STUDY OF WATERPROOF CAPABILITIES OF THE ENGINEERED BARRIER CONTAINING BENTONITE IN NEAR SURFACE RADIOACTIVE WASTE REPOSITORIES

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Project Information:

- **Code: CS/16/03-02**
- **Managerial Level: Vietnam Atomic Energy Institute**
- **Allocated Fund: 80,000,000 VND**
- **Implementation Time: 12 months (Jan 2016 – Dec 2016)**
- **Contact Email: lcnguyen0210@gmail.com**
- **Papers published in relation to the project:**

  Lưu Cao Nguyen, Nguyen Ba Tien, Doan Thi Thu Hien, Nguyen Van Chinh, Vuong Huu Anh; A study on waterproof capabilities of the Bentonite-containing engineered barrier used in near surface disposal for radioactive waste; To be published in J. Nuclear Science and Technology.

Abstract: In Vietnam, the study of nuclear fuel cycle is in first steps, such as the exploitation and uranium processing… These processes generated large amounts of radioactive waste over-timing. The naturally occurring radioactive material and technologically enhanced radioactive material (NORM/TENORM) waste, which would be large, needs to be managed and disposed reasonably by effective methods. These wastes were used to be disposal in the near surface. It was therefore very important to study the model of radioactive waste repository, where bentonite waterproofing layer would be applied for the engineered barrier. The aim of this study was to obtain the preliminary parameters for low-level radioactive waste disposal site being suitable with the conditions of Vietnam. The investigation of the ratio between soil and bentonite was taken part. The experiments with some layers of waterproofing material with the ratio of soil and bentonite as 75/25, 50/50 and 25/75 were carried out to test the moving of uranium nuclide through these waterproofing material layers. Analyzing the uranium content in each layer (0.1 cm) of pressed soil - bentonite mixture (as a block) to determine the uranium nuclide adsorption from solution into the materials in the different ratios at the different times: 1, 2 and 3 months was carried out. The results showed that the calculated average rate of uranium nuclide migration into the soil - bentonite layer was $5.4.10^{-10}$, $5.4.10^{-10}$ and $3.85.10^{-10}$ m/s corresponding to the waterproofing layer thickness (for 300 years) 4.86 m, 4.86 m and 3.63 m respectively, which was due on the ratio of soil and bentonite 75/25, 50/50, 25/75 to keep the safety for the repository. [3-5].

Keywords*: *Bentonite, Ratio of soil and bentonite, Near surface disposal site, radioactive waste

I. INTRODUCTION

The disposal of very low and low radioactive waste in near surface repositories with engineered barrier were much studied in the world. In this theme, the mix between soil and Vietnamese bentonite was studied to use as the engineered barrier for the near surface disposal. Soil and bentonite were mixed with different ratio: 75/25, 50/50 and 25/75 and then these mixture were pressed in to PVC pipes to investigate the migration of uranium nuclide in the uranium solution through these materials. The time of migration were changed from 1, 2 and 3 months. Determining the content of uranium in each layer of 0.1 cm of PVC pipes to identify the rate of uranium nuclide migration through engineered barrier layers was done using XRF technique. From the results of these rates, the primary calculation of the engineered barrier layers thickness for the near surface disposal was reported.

II. EXPERIMENT

Preparation of samples and testing conditions: [12,13].

- Samples of soil and bentonite were mixed in different proportions (75/25, 50/50, 25/75 respectively) to get homogeneous material. Each sample were loaded into 03 PVC tubes and compressed at a pressure of 1.5 tons, to ensure the uniformity at every point, with no gap between the material and inside wall of the tube.

- For the experiment, the testing conditions were chosen as follows:

o The height of liquid column to soak the sample tubes was 5 cm.

o The sample tubes must be closed during permeability test experiments.

o Determining the infiltration level of uranium into the sample tubes after the period of 1, 2 and 3 months.

o Analyzing the content of uranium in each 0.1 cm layer of the samples tube to determine the migration of uranium from solution into the materials in different ratios of soil and bentonite.

Test procedure

- For each sample, prepare 500g with the different ratio of soil and bentonite (ratio S/B).

Table 1: The component weight of mixed materials in experiments

Ordinal	Name of amples	Ratio S/B	Weight of soil (gram)	Weight of bentonite (gram)
1	M1	75/25	375	125
2	M2	50/50	250	250
3	M3	25/75	125	375

- PVC pipe with a diameter of 2.7 cm was cut to parts with the length of 10 cm.

- Each mixed material of 100g weight was loaded into a PVC tube then compressed by CARVER pressure press (USA) at 1.5 tons.

- Use a measuring cylinder to take out 100 ml of uranium containing solution into the cup for soaked sample.

- Soaking the PVC tube with compressed material into the solution. The solution was oriented to suck from bottom to top. Check the extent of infiltration after the period of 1 month, 2 months and 3 months.

- When finishing the soaking of PVC tube with experimented materials, cut the PVC tube to determine uranium content at the each 0.1 cm layer. The uranium content of each sample layer was measured by X-ray fluorescence (XRF) at the Institute of Technology for Radioactive and Rare Elements.

- XRF measurement was done as the following:

o The sample tube was cut out of the PVC plastic to obtain cylindrical sample and it was analyzed.

o Surface of the sample was grinded for flat surface (about 0.1 mm of tube height) and kept on the XRF sample stand for the measurement of the surface. Measurement was performed directly on the surface of that cylindrical sample.

o For second measurement, it needed to remove the thickness of sample layer by cutting at a distance of 0.1 cm. Uranium content on this surface layer was measured. This step was repeated until the uranium content on the surface layer was under the detection limit of XRF method.

- Analyzing the uranium content in each layers of material pipe to determine the amount of uranium nuclide adsorbed from solution into the material with different ratios of soil/bentonite. Uranium concentration of solution before and after the experiment was also checked.

III. RESULTS AND DISCUSSION

Examine the movement of uranium nuclide from radioactive waste solution through engineering barrier layer containing betonite

III.1. Analysis of low - level radioactive waste solution

Solution of low- level radioactive waste has pH = 3 and uranium concentration of 12 mg/g was used for the present study. The concentration was analyzed using a standard method.

III.2. Analysis of the original Bentonite compositions

Table 2: Compositions of bentonite-Binh Thuan (% concentration)

Composition	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	CO_2	K_2O	Na_2O	H_2O
Bentonit	65.5 - 76.5	6.71 - 11.81	1.44 - 2.27	0.21 - 0.75	1.05 - 2.13	3.29 - 8.32	0.82 - 5.81	0.62 - 1.92	1.35 - 2.40	3.98 - 7.65

Among the original bentonite mines found in our country, Nha Me mine at Binh Thuan province contains higher alkali content. This is the biggest advantage in applying to make waterproofing materials for the waste backfill. Therefore, original bentonite of Nha Me mine for the buffer in this waste backfill was used.

III.3. Examination of the uranium nuclide migration from radioactive waste solution through layers of the bentonite engineering barrier

The uranium content in samples with different ratio of soil and bentonite (ratio S/B = 75/25, 50/50, 25/75) in mixture before experiments were analyzed. The results showed that in these samples uranium was not detected (the detection limit of this method was 10 μg/g).

Three samples (M1-1, M1-2, M1-3) with the same ratio S/B = 75/25 were soaked in 1, 2, 3 months, respectively. Uranium contents in different layers of materials were determined by the method described above. The results were presented in Tables 3 and illustrated in Fig. 1.

The similar experiments were carried out with two other series of samples corresponding to ratios S/B = 50/50 and 25/75, which were denoted as M2 (M2-1, M2-2, M2-3) and M3 (M3-1, M3-2, M3-3). These results were shown in Tables 4, 5 and plotted in Figs 2, 3, respectively.

Table 3: Uranium content in different layers of materials
with ratio S/B = 75/25 after 1, 2 and 3 months

Ordinal	Distanced (cm)	Content of U (µg/g) M1-1	Content of U (µg/g) M1-2	Content of U (µg/g) M1-3
1	0.01	110	112	113
2	0.1	82	80	86
3	0.2	57	57	61
4	0.3	38	39	42
5	0.4	ND	31	32
6	0.5	ND	ND	ND
7	0.6	ND	ND	ND

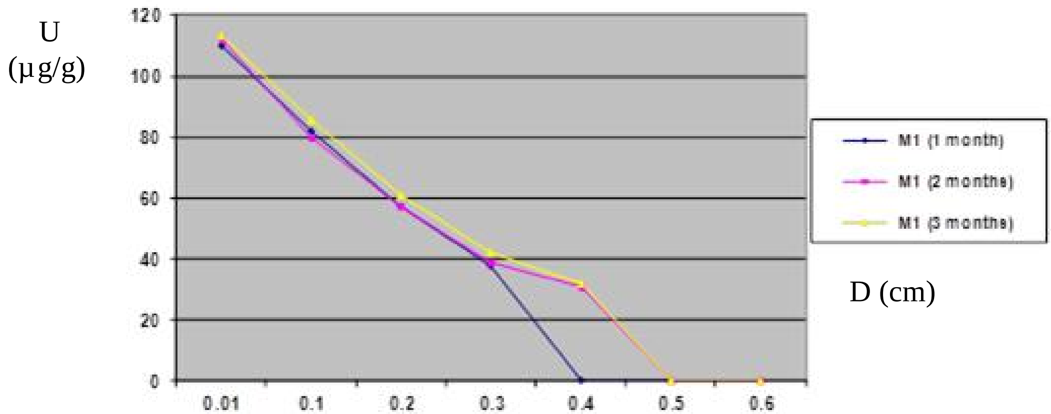

Figure 1: The change of uranium content vs. the depth of M1 cylindrical sample

Table 4: Uranium content in different layers of materials
with ratio S/ B = 50/50 after 1, 2 and 3 months

Ordinal	Distanced (cm)	Content of U (µg/g) M2-1	Content of U (µg/g) M2-2	Content of U (µg/g) M2-3
1	0.01	103	105	106
2	0.1	67	68	69
3	0.2	42	44	48
4	0.3	24	27	29
5	0.4	ND	ND	10
6	0.5	ND	ND	ND
7	0.6	ND	ND	ND

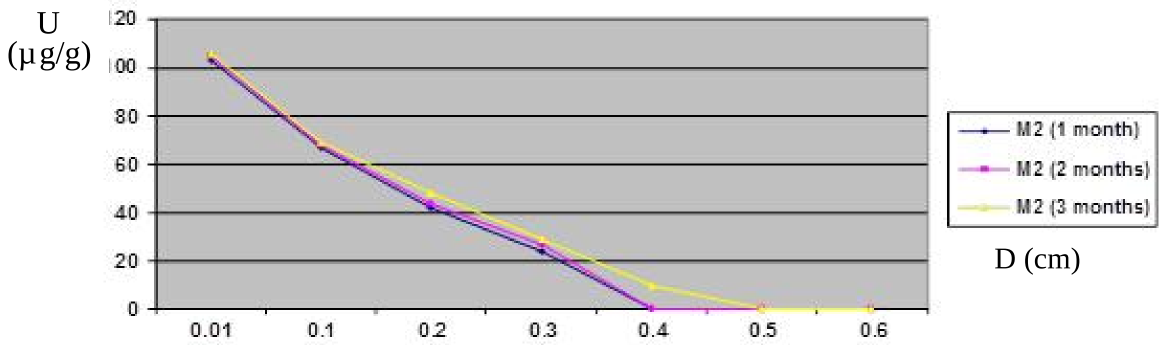

Figure 2: The change of uranium content vs. the depth of M2 cylindrical sample

Table 5: Uranium content in different layers of materials with ratio M3 after 1, 2 and 3 months

Ordinal	Distanced (cm)	Content of U (µg/g) M3-1	Content of U (µg/g) M3-2	Content of U (µg/g) M3-3
1	0.01	98	100	103
2	0.1	60	62	65
3	0.2	20	33	37
4	0.3	ND	18	19
5	0.4	ND	ND	ND
6	0.5	ND	ND	ND
7	0.6	ND	ND	ND

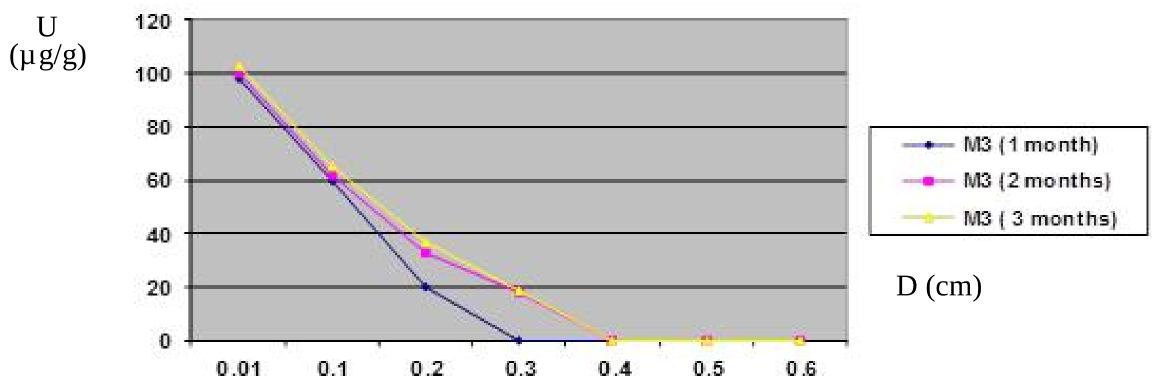

Figure 3: The change of uranium content vs. the depth of M3 cylindrical sample

The results of experiments showed that the rate of uranium adsorption decreased with the depth of the material layers. According to these results the *migration rates and the thickness of waterproofing layer* could be calculated using the following formula [12] if the bentonite layers were assumed as the constructed soil base.

$$V = D/t$$

where: V is the migration rate of the uranium nuclide into the soil-bentonite layer (m/s);

D is the distance of uranium nuclide migrated in soil-bentonite layer (m)

t is the time of uranium nuclide migrated in soil-bentonite layer (s)

$$T = V \times L$$

where: T is the thickness of waterproofing layer (m);

V is the migration rate of a radioactive nuclide into the soil-bentonite layer (m/s);

L is the life of disposal for low and very low radioactive waste (expected time: 300 years);

The calculated results were presented in the tables 6.

Table 6: Migration rates and the thickness of waterproofing layer for materials with different ratio S/B

Ordinal	Material	Design	Migration rate (m/s)	Thickness of waterproofing layer (m)
1	M1	Life of disposal for low and very low radioactive waste in 300 years	$5.14. 10^{-10}$	4.86
2	M2		$5.14. 10^{-10}$	4.86
3	M3		$3.85. 10^{-10}$	3.63

All three types of studied materials were waterproof and could prevent from the movement of uranium nuclide and could thus be used as an engineering barrier in near surface disposal for low and very low level radioactive waste.

IV. CONCLUSIONS

Based on the preliminary results obtained, the following conclusions would be made: the migration rate of the uranium nuclide into the soil-bentonite layers and the thickness of waterproofing layer could be calculated for each material ratio. Due to the short period of study time, the calculated results were only oriented.

Experiments were conducted to study the penetration of uranium elements through the above mentioned layers with periods of 1 month, 2 months and 3 months. Initial data show that the permeability of uranium through the study materials is in the range of $3.85. 10^{-10} – 5.14.10^{-10}$ m/s.

According to these preliminary data and depending to economic viability material M1 (with the ratio S/B = (75/25)) should be chosen for using as waterproofing materials in near surface disposal of low and very low radioactive waste.

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