Chapter 14

Deep Geological Disposal of Spent Nuclear Fuel and High-Level Waste: Current State and Future Challenges

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ABSTRACT

Management of Spent Nuclear Fuel (SF) and High-Level Waste (HLW) is one of the most important and challenging problems of the modern world. Otherwise a clean, cheap, constant, and secure way to produce electricity, nuclear power plants create large amounts of highly hazardous waste. Repositories—deep Geological Disposal Facilities (GDF)—for these types of waste must prevent radionuclides from reaching the biosphere, for up to 1,000,000 years, migrating from a deep (more than 300m), stable geological environment. At present, there are no operating GDFs for SF and/or HLW, mostly due to the difficult and complex task of preparing safety cases and licensing. The purpose of this chapter is to validate the generic R&D activities in this area and present alternative concepts of Radioactive Waste (RW) management: retrievability, reversibility, regional GDFs, long-term storage, and deep borehole disposal, demonstrating the main engineering tasks in solving the problem of RW management and disposal.

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INTRODUCTION

The basic reason why spent nuclear fuel (SF) and high level waste (HLW) have to be disposed in a deep geological facility is their toxicity and significant radiation that will last for a long period of time, well in excess of time for which the surveillance and maintenance of the surface facility can be guaranteed. Radioactivity of HLW will in time reach that of the original uranium ore, however, that interval and interpretation of the duration of the “environmentally predictable future” is approximately 10 000 years (Neall et al, 2008). According to certain research the time for HLW to reach relative hazard index (times hazard of uranium ore) of ‘1’ is 100 000 years (Cohen et al., 1989) and the SF life span of a disposal facility is considered to be as long as 1 000 000 years (NW, 2005), during which the hazard index of spent fuel is dominated by Radium-226, a daughter of Uranium-238 (Nilsson & Papp, 1995). Practically there is no guarantee that any form of surveillance and maintenance can and will be provided at a site (facility) after such a long period of time, and providing them is more philosophically than a technical question, considering that 100 000, or even 10 000 years can be easier to comprehend through geological than historical relations.

There are many issues related to such solution. One is: whether the location should be marked and how? What kind of mark will last for such a long time? Should it be written and in what language, or should it be some kind of visual representation of a danger, warning for the future generations. Another approach to this problem is not to mark the location at all. After surveillance and maintenance mechanisms fail it might be best to leave it unmarked because vague mark might just make the location interesting in some future sense for its archaeology or mining prospecting. The second question is: should we wait? The basic presumption is that with the advance in science and technology it will be possible to reuse HLW and/or SF, diminish its radioactivity, contain it in a better and safer way, or basically manage and dispose it better than it is possible with the contemporary methods. The third question considering deep geological disposal facility is: retrievability. Should it be possible to retrieve HLW and/or SF in case of technological and scientific advance? Most countries have lately changed their policies in order to assure the possibility of retrieval of HLW and SF in case of deep geological disposal. The disposal technologies change through time in order to assure that retrievability is feasible, even if it means the increase in the prices of disposal.

The basic idea of deep geological disposal is “to concentrate and contain” and isolate it from the biosphere until its activity drops to a level of a background, practically to that of uranium ore. In order to provide long term and secure isolation of radionuclides, contained in the HLW and SF, from the biosphere, the disposal facility has to be located underground, deep in a stable geological formation. The proposed depths vary from 250 to more than 1 000 m, depending on national programs, geological formations considered, hydrogeological conditions etc.

The containment of radioactive waste is provided by:

- Containment by the waste form itself;
- Waste packaging;
- Backfill materials;
- Host rock geology.

In order to ensure operational phase safety, engineered features and operational controls are provided and the post-closure safety is ensured by the engineered and geological barriers. Basically this means that due to the passive safety of deep geological disposal facility it is not necessary to provide any other type of protective actions, and the idea of institutionalized monitoring is feasible at the start of the project. However, due to disposal