USE OF RISK ASSESSMENT BY THE USNRC FOR NON-REACTOR APPLICATIONS

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Abstract

This paper discusses the use of risk assessment and related techniques for non-reactor nuclear systems regulated by the U.S. Nuclear Regulatory Commission (USNRC). There is a wide diversity of activities, hazards, and populations at risk among regulated uses of nuclear materials. This has given rise to a diversity of risk assessment methods within USNRC. Major characteristics of the different assessment methods have been summarized. These methods have been used extensively in the materials and waste arenas, but are in different stages of development in different areas. The status of the use of these methods in analyzing specific types of installations is summarized. Finally the agency program to promote non-reactor risk assessment, to develop risk-informed regulatory approaches, and to harmonize these approaches is then outlined.

1. INTRODUCTION

This paper discusses the use of risk assessment techniques in the materials and waste arenas of the U.S. Nuclear Regulatory Commission (USNRC). There is a wide diversity of situations outside reactors where nuclear materials may give rise to risk. This has given rise to a diversity of risk assessment methods within USNRC. The major types of assessment methods and the general uses to which they have been applied will be described briefly in Section 2, and references given to more complete descriptions. The application of these methods to specific non-reactor applications is then discussed more fully in Section 3. Section 4 describes the recent program to promote non-reactor uses of risk assessment within the USNRC and to harmonize its use in risk-informing regulation in the nuclear materials and waste arenas.

2. RISK ASSESSMENT METHODS IN THE USNRC

The four major types of assessment discussed here are: Probabilistic Risk Assessment (PRA), Integrated Safety Assessment (ISA), Performance Assessment (PA), and expert elicitation. These could all be considered simply different varieties of the generic category of probabilistic risk assessment. However, within the USNRC the types of assessments bearing these names differ markedly in terms of the types of techniques used, risks assessed, and areas of application.

2.1 Probabilistic Risk Assessment

Within the USNRC Probabilistic Risk Assessment (PRA) typically refers to the use of fault trees, event trees, accident progression analysis, and consequence calculations to evaluate the frequency and consequences of events with adverse effects. In practice, PRA methods differ between application areas. The classic area in which PRA is used is for complex engineered safety hardware, like reactor plants. This type of PRA uses event trees consisting primarily of failures of safety functions provided by automatic equipment. Fault trees are used to quantify probabilities in the event trees. In simpler application areas, a PRA model may consist of event trees quantified directly by event statistics, or by applying systematic criteria. Examples of such systematic criteria are the performance shaping factors that may be used as criteria for assigning human error probabilities. PRA methods are widely used and documented.

2.2 Integrated Safety Analysis

Integrated Safety Analysis (ISA) refers to a systematic method for identifying accidents and evaluating their likelihood and consequences. In ISA an integrated team assesses multiple hazards, such as radiological, chemical, criticality, and fire. The intent of ISA is not to quantify risk for its own sake, but to identify and evaluate the adequacy of safety controls. A quantified PRA would be one acceptable form of ISA. However, an ISA could use PRA methods, such as fault trees, for accident identification, but then use qualitative methods of evaluating their consequences and likelihoods. In qualitative methods of evaluation, accidents are assigned to broad categories of consequences and likelihood based on criteria that may be qualitative. ISA is relatively new, but has already been applied to a wide variety of fuel cycle process designs. References 1 and 2 describe ISA methods and standards. In addition to its use at fuel cycle facilities, ISA is being considered for the pre-closure phase of a high-level waste repository.

2.3 Performance Assessment

Performance Assessment (PA) is a technique for evaluation of the long-term dose rate due to radioactive materials at decommissioned sites or engineered waste sites. Performance Assessment may include a probabilistic assessment of discrete events, such as volcanic eruptions, but it has a larger emphasis on assessing the contribution to individual dose by the eventual long-term continuous release of the emplaced waste. The quantification in a PA is performed using complex computer codes to model physical processes such as degradation of waste packages, transport of radionuclides in water or air, and exposure of the critical group by various pathways. Performance Assessment models typically feature probabilistic quantification of the uncertainty in the assessed dose. This epistemic uncertainty is calculated by propagating parameter uncertainty through models, and by the use of alternative models. Performance Assessment is being used for the U.S. High-Level Waste repository at Yucca Mountain. Guidance has also been developed for using PA in assessing performance of low-level waste sites, and for decommissioning of sites where nuclear materials have been used. The Performance Assessment approach is described in Reference 3.

2.4 Expert Elicitation

Expert elicitation refers to risk assessments that are performed by having informed experts identify what can happen, then judge its likelihood and consequences. Such elicitation is usually structured, and limited information and statistics are used by experts to infer risk. Such studies may be conducted as a panel or via surveys. This method has been used to assess risks from the Gamma Knife medical instrument.

3. USE OF RISK ASSESSMENT IN NUCLEAR MATERIALS AND WASTE

The four risk assessment methods described above have been applied to a wide variety of non-reactor nuclear installations and activities within the USNRC. Many of these application areas are installations with a large inventory of radioactive material, but some are not. Much of the discussion below has been adapted from Reference 4 which has further details.

Broadly the non-reactor applications of risk assessment can be categorized in four groups: (1) activities that involve long-term commitment of a site or facility to the presence of nuclear material at a planned, acceptable level (e.g., HLW disposal); (2) activities that involve use of engineered casks to isolate nuclear material under a variety of normal and off-normal conditions (e.g., transportation and storage); (3) activities that involve physical and chemical processing and possession of nuclear material at a large-scale facility (e.g., fuel fabrication); and (4) activities that involve the use of either sealed or unsealed byproduct material in a wide variety of industrial and medical applications. The differences in these application areas necessarily create differences in the assessment methods used. These differences include: the facilities, systems, or devices employed; potential exposure pathways; potential accident initiators and frequencies; potential consequences; and populations at risk. Systematic analysis of these specific features is the crux of any risk assessment that might be applied to a regulated activity. Therefore, different risk assessment methods are more efficient and effective for the activities of each group. Such methods have been developed, or adapted from methods used for other similar technologies, as the need has arisen. Accordingly, the degree of development of and experience in using these methods differs. The following sections discuss each of the above four major application areas.

3.1 Waste Sites and Decommissioning

One of the primary regulatory requirements for waste sites and decommissioned nuclear sites is that the long-term radiation exposure to a critical group of persons meet a performance standard, such as having a mean dose rate less than 0.25 millisieverts (25 mrem) per year. Thus, <u>quantitative</u> Performance Assessment of the emplaced waste is needed to assess this exposure. In addition, for the pre-closure operational phase of a waste site, and for the active phase of decommissioning of sites, Integrated Safety Analysis or PRA may be necessary to assess the safety. For high-level waste, the governing USNRC regulation specifies requirements for pre-closure and post-closure safety assessments. Post-closure assessments have been performed by the U.S. Department of Energy, which is responsible for constructing and evaluating the high-level waste repository, and the final PA will be reviewed independently by the USNRC. Since the final repository design has not yet been determined, the DOE assessments are preliminary.

3.2 Transportation and Storage in Casks

The USNRC staff made early efforts to apply probabilistic risk assessment methodology for the analysis of the risk of transportation of nuclear materials by various modes (References 5 and 6). Recently, the USNRC completed a reexamination of spent fuel risk estimates (Reference 7). This reexamination compared its results to the earlier studies. It demonstrated that both of the earlier studies made a number of very conservative assumptions about spent fuel and cask response to accident conditions, which caused their estimates of accident source terms, accident frequencies, and accident consequences to also be very conservative. The results demonstrated that the risks associated with the shipment of spent fuel by truck or rail remain very small. An additional example application in this area was the application of PRA methodology in deciding to approve the one-time shipment by barge of the Trojan reactor pressure vessel for disposal at a waste site in the State of Washington.

Dry cask storage of spent fuel is another important application area in this group. The staff believes that ISA or PRA can be appropriate risk assessment tools for activities in this area. USNRC is proceeding with the development of a PRA for interim storage of spent nuclear fuel. It has also been used in probabilistic assessment of dry cask weld failures.

3.3 Fuel Cycle Facilities

Uranium or mixed oxide reactor fuel fabrication, uranium processing and enrichment, and mining and milling of source material exemplify facilities in this group. The staff and the major fuel cycle licensees have adapted integrated risk assessment technology that was developed for the chemical process industry after the Bhopal accident. This adaptation is called ISA, and has been in use at several fuel fabrication facilities for about 5 years. It is used to identify accident scenarios in processes, then to assess their consequences and evaluate the protection systems. An ISA of one major fuel site is nearly complete. Three other licensees have completed ISA's for significant portions of their installations. Two licensees are just in early stages of this program. On September 18, 2000, the Commission published in the Federal Register a revision of the regulation governing these licensees, 10 CFR Part 70, to require that ISA's be completed within 4 years.

3.4 Industrial and Medical Sources

Industrial radiography, nuclear medicine, and well-logging exemplify this group of applications. The situation regarding use of risk assessment for the wide variety of activities in this group is complex. In the early 1990s, the staff tested the expert elicitation form of risk methodology by studying the risk associated with a new medical procedure (gamma stereotactic surgery). The results were positive, but the approach was expensive and had some significant limitations. The PRA correctly predicted that operator error would be the principal accident initiator, but existing risk methods were in need of development.

Based on this experience, the staff undertook a planned effort to develop and apply methods. The results of this effort have been published under the title, “Risk Analysis and Evaluation of Regulatory Options for Nuclear Byproduct Material Systems” (Reference 8). This study involved the development of risk assessment methods appropriate to address byproduct activities. The study addressed 40 categories of byproduct systems including such diverse activities as laboratory use, sterilization irradiators, brachytherapy, well logging, and field radiography. Both routine and accident risks were assessed. A generic event tree was developed that starts with an initiating event, and contains events for three safety functions: shielding, confinement, and access. The trees for each application group were quantified by a combination of event statistics and systematized expert judgement. The resulting range in the quantified risk among the 40 systems was large. This work documented substantial progress towards developing a sound technical basis for risk-informed regulation of these activities.

Recently, the staff completed a risk analysis of fixed nuclear gauges (Reference 9). The risk studied here was that of these gauges being improperly disposed of as scrap. In particular, the possibility of incorporation of these gauges in steel produced from such scrap was analyzed. Scenarios were identified, and equations for quantifying risk in a variety of situations were developed, but quantification was not performed due to a lack of sufficient data.

3.5 Summary

Technical strengths and weaknesses of the individual risk assessment methods have not been discussed in this paper as they have been documented in the literature. A formal program to harmonize risk-informing methods within the materials and waste arenas is discussed in the following section. Since this harmonization program is still in progress, evaluative comments on use of the various applications will not made here.

4. RISK-INFORMED REGULATION IN THE USNRC MATERIALS AND WASTE ARENAS

The U. S. Nuclear Regulatory Commission is producing and using risk information in its decision making in the nuclear materials and waste arenas. These arenas include diverse types of activities, types of hazards, and populations at risk. A diversity of risk assessment techniques are in use. A number of risk studies have been carried out. Methods for using the risk information from these studies to guide regulatory decisions are being formulated. A program has been initiated to promote this process, and to harmonize methods for the use of risk information.

The Commission paper, SECY-99-100, “Framework for Risk-informed Regulation in the Office of Nuclear Materials Safety and Safeguards” (Reference 4), discusses the background and considerations behind risk-informing non-reactor nuclear activities, as well as defining a framework for doing so. The framework itself consists of four parts:

1) definition of different regulatory application areas,
2) evaluation of current regulatory considerations underlying each application area,
3) evaluation of new risk considerations for proposed regulatory actions,
4) integration of 2) and 3).

This framework is to be implemented in a five-step process:

1) Identify: (a) candidate regulatory applications for risk-informed approaches;
(b) responsible organizations.
2) Decide how to modify current regulatory approaches.
3) Change regulatory approaches.
4) Implement risk-informed approaches.
5) Develop or adapt risk-informed tools.

To facilitate this implementation process a Risk Task Group has been established. The Task Group will support ongoing activities that utilize risk information to add value to regulatory decisions. Specific areas to be addressed include the development and testing of screening criteria, material safety goals, identification of candidate applications that are amenable to risk-informed approaches, development of tools necessary to implement risk-informed initiatives, and implementation of new approaches that utilize risk in regulatory decision making activities.

A plan for developing methods to risk-inform regulatory activities in the materials and waste arenas studies has been developed and has been presented to stakeholders.

5. SUMMARY

Several risk assessment methods have been used in a diversity of applications in the materials and waste arenas of the USNRC. The results of these applications have been useful, in some cases essential, to the regulation of safety in these arenas. The selection of methods for different applications has not been arbitrary, but has been governed by the nature of the hazard, the type of result needed, and the availability of data. A common difference between these and the reactor application is the need to model exposures from continuing normal operations, in addition to those from rare accident events.

REFERENCES

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