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DERIVATION OF QUANTITATIVE ACCEPTANCE CRITERIA FOR DISPOSAL OF RADIOACTIVE WASTE TO NEAR SURFACE FACILITIES: REVIEW AND IMPLEMENTATION OF AN APPROACH FOR THE OPERATIONAL PHASE

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Abstract

The International Atomic Energy Agency has developed an approach to derive quantitative waste acceptance criteria for near surface disposal of radioactive waste. This approach has been successfully used to derive activity limits with regards to post-closure safety assessment. In a second step it has been recognised as necessary to take into account operational safety considerations and to study how this approach could be used for the derivation of operational safety acceptance criteria. The paper presents the work currently being undertaken for the operational phase, following the step by step approach already developed for the post-closure phase, with particular emphasis on the assessment context, system description and the selection of scenarios.

1. INTRODUCTION

In April 1998, the International Atomic Energy Agency (IAEA) held a Technical Committee Meeting to review a project begun in April 1997 concerning the derivation of quantitative waste acceptance criteria for near surface disposal. One of the main key necessities identified was to extend the scope of the approach already existing for post-closure to operational safety considerations. Indeed, in order to develop a integrated approach that allows the derivation of relevant acceptance criteria for all surface disposal facility phases it is necessary to take into account normal and abnormal operations which could lead to exposure affecting both the public and workers. Work has been undertaken since November 1998 in order to deal with the operational safety issues. The paper outlines this work. The approach developed for post-closure safety is detailed in [1] and summarised in [2]. This paper follows the different steps mentioned in [1] and [2] and focusses in particular on the key aspects of the assessment context, system description, and the development and justification of scenarios. The scope of the paper is limited to the activity limits, and, for this illustrative exercise, the radiological consequences of pre-disposal waste management and of on-site conditioning of waste are excluded.

2. APPROACH

The applicability of the approach already developed for the post-closure assessment to the operational safety was reviewed in [3]. Although certain details such as the nature of the assessment context and scenarios would have to be modified accordingly, it was concluded that the overall approach could be used. Hence the key components of the approach for operational safety remain:

- the specification of the assessment context;
- the description of the disposal system;
- the development and justification of scenarios;
- the formulation and implementation of models; and
- the calculation and derivation of example values.
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3. ASSESSMENT CONTEXT

3.1. Calculational end points

As noticed in [1, 2], in contrast with most safety assessments, in this study the calculational end point is the waste activity and the measures of impact on humans and/or the environment are the starting point.

3.2. Radiological protection criteria

In order to calculate the default values, it is necessary to specify the radiological protection criteria of interest. In light of recommendations given by [4] and [5], annual individual effective doses to a worker and a member of the public are used as the primary measures of impact. Occupational exposure of a worker shall be controlled so that the following limits are not exceeded: an effective dose of 20 mSv y^{-1} averaged over 5 consecutive years; and an effective dose of 50 mSv in any single year. For the member of the public, a dose limit of 1 $mSv.y^{-1}$ is used, with an effective dose of up to 5 mSv in a single year being used in special circumstances, provided that the average dose over 5 consecutive years does not exceed 1 $mSv.y^{-1}$. It should be recognised that doses are an indicator of the impact that might arise from exposure to radionuclides [6, 7]. Calculated doses should not be seen as predictions of future impacts. Furthermore, constraints can be applied to these values but, for the purpose of the calculations in this study, no constraints are applied.

3.3. Timeframes

When undertaking an operational safety assessment for the disposal of radioactive waste to a near surface disposal facility, the key timescale of interest is the duration of the operational phase. This duration will vary from facility to facility, depending upon the volume and rate of waste disposals and the capacity of the site. For the purpose of illustration, an operational phase of 50 years is considered in this study.

4. DISPOSAL SYSTEM

4.1. Waste characteristics

Radioactive wastes can be classified according to their source. Two major categories have been identified: nuclear fuel cycle wastes; and non-nuclear fuel cycle wastes. Consideration of sealed sources is specifically excluded from this study, although it could be addressed in future studies.

The waste can be disposed in unconditioned (i.e. raw waste) or conditioned form. Different types of conditioning can be used depending upon the nature of the waste and the disposal facility. Conditioning can be undertaken at the disposal facility or off-site. The nature of the waste conditioning for the example assessment is described in Section 4.2.

A range of operational safety assessments of near surface disposals has been undertaken (for example [8, 9, 10]). Through consideration of the results of these assessments, it is possible to identify key radionuclides disposed, which are commonly identified as being of greatest interest over the timescales of concern (Table 1). It is recognised that, for any specific disposal facility, the list of radionuclides of interest will depend upon factors such as the source and nature of the waste streams, the disposal system characteristics and the duration of the operational phase. Nevertheless the list provided in Table 1 is considered to provide a relatively complete list of disposed radionuclides of common interest.

TABLE 1. DISPOSED RADIONUCLIDES COMMONLY CONSIDERED IN OPERATIONAL SAFETY ASSESSMENTS OF NEAR SURFACE DISPOSAL FACILITIES

^{3}H	^{90}Sr	^{134}Cs	^{227}Ac
^{10}Be	^{93}Zr	^{137}Cs	^{232}Th
^{14}C	^{94}Nb	^{144}Ce	^{234}U
^{22}Na	^{99}Tc	^{147}Pm	^{235}U
^{41}Ca	^{106}Ru	^{151}Sm	^{238}U
^{54}Mn	^{110m}Ag	^{152}Eu	^{237}Np
^{55}Fe		^{154}Eu	^{238}Pu
^{59}Ni	^{121m}Sn	^{204}Tl	^{239}Pu
^{63}Ni	^{125}Sb	^{210}Pb	^{240}Pu
^{60}Co	^{126}Sn	^{226}Ra	^{241}Pu
^{65}Zn	^{129}I	^{228}Ra	^{241}Am

4.2. Disposal system characteristics and associated operational practices

Consistent with [1, 2], two disposal facilities and associated operational practices are considered which represent the opposite ends of the spectrum.

At one end, there is the minimally engineered facility (trench) which is excavated into the ground, and is operated by loose tipping, unconditioned waste and covering it with a soil cover. Infiltrating rain water is collected by a drainage system which discharges to a local water body. Unconditioned waste is driven by lorry to the tipping face of the trench and it is then tipped into the trench from the back of the lorry. As each load of waste is tipped, the tipping face moves towards the end of the trench by this tumble tipping process. Large items, such as decommissioned plant, are lowered into the trench by mobile crane. At the end of each day, the upper surface of waste is covered by uncontaminated soil/fill material, a geotextile layer, stones and finally ashes/small aggregate in order to ensure a stable and contamination free interface between the waste and the tipping vehicles. It is assumed that the tipping face remains uncovered because of the practical difficulties in achieving a uniform thickness of cover, and the associated problem of wasted disposal volume.

At the other end of the spectrum, there is the heavily engineered facility (vault) which is excavated into the ground and lined with concrete. Any infiltrating rain water is collected by a drainage system and monitored for activity prior to release to a local water body. Conditioned waste in waste packages (metallic drums and concrete containers) are driven by truck into the vault. The waste is assumed to be grouted into the drums and concrete containers at an off site facility. For the purposes of filling, the vault is divided into four sub-vaults by internal concrete walls. The truck stops in the sub-vault adjacent to the one currently accepting waste packages. The driver is protected from direct irradiation by the thickness of the concrete wall between the adjacent sub-vaults. A crane operator is situated in a cabin directly above the sub-vault in which the truck is unloaded. Each waste package is picked up from the truck by the crane and lowered remotely into the disposal sub-vault. The crane operator is protected from direct irradiation by the concrete wall separating the sub-vaults. The waste packages are disposed layer by layer, each layer is immobilised in grout, which is pumped into the vault. Once the vault has been filled, concrete shielding is poured on top of the vault. Before the building is moved to the next vault of the line, a cover as set up above the closure slab to protect it from rainwater until it is covered with a temporary cap.

5. DEVELOPMENT AND JUSTIFICATION OF SCENARIOS

Following the technique used in [1] and [2] (as applicable for operational safety), the following steps have been performed:

- defining the main elements to be considered in the assessment (i.e.the disposal facility components, and operational conditions);
- defining the states of the components of the disposal system and operational conditions (i.e. the nature of the waste, location of wastes and operational conditions);
- constructing the state combinations; and
- checking the scenarios generated and grouping them into main categories.

5.1. States of the system components

The first component of the disposal system is composed of the wastes. They can be mixed or not mixed with a matrix (e.g. grouted), placed or not placed in containers. Their possible states are given below:

- Completely conditioned off site. They could be heterogeneous or homogeneous solid wastes incorporated in inorganic or organic matrix and conditioned in concrete containers or metal drums. Their containment is designed to minimise the release of radionuclides by water and air.
- Partly conditioned on or off site, but necessiting a complementary treatment on site before their final disposal. They could be drums to be compacted or boxes to be grouted. Because of the treatment necessary on site, they present a risk of releasing radionuclides in the case of an incident before their disposal.
- Unconditioned wastes for direct disposal. They are raw solid wastes that do not provide any containment barrier against leaching or release by air.

For the illustrative case of the study, the partly conditioned wastes for the waste states is not applicable since the waste are assumed to arrive conditioned for disposal in the vaults and unconditioned for disposal in the trenches (Section 4.2).

The second component of the disposal system, the states of which are discretised, is constituted by the location where the wastes are situated. It depends on the nature of the disposal site and the different actions carried out on the wastes and the way they are received, handled, processed, stored, and finally disposed. By the specificity of the activities carried out inside this location, the states of this component affects the potential release by leaching and by air as well as the direct radiation. Possible locations are listed below:

- The operating buildings, which could be: the compacting building, the grouting building, the setting building, the temporary store, etc... .The specific operational activities in those building generate specific risks.
- The disposal unit, which could be a vault or a trench. The way the disposal unit is operated is of great importance for the safety.
- In transit can be considered as a third state because specific risks can be associated with the transport of the wastes around the facility.

For the illustrative case of this study, the operating buildings for the location states is not applicable since no such buildings are considered in the example. Furthermore, the in transit location is also not applicable since the focus of the current study is on the assessment of impacts arising from the disposal of waste rather than its transport around the disposal facility.

In addition to issues related to the design and construction, the short-term safety of a facility also depends on aspects of the operation of the site such as procedures, controls and monitoring. Hence, the system description must provide enough information and allow the distinction of the various possible states of the operational conditions:

- in normal operation conditions, the operation of the facility complies with what is expected by adequate design, construction, procedures, controls, monitoring, that ensure adequate performance levels of equipment and personnel;
- in abnomal operation conditions, failure to meet performance objectives could result from non respect of waste specifications, equipment failure, operating error, or also from events and processes generated outside the facility (natural and human).

5.2. List of selected scenarios

Having defined the main assessment components with their different states for the current study, it is possible to combine them, to obtain four combinations with associated scenarios. These scenarios have been discussed and screened in order to provide the following limited set of scenarios that need to be taken into account:

- gas release for conditioned wastes in a vault in abnormal condition;
- dropping and crushing of a waste package to be disposed into a vault during unloading;
- direct irradiation for unconditioned waste in a trench in normal conditions;
- liquid release in leachate from unconditioned waste in a trench in normal conditions;
- solid release in dust from unconditioned waste in a trench in normal conditions before the covering of the waste;
- gas release for unconditioned wastes in a trench in normal conditions;
- fire in the unconditioned waste tipped into a trench before covering;
- direct irradiation and ingestion for unconditioned waste in a trench in abnormal conditions.

6. CONCLUSION

The illustrative study undertaken has shown that the same approach as used for the post-closure phase is relevent and applicable for deriving example waste acceptance criteria for the operational phase. The application of the approach has already allowed the specification of the assessment context; the description of the disposal system; and the development and justification of scenarios.Model formulation and implementation, and calculations are being undertaken now and will allow the derivation of example operational safety values by the begining of the year 2000. The approach and associated example values for the operational phase will then be integrated with those for the post-closure phase. It is planned that a third phase will then begin incorporating into the analysis other safety-relevant qualitative and quantitative acceptance criteria.

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