Needs for Integrated Risk Assessment to Support Optimal Environmental Management Decisions – 15455

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ABSTRACT

Cleaning up legacy waste from 50 years of nuclear weapons production and energy research still remains a challenge for the U.S. Department of Energy (DOE). The DOE environmental management program is currently forecasted to run through at least late 2060s with an estimated liability of $204 billion. Risks to human health of workers and the public, the ecological system, and nuclear safety of cleanup activities continue to drive the cost of DOE's cleanup programs.

Currently, these risks are generally assessed and managed independently of each other. Except for DOE self-regulated on-site disposal activities of low-level radioactive waste, risks to human health and the environment are generally under the purview of U.S. Environmental Protection Agency and State regulatory agencies, while nuclear safety risks are regulated by DOE with oversight from the U.S. Nuclear Regulatory Commission and the Defense Nuclear Facilities Safety Board where appropriate. When managing health and environmental risks, the individual regulatory authorities often use an area-by-area (or unit-by-unit), contaminant-by-contaminant (chemical-by-chemical or radionuclide-by-radionuclide) approach, focusing on a single medium (soil, water, or air), a single source (e.g., a burial ground or a processing facility), and a single receptor (e.g, a groundwater well or a creek). This level of segregation in risk evaluations by risk category, geographical location, and operational unit, as well as the corresponding separation of regulatory authorities poses a significant challenge to reaching an optimal decision in prioritizing and managing cleanup activities. This management challenge adds another layer of complexity to large-scale cleanup effort at complex sites such as the Hanford site in eastern Washington.

Therefore, to support a scientifically sound, operationally robust decision making process, there is a need for an integrated, holistic approach to risk assessment that addresses the combined effects of all major contributing factors. Previous studies have pointed out the need for integrated risk assessments that address multicontaminant, multimedia, multipathway exposures, for the purposes of evaluating risks to human health and the environment. We believe that a comprehensive risk assessment should also take into nuclear safety risks that are associated with handling of nuclear material either retrieved from burial sites or to be decommisioned from nuclear facilities. Recent efforts, such as the Consortium for Risk Evaluation with Stakeholder Participation (CRESP)-led Hanford site-wide independent risk review that will categorize all types of risks at the Hanford site and the DOE complex-wide risk review mandated by the Fiscal Year 2014 Consolidated Appropriations Act ("Omnibus bill"), are beginning to more comprehensively address this need.

This paper provides a categorization of various types of risks present at typical DOE sites, reviews the current risk assessment and management practices, and discusses the needs for integrating nuclear safety into performance and risk assessments for optimal cleanup decisions.

INTRODUCTION

Cleaning up legacy waste from 50 years of nuclear weapons production and nuclear energy research is the U.S. Department of Energy (DOE)'s third largest program, following nuclear security and sciences, and it still remains a challenge for the DOE. The liabilities of the DOE environmental cleanup and disposal programs are currently estimated at $300 billion, of which the Office of Environmental Management (EM)'s liability is $204 billion, the portion of the Office of Legacy Management is $66 billion, and the liability for disposition of active and surplus facilities is $30 billion [1]. EM's cleanup activities are forecasted to run through at least late 2060s.

Since its inception in 1989, DOE EM has been conducting its cleanup program according to the following overall priorities: (1) Maintain a safe and secure posture in the EM complex; (2) Stabilize, treat, and dispose of radioactive tank waste; (3) Store, transport, and disposition spent nuclear fuel; (4) Consolidate, process, and disposition special nuclear material; (5) Remediate high-risk soil and groundwater; (6) Disposition transuranic and mixed/low-level waste; (6) Remediate other contaminated soil and groundwater; and (7) deactivate and decommission excess facilities. As of the beginning of 2015, 90 of the 107 sites have been cleaned up and transitioned into the long-term stewardship program managed by the Office of Legacy Management.

For the remaining 17 legacy waste sites, risks to human health of workers and the public, the ecological system, and nuclear safety of ongoing and future cleanup activities continue to drive the cost of DOE's environmental cleanup program. Management of these risks is a major part of the overall surveillance and maintenance (MinSafe) operations as required by Federal Facility Agreements (FFAs). In recent years, DOE EM has been investing about one half of its annual appropriations in its MinSafe activities, especially on large sites such as Hanford and the Savannah River Site [2].

REGULATORY FRAMEWORK

DOE's environmental cleanup program is driven by requirements to comply with various Federal and states environmental laws and regulations (e.g., Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and National Environmental Policy Act (NEPA)). 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 (FFAs). 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 [3].

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* [4]. The 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 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.

In addition, DOE EM self regulates radioactive waste management under DOE Order 435.1, *Radioactive Waste Management*, which includes disposal of radioactive waste. U.S. Nuclear Regulatory Commission has a consultative and monitoring role in determining when waste is no longer high-level waste.

RISK-INFORMED DECISION MAKING IS A MANAGEMENT CHALLENGE FACING THE DOE ENVIRONMENTAL MANAGEMENT PROGRAM

As part of the Reports Consolidation Act of 2000, the DOE Office of Inspector General (OIG) reviewed DOE operations to identify management challenges facing the Department. In its 2011 Special Report IG-0858 [3], 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 [3]:

> *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.*

Consistent with the IG recommendations, Congress in the 2014 Appropriations Act mandated DOE to conduct a complex-wide risk review by an independent organization. Independent of the Congressional mandates, senior DOE management also commissioned an independent site-wide risk review of the Hanford site. The status of these independent reviews will be discussed later in the paper.

TYPES OF RISKS

Difficult environmental management decisions, like those facing Food and Drug Administration [5], require careful characterization of risks. For the purpose of this discussion, we define risk as the product of probability of an undesirable exposure event occurring and consequence of the exposure. Natural or introduced hazards or threats lead to risks when exposure occurs in an event. Therefore, if there is no exposure, then there is no risk -- even in the presence of hazards.

U.S. EPA considers risk to be the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor. A stressor is any physical, chemical, or biological entity that can induce an adverse response. Stressors may adversely affect specific natural resources or entire ecosystems, including plants and animals, as well as the environment with which they interact [6].

In the context of management of the DOE environmental cleanup program, risk normally refers to hazards or threats to safety of nuclear facility operations, human health, or the environment. More specifically, these risks can be categorized into the following groups: (1) Health risks to workers during cleanup and surveillance and maintenance operations; (2) Health risks to the public who visit the site; (3) Risks to the ecological systems of the environment; and (4) Risks to nuclear safety of operating or excess nuclear facilities.

Among these, risks to nuclear safety are often assessed by separate teams of experts with different criteria and documented separately, and are normally not fully integrated into the assessments of the health and environmental risks. We argue in this paper that there is a need for a better integration between these activities and to incorporate nuclear safety risks into plans and actions to reduce health and environmental risks.

Although this paper is not intended to discuss in detail other types of risk such as the risk to costs and schedule of environmental cleanup projects, recent experience serves as a reminder that these factors also need to be taken into account in risk management decisions, preferably early on in the planning and execution of the cleanup work. For instance, the interim ROD for the Hanford 100-D Area called for soil excavation to a depth of 15 feet to remove hexavalent chromium. However, in implementing the ROD one large waste site in the area, 100-D-100, was excavated 85 feet to groundwater in an area of the size of several football fields to satisfy regulators' requirements. Subsequent monitoring still showed residual concentrations in the groundwater and sediment. The site was therefore excavated an additional 10 feet into the sediments to expedite treatment of contaminated groundwater beneath the 100-D Area. The additional

excavation and backfilling work at this site alone cost more than $100M, while the real impact of these actions on reducing groundwater concentrations or risks to the ecological environment has not demonstrated.

INDEPEDENT RISK REVIEWS

To objectively assess all major risks in DOE's remaining cleanup work, several independent program risk reviews are being conducted as either mandated by the Congress or chartered by the DOE senior management. Results of these initiatives will provide critically needed information to help inform the DOE management decisions.

"Omnibus" Complex-Wide Risk Review

In the FY2014 Appropriations Act (i.e., 2014 "Omnibus" Bill), Congress directed the DOE to "retain a respected outside group...[to] undertake an analysis of how effectively the Department of Energy identifies, programs, and executes its plans to address those risks [to public health and safety from the DOE's remaining environmental cleanup liabilities], as well as how effectively the Defense Nuclear Facilities Safety Board (DNFSB) identifies and elevates the nature and consequences of potential threats to public health at safety at the defense environmental cleanup sites." In response, DOE EM has retained an independent organization, the Center for Risk Evaluation with Stakeholder Participation (CRESP), to carry out a review of the use of risk and risk-informed management as directed by Congressional language indicated above and with the following specific objectives: (i) identify and review how specific federal policies and guidance shape DOE-EM's evaluation and use of risks to human health and safety as part of program decisions; (ii) review how the DNFSB identifies and elevates threats to public health and safety, and how DOE considers DNFSB concerns as part of program decisions; (iii) how risks to public health and safety are considered as part of state and federal regulatory compliance and priorities at DOE EM cleanup sites; (iv) how DOE EM uses human health risk and public safety input and information from a broader range of sources as part of program decisions; and (v) how DOE EM uses the range of human health risk and safety information available along with the broader range of input and constraints to balance cleanup priorities within and between cleanup sites.

The review committee is comprised of nationally distinguished individuals with diverse experience in risk evaluation, public health and safety, nuclear safety, risk management, and public policy. The review is carried out through review of documents and interviews and meetings with current and former managers and senior staff at EM HQ and sites, state regulators, EPA, DNFSB members, Office of Management and Budget examiners, and other individuals as the committee finds appropriate. A final public report, reviewed for factual accuracy by DOE and the DNFSB, is expected in the Spring of 2015.

Hanford Site-Wide Risk Review

In another related effort, CRESP was requested by the DOE Deputy Under Secretary for Management to conduct an independent evaluation of Hanford site-wide risks to human health, nuclear safety, environmental and cultural resources. The goal of the Risk Review is to identify and characterize potential risks to the public, workers, groundwater and the Columbia River, and ecological and cultural resources (collectively referred to as" receptors") at the Hanford Site.

Results from the Risk Review are expected to provide DOE and regulators with a common understanding of the risks and impacts cleanup options may have on human health and the environment and also help inform the efficient use of DOE EM resources. Specific objectives of the Risk Review Project are:

1. To review sources of contamination site-wide and determine the potential for contaminants and cleanup actions to cause risks to receptors;
2. To provide relative ratings of risks to receptors from sources, in order to better enable the Tri-Parties (DOE, U.S. Environmental Protection Agency (EPA) and Washington Department of Ecology) to make decisions on the sequencing of Hanford cleanup activities; and
3. To provide context for understanding how the risks posed by cleanup at the Hanford Site compare to risks and other impacts posed by similar cleanup activities conducted at non-DOE sites located either on-site or nearby, as well as at other non-DOE, large-scale regional sites.

CRESP, with technical support of PNNL, has led the effort with a core team of CRESP senior researchers and DOE (RL, ORP and EM), Washington Department of Ecology and U.S. EPA (Regional and Headquarters) participants. The information basis for the review includes such documents as environmental impact statements, safety documents, remedial action decision documents, performance assessments, etc. Several workshops and stakeholder-specific interactions (e.g., tribes and DNFSB) provide the basis for gaining broad stakeholder input and feedback. The effort is expected to take approximately 2 years. An interim report was released for factual accuracy review in March 2015 with the methodology of evaluation and the evaluation of an initial set of evaluation units [7]. A public workshop is being planned for the Summer of 2015 to discuss results of the review and collect additional stakeholder inputs. The team is expected to finalize the report by the end of 2015.

CURRENT RISK ASSESSMENT AND MANAGEMENT PRACTICES

In environmental compliance activities regulated by EPA and state agencies, risk assessment is used to characterize the nature and magnitude of health risks to humans (e.g., residents, workers, recreational visitors) and ecological receptors (e.g., birds, fish, wildlife) from chemical contaminants and other stressors, that may be present in the environment [6]. EPA has recently released the *Framework for Human Health Risk Assessment to Inform Decision Making* that describes a process for conducting human health risk assessments that are responsive to the decision-making needs of EPA [8].

Similarly, in DOE's self-regulated radioactive waste management program, performance assessment is often used to assess the risks to human health and the ecological environment from radiological contaminants present in nuclear facilities and waste sites. In this paper, these types of analyses are collectively termed performance and risk assessments (P&RAs), or for simplicity, risk assessments.

Risk management generally refers to the process which develops and manages options for addressing risks to human health and the environment. Examples of risk management actions include deciding how much of a substance a site may discharge into a river; deciding which

substances may be stored at a hazardous waste disposal facility; deciding to what extent a hazardous waste site must be cleaned up; setting permit levels for discharge, storage, or transport; establishing national ambient air quality standards; and determining allowable levels of contamination in drinking water. Therefore, risk assessment provides "INFORMATION" on potential health or ecological risks, and risk management is the "ACTION" to be taken based on consideration of risk assessment and other information such as laws and regulations, technology constraints, economics, and stakeholder inputs [6].

Currently, DOE's environmental cleanup work is normally managed by operable units (OUs) -- groupings of sites that are aggregated for regulatory purposes either by function, type of contaminated media (i.e., near surface soils, groundwater, etc.), cleanup requirements (e.g., facility decommissioning, soil remediation), and/or geographic area. Management of the OUs often involves oversight by different regulators. On the Hanford Site, for example, the Hanford FFAs (also known as the Tri-Party Agreement (TPA) among DOE, EPA, and Washington State Department of Ecology) classifies Waste Management Units as OUs subject to CERCLA or RCRA requirements. OUs have been formed which group multiple units for action in accordance with the TPA Action Plan. Some OUs may be subject to requirements of both RCRA and CERCLA. The TPA set forth roles and responsibilities for EPA's oversight of CERCLA, Washington Ecology's oversight of RCRA, and DOE's obligation to comply with applicable CERCLA and RCRA requirements.

Risk assessment and management practices tend to be segregated, and focus on only the specific OU under evaluation. Risk assessment is rarely done holistically for the entire environmental system where multiple OUs overlap and/or interact with each other. For example, during recent implementations of interim RODs to clean up the Hanford River Corridor, it was reported that dust control measures used for soil excavation have introduced a significant amount of water into the vadose zone, causing leaching and remobilization of hexavalent chromium resulting in spikes in its groundwater concentrations in some areas at 100-BC [9]. This, in turn, exacerbated the conditions of groundwater contamination and increased the burden for groundwater remediation. Therefore, the current practice of risk assessment and management presents a significant challenge for addressing the true health and environmental risks that are present in the environment, particularly in cases where RCRA and CERCLA requirements lead to conflicting requirements for actions for the same OU. Although previous studies have pointed out the need for integrated risk assessments that address multicontaminant, multimedia, multipathway exposures, for the purposes of evaluating risks to human health and the environment [10], previous attempts to integrate CERCLA and RCRA requirements [11] have not always been successful in practice on some large, complex sites.

We also believe that a comprehensive risk assessment should take into potential nuclear safety risks that are associated with handling of nuclear material either retrieved from burial sites or to be decommissioned from nuclear facilities. Deactivation & decommissioning (D&D) of excess nuclear facilities poses significant safety risks, if not managed properly. A case in point is that on July 27, 2007, a radioactive waste spill occurred at the S-102 tank in Hanford's S tank farm during tank mixing/transfer procedures [12]. Washington State Department of Ecology levied a fine of $500,000 for this accident. However, for similar reasons as discussed above, current practices of assessing and managing environmental and nuclear safety risks separately make it difficult to address the combined risks effectively.

There are also cases where unknown nuclear safety conditions have significantly altered plans for facility D&D and soil remediation. For example, when preparing the 324 Building at the Hanford Site for demolition, highly contaminated soil conditions were discovered in Waste Site 300-296 underneath the building. Due to the extremely high level of contamination directly under the building's "B" hot cell, it was determined that workers cannot safely demolish the structure until the underlying waste site is remediated. This requires the delay of building demolition activities until approximately 2018 to allow for characterization and remediation of the waste site. The waste site remediation will involve the use of the building structure as a radiation shield during remediation. The building will be demolished after the highly contaminated soil is removed through the building floor and treated.

Similarly, remediation of old burial grounds could expose workers and the public to the previously buried nuclear material causing significant safety risk. Therefore, the benefits in reducing risks to human health and the environment through contaminant removal and treatment actions should be weighed carefully against potentially increased nuclear safety risks that may be introduced by the proposed actions themselves. This factor needs to be considered when deciding the fate for existing contamination present in cribs and trenches in the deep vadose zone on Hanford's Central Plateau. For the Hanford 600 Area, the interim ROD calls for the cleanup of the 618-10 and 618-11 burial grounds. The original plan was to remediate the 2 burial grounds in parallel. It has since been modified to remediate the 618-10 burial ground first, so that the work at the 618-11 burial ground can benefit from the lessons learned from the 618-10 burial ground. One of the remaining issues that need to be resolved before the commencement of the 618-11 burial ground cleanup is the concern about nuclear safety from the Columbia Generating Station (CGS) which is located next to the site. Since the CGS operations license does not expire until the 2040s, it may be prudent not to start the cleanup work until the CGS ceases operation, because of potential risks that could result from excavation and removal of highly contaminated materials from vertical pipe units and caissons in the burial ground.

Under certain conditions like those present on the Central Plateau, the additional safety risks that may be introduced may not justify the proposed remedial action, and therefore it may be safer from a nuclear safety standpoint and environmentally more protective to leave the existing contaminants where they are. On other sites of commercial origin, similar considerations have led to decisions that involve the technical impracticality waiver and monitored natural attenuation (see e.g., the EPA ROD for the groundwater OU at the Del Amo and Montrose Superfund Sites in the Los Angeles metropolitan area [13]).

These examples illustrate the problems in implementing CERCLA and RCRA requirements separately for separate OUs on complex sites like Hanford. They also demonstrate the need for integrated P&RAs, in which impacts on nuclear safety that proposed facility D&D or soil remedial actions may have need to be considered in order to help develop optimal environmental management decisions.

NEED FOR FURTHER INTEGRATION OF NUCLEAR SAFETY RISKS WITH RISKS TO HEALTH AND ENVIRONMENT

From the above discussion, we reason that nuclear safety analysis needs to be better integrated

into comprehensive performance and risk assessments (P&RAs) when deciding on proposed actions for nuclear facilities or waste sites. Integrated P&RAs will provide the information necessary for optimal risk management decisions. Currently, performance assessments actives are governed by DOE Order 435.1, *Radioactive Waste Management*, while nuclear safety issues are addressed in accordance with DOE-STD-3009-2014, *DOE Standard Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*. Performance assessments and composite analyses are conducted for the construction and operations of on-site disposal facilities for low-level nuclear wastes in accordance with DOE Order 435.1. In accordance with DOE-STD-3009-2014, nuclear safety analysis, documented in the safety analysis (DSA) process, including hazards analysis, accident analysis, preliminary DSA, and final DSA, provides a detailed evaluation of operational and external initiating events and scenarios that can result in risks to human health from existing hazards. The DSA process includes an accident dose calculation of radiological consequences of the initiating events by considering dispersion from the source location to the receptor [7]. For environmental restoration and waste management practices, better integration between the sets of compliance activities may be needed for sites where both concerns exist. This is potentially important for cases where beyond design/evaluation basis accidents or other disruptive initiating events could lead to changes in e.g., engineered barrier degradation mechanisms, subsurface flow patterns, contaminant transport rates, and environmental exposure pathways.

To facilitate the development of best practices in integrated P&RAs and articulate and develop consensus for resolving integration issues such as those discussed herein, DOE has sponsored the Interagency Performance and Risk Assessments Community of Practice (P&RA CoP). Since late 2013, the P&RA CoP has organized 5 webinars, each attended by 50+ participants on average from DOE HQ and field offices, NRC, EPA, state regulatory agencies, national labs, universities, DOE contractors, and other practitioners. The group's Annual Technical Exchange held in December 2014 attracted more than 70 attendees. Additional information about the P&RA CoP can be found in Zhu et al. (2014) [14] and on the DOE Website: http://www.energy.gov/em/services/site-facility-restoration/performance-risk-assessment-community-practice-pra-cop.

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