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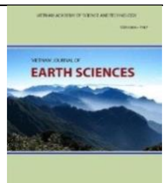

Assessment of the usability of Tam Bo bentonite (Di Linh - Lam Dong) for peloid

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ABSTRACT

The study was carried out to assess the suitability of Tam Bo bentonite for application in peloid. By using the XRD analysis method, the results showed that the mineral component of Tam Bo bentonite was mainly smectite (montmorillonite) (55-73%), illite (10-14%), quartz (10-16%), and minor minerals such as siderite, feldspar, goethite, chlorite and kaolinite. Chemical composition of the samples analyzed by the XRF method composed of a high amount of SiO_2 (51.38-55.16%) and Fe_2O_3 (5.31-7.97%), low content of Al_2O_3 (14.58-20.87%), and the other oxides with low content. The analysis result using the ICP-OES method indicated that bentonites in Tam Bo consisted of trace elements such as As, Ba, Cr, Cd, Co, Cu, La, La, Pb, Sb, Sc, V, Zn, and their content is similar to the values in peloid for the commercial use. Tam Bo bentonite has a pH value of 8.17, a very high CEC index (71 mg/100 g), a plasticity index of 28%, expandability of 70%. All of the samples did not contain pathogenic bacteria. The study result confirms that Tam Bo bentonite responses to the criteria for making the peloid and similar to the peloids of Vale das Furnas (in Portugal), Calda (in Italy), Archena (in Spain).

Keyword: Peloid, bentonite, montmorilonite, clay mineral.

1. Introduction

According to Gome et al. (2013), “Peloid is a maturated mud or muddy dispersion with healing and/or cosmetic properties, composed of a complex mixture of fine-grained natural materials of geologic and/or biologic origins, mineral water or seawater, and common organic compounds from biological metabolic activity”. The peloid was classified into two major groups: Natural peloids defined “as maturated in situ healing mud or muddy dispersion composed of a complex mixture of fine-grained materials, mineral water or seawater, and often organic compounds from biological metabolic activity” and Artificial peloids or peloids s.s. defined “as a healing mud or muddy dispersion resulting from the mixture clay/mineral water (natural mineral water or seawater) dressed and maturated in an artificial environment, more precisely in open or closed tanks with or without stirring” (Gome et al., 2013).

In the pelotherapy, there is a lack of standards for the quality of peloid. However, there are many successful studies on the Physico-chemical characteristics of the materials used to make peloids. Most studies showed that the most important characteristics of materials for peloid use were chemical

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composition, mineral component, cation exchange capacity, and particle size distribution (Khlaifat et al., 2010; Mihelčić et al., 2012; Rebelo et al., 2011; Summa & Tateo, 1998). The most suitable material for making the peloid is clay minerals, especially smectite (Cara et al., 2000a, 2000b). Several studies have also shown that the presence of microorganisms and the heavy metal content of peloid was also important (Summa & Tateo, 1998; Tateo et al., 2009).

Peloid made from bentonite was used in many places in the world like in Sardinia (Italy) (Cara et al., 2000a), Archena (Spain) *(*Carretero et al., 2010), Guas de Lindóia(Torrecilha et al., 2019), Turkey (Kayrakayaet al., 2010). Bentonite used as raw material for pharmaceutical and cosmetic applications must have no harmful chemical, mineral, and microbiological composition. This means that this type of clay does not contain cancer-causing elements (As, Pb, Cd, Hg,...), minerals such as fine-grained silica and quartz, or pathogenic microorganisms (Escherichia coli, Pseudomonas aeruginosa, Salmonella spp., and Staphylococcus aureus), unless the content of these component satisfies the requirements which were specified by the different Pharmacopoeias (Gome et al., 2015).

In Vietnam, the source of bentonite clay is quite abundant and had been found in many places such as Co Dinh - Thanh Hoa, Tuy Phong - Binh Thuan, and in Center Highlands were Tam Bo - Di Linh - Lam Dong, Chu Se - Gia Lai,... From the 1990s, bentonite mines, especially the Tam Bo bentonite, were investigated and studied in detail on reserves and characterization of material component (Doan S.H., 1982; Hoang M.T. et al., 2014; Pham T.N. et al., 2016). For application, Tam Bo bentonite was used in many fields including drilling fluids(Ta D.V., 1990), environmental treatment (Kieu Q.N., 2004; Kieu Q.N., Nguyen H.T.P., 2005), feedstuffs for the animal (Nguyen V.H. et al., 2008; Le H.S. et al., 2008; Bui Q.C. et al., 2014), nanocomposite (Trinh T.K.T. et al., 2005). Bentonite clay with special properties has been studied and applied in a variety of fields. However, the study of the use of this clay in beauty and health care in spas, typically in ecotourism destinations and resorts has not yet been attended widely, although it promises to bring to high potential in new tourism product development.

Besides, the Central Highlands of Vietnam is one of the most fascinating areas because of stunning natural beauty with many beautiful sights such as Lak Lake (Dak Lak), Bien Ho (Gia Lai); a lot of waterfalls including Dray Sap, Dieu Linh, Phu Cuong, Luu Ly, Cam Ly, Pren; many hot springs consisting of Konnit, Kon Dao, Dak Ring, Dam Rong (Lam Dong)…; and recently, lava caves discovered in Krongno Volcano Geopark, Dak Nong (La T.P. et al., 2017; 2018). This region was considered as one of seven key tourism regions in Vietnam in the development strategy for Vietnam tourism to 2020, vision 2030 (Le V.M., 2019). At present, the region has been building many luxurious resorts such as Tuyen Lam, Dan Kia (Da Lat - Lam Dong), Mang Den (Kon Tum). This is a promising prospect of the use of bentonite for human health. On the one hand, it will raise the use-value of this mineral material, but on the other hand, it will improve the quality of tourism products in spas, resorts in the Central Highlands and in Vietnam in general.

In this paper, the authors present the results of mineralogical, chemical composition, and physicomechanical, physicochemical properties. From these results, we conduct to assess the ability of the use of this raw material in making the peloid.

2. Sample and methods

2.1. Sample

Studying samples were collected in 9 positions at the bentonite mining open pit of

Lam Dong Minerals and Building Materials Joint Stock Company in Tam Bo commune, Di Linh district, Lam Dong province. The research area was in the margin of the Cenozoic Di Linh - Bao Loc Basin, formed on Mesozoic Da Lat superimposed depression, composed of La Nga Formation (J_2*ln*), Dak Rium Formation (K_2 *đr*), Don Duong Formation (K_2*đd*), Di Linh Formation (N_1^3-N_2^1*dl*), Tuc Trung Formation (βN_2-Q_I*tt*), Xuan Loc Formation (βQ_{II}*xl*) (Doan S.H, 1982) (Fig. 1). The Tam Bo bentonite mine was in Neogene sediments of the Di Linh Formation with an exposed area of about 10 km, belonged to lacustrine facies. Neogene sediments at Tam Bo were rhythmic sedimentation, divided into three rhythms. The lower part contained coarse-grained materials such as sandstone, gritstone, tuff, and basalt, and the upper part consisted of silty clay such as bentonite, kaolinite, diatomite (Fig. 1).

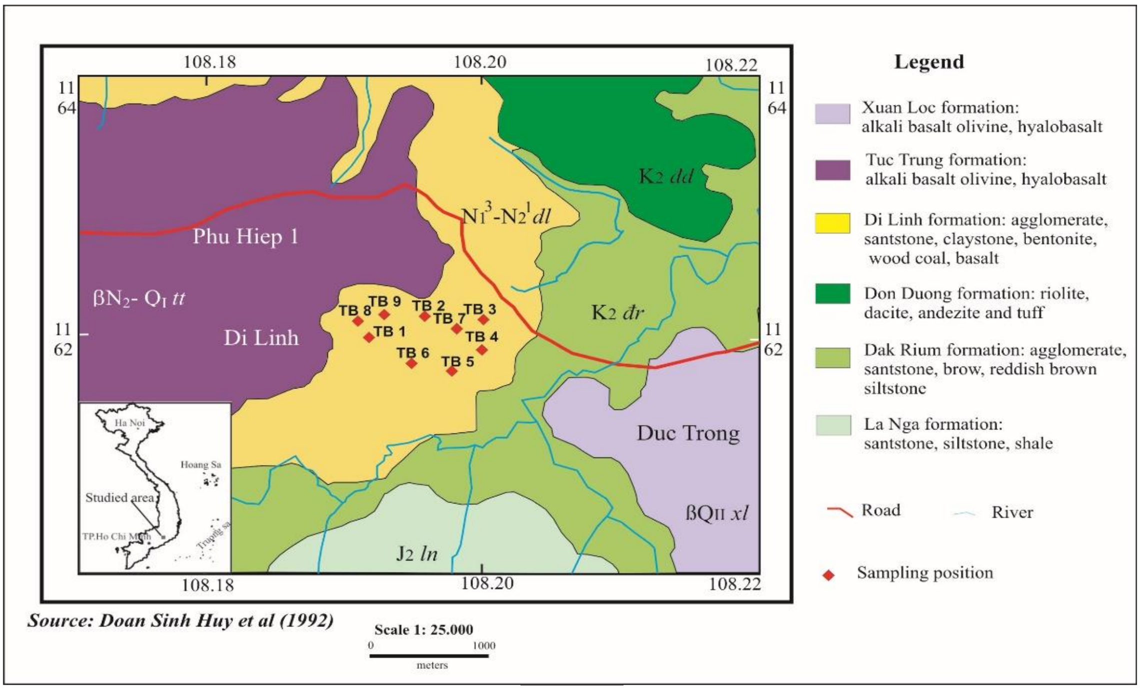

Figure 1. Shemical map of positions for sampling

Samples were taken to ensure the original state according to the Vietnamese standard TCVN-7538-2:2005 (ISO 10381-2:2002). The bentonite samples were soft and flexible with yellow, greyish yellow, yellowish green, and green colors (Fig. 2).

2.2. Methods

The mineralogical analysis was performed by the X-ray diffraction method (XRD), using the Empyrean-PANalytical system with Cu-Kα radiation and the 0.013^o/s step, at Institute of Geological Sciences - Vietnam Academy of Science and Technology. The samples for XRD analysis were prepared in powder form. The obtained XRD phases were processed by HighScore Plus software for calculating thesemi-quantitation of minerals.

Differential thermal analysis method (DTA) is used for quantitative analysis of mineral phases based on their chemical reactions and physical properties. This method was carried out on the STD-PT 1600 system-Center for Geological Experimental Analysis

- General Department of Geology and Mineral Vietnam.

X-Ray Fluorescence (XRF) method was used to determine main elements and was performed at the Institute of Geological Sciences - Vietnam Academy of Science and Technology. Trace elements were determined by Inductively coupled plasma optical emission spectroscopy (ICP-OES) (Performed at the National Institute of Mining Metallurgy science & technology).

Cation exchange capacity (CEC) was determined by the methylene blue adsorption method. Bentonite was dispersed to make a suspension solution so that the pH reached the value of 2.5-3.8, then added by methylene blue solution (3g/l concentration) until a pale blue halo appeared. The volume of the methylene blue solution at the endpoint was measured and calculated. The plasticity index was determined by the difference of the humidities at the liquid limit and the plastic limit, according to TCVN-4197:2012. Expandability was determined according to TCVN-8719:2012. Analysis of particle size of samples was determined by the pipette method, and described as follows: Samples were stirred by an ultrasonic stirrer to disperse particles of clay. At different temperatures and times, a solution containing clay particles was sucked out at a certain depth. Based on the amount of the solution taken out, the percentages of grain levels were calculated. Microorganism content in samples was also determined by colony counting method at Soils and fertilizers research institute. The method was performed as follows: dilute the sample with Saline peptone water solution at the ratio of 10 g of sample + 90 ml of diluted solution, then the sample was put into the environment, incubate the sample, count the colonies formed and calculated.

(a) (b)

Figure 2. Open-pit mining of the Tam Bo bentonite (a) and samples (b)

3. Results

Mineral composition of Tam Bo Bentonitewas mainly montmorillonite from 55-73% (average 70%), illite from 10-14% (average 12%), quartz from 10-16% (average 14%) and some minor minerals (kaolinite, chlorite, feldspar, goethite, siderite) (Table 1, Fig.3, Fig.4).

Tam Bo bentonite had SiO_2 content from 51.38-55.16% (Average 53.13%), a low amount of Al_2O_3 from 14.58-20.87% (Average 18.34%), a quite high concentration of Fe_2O_3 from 5.31-7.97% (Average 6.59%), and all contents of the other oxides were low (Table 2). The study samples contained trace elements including As, Ba, Cr, Cd, Co, Cu, La, Li, Pb, Sb, Sc, V, Zn (Table 5).

Table 1. Mineral composition of Tam Bo bentonite (Unit: %)

Sample	Montmorilonite	Illite	Kaolinite	Chlorite	Quartz	Feldspar	Goethite	Other minerals
TB 1	73	12		-	12	few	few	Siderite-3%
TB 2	72	11	-	-	13	-	few	Siderite-2%
TB3	58	13	9	2	14	3	1	-
TB4	55	12	10	2	16	2	3	-
TB 5	63	14	2	2	14	2	few	Amphibol-3%
TB6	67	10	4	1	12	3	2	Lepidonite-1%
TB7	72	10		2	12	few	few	Amphibol-2%, Calcite-2%
TB 8	73	12		3	13	few	1	Dolomite -1%
TB 9	73	10		3	10	few	few	Siderite - 4%
Average	70	12	<3	<3	14	<3	<3	Siderite -3%

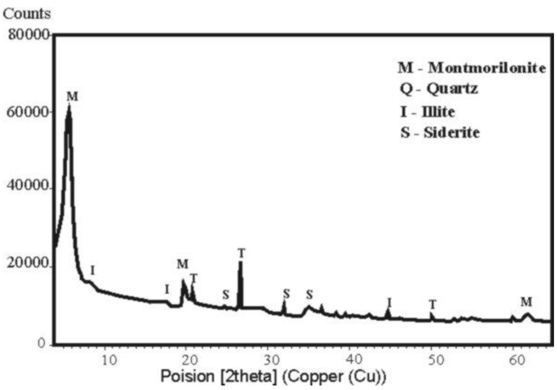

Figure 3. XRD diagram of Tam Bo bentonite

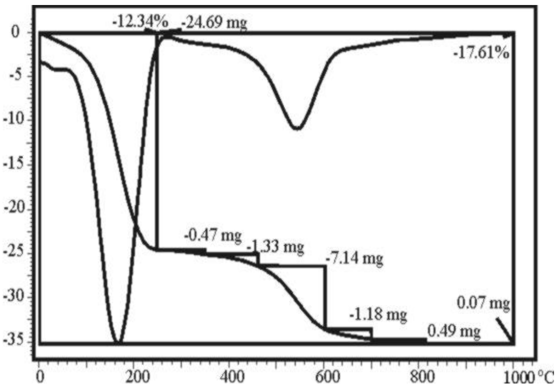

Figure 4. DTA diagram of Tam Bo bentonite

Table 2. Main element composition of Tam Bo bentonite

Composition(%)	Sample					Average
	TB 1	TB 2	TB 4	TB 6	TB 7	
SiO_2	52.61	51.38	53.11	53.37	55,16	53,13
Al_2O_3	17.27	19,49	20,87	19,47	14,58	18,34
Fe_2O_3	7.97	6,89	5,31	5,78	7,02	6,59
TiO_2	1.22	0,84	0,6	0,54	0,66	0,77
CaO	1.85	1.37	0.97	0.96	1.59	1.35
MgO	3.54	3.96	3.64	3.69	4.05	3.78
Na_2O	< 0.01	< 0.01	< 0.01	< 0.01	0.03	0.03
K_2O	0.35	0.97	1.08	1.12	0.7	0.84
P_2O_5	0.05	0.06	0.07	0.06	0.06	0.06
MnO	0.06	0.08	0.08	0.05	0.07	0.07
SO_3	0.05	0.04	0.07	0.05	0.07	0.06
LOI	15.03	14.92	14.2	14.91	16.01	15.01

The analysis result of particle size showed that clay particle size accounted for 81.4%, sand particle size (> 0.25 mm) was 3.2%. The clay had a high dispersion with particle size of < 0.005 mm accounting for 50.1%.

The pH value was 8.17, CEC index was relatively high (71 mg/100g). The plasticity index was 28% and classified in the medium type, expandability was 70%. The bacterial analysis showed that all samples did not contain bacteria, especially pathogenic bacteria such as E.coli and Samolina.

4. Discussions

The main mineral component of Tam Bo bentonite was clay (82%) in which smectite (montmorillonite) was predominantly (55-73%), illite (10-14%). In addition, some other minerals included quartz (10-16%), siderite (3%), feldspar (< 3%), goethite (< 3%), chlorite (< 3%), and kaolinite (< 3%). Comparing with some commercial peloid samples in the worldshown in Table 3, Tam Bo bentonite is one of the samples with a high amount of clay mineral. According to Cara et al. (2000a, b), if the peloid contained a high content of clay mineral, especially the smectite group, it will have high expandability, surface area, and cation exchange capacity. These properties determine the capacity to adsorb toxic elements of the peloid and make human skin more comfortable when using. Thus, for mineral composition, Tam Bo bentonite clay is suitable for making peloids.

Table 3. Mineral composition of Tam Bo bentonite and peloid in the world (Unit %)

	BK_1	BK_2	BK_3	BK_4	BK_5	BK_6	BK_7	BK_8	BK_9	BK_{10}	**TB**
Quart	15	27	21	2	10	6	10	9	< 1	< 1	**14**
Feldspar	25	10	11	-	< 1	-	3	< 1	-	1	**< 3**
Alunit	25	-	-	-	-	-	-	-	5	2	**-**
Fe Oxide	7	-	-	-	-	-	-	-	3	4	**< 3**
Anatas	-	-	-	-	-	-	-	-	1	1	**-**
Sulfur	-	-	-	-	-	-	-	-	52	41	**-**
Calcite	-	17	23	1	30	15	20	40	-	-	**-**
Siderite	-	-	-	-	-	-	-	-	-	-	**3**
Anhydrite	10	-	-	-	-	-	-	-	-	-	**-**
Gypsum	-	-	-	-	-	1	-	4	-	-	**-**
Dolomite	-	2	1	-	-	-	-	< 1	-	-	**-**
Halite	-	-	-	-	< 1	-	-	6	-	-	**-**
Silicon	-	-	-	-	-	-	-	-	-	6	**-**
Illite	-	28	19	6	32	17	19	35	-	-	**12**
Kaolinite	13	1	4	-	5	2	1	4	9	6	**< 3**
Smectite	5	-	17	89	23	21	45	-	27	39	**70**
Mixed layers	1	8	-	-	< 1	< 1	-	-	-	-	**-**
Chlorite	-	7	5	-	< 1	2	-	2	-	-	**< 3**

Note: BK_1-*Vale das Furnas (Portugal)* (Terroso et al., 2006), BK_2-*Calda (Italy)* (Summa & Tateo, 1998), BK_3-*Cappetta (Italy)* (Summa & Tateo, 1998), BK_4-*Archena (Spain)* (Carretero et al., 2010), BK_5-*Arnedillo (Spain)* (Carretero et al., 2010), BK_6-*Caldas de Boi (Spain)* (Carretero et al., 2010), BK_7-*El Raposo (Spain)* (Carretero et al., 2010), BK_8- *Lo Pagan (Spain)* (Carretero et al., 2010), BK_9- *Laguna del Chancho (Argentina)* (Baschini et al., 2010), BK_{10}- *Laguna Sulfurosa Madre (Argentina)* (Baschini et al., 2010), *TB-Tam Bo bentonite*

Measurement of particle size, especially fine grained-clay is to determine contact surface area, cation exchange capacity, or water holding capacity and clarify the interaction between particles of peloid. The peloid should be contained at least 70-80% of clay soil (< 2 µm) (Veniale et al., 2007). The peloid was recommended to have at least 60 to 70% of swelling-exchanging clay minerals (IARC, 1997). Besides, quartz is considered a carcinogen by inhalation if ít grain size is > 5µm (IARC, 1997). In Tam Bo bentonite, the content of clay particles was 81.4%, in which swelling-exchange clay (montmorillonite) was 70%, and the grain size distribution of sand (> 0.25 mm) was 3.2%. These results confirmed that the grain size of Tam Bo bentonite is very suitable for making peloids.

According to the main element composition shown in Table 4 and Fig. 5, it can be seen that Tam Bo bentonite was Ca-bentonite because they had a high content of Ca (CaO-1.35%) and a low amount of Na (Na_2O-0.03%) (Na_2O/CaO = 0.02). The main elements in Tam Bo bentonite samples were Si (52.83%), Al (18.34%), Fe (6.59%), Mg (3.78%), Ca (1.35%). All of the chemical elements such as H, O, C, N, Na, K, Ca, Mg, P, S, and Cl can be essential or probably essential to human body equilibrium (Lehninger et al., 2004). Accordingto Gome and Silva (2007), the Si element is used on osteoarticular and muscular pathologies because it is considered to be necessary for the synthesis of collagen. The trace elements and Ca^{2+} content in the peloid are important factors in the treatment of mud, involving penetration through the skin and deposition in bone. Besides, Ca, P, and Mg are the basic elements for a good state of bone; and S element helps stabilize protein structure (Gomes & Silva, 2007). Although the elements in the peloid samples of the spas in the wold have a great change in the value, the content of the main elements of Tam Bo bentonite is in this range of the value. Bentonite in the study area is quite similar to peloid samples in Vale das Furnas (Portugal) (Terroso et al., 2006), Calda (Italy) (Summa & Tateo, 1998), and Archena (Spain) (Carretero et al., 2010).

Table 4. Main elements of Tam Bo bentonite and peloid in the world (*Unit %)*

	BK_1	BK_2	BK_3	BK_4	BK_5	BK_6	BK_7	BK_8	BK_9	BK_{10}	**TB**
SiO_2	52.16	52.02	44.14	51.12	39.35	19.38	39.73	18.41	16.33	27.48	**52.83**
Al_2O_3	19.79	13.78	11.93	5.25	12.24	3.85	10.08	3.58	7.12	10.72	**18.34**
Fe_2O_3	1.76	5.78	5.27	1.70	5.24	1.88	4.49	1.72	2.96	6.84	**6.59**
MgO	0.27	2.66	2.81	22.35	1.35	0.98	1.25	4.06	0.31	0.67	**3.78**
CaO	0.17	9.40	13.89	2.27	18.19	17.56	18.30	26.48	0.27	0.74	**1.35**
Na_2O	1.20	0.83	0.66	1.86	0.58	0.30	0.32	4.34	0.18	0.3	**0.03**
K_2O	2.45	2.22	2.03	1.07	2.57	0.57	1.52	1.10	0.37	0.44	**0.80**
TiO_2	1.24	0.65	0.58	0.32	0.44	0.26	0.55	0.22	0.76	0.78	**0.77**
P_2O_5	0.19	0.14	0.15						0.12	0.13	**0.06**
MnO	0.03	0.08	0.07	0.03	0.61	0.03	0.06	0.02	0.01	0.03	**0.07**
LOI	15.34	12.47	18.48	13.95	19.29	53.84	23.60	37.66	71.4	51.7	**15.01**
SO_3	4.84	0.19		0.07	0.06	1.30	0.10	2.37			**0.06**

Note: BK_1-*Vale das Furnas (Portugal)* (Terroso et al., 2006), BK_2-*Calda (Italy)* (Summa & Tateo, 1998), BK_3-*Cappetta (Italy)* (Summa & Tateo, 1998), BK_4-*Archena (Spain)* (Carretero et al., 2010), BK_5-*Arnedillo (Spain)* (Carretero et al., 2010), BK_6-*Caldas de Boi (Spain)* (Carretero et al., 2010), BK_7-*El Raposo (Spain)* (Carretero et al., 2010), BK_8-*Lo Pagan (Spain)* (Carretero et al., 2010), BK_9-*Laguna del Chancho (Argentina)* (Baschini et al., 2010), BK_{10}-*Laguna Sulfurosa Madre (Argentina)* (Baschini et al., 2010), *TB-Tam Bo bentonite*

The trace elements of Tam Bo bentonite were shown in Table 5, Fig. 5, and can be divided into 3 groups as follows:

The elements such as Ba, Cu, Hg, La, Mo, Sb, Sc, Se, Sn, Sr, W and Zn satisfy the limit established by the US Pharmacopoeia, Health Canada as well as in the limit of commercial peloids.

Some elements such as As, Cr, Ni, Pb, and V are in the limit of peloids using in spas. However, they exceed the allowable limit, especially Cr according to the standards in pharmaceuticals. Carretero et al. (2010) studied the mobility of element interaction between artificial sweat of skin and peloid. The main elements in peloid were leached through the skin as the following order: Na, Ca, Mg and K; Si and Sr; Ba and B; Al and Li; Fe, Mn, Mo and V; As, Sb and U were leached at the smaller proportion. Heavy metals such as Cu, Ni, Pb, and Zn in the peloid are leached from the sweat. The other trace elements (Ag, Be, Cd, Co, Cr, Hg, Rb, Se, Th, Tl) are not leached or leached in a lower concentration (below 0,05 µg/g). Thus, the elements including As, Cr, Ni, Pb, and V are in the group of elements that can be leached through the skin at low content or not leached.

Table 5. Trace elements in Tam Bo bentonite, peloids in the world and their limits in pharmaceutical and cosmetic products (Unit: ppm)

	BK$_1$	BK$_2$	BK$_3$	BK$_4$	BK$_5$	BK$_6$	BK$_7$	BK$_8$	BK$_9$	BK$_{10}$	**TB**	USP	HC
As	39	4.0	3.4	16.6	29.6	4.4	8.0	6.4	2.5	3.7	**6.7**		< 3
Ba	290			147.7	799	204.5	587.9	159.2	254	422	**187.8**		
Cr	23			14.6	68.2	50.5	65.4	42.3	601.1	578.4	**363.4**	< 25	
Cd		0.5	0.1	-	-	-	0.2	0.4	-	0.2	**1.0**		< 3
Co	-			5.1	16.8	5.7	14.6	4	9.5	13.8	**27.2**		
Cu	52	27	24	11.5	52.3	14.5	29.2	24.7	601.1	578.4	**10.6**	< 250	
Hg	-	0.05	< 0.02	-	-	-	-	-	-	-	**-**		< 3
La				15.9	43.1	14.9	37.9	17.8	13	13.7	**17.9**		
Mo				-	2.9	4.4	-	3.1	0.9	1.2	**0.6**	< 25	
Ni	10	58	67	3.4	50.8	21.1	35.1	20	15.9	54.1	**30.2**	< 25	
Pb	28	14	8.5	10.9	37	24.6	33.3	37.5	16.1	30.3	**18.1**		< 10
Sb			< 0.05	-	4.3	-	2.5	2.8	0.3	0.1	**5.0**		< 5
Sc				5	10.5	3	11.5	2.6	13	14	**8.5**		
Se		< 0.5	0.25	-	-	1.6	-	-	2.2	2.1	**0.5**		
Sn	17			-	2.3	-	-	-	2	2	**0.1**		
Sr	304			126	247.6	386.7	87.3	1879	130.9	162.7	**106.3**		
V	55			31.6	90.9	37.7	76.5	41.8	61	98	**82.3**	< 25	
W	-			3.6	-	4.3	3	4.2	1.1	19	**0.7**		
Zn	78	109	67	33.1	89.8	56.9	160.4	85.9	48	89	**85.8**	< 1300	

Note: BK$_1$-*Vale das Furnas (Portugal)* (Terroso et al., 2006), BK$_2$-*Calda (Italy)* (Summa & Tateo, 1998), BK$_3$-*Cappetta (Italy)* (Summa & Tateo, 1998), BK$_4$-*Archena (Spain)* (Carretero et al., 2010), BK$_5$-*Arnedillo (Spain)* (Carretero et al., 2010), BK$_6$-*Caldas de Boi (Spain)* (Carretero et al., 2010), BK$_7$-*El Raposo (Spain)* (Carretero et al., 2010), BK$_8$-*Lo Pagan (Spain)* (Carretero et al., 2010), BK$_9$-*Laguna del Chancho (Argentina)* (Baschini et al., 2010), BK$_{10}$-*Laguna Sulfurosa Madre (Argentina)* (Baschini et al., 2010), *TB-Tam Bo bentonite*, USP-*US Pharmacopoeia* (US Pharmacopoeia 29-NF 24, 2007), *HC-Health, Canada* (Health, Canada, 2009)

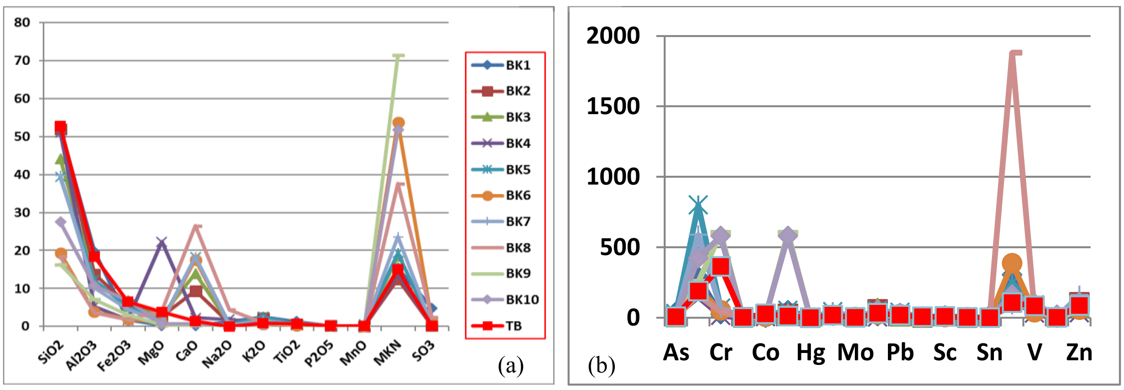

Figure 5. Comparing chart of main elements (a) and trace elements (b) of Tam Bo bentonite and some peloids in the world

The suitability of bentonite to peloid application is determined by its many other characteristics such as pH, cation exchange capacity, expandability, plastic index, microorganisms (Table 6).

Table 6. Physicomechanical characteristics of Tam Bo bentonite and peloids in the world

	BK_1	BK_9	BK_{10}	TB
CEC (mg/100g)	18.4			71
Expandability (%)	26.5			70
Plasticity Index	37.7	17.3	14	28

Note: BK_1-*Vale das Furnas (Portugal)*, BK_9-*Laguna del Chancho (Argentina)*, BK_{10}-*Laguna Sulfurosa Madre (Argentina)*, TB-*Tam Bo bentonit*

It is known that the natural pH of the skin is approximately 5 (Klee et al., 2009). The US Pharmacopeia specification indicates that a pH for smectites in pharmaceutical products ranges from 9 to 10 (US Pharmacopoeia 29-NF 24, 2007). The pH value of Tam Bo bentonite was 8.17 so it was alkaline. With this property, it can be used in clearing skin, especially oily skin and for sensitive skin, it should be avoided to use regularly because the skin will be dry and cracked.

In studies of the peloid which were used at spas in the world, there is only some information about important properties of peloid for pelotherapy use, includingcation exchange capacity (CEC), expandability, plasticity index. CEC values of Tam Bo bentonite ranged from 49.5 to 84.4 mg/100g; The average value was 71 mg/100g. Cation exchange capacity depends mainly on clay mineral composition. It is known that kaolinite and illite/chlorite exhibit lower CEC (<15-20 mg/100g and 10-40 mg/100g, respectively) than smectite (100-200 mg/100g) (Gomes, 2002, Lopez et al, 2007). CEC is one of the most important properties that make a peloid suitable for thermal (Veniale et al*.,* 2004). High CEC values of raw geological materials allow an exchange of nutrients when the peloid is in direct contact with skin (Carretero et al., 2006) and clear skin through the absorption of toxins, bacteria, and unwanted substances of the peloid from the skin (Matike et al., 2011). However, the ion exchange capacity of peloid can also transfer some ions from peloid to skin depending on the concentration (Matike et al., 2011). Thus, specific studies focused on the mobility of elements are necessary to determine the therapeutic role of a peloid for each special purpose.

For pelotherapy uses, peloids should possess enough plasticity to allow easy handling, adequate adherence properties, and effortless removal of peloids from the skin (Karakaya et al., 2010). According to the Casagrande chart adapted by Grabowska-Olszewska (1998) for peloid plasticity evaluation, the plasticity indexes of peloids ranged from 14.0 to 85.6 being classified as medium to high and very high plasticity. Tam Bo bentonite had a plastic index of 28% classified as medium.

The hygienic quality of the Tam Bo bentonite sample was also ensured because there was no pathogenic microorganism such as Escherichia Coli, Pseudomonaseruginosa, Staphylococcus Aureus, or Cyphanthera Albicanswas.

5. Conclusions

The studied results showed that the mineral component of Tam Bo bentonite was mainly smectite (montmorillonite) (55-73%), illite (10-14%), quartz (10-16%), and some minor minerals. Chemical composition composed ofa high amount of SiO_2(51.38-55.16%) and Fe_2O_3(5.31-7.97%), low content of Al_2O_3(14.58-20.87%), and the other oxides with the trace elements with low content. Tam Bo bentonite had a pH value of 8.17. CEC index was relatively high (71 mg/100g). The plasticity index was 28%. The expandability was 70%. All research samples had no pathogenic bacteria.

With these characteristics, Tam Bo bentonite meets the criteria of the peloid and can be used as a peloid.

However, Tam Bo bentonite is alkaline and suitable for oily skin, people with sensitive skin should not use regularly to avoid having dry, cracked skin.

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