Analysis of effect of groundwater discharge pattern assumptions and multiple canister failures to potential doses from a spent fuel repository

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INTRODUCTION

In Finland, Posiva Oy (Posiva) is responsible for implementing the final disposal programme for spent nuclear fuel, and is currently compiling a Safety Case to provide the safety basis for the construction license application for a geological nuclear waste repository at the Olkiluoto site. A safety assessment of a preliminary design of a KBS-3H repository for spent nuclear fuel located at the Olkiluoto site has recently been performed (Smith et al. 2007).

The Finnish regulation (STUK 2001) states that the annual effective dose to the most exposed members of the public shall remain below 0.1 mSv, the average annual effective doses to other members of the public shall remain insignificantly low, and that the disposal of spent fuel shall not affect detrimentally to species of fauna and flora.

The biosphere assessment (BSA) in the Posiva Safety Case aims at describing the past, present and future conditions of the surface systems of the Olkiluoto site, track the fate of hypothetical releases of radionuclides from the repository reaching the biosphere, and assess possible radiological consequences on humans and other biota. The temporal extension of the assessment is chosen to 10 000 years. The main end-point for demonstrating compliance to the regulatory dose criteria is the annual effective dose to most exposed individuals, derived from landscape modelling (a network of biosphere objects, based on time-dependent terrain and ecosystem forecasts and ecosystem specific radionuclide transport models). The BSA also utilises safety indicators, resulting in indicative annual doses from two stylised well scenarios.

Because of separate modelling domains of geosphere and biosphere, the source term to the biosphere – usually expressed merely as Bq/y out from “upper bedrock” – contains not only the uncertainty burden from the earlier part of the modelling chain but also its own spatial and temporal, and conceptual, uncertainty. This is often called the issue of geosphere-biosphere interface. This contribution presents case studies shedding light to the importance of the issue.

METHODOLOGY

The landscape model constructed for the KBS-3H safety assessment (Broed 2007b) was utilised also in this work. The model is briefly presented also in another contribution to this conference by Broed et al. Various cases of the release pattern definition to the biosphere were defined: release distributed to a large number of objects (TILA-99m with three variants, Structures, Lineaments, Equal share to each biosphere object), release received by one object alone (7 forests, 1 lake with 3 variants), and a variant of the TILA-99m case with varying time of the release. The details on the distributed and single object cases are presented in (Broed 2007b).

In this study, the maximum of the annual landscape dose (Sv/y) to the most exposed individual within simulation time from the present to 10 000 years later was used as the endpoint. This dose quantity is based on the assumption that the individual spend all his or her time within the single biosphere object producing the highest dose, including external exposure as well as internal exposure from eating and drinking food produced in and water available from that same biosphere object.

RESULTS AND CONCLUSIONS

Spatial distribution of the release

The annual landscape doses for cases addressing spatial distribution of the release are presented in Fig. 1 for the most important radionuclides.

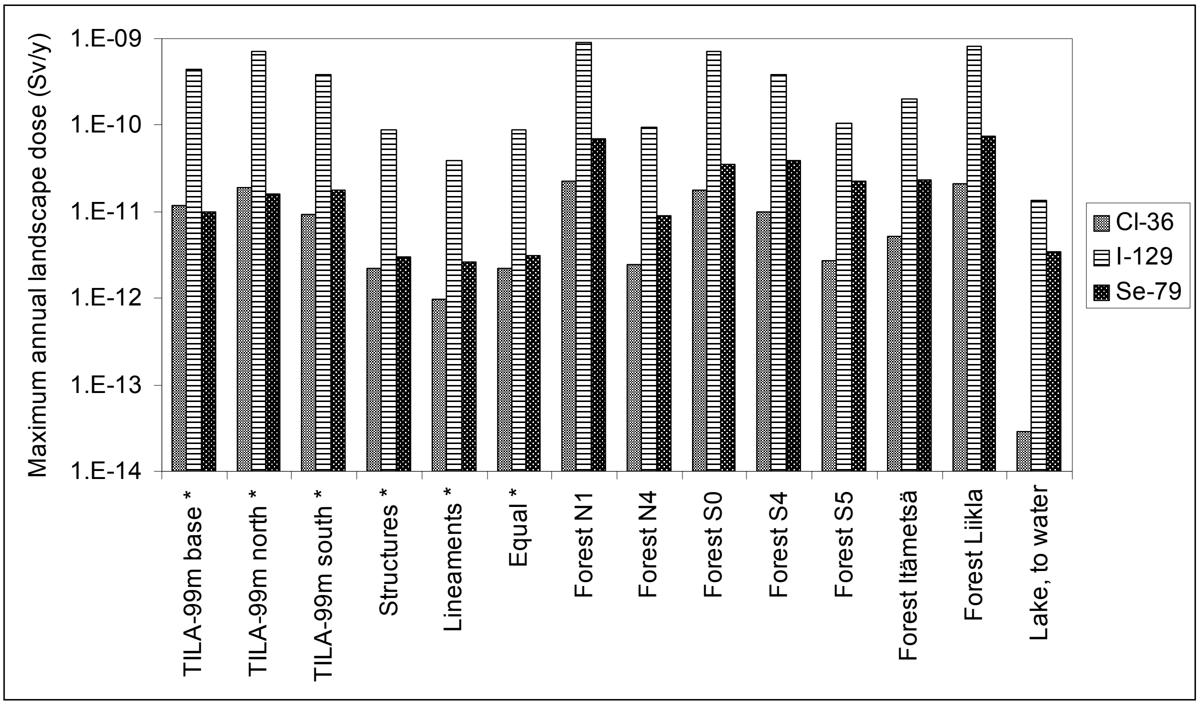

Figure 1. Maximum annual landscape to the most exposed individual dose per unit release rate (1 Bq/y) within 0-10 000 years to the future in the calculation cases addressing the spatial distribution of the release. Cases assuming a distributed release pattern are marked with *.

In the cases assuming the release distributed to several objects (on the basis of bedrock lineaments, badly-sealed drill holes etc.), the variation for a nuclide is approximately one to two orders of magnitude between the lowest and the highest value across the cases (Fig. 1). Comparison of the cases confirms the hypothesis on spatial dilution: highest doses per the unit release follow the order TILA-99m north (where only the northern branch of the default release pattern is considered), TILA-99m base case (where the release point moves with time from a shoreline forest object to another on both the northern and the southern side of the site, based on the earlier safety assessment modelling results (Vieno & Nordman 1999)), TILA-99m south (the southern branch alone), Structures and Equal (release from current drill holes and shafts, and release equally distributed to all objects potentially receiving releases), and Lineaments (observed fracturing points along the interpreted bedrock lineaments).

The lowest doses are resulting from the lake cases. There are no significant differences in respect to the dose to the most exposed human between the cases of release directed to the water column or through the bottom sediment. The result is a logical consequence of the short turnover time caused by the large surface water flow at the site; two rather large rivers flush the shores of the present Olkiluoto Island.

If the release is directed to a single forest object, the doses are always close to the highest cases of distributed releases, since the same forest objects dominate also their highest dose. Highest doses in these cases are from the forest object N1 and Liikla, the former being a case with the forest object being most upstream and latter with a forest object directly connected to a wetland sink. The other cases of forests have less forest objects being contaminated. It is also interesting that the object having most downstream objects (Itämetsä) gives only medium-level doses. The explanation is that the downstream system is formed from only wetland and aquatic objects with high turnover.

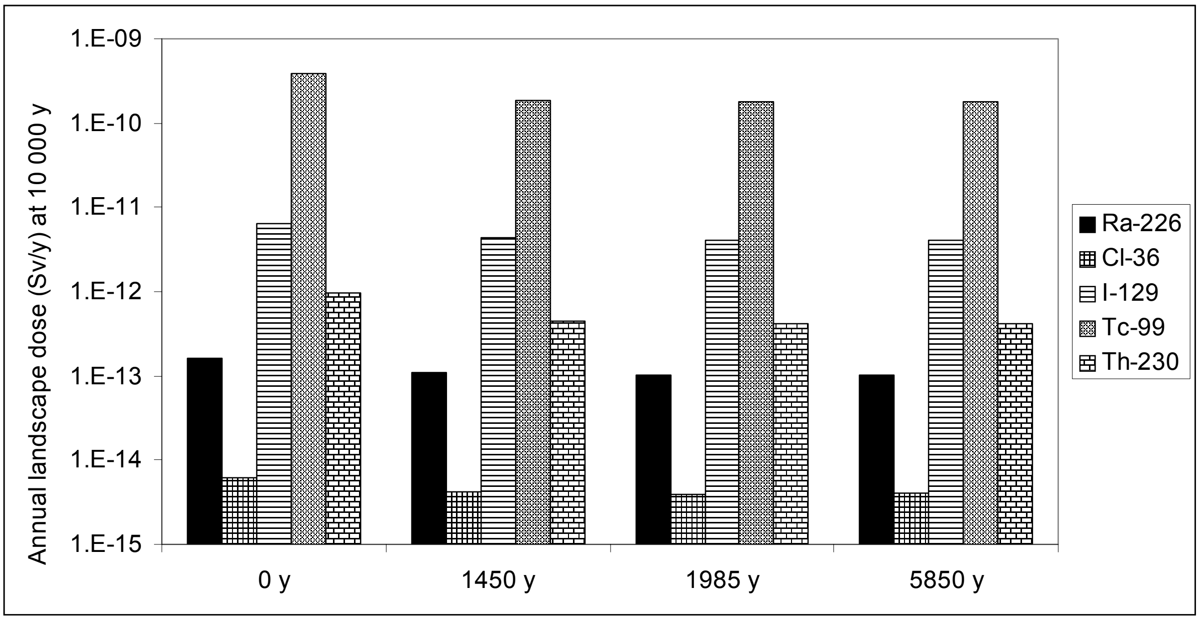

Figure 2. Annual landscape to the most exposed individual dose per unit release rate (1 Bq/y) at 10 000 years from landscapes assuming the present situation (0 y), southern side of the site forming limnic ecosystems (1450 y), also northern side having lakes instead of sea (1985 y) and far future with coastline far from the site (5850 y). Data from (Broed 2007a).

Timing of the release

Considering the timing of the release, the cases reported by Broed (2007a) can be analysed in the terms of the landscape-specific dose conversion factors for different landscape set-ups resulting from the post-glacial land uplift at the site (Fig. 2). The dose conversion factor is defined as the annual landscape dose at 10 000 years from the start of the simulation. There are no significant differences between the time frames since the present forest objects dominate the dose.

Release through bottom sediment or directly to the water column of an aquatic object

Assuming the release into aquatic objects directly to the water column overestimates the dose to humans, but for the case of release occurring through the bottom sediment might be more conservative in respect of the exposure of some biota or e.g. when use of the bottom sediment as agricultural land is considered. However, the concentrations in water vary only within one order of magnitude in these cases (Broed 2007b).

Failure of several canisters
For the time period when doses are calculated according the STUK regulations (i.e. first several thousands of years (STUK 2001)) there is little reason to believe in any canister failure at all. Theoretically, the failure probability would scale with the number of canisters, but with a reasonable inventory, the consequence of early failures is still overestimated by the consequence of a postulated single failure. From a computational point of view this means that predicted maximum doses would be insensitive to a wide range of inventory. The issue, taking into account also the temporal aspect, will be discussed further in the final contribution to the conference.

Conclusions
On the basis of these results, it seems that for the highest dose, a forest object with maximal amount of downstream terrestrial object should be selected. However, these kind of scenarios appear to be overly pessimistic: in reality the discharges of deep groundwater would be directed towards the lowest location within about a 1 km range – probably a single shoreline forest. Furthermore there is relatively little difference between the different hypothetical cases; if the release may be received by a terrestrial object, that will dominate the dose according to the current models.

ACKNOWLEDGEMENT

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