Chinese buffer material for high-level radiawaste disposal

--Basic features of GMZ-1

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Abstract

Radioactive wastes arising from a wide range of human activities are in many different physical and chemical forms, contaminated with varying radioactivity. Their common feature is the potential hazard associated with their radioactivity and the need to manage them in such a way as to protect the human environment. The geological disposal is regarded as the most reasonable and effective way to safely disposal high-level radioactive wastes in the world. The conceptual model of geological disposal in China is based on a multi-barrier system that combines an isolating geological environment with an engineered barrier system. The buffer is one of the main engineered barriers for HLW repository. The buffer material is expected to maintain its low water permeability, self-sealing property, radio nuclides adsorption and retardation property, thermal conductivity, chemical buffering property, overpack supporting property, stress buffering property over a long period of time. Benotite is selected as the main content of buffer material that can satisfy above. GMZ deposit is selected as the candidate supplier for Chinese buffer material of High Level Radioactive waste repository. This paper presents geological features of GMZ deposit and basic property of GMZ Na bentonite. GMZ bentonite deposit is a super large scale deposits with high content of Montmorillonite (about 75%) and GMZ-1, which is Na-bentonite produced from GMZ deposit is selected as reference material for Chinese buffer material study.

Key words: GMZ-1; Basic features; Buffer material; HLW disposal

Introduction

The concept of geological disposal of high level radioactive waste in China is based on a multi-barrier system which combines an isolating geological environment with an engineered barrier system (EBS). The EBS consists of the vitrified HLW, a rigid vessel (overpack) for containment of the vitrified waste and a buffer that fills the gaps between the overpack and the surrounding rock mass.

The buffer material is expected to maintain its low water permeability, thermal conductivity, self-sealing, radionuclide sorption and retardation, chemical buffering, overpack support and stress buffering properties over a long period of time (PNC, 1992). Natural clay is a material that can satisfy all the above functions, to a greater or lesser extent (Pusch, 1983). Among the types of natural clay, bentonite, when compacted, is considered superior because (i) it has exceptionally low water permeability to control the movement of water in buffer, (ii) it fills void spaces in the buffer and fractures in the host rock as it swells upon water uptake, (iii) it has the ability to exchange cations and to adsorb cationic nuclides. In order to confirm these functions for the purpose of safety assessment, it is necessary to evaluate buffer properties through laboratory and engineering scale tests (JNC, 2000).

The required properties of the buffer can therefore be summarised as (Cho et al., 2000):

1) Low gas permeability The buffer is utilized to prevent gases formed by chemical and nuclear reactions from escaping to the bedrock and ultimately dispersing in the environment;

2) Low hydraulic conductivity The buffer is utilized to limit the flow rates of groundwater, potentially containing corrosive substances, to the canister surface

and of pore water, perhaps contaminated with radionuclides from a leaking canister, to the bedrock;

3) High radionuclide retardation capacity the ability to remove dissolved radioactive material from pore water by sorption on the surface of the bentonite particles;

4) High swelling potential the ability to adsorb large quantities of water such that the bentonite expands and seals any cracks in the buffer to hinder material transport to and from the canister.

5) High thermal conductivity The buffer will also have to conduct the fuels' residual power, i.e., the energy emitted when radioactive material decays and which is converted to heat in the canister and its' contents. By having high thermal conductivity, recrystallization of glass, which is caused by elevated temperature due to heat production from vitrified waste, is inhibited.

6) Sufficient mechanical support of canister While the overpack is functioning after waste packages are emplaced, the buffer mechanically supports the overpack and has the strength to maintain its integrity even in the event of earthquakes.

7) Stress buffering Expansion of corrosion products of the overpack and creep deformation of the host rock should be mechanically buffered by plasticity of the buffer for the period when the overpack functions are maintained after emplacement of the waste packages.

1. Historical practices of buffer study in China

In China, from 1985 on, Chinese scientists began to study the bentonite's behavior and its feasibility as buffer material in HLW repository. The related scientific activities cover literature investigation and use of inorganic sorbents as backfill materials for underground repository (Gu and Du, 1992), bentonite deposit screening (Xu et al, 1996), study of basic property of GMZ Ca-bentonite (Liu et al, 2000) and GMZ Na-bentonite (Wen et al, 2002) and comparison study of basic property between GMZ-1 and KunigelV1 Bentonite (Wen & Jintoku, 2003).

2. Bentonite deposits in China

The reserve of bentonite in China ranks the first in the world. The bentonite deposits are extensively located in 23 provinces in China. There are 84 bentonite deposits that are found throughout the China. The two most important metallogenetic province of bentonite in China is Guangxi Autonomous region (about 27% of the national reserves) and Xinjiang Uygur Autonomous Region (about 17% of the national reserves). In China, the bentonite deposits are divided into large-scale (proved reserves > 50 million tons), middle-scale (5 million tons <proved reserves < 50 million tons) and small scale deposits (proved reserves < 5 million tons) according to the proved reserves. The 12 large-scale bentonite deposits are distributed in Guangxi Autonomous region (2), Xinjiang Uygur Autonomous Region (2), Inner Mongolia Autonomous region (1), Jiangsu province (1), Hebei province (1), Anhui province (1), Hubei province (1), Shandong province (1), Zhejiang province (1), Shanxi province (1). Beside the large-scale bentonite deposits, there are 26 middle-scale bentonite deposits, 45 small-scale bentonite deposite as well.

The genetic characteristics of Chinese bentonite is summarized as follows:

(1) The bentonite deposits in China are mostly developed in Earlier Cretaceous to Later Jurassic period.

(2) The distribution of bentonite mineralization is consistent with the development

of acidic and medium volcanic. The regional extent of bentonite deposits is controlled by the limit of the regional deposition environment, paleogeography and distribution of the volcanic pyroclastic unit

(3) The bentonite can be formed through various geological mineralizations: sedimentation, weathering, hydrothermal alteration etc. Bentonites are hosted by and associated with argillite, mudstone, siltstone, sandstone, tuff, agglomerate, ignimbrites, marl, shale, zeolite beds and coal. Alteration consists of devitrification of the volcanic ash with hydration and crystallization of the smectite mineral. In some instances there is evidence of a loss of alkalies during the alteration. Also, silicification of beds underlying some bentonites indicates downward migration of silica. There is also sometimes an increase in magnesium content compared to parent material. Besides smectite minerals, other alteration products in the volcanic ash include cristobalite, opaline silica, zeolites, calcite, selenite and various iron sulphate minerals.

(4) Bentonite is bedded, with a soapy texture and waxy appearance. It ranges in colour from white to yellow to olive green to brown to blue. Depending on the nature of their genesis, bentonite contains a variety of accessory minerals in addition to montmorillonite. These minerals may include quartz, feldspar, calcite and gypsum. The presence of these minerals could impact the industrial value of the deposit, reducing or increasing its value depending on the application.

(5) The main exchangeable cation can be different between the surface bentonite and the underground bentonite due to the interaction of the original bentonite with underground water. In general, the surface bentonite is characterized of Ca-bentonite, whereas the deep bentonite is mainly composed of sodium bentonite. The location of boundary of the two different kind of bentonite is different in different bentonite deposits due to the different mineralization and

generic environment.

3. Bentonite deposit screening in China

Bentonite deposit screening was conducted in China during 1994 to 1996. The comprehensive screening criteria that were cited for bentonite deposit screening are listed as following:

(1) Scale

The candidate bentonite deposit should be large-scale deposit in order to meet the demand for the installation of HLW repository 30 or 40 years later.

(2) Quality

As the reference material for buffer in HLW repository, the bentonite must be extremely low permeability, high adorability, high swelling property, suitable thermal conductivity and reasonable stability to ensure safety over the long timescales of interest. As a result, Na-bentonite with high content of montmorillonite and low contents of detrimental are of more interest because of swelling properties and in general higher cation exchange capacity.

(3) Economic limitation

Apart from large reserves, this mine also should satisfy the mineability and economic feasibility. In other words, the candidate mine would be a thin superstratum, which is easy for strip mining.

(4) Location

Transpotation of bentonite from the mine to the candidate HLW repository could be convenient and the cost had better as low as possible.

In 1996, Chinese scientists selected the GMZ deposit as the candidate supplier for Chinese buffer material (Xu et al, 1996).

4. Geological features of GMZ-1

The GMZ deposit is located in the northern Chinese Inner Mongolia autonomous region, 300 km northwest of Beijing. The reserve in GMZ is more than 100 million tons with about 80% Na-bentonite reserves. The deposit is composed of 5 ore bed, numbered by 0, I, II, III, IV. The third ore bed is the most important part that is the main industrial ore bed. All the ores are occurred bedded appearance. The third ore bed extends about 8,150m with thickness from 8.78m~20.47m. The GMZ bentonite deposit is formed in later Jurassic period. Bentonite is bedded, with a soapy texture and waxy appearance. It ranges in color from white to yellow to olive green to brown to pink. The mineralization is a process of firstly continental volcanic sediment and then suffering from interaction with ground water and weathering.

The GMZ crude bentonites are mined by shaft sinking. The bentonite, the "crude clay", is transported to the factory nearby for further processing. For further processing, the crude clay is homogenized and made dry in the air. then the bentonite is milled to fine powder.

5. Basic features

The mineralogical composition of GMZ-1 has been quantitatively analyzed by X-ray diffraction analyses. The bulk composition was determined as: quartz 11.7%, cristobalite 7.3% feldspar 4.3%, Calcite 0.5%, kaolinite 0.8%, montmorillonite 75.4%.

Methylene Blue exchange capacity (MBC) of GMZ-1 is 102 mmol/100g (measured 2 times). According to Kunipia F, MBC is 140mmol/100g.

The bulk chemical component of GMZ-1 has been analyzed by X-ray fluorescence spectrometry: Al_2O_3 14.20%, SiO_2 67.43%, P_2O_5 0.02%, CaO 1.13%, K_2O 0.73%, TiO_2 0.12%, FeO 0.29%, TFe_2O_3 2.40%, MgO 0.10%, Na_2O 1.75%, MnO 0.02%, loss on ignition, 11.38%

Table 1 CEC and exchangeable cation of GMZ-1

Sample	CEC (mmol/100g)	Exchangeable cation (mmol/100g)				Alkali Index
		$E(k^+)$	$E(Na^+)$	$E(1/2Ca^{2+})$	$E(1/2Mg^{2+})$	
GMZ-1	77.06	0.55	37.52	23.18	10.17	1.14

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