Needs for Risk Informing Environmental Cleanup Decision Making – 13613

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ABSTRACT

This paper discusses the needs for risk informing decision making by the U.S. Department of Energy (DOE) Office of Environmental Management (EM). The mission of the DOE EM is to complete the safe cleanup of the environmental legacy brought about from the nation's five decades of nuclear weapons development and production and nuclear energy research. This work represents some of the most technically challenging and complex cleanup efforts in the world and is projected to require the investment of billions of dollars and several decades to complete. Quantitative assessments of health and environmental risks play an important role in work prioritization and cleanup decisions of these challenging environmental cleanup and closure projects. The risk assessments often involve evaluation of performance of integrated engineered barriers and natural systems over a period of hundreds to thousands of years, when subject to complex geoenvironmental transformation processes resulting from remediation and disposal actions.

The requirement of resource investments for the cleanup efforts and the associated technical challenges have subjected the EM program to continuous scrutiny by oversight entities. Recent DOE reviews recommended application of a risk-informed approach throughout the EM complex for improved targeting of resources. The idea behind this recommendation is that by using risk-informed approaches to prioritize work scope, the available resources can be best utilized to reduce environmental and health risks across the EM complex, while maintaining the momentum of the overall EM cleanup program at a sustainable level.

In response to these recommendations, EM is re-examining its work portfolio and key decision making with risk insights for the major sites. This paper summarizes the review findings and recommendations from the DOE internal reviews, discusses the needs for risk informing the EM portfolio and makes an attempt to identify topics for R&D in integrated risk assessment that could assist in the EM prioritization efforts.

INTRODUCTION

Fifty years of nuclear weapons production and energy research generated millions of liters of liquid radioactive waste, millions of cubic meters of solid radioactive wastes, thousands of tons of spent nuclear fuel and special nuclear material, along with huge quantities of contaminated soil and water. The mission of the DOE EM is to complete the safe cleanup of the environmental legacy brought about from the nation's nuclear weapons development and production and nuclear energy research. Although the program has made significant progress in reducing the environmental footprint of the legacy waste since its inception in 1989, risks to the environment and public health still remain at a number of contaminated sites across the country. At the end of

FY2010, the Department's unfunded environmental remediation liability was still estimated to be approximately $250 billion, of which the EM portion was $165 billion. The EM cleanup effort involves 8 billion square meters (2 million acres) of land located in 35 states and employs more than 30,000 Federal and contractor employees [1]. DOE spends about $6 billion per year on its environmental remediation activities. The EM FY2012 enacted budget was $5.8 billion, and the President's budget request for FY2013 is $6.2 billion [12]. The EM program costs are largely "driven" by 37 Federal Facility Agreements (FFA) individually negotiated with state regulators at key DOE sites across the country. The FFAs involve no fewer than 350 milestones at these sites. The FFAs are augmented by numerous other local agreements with their own set of actions, requirements, milestones, and due dates [1].

A major portion of the EM's environmental liability is associated with legacy management at two large sites: the Hanford site at Richland, WA and the Savanah River Site at Aiken, SC. Most of the costs are atrributed to the one-of-a-kind technical challenges in, e.g., designing and constructing the Waste Treatment and Immobilization Plant and developing effective technologies for remediating wastes from the deep vadose zone of the Central Plateau, both at the Hanford site. For these reasons, with the current level of funding, the cleanup activities at the Hanford site are projected to continue through at least the early 2060s [2].

Given the significant technical challenges facing the EM program and the high potential impacts on costs and schedule at stake, it is imperative to periodically examine the program status and priorities in order to most effectively address these challenges. To this end, various DOE internal reviews have provided valuable findings and recommendations for the prioritization of the program to focus on the reduction of risks to public health and the environment.

This paper will summarize the findings and recommendations of these recent reviews. It will discuss the needs for prioritizing the EM cleanup work scope to reduce risks to health and the environment. The paper will also discuss current practices and potential data gaps in integrated risk assessments to aid in the efforts to develop a strategy for re-prioritizing the EM cleanup portfolio. We recognize that to transition the EM program to a fully risk-informed paradigm will require a thorough, systematic evaluation of many technical, regulatory, programmatic, and other factors; it will also pose tremendous difficulty and challenges. Thus the scope of this paper is limited to consideration of technical information related to risk assessments.

DOE ENVIRONMENTAL LIABILITIES

The DOE's environmental liabilities result primarily from research, production, and testing of nuclear weapons during World War II and the Cold War eras. Prior and current mission work, such as nuclear weapons stockpile activities and nuclear power technology development, also result in environmental liabilities.

DOE EM is responsible for managing the legacy of contamination from the nuclear weapons complex. As such, EM manages thousands of contaminated facilities formerly used in the nuclear weapons program, oversees the safe management of large quantities of radioactive waste and nuclear materials, and is responsible for the cleanup of large volumes of contaminated soil and water. This component of the environmental liability drives the EM life-cycle cost estimate and strategic vision to complete this cleanup mission. The strategy provides for a site-by-site projection of the work required to complete all EM projects, while complying with regulatory agreements, statutes, and regulations. These projections have been documented in detailed plans. Each project estimate includes detailed projections of the technical scope, schedule, and estimable costs at each site for the cleanup of contaminated soil, groundwater, and facilities; treating, storing, and disposing of wastes; and managing nuclear materials. The estimates also include costs for related support activities, such as landlord responsibilities, program management, grants, and cooperative agreements for participation and oversight by Native American tribes, regulatory agencies, and other stakeholders.

Environmental liabilities not under the EM program include the remediation of facilities, structures, and land, as well as various radioactive or hazardous materials managed and/or in use by the Department's other programs. These liabilities also include the estimated cleanup and post-closure responsibilities, including surveillance and monitoring activities. The Office of Legacy Management (LM) is responsible for the legacy activities at closed sites that include former uranium mills and certain sites remediated by the U.S. Army Corps of Engineers. Also included in these liabilities are estimates for the disposition of various materials. The most significant of these materials is surplus plutonium.

The life-cycle cost for the cleanup program was estimated to be $147 billion in 1998. In 2002, the life-cycle cost estimate increased to $220 billion [3]. At the end of FY2010, the DOE's unfunded environmental remediation liability was approximately $250 billion, of which the EM portion was $165 billion, a reduction of approximately $19 billion from Fiscal Year 2009 [11]. At the end of FY 2011, EM had completed cleanup activities for 90 sites in 30 states; EM is responsible for the remaining cleanup at 17 sites in 11 states. It is EM's goal to complete the cleanup in approximately six decades within the currently estimated life-cycle cost of $274 billion to $309 billion. This estimate includes $100 billion in actual costs from 1997 through 2011, and an additional cost of $174 billion to $209 billion to complete EM's remaining mission by 2050 to 2062 [12, p. 9]. The huge environmental liabilities indicate a need for an improved stragetgy for reducing the environmental and health risks of the remaining sites across the DOE complex.

DOE REVIEW FINDINGS AND RECOMMENDATIONS CONCERNING EM CLEANUP PRIORITIZATION

As part of the Reports Consolidation Act of 2000, the DOE Office of Inspector General reviews DOE operations to identify management challenges facing the Department. In its 2011 Special Report IG-0858 [1], the DOE OIG states that:

> *The FFAs and related requirements are the result of individual, site-specific negotiations between the Department and Federal and state regulators. In many cases, these agreements were reached after complex, painstaking negotiations over many years. In some cases, the courts are also involved in these agreements. Modifying these agreements would be a very costly and time-consuming process and would, understandably, be extremely unpopular with a variety of constituencies. However, the current strategy may not be sustainable if the Department's remediation budget suffers major reductions.*

The IG report questions that if existing environmental remediation commitments are sustainable in light of current budget realities and, as a corollary, would a risk-based strategy applied throughout the complex allow for improved targeting of scarce remediation resources. In conclusion, the DOE IG recommends the following path forward [1]:

> *The Department should consider revising its current remediation strategy and instead address environmental concerns on a national, complex-wide risk basis. This would result in a form of environmental remediation triage. Looking at the program holistically, fund only high risk activities that threaten health and safety or further environmental degradation. Consistent with this philosophy, where appropriate and consistent with U.S. Environmental Protection Agency guidance and long term Department land-use planning policies, reduce costs by remediating to "brownfield" rather than "greenfield" standards. To ensure that risk drives funding choices and priorities rather than potential local or regional influences, the Department should retain a respected outside group, such as the National Academy of Sciences, to rank and rate, on a national, complex-wide risk/priority basis the Department's environmental remediation requirements. The Department's National Integrated Priority List could serve as a logical starting point for this exercise.*

Note that similar concerns about the need to risk inform the EM portfolio have also been raised in previous reviews. For example, the EM's *Top-to-Bottom Review* conducted in 2002 [3] concludes that the EM management of contracts was not focused on accelerating risk reductions and applying innovative approaches; that EM's cleanup strategy was not based on comprehensive, coherent, technically supported risk prioritization; and EM's business processes were not structured to support accelerated risk reduction. The Review Team recommended moving EM to an accelerated, risk-based cleanup strategy, including prioritizing cleanup work to achieve the greatest risk reduction at an accelerated rate, choosing approaches to cleanup and waste management based on technical risk evaluation, and assessing cleanup agreements for their contribution to reducing risk to workers, the public, and the environment.

The DOE IG-0712 report of 2005 [4] notes that a 2002 EM program-wide review revealed that EM had not focused on a systematic approach to facility decontamination and decommissioning that emphasized the most expeditious means of addressing health risks and environmental concerns. It also mentions that a National Research Council study in 2005 [5] found that the Department was demolishing facilities that were neither contaminated nor in structural jeopardy, and another audit found that the Department's deactivation and decommissioning activities did not always reduce the risk posed to the environment, workers, or the public [6].

CURRENT REGULATORY FRAMEWORK FOR CLEANUP DECISION MAKING

DOE negotiates and executes environmental compliance and cleanup agreements with the U.S. Environmental Protection Agency and state regulatory agencies, as appropriate. These agreements include the Federal Facility Agreements (FFA). The FFAs are augmented by numerous other local agreements with their own set of actions, requirements, milestones, and due dates. Key parameters such as required cleanup levels and milestones are negotiated with the appropriate regulators and stakeholders for each site. In 2011, the FFAs involved no less than 350 milestones at these sites. Compliance with environmental laws and agreements continues to be a major cost driver for the EM program.

For example, throughout much of the history of plutonium production at the Hanford site, DOE regulated waste management and environmental protection under a set of orders implementing the Atomic Energy Act, including DOE Order 435.1, *Radioactive Waste Management* [13, Section 1.2.1]. The Resource Conservation and Recovery Act (RCRA) enacted in 1976 gave other Federal agencies a major role in the regulation of hazardous waste. In 1986, State of Washington Department of Ecology (Ecology) was authorized by the U.S. Environmental Protection Agency (EPA) to administer its own hazardous waste program (through the state's Hazardous Waste Management Act) in lieu of the Federal RCRA program. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and its amendments established Federal agencies' responsibilities to investigate and remediate releases of hazardous substances, including radioactive contaminants, from their facilities. Beginning in 1986, Ecology and EPA began working with DOE to develop one compliance agreement that set milestones for cleaning up past disposal sites under CERCLA and bringing operating facilities into compliance with RCRA. The Hanford Federal Facility Agreement and Consent Order, also known as the Tri-Party Agreement (TPA), was signed by the three agencies in May 1989. Because the TPA, which addresses DOE's mixed waste that is subject to the RCRA storage prohibition, preceded the Federal Facility Compliance Act of 1992, the TPA also satisfies the act's requirement for a site treatment plan addressing mixed waste in storage at Hanford.

To demonstrate compliance with performance objectives specified in these regulatory agreements for protection of human health and the environment, performance assessments (PAs) and risk assessments (RAs) are often used. PAs and RAs are also used to identify critical data, facility design and information needs, and model development needs for: i) defensible and cost-effective licensing decisions and ii) developing and maintaining operating limits, such as, waste acceptance criteria [17]. The modeling evaluations conducted typically include PAs of contaminant migration through environmental pathways (e.g., air, groundwater, and surface water) and potential human exposures to the contaminants in various exposure media (e.g., soil, drinking water, crops, and livestock), or RAs, for the purpose of: a) evaluating effectiveness of remedial alternatives, including monitored natural attenuation; b) assessing performance of the selected remedy for a given site/project (either during pre-construction design or performance confirmation/monitoring after implementation of the remedy); and c) decision analyses for planning and budgeting purposes (i.e., what-if scenario analyses).

These PA and RA modeling analyses provide useful input that support many decision-making points throughout the lifecycle of various waste management activities (e.g., siting, design decisions, operational limits, monitoring programs, closure options, remediation of contaminated areas, in-situ decommissioning). The analyses can support environmental cleanup decisions made with external oversight of, e.g., EPA and U.S. Nuclear Regulatory Commission (NRC) under CERCLA, National Environmental Policy Act (NEPA), and RCRA, as well as decisions made in association with DOE self regulated on-site disposal of LLW under DOE Order 435.1, in some cases satisfying overlapping requirements of both DOE 435.1 and CERCLA or RCRA. For example, at the Hanford Site, the Hanford Tank Closure and Waste Management Environmental Impact Statement conducted under CERCLA, NEPA, and RCRA [13] was used to evaluate options for managing and disposing of waste, selecting supplemental treatments, closing tanks, and closing the Fast Flux Test Facility (FFTF). In addition, efforts are underway to define the scope and approach for tank farm closure performance assessments under DOE Order 435.1, using Waste Management Area (WMA) C as a starting point.

Several pending regulatory actions could significantly affect the use of PAs and RAs in support of environmental remediation. These include the pending update of DOE Order 435.1, the amendments of 10 CFR 61, and the pending action concerning final disposal of HLW and SNF.

Update of DOE Order 435.1 for On-Site LLW Disposal: For LLW disposal decisions and operations, DOE Order 435.1, *Radioactive Waste Management* requires the development of sitewide performance assessment and composite analyses to demonstrate compliance with specific performance objectives set forth for LLW and MLLW management facilities that DOE self regulates. Since its issuance in July 1999, the order has been used alone or in combination with CERCLA for waste management of DOE environmental cleanup activities. It is currently being revised to incorporate lessons learned as well as science and regulatory updates such as the approach for probabilistic analyses over the last 13 years.

NRC Proposed Rule Changes to 10 CFR 61: NRC has recently announced its intention to amend 10 CFR 61, *Licensing Requirements for Land Disposal of Radioactive Waste*. These amendments are being developed to ensure that waste streams that are significantly different in terms of radiological characteristics (e.g., half-life) from those considered in the technical basis for the current regulations can be disposed of safely and meet the performance objectives. These amendments are also intended to increase the use of site-specific information to ensure that public health and safety would continue to be protected. These changes would revise the existing site-specific analysis for protection of the general population to include a 10,000-year compliance period (i.e., performance assessment); add a new site-specific analysis for the protection of inadvertent intruders that would include a 10,000-year compliance period and a dose limit (i.e., intruder assessment); add a new long-term analysis for certain long-lived wastes that would include a post-10,000-year performance period; and revise the pre-closure analysis to include updates to the performance assessment, intruder assessment, and long-term analyses. Although 10 CFR 61 does not apply to waste from the defense program, DOE and other stakeholders have provided inputs to the development and reviews of the proposed rule changes to 10 CFR 61 because of their concerns about performance objectives in comparison to DOE Order 435.1.

Pending Action for Final Disposal of HLW and SNF: High level waste produced at DOE legacy waste sites such as Hanford and SRS ultimately needs to be disposed of in a national geological repository for HLW and SNF, and current compliance agreements all assume that the HLW will be disposed of in the Yucca Mountain repository. The license application for constructing the Yucca Mountain repository was withdrawn in 2010. Since then, the Blue Ribbon Commission has submitted several recommendations to the DOE Secretary for managing America's nuclear future (BRC 2012). At the submittal of this paper, a final decision is still pending on the implementation of the BRC recommendations. This decision will have significant impacts on waste disposition paths and PA/RA analysis approaches for sites such as Hanford and SRS.

Limitations of Current Performance Assessments

Consistent with the current regulatory framework, performance and risk assessments are developed to support cleanup decision making, using discrete models for individual operable units or subsystems of a given site. Depending on the particular site conditions and regulatory requirements, the PA/RA is performed using codes that can range from relatively simple analytical screening models to complex, multidimensional, multiphase flow and transport simulators. DOE Order 435.1 also requires a site-wide "composite analysis" (CA) to assess the overall performance of all operable units or subsystems that may interact with the LLW disposal facility.

However, as discussed below, there are several science and technology gaps that affect the application of PA/RA models [15]. In addition, there are concerns about the lack of a comprehensive modeling strategy and guidance for EM's model uses [8]. Furthermore, the current modeling practice cannot allow for the incorporation of cost analyses into the PA/RA models. These gaps present significant challenges for the use of current PA/RA models in support of objective and effective decision making for environmental cleanup. (For example, the remedial decision is still pending for the Hanford 300 Area, after an earlier PA model using simplified assumptions was found inadequate to account for the complex uranium geochemistry in the vadose zone influenced by the hydrodynamics of the river water-groundwater interactions.) Therefore, the final cleanup decision often has to rely on the (subjective) synthesis of multiple inputs, supported by results from the PA/RA calculations. It is also partly due to these reasons that not all environmental decisions can be fully risk informed at the present time.

<u>National Academy of Sciences Review of Science and Technology Gaps of the EM Program:</u> In response to a congressional request, EM developed a roadmap that identifies the key engineering and technology gaps for its cleanup program [14]. At the request of EM, the National Research Council (NRC) of the National Academies reviewed the EM roadmap and provided advice to EM for addressing principal science and technology gaps that could adversely affect EM's ability to meet its cleanup milestones on time and/or on budget and provides recommendations for improving the EM Roadmap [15]. Among these, there are several key science and technology gaps that affect the application of PA/RA models. Principal gaps that are ranked high as R&D priorities include: i) contaminant behavior in the subsurface is poorly understood and ii) long-term ability of cementitious materials to isolate wastes is not demonstrated.

<u>Government Accountability Office Review of EM Model Uses:</u> In response to a congressional request, the Government Accountability Office (GAO) conducted a performance audit between October 2009 and February 2011 of the use of computer models in EM for making cleanup decisions [8]. GAO audited three types of decisions that were representative of major decisions DOE has made at these sites between 2002 and 2010, including: (1) decisions made for remedial actions under CERCLA and NEPA; (2) performance assessments of on-site disposal of LLW under DOE Order 435.1; and (3) budgeting and planning decisions for liquid tank waste treatment and disposal. The audit focused on the Hanford and Savannah River Sites because together these two sites account for more than one half of EM's annual cleanup spending and approximately 60% of the total projected cost of the overall cleanup of nuclear wastes at all DOE sites.

The GAO auditors raised concerns that: 1) EM's oversight of the quality of the models and its management in the development, evaluation, and use of the models has not always been commensurate with the importance of the model to cleanup decisions (which cost hundreds of million dollars and need to protect health and environment for thousands of years), and 2) EM's failure to fully oversee its contractors' implementation of quality procedures has led to a reduced level of confidence in the models developed. Based on these findings, GAO recommended that DOE:

1. Clarify specific quality assurance requirements for computer models used to analyze the potential effectiveness of cleanup alternatives, assess the performance of selected cleanup activities, and assist in planning and budgeting cleanups;
2. Ensure that the models are assessed for compliance with these requirements; and
3. Develop a comprehensive strategy and guidance for the management of computer models to promote consistency, reduce duplication, and ensure sharing of lessons learned.

<u>Recent DOE Initiatives</u>: Similar model consistency and integration issues have been self-identified in recent DOE and EM reviews, which led to the initiation of the Advanced Simulation Capability for Environmental Management (ASCEM) project, making use of significant modeling expertise retained in EM from the Yucca Mountain Project [16]. GAO acknowledged this effort by DOE EM to develop standardized approaches for performance assessments in its reviews [8]. Another DOE EM effort is also under way to develop a capability for system/process modeling, which is another important factor, in addition to performance assessment, for estimating life cycle costs of environmental remediation projects [18]. In response to the GAO concerns, DOE EM has committed to develop a comprehensive strategy and guidance for modeling and simulation activities that support EM's cleanup decisions. A comprehensive modeling strategy and guidance would be helpful to the development of a risk-informed, performance-based approach for work prioritization across the EM complex.

RISK-INFORMED, PERFORMANCE-BASED REGULATIONS

An example of adopting a risk-informed, performance-based regulatory framework is the implementation of the Nuclear Waste Policy Act during the license application of the Yucca Mountain repository for high level waste and spent nuclear fuel. In 10 CFR Part 63, *Disposal of high-level radioactive wastes in a geologic repository at Yucca Mountain, Nevada*, the Nuclear Regulatory Commission uses a framework for risk-informed, performance-based decision making. This requirement is implemented through the development and application of the total system performance assessment (TSPA), which is a comprehensive risk assessment of the performance of the repository system for a period of 1 million years after the permanent closure of the repository. Each subsystem or component of the repository disposal system is incorporated into the TSPA with varying level of details based on its relative contribution to the system performance.

It may be possible to adopt a similar risk-informed, performance-based approach for the management of legacy waste within the EM program, in order to minimize total program costs and to optimize the reduction of health and environmental risks. This could be done after a TSPA-like system risk assessment model is developed for a given site. Then, work prioritization can be made using this model, in an iterative manner, to further risk-inform data collection activities or remedial actions.

RECENT REVIEW OF DOE ENVIRONMENTAL CLEANUP PORTFOLIO

In a recent effort to inform FY2014-2018 budget planning, EM conducted a systematic review of the EM cleanup projects at major sites [7]. The review provided valuable information about key contributors to environmental and health risks, which provides an input for strategic planning for the EM program for the next 5 year period of FY2014-FY2018. The analysis shows the projected cost is $174 billion to $209 billion as of July 2012. It shows that compliance baselines at many sites were built assuming higher funding targets than EM has recently received, and the gap between projected cost and target for EM is approximately $14 billion to $29 billion assuming availability of current funding targets. Certain types of projects and operating activities have a greater cost to defer than others, so renegotiation of certain FFAs and other compliance agreements would be beneficial to the rebalancing of the EM portfolio in light of potentially flat or reduced funding for EM. For Richland Operations (RL) of the Hanford Site alone, the funding gap was estimated to be more than $5.6 billion. The analysis shows that the major cost drivers for RL include the completion of the River Corridor cleanup, the K Basin sludge remediation, and the D&D of the plutonium finishing plant. In comparison, delaying the D&D and soil and groundwater remediation of the Central Plateau would have less impact on the total cleanup cost. An alternative funding scenario could be developed by integrating this cost information with the insights from risk assessments that estimate remaining risk to human health and the environment for each major adjustment to the cleanup activities.

The analysis also reveals that without a risk-informed framework for evaluating work priorities across the complex, funding levels may appear to be inconsistent between similar sites. For instance, although the overall budget requests for the Hanford Site and the SRS Site are comparable, the annual budget for the groundwater and soil remediation project (PBS 30) at the Hanford site is about an order of magnitude higher than that for the SRS site. Although the difference in project costs may be partly explained by different site hydrogeologic and contamination conditions, the lack of a risk-informed approach for work prioritization makes the justification of the appropriate level of funding level a challenge.

INTEGRATED RISK ASSESSMENT TO AID IN DECISION MAKING

Quantitative assessments of health and environmental risks play an important role in the environmenral decision-making process [8]. Such assessments provide critical information to assess the potential effectiveness of cleanup alternatives, assess the likely performance of selected cleanup activities, and assist in planning and budgeting cleanups. Risk assessments often involve evaluations of performance of integrated engineered barriers and natural systems over a period of hundreds to thousands of years, subject to complex geoenvironmental transformation processes resulting from remediation and disposal actions and natural processes.

For similar reasons, risk assessments may also provide useful inputs for prioritization of challenging cleanup and closure projects. For example, insights gained from the scientific analyses based on the total system performance assessment (TSPA) for Site Recommendation model provided useful data for the prioritization of R&D workscope during the preparation of the license application for the Yucca Mountain repository [9]. Results from the preliminary TSPA model helped to focus resources on the improvement of, e.g., the waste package degradation model, which in turn reduced the uncertainty in TSPA results and enhanced confidence in the use of an improved TSPA for license application [10].

The use of integrated risk assessments to help inform EM management decisions would be consistent with recent updates of DOE Order 413.3B with respect to assessments and management of technical, performance, schedule, and cost risks. This approach could help drive key enterprise risk management decisions throughout the life cycle of EM cleanup projects and activities.

New Approaches for Integrated Risk Assessment (IRA)

New approaches for various components of risk assessments may bridge the gaps in research and practice in this area, and thus provide useful inputs to the EM's work prioritization efforts. To assist in integrated risk assessments (IRA), it would be useful to assess recent developments and evaluate R&D needs in the approaches and methodologies for IRA. These may include the following topical areas:

1) New approaches for performance assessments, multimedia risk assessments, and multi-attribute decisional analyses in support of remedy selection for environmental cleanup and closure projects: Develop robust multi-attribute decisional analyses, based on reducing contaminant concentration/mass and optimizing costs of remedial actions.

   Conventional risk management in environmental remediation practice uses four types of information: results of PA/RA modeling and data from environmental monitoring, risk analysis, cost or cost-benefit analysis, and stakeholder preferences. A systematic method of combining quantitative and qualitative inputs from scientific risk, cost, and cost-benefit analyses, and stakeholder viewpoints has yet to be fully developed for environmental decision making. As a result, decision makers often do not optimally use all available and useful information in choosing between identified remedial alternatives.

   Recent studies conducted by Linkov and his coworkers at the U.S. Army Corps of Engineers [19] suggest that comparative risk assessments which involve a 2-dimensional decision matrix with assigned weights, or better yet, multi-criteria decisional analyses are preferable for more objective and robust decisional analyses.

2) Developments in methodologies and tools for multimedia environmental modeling, particularly data management and visualization, (conceptual model and data) uncertainty quantification, and dose calculations: Develop open-source, integrated frameworks and platforms. Couple multi-process models with uncertainty analyses. Integrate risk and dose calculations with surface and subsurface flow and transport models.

   EM has made significant investments in the development of the ASCEM framework and toolsets. The ASCEM project has completed two phases of demonstration of the toolsets it has developed so far, using data for selected EM sites. The ASCEM's high-performance computing platform looks promising for managing and visualizing various datasets as well as for organizing workflow to support the development of conceptual and numerical models [20]. Further development of its multi-process module or incorporation of existing multi-process models such as PFLOTRAN could make ASCEM a powerful tool for a variety of environmental applications.

3) Integration of performance/risk assessment models into life cycle cost analyses: Link system planning analyses to IRA models to support realistic planning and budgeting.

   EM is continuing to develop system planning toolsets with support of the MITRE Corporation [18]. It is also in the process of refining analytical tools to explore strategic options for meeting flat or reduced funding targets, using net present value to understand the impact of delaying projects and operating activities [7]. Eventually, the cost analysis toolsets can be integrated into the PA/RA framework to support the full risk assessment required for life cycle cost analyses.

4) Integration of monitoring and modeling approaches for the purpose of validating multimedia environmental models and optimizing environmental monitoring: Optimize monitoring programs for minimal cleanup time and/or total project cost. Develop strategies for validating IRA models using post-PA/RA testing/monitoring data.

   The Federal Interagency Steering Committee on Multimedia Environmental Modeling (ISCMEM) is planning to set up a new working group to facilitate the R&D activities on the integration of monitoring and modeling in support of risk assessment. At its Annual Public Meeting held in November 2012, the ISCMEM steering committee discussed collaboration in this area to support evaluation of potential environmental impacts of unconventional shale gas exploration (i.e., hydraulic fracturing) [21]. Analysis techniques developed and insights gained from these ISCMEM activities could be applied to support EM's PA/RA activities.

In addition to achieving technical breakthroughs, the waste management community also needs to address another programmatic challenge to implement risk-informed cleanup strategies: renegotiating existing compliance agreements, which cannot be accomplished without full support from the Federal and state regulators and other stakeholders. To that end, sharing of lessons learned and recent developments in integrated environmental modeling in DOE, other Federal agencies and with other stakeholders (including those involved in the cleanup of the Fukushima Daiichi nuclear accident) will help the waste management community build confidence in the models used in support of IRAs, which in turn, could faciliate the transition of the EM program to a risk-informed paradigm.

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