts' bias. The major contributor to minimizing bias is the formal structure of a TEF evaluation. The basic units of TEF analysis are questions known as enabling questions, which are further organized into criteria. TEF enabling questions prompt the analyst to identify and describe uncertainties and assumptions before answering the question. A second major component of the TEF process is analysis of data quality, which provides a measure of the

certainty and objectivity of the accompanying analysis. The TEF provides for risk management planning by examining the adequacy of current waste treatment plans in a methodical manner.

TEF is modeled loosely after the CERCLA technology selection process, which includes a screening process and a group of criteria by which technologies are evaluated. Similarly, TEF contains two phases: Phase I is a screening analysis where unsuitable technology/waste form interfaces are eliminated; Phase II is an analytical process that further develops the TEF database by using enabling questions grouped into eight criteria. The TEF criteria, while not identical to CERCLA criteria, can be roughly correlated to the CERCLA criteria. Weighing factors assigned to the TEF criteria are based on the CERCLA guidance on the relative importance of the CERCLA criteria (2).

Other technology selection methodologies within the DOE complex were also studied. The initial methodologies examined include the RFP Technology Investment Strategy (3), the RFP Comprehensive Treatment and Management Plan (4), the DOE Mixed Low-Level Waste National Program (5), the Hanford Integrated Planning Process, and the Idaho National Engineering Laboratory Performance-Based Technology Selection Filter (6). In addition, other technology selection methodologies within the DOE complex include the Los Alamos National Laboratory Multiattribute Technology Evaluation, Fuzzy-Set Methodologies in Multicriteria Analysis, the Oak Ridge National Laboratory Criteria for Assessing Process Technology Options, the Western Governors' Association Decision-Methodology Effort, and the Pacific Northwest Laboratory Evaluation Methodology. Additional methodologies have been suggested by various DOE technical support groups (7). TEF was compared to these other methodologies as a check on the completeness of the TEF methodology.

Two special factors contributed to the need for a formal technology selection methodology: 1) the intense scrutiny to which technology selection decisions at RFP will be subjected and 2) the concern that the technologies selected in the CTMP might not be able to treat all waste forms in a treatability group or all RCRA constituents and characteristics of the treated wastes. For these reasons, a technology selection framework was devised that focused on the intersection of one technology and one waste stream. The framework, which became known as the Technology Evaluation Framework, specifically focused on primary treatment technologies, not entire systems, and on waste streams as subpopulations of waste forms.

Information about the CTMP technologies is dispersed throughout many sources. The goal of the TEF process is unite all those sources and objectively answer a set of questions, called enabling questions. These enabling questions are divided into eight criteria: technical effectiveness, level of development, health, safety, compatibility with existing permit conditions, cost, schedule, and public confidence in selected technologies. In the initial iteration of the TEF, two scores were awarded for each criterion: one score was based on the technical merits of the specific technology/waste stream intersection with respect to the enabling questions, and the other score was based on data quality. The data quality score for a criterion is a measure of whether the enabling question scores are backed by documented data or are merely the analyst's personal judgment. For the purposes of the TEF, data quality consists of the following four factors: 1) number of sources of primary data, 2) credibility of the sources, 3) comparability of sources, and 4) applicability and representativeness of research questions, models, and variables. Analysts are requested to note any impending research or waste characterization results and propose research questions for further data collection.

Weights are assigned to the criteria, and an overall composite score is generated for each technology by adding the weighted criterion scores. The criterion scores are enhanced by requirements for extensive written comments on the scoring rationale and an assessment of the quality of the data used to arrive at the score. Sensitivity analyses are performed during the preparation of Decision Analysis Reports by using different sets of weighing factors.

Trial Iterations and Lessons Learned

Three trial technology evaluation iterations were conducted. The first two trial iterations were partial TEF iterations whose purpose was to highlight elements of the TEF that needed further development. The third of these trial iterations was known as the combustibles iteration. The combustibles iteration was the first attempt to perform a full-scale iteration of the TEF. The combustibles iteration examined one waste form, combustibles, and nine technologies. The nine technologies were part of a group of technologies called alternatives to incineration. The following lessons were learned from the combustibles iteration:

- Despite the structure of TEF, individual bias was present in the evaluations; this bias manifested itself in several ways:
  - Exclusive focus on the primary technology introduced significant uncertainty for the analysts
  - Scoring only for each criteria, not each question, caused some level of detail to be lost
  - The enabling question scores and data quality scores assigned by the analysts did not always match the corresponding comments
  - The enabling question scores, data quality scores, and corresponding comments were sometimes technically suspect
- Using the costs and schedule of the combustibles iteration as a basis for estimating, the conclusion was reached that the time and budget required to fully implement the existing TEF process for all technology/waste stream interfaces was not feasible and congruent with CTMP program implementation timelines
- Results of the evaluation process and analysis of the data must be transparent to audiences of varying technical expertise and interest; the report following the combustibles iteration concentrated on summary and presentation of data and did not attempt to draw conclusions from that data

STREAMLINED TEF IMPLEMENTATION

Lessons learned during the trial runs influenced the evolution of the TEF methodology. The focus changed from developing the best, most comprehensive methodology to developing a methodology that could be implemented given the resource constraints present. Changes to the methodology included modifying the scoring methodology to reduce bias,

reducing the number of waste streams to be evaluated, and adding extensive post-evaluation analysis of the data.

After the combustibles iteration, the content of some enabling questions and the overall scoring structure of the TEF were changed. The major change to the enabling questions was a retreat from the exclusive focus on the primary treatment technology. During the trial runs, examining the primary technology without the context of a treatment system created uncertainties for the analysts. The revised TEF focus remains on the individual primary treatment technologies. However, the analysts are required to sketch a proposed treatment system, and the analysis of the primary technology is within the context of the proposed treatment system. The revised scoring structure requires a technical score for each enabling question. Data quality scoring remains the same, with a data quality score required for each criteria.

To counter the elements of bias regarding the agreement between scores and comments and the technical correctness of scores and comments, all enabling question scores, enabling question scoring comments, data quality scores, and data quality scoring comments are subjected to a "reasonable person" test. This "reasonable person" test includes checking that each enabling question score matches the enabling question comment, each data quality score matches the data quality comment, and all scores and comments are congruent with the existing knowledge about the technologies and waste forms. Any possible discrepancies are noted within the newly developed Decision Analysis Reports, which summarize and analyze the raw data generated by the TEF analysts. These Decision Analysis Reports are then subjected to peer review by reviewers familiar with the technologies to further mitigate bias.

The initial TEF methodology proposed that all waste forms be analyzed with respect to all possibly relevant technologies. The streamlined TEF methodology utilizes treatability groups to minimize the number of waste forms requiring a full TEF iteration. Three main information sources went into the development of treatability groups for the TEF: 1) CTMP treatability groups, which grouped the wastes into candidates for organic destruction, direct immobilization, surface organic contaminant removal, and water treatment (4); 2) DOE guidance on waste treatability groups for the Interim Mixed Waste Inventory Report (8), which is based on radiological category, physical/chemical matrix, and hazardous characteristics and contaminants, was utilized to check the assignments made in the CTMP; and 3) current characterization information (9) was used to update the treatability groups. The percent volume of LLM wastes currently assigned to proposed primary treatment methods, in order of decreasing volume, are as follows: immobilization (83%), surface organic contaminant removal (3%), water treatment (6%), and organic destruction (8%).

After a treatability group for a type of waste treatment was defined, three to six representative waste forms are selected. The representative waste forms are high volume waste streams that represent the different physical/chemical waste matrices and the different RCRA constituents and characteristics present in the treatability group. The representative waste forms are analyzed with a complete TEF evaluation. The remaining waste forms in the treatability group are analyzed with an abbreviated analysis called a suitability analysis. This suitability analysis consists of examining the information about a waste form's physical matrix and RCRA constituents and characteristics, determining whether any incompatibilities exist between the waste form and the technology in question, and scoring the suitability of the technology to treat the waste form based on technical effectiveness and health and safety.

For each technology, all waste forms in the treatability group are analyzed either by a full TEF evaluation or a suitability analysis. The raw data generated by the TEF analysts are further summarized, subjected to a "reasonable person" test, and analyzed using sensitivity analysis in Decision Analysis Reports. Analysis of all waste forms enables the technology's benefits and drawbacks to be examined in the context of treating all wastes in the treatability group. Treatment technologies are assigned one of three designations for each waste form: 1) "Best Technology", 2) "Suitable Technology", and 3) "Not Suitable Technology". These designations allow coverage set analysis to be performed. Coverage set analysis is an examination of the benefits and drawbacks of possible combinations of technologies that provide complete treatment coverage of the treatability group. From this coverage set analysis, recommendations can be made regarding the most attractive treatment technologies. A peer review by reviewers familiar with the technologies can be conducted on the Decision Analysis Reports to verify the results and conclusions.

TEF COMPREHENSIVE REPORT

The objective of the TEF Comprehensive Report is to take the TEF Decision Analysis Reports and overlay a systems engineering approach to describe optimal combinations of technologies for implementation in the CTMP Treatment Systems. The TEF Comprehensive Report should summarize the technical merits and describe the uncertainties of proposed CTMP technologies in a treatment systems context, performing systems analyses with various combinations of technologies, while identifying the associated implementation risks to derive optimal low-risk, cost-effective mixed waste treatment systems for RFP wastes.

The Decision Analysis Reports should yield "Best Technology" applications for all CTMP treatability groups. These reports can be used for the definition of CTMP treatment systems in the TEF Comprehensive Report. This step will evaluate combinations of the "Best Technology" applications, prompt experimental testing and design to mitigate uncertainties associated with the technology system applications, and propose optimal permutations of technologies for future implementation. A mixed waste treatment system can be developed to incorporate the optimal "Best Technology" applications by CTMP treatability group and can include pretreatment and post-treatment requirements for the existing waste forms, sampling and analysis requirements, and final waste form packaging and shipping requirements. The mixed waste treatment systems will also be examined for the purpose of identifying common elements or synergies that may become available by combining some pre- or post-treatment components and ancillary technology applications. Examples of common ancillary technology components that may be candidates for consolidation are size reduction systems or break open systems to facilitate the introduction of existing mixed waste inventory into the treatment system and post-treatment immobilization systems that may be required to meet U.S. Department of Transportation (DOT) shipping standards or disposal facility waste acceptance criteria. Ideally, the optimal

set of technologies will be the set of technologies that are publicly acceptable, that can treat all constituents and characteristics of RCRA concern with an acceptable degree of certainty, and that can be implemented with the fewest resources in the least amount of time.

The TEF Comprehensive Report can identify data gaps through the use of data quality scores to direct future waste characterization and technology development activities. Promising technologies with low data quality-scores can be included in the optimal implementation set for mixed waste treatment systems if pilot, bench, or demonstration scale studies are conducted to dispel uncertainties surrounding the technology application.

PATH FORWARD FOR TEF METHODOLOGY DEVELOPMENT

The underlying premise behind both FFCA I and FFCA II at RFP and the FFC Act for all DOE facilities involves the development and implementation of treatment capabilities to treat mixed waste. Because such major waste management decisions have the potential to affect local communities surrounding each site, it is vital to solicit public involvement in the decision-making process. Although the codified RCRA process itself provides a mechanism for public input during the permitting process, it was determined that public involvement at this late stage in the waste management process would not be as useful as it would during earlier stages where public comment could be converted to actual public involvement in the decision-making process.

DOE recognizes that the public should be informed and involved in the development of the Site Treatment Plans. In fact, the FFC Act requires the regulatory agencies that receive submittals of the Site Treatment Plans to provide for public participation during its own review of the plans provided by DOE. Rather than a single submittal, the process DOE has developed will offer additional opportunities for involving the public in the development of options being considered for treatment of mixed waste. The affected states, in turn, also recognize the importance of public involvement and have chosen the National Governor's Association to facilitate discussion on the development of the Site Treatment Plans with all affected parties.

On a national level, decisions regarding locations of mixed waste treatment facilities, types of treatment to be utilized, facilities where the waste will be transported for treatment, and final waste disposal methods are all decisions that necessitate public involvement. Additionally, on a local level, stakeholder groups continue to express concern over issues such as public health, safety, the environment, land values, economics, legal/regulatory compliance issues, transportation risks, and other public policy issues. By providing early opportunities for the public to participate in the decision-making process, a more complete identification and consideration of issues and alternatives is achieved. Addressing public and state concerns and comments early will help DOE and the regulators to develop final Site Treatment Plans that reflect public interests and can be more readily accepted and approved by the regulators.

The TEF process was instituted to provide formal documentation of the technology selection process for the CTMP Treatment Systems implementation. Future evolution of the TEF methodology is being mapped out to include active public participation in the RFP technology selection process. Representatives from community oversight groups established by the State of Colorado and local civic groups interested in the disposition of mixed wastes presently stored at RFP can be involved in the TEF process directly in several ways. First, representatives of public groups can respond to the enabling questions designed to measure public confidence and concerns regarding technology applications in mixed waste treatment systems. Secondly, future TEF iterations with public representatives filling the roles of technical and non-technical analysts can be conducted to review the available technology data or new information derived from waste characterization activities, cost and schedule developments, or results from technology development research, testing, and demonstrations.

Another approach under consideration is to summarize the TEF evaluation results from the TEF Comprehensive Report and present the information to public/civic groups for discussion of TEF logic and identification of "Best Technology" applications proposed for RFP mixed wastes. In either scenario, TEF criteria can be assigned weights by the public for sensitivity analysis in order to examine which technology application might consistently reflect those criteria of greater importance to the public. This type of interactive public involvement can lead to technically feasible and publicly acceptable combinations of technologies for RFP mixed waste treatment systems.

Previous RFP experiences with public interaction has proven that the TEF process must include the public's input to weighing the evaluation criteria and recognizing the corresponding areas of greatest public concern. Public involvement with the TEF can become an invaluable guide for directing treatment system design, siting, equipment configuration, and certified operations. After RFP has completed the initial development of technical data with the initial implementation of the TEF process, the TEF can become an excellent mechanism to present RFP's best ideas for technology applications to the public, explore community concerns regarding the treatment of mixed wastes, and obtain active local involvement in the technology selection process.

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