ON RISK ASSESSMENT FOR DETERMINATION OF IN-SITU DATA REQUIREMENTS

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Abstract. The use of formal risk assessment techniques to determine in-situ data needed for nuclear waste disposal sites is discussed. Considerations of accident sequences, transport pathways to the biosphere, and dose factors lead to identification of the radionuclides which contribute to potential public radiation exposure as a function of time. Generic risk assessments have identified ^{14}C, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, ^{226}Ra (from ^{238}U), ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{241}Am as nuclides of interest. Site-specific studies can establish the relative importance of each and thus the precision needed for measurement of nuclide inventory and distribution. Instrumentation needs can then be established for measurement of these nuclides. The presence of low-energy beta emitters and several actinides on the list offers considerable challenge for instrument developers.

INTRODUCTION

The need for in-situ measurements on nuclear waste burial sites is increasing as regulatory and public concerns are expressed about the perceived hazard of nuclear waste. This paper is intended to stimulate the development and application of in-situ instrumentation for collection of data based upon risk assessment needs rather than subjective impressions and judgement. In principle the data requirements are almost infinite, including radionuclide inventories and distributions, chemical form, physical and chemical interactions with the host medium and chemicals in the waste, as well as the geological and hydrological properties of the site, both near and far field. This discussion will consider the need for radionuclide data as part of the characterization of a nuclear waste disposal site.

Much of the need arises from the perception of radionuclide hazard, rather than the real potential for transport to the biosphere. Thus many requirements can be relaxed, or at least the precision needed can be reduced, if current risk assessment techniques are applied with sensitivity analysis to determine the controlling parameters and transport mechanisms for nuclear waste site characterization. For example, considerable attention is focused on plutonium in nuclear waste, in spite of the many studies which have shown that plutonium in its usual chemical forms does not move with ground water and poses no threat of contamination to public water supplies. A formal risk assessment can determine the radionuclide and transport parameters which need to be measured in order to characterize the potential hazard (if any) of nuclear waste disposal.

This paper will consider the general format of risk assessment to indicate the controlling parameters that might influence requirements for instrumentation to provide nuclear data. Then past studies will be examined to determine the nuclides found to be important in those studies and their impact on data and instrumentation requirements.

DISCUSSION

The risk of a nuclear waste disposal site concerns the possibility of some impact resulting from the site. This discussion considers the radiological impact on members of the public after completion of disposal operations. The risk is a function of the probability and consequence of events that might cause release of radionuclides. Consequence is expressed as radiation exposure to people. For the purpose of determining data requirements, detailed risk calculations are not required, although such calculations would be useful in later assessment of site impact. Instead, probabilities are used only to select events to be considered and the resulting exposure pathways. The consequence of an event in terms of potential exposure from release of radionuclides can be expressed as the product of several factors for each nuclide:

Dose = Nuclide Inventory (NI) x Release Fraction (RF) x Transport Fraction (TF) x Dose Factor (DF)

Several risk assessments have been performed regarding repositories for nuclear waste. Koplic, et al[1] have analyzed and compared the results of 10 of these studies. Leddicotte, et al[2] and Rogers[3] have used the techniques of risk assessment to propose concentration limits and classification of wastes for shallow land burial. The parameters of these studies were quite conservative so the results should be considered as bounding cases with the results of more realistic analysis expected to show less impact of the nuclides.

The inventory distribution used as a basis for Reference 3 (given by Adam and Rogers[4]) is not too different from the distribution applicable to Reference 1, since both are based on power reactor fuels and wastes. Fission products included ^{3}H, ^{14}C, ^{55}Fe, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{129}I, and ^{137}Cs. Actinides included isotopes of U, Np, Pu, Am, and Cm. Sites were usually generic rather than specific. The results are dependent on the actual site inventories, so the discussion here is concerned primarily with methodology. The technique can be applied to defined sites with specific inventories, although the nuclides found to be of interest could change for different inventory distributions. The site-specific results would then establish the data needed and thus the instrumentation required to provide nuclide distributions. The relative impact of the nuclides could be used to rank the accuracy needed for the measurements.

The referenced studies have identified three classes of accident sequences for release of nuclides to the biosphere: human-induced intrusive events, natural expulsive or intrusive events, and ground water transport. Some of the events considered are:

Human Intrusion:	Reclaimer - dust inhalation
	Reclaimer - direct gamma exposure
	Residents - food production
Natural Events:	Erosion
	Meteorite impact
	Earthquake
Ground Water:	Transport to river
	Well drilled

Certain events release a fraction of the total contents while the release from others depends on the

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concentration in a small volume of the site. Thus the data needs could include both total content and concentration distribution in 3 dimensions for the nuclides.

The transport mechanisms identified were direct gamma (to reclaimer), air dispersion (to reclaimer or population), plant uptake (crops), and ground-water transport (to river or well). For direct gamma exposure the primary contributors are ^{60}Co and ^{137}Cs. For air dispersion most nuclides have about the same tranpsort factor, so impact is determined by inventory and dose factors. For crops, the uptake factors vary widely. Of the nuclides considered in Reference 3, those with high uptake factors are ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc, and ^{129}I.

Waterborne transport is somewhat different, since ground water moves slowly and many nuclides decay before reaching a potential release point. A simple screening can be performed by considering the retardation factor, K_f, which in the simplest view is the ratio of nuclide transport time to ground water transit time. Relative values of K_f are:

High:	U, Pu, Am, Cs
Medium:	Np, Ra*, Sr
Low:	H, C, Tc, I

In general the nuclides with low K_f might be released soon after the ground water reaches a release point; those with medium K_f might be released, but only after a delay of thousands of years or more; and those with high K_f appear only after much longer times, if ever. Decay during transit is also important, since some nuclides decay before reaching a release point. The relative half-lives of the nuclides are:

High (over 100,000 years):	^{99}Tc, ^{129}I, ^{235}U, ^{238}U, ^{237}Np, and ^{242}Pu
Medium (100 to 100,000 years):	^{226}Ra*, ^{241}Am, ^{243}Am, ^{14}C, ^{239}Pu, and ^{240}Pu
Low (under 100 years):	^{3}H, ^{55}Fe, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{241}Pu, ^{243}Cm, and ^{244}Cm

The final factor is the conversion from nuclide intake to radiation dose. These factors are given by Hoenes and Soldat[5], who give doses to several organs in terms of the 50-year dose commitment to several age groups as millirem per picocurie ingested or inhaled in the first year. These factors are too complex to categorize easily and the variations are extreme. For example, the adult whole-body ingestion factor for ^{90}Sr is 37,000 times higher than the factor for ^{99}Tc and the same factor for ^{226}Ra is 10,000 times higher than the factor for ^{239}Pu.

The considerations above give a qualitative impression of the factors to be considered when evaluating data needs. References 1-4 then proceed to use the techniques of formal risk assessment to determine nuclides of importance on a quantitative basis. The results can be summarized as follows:

A) For shallow land burial considered in References 2-4, the nuclides of most interest for each pathway are:

   1. ^{137}Cs for direct gamma exposure to a reclaimer.
   2. ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{240}Pu, ^{241}Pu, and ^{241}Am for airborne transport.
   3. ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc and ^{129}I for plant uptake.
   4. ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc, ^{129}I, ^{226}Ra, and ^{237}Np for waterborne transport.

*Radium has been added due to its importance as a daughter product of ^{238}U.

B) For deep geologic disposal considered in Reference 1, the nuclides of interest are primarily those with longer half-lives that might be transported through the ground water pathway: ^{14}C, ^{99}Tc, ^{129}I, ^{226}Ra (from ^{238}U), and ^{237}Np.

C) Concentration distributions are needed except that depth distribution might be adequate for nuclides transported by plant uptake and total quantity might be adequate for nuclides transported only by ground water.

The methodology can be applied to specific disposal sites although gross inventory changes might change the results in terms of nuclides of interest. The results would indicate data and instrumentation needs to measure the nuclides with highest impact. Use of actual site-specific data instead of the very conservative generic parameters in the referenced studies would be likely to reduce the list of nuclides. In addition, good barrier design for shallow land burial sites should reduce the importance of some nuclides through the air transport and plant uptake pathways. For waterborne pathways, a proper selection of site location and host material would be expected to eliminate additional nuclides from the list.

Thus instrumentation is needed to assay the nuclides listed above, or a reduced list based on a site-specific assessment. One of the challenges to in-situ instrumentation is the presence of several low-energy beta emitters in the list of nuclides. Thus gross beta measurements are not enough - the need is for nuclide-specific assay techniques. The actinides pose a similar problem. In particular, several isotopes of Pu are needed for the airborne pathways. Most in-situ instrument concepts for Pu assay determine only one or a few of the isotopes, so an independent estimate of isotope fractions is needed.

CONCLUSION

Instrumentation for in-situ analysis of several nuclides is needed to provide the source data for evaluation of public risk from nuclear waste disposal. Generic risk studies have already identified the major contributors, and site-specific analyses will further determine the relative impact of each nuclide. Instrument development can be guided by such site-specific assessments, based upon release scenarios, pathway contributions, and dose factors.

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