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A preliminary comparison study of two options for disposal of high-level waste

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ABSTRACT

To compare two options for disposal of spent nuclear fuels (SFs) a generic GoldSim model for deep boreholes for disposal (DBD) of SFs was developed. As a desktop study, nuclide release and transport from a DBD after the closure of a repository were roughly evaluated and compared to a KBS-3 type disposal in a less deep geological repository (DGD). An assessment result from the DBD is shown to be remarkable and seems to give a sufficient radiological safety margin, compared to the DGD, even though this study was done in a very straightforward manner. A remarkable sensitivity of the travel lengths involved in the fractured geological media around the DBD to the exposure dose rates are not observed with rather fast and short travel times for non-sorbing nuclides with long-half lives.

1. Introduction

Disposal in a very deep borehole (Deep Borehole Disposal; DBD) of high-level radioactive waste (HLW) such as spent nuclear fuels (SFs), which has been considered as an alternative option for HLW for decades, has recently been reinvestigated worldwide, e.g., at Sandia National Labs. (Arnold et al, 2013; Lee et al, 2012; Swift et al, 2011; Brady et al, 2009). This is probably because, unlike the past, deep drilling technology down to a depth of ~5 km in the rock has been implemented in the petroleum/geothermal drilling.

Potential advantages, among possible others, of a DBD over other less deep geological disposal (DGD) concepts might be its simple structure, with which, e.g., buffer barriers are minimized or even completely eliminated and much higher degree of isolation of the wastes from the biosphere can be achieved. At such degree of depths stable hydrogeological condition could be anticipated and for nuclides released from the repository, travel distances to the biosphere become much farther, reducing or even avoiding the impacts to the biosphere since the disposal of wastes at a great depth where an extremely lower degree of permeability in the potentially steady rock condition will be beneficial for preventing nuclide movement to the biosphere. Furthermore, groundwater in the deep basement rock could have salinity resulting in a lesser chance to mix with the subsurface groundwater.

The concept currently being considered for DBD is quite straightforward and looks even simple, which seems to be required only for deep and straight borehole drilling technology. Waste canisters are simply emplaced and isolated in the lower 2 km part of the narrow borehole, down to 5 km deep without complex near-field barrier components.

In recent years in Korea, DBD has also become conceived as an alternative option for the permanent disposal of SF. Especially when considering the potential long-term safety of disposal in relatively small foot print of practical candidate site within the small peninsula of Korea and more importantly, acceptability to the local public, investigating its abovementioned advantages over the conventional DGD concept has become worthwhile (Kang, 2010).

The purpose of the current study is to carry out a rough and straightforward assessment of the DBD of SFs, which are the only type of HLWs in Korea and also conduct a comparison with direct disposal in a DGD, which has been seriously considered for many years as a principal option for disposal of SF in view of the radiological exposure dose rates to human beings living in the biosphere.

To this end, a conceptual and typical DBD in a crystalline rock is modeled as a GoldSim (GoldSim, 2006) template, which means a program developed with the aid of commercial GoldSim

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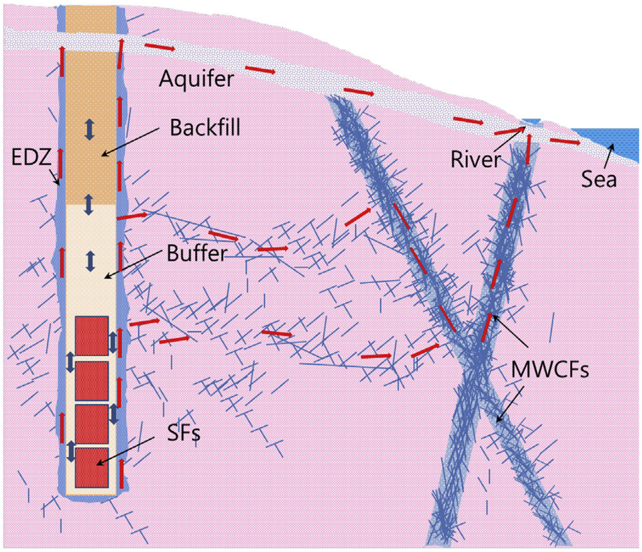

Fig. 1. Concept of the DBD System (single direction arrows and bidirection arrows represent advection and diffusion nuclide transport pathways, respectively).

developing tool, and assessed using assumed and arbitrarily chosen data in view of radiological safety and compared to the case of DGD which is at a depth of around 500 m in the same crystalline rock, keeping all other features of the disposal system except the repository unchanged.

Through this study, not only under a normal scenario but also under a disruptive scenario due to an earthquake, a DBD is assessed and compared with the DGD option in terms of long-tern radiological safety of a new repository concept.

A simple sensitivity evaluation for varying transport distances in geological media was also made as distances can represent the degree of isolation for DBD.

2. Modeling and GoldSim implementation

2.1. DBD

As illustrated in Fig. 1, a total of 400 SF canisters are to be placed at the repository, a deep bottom section of the borehole between 3 km and 5 km in depth, over which an additional 1 km-thick compacted bentonite is buffered, and the remaining most upper part of the borehole is backfilled with a mixture of crushed rock and bentonite. Then, the whole 5 km-deep borehole has three distinguished zones: a disposal zone, which is a repository, for a 2 km depth at the bottom, a buffer zone at the next upper 1 km depth, and a backfill zone at the remaining top 2 km depth.

A deep stable crystalline rock around the repository of the DBD usually shows extremely low permeability and then is expected to have isolated groundwater with high salinity, which has a greatly lower chance to be mixed with upper shallow fresh groundwater. But through the study, on the contrary, a very simple, conservative, and primitive approach to this possibility of this isolation is eliminated. All other thermo-mechanical consideration are also excluded.

Since an upward groundwater flow inside the borehole is not expected to be that great due to a low permeability of the bentonite barrier, diffusion through a thin bentonite hollow between the waste canister and the inner surface of the borehole, as well as the upper buffer plug in the buffer zone is assumed to be the dominant transport mechanism. However groundwater flow and advection transport might be possible to occur through the excavated

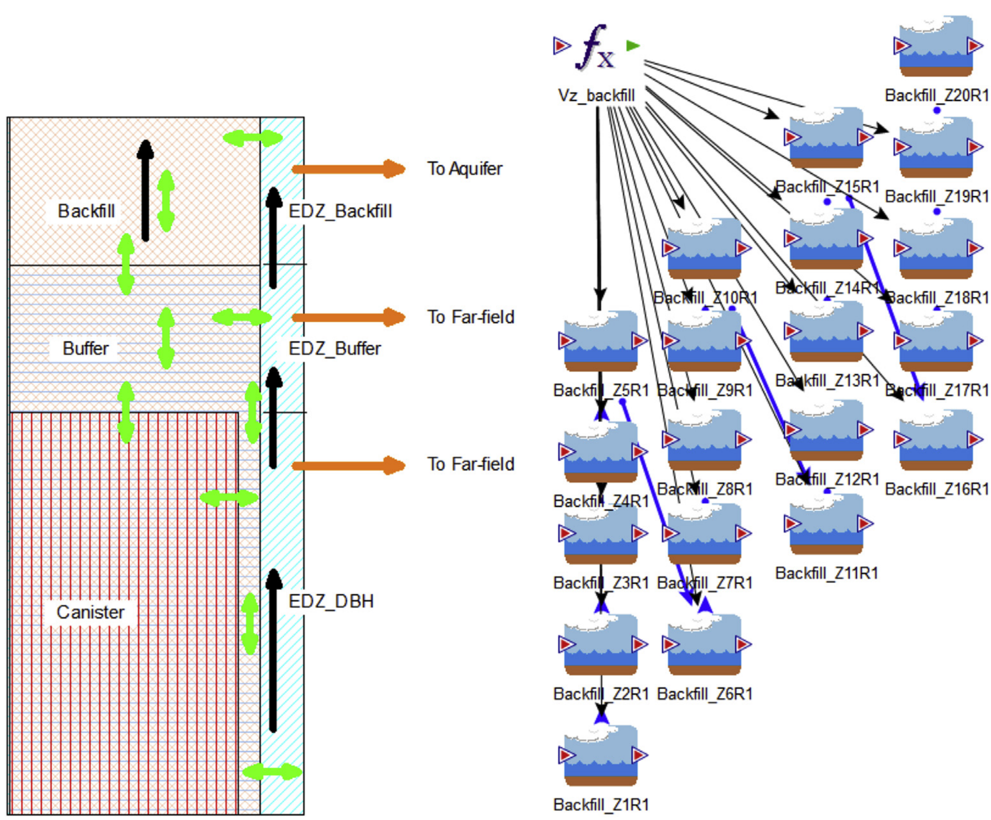

Fig. 2. Near-field transport concept and GoldSim module for transport through backfill.