International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

MATERIAL COMPOSITION AND PROPERTIES OF RED MUD COMING FROM ALUMINA PROCESSING PLANT TANRAI, LAMDONG, VIETNAM

Luu Duc Hai, Nguyen Manh Khai, Tran Van Quy, Nguyen Xuan Huan
Faculty of Environmental Sciences, VNU-University of Science, Vietnam National University, Hanoi, Vietnam
Corresponding author email: haild@vnu.edu.vn

Abstract

Red Mud coming from Tanrai Alumina Processing plant, Lamdong, Vietnam contains high excess alkaline component and many toxic heavy metals. The results showed that Red mud does not contain artificial radioactive isotopes such as ^{137}Cs, ^{7}Be; concentration of Uranium, Thorium in Red mud are less than the average concentration values of Uranium (2ppm) and Thorium (12ppm) in the earth's crust; annual effective dose caused by gamma radiation is smaller than the average effective dose was recommended by UNSCEAR. Physical texture of Red mud classified by equilateral triangle are sandy loam (57.1% sand; limon 33.8%; clay 9.1%). Chemical composition of Red mud is, by weight (% w/w): Fe_2O_3 - 30.8; SiO_2 - 31.7; Al_2O_3 - 15.6; TiO_2 - 2.58; Na_2O - 3.14, CaO - 3.51; K_2O - 0.11; MgO - 0.27; MnO - 0.02; P_2O_5 - 0.22. Red mud also contains some heavy metals and have pH_{H2O} and pH_{KCl} are 11.23 and 11.12 respectively. The seearch results are an important basis to orient treatment and recovery this source for construction materials production.

Keywords: Red mud; Bauxite; Alumina; Radiation; Chemical and Physical characteristics.

1. INTRODUCTION

Red mud is hazardous waste generated in the Bayer process alumina production (Al_2O_3) from Bauxite ore which contains high levels of residual alkalinity and toxic heavy metal. Therefore, Red mud is a hazardous waste of alumina industry. The volume of Red mud which generated in the alumina processing plant depends on the quality of crude Bauxite ore, may be greater than the volume of alumina 1-1.5 times. The alumina processing plant usually disposes liquid Red mud into reservoirs, which cause the risk of major environment pollution for lowland [1]. The particle dimention of red mud usually less than 1mm. Therefore, dry Red mud easy spreads into the air and causes dust pollution. It is often exposured to dust cause skin and eyes diseases. Red mud in an liquid state causes harmful effects to human skin. Composition and properties of Red mud in the World have been presented by many researchers in their publications. The result showed that: Red mud Tanrai Alumina Processing plant contains a big content of oxides, such as: Fe_2O_3, Al_2O_3, SiO_2, TiO_2, NaO, K_2O, CaO.. and sometimes a high concentration of valuable metal elements (V, Ga, ..) and radioactive elements [1-8]. The reuse of red mud for construction or building material production is a economic way to prevent hazardous impact of solid waste coming from alumina processing plants. However, due to the Bauxite origin and utilizing technology of alumina processing plants, the composition and properties of Red mud is very different. Tanrai Alumina Processing plant, Lamdong, Vietnam is a new and big aluminium prodution plant in Vietnam with capacity 650,000 tons alumina annually. The plant uses local Bauxite from Baoloc mine, Lamdong province and Bayer technology for alumina prodution. The plant began to produce production at the end of 2012. Investigation on material composition and properties of Red mud coming from Tanrai Alumina Processing plant, Lamdong in orientation of it's use for construction building material is a main objective of VNU project "Research on Manufacture of Construction Building Materials from Red Mud coming from Alumin Production Technology in Taynguyen"

International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

2. MATERIALS AND METHODS

2.1. Materials

- Red mud (BĐ) was taken from Red mud reservoir of Tanrai Alumina Processing plant in March, 2013.
- Bauxite ore (BQ) was taken from Baoloc Bauxite mine in March, 2013. It's located about 5 km from Tanrai Alumina Processing plant.

2.2. Research methods

2.2.1. Method of determination of radioactive elements.

- Radioactive elements have analysed by Gamma spectrum method to detemine the spectific activity (Bq/kg) of radioactive isotopes and content of U, Th, K in the samples. Radioactive activity was determined by total absorption peak of intensity gamma line; such as: 295,22 KeV and 351,93 KeV of Pb-214; 609,31 KeV; 1120,22 KeV of Bi-214; 238 KeV of Pb-212; 583,19 KeV of Tl-208 and 1,46 MeV of K-40. Calculation the annual effective dose at the sampling location based on the content of elements and radioactive activity measured.
- Equipment and standard sample: the gravelly samples were grinded before locked up in 20 days to set up radioactive equilibrium status between Radium and Radi's product. After locked, the samples were measured by ultra-pure wide band semiconductor Gamma spectrometer system BEGe – BE 5030 (Camberra supplied). It used Genie software 2000-3.0 to analyse Gamma spectrometer. The calculation of radioative isotopes activity were performed by software accompany the measured system, based on radioative standard sample set IAEA –RGU-1 and IAEA RGTH supplied by The International Energy Agency (IAEA) and standard sediment samples supplied by Bordeaux Nuclear Research Institue, French Republic were control samples.

2.2.2. Method of define several basic chemical and physical characteristics of Red mud

- Physical texture of Red mud were defined by using straws Robinson according to TCVN 5257:1990;
- Red mud samples was broken by fusing Na_2CO_3 and K_2CO_3 in platin cup at 1.000^0C. The sample was dissolved by hot acid HCl 1:1, norm up to 250 mL. The solutions were used to determine percent of the oxides and heavy metals, specifically:

+ Fe_2O_3 was defined by complexon titration method according to ISO 141:2008;
+ Al_2O_3 was defined by complexon titration method according to TCVN 7891:2008;
+ SiO_2 was defined by gelatin method according to TCVN 7891:2008;
+ Na_2O; CaO; K_2O and MgO were defined by Absorption spectrum method on the AAS 6800 Shimazdu firm, Japan according to TCVN 4053:1985;
+ P_2O_5 was defined by molipden clolourimetry method in wavelength λ = 710 nm according to TCVN 4052:1985;
+ TiO_2, MnO, Cu và Zn were defined by flame element absorption spectrum method on AAS 6800 Shimazdu firm, Japan according to TCVN 6496 ISO 11047:1995;
+ Pb và Cd: were defined by not flame element absorption spectrum method on AAS 6800 Shimazdu firm, Japan according to TCVN 6496 ISO 11047:1995.
+ Other metals determined by Neitron Activation analysis in Nuclear Research Institute, Dalat city, Vietnam.

2.2.3. Method of mineral analyse

Mineral composition of red mud has been determined by X-rays method on Rongen diffractometer XRD D5005 with Cu anticatode in VNU-University of Science. X-ray diffraction angle changes from 5^O to 72^O, U_{AK} =40 KV, I=40 mA.

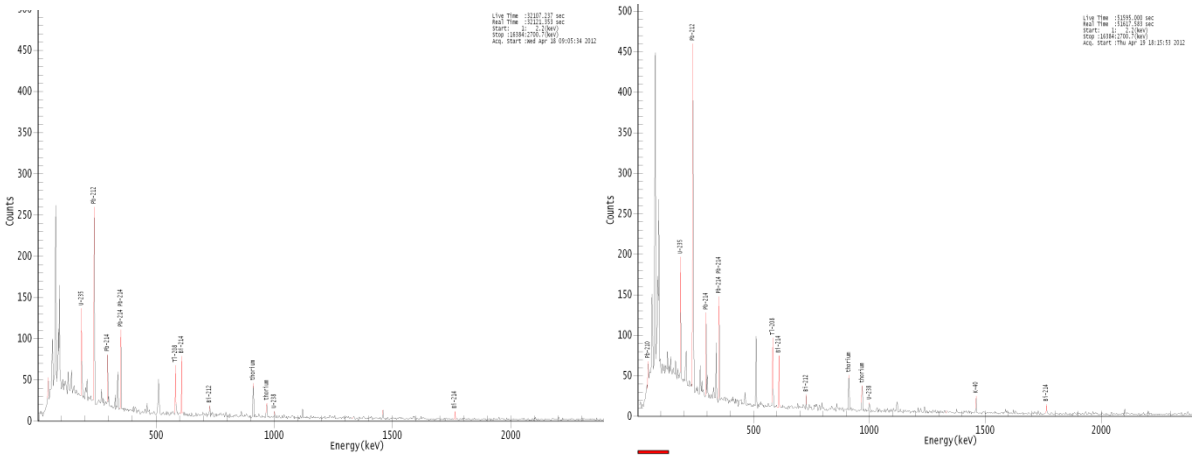
International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

3. RESULTS AND DISCUSSION

3.1. Identification the radioactive elements.

Gamma spectrum of 02 samples including Bauxite ore (BQ), Red mud (BĐ) are showed in Figure 1 and Table 1-2.



a **b**

Figure 1. Gamma spectrum of studied samples (a. Bauxite ore; b. Red mud)

Research results in Figure 1 showed that in the Gamma spectrum apppeared clearly the large intensity line of radioactive isotopes in the natural radioactive U and Th.

Table 1. Radioactive activity of some natural radioactive isotopes in the Uranium, Thorium and Potassium in Bauxite ore

adioactive isotopes	Particular activity (Bq/Kg)	Note
Pb-214	19,90±2,62	Row U^{238}
Bi-214	17,73±2,14	Row U^{238}
Ac-228	37,72±4,53	Raw Th^{232}
Pb-212	30,54±3,66	Raw Th^{232}
Tl-208	29,76±3,66	Raw Th^{232}
K-40	11,3±1,6	

Table 2. Radioactive activity of some natural radioactive isotopes in the Uranium, Thorium and Potassium in red mud

Radioactive isotopes	Particular activity (Bq/Kg)	Note
Pb-214	15,05±0,13	Raw U^{238}
Bi-214	16,24±1,45	Raw U^{238}
Ac-228	29,39±2,64	Raw Th^{232}
Pb-212	30,09±2,78	Raw Th^{232}
Tl-208	28,68±2,58	Raw Th^{232}
K-40	12,57±0,95	

Research results in Table 1 to 2 showed that in the samples did not find artifical radioactive isotopes such as ^{137}Cs, ^{7}Be; Radioactive activity of the Uranium's descendants and Thorium's descendants respectively approximation. The radioactive isotopes in the Uranium and Thorium content in the radioactive equilibrium status. The content of Uranium and Thorium in Bauxite ore and Red mud lower than the average content of Uranium (2ppm) and Thorium (12ppm) in the Earth's crust (Table 3). Uranium content varied from 1,27 ppm for Red mud to 1,53 ppm for Bauxite ore, which are both lower and close the average value of Uranium content in the Earth's crust. Thorium content varied from 7,22 ppm for red mud to 8,03 ppm for Bauxite ore, are lower than the average value of Thorium content in the Earth's crust. Potassium content were little and varied from 0,045 % for red mud model to 0,042 % for Bauxite ore, are lower than the average value of Potassium content in the Earth's crust.

International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

Table 3. Content of U, Th, K in samples and to cause of effective annual dose of gamma radiation font

No.	Sample	Colour	U (ppm)	Th (ppm)	K (%)	*Effective annual dose* (mSv/year)
1	BQ	Grey	1,53	8,03	0,042	0,26
2	BĐ	Yellow	1,27	7,22	0,045	0,23

Research results in Table 3 showed that, according to United Nations Scientific Committee on the Effects of Atomic Radiation to the General Asembly (UNSCEAR), the annual effective dose due to natural gamma font is 0,5 mSV. According to the standard of Vietnam (TCVN 6866:2001) for residents, the limit effective dose annual total is 1mSv. The effective dose annual of research Red mud and Bauxite ore of Tanrai Alumina Processing plant appropriate varied range from 0,23 for Red mud to 0,26 mSv/year for Bauxite ore, which lower than the average effective annual dose due to gamma radiation front (0,5 mSv/year).

3.2. Several basic chemical and physical characteristics of Red Mud

3.2.1. Physical texture of Red Mud

Analysising results of physical texture of Red mud was shown in Table 4.

Table 4. Physical texture of red mud

Sand (0,05<x<1 mm)	Limon (0,001<x<0,05 mm)			Clay (<0,001 mm)
57,056 %	33,814 %			9,13 %
	Limon rough	Limon average	Fine-grained Limon	
	20,13 %	10,076 %	3,608 %	

Results in Table 4 showed that, the physical texture of Red mud classified by equilateral triangle are sandy loam (57,056% sand; limon 33,814%; clay 9,130%)

3.2.2. Concentration of oxides

Analysing results of the oxides in the Red mud Tanrai Alumina Processing plant can be compare with Red mud of Australia, Germany and Italy showed in Table 5.

Table 5. Concentration of oxides in Red mud of Tanrai Alumina Processing plant (Vietnam) and some other countries in the world [9], (%)

	Fe_2O_3	MnO	TiO_2	CaO	K_2O	P_2O_5	SiO_2	Al_2O_3	MgO	Na_2O
Red mud Vietnam	30,8	0,02	2,58	3,51	0,11	0,22	31,7	15,6	0,27	3,14
Red mud (Australia)	29,6	0,02	2,65	3,64	0,46	0,24	30,0	17,3	0,23	3,2
Red mud (Germany)	44,8	0,06	12,33	5,22	0,27	0,45	5,4	16,2	0,13	4,0
Red Mud (Italy)	15,2	0,01	6,15	4,23	1,10	0,15	18,6	24,7	0,46	11,7

In the Bauxite ore, iron is common find in the composition of the minerals such as: Hematite (Fe_2O_3), Magnetite (Fe_3O_4), Limonite (FeOOH), clay minerals [9]. Analysing results of Table 5 showed that: Fe_2O_3 content in Red mud of Tanrai Alumina Processing plant was 30,8% in 2,0 times higher than in Italy's Red mud but lower than in Germany's Red mud and equivalent Autralia's Red mud.

Silicon element which is the second at percentage after oxygen (27,6%) in the soil is common in form of Quartz (SiO_2). Silicon can be find in Red mud in form of Quartz and clay minerals (Kaolinte, Monmorillonite, Illite). Analysising results of Table 5 showed that SiO_2 concentration in Red mud of Tanrai Alumina Processing plant was 31,7%, higher than concentration of SiO_2 in Germany's and Italy's Red mud and equivalent of Australia's Red mud.

International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

Analysing results of Table 5 showed that TiO_2 concentration was 2,58% in Red mud of Tanrai Alumina Processing plant, higher than concentration of TiO_2 in Germany's and Italy's Red mud and equivalent of Australia's Red mud.

Analysing results of Table 5 showed that Al_2O_3 concentration in Red mud of Tanrai Alumina

Processing plant was 15,6%, lower than Al_2O_3 in Germany's, Italy's and Australia's Red mud.

Concentration CaO was 3,51% in Red mud Tanrai Alumina Processing plant lower than CaO content in

Germany's, Italy's and Australia's Red mud. MgO content in Red mud of Tanrai Alumina Processing plant was 0,27% respectively with 59% MgO content in Italy's Red mud but higher than MgO content in Gemany's and Australia's Red mud.

3.2.3. pH of Red mud sluge

Analysing results of the pH value for Red mud solution coming from Bayer technology of Tanrai Alumina Processing plant were shown in Table 6. High pH of Red mud solution can become a strong environmental impact to soil and water basin.

Table 6. pH and concentration of some heavy metals in Red mud

No.	Heavy metal	Unit	Red mud	QCVN 03:2008/BTNMT (industrial soil)
1	pH_{H2O}	-	11,23	-
2	pH_{KCl}	-	11,12	-

3.2.4. Heavy metals and rare elements concentration of Red mud

Complete analysing result of heavy metals and rare elements concentration in Red mud of Tanrai Alumina Processing plant was given in Table 7.

Table 7. Concentration of heavy and rare metals in Red mud from Tanrai Alumina Processing plant, Lamdong, Vietnam

N^0	Heavy metal	Unit	Concentration	N^0	Heavy metal	Unit	Concentration
1	Sr	Ppm	52.7	24	Nd	Ppm	4.12
2	Th	Ppm	0.50	25	Sm	Ppm	0.82
3	Nb	Ppm	13.0	26	Tb	Ppm	0.70
4	Ni	Ppm	25.7	27	Er	Ppm	0.34
5	Zr	Ppm	10.24	28	Y	Ppm	0.99
6	Hf	Ppm	1.80	29	As	Ppm	10.4
7	Ce	Ppm	11.4	30	Cd	Ppm	0.80
8	Sc	Ppm	0.81	31	Co	Ppm	52.1
9	Co	Ppm	47.5	32	Cr	Ppm	34.9
10	La	Ppm	5.31	33	Cu	Ppm	9.86
11	Pr	Ppm	0.61	34	Li	Ppm	13.9
12	Eu	Ppm	1.71	35	Mo	Ppm	1.01
13	Gd	Ppm	0.69	36	Mn	Ppm	303
14	Dy	Ppm	0.61	37	Ni	Ppm	22.1
15	Ho	Ppm	0.19	38	Pb	Ppm	34.3
16	Tm	Ppm	0.05	39	Sb	Ppm	2.41
17	Yb	Ppm	0.20	40	Se	Ppm	0.71
18	Lu	Ppm	0.04	41	Sr	Ppm	50.6
19	Rb	Ppm	25.8	42	Tl	Ppm	0.32
20	Ba	Ppm	61.2	43	V	Ppm	6,035
21	U	Ppm	1.73	44	W	Ppm	22.9

International Journal of Research In Earth & Environmental Sciences

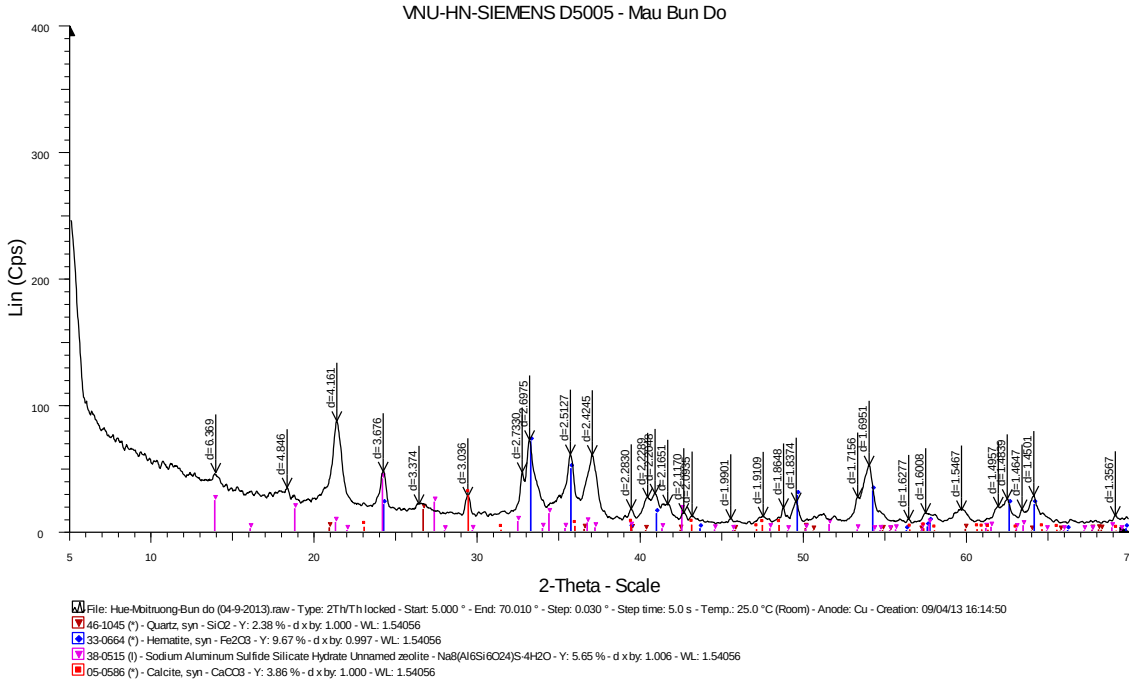
http://www.ijsk.org/ijrees.html

22	Ta	Ppm	0.85	45	Sn	Ppm	6.03
23	Cs	Ppm	1.14	46	Zn	Ppm	52.7

Accoding to results in table 7, Red mud of Tanrai Alumina Processing plant contents many heavy metals with high concentration (V, Zn, Ba, As, Co, Cr, Mn, Pb, Sr,..) and rare elements. Heavy metals will become hazardous matter for environment (soil, water and air) where they can to penetrate to water basins or cultural fields. Some of heavy metals in Red mud (V, Ti, Fe) can be extract as mineral resources.

3.2.5.Mineral composition of Red mud

Mineral composition of Red mud of Tanrai Alumina Processing plant has been determined by X-ray method showed in figure 2. Accoding to figure 2, almost of Red mud component is in amosphous or microcrystal state and some part can be determined by X-ray diffraction patterns, such as Hematite (Fe_2O_3), Quartz (SiO_2), Calcite ($CaCO_3$) and new synthetic mineral with chemical formula $Na_8(Si_6Al_6O_{24})S.4H_2O$.



4. CONCLISIONS

Red mud of Tanrai Alumina Processing plant did not contain artificial radioactive isotopes such as ^{137}Cs, ^{7}Be; concentration of Uranium, Thorium in Red mud are less than the average concentration values of Uranium (2ppm) and Thorium (12ppm) in the earth's crust; annual effective dose caused by gamma radiation font was smaller than the average effective dose was recommended by UNSCEAR. Physical texture of Red Mud classified by equilateral triangle are sandy loam 57,056%; limon 33,814%; clay 9,130%. Chemical composition of Red mud was, by weight (%): Fe_2O_3 - 30,8; SiO_2 - 31,7; Al_2O_3 - 15,6; TiO_2 - 2,58; Na_2O - 3,14, CaO - 3,51; K_2O - 0,11; MgO - 0,27; MnO - 0,02; P_2O_5 - 0,22. Red mud also contains some heavy metals including lower than the standard QCVN 03:2008/ BTNMT. Almost of Red mud is in amorphous and microcystal state, small part Red mud can be determined by X-ray method as minerals: Hematite, Quartz, Calcite, new synthetic mineral. That Red mud Tanrai Alumina Processing plant can be used to produce building materials for civil construction.

ACKNOWLEDGEMENT

Research was completed under the support of Vietnam National University Hanoi Project, code: QGTĐ-11-06. The authors would like to thank a lot.

International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

REFERENCES

1. Wanchao Liu, Jiakuan Yang, Bo Xiao, *Aplication of Bayer red mud for ion recovery and building material production from alumosilicate residues*; J. Hazardous Materials, 161 (2009), 474-478.
2. Jiakuan Yang, Bo Xiao, *Development of Unsintered construction materials from red mud wastes produced in sintering alumina process*, J.Construction and Building Materials, 22 (2008), 2299-2307.
3. Huizhi Yang, Chanping Chen, Lijun Pan, Hongxia Lu, Hongwei Sun, Xiang Hu; *Preparation of double-layer glass-ceramic tile prom bauxit tailings and red mud*, J of the European Ceramic Society, 29 (2009), 1887-1894.
4. S.D. Muduli, P. K. Rout. S. Pany, S.M, Mustakim, B.D. Nayak, B.K. Mishra; *Inovative Process in Manufacture of Cold Setting Building Brick from Mining and Industrial Wastes*, The Indian Mining and Engineering Journal, 2003, p. 127-130.
5. Taner Kavas, Use of Boron Wastes as a Fluxing Agent in Production of Red Mud Bricks, J. Building and Environment, 42 (2006), p. 1779-1783.
6. Ekrrem Kalkan, *Utilization of Red Mud as a Stabilization Material for the Preparation of Clay Liners*, Engineering Geology 87 (2006) p. 220-229.
7. A.Acosta, I. Iglesias, *Utilisation of IGCC Slag and Clay Steriles in Soft Mud Bricks (by Pressing) for use in Building Bricks Manufactering*, Waste Management 2002, vol 22, p.887-891.
8. Vincenzo M. Sglavo, Stefano Maurina, Alexia Conci, Antonio Salviati, Giovani Carturan, Giorgio Cocco, *Bauxite Red Mud in Ceramic Industry. Part 2; Production of Clay-based ceramics*, Journal of the European Ceramic Society 20 (2000) p.245-252.
9. K. Snars, R.J. Gilkes, *Evaluation of bauxite residues (red muds) of defferent origins for environ-mental applications*; J. Applied Clay Science, 2009.