Radiological risk assessment and biosphere modelling for radioactive waste disposal in Switzerland

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INTRODUCTION

The Swiss regulatory guideline for radioactive waste disposal[1] states that "the release of radionuclides from a sealed repository subsequent upon processes and events reasonably expected to happen, shall at no time give rise to individual doses which exceed 0.1 mSv per year." This means that in Switzerland, safety assessments for repositories for radioactive waste have to provide calculated dose rates, which can then be compared to the regulatory guideline.

The key role of the barrier system (i.e. the engineered barrier system and the host rock) of a repository is to limit radionuclide release to the biosphere. The performance of the barrier system is, to some extent, adjustable by the design of the repository and by the choice of a suitable host rock in a suitable geological setting. In contrast to the barrier system, the biosphere properties are not adjustable. In addition, the evolution of the barrier system for a well-designed repository and a well-chosen site and host rock can be bounded with more confidence than that of the biosphere, which depends, e.g., on the surface environment and on human behaviour (Fig. 1). The main role of biosphere modelling in a typical safety assessment is to provide a "measuring stick" to convert calculated radionuclide releases from the barrier system into a dose rate, which serves as an indicator for the evaluation of the capability of the repository to provide the required level of safety (see also NEA, 1999).

CONCEPTS AND METHODS

In view of the limited knowledge of the evolution of the biosphere, a wide range of "stylised" biosphere models are used, with properties that are assumed to be constant in time, bounding the "endpoints" of possible evolutions of the surface and near-surface environments where releases from the repository might occur. The stylised models are set up based on information of the geological, geomorphological and climatological history of the surface and near-surface environment. Evaluating this wide range of biosphere models with radionuclide releases calculated from a reference-case data set for the barrier system illustrates the range of uncertainties associated with biosphere evolution.

In our reference scenario (Nagra, 2002b), we assume that radionuclides released from a deep geological repository are transported through the geosphere to the biosphere by deep groundwater. Part of this deep groundwater is then transported into the local biosphere aquifer, which contains the shallow groundwater used for drinking water supply and agriculture. Radionuclides in the biosphere aquifer are then distributed within the whole near-surface environment, which is modelled as a network of different compartments reflecting different subsystems (Fig. 2):

- The biosphere aquifer (shallow groundwater)
- Surface water (rivers, streams)
- The sediment layer beneath the surface-water body
- The 'top' soil (the uppermost soil layers which comprise the roots of crops)
- The 'deep' soil (the soil layers below the root zone)

[1] Currently under revision

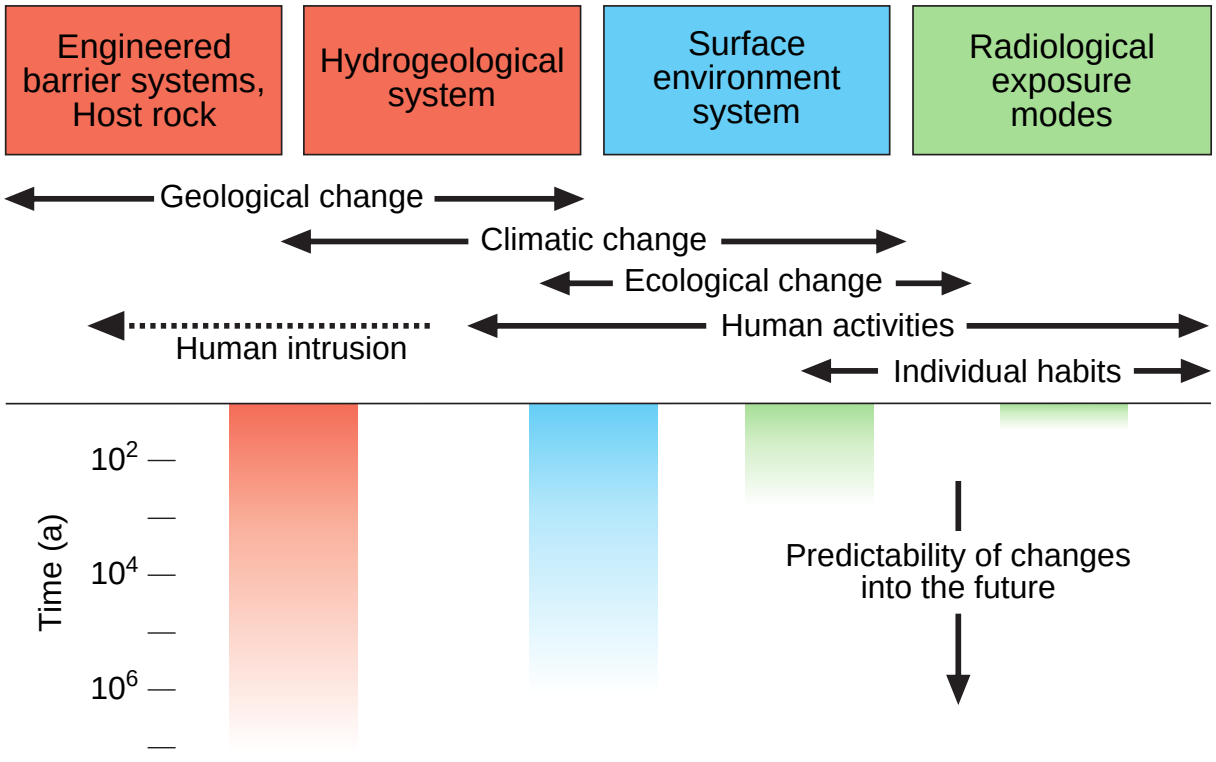

Figure 1. Schematic illustration of the limits of predictability of the different elements of a geologic disposal system (after NEA, 1999).

Radionuclide transport is assumed to occur by the exchange of water and solid matter between the different compartments. Care is taken to choose these fluxes of water and solid matter such that the mass of water and solid matter within the biosphere compartments is conserved at all times. Radionuclide input from the geosphere to the biosphere system is assumed to occur via the local aquifer. Radionuclide input via a river (surface water) instead of the local aquifer would result in lower dose rates because the higher water flow rate in rivers results in a larger radionuclide dilution.

Doses to humans are estimated by considering ingestion of radionuclides in drinking water and food, external irradiation from radionuclides in soil, and inhalation of radionuclides on airborne dust particles (Fig. 2). To model these exposure paths, we assume present-day human behaviour and habits, with the following exceptions:

- All food and drinking water is produced in the area where radionuclides are released.
- Humans spend their entire life in the area where radionuclides are released.
- The assumptions on human habits are adjusted to be consistent with the climatological and geomorphological environment assumed in a given biosphere model.

RECENT ACHIEVEMENTS AND FUTURE WORK

This general approach to biosphere modelling was used as part of a comprehensive post-closure radiological safety assessment of a potential repository for spent fuel, vitrified high level waste and long-lived intermediate level waste, sited in Opalinus Clay (Nagra, 2002a,b). Subsequent national and international reviews confirmed the maturity of the project. Based on these positive review comments, the Swiss Government formally approved the project in June 2006.

Currently, the Swiss Federal Office of Energy is preparing a formal site-selection procedure both for low and intermediate-level waste as well as for spent fuel, vitrified high-level waste

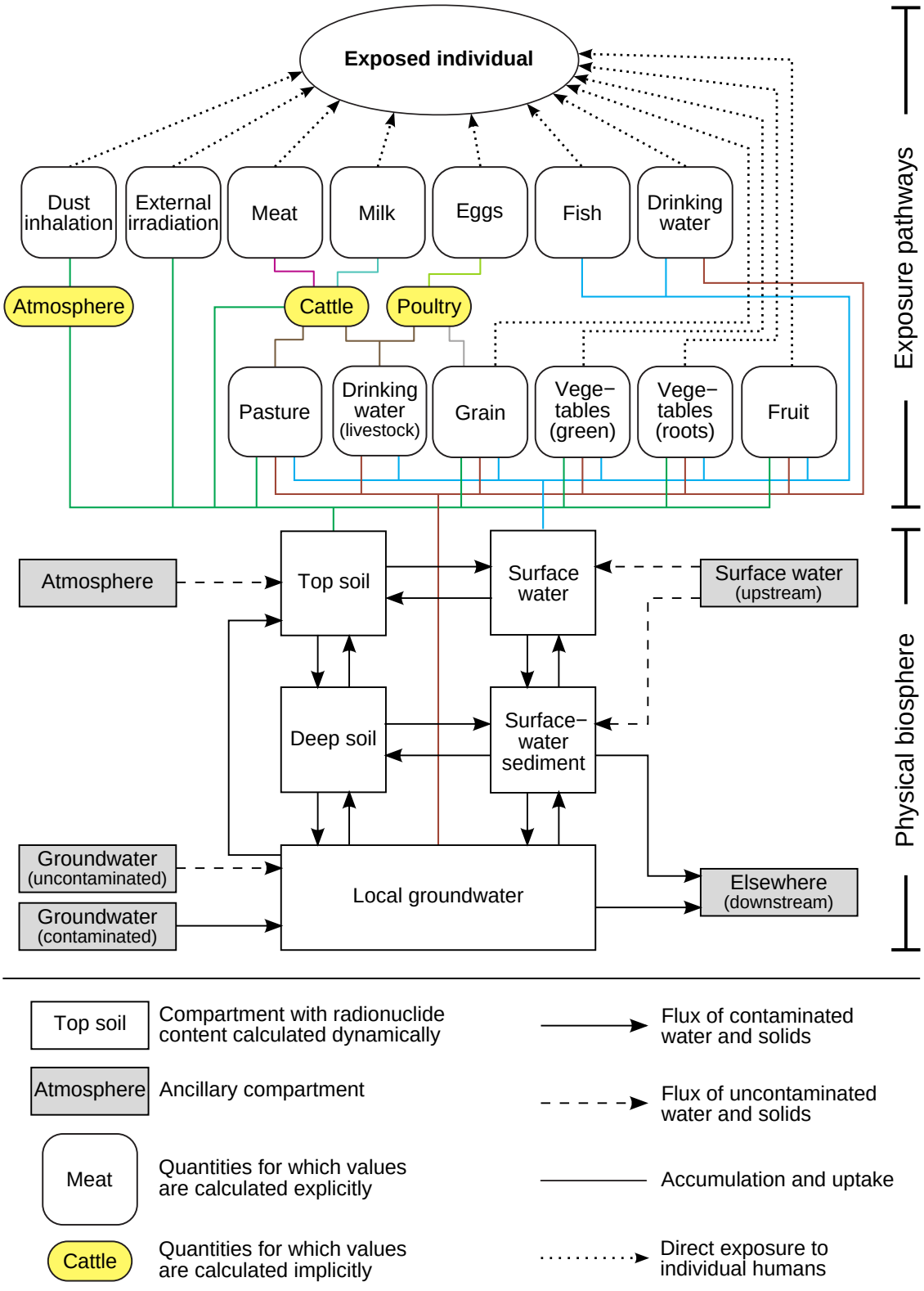

Figure 2. Structure of the biosphere model (after Kłos et al., 1996; Nagra, 2002a). The physical biosphere (near-surface environment) is reflected by the compartments 'local biosphere aquifer', 'surface water', 'surface-water sediment', 'top soil', 'deep soil'. The ancillary compartments reflect the boundary conditions that force the input and output of radionuclides to/from the considered model region. The radiation dose to humans is estimated by modelling the exposure due to external irradiation, inhalation, and ingestion of contaminated food and drinking water (exposure pathway model).

and long-lived intermediate-level waste. As a consequence, various regions for the siting of repositories for different types of radioactive waste will be considered in future assessments. For this task we intend to incorporate new process-based sub models in our biosphere assessments that will allow us to provide more realistic estimates of the radiological impact of radionuclides released from a geological repository.

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