

ADSORPTION OF URANIUM SIMULATION WASTE USING BENTONITE:TITANIUM DIOXIDE

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(Naskah diterima: 11-12-2018, Naskah direvisi: 25-01-2019, Naskah disetujui: 08-02-2019)

ABSTRACT

ADSORPTION OF URANIUM SIMULATION WASTE USING BENTONITE:TANIUM DIOXIDE.

Bentonite is a clay material of high surface area that have galleries within its structure. Bentonite that is modified with TiO_2 will have high adsorption capability. In this study, natural bentonite and bentonite: TiO_2 were characterized with FTIR, XRD and BET instruments to determine functional group, basal spacing, and specific surface area. This study also investigates the adsorption of bentonite: TiO_2 in various environmental factors, such as pH (pH 1, 3, 5, and 8), contact time (10, 20, 30, 40, 50, 60, 70, 90, and 120 min), and initial uranium concentration (20, 40, 60, 80 ppm), and their influences on adsorption capacity, and determine the kinetics equation and adsorption isotherm. Based on FTIR analysis, a decrease in the band of O-H bond from water molecule was observed, which indicates the presence of TiO_2 in bentonite interlayer structure. The XRD characterization of bentonite: TiO_2 does not show diffraction peak in 001 plane. This is due to delamination of bentonite interlayer structure. Delamination is caused by the presence of TiO_2 in large quantities, thus damaging the bentonite interlayer structure into irregular sheets. Bentonite as sheets will cause the basal spacing to increase and it is anticipated that XRD will find it difficult in detecting the 001 plane at a low 2 theta angle. The surface area of bentonite: TiO_2 has increased by $12.04 \text{ m}^2/\text{g}$. The maximum adsorption capacity of U(VI) took place at pH 5.0 for 70 minutes contact time and uranium concentration of 60 ppm. In this study, the adsorption kinetic and adsorption isotherm are pseudo second-order kinetic and Langmuir isotherm. The kinetic constant and maximum adsorption capacity of bentonite: TiO_2 are $0.075 \text{ g}/\text{mg}\cdot\text{min}$ and $5.848 \text{ mg}/\text{g}$ respectively.

Keywords: Bentonite, TiO_2 , Adsorption, Uranium

ABSTRAK

ADSORPSI LIMBAH SIMULASI URANIUM MENGGUNAKAN BENTONIT:TITANIUM DIOKSIDA. Bentonite adalah material lempung yang mempunyai luas permukaan yang besar dan mempunyai ruang antar lapis. Ruang antar lapis pada bentonit dapat dimodifikasi menggunakan TiO_2 yang mempunyai kemampuan mengadsorpsi limbah uranium. Memodifikasi bentonit dengan TiO_2 akan menjadikan material tersebut mengalami peningkatan kemampuan mengadsorpsi limbah uranium. Pada penelitian ini telah dilakukan karakterisasi bentonite dan bentonit: TiO_2 menggunakan instrumen FTIR, XRD dan BET untuk mengetahui gugus fungsi, basal spacing, dan luas permukaan. Selain itu juga untuk mengetahui pengaruh pH larutan uranium (1, 3, 5, dan 8), waktu adsorpsi (10, 20, 30, 40, 50, 60, 70, 90, dan 120 menit), dan konsentrasi larutan uranium (20, 40, 60, dan 80 ppm) terhadap kapasitas adsorpsi bentonit: TiO_2 , serta menentukan persamaan kinetika dan isotherm adsorpsi. Hasil penelitian FTIR menunjukkan terjadi penurunan bilangan gelombang pada ikatan O-H dari molekul air yang mengindikasikan adanya TiO_2 menyisip di daerah interlapis bentonit. Hasil karakterisasi XRD pada bentonit: TiO_2 tidak menunjukkan puncak difraksi di bidang 001, sehingga basal spacing tidak dapat ditentukan. Hal ini diperkirakan karena delaminasi struktur bentonit. Delaminasi disebabkan oleh jumlah TiO_2 yang terlalu banyak sehingga merusak struktur interlapis bentonit menjadi lembaran-lembaran yang tidak teratur. Struktur bentonit berbentuk lembaran akan menyebabkan jarak interlapis mengalami peningkatan yang sangat besar sehingga diperkirakan XRD sulit mendeteksi bidang 001 pada sudut 2 theta yang rendah. Luas permukaan bentonit: TiO_2 mengalami kenaikan sebesar $12,04 \text{ m}^2/\text{g}$. Kapasitas adsorpsi terbaik didapatkan pada kondisi pH 5, waktu penyerapan selama 70 menit dan konsentrasi uranium sebesar 60 ppm. Kinetika adsorpsi dan isotherm adsorpsi dalam penelitian ini adalah kinetika pseudo orde dua dan isotherm Langmuir. Konstanta kinetika dan kapasitas adsorpsi maksimum yang diperoleh sebesar $0,075 \text{ g}/\text{mg}\cdot\text{menit}$ dan $5,848 \text{ mg}/\text{g}$.

Kata kunci: Bentonit, TiO_2 , Adsorpsi, Uranium.

INTRODUCTIONS

In the Mo99 radioisotope production process, 92.3 % uranium enrichment of U₃O₈ powder target was irradiated in GA Siwabessy reactor for 96 hours at a 15 MW reactor power [2]. Radioactive Mo99 will be separated from target (U₃O₈) by dissolution of U₃O₈ powder in concentrated nitric acid solution (HNO₃) and extraction process. The extraction process has the potential to produce raffinate waste which contains uranium and fission process product.

Uranium has five oxidation states characterized by +2 to +6, that the U(IV) and U(VI) are the most common [2]. Uranium U(IV) does not dissolve in the water and usually gives precipitation, whereas uranium (VI) forms an ion solution [2-4]. The natural radioactive forms of uranium such as ²³⁵U and ²³⁸U, have a half-life of 7×10^8 and 4.4×10^9 years respectively which makes them persistent in the environment and ultimately accumulates in the ecosystem in one or another form [5]. In animals and humans, uranium is adsorbed through the digestive tract and damage the tubular cells in the kidney [5,6]. Uranium once released into the natural environment, it will lead to long-time potential precipitate to the soils, surface water and groundwater [7]. The World Health Organization (WHO) has classified uranium as a human cancer-causing agent and its concentration in water should not exceed 15 µg/L [8,9]. Uranium waste is a very dangerous waste, therefore it needs to be processed so that it is not polluted to humans and the environment.

The processing process that widely used in reducing uranium waste is precipitation. Precipitation method has high efficiency in waste treatment, but this method still has some disadvantages such as requires a lot of coagulant, filtration process, and produces toxic sludge [10].

Adsorption process is an alternative method of waste treatment that does not require flocculation and filtration processes, and does not produce sludge. Furthermore,

adsorption method showed advantage such as easily-operability, low costs and high efficiency [11,12]. Formation of secondary waste is the main disadvantage of adsorption, such as the spent adsorbent, unusable recovered organic compounds, and organics in waste water if steam is used for regeneration. Secondary waste may require off-site treatment or specialist disposal [31]. Adsorption is a mass transfer process in which the adsorbent can selectively remove dissolved elements or molecules by capturing the molecule to its surface. Adsorption is divided into two types, namely chemical and physical adsorption. Chemical adsorption occurs due to chemical bonds between adsorbates and adsorbents such as ionic, hydrogen and covalent bonds. Physical adsorption enabled by the van der Waals forces between molecules and/or atoms on the adsorbent surface and adsorbate, whereas adsorbate resembles a condensed liquid form of the adsorptive [32]. Adsorbate approaches the surface of the adsorbent via van der Waals forces or hydrogen bonds then is followed by chemical adsorption by forming chemical bonds [13]. In physical adsorption, the adsorbed molecules can be bilayer or multilayer and the specific surface of the adsorbent depends on the area of the adsorbate molecule with a certain orientation to the surface [14]. The difference between chemical adsorption and physical adsorption are shown in Table 1.

A large number of studies have been dedicated to finding suitable and cheap adsorbents for treatment or removal of uranium from water. Bentonite consists essentially of clay minerals of the smectite (montmorillonite) group. It has a wide range of industrial applications including clarification of edible and mineral oils, paints, cosmetics, and pharmaceuticals [16]. Bentonite has interlayer cations with weak bonds to compensate the negative charge on the surface of the clay mineral [17] as illustrated in Fig 1.

Table 1. The Differences between Chemical Adsorption and Physical Adsorption [32]

Parameter	Chemical Adsorption	Physical Adsorption
Type of Bonding Forces	Similar to chemical bond	Van Der Waals
Adsorption Heat	20 – 400 kJ/mol	10 – 40 kJ/mol
Chemical Change of Adsorptive	Formation of a surface compound	None
Reversibility	The process is irreversible, adsorbed ones are different from desorbed compounds	Reversible. Decreasing the activity of the adsorptive in the fluid surrounding the surface cause desorption of adsorbate occurs.
Activation Energy	High (similar to chemical reaction)	Very low (close to zero)
Effect of Temperature	In some extent of temperature positive, so called activated adsorption	Negative
Specificity of Adsorbate-Adsorbent Interactions	High	Very Low
Formation of Multilayers	No	Yes. In gas phase adsorption usually accompanied by liquefactions in micro- and mesopores.

The interlayer cations are easily hydrolyzable, resulting in a swelling and opening of the interlayer space, and permits to exchange with other external cations [17,18]. This property is responsible for great adsorbent power of bentonite, especially toward ions in solution [19]. Cationic or anionic contaminants accumulate on bentonite surfaces leading to their immobilisation through the process of ion exchange, coordination, electrostatic attraction, ion-dipole interaction, H-bonding, van der Waals interactions or hydrophobic bonding [9,20]. However for practical application bentonite as adsorbent need improvement in sorption capacity. Adsorption capacities of natural bentonite can be increased by pillaring process.

The clay pillaring process involves exchange of the interlayer cations with large inorganic polymeric oxy-hydroxy cationic species, which prop open the silicate layers [9]. Thus, the interlayer and specific area increase. The pillaring process is followed by

calcination. The interlocation of polycation and calcination results in a stable structure with constant interlayer system to high temperature [22]. Intercalation in the interlayer of bentonite will change basal spacing as indicated by the diffraction peak shift. The bentonite diffraction peak that interpret basal spacing area is the 001 plane.

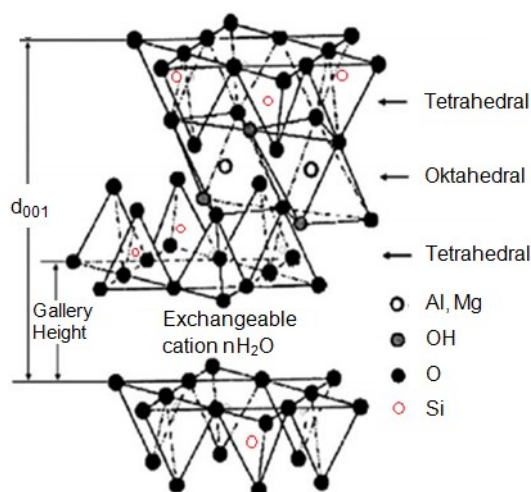


Fig. 1. Bentonite Interlayer Structure [15]

The polycation that can be used as pillaring agent is Titanium Dioxide (TiO₂). Titanium dioxide has large specific surface area that allows combining with other materials without blocking the pores and high thermal stability [24]. Pillarization of bentonite using Ti cation is expected to increase basal spacing and specific surface area.

In this study, the bentonite:TiO₂ was used as adsorbent for the adsorption of uranium. The purpose of this study as: (1) to know the effect of TiO₂ modification to adsorption capability of Bentonite; (2) to research the effect of environmental conditions, such as pH, contact time, and initial uranium concentration on the adsorption of uranium on bentonite:TiO₂; (3) to determine the suitable adsorption kinetic and adsorption isotherm equation in describing the uranium adsorption process by bentonite:TiO₂

METHODOLOGY

a. Preparation of Bentonite:TiO₂

The sample was technical grade bentonite, with the major elements being Si (52,02%), Al (4,67%), Fe (6,798%), Ti (0,05%), Ca (0,327%), K (0,012%), Na (0,024%), and Mg (10, 942%). Technical grade Titanium Dioxide, HCl, HNO₃, NaOH, Arsenazo (III) and Uranyl Nitrate Hexahydrate were also used in this study.

Fifty grams of Bentonite mixed with 750 mL of HCl solution 2 M. Activation was carried out at 65°C and stirred constantly for 4 hours. Then, activated bentonite was washed by distilled water until reached pH 5 and dried at 100°C for 12 hours.

Ten grams of activated bentonite were mixed with 150 mL of distilled water and stirred using a magnetic stirrer for 2 hours. Then, 4 grams of TiO₂ powder were mixed with bentonite slurry and stirred using a magnetic stirrer for 4 hours. In the stirring process, it is expected that Ti⁴⁺ cations on TiO₂ can exchange with interlayer cations in the bentonite structure. Bentonite: TiO₂ is

dried using an oven at 100°C for 12 hours. A mixture of bentonite and TiO₂ is then calcined using a furnace at 500°C for 4 hours. Calcination aims to stabilize the intercalant and eliminate water content in the bentonite structure.

b. Uranium Adsorption

The adsorption process was performed by a batch technique at room temperature. Batch adsorption experiments were carried out by allowing an accurately weighted amount of bentonite to reach equilibrium with uranium solutions of known concentrations. Bentonite:TiO₂ adsorbent had contacted with 10 mL of uranium solution. The mass of adsorbent used is 0.05 gram. Initial concentration of uranium were 20, 40, 60, 80 mg/L. For purpose of determining the period required to reach the adsorption equilibrium, each batch was conducted at various time intervals (10, 20, 30, 40, 50, 60, 70, 90, and 120) min. According to previous experiment, bentonite had a maximum capacity of uranium at 120 min contact time [33]. Optimum pH was determined by conducting adsorption experiments on various pH (pH 1, 3, 5, and 7). The selection of solution pH value had determined base on the research that has been done by Jiaquan. In their experiment, bentonite had a minimum capacity at alkaline pH [30]. The pH was adjusted using dilute HNO₃ or NaOH solutions.

The initial and equilibrium concentrations of uranium in clear solutions were analysed by Uv-Vis with Arsenazo method [13]. The amount of uranium adsorbent (q_t in mg/g) was determined as follows:

$$q_t = \left(\frac{C_t - C_0}{m} \right) V \quad (1)$$

where, q_t is the amount of uranium ions adsorbed onto unit amount of the adsorbent (mg/g), C_0 and C_t are the initial and final concentrations of uranium in solution (mg/L), V is the volume of solution (L) and m is the mass of the adsorbent (g), respectively.

c. Adsorption Isotherm

To obtain adsorption isotherm, a known volume (10 mL) of uranium solution of varying initial concentrations (20 to 80 mg/L) in beaker glass was stirred with a desired dose (0.05 g) of adsorbent at contact time for 70 min, room temperature, and pH 5. Parameters that provide maximum adsorption capacity during adsorption experiment are used in determining the adsorption isotherm.

The experimental data for uranium adsorption by bentonite:TiO₂ was fitted with the Langmuir and Freundlich isotherm. The linear form of the Langmuir isotherm model can be expressed by Eq. (2).

$$\frac{1}{q_e} = \left[\frac{1}{k q_0} \right] \frac{1}{c_e} + \frac{1}{q_0} \quad (2)$$

where q_e (mg/g) is the equilibrium adsorption capacity, c_e (mg/L) is the uranium ion concentration remaining in the solution at equilibrium, q_0 (mg/g) is the monolayer adsorption capacity of the adsorbent, and k (L/mol) is the Langmuir adsorption constant.

Langmuir isotherm model suggests monolayer sorption on a homogeneous surface without interaction between sorbed molecules, adsorption occurs at specific homogeneous adsorption sites within the adsorbent and intermolecular forces decrease rapidly by distance from the adsorption surface [25].

d. Adsorption Kinetic

To obtain adsorption kinetic, a known volume (10 mL) of uranium solution of varying contact time (10-120 min) in beaker glass was stirred with a desired dose (0.05 g) of adsorbent at 60 ppm uranium concentration, room temperature, and pH 5. The parameter used are parameters that provide maximum adsorption capacity during adsorption experiment.

The kinetics experimental data to determine the kinetics of uranium adsorption

on bentonite:TiO₂ were simulated using pseudo-first order (Lagergren) and pseudo-second order (Ho). The linear form of pseudo-first order kinetic model can be represented by following equation :

$$\ln(q_e - q_t) = \ln q_e - \frac{k_1}{2,303} t \quad (3)$$

Where k_1 represents the pseudo-first order adsorption rate constant (L/min), q_e (mg/g) is the adsorption capacity of uranium at equilibrium, t is the contact time (min) and q_t is the amount of adsorbed uranium at time t (mg/g). The linear pseudo-second order model can be represented as Eq. (4)

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_t} t \quad (4)$$

where k_2 is the pseudo-second order adsorption rate constant (g/mg.min).

Freundlich assumes that adsorption occurs on a heterogeneous surface [9,26]. The Freundlich isotherm model can be expressed by Eq. (5).

$$\ln q_e = \ln k_f + n \ln C_e \quad (5)$$

where k_f (mg/g) $((\text{mg/L})^n)^{-1}$ is the Freundlich constant, and n is an empirical factor relating to the adsorption intensity.

RESULTS AND DISCUSSION

a. Characterisation of Bentonite:TiO₂

1. FTIR

The FTIR spectra of bentonite:TiO₂ differed from that of raw bentonite. The broad band on 3456.51 and 3439.27 cm⁻¹ was due to the interlayer H-bonded O-H stretching. The band at 1640.84 and 1636.22 cm⁻¹ represented the H-O-H bending vibration of water. This shows that the H-O-H bending of bentonite:TiO₂ was decreased. We suggest that water molecules in the bentonite:TiO₂ structure after being added by titanium dioxide have decreased due to drying process at high

temperature. The band of 1044.23 and 1050.55 cm^{-1} might be attributed to the siloxane (Si-O-Si) group stretching. The band at 792.87 cm^{-1} might correspond to the O-Si-O bonds. The band at 472.08 and 470.92 represented the Si-O bending.

The FTIR curve of bentonite and bentonite:TiO₂ is illustrated in Fig 3 and Fig 4, respectively. It can be seen that the band of bentonite at 3456.51 cm^{-1} (Fig 3) has decreased towards a shorter band, which is 3439.27 cm^{-1} (Fig 4) indicates a decrease in

O-H bond. This is expected to occur due to the addition of TiO₂. We suggest that the bond between Ti cations and TiO₂ with oxygen (O) from O-H occurs in the bentonite structure so that the O-H bond decreases. The presence of TiO₂ in bentonite structure cause increasing the adsorption capacity of bentonite. According to previous research journal, the UO₂²⁺ ion is specifically adsorbed on titanium dioxide [33]. The adsorption reaction is explain by Eq.6.

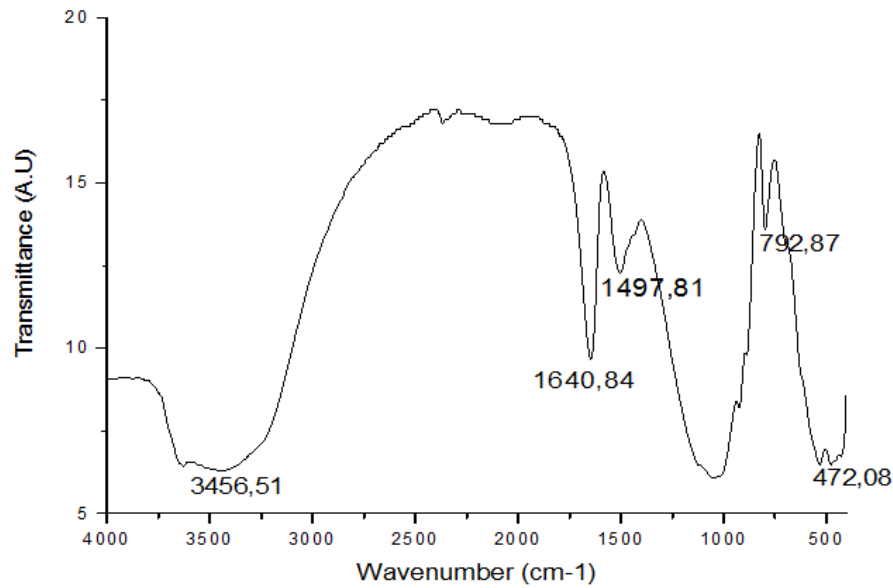


Fig. 3. Natural Bentonite FTIR Curve

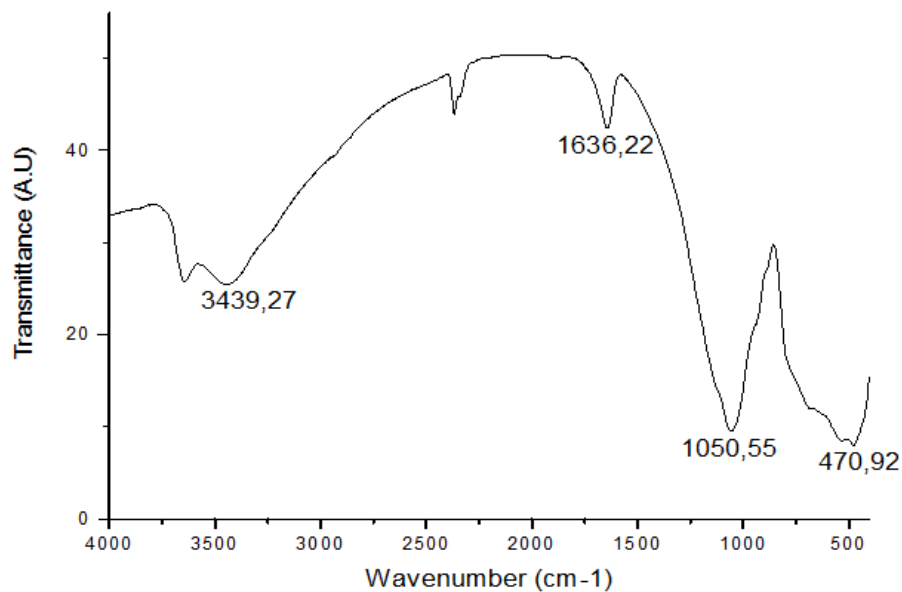
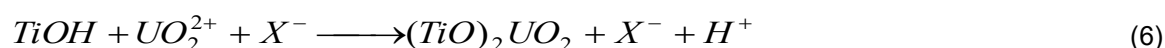


Fig. 4. Bentonite:TiO₂ FTIR Curve



2. XRD Analysis

The XRD patterns of raw bentonite and bentonite:TiO₂ were shown in Fig 5. The basal spacing for raw bentonite was, representing the typical XRD pattern of bentonite with the d₀₀₁ plane presenting in 12,27 Å peak at about 7,21°. After modification with TiO₂, there is no characteristic peak in the 001 plane, so the basal spacing of bentonite:TiO₂ can not be calculated. We suggest that the loss of 001 plane of bentonite:TiO₂ occurred due to delamination [27].

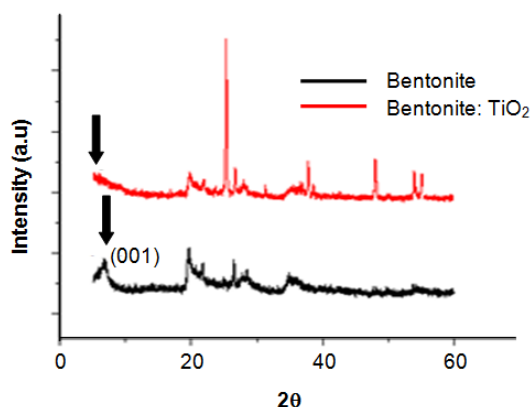


Fig. 2. Bentonite and Bentonite:TiO₂ Diffractogram

Table. 2 BET Analysis of Bentonite and Bentonite:TiO₂

	Bentonite	Bentonite:TiO ₂
Specific Surface Area (m ² /g)	68.23	80.27
Pore Diameter (Å)	27.02	17.11

b. Adsorption Study

1. Effect of pH

The solution of pH can affect the charge of adsorbent and adsorbate, then it affects the electrostatic interaction between adsorbent and adsorbate [28]. The strong interactions such as electrostatic attraction or complexation are exist between adsorbent and adsorbate only in suitable pH value. In this study, the effect of pH on uranium adsorption on bentonite:TiO₂ was investigated in the pH range of 1.0 – 8.0. As

The occurrence of delamination causes the bentonite interlayer structure was delaminated to become sheets and hence, the basal spacing becomes very large. Basal spacing is inversely proportional to the value of 2 theta angle. Basal spacing is very large due to the irregularity of the bentonite structure after delamination causes the smaller 2 theta angle. The position of 2 theta angles that are too small are estimated to be difficult to detect using an XRD instrument.

3. BET

Surface area of bentonite and bentonite:TiO₂ is shown in Table 2. The BET characterization results are related to the XRD characterization results in the previous discussion. During the delamination process, the bentonite structure changes into smaller sheets and results in a surface area of bentonite: TiO₂ increases.

Similar results were also obtained in the research conducted by Carriazo [27]. Carriazo obtained the surface area of TiO₂-laminated bentonite which increased from 42.8 m²/g to 86.4 m²/g.

illustrated in Fig 6, The adsorption increases until pH 5.0 and then decreases with further increasing of pH value. The surface properties of adsorbent and the chemical form of uranium in solution can affected by the pH value. Pfano [9] reported similar results when investigating the adsorption uranium by hydrous ferric oxide-modified zeolite.

Uranium is present in solution predominantly in the form of UO₂²⁺ ions, and the concentration of H⁺ ions far

surpasses that of the uranium ions at pH 1 and pH 3, and hence, they compete with uranium ions for the active sites on the surface of bentonite:TiO₂. At pH 8, hydrolysis of uranium ions occurs, producing complexes such as UO₂(OH)₃⁻, UO₂(OH)₄²⁻, and (UO₂)₃(OH)₇⁻ [31]. Negatively charged species will cause the attractiveness of the adsorbate to become low and limit the amount of adsorbate absorbed by bentonite:TiO₂.

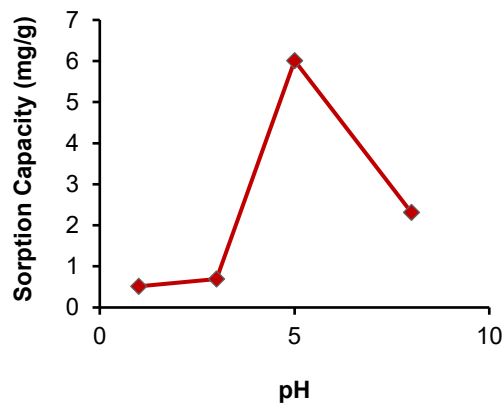


Fig. 3 pH vs Sorption Capacity

2. Effect of Initial Concentration and Contact Time

The influence of contact time and initial uranium concentration on the sorption capacity of uranium (q_t) is illustrated in Fig 7. At 40, 60 and 80 ppm uranium concentrations, the q_t value relatively increases with increasing time of absorption. At 20 ppm uranium concentration, the q_t value is relatively constant. This is due to concentration of uranium is relatively small and hence, there is no significant increase in q_t value in each contact time. In this study, uranium concentrations of 60 and 80 ppm will be used as the optimum concentration adsorbed by bentonite:TiO₂. A concentration of 60 ppm will be compared with a concentration of 80 ppm to determine the difference in q_t results obtained at each time of absorption. Determination of optimum concentration was determined using ANOVA analysis.

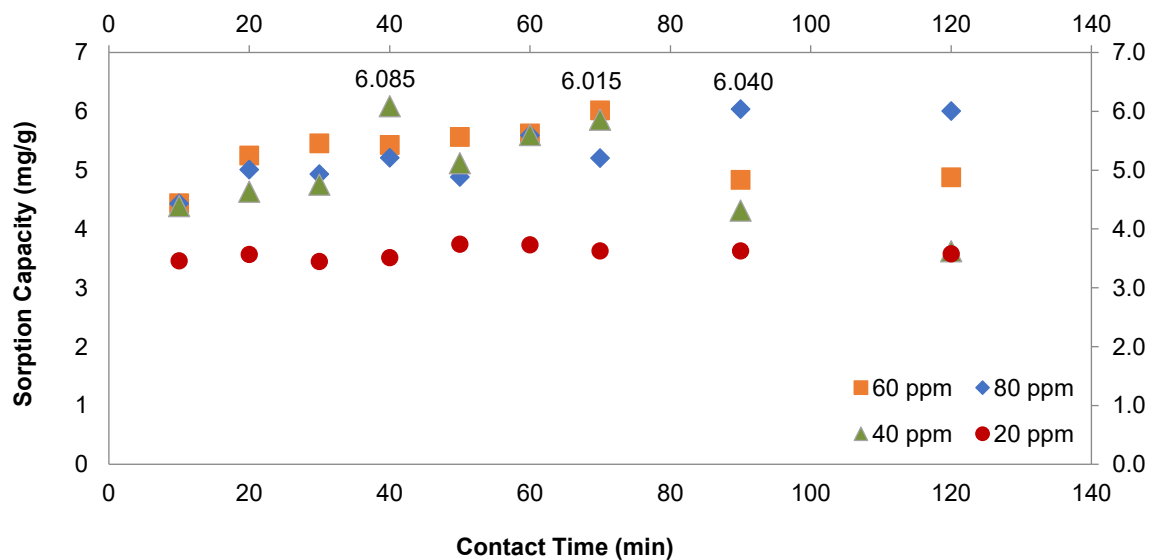


Fig. 4 Contact Time vs Sorption Capacity

F value is smaller than Fcrit value and consequently, there is no significant effect by increasing uranium concentration from 60 ppm to 80 ppm to the values of sorption capacity. The average distribution of q_t values at 60 and 80 ppm were not significantly different. At concentration

uranium of 60 ppm, maximum sorption capacity is obtained at 70 minutes of contact time, while at concentration of 80 ppm, the maximum adsorption capacity was generated at 90 minutes contact time. The shorter contact time is better because it will be more profitable and economical.

Therefore, 70 minutes and 60 ppm were chosen as optimum contact time and uranium concentration for uranium adsorption by bentonite:TiO₂, respectively.

3. Adsorption Kinetic

Kinetic models were applied to the experimental data in order to understand the potential rate controlling steps and mechanism of reaction. The pseudo first-order and pseudo second-order kinetic models were applied to describe the kinetic characteristic of uranium ions adsorption by bentonite:TiO₂.

The Pseudo-first order constant (k_1) could be obtained by plotting $\log(q_e - q_t)$ versus t . The pseudo-second order constant (k_2) can be determined from the slope of plot t/q_t versus t . The kinetic parameter with the corresponding coefficient of determination (R^2) are shown in Table 3. The coefficient of determination of the pseudo second-order kinetic model is higher than that of the pseudo first order kinetic model. Therefore, the pseudo second-order kinetic model can be adopted to explain the sorption process of uranium onto bentonite:TiO₂.

Table. 3. Adsorption Kinetic Parameters

No	Adsorption Kinetic	K	R ²
1	Pseudo-First Order	0.004 min ⁻¹	0.054
2	Pseudo-Second Order	0.075 g/mg.min	0.992

4. Adsorption Isotherm

Isotherm adsorption is a mathematical model that describes the distribution of adsorbate in solution and adsorbent using assumption in the form of heterogeneity and homogeneity of the adsorption process, and interactions between adsorbate and adsorbent [30]. The adsorption isotherm used to describe the mechanism of uranium adsorption by bentonite:TiO₂ were Langmuir isotherm and Freundlich isotherm.

The corresponding coefficient of determination (R^2) on Freundlich and Langmuir isotherm are shown in Table 4.

The type of adsorption isotherm that has the R^2 value closest to 1 is the langmuir isotherm. Therefore, uranium adsorption process on the surface of bentonite: TiO₂ occurs homogeneously to form one layer and there is no interaction between adsorbates. Maximum adsorption capacity of bentonite:TiO₂ to form one layer in the adsorption process of 5.848 mg/g.

Table. 4. Adsorption Isotherm Parameters

No	Adsorption Isotherm	R ²
1	Freundlich Isotherm	0.768
2	Langmuir Isotherm	0.954

Table. 5. Uranium Sorption Capacity by Different Adsorbent

No	Adsorbent	Sorption Capacity (mg/g)
1	Bentonite:TiO ₂	5,848
2	Natural Bentonite (In this study)	2,355
3	Hematite [27]	3,540
4	Bentonite [30]	4,150
5	Ferric Oxide-modified Zeolite [21]	0,240

The adsorption capacity of bentonite:TiO₂ with several adsorbents is shown in the Table 5. The capacity of uranium adsorption by bentonite: TiO₂ is

greater than some types of adsorbents and bentonite without TiO₂. Based on the results obtained, the addition of TiO₂ can increase the capacity of natural bentonite.

CONCLUSIONS

A natural bentonite and bentonite: TiO₂ sample were characterized by using FTIR, XRD, and BET determined its functional group, basal spacing, and specific surface area, and investigate the adsorption of bentonite:TiO₂ in various environmental factors such as pH, contact time, and initial uranium concentration. The adsorption of uranium on bentonite obviously depends on pH values. The higher the concentration of uranium solution and the contact time, the adsorption capacity of uranium by bentonite TiO₂ is relatively increased before reaching equilibrium conditions. In this study, the optimum uranium concentration and contact time were taken at 60 ppm and 70 minutes, respectively. The surface area and adsorption capacity of uranium by bentonite increased after delamination occurs. The surface area of bentonite before and after TiO₂ added were 68.23 m²/g and 80.27 m²/g. Adsorption capacity has increased by 3.493 mg/g. The kinetic data signified that sorption of uranium onto bentonite:TiO₂ followed the pseudo second-order kinetic model. Sorption of uranium onto bentonite:TiO₂ was best described by the Langmuir isotherm model. The reaction kinetics constant and adsorption capacity obtained were 0.075 g/mg.min and 5.848 mg/g, respectively. The adsorption capacities of uranium onto bentonite:TiO₂ were found to be higher than for natural bentonite.

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