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SAFETY ASSESSMENT OF A VAULT-BASED DISPOSAL FACILITY USING THE ISAM METHODOLOGY

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Abstract.

As part of the IAEA's Co-ordinated Research Project (CRP) on Improving Long-term of Safety Assessment Methodologies for Near Surface Waste Disposal Facilities (ISAM), three example cases were developed. The aim was to testing the ISAM safety assessment methodology using as realistic as possible data. One of the Test Cases, the Vault Test Case (VTC), related to the disposal of low level radioactive waste (LLW) to a hypothetical facility comprising a set of above surface vaults. This paper uses the various steps of the ISAM safety assessment methodology to describe the work undertaken by ISAM participants in developing the VTC and provides some general conclusions that can be drawn from the findings of their work.

1. Introduction

In 1997 the ISAM CRP was launched by the IAEA with the aim of focusing on the methodological aspects of long-term safety assessment for near surface radioactive waste disposal facilities [1]. Part of the work undertaken by participants was to test the safety assessment methodology developed during the ISAM CRP using three Test Cases based on: current practices (vault facility); older practices (RADON type facility); and a proposed future disposal option for disused sealed sources (borehole facility) [2]. Sections 2 to 6 provide a brief summary of the steps followed in the assessment of the Vault Test Case (VTC), whilst overall conclusions are presented in Section 7.

2. Specification of the assessment context

The assessment context defines the basis for the assessment by focussing on what is being assessed and why it is being assessed. It provides information concerning key aspects of the assessment, namely: the purpose; the stakeholders; the regulatory framework; the end-points; the philosophy; disposal system characteristics; and timeframes. Table I summarises these components of the assessment context as developed for the VTC.

3. Description of the waste disposal system

The VTC disposal system was hypothetical. The disposal facility was a modified version of proposed near-surface disposal facility in the United States of America, whilst the geosphere and biosphere were based upon the Vaalputs site in South Africa.

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Table I. Assessment context for the Vault Test Case

Purpose	• Assess the level of safety using currently available information • Identify the most important uncertainties • Suggest further data collection and/or alternative conceptual models • Increase confidence that the site and facility design are suitable
Stakeholders	Regulators and staff involved in producing the safety assessment
Regulatory framework	Based on broadly accepted international IAEA and ICRP principles
End-points	Individual effective dose to a member of the critical group.
Philosophy	Cautious
Disposal system characteristics	Hypothetical but realistic. Disposal facility based on above grade LLW engineered vaults. Geosphere and biosphere based upon South African site in semi-arid rural setting
Timeframes	No cut off time for calculations specified

The facility design was based on projected LLW arisings from nuclear power plants, medical and research institutions, industrial applications, and other miscellaneous waste producers over a 30-year period. The radionuclides considered were ^{3}H, ^{14}C, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, ^{234}U, ^{238}U, ^{238}Pu, ^{239}Pu, ^{241}Pu and ^{241}Am. The disposal facility was assumed to consist of a set of above grade concrete vaults. Waste was assumed to be grouted in standard 200 litre drums which in turn were grouted into concrete cubes. The cubes, each containing eight drums and concrete backfill, were then assumed to be stacked in the vaults. Upon closure the vaults was assumed to be covered with a multiple layer cover consisting a waterproof cover on the vault roof, a layer of compacted clay, a soil cover and finally a thick erosion-resistant rock/gravel layer.

The unsaturated zone extended 50 to 70 m below the surface and consisted of the weathered overburden (sands and clays) and fractured bedrock (granite). The saturated zone was fractured granite and water flow was predominantly along fractures and controlled by fault zones.

The facility was assumed to be situated in a semi-arid region with an annual rainfall of 80 mm. Agriculture was the main activity, primarily sheep farming. The sheep diet was natural vegetation supplemented by imported fodder and borehole water. Water was obtained for domestic and agricultural purposes from boreholes sunk into the fractured aquifer.

4. Development and justification of scenarios

One of the principal activities of the VTC participants was the development and application of an approach to generate scenarios using information concerning the assessment context and system description, and the ISAM FEP list [3]. The approach is outlined below.

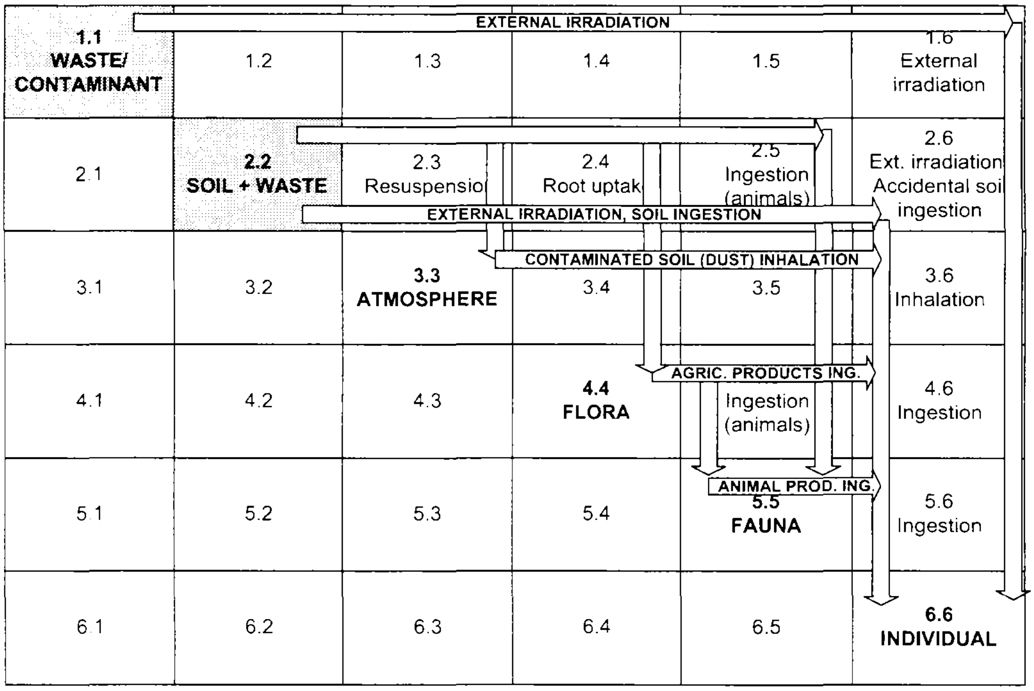
- Screen the ISAM FEP list on the basis of the assessment context and system description, recording the justification for excluding any FEPs from further consideration.
- Focus initially on one scenario termed the 'Design Scenario', which represents how the system might be expected to evolve assuming the design functions as planned.
- Decide the status of external FEPs (scenario generating FEPs) for the Design Scenario.
- Identify the safety-relevant features and associated safety functions for the Design Scenario.

- Develop a description for the Design Scenario. This includes estimates of the expected lifetime/performance of the identified safety-relevant features and their safety functions.
- Identify alternative scenarios at a high level by revisiting the screened ISAM FEP list, especially focusing on the external FEPs, and select which alternative scenarios should be assessed in detail.
- Decide the status of external FEPs for each Alternative Scenario to be assessed.
- Identify safety-relevant features and associated safety functions for each Alternative Scenario to be assessed.
- Develop a description for each Alternative Scenario. This includes estimates of the expected lifetime/performance of the identified safety-relevant features and their safety functions.

Through the use of this approach, one design scenario and four alternative scenarios (poor design/performance; earthquake; human intrusion; alternative human activities) were initially identified. Releases in the liquid, solid and gaseous phases were considered in the scenario. In light of resource constraints, it was decided to select only one alternative scenario for development. Given the potentially high consequences of human intrusion, it was decided to develop the human intrusion scenario.

5. Formulation and implementation of models

Using Interaction Matrices, conceptual models were developed for the design and human intrusion scenarios (see for example Figure 1). The matrices allowed the identification of interactions between the key components of the disposal system, and the mapping of radionuclides movement around the system and the resulting human exposures. Three participants developed and applied mathematical models for the design and human intrusion scenarios (Table II). Data for models were taken from site measurements and a range internationally recognised data compilations.



1.1 WASTE/ CONTAMINANT	1.2	1.3	1.4	1.5	1.6 External irradiation
2.1	**2.2 SOIL + WASTE**	2.3 Resuspensio	2.4 Root uptak	2.5 Ingestion (animals)	2.6 Ext. irradiation Accidental soi ingestion
3.1	3.2	**3.3 ATMOSPHERE**	3.4	3.5	3.6 Inhalation
4.1	4.2	4.3	**4.4 FLORA**	Ingestion (animals)	4.6 Ingestion
5.1	5.2	5.3	5.4	**5.5 FAUNA**	5.6 Ingestion
6.1	6.2	6.3	6.4	6.5	**6.6 INDIVIDUAL**

Figure 1. Interaction Matrix for the Human Intrusion Scenario

Table II. Computer codes used by participants to model the Design and Human Intrusion Scenarios

Scenario	Organisation (Participant)	Code
Design – liquid release	KHNP (Kim)	DUST-MS and GWSCREEN
	Quintessa (Little)	AMBER
Design – gas release	Quintessa (Little)	AMBER
Design – solid release	Quintessa (Little)	AMBER
Human Intrusion	NRI (Lietava)	RESRAD
	Quintessa (Little)	AMBER

Table III. Example results from the Vault Test Case

	Design Scenario				Human Intrusion Scenario	
	Liquid Release		Gas Release	Solid Release		
Organisation (Participant)	KHNP (Kim)	Quintessa (Little)	Quintessa (Little)	Quintessa (Little)	NRI (Lietava)	Quintessa (Little)
Peak Dose (Sv y^{-1})	2E-5	3E-5	2E-3	2E-2	4E-4	1E-3
Time of Peak (y)	7E+3	8E+3	>1E+5	>1E+5	3E+2	3E+2

6. Analysis of results and building of confidence

Table III summarises the initial results obtained by the participants for the various sets of calculations. For the *liquid release* calculations, the peak dose is about an order of magnitude below the dose constraint of 3E-4 Sv y^{-1} proposed in [4]. For the *gas and solid release* calculations, the peaks are about one and two orders of magnitude above the dose constraint, respectively. However, these doses do not occur until at least 10^5 years due to the contribution of radiologically significant daughters ingrown from ^{234}U and ^{238}U. Over such timescales, dose calculations must be seen, at best, as only illustrative. Furthermore, the assumptions underlying the calculations are highly cautious. For the *human intrusion* scenario, the total doses calculated are about an order of magnitude below the reference level below which intervention is not likely to be justifiable level [4].

Several philosophical points were identified by VSC participants relating to the gas and solid release calculations. First the associated conceptual model assumed that a house was built on exposed waste and it might be argued that this is a form of human intrusion. Second, and directly related to the first, there is the question of whether it is appropriate to apply the same dose constraint to the gas and solid release as used for the liquid release. Third, the exposure groups were considered to be different for each scenario, where as it could be argued that a single exposure group could be considered for the gas and solid releases. Time constraints did not allow this philosophical debate to be resolved by the members of the VSC Group.

In light of the above results, it was considered that the site was suitable for a LLW disposal facility but there was scope for the design to be modified with the introduction of a thicker cover and/or a below grade facility. This would significantly reduced the rate of erosion and the time at which waste might become exposed thus reducing the impact of the gas and solid releases. However, even with such a facility, long-term isolation of the waste over time-scales that would ensure acceptable doses from the ^{234}U and ^{238}U chains could not be guaranteed.

Therefore, in addition to the revision in the design, it was suggested that it might be necessary to reduce the inventory of these long-lived radionuclides by one or two orders of magnitude.

7. Overall conclusions

From a methodological point of view, it can be said that the ISAM safety assessment methodology was successfully applied to the VTC. It was shown to be a practical approach that, through encouraging the use of flow diagrams, lists and tables to summarise key information, helped ensure the VTC assessment was logical, well structured, well documented, transparent, and auditable. Considerable emphasis was on the development and demonstration of associated procedures (such as the scenario generation approach), and the documentation of the hypotheses and arguments in an auditable manner. It was recognised that the final decisions about the acceptability of a disposal facility would depend on such factors and not solely on the calculated values of dose. The VTC also allowed participants to develop an understanding of the ISAM methodology and to gain practical experience in its implementation. In addition it provided the basis for open discussion of the many practical issues which can be encountered when undertaking an assessment.

The illustrative results obtained demonstrated the need to consider release mechanisms other than liquid release. Human intrusion, gaseous and solid release can all be important. Participants applied a range of different conceptual models, mathematical models and computer codes to model the design scenario liquid release and human intrusion scenario calculations. The resulting differences were often small (an order of magnitude or less), especially for the key radionuclides.

Although the ISAM methodology should be applied in an iterative manner, only one iteration was possible in its application to the VTC due to time constraints. Thus a further iteration of the assessment process could be undertaken to investigate further some of the key issues identified in the first iteration (for example the modification of the design, the limitation of certain radionuclides' inventory, and the more detailed investigation of further alternative scenarios).

References

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