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Refining to Enhance Quality and Improve Specific Surface Area of Di Linh Bentonite for Adsorption Application

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Abstract

Bentonite derived from Di Linh, Lam Dong has a low SiO_2/Al_2O_3 ratio (1.29), so the montmorillonite content in the bentonite is quite low. The mineral and chemical compositions show that this bentonite is of low quality and contains many impurities. A series of experimental conditions were considered to provide the appropriate process and conditions for refining to enhance the quality and improve the specific surface area of Di Linh bentonite. Specifically, the bentonite (2 wt.%) was soaked for 24 hours in water before stirring for 8 hours at 1000 rpm. After drying, the refined bentonite was annealed for 2 hours at 500 °C in a furnace. The final product obtained with the basal spacing of 17.38 Å and the specific surface area of 72.97 m^2g^{-1} was used to adsorb Pb^{2+} and active dyes. Thanks to the increase in the layer spacing and the specific surface area, both the adsorption capacity and the adsorption efficiency of Ben2-24-8-2 increased by 2.8 times compared to bentonite. While the dye adsorption took place slowly, the adsorption of Pb^{2+} ions was very fast and reached equilibrium after only about 0.5 hours. The Pb^{2+} ion adsorption capacity was 61.72 mg/g. The adsorption efficiency was 95.24% when using the Ben2-24-8-2 content of 2 g/l.

Keywords: Di Linh bentonite, specific surface area, refining, adsorbent.

1. Introduction

Bentonites are usually formed by alteration of volcanic ash or tuff, mainly rhyolitic or dacitic, either in situ or transported and redeposited [1,2]. Bentonite is mainly composed of smectites, a group of expandable clay minerals with a wide range of chemical compositions. Its smectites 2:1 structural unit is three-layer clay minerals in which one octahedral sheet is centered between two tetrahedral sheets by forming one unit layer and one tetrahedral sheet of one unit layer is adjacent to another tetrahedral sheet of another layer [2,3]. Tetrahedral sheets consist of corner-linked tetrahedra with oxygens in the corners and cations in the center. Dominant cation is Si^{4+}, but Al^{3+} is substituted for it frequently, up to half of the Si. Fe^{3+} is substituted for Si^{4+} occasionally. Octahedral sheets consist of edge-linked octahedra with OH in the corners and cations in the center. The cations are usually Al^{3+}, Mg^{2+}, Fe^{2+} or Fe^{3+}, but all other transition elements and Li are possible [1]. This special structure gives bentonite unique properties such as high cation exchange capacity, plasticity, and outstanding swelling performance [4]. Therefore, bentonite minerals have a wide range of applications in different industrial fields such as ceramic, cement, paints, drilling fluids, pharmacy, and paper industries [4].

According to the documents of geologists, Vietnam has discovered more than two dozen mines and points of bentonite clay ore. Prospective and large-scale mines are distributed in the southern provinces such as Lam Dong, Binh Thuan, and Ho Chi Minh City. In the North, bentonite clay is mainly distributed in the northern flat region like Thanh Hoa [7,8]. With abundant resources, bentonite is widely applied in the industry as well as in social life. However, the composition of bentonite in different regions is different and generally low-quality, contains many impurities and has a high iron oxide content, so it is often reddish brown in color [5-7]. Even so, it can still be applied in certain areas. However, in some other areas, bentonite needs to be refined, treated to improve quality to suit the unique requirements of each application. In the application as an adsorbent, the specific surface area is one of the important factors determining the adsorption efficiency [8]. Therefore, research to improve the specific surface area of bentonite is necessary for it to become an adsorbent. Refining bentonite to improve quality thereby improving specific surface area is the simplest method. Libing Liao and Guocheng Lv used a simple method to purify bentonite using sodium hexamethaphosphate $(NaPO_3)_6$ [9].

This paper deals with the refining process to enhance the quality and improve the specific surface area of Di Linh bentonite. Although using a simple method to purify bentonite, this paper did not need to use sodium hexamethaphosphate. The obtained product was used as an adsorbent to adsorb Pb^{2+} and active dyes.

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2. Materials and Methods

2.1. Materials

Bentonite is originated from Di Linh, Lam Dong, Vietnam. The chemical composition, element composition, and characteristics of bentonite are given in Table 1, Table 2, and Table 3, respectively. $Pb(NO_3)_2$ and Cibanon navy blue were purchased from Xilong, China, and Bestchem, Hungary, respectively.

Table 1. The chemical compositions of Ben and Ben2-24-8-2

Chemical composition	Content, %	
	Ben	Ben2-24-8-2
OH	10	10
Al_2O_3	29.677	30.943
SiO_2	38.395	38.930
K_2O	1.12	0.544
$CaCO_3$	3.107	2.613
TiO_2	2.071	1.558
Cr_2O_3	0.031	0.041
MnO	0.139	0.067
Fe_2O_3	15.298	15.134
NiO	0.015	0.016
CuO	0.019	0.037
ZnO	0.029	0.046
Rb_2O_3	0.015	0.008
SrO	0.025	0.021
ZrO_2	0.059	0.043

Table 2. The element compositions of Ben and Ben2-24-8-2

Element composition	Content, %	
	Ben	Ben2-24-8-2
H	0.593	0.593
C	0.373	0.314
O	51.009	51.288
Al	15.707	16.377
Si	17.948	18.197
K	0.930	0.452
Ca	1.244	1.046
Ti	1.241	0.943
Cr	0.021	0.028
Mn	0.107	0.052
Fe	10.700	10.585
Ni	0.012	0.012
Cu	0.015	0.029
Zn	0.024	0.037
Rb	0.012	0.006
Sr	0.021	0.018
Zr	0.044	0.032

2.2. Methods

2.2.1. Refining procedure

Bentonite is soaked in water to swell before being stirred at 1000 rpm for a specified time to form a suspension. This suspension is allowed to settle for 4-5 hours before removing the residue. The obtained fine suspension will be centrifuged to get a paste. This paste is dried to obtain refined bentonite. This refined bentonite can be further annealed at 500 °C to obtain the refined and heat-treated bentonite. The refining process and heat treatment of bentonite are shown in Fig. 1. The product is named a BenA-B-C-D, where A is a concentration of the suspension, B is a soaking time, C is a stirring time, and D is an annealed time.

Table 3. BET area, pore size, and volume for Ben and Ben2-24-8-2

Characteristics	Value	
	Ben	Ben2-24-8-2
Specific surface area, m^2g^{-1}	18.58	72.97
Pore size, nm	8.129	-
Pore volume, cm^3g^{-1}	0.09	-
CEC, meq/100g	28.0	32.2

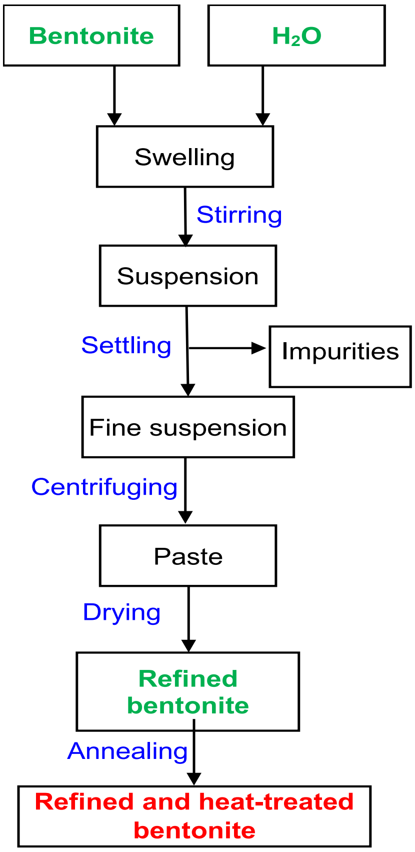

Fig. 1. Refining and heat-treating process

2.2.2. Analytical techniques

The chemical composition of bentonite was analyzed by x-ray fluorescence spectroscopy (XRF) on VietSpace 5008 (USA). The specific surface areas were determined by nitrogen adsorption via the Gemini VII, Micromeritics (USA). X-ray diffractometer patterns were obtained using a D8-Advance Bruker (Germany) with Cu Ka radiation (λ = 1.54178 Å) and a basal spacing of bentonite was determined by using (1).

$$d_{001}(\text{Å}) = \frac{\lambda}{2 \times sin\theta} \tag{1}$$

in which d_{001} is the basal spacing, θ is the incident ray angle, λ is the x-ray wavelength.

2.2.3. Cation exchange capacity test

The determination of cation exchange capacity (CEC) followed the Standard Test Method for Methylene Blue Index of Clay, according to the ASTM C 837 -81.

2.2.4. Adsorption test

1) A Pb^{2+} ion adsorption: The adsorbent (1-2 g/l) was added to a solution of $Pb(NO_3)_2$ with a concentration of about 150 mg/l. The mixture was stirred at 200 rpm and the temperature was maintained at 25 °C. After a certain time, the adsorbent was removed by centrifugation. The Pb^{2+}concentration in solution before and after adsorption was determined by AAS atomic spectrum analysis on AAS - AA6800 device (Shimadzu). A Pb^{2+} adsorption capacity, Q_e (mg/g) and adsorption efficiency, H_e (%) of adsorbent are determined according to Eq. (2) and (3), respectively. In which, V(l), C_o (mg/l) and C_e (mg/l) are solution volume, solution concentration before and after adsorption, respectively.

$$Q_e = \frac{C_o - C_e}{m} \times V \tag{2}$$

$$H_e = \frac{C_o - C_e}{C_o} \times 100 \tag{3}$$

2) A cibanon navy blue dye adsorption: The adsorbent (1-3 g/l) was added to a solution of cibanon navy blue with a concentration of 200 mg/l. The mixture was stirred at 200 rpm and the temperature was maintained at 25 °C. After 8 hours, the adsorbent was removed. The color of the solution before and after adsorption was assessed through UV-vis analysis on a Cary 5000 instrument (Varian). A cibanon navy blue adsorption capacity, Qe (mg/g) and adsorption efficiency, He (%) of adsorbent are determined according to (4) and (5), respectively. These expressions, Ao and dashed line are the adsorption intensity of dye solution before and after adsorption, respectively. V (l), Co (mg/l), and *m* (g) are solution volume, initial dye solution concentration and mass of adsorbent, respectively.

$$Q_e = \frac{A_o - A_e}{A_o \times m} \times C_o \times V \tag{4}$$

$$H_e = \frac{A_o - A_e}{A_o} \times 100 \tag{5}$$

3. Results and Discussion

3.1. Mineral Composition of Di Linh Bentonite

The mineral composition of bentonite Di Linh (Ben) was determined by x-ray diffraction analysis. The results shown in Fig. 2 show that Di Linh bentonite has a low montmorillonite content. Its composition contains many impurities such as quartz (black dashed line peaks), talc (green dashed line peaks) and especially gismondine (purple dashed line peaks). This is clearly shown by the purple peak for gismondine is much higher than the light blue peak for montmorillonite. This proves that Di Linh bentonite is quite low-quality.

Table 1 shows that Ben has low SiO_2 content (38.395 wt.%) and high Fe_2O_3 content (15.298 wt.%), so Ben has a yellow-brown color. In addition, the Ben also contains many other metal oxides such as NiO, CuO, ZnO, Rb_2O_3, SrO, ZrO_2, and the low mass ratio of SiO_2/Al_2O_3 (1.29) shows that the montmorillonite content in Ben is low. Thus, the results of chemical composition analysis also show that Ben contains many metal oxides which are impurities with quite high content, so the quality of Ben is low. This is consistent with mineral composition analysis results of Ben in Fig. 2.

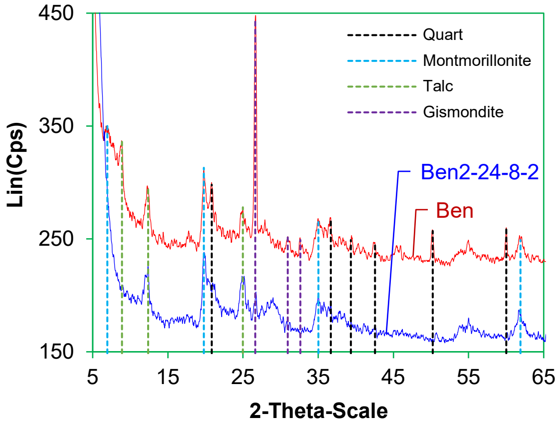

Fig. 2. X-ray diffraction analysis of bentonite.

3.2. Experimental Conditions

3.2.1. The soaking time for swelling

Bentonite was purified at 1 wt.% suspension and stirred for 8 hours. The soaking time for swelling varied from 0 to 32 hours. The product is obtained without annealing. They are named Ben1-8-0-0, Ben1-16-0-0, Ben1-24-0-0, and Ben1-32-0-0. Their specific surface areas are shown in Fig. 3.

Bentonite is an aggregate of silicate layers, packed together by electrochemical forces and containing interposition water. Thus, the crystallographic structure of bentonite is much like a sandwiched deck of cards. Sodium, potassium, calcium ions located between these platelets allow water to hydrate the clay mineral in an absorption reaction that results in its swelling characteristics (Fig. 4). Hence, when placed in water, these cards or clay platelets shift apart, the interlayer spacing is expanded [2,3,10,11]. Therefore, the specific surface area increases. This is the reason for the increase in the specific surface area of bentonite when it contacts with water (Fig. 4). On the other hand, when the interlayer spacing is expended, the water-soluble impurities have more chances to contact the water and dissolve into the water, thereby increasing the specific surface area of the bentonite. Experiments have shown that the specific surface area of Ben was only 18.58 m^2/g. It increased more than 2 times after the bentonite was purified for different soaking times (Fig. 3).

Although it was not stirred, bentonite was still soaked for 8 hours in water, so the specific surface area of Ben1-8-0-0 was 40.54 m^2g^{-1}. As the soaking time increases, the more water is absorbed by the bentonite because the cations have a very strong affinity for the water molecule (Fig. 4), the more interlayer spacing is expended, so the specific surface area increases. At the same time, the soaking time for swelling increases, the more water-soluble impurities will be dissolved, thus contributing to an increase in specific surface area. Therefore, the specific surface area of the Ben1-24-0-0 sample has reached 50.46 m^2g^{-1}. However, when the soaking time is greater than 24 hours, the specific surface area is almost unchanged, meaning that the bentonite needs at least 24 hours in water for complete swelling (Fig. 3).

3.2.2. The stirring time

Bentonite was purified at 1 wt.% suspension and soaked for 24 hours in water. The stirring time varied from 0 to 12 hours. The product is obtained without annealing. They are called Ben1-24-0-0, Ben1-24-4-0, Ben1-24-8-0, and Ben1-24-12-0. Their specific surface areas are shown in Fig. 5. In which the specific surface area of the sample Ben1-24-0-0 was obtained from the study of the effect of soaking time in section 3.2.1. Although the bentonite was almost completely expanded after 24 hours of soaking, the stirring time will contribute to the bentonite swelling more fully, the interlayer spacing is wider. At the same time, stirring also acts mechanically to help water-soluble impurities to dissolve more and water-insoluble impurities can leave the crystal lattice of bentonite. Therefore, the specific surface area of bentonite will increase. The longer the stirring time, the more water-soluble impurities are dissolved, the insoluble impurities are also separated from the bentonite crystal lattice more, so the specific surface area will increase. Therefore, the surface area of bentonite increased from 50.46 to 67.46 m^2g^{-1} as the stirring time increased from 0 to 8 hours. However, this value will hardly increase if the stirring time continues to increase up to 12 hours (Fig. 5). It shows that outside of 24 hours of soaking, bentonite takes at least about 8 hours of stirring to remove water-soluble impurities and some insoluble impurities in the crystal lattice structure.

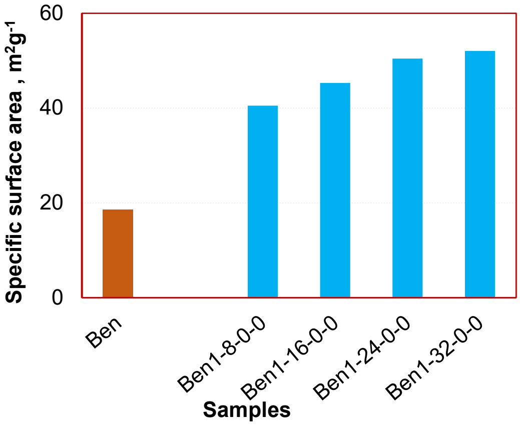

Fig. 3. The effect of soaking time on the specific surface area of samples

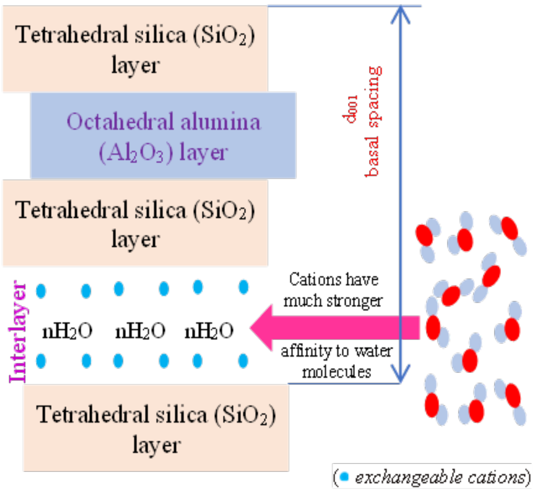

Fig. 4. The platelets absorb water.

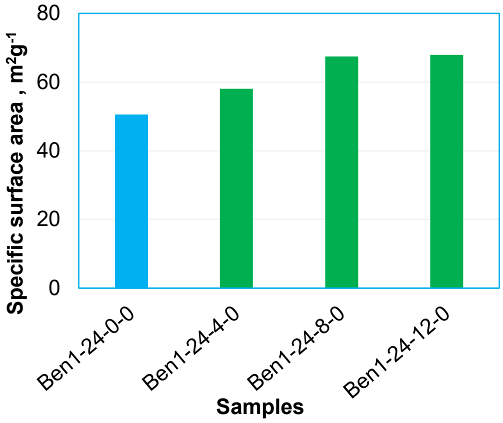

Fig. 5. The effect of stirring time on the specific surface area of samples

3.2.3. The annealed time

Bentonite was purified at 1 wt.% suspension, soaked for 24 hours in water, and stirred for 8 hours. The product is annealed at 500ºC in a definite time. They are called Ben1-24-8-0, Ben1-24-8-1, Ben1-24-8-2, and Ben1-24-8-3. Their specific surface areas are shown in Fig. 6. In which the specific surface area of the sample Ben1-24-8-0 was obtained from the study of the effect of soaking time in section 3.2.2.

Soaking and stirring helped swell the bentonite and remove water-soluble impurities, but some water-insoluble organic impurities were not removed. However, these organic matters will undergo thermal decomposition when the sample is annealed at 500 ºC. The decrease in carbon content from 0.373 to 0.314% in the elemental composition (Table 2) was evidence for the decomposition of organic compounds during the anneal process. This explains the improvement in specific surface areas when the refined bentonite sample is annealed in a furnace. The longer the annealing time, the more water-insoluble organic impurities are decomposed, so the specific surface area increases. However, after 2 hours of annealing, the specific surface area was almost not improved (Fig. 6), indicating that a minimum of two hours of annealing is required to remove all organic impurities.

Although the heat treatment process removed organic compounds thereby improving the specific surface area, the results in Fig. 6 showed that the improvement is not much. Specifically, the specific surface area increased from 67.46 m^2/g (without annealing) to only 70.70 m^2/g with 1-hour annealed sample (increased 4.8%) and 72.70 m^2/g with 2-hour annealed sample (increased 7.8%). Therefore, it is necessary to consider the economic factor and the benefit of the heat treatment process in the application.

The results from 3.2.1 to 3.3.3 have shown that the experimental conditions are suitable for the refining process to enhance the quality and improve the specific surface area of bentonite. Specifically, bentonite of 1 wt.% needs to soak for 24 hours to swell before stirring for 8 hours at 1000 rpm. The refined bentonite is then annealed for 2 hours at 500 ºC in a furnace. The product has a specific surface area of 72.70 m^2/g. Table 1 and Table 2 showed that the refining process reduced the content of K, Ca as well as K_2O, and $CaCO_3$ but increased the content of Al and Si as well as Al_2O_3 and SiO_2. At the same time, the cation exchange capacity (CEC) of bentonite was also improved (Table 3).

3.3. Suspension Concentration

Bentonite was soaked for 24 hours in water and stirred for 8 hours. The product is annealed at 500ºC in 2 hours. The suspension concentration varies from 1-4 wt.%. They are called Ben1-24-8-2, Ben2-24-8-2, Ben3-24-8-2, and Ben4-24-8-2. Their specific surface areas are shown in Fig. 7, in which the specific surface area of the sample Ben1-24-8-2 was obtained from the study of the effect of soaking time in section 3.2.3.

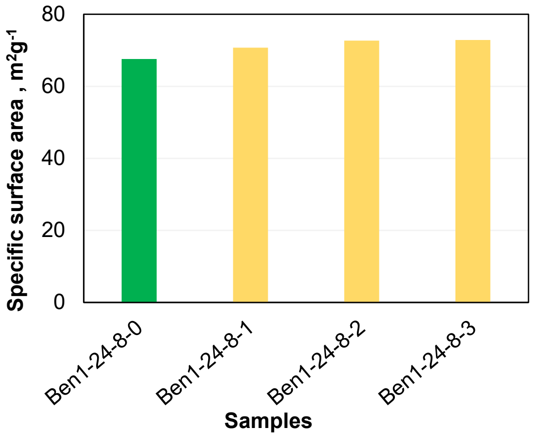

Fig. 6. The effect of anneal time on the specific surface area of samples.

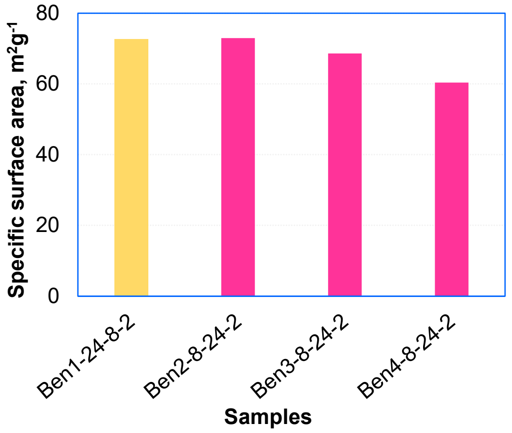

Fig. 7. Effect of suspension concentration on specific surface area.

A water absorption and swelling depend on the moisture content. However, when bentonite is placed in an excess of water, the swelling of bentonite will theoretically be considered as free swelling and is independent of the suspension concentration. Therefore, the specific surface area of bentonite does not change as the suspension concentration increases from 1 to 2 wt.%. However, when the suspension concentration is higher, the suspension becomes denser and more viscous, thus negatively affects the solubility of water-soluble impurities as well as the settling and separation of coarse residues. So, the specific surface area is reduced. This reduction was evident at the suspension concentration of 4 wt.% (Fig. 7). Therefore, refining to improve the specific surface area of bentonite should only be stopped at a 2 wt.% suspension concentration. However, in practice, it is necessary to balance the economic factor and the quality requirements of bentonite to choose the concentration of the suspension for the treatment process.

3.4. Mineral Composition and d_{001} Basal Spacing of Product

The mineral composition results obtained from x-ray diffraction analysis of the Ben2-24-8-2 with the specific surface areas of 72.97 m^2/g in Fig. 2 show that impurities such as talc, quartz, gismondine have been largely removed during the refining process. This is shown very clearly by their characteristic peaks on x-ray diffraction of Ben2-24-8-2 which are significantly reduced compared to that of Ben sample. The peak related to the d_{001} basal spacing of montmorillonite on the x-ray diffraction of Ben at 2θ angle of 6.95° corresponding to the basal spacing of 12.71 Å did not appear on the x-ray diffraction of Ben2-24-8-2 (Fig. 2). This proves that water treatment has widened the interlayer spacing because the 2θ angle has been reduced to 5.08°, so the d_{001} basal spacing has increased to 17.38 Å (Fig. 8). This result is consistent with the increase in specific surface area from 18.58 m^2/g (Ben) to 72.97 m^2/g of sample Ben2-24-8-2.

Thus, in addition to the appropriate experimental conditions obtained from section 3.2, the bentonite of 2 wt.% is also considered to be the suitable suspension concentration for purification to enhance the quality and improve the specific surface area of the bentonite.

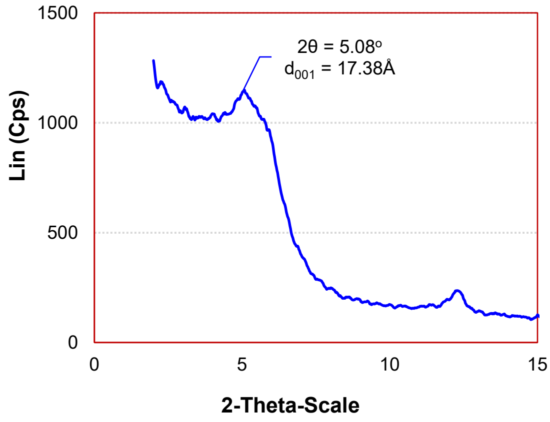

Fig. 8. X-ray diffraction analysis of Ben2-24-8-2.

3.5. Adsorption

3.5.1. The Pb^{2+} adsorption

Ben and Ben2-24-8-2 were used as adsorbents to adsorb Pb^{2+} ion in water. The adsorption results (Table 4) showed that refining to enhance quality and improve surface area of bentonite significantly increased the Pb^{2+} adsorption capacity and adsorption efficiency. Specifically, the Pb^{2+} adsorption capacity and adsorption efficiency of the Ben2-24-8-2 were about 2.8 times higher than that of the Ben. The increase in Pb^{2+} adsorption capacity and adsorption efficiency of the Ben2-24-8-2 was attributed to the increase in CEC (Table 3). Moreover, the Ben2-24-8-2 adsorbed Pb^{2+} very quickly. When using adsorbent content of 1 g/l, after only 0.5 hours, the adsorption efficiency was over 50% and the adsorption capacity reached 61.72 mg/g. They only increased slightly if the adsorption time was extended further. It is shown that after 0.5 hours, the adsorbent has almost reached saturation.

The Pb^{2+} adsorption efficiency was about 50% when using the Ben2-24-8-2 adsorbent content of 1 g/l and the adsorbent reached saturation after 0.5 hours, demonstrating that the amount of adsorbent may not be sufficient to adsorb all Pb^{2+} ions in the test solution. To improve the adsorption efficiency, it is necessary to use higher adsorbent content. The adsorption time was still maintained at 0.5 hours. The result of the adsorption capacity and the adsorption efficiency is shown in Table 5.

Table 4. The effect of adsorption time on the Pb^{2+} ion adsorption capacity and adsorption efficiency

Time, hour	Q_e, mg/g		H_e, %	
	Ben	Ben2-24-8-2	Ben	Ben2-24-8-2
0.5	22.61	61.72	18.36	50.11
2	23.13	62.16	18.78	50.46
4	23.76	62.42	19.29	50.67

Table 5. The effect of the Ben2-24-8-2 adsorbent content on the Pb^{2+} ion adsorption capacity and adsorption efficiency

Adsorbent content, g/l	Q_e, mg/g	H_e, %
1	61.72	50.11
1.5	59.39	72.32
2	39.11	95.24

The adsorbent content was raised while the Pb^{2+}concentration of the solution was fixed, so the opportunity for the adsorbent to approach Pb^{2+} ion decreases, resulting in a decrease in the adsorption capacity. This reduction was evident at the 2 g/l adsorbent content. On the other hand, by increasing the adsorbent content, the number of Pb^{2+} ions in the solution would be more adsorbed by the adsorbent, so the adsorption efficiency increase. Using the adsorbent content of 2 g/l, more than 95% of Pb^{2+} ions were removed from the solution (Table 4). Therefore, depending on the requirements of the application as well as the balance with economic factors, select the appropriate adsorbent content.

3.5.2. The cibanon navy blue dye adsorption

In contrast to the Pb^{2+} ion adsorption, the cibanon navy blue adsorption was much slower. The solution before and after 8 hours of adsorption was evaluated by UV-vis analysis. The UV-vis spectra of the solutions before and after adsorption are shown in Fig. 9. The adsorption capacity and adsorption efficiency of adsorbents are shown in Table 6.

Table 6. The effect of adsorbents on the cibanon navy blue adsorption capacity and adsorption efficiency

Sample	Ben	Ben2-24-8-2
Q_e, mg/g	11.16	31.36
H_e, %	5.58	15.68

Although cibanon navy blue was adsorbed very slowly, the UV-vis spectra (Fig. 9) and the results in Table 6 showed improvement with the Ben2-24-8-2 adsorbent. Thanks to the increase in the basal spacing and the specific surface area, both the adsorption capacity and the adsorption efficiency of Ben2-24-8-2 were about 2.8 times higher than that of Ben.

The cibanon navy blue adsorption capacity of Ben2-24-8-2 is low, so the adsorption efficiency is also low. To enhance the adsorption efficiency, the adsorbent content was increased, and the adsorption time was kept constant at 8 hours. The UV-vis spectra of the solutions before and after adsorption are shown in Fig. 10 and the effect of adsorbent content on the cibanon navy blue adsorption capacity and adsorption efficiency is presented in Table 7.

Table 7. The effect of the Ben2-24-8-2 adsorbent content on the cibanon navy blue adsorption capacity and adsorption efficiency

Adsorbent content, g/l	1	2	3
Q_e, mg/g	31.36	30.03	25.86
H_e, %	15.68	30.03	38.79

Similar to the case of Pb^{2+} adsorption, the adsorbent content increased the chance of the adsorbent in contact with Pb^{2+} ions decreased, so the adsorption capacity reduced a stronger decrease occurred at 3 g/l adsorbent content. On the contrary, the higher the adsorbent content, the more Pb^{2+} ions would be adsorbed, so the adsorption efficiency increases. However, using up to 3 g/l of Ben2-24-8-2 adsorbent, the adsorption efficiency only reached about 39%. It proves that it is not appropriate to use Ben2-24-8-2 adsorbent to adsorb cibanon navy blue.

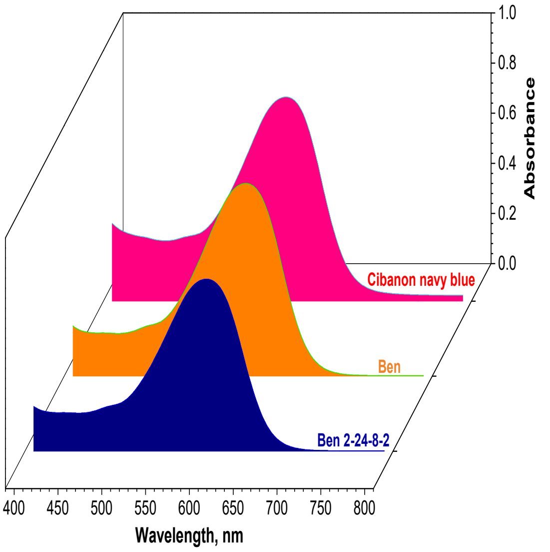

Fig. 9. UV-vis spectra of solutions before and after adsorption.

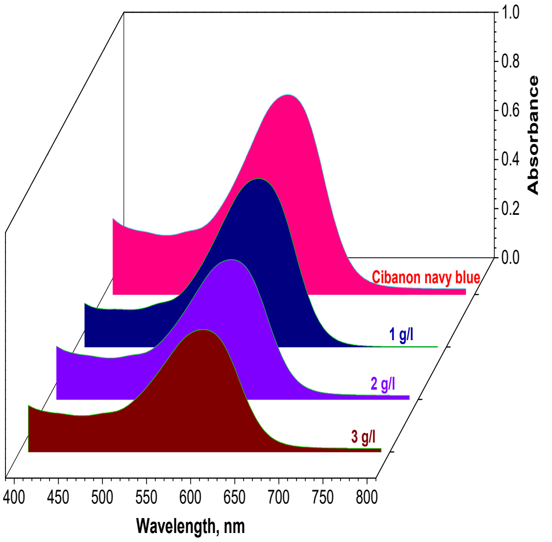

Fig. 10. UV-vis spectra of solution after adsorption by different adsorbent content

The fast and efficient Pb^{2+} adsorption is attributed to the inherent cation exchange properties of bentonite [4,5]. However, cibanon navy blue belongs to organic dyes, so it will be difficult to be adsorbed by bentonite because inorganic oxides are the main constituents of bentonite. Therefore, in order to apply bentonite in dye adsorption in particular and organic compounds in general, in addition to refining to enhance quality and improve the specific surface area, bentonite needs to be further modified [12].

4. Conclusion

There have been many works mentioning bentonite refining, but the common point of these works is to perform refining under a specific condition. The work has carried out a systematic study on the influencing factors to give suitable processing conditions for Di Linh bentonite.

By evaluating the influence of a variety of experimental conditions and suspension concentrations on the specific surface area of bentonite, the appropriate process and conditions for refining to enhance quality and improve the specific surface area of bentonite have been proposed. Specifically, the bentonite (2 wt.%) was soaked for 24 hours before stirring for 8 hours. After drying, the refined bentonite is annealed for 2 hours at 500 °C in a furnace. The final product received has the basal spacing of 17.38 Å and the specific surface area of 72.97 m^2g^{-1}. Thanks to the expansion of the basal spacing and the specific surface area, the Pb^{2+} and cibanon navy blue adsorption capacity and efficiency of Ben2-24-8-2 have improved significantly compared to those of Ben. Thanks to the inherent cation exchange properties of bentonite, Pb^{2+} was quickly and efficiently adsorbed by Ben2-24-8-2. After only 0.5 hours and using the Ben2-24-8-2 adsorbent at concentration of 1 g/l, up to 61.72 mg/g of Pb^{2+} ion were adsorbed, and the adsorption efficiency reached 95.24% when Ben2-24-8-2 with a concentration of 2 g/l was used as adsorbent. The adsorption of cibanon navy blue dyes took place slowly and the adsorption capacity was not high. Therefore, in addition to the refining, it needs to be further modified to increase the adsorption efficiency.

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References

[1] L. Carlson, Bentonite Mineralogy, Posiva Oy Fin-27160 Olkiluoto, Finland, 2004,

[2] A. Alemdar, N. Güngör, F. B. Erim, Effect of sodium dodecyl sulfate and sodium dodecyl benzene sulfonate on the flow behavior of purified bentonite dispersion, J. Mater. Sci. Lett., vol. 22, no. 2, pp. 89-90, Jan. 2003, https://doi.org/10.1023/A:1021836115359

[3] Paul F. Luckham, S. Rossi, The colloidal and rheological properties of bentonite suspensions, Adv. Colloid Interface Sci., vol. 82, no. 1-3, pp. 43-92, Oct. 1999 https://doi.org/10.1016/S0001-8686(99)00005-6

[4] M. Zhao, Y. Wang, L. Liu, L. Lixian, M. Chen, C. Zhang, Q. Lu, Green coatings from renewable modified bentonite and vegetable oil based polyurethane for slow-release fertilizers, Polym. Compos., vol. 9, no. 12, pp. 4355-4363, July. 2017 https://doi.org/10.1002/pc.24519

[5] T. T. Man, T.T. Lan, N. A. Duong, P. L. Anh, Assessment of the usability of Tam Bo Bentonite (Di Linh-Lam Dong) for peloid, Vietnam Journal of Earth Sciences, vol. 42, no. 4, pp. 384-394, Oct. 2020, https://doi.org/10.15625/0866-7187/42/4/15430

[6] P. T. Ha Thanh, N. X. Thung, Bentonite: natural resourses, processing technology and application in vietnam, JST., vol. 65, no. 03, pp. 159 - 164, 2010.

[7] H. T. Minh Thao, J. Kasbohm, N. T. Lan, Quality, characteristics of bentonite in Di Linh, Lam Dong, The 4th National Science and Technology Conference on Mineral Selection, pp. 348 - 358, 2014.

[8] R. Naseem, S. S. Tahir., Removal of Pb(II) from aqueous/acidic solutions by using bentonite as an adsorbent. Wat. Res., vol. 35, No. 16, pp. 3982-3986, 2001.

[9] Z. Gong, L. Liao, G. Lv, X. Wang, A simple method for physical purification of bentonite, Appl. Clay Sci., vol. 119, pp. 294-300, 2016.

[10] I. Belbachir, B. Makhoukhi, Adsorption of Bezathren dyes onto sodic bentonite from aqueous solutions, J Taiwan Inst Chem Eng., vol. 75, pp. 105-111, 2017, http://dx.doi.org/10.1016/j.jtice.2016.09.042

[11] S. F. Diman, C. Wijeyesekera, swelling characteristics of bentonite Clay Mats, Advances in Computing and Technology, The School of Computing and Technology 3rd Annual Conference, pp. 179-185, 2008.

[12] T. S Anirudhan, M. Ramachandran. Adsorptive removal of basic dyes from aqueous solutions by surfactant modified bentonite clay (organoclay): Kinetic and competitive adsorption isotherm, Process Saf. Environ. Prot., vol. 95, pp. 215-225, May. 2015, https://doi.org/10.1016/j.psep.2015.03.003