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SIMPLIFIED RISK MODEL FOR WASTE MANAGEMENT AND ENVIRONMENTAL RESTORATION ACTIVITIES[1]

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ABSTRACT

A Simplified Risk Model (SRM) is being developed to support environmental restoration and waste management (EM) planning activities. The SRM is designed to be able to quantitatively estimate risk for various EM alternatives within hours or days, given limited information about the processes covered within the alternative. The risk model covers radiological, chemical, and industrial risk from both accidents and normal, incident-free operations. A simple risk equation is used to model accident risk. Normal, incident-free operation risk is modeled using a multiplier on accident risk. Ongoing applications of the SRM are expected to lead to significant improvements to the model in the near future.

1. INTRODUCTION

Risk models for environmental restoration and waste management (EM) activities range from simple qualitative estimates (high, medium, or low risk) to very detailed and complex models of radionuclide and hazardous chemical release and transport and receptor response (see Figure 1). The simple qualitative estimates may take minutes or hours to generate, while the complex models may take years to complete. For EM integration planning efforts, a simplified quantitative risk model was developed and applied at the Idaho National Engineering Laboratory (INEL). This Simplified Risk Model (SRM) allows for efficient risk evaluation of numerous potential EM activities, including waste management, environmental restoration, and decontamination and decommissioning (D&D), to support the selection of optimum EM integration alternatives. Typical risk assessments using the method can be completed within hours, given some basic information about the processes to be analyzed. Therefore, the SRM fills the void shown in Figure 1 for simplified, quantitative risk models.

The SRM is a comprehensive risk model. It covers radiological, chemical, and industrial risk from both accidents and normal, incident-free operations. Contaminant transport pathways include both atmospheric dispersion and groundwater dispersion. Most risk predictions involve atmospheric dispersion; however, environmental restoration analyses and disposal analyses can include groundwater dispersion.

The overall philosophy of the SRM is to predict unitless risk numbers for relative comparisons. However, the units of risk from the SRM for radiological inventories can be converted to person-rem or latent cancer fatalities, covering worker and public exposure. Also, hazardous chemical risk can be converted to latent cancer fatalities.

2. RISK MODEL DETAILS

The SRM methodology involves modeling risk from accidents and then approximating risk from normal, incident-free operation by scaling from the accident risk. This philosophy is founded upon the belief that accidents from a wide variety of EM activities can be modeled similarly (using a simple risk model), while normal exposure estimation requires a variety of different approaches. The SRM accident model is based upon the following equation:

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$$Risk = P * I * ST * FR * TE * HR,$$

where P = probability of accidents considered
I = inventory of contaminant (radionuclides and hazardous chemicals)
ST = specific toxicity of contaminant
FR = fraction of contaminant that is released from confinement
TE = effectiveness of environmental transport pathways in moving the released contaminant to the receptors
HR = number and proximity of human receptors.

Each of the equation components is discussed below.

The accident probability, P, is the aggregation of various types of accidents, such as natural phenomena (seismic events, fires, and floods) and process-related events (explosions, fires, handling accidents, criticality, and others). Each accident probability is weighted by the severity of the accident, represented by the estimated fraction of the total inventory that may be affected by the accident. Accident probabilities and severities were estimated from various facility Safety Analysis Reports (SARs), Environmental Impact Statements (EISs), and detailed risk assessments.

The inventory, I, is the total amount of radiological and hazardous chemical inventory present. The radiological inventory is divided into two categories, actinides and non-actinides. For each category, the total number of curies (Ci) must be estimated. If some of the EM activities will take place many years in the future, then both categories of radionuclides are reduced to account for radionuclide decay. The hazardous chemical inventory is represented by a few dominant chemicals. For each dominant chemical, the kilograms (kg) and chemical form are needed.

Specific toxicity, ST, is used to weight the radionuclide categories and dominant hazardous chemicals with respect to their toxicity to humans for inhalation, ingestion, and external exposure pathways. The STs were obtained from Environmental Protection Agency (EPA) and Department of Energy (DOE) documents. [1,2]

The release fraction, FR, models both the fraction of affected waste (from the accident frequency, P) that could be released to the atmosphere in respirable form and the probability of confinement failure, given the accident. The fraction of affected waste that is released to the atmosphere was obtained from the most recent DOE guidance. [3] For groundwater modeling, FR represents the fraction of affected waste that will eventually migrate to the groundwater, and the probability of confinement failure.

The environmental transport factor, TE, represents the dilution of the contaminant as it is dispersed through the atmosphere or groundwater, following a release of waste from an accident. The air dispersion results were obtained from simple Gaussian Plume modeling, assuming a ground level release. For groundwater modeling, TE represents the reduction in contaminant concentration in the groundwater as the distance from the source increases. At present, TE is not specific to a given DOE site.

Finally, the human receptor factor, HR, models the number of people within 50 miles of the DOE site and their respective distances from the site. HR also models workers at the DOE site in question. At present, HR is modeled for 17 DOE sites.

Except for the contaminant inventory, the SRM provides look-up tables for guidance in determining the rest of the risk equation factors. An example of such a look-up table is presented in Figure 2. One portion of the release fraction factor, FR, is the mobility of the waste, given an accident. The values for mobility, also termed respirable airborne release fraction, are presented in Figure 2 for various forms of waste. The risk analyst needs only to know the form of the waste being considered in order to pick a value out of Figure 2. Similar look-up tables are provided for the other risk equation factors.

3. RISK MODEL SAMPLE APPLICATION

As an example application of the SRM to waste management alternatives, spent nuclear fuel (SNF) at a DOE site is considered. The SNF is currently being stored in cannisters in underground storage vaults. The base case plan for this SNF is to remove it from storage, repackage it in newer cannisters, place it back into storage, and in five years ship it to another DOE site for longer-term storage. Alternative 1 involves the same plan except that only 53% of the SNF will be repackaged. Alternative 2 involves 53% repackaging and immediate shipment to the other DOE site for storage. Finally, alternative 3 is similar to 2, but with 100% repackaging.

The initial step in modeling risk with the SRM is to develop a flow diagram, as presented in Figure 3. This flow diagram applies to all four base and alternative cases. However, the SNF inventories for various steps in the flow diagram and the timing vary. Given an initial SNF inventory of 86,000 Ci, the base case and alternative 3 process this total inventory through all of the steps in the flow diagram. However, alternatives 2 and 3 process only 53% of the inventory through the retrieval, repackaging, and return to storage steps. The other steps consider 100% of the inventory. Also, all four base and alternative cases consider a five-year period.

Given the flow diagram, inventory, and timing information discussed above, the SRM risk predictions for each of the steps in the flow diagram can be assembled. Results are presented in Figure 4 for all four cases. Examination of Figure 4 indicates that most of the radiological risk results from the retrieval and shipping steps. The retrieval step has a higher risk than the other steps because only a single barrier exists between the SNF and the workers, and the probability of dropping a cannister is higher because of aging cables attached to the cannisters (used to retrieve the cannisters from storage). Shipping risk is higher than most of the other steps because of normal, incident-free exposure to the public from direct radiation from the transport cask containing SNF. Storage risk is negligible for the short, five-year period considered. Finally, alternative 2 has the lowest risk of the four cases, because only 53% of the SNF is repackaged and the extra step of returning the repackaged SNF to storage (before shipping to another DOE site) is eliminated. The radiological risk associated with alternative 2 is approximately 36% lower than the base case.

It should be noted that the sample risk analysis outlined above does not include non-radiological and non-hazardous-chemical injuries and deaths from construction, operation, and shipping accidents. Such risks can be included in SRM analyses; however, the sample problem was kept simple to indicate how radiological risks rank between the activities and alternatives.

4. RISK MODEL VALIDATION

The SRM is still considered to be in a developmental stage. At present, limited comparisons of SRM risk results have been made with more detailed risk analyses, especially in the areas of transuranic waste and SNF. However, the chemical risk modeling, groundwater pathway modeling, and normal, incident-free operation exposure modeling need to be reviewed and validated. A detailed review of such models and a comprehensive comparison of SRM results with more detailed SAR, EIS, and risk analysis results are planned for the near future.

5. RISK MODEL APPLICATIONS

At present, the SRM has been used on a trial basis for some EM alternative evaluations involving multiple DOE sites. It will also be used to help to evaluate environmental restoration methodologies at over 200 DOE sites. Future applications to DOE EM integration efforts are also anticipated. These types of applications involve top-level, management evaluations of various EM alternatives to identify one or more candidates for further, more detailed evaluations. These types of applications are ideal for the SRM.

6. SUMMARY

The SRM is being developed to provide simple, quantitative risk estimates for DOE EM planning efforts. The model attempts to reproduce the risk results of more detailed analyses from SARs, EISs, performance assessments, and risk assessments, but at a more approximate level. The SRM risk results can be obtained within hours or days, thereby filling a void in the availability of comprehensive, simple, and quantitative risk models. Initial efforts have supported the SRM concept. However, significant additional work is needed to test all of the capabilities of the model and compare results with more detailed risk results.

REFERENCES

1. *Health Effects Assessment Summary Tables*, FY-1995 Supplement, PB95-921101, U.S. Environmental Protection Agency, Washington, D.C. (1995).

2. *Internal Dose Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0071, U.S. Department of Energy, Washington, D.C. (July 1988).

3. *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, DOE-HDBK-3010-94, U.S. Department of Energy, Washington, D.C. (December 1994).

Type of Risk Assessment	Simple, Qualitative (Level 1)	Simple, Quantitative (SRM)(Level 2)	Detailed, Quantitative (Level 3)	Very Detailed, Quantitative (Level 4)
Level of Detail	Least detailed	Less Detailed	Detailed	Most detailed
Time to Perform	Hours	Hours to days	Months to years	Years
Types of Studies	High-level management evaluations of alternatives	High-level management evaluations of alternatives	EISs	SARs, baseline risk assessments, performance assessments, probabilistic risk assessments

Figure 1. Types of risk assessment methodologies.

Physical Form of Waste	Mobility for Airborne Releases (fraction of waste released)	Mobility for Groundwater Releases (fraction of waste released)
Gas or vapor from a highly volatile liquid	1.0	1.0
Low-volatility liquid or bulk quantity of volatile liquid	3E-3	1E-1
Loose contamination on surface of solids	1E-3	1E-3
Powder (with 10% of mass in particulate within respirable size range)	1E-3	8E-4
Calcine (a granular solid)	6E-4	6E-4
Sludge	3E-4	3E-4
Cement and concrete	1E-4	1E-4
Glass and ceramic	1E-5	1E-5
Metals (nonpyrophoric)	1E-5	2E-6

Figure 2. Look-up table for waste mobility values for airborne and groundwater releases.

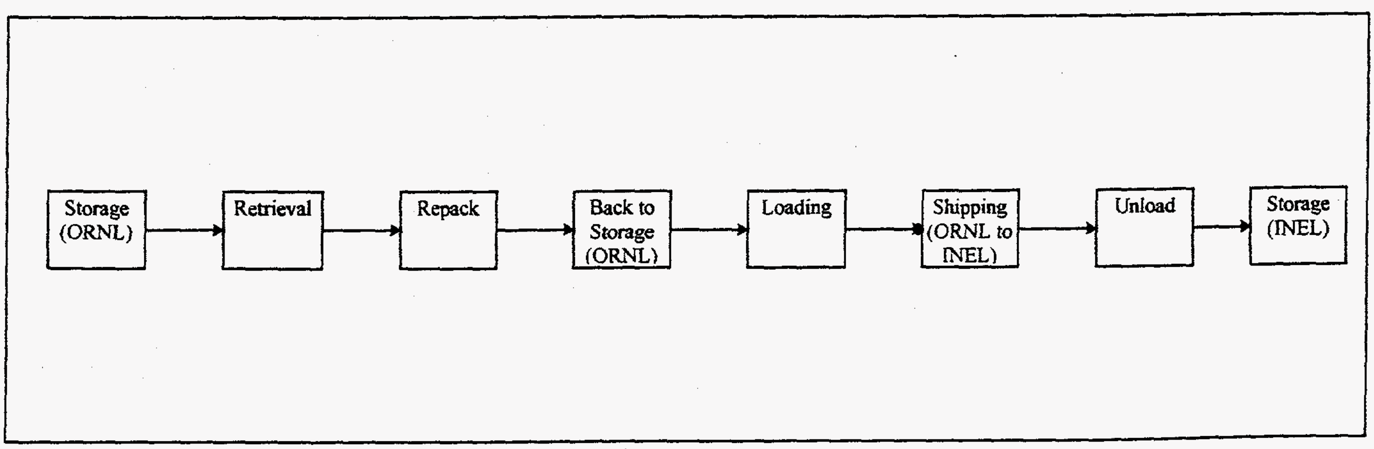

Figure 3. SNF flow diagram for base case and alternatives.

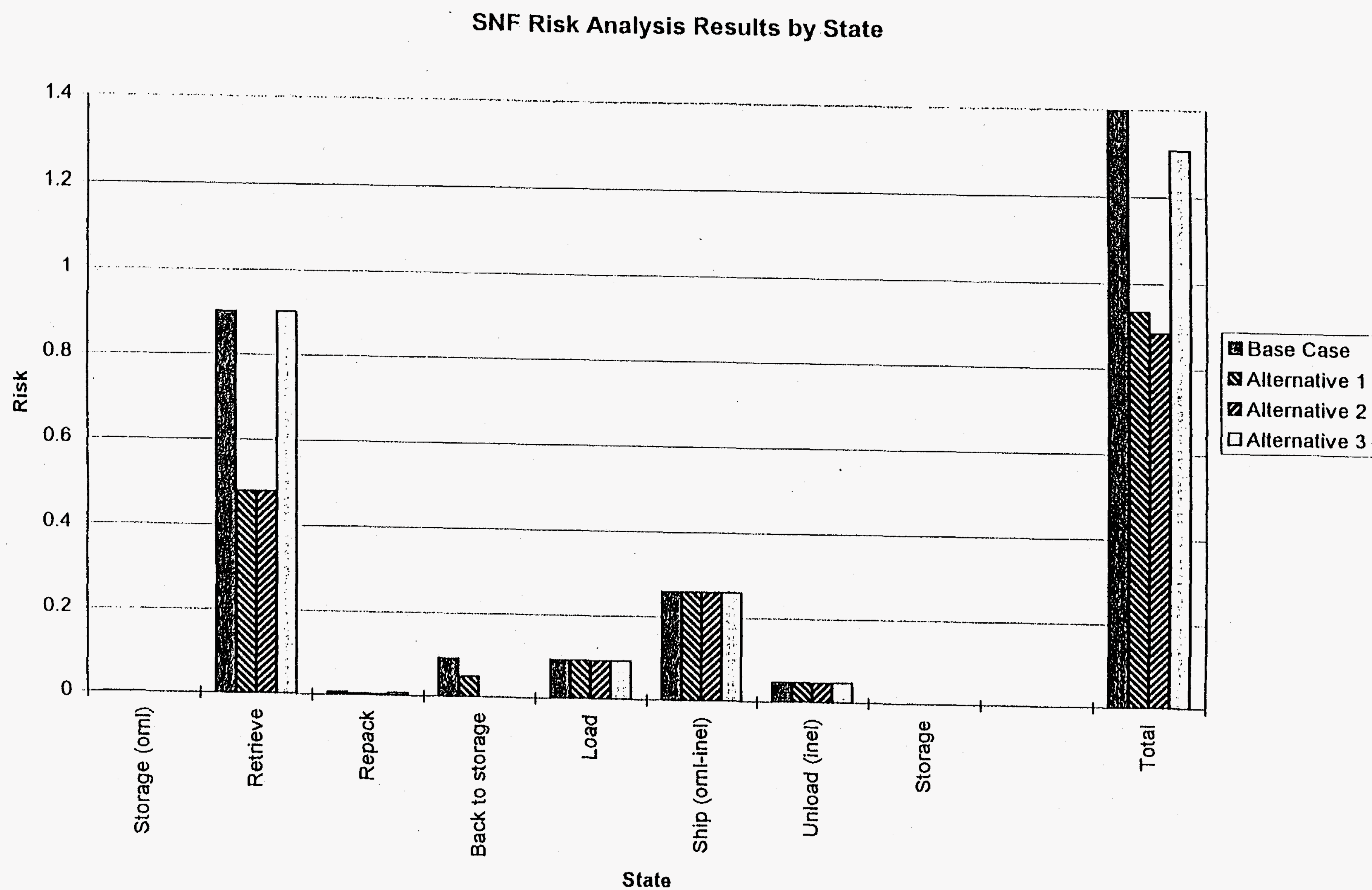

Figure 4. Radiological risk (person-rem) results for SNF analyses.