Nucl. Sci. and Tech., Vol.7, No. 1 (2017), pp. 37-42

Nuclear Science and Technology

Journal homepage: https://jnst.vn/index.php/nst

A study on waterproof capabilities of the bentonite-containing engineered barrier used in near surface disposal for radioactive waste

Luu Cao Nguyen, Nguyen Ba Tien, Doan Thi Thu Hien,
Nguyen Van Chinh, Vuong Huu Anh

Institute for Technology of Radioactive and Rare Elements (ITRRE), VINATOM

Abstract: Study of nuclear fuel cycle in Vietnam at the aspect of domestic production, the exploitation and process of uranium ore were began. 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. It was therefore very important to study the model of the radioactive waste repository, where bentonite waterproofing layer would be applied for the low and very low level radioactive waste in disposal site. The aim of this study was to obtain the preliminary parameters for low-level radioactive waste disposal site suitable with the conditions of Vietnam. The investigation of the ratio between soil and bentonite was interested in the safety of the uranium tailings disposal site. The experiments with some layers of waterproofing material with the ratio of soil and bentonite are 75/25; 50/50; 25/75 were carried out to test the moving of uran nuclide through these waterproofing material layers. Waterproofing layers containing bentonite combined with soil were compacted into PVC pipes. One end of the plastic tube is sealed, the other end is embedded in a solution containing uranium nuclide. Analyzing the uranium content in each layers (0,1 cm) of material pipe is to determine the uranium nuclide adsorption from solution into the material in the different ratios at the different times: 1, 2 and 3 month. The results showed that the calculated average speeds of the migration of uranium nuclide into the soil- bentonite layer are $5.4.10^{-10}$, $5.4.10^{-10}$ and $3,85.10^{-10}$ m/s and thickness waterproofing layer (for 300 years) are 4,86 m, 4,86 m and 3,63 m for layer with the ratio of soil and bentonite are 75/25; 50/50; 25/75 respectively.

Keywords: *Bentonite, Ratio of soil and bentonite, Near surface disposal, uran nuclide.*

I. INTRODUCTION

When domestic production of the nuclear fuel cycle in Vietnam, exploitation and process of uranium ore will be began [1]. These processes produce large amounts of radioactive waste over time. The naturally occurring radioactive material and technologically enhanced radioactive material (NORM/TENORM) waste, which will be large, needs to be managed and disposed reasonably by effective method [2-4]. Low – very low level radioactive waste is usually disposal at near surface repository with the deep of 0 - 20 m, then covered by clay or bentonite layers as engineered barriers. The aim of the low and intermediate level radioactive waste disposal is to store and to manage the radioactive waste in technical conditions, thus to ensure the isolation of radioactive wastes and the safety for humans and the environment [3-5]

Waterproof materials meet the specified standards, which are important issues because the waterproofing layer is the isolation layer between the waste and the environment, ensuring the safety of natural environment and human [5-8]. In fact, a mixture of soil and bentonite is often chosed for making waterproofing material [7,9-11]. The investigation of optimal proportion of soil and

https://doi.org/10.53747/jnst.v7i1.117
Received 20 December 2017, accepted 23 August 2017

bentonite is very important for the safety of disposal sites.

The aim of this study is to determine the ratio between soil and bentonite in layers of waterproofing material and simply calculate the preliminary parameters for low-level radioactive waste disposal with the conditions of Vietnam

II. EXPERIMENTAL

Experimental methods were refered in [12,13].

Preparation of samples and testing conditions:

- Samples of soil and bentonite were mixed in different proportions to get homogeneous material (waterproofing materials containing soil and bentonite with the ratio of soil / bentonite respectively: 75/25; 50/50; 25/75). Each sample of waterproofing material was loaded into 03 PVC tubes (for testing at the different period of times: 1, 2 and 3 months) and compressed at a pressure of 1.5 tons, to ensure the uniformity at every point, with no gap between the material and inside of the tube wall.

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

+ The hight of liquid column to soak the sample tubes was 5 cm.

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

+ Determining the infiltration level after the period of 1 month, 2 months and 3 months.

+ Analyzing samples to determine the migration of uranium from solution into the materials in different ratios of soil and bentonite.

+ Analyzing uranium concentration of the solution before and after experiments.

Test procedure

- Prepare samples with the different ratios of soil and bentonite (ratio S/B) in mixture and with the total weight of 500g.

Table I. The component weight of mixed materials in experiments

Ordinal	Name of samples	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 weigh was poured into a PVC tube then it was 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 compressed material PVC tube into 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 layer. The uranium content of the sample was measured by X-ray fluorescence at the Institute of Technology for Radioactive and Rare Elements.

- Description of measurement process:

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

Surface of the sample was grinded for flat surface (about 0.01 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.

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

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

III. RESULTS AND DISCUSSION

A. Analysis of low - level radioactive waste solution

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

B. Analysis of the original Bentonite compositions

Table II. 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, the research group used original bentonite of Nha Me mine for the buffer in this waste backfill.

C. Examination of the uranium nuclide migration from radioactive waste solution through layers of the bentonite- containing 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 = 75/25n 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 experiements 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 IV, V and plotted in Figs 2, 3, respectively.

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

Ordinal	Distance d (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

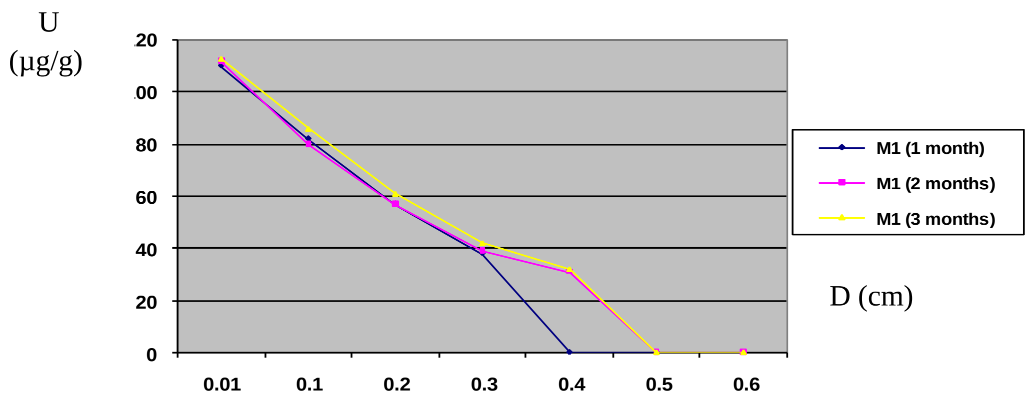

Fig. 1. The change of uranium content vs. the depth of M1 cylindrical sample

Table IV. 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

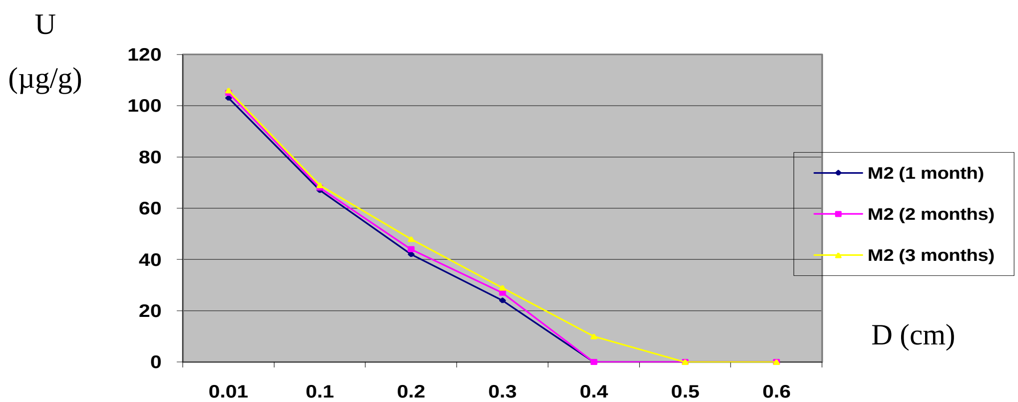

Fig.2. The change of uranium content vs. the depth of M2 cylindrical sample

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

Ordinal	Distance d (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

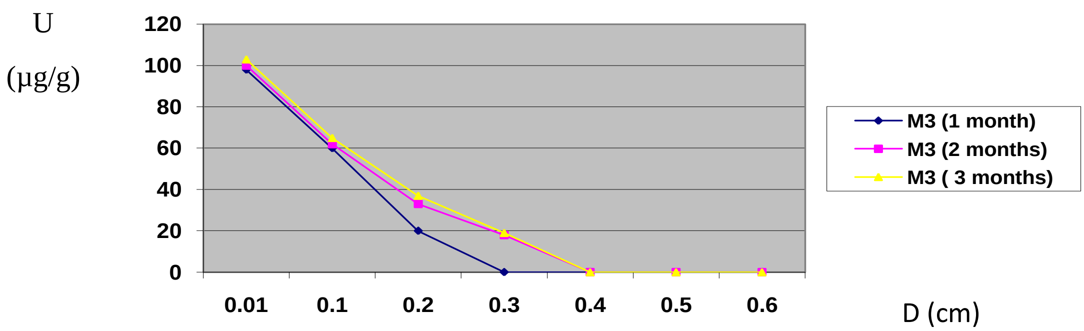

Fig. 3. The change of uranium content vs. the depth of M3 cylindrical sample

The results of experiments showed that the rate of uranium adsorption decreased with the depth of the material layer. According to these results the *Migration rates and Thickness of waterproofing layer* could be calculated using the following formula [12] if the bentonite layers were assumed as the contructed 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 x 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 VI.

Table VI. Migration rates and 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 prevent the movement of uranium nuclide and can be used as a engineering barriers 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 withdrawn: 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.

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.

REFERENCES

1. Tien Nguyen Ba, Lecture on Nuclear Fuel Cycle and Management of Radioactive Waste, Nuclear Training Center, VINATOM, 8-2014.
2. V. M. Efremenkov, Radioactive waste management at nuclear power plants, An overview of the types of low- and intermediate-level wastes and how they are handled, IAEA BULLETIN, 4/1989.
3. Safety series No. 111-G-1.1; Classification of Radioactive Waste, A Safety Guide; A Publication within the RADWASS Programme, IAEA, Vienna 1994.
4. Technical design and evaluation of potential repository concepts for long-lived low and intermediate level waste, Par Grahm, David Luterkort, Per Martensson, Predrik Nisson,(P. 40-45, 49-54), 2013- Stockholm.
5. Performance of engineered barrier materials in near surface disposal facilities for radioactive waste (Chapter 2), IAEA-2001 Viena.
6. Bentonite Barriers- New Experiments and State of the Art, GRS-300, (P. 5-19) [2012]
7. A Review of Non-Traditional Dry Convers MEND 2.21.3b, Dr. M.D.Haug, Ph.D.Gordon Pauls,(P. 92-95; 104), 2001.
8. Millet, R.A., Perez, J.-Y., Davision, R. R., “USA practice slurry wall specifications 10 year later,” Slurry walls: design, contruction and quality control, ASTM STP 1129.
9. DAY, S., Envirocon Soil-Bentonit Slurry Wall Design Mix Submittal for Denver Water Hazeltine, Road Runner’s Rest II and Brinkmann-Woodward Gravel Reservoirs, October, 8 p, 2003.
10. Sandra Sanschez González, The swelling pressure of bentonite and sand mixtures, Stockholm, Swenden-2013.
11. Thai Nguyen Canh, Tu Nguyen Anh, Cuong Bui Quang, "Test construction of trench wall - Bentonite waterproofing", Journal of Water Resources Engineering and Environmental Science, 2011.
12. National standard TCVN 8723, (Land for construction of irrigation works - Method of determining the coefficient of permeability of soil in the experiment), 2012.
13. Lawrence K. Wang, Jiaping Paul Chen, Membarane and Desalination Technologies, 2011.