Key Factors to Determine the Borehole Spacing in a Deep Borehole Disposal for HLW

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1. Introduction

If high-level radioactive wastes(HLW) can be disposed of in deeper and more stable rock formation than deep geological disposal depth, it has several advantages. For example, significant fluid flow through basement rock is prevented, in part, by low permeability, poorly connected transport pathways, and overburden self-sealing. Deep fluids also resist vertical movement because they are density stratified and reducing conditions will sharply limit solubility of most dose-critical radionuclides at the depth. Finally, high ionic strengths of deep fluids will prevent colloidal transport. Therefore, as an alternative disposal concept, i.e., deep borehole disposal technology is under consideration in number of countries in terms of its outstanding safety and cost effectiveness.

In this paper, the general concept for deep borehole disposal of spent fuels or high level radioactive wastes which has been developed by some countries according to the rapid advance in the development of drilling technology, as an alternative method to the deep geological disposal method, was reviewed. After then an analysis on key factors for the distance between boreholes for the disposal of HLW was carried out.

2. Concept of Deep Borehole Disposal

2.1 General Concept

Deep borehole disposal of spent fuel from nuclear power plants or solidified high-level radioactive waste from the reprocessing of nuclear fuel is a concept that dates from the 1950s in USA as one of several disposal concepts. This concept was considered again in the 1990s and early 2000s in USA and some countries in Europe such as Sweden, Denmark and the UK[1].

Recently it has been mentioned as an alternative to disposing of SNF and HLW in a deep geological disposal concept. In 2012, the Blue Ribbon Commission (BRC) on America's Nuclear Future recommended further research and development to help resolve some of the uncertainties associated with deep borehole disposal. The BRC particularly emphasized that deep borehole disposal might be considered for certain forms of waste that have essentially no potential for reuse.

A recent deep borehole disposal concept consists of drilling a borehole (or array of boreholes) into crystalline basement rock to a depth of about 5,000 m, emplacing waste canisters containing spent nuclear fuels or vitrified high-level waste in the lower 2,000 m of the borehole, and sealing the upper 3,000 m of the borehole[2].

The waste packages would be emplaced individually or as a string of 10-20 packages. A single borehole could contain up to 400 waste packages, each approximately 5 m in length. The sealing material for the borehole can be compacted bentonite, asphalt and concrete (Figure 1.)

2.2 Potential advantages

Because the proposed disposal zone in a deep borehole disposal concept is significantly deeper than that of a deep geological disposal, waste isolation from the biosphere and ground water systems could be enhanced by several factors(Figure 2).

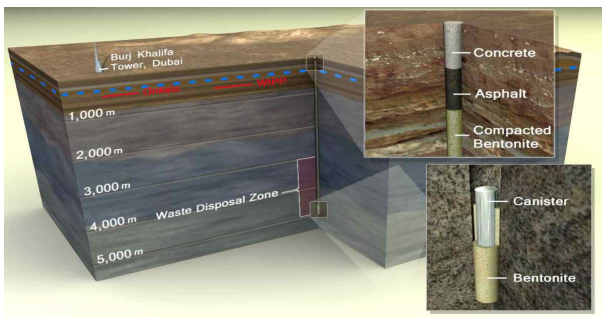

Figure 1. General concept of deep borehole disposal [2]

- The greater depth of emplacement
- The low permeability of the host rock at depth, as well as longer distances to the surface, which would result in very long travel times
- Deep fluids also resist vertical movement because they are density stratified.
- The reducing conditions (i.e., low concentrations of oxygen), which would result in greater geochemical isolation of the waste due to the lower solubility and mobility of some radionuclides, such as the actinides.

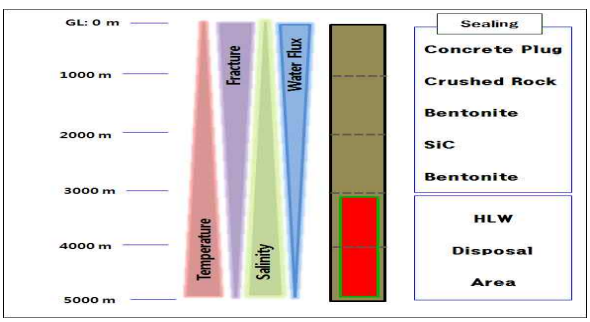

Figure 2. Deep borehole disposal environment.

And also, multiple disposal sites could be located near nuclear power plants with suitable geologies, thus reducing the need to transport spent fuels.

3. Analyses on Key Factors for Borehole Spacing

In deep borehole concept, the distance between boreholes is very important in determining the disposal efficiency. So, the distance between boreholes for HLW should be optimized. The key factors to set the disposal hole spacing are thermal effect between boreholes and verticality of borehole.

3.1 Thermal effect

In deep borehole disposal system, boreholes should have spacing not to thermally affect another borehole. So minimum spacing of the boreholes at the depth of 5 km, disposal zone, should be more than 50 m. And, in the waste emplacement procedure of deep borehole disposal system, bridge plugs will be constructed to support the weight of canister strings. One of the issues related to the bridge plug is the maximum temperature for commercially available bridge plugs and the temperature increases from the radioactive waste. Several standard designs for bridge plugs in the disposal zone are rated up to 400 ºF (204 ºC)[3]. Figure 4 shows the temperature at the depth of 5 km in the case of 50 meter distance between boreholes.

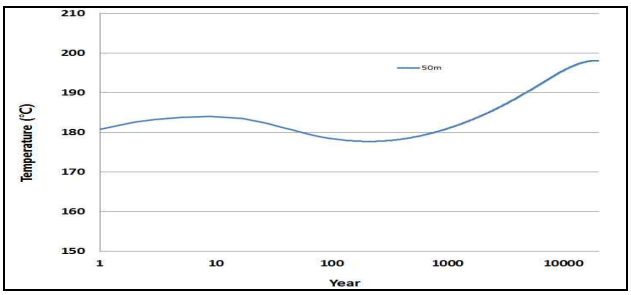

Figure 4. Temperature of 5 km depth of borehole (Distance between boreholes :50 m).

As shown in the figure 3, the spacing of waste disposal holes at sites with multiple boreholes can meet thermal management requirements for disposal.

3.2 Verticality of borehole

Drilling of multiple boreholes in an array must preclude the possibility of intercepting another borehole in which waste has already been emplaced. Deviation of the borehole from its designed trajectory must be controlled such that the distance between any two boreholes is greater than 50 m at a bottom depth of 5 km.

The requirement that the minimum distance between storage intervals of separate holes should be 50 m implies that directional drilling will be necessary to control or correct deviation[3]. There are several ways to accomplish this with standard technology. Verticality can now be controlled accurately with liquid mud systems using vertical drilling systems.

Table 1 shows departures for different average deviation for 5 km borehole [4].

TABLE 1 Departures for different average inclinations for 5 km borehole

Average deviation (deg)	Departure (m)	Average deviation (deg)	Departure (m)
0.5	45	2.5	220
1.0	90	3.0	165
1.5	135	3.5	310
2.0	180	4.0	350

4. CONCLUSIONS

A deep geological disposal system is considered as the safest method to isolate the spent fuels (SF) or high-level radioactive waste from the human environment with the best available technology at present time[5]. However, as an alternative disposal concept to deep geological disposal concept, a deep borehole disposal technology is under consideration in number of countries in terms of its outstanding safety and cost effectiveness.

In this paper, the general concept for deep borehole disposal of spent fuels or HLW wastes, as an alternative method to the deep geological disposal method, were reviewed. After then an analysis on key factors for the determining the distance between boreholes for the disposal of HLW was carried out. These results can be used for the development of the HLW deep borehole disposal system.

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