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Synthesis of Chitosan Modified Polyurethane Foam for Adsorption of Mercury (II) Ions

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Abstract

Mercury from the traditional gold mining activities in Aceh Jaya Regency causes water source and thus residents are exposed to mercury metals. In organic and inorganic conditions, mercury is toxic to the human body, causes damage to the nerve system, kidney failure, heart failure, blood pressure disorders, and damage to the immune system. The problem of mercury contamination can be chemically solved in various ways. This research uses polyurethane foam to adsorb mercury from water. The adsorption and selectivity of polyurethane foam adsorption can be improved through modification with Chitosan. In this research, preheating temperature, glycerol and toluene di-isocyanate (TDI) compositions greatly affect the physical form of foam. The condition under which optimal glycerol composition used for synthesizing the polyurethane foams is 20% (w/w of mixture A). This glycerol composition results in polyurethane foams with an optimum ratio of the mixture A/TDI/distilled water of 2 : 1 : 1. The best adsorption is obtained with polyurethane foam added by 2.5% Chitosan. The optimum mercury adsorption 25% is resulted from the operating time of 60 minutes with adsorption capacity of 0.313 mg/g. For Chitosan modified polyurethane foam, research points out that the reaction is the second order reaction. The result concluded that the polymer has semi crystalline crystallization and melting temperatures.

INTRODUCTION

Many gold minerals are present in Aceh Jaya, helping the people's economic, but they have adverse impacts on the environment and health (World Health Organization, 2016). The increase of traditional gold mining activities using mercury in the process of splitting of gold ore in Aceh Jaya Regency caused mercury contamination (Harian Serambi Indonesia, 2015). The traditional mining, conducted by the Aceh Jaya community, does not yet have proper operational standards for waste management. Therefore, the waste pollutes the river water and residents' wells. It is reported that 62% of the sample of residents' water source was contaminated by mercury (Harian Serambi Indonesia, 2015). The water samples are taken from various sources such as the river water, excavation wells, and the drilled well. Based on Government Regulation Number 82 year 2001, the mercury threshold value of drinking water is 1 ppm while for infrastructure is 2 ppm. The discovery of mercury above the threshold values in residents' well indicates a high risk of the exposure to mercury.

The permanent mercury exposure can damage the nervous system, cause symptoms of paresthesia, ataxia, disturbances of stimulation, tremors, nearsightedness, stuttering, hearing loss, blindness, deafness, even death. Mercury both in organic and inorganic forms can damage other systems in the body, cause kidney failure, heart failure, blood pressure disorders, and immune system damage (Choi & Grandjean, 2012).

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There were two famous cases of mercury poisoning in Minamata and Iraq. In Minamata, poisoning cases were caused by methyl mercury (MeHg) accumulation in fish consumed by the community. Whereas in Iraq, poisoning cases were caused by wheat consumption contaminated by MeHg as a fungicide. Chronic exposure to MeHg may inhibit fetal brain development because generally this can penetrate the placenta and the protective brain. Consumption of fish containing MeHg by pregnant women may lead to the various disorders of the fetus, such as IQ retardation, muscle-forming abnormalities, and abnormalities in motor function (World Health Organization, 2016).

The problem of mercury contamination can be chemically solved in various ways. One of them is using polyurethane foam to adsorb mercury from water. Polyurethane foams have polar and non-polar groups that can adsorb various chemical compounds. Soriano & Casella (2013) reports that polyurethane foam can separate free molecules, aromatic compounds, metallic dithizonates, and complex anions.

Polyurethane foams can be made from castor oil that is economical, biodegradable and has a low toxicity level. Furthermore, the castor oil is a natural product that has not been fully used because it cannot be consumed (Liu & Guo-Feng, 2014).

The adsorption and selectivity of polyurethane foam adsorption can generally be increased by modification with both organic and inorganic compounds. Khan et al. (2015) successfully modified polyurethane foams using nanotubes of multiwall carbon to adsorb safranin T and Pb (II).

Moawed et al. (2017) succeeded in adding the filler of halogen and amino groups into the polyurethane foam matrix to adsorb Bi (III), Co (II), Fe (III), and Mo (III). Riaz et al. (2016) also successfully modified polyurethane foam using cellulose acetate to adsorb Cr (VI). In this research, the polyurethane foam will be synthesized by the chitosan modification as a mercury metal adsorbent that has never been studied previously.

The addition of Chitosan as a filler is expected to increase the ability of polyurethane foam to adsorb mercury. Chitosan modified polyurethane foam (Chi-PUF) has been widely studied as an antibacterial agent (Kara et al., 2015). In addition, Rae & Gibb (2003) reported that of various chitin-derived compounds, Chitosan is the most effective material to adsorb various metals (alkali metal, alkaline earth, transition and heavy metals) from water solvents. The ability of Chitosan in the adsorption of mercury metals has also been reported by Yasemi & Abassi (2013), Rahbar et al. (2014), and Khalik et al. (2014).

RESEARCH METHODOLOGY

Material

This research was conducted in the Research Laboratory of Chemical Department College of Mathematics and Natural Science, Syiah Kuala University. This research had been carried out for 9 months in the range of February – October 2017. The materials were the well water from the Calang Well at Calang city, Chitosan (92% deacetylated, CarboMer Inc.), and castor oil (chemically pure, Fuchen LLC China) as polyol. TDI was obtained from commercial sources from isocyanate distilled to be a blowing agent. The mercury was obtained from the traditional process region in the radius of 100 meters located in Calang, Aceh Jaya Regency.

Sampling was carried out by *Purposive Sampling* method. The tools were DSC (Shimadzu), SEM-EDX (JSM-5410 LV), Atomic Absorption Spectroscopy (AAS, Shandon Southern A3400), and Fourier Transform Infrared (FTIR, Bruker Optics).

Synthesis of Polyurethane Foam from Castor Oil

Synthesis of polyurethane foams from castor oil was done by one-shoot method with a trial and error way. The polyol mixture was prepared by mixing 4 grams of castor oil and 1 gram of distilled water with various preheating temperatures (room temperature, 70°C, 80°C, 90° C, 100°C) at 750 rpm stirring rate and 5 minutes, then it was mixed with 4 grams of TDI. After mixing, the mixture is stirred at a rate of 1,000 rpm until the foam is formed or for about 20 seconds, then poured into an aluminum mold (6 cm × 6 cm × 3 cm).

The foam was then left at the room temperature for 48 hours. Its visual form was observed to determine the optimum preheating temperature. The same treatment was performed to determine the optimum composition of various masses of distilled water (0.5, 1.0, 1.5, 2.0, 6.0 grams) and TDI (2, 3, 4, 5, 6, 9 grams).

Synthesis of Polyurethane Foam with Glycerol Addition

The synthesis of polyurethane foam was performed using the glycerol to obtain semi-flexible foams. Castor oil was mixed with 10% of the glycerol in an Erlenmeyer flask to get a total mixture of 120 grams. This mixture (hereinafter referred to as mixture A) was heated at 225°C with a stirring rate of 750 rpm for 4 hours. Then, the mixture is left and stored in a dark and tightly closed bottle.

To synthesize a polyurethane foam, 0.5 grams mixture A and 1 gram distilled water were preheated at 90°C with a stirring rate of 750 rpm for 5 minutes. The polymerization was carried out by adding TDI (0.5; 1.0; 1.5 grams) into a beaker glass at a stirring rate of 1,000 rpm until the foam was formed or for about 20 seconds, then poured into an aluminum mold (6 cm × 6 cm × 3 cm). The foam formed was left at 70°C for 3 hours.

Following this, the same treatment was carried out with various compositions of TDI (0.5; 1.0; 1.5 grams) and mixture A (0.5; 1.0; 1.5; 2.0 grams) with 20% glycerol. Then, the optimum composition of glycerol, a mixture of A, TDI, and distilled water determined by visual observation was used to synthesize the Chitosan modified polyurethane foam (Chi-PUF).

Synthesis of Chitosan Modified Polyurethane Foam

The mixture A and distilled water with optimum composition was poured and mixed in a beaker glass, then stirred at 750 rpm for 30 seconds. Then, Chitosan was also mixed with composition of 0.0; 2.5; 5.0; 7.5; and 10% (w/w of mixture A). Preheating is done after adding the Chitosan at 90°C and 750 rpm for 5 minutes.

A polymerization was carried out by adding the optimal TDI with a stirring rate of 1,000 rpm until the foam was formed or for about 20 seconds, then poured into an aluminum mold (6 cm × 6 cm × 3 cm). The foam formed was left at 70°C for 3 hours. After leaving the oven and cooling, the formed Chi-PUF was then diced 0.5 cm^3 to determine the adsorption capacity of each foam against Hg (II).

Each cubic foam was incorporated into an Erlenmeyer containing 25 mL of 2 ppm (II) Hg solution. The mixture was stirred using a shaker with a speed of 420 rpm for 60 minutes at room temperature. The solution was filtered and diluted with 100 mL distilled water, then the Hg (II) concentration was measured with AAS. Chi-PUF adsorption capacity and removal percentage were calculated using equation 1 and 2.

$$q(t) = \frac{[C_0 - C_t]V}{m} \quad (1)$$

$$P_r = \frac{[C_0 - C_e]}{C_0} \times 100 \quad (2)$$

Where q was the adsorption capacity (mg/g) whereas P_r was the removal percentage. The values of C_0 and C_t were the initial concentration of the solution and the final concentration of the solution at time t (mg/L), V was the solution volume (L) used. The m value (g) was the adsorbent weight used and C_e was the equilibrium concentration of the adsorbate (mg/L).

Characterization of Chi-PUF

Chi-PUF, whose optimum adsorption ability has been determined, is characterized using various techniques. The presence of functional groups was analyzed using Fourier transform infrared (FTIR) in the range of 800–4000 cm^{-1}. The foam surface morphology was analyzed using scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX). Whereas the thermal properties of the foam were analyzed using differential scanning calorimetry (DSC).

The Optimum Contact Time

Adsorption was performed by preparing 0.1 grams of Chi-PUF in five Erlenmeyer flasks 250 mL, each contained 25 mL of 5 ppm Hg (II) solution. The mixture in each flask was stirred at room temperature with a shaker speed of 420 rpm for 5, 15, 30, 45, and 60 minutes, respectively, until the adsorption equilibrium was reached. The solution was filtered and diluted with 100 mL distilled water. Then, Hg (II) concentration was measured using AAS.

The Optimum pH

Chi-PUF of 0.1 grams was put into five Erlenmeyer flasks 250 mL containing 25 mL of 10 ppm Hg (II) solution. The mixture is stirred at room temperature with a shaker speed of 420 rpm in a pH range of 3–9 by adding a solution of HNO_3 or NaOH. After the adsorption, the solution was filtered and added by distilled water to 100 mL.

Table 1. Synthesis PUF with various preheating temperatures, distilled water, and TDI

No.	Castor Oil (gram)	TDI (gram)	Distilled Water (gram)	Preheating Temperature (°C)	Visual Description of PUF
1	4	4	1.0	Room temperature	Pale yellow, rigid, the foam is little formed and not expanded
2	4	4	1.0	70	Pale yellow, rigid, the foam is partially formed and expanded
3	**4**	**4**	**1.0**	**80**	**Bright yellow, rigid, the foam is formed thoroughly and expanded**
4	**4**	**4**	**1.0**	**90**	**Bright yellow, rigid, the foam is formed thoroughly and expanded**
5	4	4	1.0	100	Pale yellow, rigid, the foam is little formed and not expanded
6	4	4	0.5	90	Bright yellow, rigid, the foam is not formed and not expanded
7	**4**	**4**	**1.0**	**90**	**Pale yellow, rigid, the foam is formed thoroughly and expanded**
8	4	4	1.5	90	Bright yellow, rigid, the foam is formed thoroughly and expanded
9	4	4	2.0	90	Bright yellow, rigid, the foam is formed thoroughly and expanded
10	4	4	6.0	90	Pale yellow, rigid, the foam is formed thoroughly and expanded
11	4	2	1.0	90	Bright yellow, rigid, the foam is not formed and not expanded
12	4	3	1.0	90	Pale yellow, rigid, the foam is partially formed and expanded
13	4	4	1.0	90	Bright yellow, rigid, the foam is formed partially and expanded
14	4	5	1.0	90	Yellowing white, rigid, the foam is formed partially and expanded
15	4	6	1.0	90	Brownish yellow, rigid, the foam is formed partially and expanded
16	4	9	1.0	90	Yellowish white, rigid, brittle, and expanded

Then Hg (II) concentration was measured using AAS.

Adsorption of Hg (II) Ions

Chi-PUF of 0.1 grams was put into five Erlenmeyer flasks 250 mL, each contained 25 ml of Hg (II) solution at various concentrations of 5, 10, 15, 20, and 25 ppm. The mixture was stirred at room temperature with a shaker speed of 420 rpm at the optimum pH by adding a HCl or NaOH solution. After the adsorption, the solution was filtered and added with distilled water to 100 mL, then Hg (II) concentration was measured with AAS.

RESULT AND DISCUSSION

Synthesis of Polyurethane Foam

Polyurethane foam (PUF) is synthesized with various preheating temperatures (room temperature, 70, 80, 90, 100°C), distilled water (0.5, 1.0, 1.5, 2.0, 6.0 grams), and TDI (2, 3, 4, 5, 6, 9

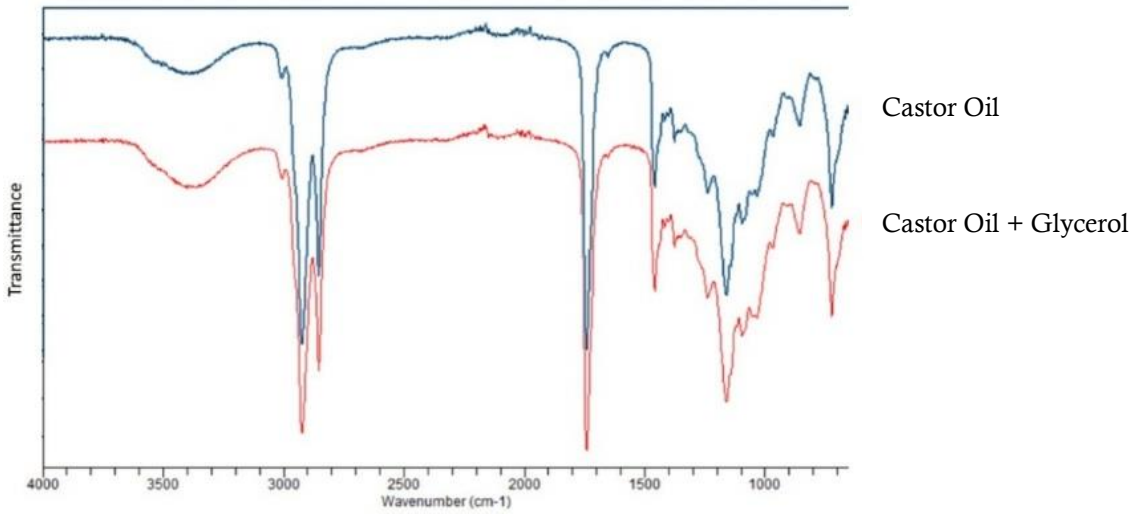


Figure 1. FTIR spectra of castor oil and the mixture A.

grams). Synthesis was carried out with a particular compositions of castor oil (4 grams), and a drying process is performed at room temperature for 48 hours. The synthesis results are observed visually to obtain a well-expanded and semi-flexible polyurethane foam. Semi-flexible property is very necessary because it simplifies the dice forming of the foam applied as an adsorbent. Table 1 shows the PUF synthesized by trial and error to determine the preheating temperature, distilled water composition, and the corresponding TDI composition.

Oppon et al. (2015) reported that various preheating temperatures and mixture compositions may affect the physical properties and polymerization time. In general, PUF synthesized has various yellow colors; pale yellow, bright yellow, brownish yellow, and yellowish white. The yellow color can be derived from the TDI color (brownish orange) and the color of castor oil (pale yellow).

The preheating temperature that increased can make the TDI more reactive so the foam can expand. Based on visual observations of various preheating temperatures, the higher temperature can enhance foam formation where the foam expands and is formed thoroughly. The foam synthesized without preheating (room temperature) produces foam formed partially, where the bottom is not foamy. However, the foam characteristic decreases when the preheating temperature is 100°C. Therefore, the optimum temperature used is 90°C to synthesize foam with various composition of water and TDI.

The water in the mixture of PUF is necessary to react with TDI to produce CO_2 gas forming the foam (Liu and Guo-Feng, 2014). In general, the amount of water does not affect the visual form of the polyurethane foam synthesized. However, based on Table 1 it can be seen that the water composition 1 gram can make the foam expands and is formed thoroughly. Meanwhile, various compositions of TDI shows significant differences in the visual form of the polyurethane foam synthesized. The more TDI is used, the more rigid and fragile the foam is formed. Nevertheless, too little TDI can inhibit the foam formation.

Based on the PUF synthesis results using various compositions, semi-flexible foam is not found. According to Ashida (2007), if PUF is flexible, thus the number of OH required is more than 280. The flexible nature of PUF can be achieved by adding polyols such as glycerol (Wool & Sun, 2011). Therefore, PUF synthesis is trial and error again by adding a new material that is glycerol to obtain a flexible PUF.

Based on Table 1, the same condition (number 4, 7, and 13) has three different visual description of PUF. It is probably caused by exposure to UV lighting that darkens the exterior color of the PUF. However, light does not induce a significant change in the structure of the PUF since the distortion can be reversed by squeezing the PUF. Since the lighting is uncontrolled, thus variations in Table 1 can be used to determine the effect of those parameter on the visual of PUF.

The Glycerol on PUF Synthesis

Glycerol is added to increase flexibility to the foam. In addition, according to Wool & Sun (2011), the glycerol may also act as a cross linker increasing the stability and maintaining the foam

Table 2. Synthesis of PUF with various compositions of TDI, castor oil, aquadest, and glycerol.

No.	Castor Oil/TDI/Distilled Water (gram)	Glycerol (%)	Visual Description of PUF
1	1.0 : 1.0 : 0.1	10	Pale yellow, rigid, not expanded
2	1.0 : 1.0 : 0.5	10	Pale yellow, rigid, well-expanded
3	1.0 : 1.0 : 1.0	10	Pale yellow, rigid, well-expanded
4	1.0 : 0.5 : 0.5	10	Bright yellow, flexible, well-expanded
5	1.0 : 1.0 : 0.5	10	Bright yellow, flexible, well-expanded
6	1.0 : 1.5 : 0.5	10	Bright yellow, flexible, well-expanded, fragile
7	**1.0 : 0.5 : 0.5**	**20**	**Bright yellow, flexible, well-expanded**
8	1.5 : 1.0 : 0.5	20	Bright yellow, flexible, well-expanded, soft and sticky
9	2.0 : 1.5 : 0.5	20	Bright yellow, flexible, well-expanded, soft and sticky

Figure 2. Chi-PUF with various chitosan; (a) 0%, (b) 2.5%, (c) 5%, (d) 7.5%, (e) 10%, and (f) 12.5%.

structure. A mixture comprising castor oil and TDI is heated at 225°C and stirred with a magnetic stirrer (750 rpm) to form a transesterification reaction.

FTIR spectra of the castor oil and mixture A used to synthesize polyurethane foam are presented in Figure 1. Both spectra of the castor oil and mixture A have similarities. Vibration of a N-H stretch is read at a wavelength of 3531–3400 cm^{-1}. Typical groups of castor oil, C=C-H and C-C-H, are read respectively at 3007 cm^{-1} and 2923–2853 cm^{-1} wavelengths. The wavelengths of 1458 and 1376 cm^{-1} show the existence of CH_2 and CH_3 bend, respectively; the groups are commonly found in aliphatic chains in castor oil. The carboxyl groups and the ester groups are shown to be concentrated on the wavelength of 1741 cm^{-1}. Wavelength 1239 cm^{-1} indicates the presence of a stretch of the C-O-C group. Wavelengths in the range of 1161–1095 indicate the presence of the C-OH stretch that is characteristic of glycerol.

Water does not significantly give different results in the PUF synthesis. However, the water composition of 50% (w/w castor oil) has been already able to make the foam expand. TDI composition also has an effect on the PUF yield. As TDI is added more, the PUF properties tend to be more rigid and fragile. Therefore, less TDI is expected to result in the flexible PUF. In Table 2, compositions number 4 and 5 give the same results on the physical form of the PUF. It indicates the different consumption of TDI attributed to the different formation rates of the PUF. The final conversion of isocyanate does not reach the theoretical 100% conversion as a result of vitrivication of the hard segments in the mixture. In this composition, either TDI equals to or less than one gram is considerably low enough to make the foaming mixture homogeneous. Therefore, TDI composition less than one gram is preferably selected for the economical reason. Increasing content of castor oil and glycerol reduced the amount of TDI as foaming agent necessary in providing the same volume of PUF during synthesis, which will be economical.

The glycerol composition increases to 20% to increase the flexibility of the foam. Various compositions of the castor oil and glycerol (20%) have a significant effect on the synthesized foam (Table 2). With glycerol 20%, the castor oil with composition more than 1 gram can affect the physical character of the foam. As a result, it becomes softer and stickier. Because of the proper flexibility, the castor oil/TDI/distilled water with a

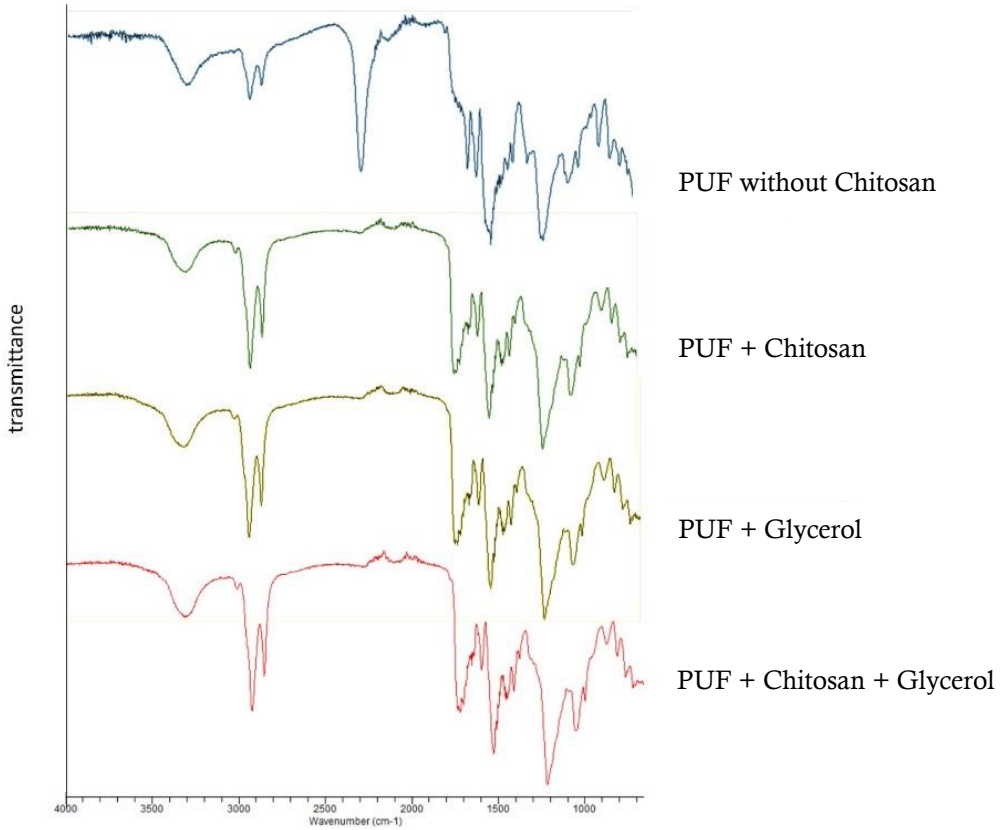


Figure 3. FTIR spectra of PUF, PUF + chitosan, PUF + glycerol, and PUF + glycerol + chitosan.

ratio of 1.0:0.5:0.5 is used to synthesize the Chi-PUF applied as an adsorbent.

Synthesis of Chitosan Polyurethane Foam

Figure 2 is a synthesis of the Chitosan modified polyurethane foam (Chi-PUF) with various masses of Chitosan (w/w castor oil). It shows that the Chi-PUF has various colors; yellow, pale yellow, and yellowish orange. The resulted color comes from the castor oil and TDI colors. Visually, it can be observed that 12.5% Chitosan produces the foam with irregular and fragile structures that negatively impact on the physical character of Chi-PUF. Therefore, the foam tested for adsorption capacity is the foam with Chitosan concentrations of 0.0, 2.5, 5.0, 7.5, and 10%.

Table 3. Concentration Hg after adsorption.

No.	Adsorbent	Adsorption Capacity (mg/g)	Removal (%)
1	Chi-PUF	3.9×10^{-3}	77.5
2	2.5% Chitosan	5.0×10^{-3}	100.0
3	5.0% Chitosan	5.0×10^{-3}	100.0

The Optimum Composition of Chitosan

Table 3 shows the results of Hg (II) adsorption in water by the Chi-PUF with various compositions of Chitosan calculated from Equations 1 and 2. Based on the data, it can be observed the measurement error where the Hg concentration after adsorption is higher than before the adsorption.

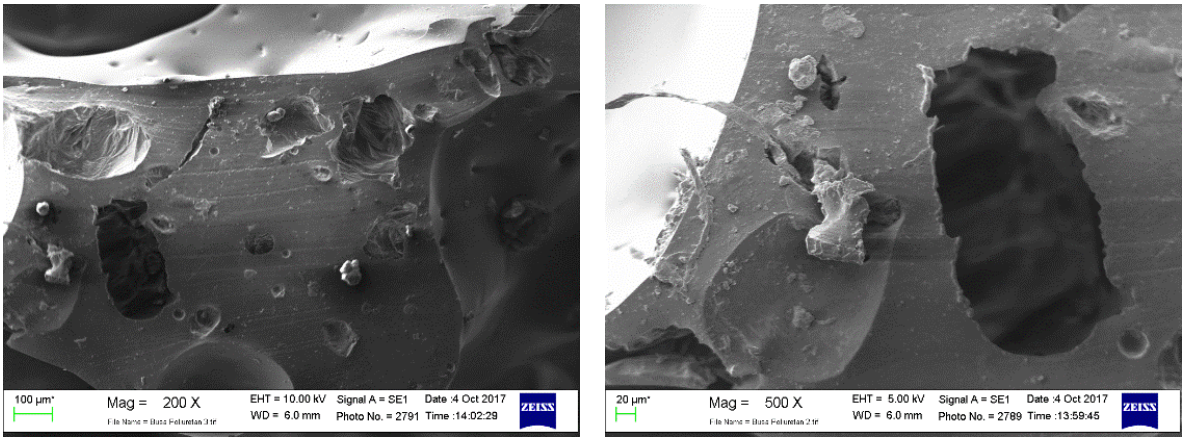
This can be caused by physical adsorption taking place on it. In addition, the results show the effect of Chitosan mass on the adsorption ability of the Chi-PUF.

The adsorption ability of the Chi-PUF tends to decrease with the increase of the Chitosan composition. The excessive Chitosan concentration can damage the structure of the PUF.

Characterization of Chi-PUF

FTIR Spectra

Figure 3 shows the FTIR spectra of the PUF, PUF + Chitosan, PUF + glycerol, and PUF + glycerol + Chitosan. The N-H groups are shown in all types of foams with each wavelength (3295 cm^{-1}, 3308 cm^{-1}, 3308 cm^{-1}, and 3313 cm^{-1}). The C=C-H stretch on PUF is unreadable, whereas in another type of foam it is read at a wavelength of



(a) (b)

Figure 4 Chi-PUF surface with magnitudes of (a) 200, and (b) 500 times

3009–3011 cm^{-1}. Meanwhile, the C≡N stretch read only on the PUF (2271 cm^{-1}) indicates the presence of excess TDI. C=O amides are the typical groups of urethane shown in all foams (1645–1508, 1596–1527, 1654–1527, and 1707–1527 cm^{-1}).

Meanwhile, the N-H group that is characteristic of Chitosan is also read on the same wavelength. C=C aromatic is a group of polyurethane and Chitosan, indicated by all types of foams at wavelength of ~ 1411 cm^{-1}. The C-OH stretch is a common group in the castor oil, glycerol, and Chitosan.

Table 4. The chemical composition of Chi-PUF.

No.	Element	Mass (%)	Number of Atoms (%)
1	C	72.32	80.91
2	O	11.88	9.98
3	N	8.38	8.04
4	Nb	5.30	0.77
5	Zr	2.12	0.31

Scanning Electron Microscopy

The surface morphology of polyurethane foam with 2.5% Chitosan (w/w castor oil) is analyzed by SEM-EDX at magnitudes of 200 and 500 times. According to Figure 4, the Chitosan modified polyurethane foam has a surface with multilayer pores. The pores have irregular size and distribution. Whereas the surface micro structure of the foam looks smooth.

Elements read in EDX are C, O, N, Nb, and Zr (Table 4) with masses of 72.32, 11.88, 8.38, 5.30, and 2.12% (w/w), respectively. The EDX results show that C is the most dominant element. In addition to C, elements of O and N are components of polyurethane foam. Whereas Nb and Zr are impurities.

Adsorption

The Determination of The Optimum Time

The effect of the adsorption time of Chi-PUF on Hg (II) ion is shown by Table 5. As the adsorption time is longer, the adsorption capacity and the removal percentage of Hg (II) ions become higher. The optimum time of adsorption is 60 minutes with adsorption capacity and the removal percentage of Hg (II) ions are 0.313 mg/g and 25%, respectively.

Table 5. The effect of the time on adsorption.

No.	Time (minute)	q (mg/g)	P_r (%)
1.	5	0.125	10
2.	15	0.150	12
3.	30	0.163	13
4.	45	0.188	15
5.	60	0.313	25

Differential Scanning Calorimetry (DSC)

Figure 5 illustrates the change in the Chi-PUF heat capacity as long as the DSC analysis. It shows that the glass transition temperature known by DSC analysis shows the second order reaction. This second-order transition is indicated by the change of the baseline to the bottom of 280°C as a result of the change in heat capacity. After passing temperature of 280°C, the foam structure can move more flexible. Therefore, it looks rubbery.

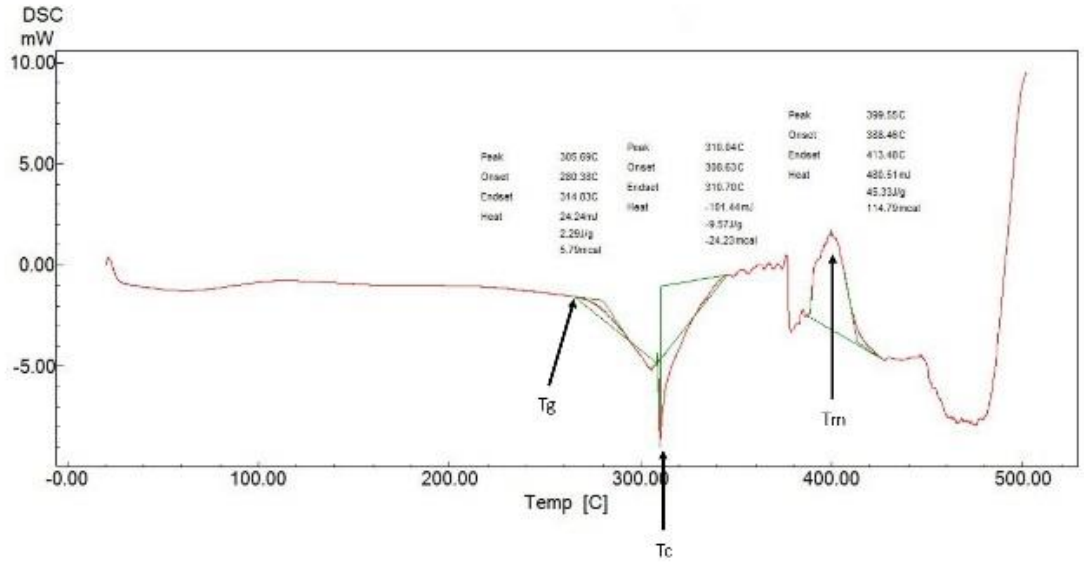


Figure 5 DSC curve of Chi-PUF

According to Liu & Guo-Feng (2014), polymers are glassy or rigid when the glass temperature (Tg) is greater than 100°C. Thus, the foam becomes rigid at room temperature. The first order transitions such as crystallization (Tc) and melting (Tm) are shown at 310°C and 399°C, respectively. The DSC curve shows the Chi-PUF has semi crystalline Tc and Tm.

CONCLUSION

The conclusion drawn based on this research is that the optimum temperature of preheating to synthesize polyurethane foam from castor oil is 90°C. The glycerol is required to synthesize semi-flexible foam to easily form an adsorbent. FTIR results of both castor oil and mixture A indicate the presence of functional groups as characteristics of castor oil and glycerol. The optimum ratio of castor oil/TDI/water for the semi-flexible polyurethane foam is 1.0:0.5:0.5 with 20% glycerol (w/w of mixture A). The optimum adsorption capacity and removal percentage of Hg (II) ions are obtained by the Chi-PUF with 2.5% Chitosan (w/w of mixture A). SEM analysis shows that the surface morphology of the Chi-PUF has pores with irregular size and distribution. Based on its thermal properties, the Chi-PUF is a semi crystalline polymer with temperatures of Tg, Tc, and Tm are 280, 310, and 399°C, respectively. The optimum time of the Chi-PUF adsorption is 60 minutes indicated by adsorption capacity and the removal percentage of Hg (II) ions of 0.313 mg/g and 25%, respectively. Further research should focus on various Chitosan compositions in the polyurethane foam because they can affect the foam's structure and its adsorption capacity.

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