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MULTILAYER POROUS COMPOSITE FROM WASTE GLASS FOR WATER FILTRATION

KOMPOSIT PORI BERLAPIS DARI LIMBAH KACA UNTUK FILTER AIR

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ABSTRAK

Komposit pori berlapis telah dihasilkan dengan proses pemanasan pada temperatur T=700^{0}C selama 2.5 jam. Komposit pori satu lapis dibuat dengan variasi persen massa polimer PEG 1% hingga 10%. Komposit pori dua lapis dibuat dengan susunan porositas (4:3)%, (4:2)% dan (3:2)%, sedangkan komposit pori tiga lapis memiliki susunan porositas (4:3:2)%. Kinerja komposit pori berlapis untuk filter air dengan polutan methylene blue 100 ppm diestimasi dari spektrum absorbansi. Rejeksi polutan methylene blue dari komposit pori satu lapis meningkat saat fraksi polimer PEG cenderung lebih kecil dalam matrik komposit. Sedangkan, komposit pori dua lapis memiliki kemampuan untuk degradasi polutan methylene blue yang lebih baik dari satu lapis. Komposit pori tiga lapis memiliki kinerja yang baik untuk filter air dimana seluruh polutan methylene blue mampu disaring.

ABSTRACT

Multilayer porous composite have been produced through the heating process at temperature T=700^{0}C for 2.5 h. Single layered porous composite was made with a varied mass percentage of from PEG polymer 1% to 10%. Double-layered porous composite were made by the arrangement of porosity (4:3)%, (4:2)% and (3:2)%, while the three-layers porous composite have an arrangement (4:3:2)%. Performance of multilayer porous composite for water filtration with pollutants of methylene blue 100 ppm was estimated from the absorbance spectrum. Rejection of methylene blue pollutants from single layered porous composite increases when the fraction of PEG polymer tend to be smaller in the matrix. Meanwhile, the double layered porous composite has a degradation of methylene blue pollutants are better than one layer. Triple layered porous composite have good performance for the water filtration where all the pollutants of methylene blue be able to be filtered.

Keywords: porous, composite, waste, glass, water.

INTRODUCTION

Porous medium has been commonly used in the fluid filtration process such as water purification (Allesina *et. al.*, 2014; Takei *et. al.,* 2012). Filtration process is carried out by flowing a fluids in a porous medium and impurities contained in fluids are expected not able to pass through the pores so that the fluid which has been filtered from impurities and then resulted fluids are clean. Various types of porous medium has been developed with a base material such as clay, zirconia, zeolites, porous carbon and membrane polymer (Unuabonah *et. al.*, 2014; Franus *et. al.*, 2014, Konrad *et. al.*, 2014, Ryu *et. al*, 2012). Masturi *et. al.* (2012) using clay from the region Plered Purwakarta-Indonesia as a base material of porous ceramic for water filtration with organic pollutants met-

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hylene blue. And also clay was used by Craver dan Smith (2008) because clay have some properties that are not corrosive, non-toxic, have a high compressive strength and formable. Meanwhile, Gestel *et. al.* (2006) developed a filter by combining the role of pores formed by the particles of zirconia (ZrO_2) and photocatalytic properties of inorganic materials such as titanium dioxide (TiO_2). Natural zeolites are used by Aslanzade (2011) as a filter because it has a high absorption.

The use of clay as a raw material in the manufacturing of filter requires a very high combustion temperature T~900°C-1200°C (Baccour *et. al.*, 2009). Meanwhile, the use of inorganic material of TiO_2 as a photocatalyst is only effective for the decomposition of organic pollutants during radiation photons of UV light or sunlight (Aliah *et. al.*, 2012).

Porous medium is relatively safe to use in the filtration process because there is no residue from the reaction product such as acid and carbon dioxide gases CO_2 that occurred in the water purification process by a photocatalyst. Mechanism process of filtration porous medium is mechanical process in which the process is dependent on the pore size of the medium. Thus, the presence of pores in the medium is very important. Porous medium in combustion process at relative low temperature T~700°C had been developed with waste glass as base material (Sulhadi *et. al.* 2014). With a melting temperature is lower than its constituent materials such as silica (SiO_2) and alumina (Al_2O_3), fabrication of porous medium of waste glass powder can be produced by tuning the time and temperature during the process of combustion. Medium pore size in the composite of waste glass powder is smaller with increasing of time and temperature combustion (Sulhadi *et. al.*, 2015).

Porous medium of composite waste glass has been used as a water filtration. The results show that porous medium effectively separates water and large size of pollutants (in the order of hundreds of micrometers), where pollutants are still able to settle. However, the porous medium of composite waste glass can not separate the small size of pollutant, where the particles dispersed in water such as particles of dye, like methylene blue in water.

Based on the simple mechanism in the filtration in which the process is conducted in a layered medium so porous medium of glass powder composites developed with layered arrangement (multilayer). Porous medium with layered arrangement for water filtration, where the pollutant is dispersed become a focus of the study.

METHODS

Waste glass are washed, chopped by the grinder, and filtered to obtain a homogeneous glass powder. Fabrication of pore was done by mixing polyethylene glycol (PEG) as a pore-forming agent and glass powder as a matrix composites. The heating process let the PEG polymer evaporate and leave empty spaces is called pore in the matrix composite. Illustrations of pore formation is shown in Figure 1.

The formation of pores in the matrix glass powder is determined by the fraction of the PEG polymer in the composites. Multilayer porous composites were made based on the value of porosity from a single layered porous composite. Engineering pores for single layered composite made with a variation of mass fraction from PEG polymer about 1% until 10%. PEG polymer mixture and glass powder were burned at a temperature T=700°C for 2.5 hours.

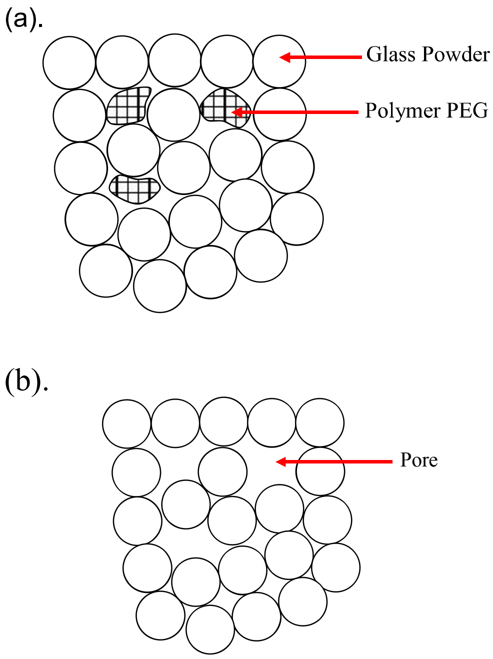


Figure 1. Illustration of (a) composite before the heating process and (b) pores formed after the heating process.

Multilayer porous composite was made based on the principle of the filtration process in which a layer structure were arranged from the layer that have porosity from the large to small, as illustrated in Figure 2.

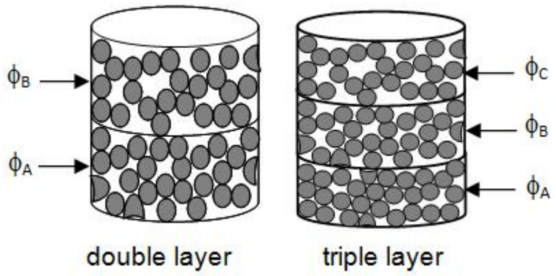


Figure 2. Illustration the arrangement of multilayer porous composite with a porosity $\phi_A<\phi_B<\phi_c$.

Performance of porous composite single, double, and triple layered were done by water filtration with organic pollutant of methylene blue with a concentration of 100 ppm. Filtration process was carried out by flowing the dirty water of methylene blue through the medium of multilayer porous composite with pressures of 0.5 bar. The filtration was observed and analyzed by using UV-Vis-NIR Ocean Optics USB type 4000.

RESULTS AND DISCUSSION

The porosity value of single layered porous composite as shown in Figure 3 becomes a basic of making a multilayer porous composite with double and triple layered. Single layered porous composite is defined that porous composite formed from first composition of the mass fraction of PEG polymer and glass powder. The value of porosity from the single layered porous composite increases with the increasing of mass fraction of PEG polymer in matrix composites. It caused the pore formed by the PEG polymer which evaporated in matrix composites. Composite porosity with mass fraction composition of PEG polymer 1% could not be measured because the fraction of PEG polymer was small in which the structure of matrix composite is very dense. While the composite with composition of mass fraction of PEG polymer 10% has a fragile structure, so the porosity could not be measured.

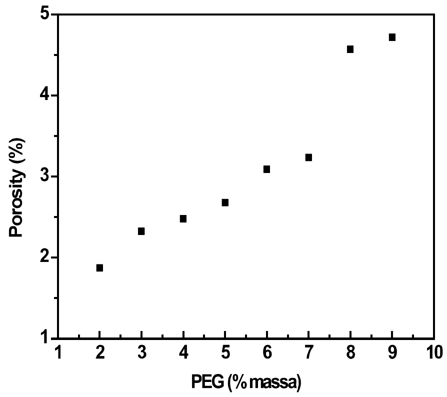


Figure 3. The distribution of porosity value of porous composite one layer.

In the early stages of development of multilayer porous composite were conducted the test of performance from single layered porous composite as a water filtration. The results of water filtration process with pollutant of methylene blue is shown in Figure 4. The results showed that there are changes in the intensity of blue color of the methylene blue solution. In simple terms, changing in the intensity of blue color describes the changing of the concentration of methylene blue particles in water.

Single layered porous composite sufficiently capable to reduce particles of methylene blue that dispersed in water, as shown in Figure 4. The intensity of color from methylene blue solution decreased by using single layered porous composite with smaller fraction of PEG. These observation results can be explained easily by using the illustrations mechanism of pore formation in Figure 1. Porous composite with higher of PEG fraction will produce pores with a fraction which increasingly large, corresponding from the measurement results of porosity in Figure 3. Similar result was declared by Sooksaen *et. al.* (2008) who was observed that the use of higher PEG fraction increasing-

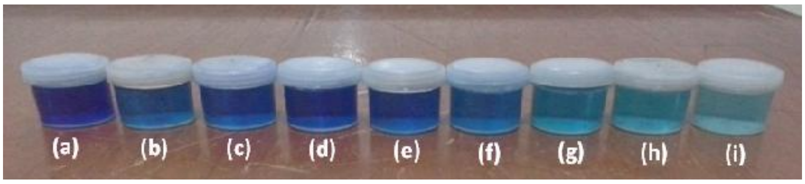


Figure 4. (a). Methylene blue solution from water filtration process through single layered porous composite with varied fraction of PEG : (b). 9%, (c) 8%, (d) 7%,(e) 6%, (f) 5%, (g) 4%, (h) 3% and (i) 2%.

ly higher will produce pores with a large size in ceramics. Thereby, methylene blue particles will be much arrested when through a medium of porous composite single layered with less PEG polymer mass fraction.

The absorption spectrum of single layered porous composite were observed by using UV-Vis-NIR Ocean Optics type USB 4000. Absorption spectrum from water of the result of filtration process using single layered porous composite with a variation of mass fraction of PEG polymer in the matrix composites was shown in Figure 5.

Absorption spectrum in Figure 5 shows the characteristic of the spectrum of methyelene blue that has absorption region in the wavelength range of 500 nm to 700 nm (Aliah *et. al.*, 2012). The intensity of absorption spectrum from methylene blue solution decreased with smaller fraction of PEG polymer. This result corresponds with Figure 4 where the color degradation of methylene blue solution causes decreasing the absorption intensity. The changing of absorbance intensity from methylene blue solution describes a changes in the concentration of methylene blue particles. In general, the relationship between intensity of absorption and concentration is declared in the Lambert-Beer equation (Räty *et. al.*, 2003) :

$$I_t = I_0 e^{-(\alpha \ell C)}$$

$$\log \frac{I_0}{I_t} = \alpha \ell C = A \qquad (1)$$

with absorption coefficient α, path length ℓ, absorption A, I_0 and I_t are intensity of light come and passed. From Lambert-Beer equation, degradation of the intensity of absorption indicates a decrease in the concentration of the solution.

Absorption spectrum of methylene blue solution which was observed from the results of single layered porous composite indicates that the porous composite is not optimal enough. The development stage of porous composite with layered arrangement, that are double and triple layered of porous composite. Double layered porous composites have 3 types, with formation of porosity (i) 4% and 3%; (ii) 4% and 2%; (iii) 3% and 2%. While the triple layered porous composite prepared by composition of porosity 4%, 3% and 2%.

The performance results of double and triple layered porous composite are shown in Figure 6. The results of the filtration process shows that the degradation of methyelene blue solution increase. Degradation of methylene blue solution are better than single layered porous composite, although there are still a particles of methylene blue in the water. While the results of filtration process with triple layered porous composite yielded clear water and without a methylene blue particles. The obser-

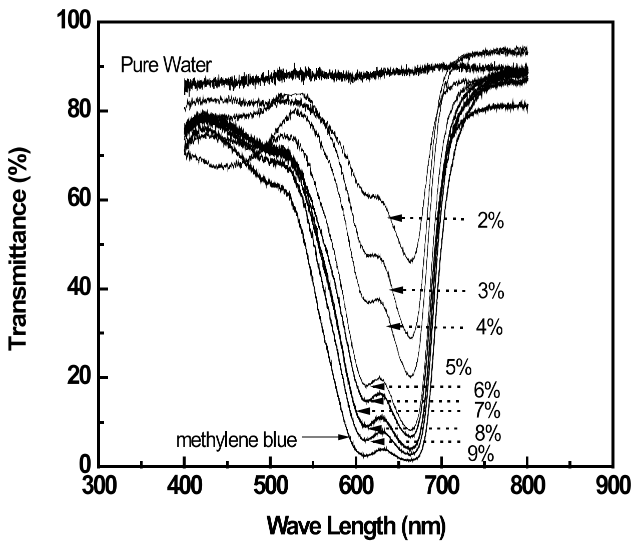


Figure 5. Absorption spectrum of filtration result with medium of single layered porous composite.

vation of color degradation of methylene blue solution corresponding to the absorption spectrum measurement results. Absorption spectrum of methylene blue particles was found in the water filtration process results. Meanwhile, water filtration process results show that triple layered porous composite can arrest absolutly the methylene blue particle in water. Thereby, triple layered porous composite can be effectively used as a water filtration to the type of pollutants with a size of constituent particles are very small such as pollutants methylene blue.

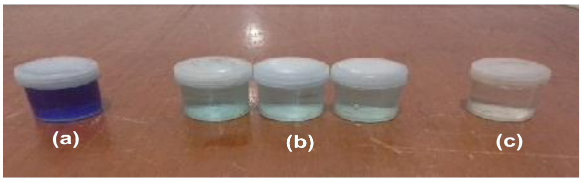
Reduction of pollutant concentrations from the filtration process known as rejection (Rj). Rj value is proportional to the number of particles that are not able to escape from the porous medium. Whereas, the concentration of particles in solution from the results of filtrantion process known as retention (R_t) (Masturi *et. al.*, 2012). R_t value is the ratio between the concentration of water filtration process results (C_f) with initial concentration (C_i). The relationship between Rj and Rt value is expressed in Equation 2.

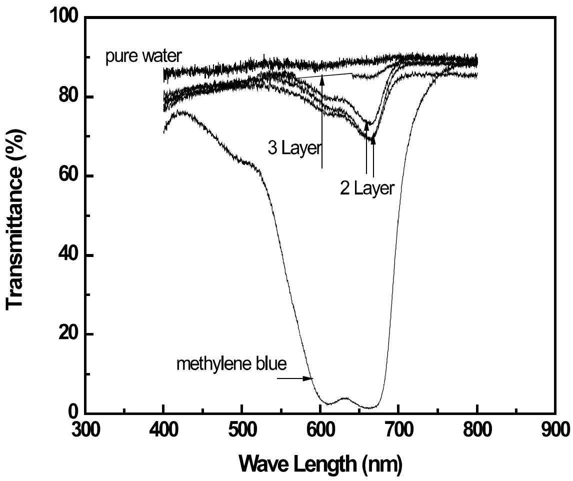
$$R_j + R_t = 1 \qquad (2)$$

The distribution of Rj value from the filtration process using the porous composite one layer, double and triple layered are shown in Figure 7. The linkage of concentration and intensity of absorption from Lambert-Beer equation is the basis for estimating Rj value from intensity of absorbance spectrum. Methylene blue particles have a characteristic of intensity of absorption spectrum at wavelength of 664 nm (Aliah *et. al.*, 2012).

The rejection Rj of porous composite single layered increases at the smaller mass fraction of PEG polymers. In this condition, a lot of filtered particles, so that the concentration of methylene blue particles in the water is lower. At double layered porous composite, Rj value is higher, with the lower concentration of methylene blue particles. Rj value is close to the value 1 where all the methylene blue particles in water are filtered by triple layered porous composite.

Porous composite with layered arrangement effectively as a water filtering. Pollutants through a porous composite medium is assumed to get different resistances on each layer. Fluid flowing through porous composite medium can be regarded as electrons charged particles which flowing in a conductor with





(d)

Figure 6. (a). Methylene blue solution; the results of water filtration process in porous composite (b) double layered, (c) triple layered; and (d) absorption spectrum from the water results of filtration process.

resistance R. The simple illustration show that the water with pollutants of methylene blue through the porous composite medium with resistance R is shown in Figure 8. In the single layered porous medium is assumed has one resistance R_1, double layered with two resistance R_2 and R_3 ($R_2<R_3$), while triple layered namely R_4, R_5 and R_6 ($R_4<R_5<R_6$).

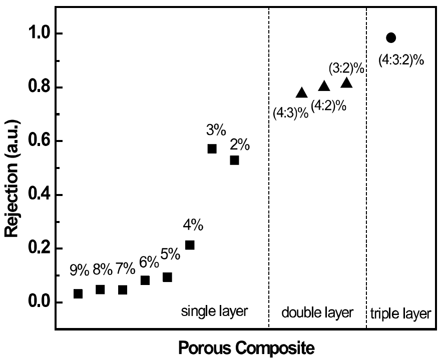


Figure 7. Distribution of pollutant rejection value from single, double, and triple layered of porous composite.

The resistance of fluid in a porous medium is declared by Abdullah and Khairurrijal (2009):

$$R = \frac{\Delta P}{Q} \quad (3)$$

with ΔP : pressure and Q : debit. Expression of the Equation (3) is similar to Ohm's law. With ΔP = 0.5 bar is equal for each process filtration, debit Q of methylene blue pollutants will be smaller in the layer with smaller porosity, so that the resistance of fluid is increased. These results are agree with a model of resistance for the multilayer porous composite in Figure 8, where resistance R is greater on the layer with smaller porosity.

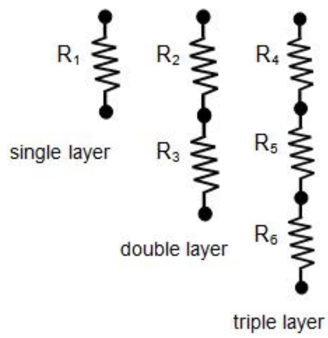


Figure 8. Illustration of a resistance model of fluid through the multilayer porous composite medium.

Multilayer porous composite was made with the arrangement from large porosity to small so that the fluid will have greater resistance with higher amount of smaller pore size. This is due to the confluence of two different pore sizes in each layer. This mechanism is a process where the particles of methylene blue in water was filtered in each layer. Thus, the process of filtration with multilayer porous composite is a repeatable filtration process. The filtration process using double layered porous composite will conduct double-filtration, while the triple layered porous composite will conduct triple-filtration process with different porosity.

CONCLUSION

Multilayer porous composite from waste glass effectively used as a water filtration with pollutants of methylene blue. Degradation of methylene blue pollutants are influenced by the number of layer on a porous composite. Single layered porous composite can reduce pollutants of methylene blue until 0.5 rejection. Whereas filtration process with double layered porous composite has a rejection about ~0.8 and triple layered porous composite can reduce all methylene blue pollutants with rejection of 0.98. Thus, triple layered porous composite have the best performance as a water filtration with pollutants of methylene blue. Multilayer porous composites have repeatable mechanisms of filtration processes, so that the rejection from pollutant of methylene blue is more optimal.

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