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Mini Review

Construction of a Sustainable Nuclear Waste Disposal Facility

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Abstract

The basic concept for disposing high-level radioactive waste or spent fuel is to dispose of these types of waste in an underground waste disposal facility. In order to clarify the technical methods used to assure the parameters required for design studies of disposal system should be carried out. At the beginning, the basic conditions required for disposal facility are established and disposal concept is developed through technical analysis. Concerning the host rock formation, the mechanical stability of the waste galleries in deep underground and the influence of heat generated from waste on the host rock are analyzed. According to results of the analysis, a design study of the cross section underground facility layout is performed. In addition, an assessment of performing construction is carried out. Technological issues concerning the handling of waste forms and the backfilling of waste galleries should be taken into consideration. In this paper, several technical parameters are identified and assessed as important design parameters for a sustainable nuclear waste disposal facility.

Keywords: Nuclear waste; Disposal; Design; Engineered barriers; Natural barriers; Host rock

Introduction

Nuclear energy is the energy released by a nuclear reaction in nuclear reactors by fission. Nuclear energy uses fuel made from mined and processed uranium to make steam and generate electricity. Nuclear waste is the material that nuclear fuel becomes after it is used in a reactor. For this reason, it is called as spent fuel. Its' appearance is exactly same with the fuel that was loaded into the reactor. But because of the nuclear reactions, the contents of the fuel are different. Initially, the fuel was mostly Uranium (or Thorium), oxygen and steel. Afterwards, many Uranium atoms have split into various radioisotopes. These radioisotopes are dangerously radioactive and toxic. Radioactivity; refers to the spontaneous disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation. The most of them remains radioactive for thousands of years (Figure 1).

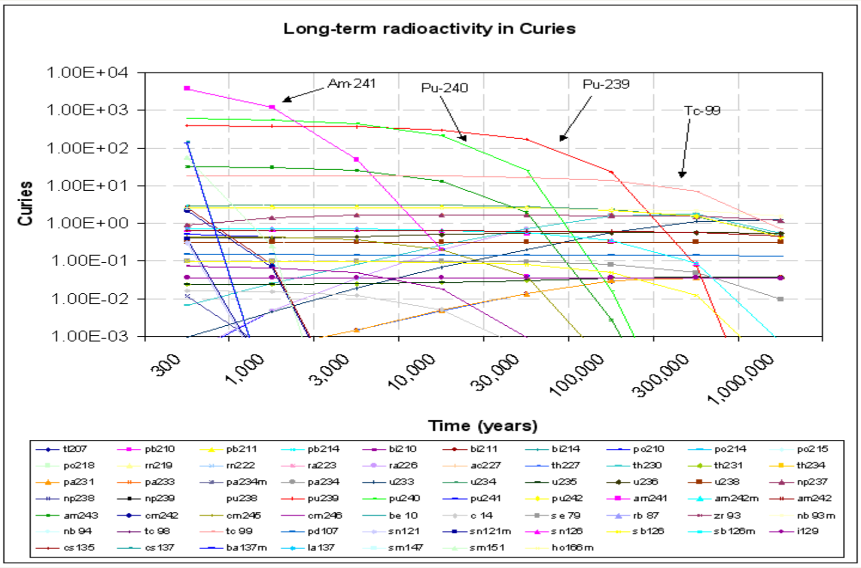

Figure 1: A chart of the activity of all the radioactive nuclides as a function of time up to 1 million years from 1 MT of nuclear waste, burned to 45MWd/kg.

Data was computed on the most recent version of ORIGEN-S from Oak Ridge by whatisnuclear.com. The radioactivity of a radioisotope decreases with the passage of time, through a process called radioactive decay. The amount of time necessary to decrease the radioactivity of radioisotope to one-half the original amount is called the radioactive half-life of the radioisotope. According to radioactivity levels of nuclear waste, general classification is presented by International Atomic Energy Agency [1].

Nuclear waste disposal

The fundamental objective of geological disposal is retaining radionuclides in either the engineered repository or in the host rock, so they do not enter the biosphere over a pre-defined time span [2]. Geological environment of selected formations in deep underground is more stable compared to areas near surface. By this way the nuclear waste could be safely isolated for a long period of time in stable formations. Even if the radionuclides from nuclear waste released into groundwater, migration of such nuclides will be retarded significantly. Because they are adsorbed by the minerals along the groundwater pathway. In-situ migration tests for candidate host rocks show that probability of preserving environmental safety is enough. For this reason, site characterization is necessary prior to the construction of a disposal facility. Site characterization should cover aspects as the geological, mechanical, hydrological and geochemical properties of the host rock. Drilling is generally necessary for characterization of these features, but non-destructive methods should be considered to avoid disturbance to the geological environment. The design of the nuclear waste repository must consider two important factors; the site and its physical features and the waste that will be received at the facility [3].

Nuclear waste disposal is composed of a surface facility to receive the waste. Surface facility is necessary for conducting required inspections and encapsulation the waste in an over-pack. Underground facility is constructed to emplace nuclear waste forms. An underground facility is composed of access shafts which connect the surface facility with the underground facility, disposal tunnels for emplacement of waste forms, connection tunnels and infrastructure for transportation, construction of tunnels and maintenance of the safety of all operations. Following conditions are required for a disposal facility;

a. To provide mechanical stability of underground openings (tunnels, galleries, waste rooms etc.) during construction, operation and closure of the facility.

b. To provide radiation protection of workers and minimize incidental releases.

c. To provide measures to handle heat generated from nuclear waste forms

d. To avoid damage to the host rock and groundwater level lowering.

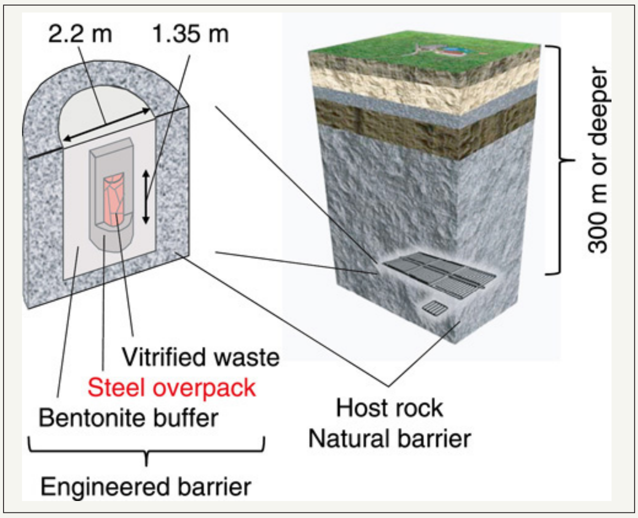

Figure 2: Natural and engineered barriers.

A layout of the underground facility can be considered to perform construction, operation and closure independently. Therefore, a system for dividing the area to dispose of the waste into several independent panels. Instead of shafts, various options of access from the surface to the underground facility are available such as ramps or spiral tunnels. Engineered barriers are composed of waste form, over-pack and buffer material as indicted in Figure 2.

Design parameters

Table 1: Typical properties of host rocks.

Host Rock Properties	Wet Density (kg/m^3)	Elastic Modulus (MPa)	Poisson's Ratio	Cohesion (MPa)	Angle of Internal Friction (deg)
Crystalline	2,700	10000 - 30000	0.20	6.0-7.5	35
Sedimentary	2,300	1000-4000	0.3-0.4	1.0-4.0	25-30

Table 2: Typical thermal properties of barriers.

	Thermal Conductivity (Wm^{-1} K^{-1})	Specific Heat (kJ kg^{-1} K^{-1})	Density (kg m^{3})
Vitrified Waste	1.2	0.96	2,800
Overpack	53	0.46	7,800
Buffer Material	0.9-1.7	0.6-1.0	1,900-2,100
Crystalline rock	2.9	0.84	2,700
Sedimentary rock	2.3	0.84	2,300

During the long-term operational period of construction, operation and enclosure, it is necessary to secure stability. Several host rock properties should be determined for assessment in design studies. Typical values of potential host rocks are presented in Table 1. In order to examine the thermal influence on engineered barriers and surrounding host rock from heat generated by nuclear waste, thermal analysis should be carried out. According to thermal analysis results; emplacement spacing and disposal depth of waste packages will be determined. Less than 100 °C generally thermal alteration in buffer materials are not measured. Thermal properties of engineered barriers and host rock are presented in Table 2.

Conclusion

The present study was based on the determination of basic effective design parameters for a sustainable nuclear waste disposal facility. A preliminary analysis for a particular site should be conducted each of processes which may influence the mechanical stability of the engineered barriers and host rock. Such as chemical properties of the groundwater, which will come into contact with the waste, should be taken into account. Design parameters are determined from each site during site characterization process and used in analysis for ensuring long-term safety and stability of disposal facility.

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