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Fe Filtration Comparison of Micro-Size Carbon Materials from Coconut Shell, Rice Straw, and Bamboo for Mataram Canal Water

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Abstrak

Tujuan penelitian ini adalah menghasilkan material karbon berukuran mikro (MSC) berbahan dasar tempurung kelapa, bambu, dan jerami padi melalui ultrasonikasi dalam fase cair. Bahan MSC yang telah dihasilkan selanjutnya digunakan sebagai material filtrasi logam besi (Fe) untuk sampel air yang diambil dari selokan Mataram Yogyakarta. Kandungan Fe untuk berbagai sampel air setelah proses filtrasi menggunakan ketiga material MSC dibandingkan berdasarkan *atomic absorption spectroscopy* (AAS). Dalam penelitian ini, alat-alat ultrasonikasi dan filtrasi sederhana merupakan hasil rakitan sendiri. Hasil penelitian ini mengindikasikan bahwa kandungan Fe dalam sampel air selokan Mataram mengalami penurunan setelah difiltrasi menggunakan material MSC. Kandungan Fe dalam sampel air sebelum difiltrasi adalah 0,9039 ppm, namun setelah difiltrasi menggunakan material MSC berbahan tempurung kelapa, bambu, dan jerami, kandungan Fe berturut-turut menjadi 0,0439 ppm; 0,0430; dan 0,0671 ppm. Dengan demikian, filtrasi Fe yang paling baik untuk sampel air selokan Mataram adalah menggunakan material MSC berbahan bambu.

Abstract

This study aims to produce micro-sized carbon (MSC) materials from coconut shell, bamboo, and rice straw via ultrasonication in liquid-phase. The MSCs obtained are utilized as iron (Fe) filtration for Mataram canal water. The Fe content of the water samples after filtration using the three MSC materials are compared based on atomic absorption spectroscopy (AAS). In this study, the ultrasonication and simple filtration apparatuses are self-custom made. The results of this study indicate that Fe content has decreased after filtration treatments. The Fe content of the Mataram canal water sample before filtration is 0.9039 ppm, but after filtration using coconut shell, bamboo, and rice straw carbon materials the Fe content becomes 0.0439 ppm, 0.0430 ppm and 0.0671 ppm, respectively. Thus, the best Fe filtration for Mataram canal water sample is using MSC material from bamboo.

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INTRODUCTION

Clean water is used for everyday purposes provided that it meets certain health requirements and can be consumed after being treated (Gleick 1996; Macedonio *et al*. 2012). However, many cases of water pollution hinder clean water to be obtained. Water pollution may be caused by industrial and domestic waste disposals, such as metals. One substance that contributes to the low quality of water is the excessive presence of iron (Fe) metal. The recommended level of Fe in the human body is about 7 to 35 mg (Kohgo *et al.* 2008). Fe overload can damage intestinal wall, irritation of the eyes, and skin (Boyce *et al.* 2008).

In Indonesia, especially Yogyakarta Special District there exist an irrigation source of water called Mataram canal. This canal was built during the occupation of Japan over Indonesia during World War II (Maddison 2001). This canal is a historical site that extends from west to east and divides Yogyakarta into North and South regions. This canal is generally used as irrigation for rice fields along the canal. However, as housing is developing along the Mataram canal, it is used for washing, bathing livestock, and disposal of household wastes (Eklind & Kirchmann 2000). Hence, the Mataram canal water becomes dirty and murky. People who consume unclean water may contract various diseases, such as diarrhea (Arnold & Colford 2007), poisoning (Snider 2004), and skin diseases (Robert & Kupper 1999). So, it is very important to restore the adequacy, cleanliness, and hygiene of Mataram canal water (Thompson *et al.* 2003).

In general, the waste metal ion as well as the sediment in water is usually eliminated using a range of processes, including evaporation (Craig *et al*. 1963), ion exchange (Medve *et al.* 1998), and filtration (Savage & Diallo 2005). Especially the latter consists of macro and micro filtration. Many studies have been dedicated to the filtration of water into clean and consumable water (Ren *et al*. 2013; Shannon *et al.* 2008; Sobsey *et al.* 2008). Filtering generally uses sand (Mandi & Ouazzani 2009; Wotton 2002) and gravel (Sherard *et al.* 1984). In this study, the filtration method utilizes micro-size carbon (MSC) material integrated in a self-custom made micro filtration system. The system is simple and inexpensive. The MSCs are synthesized from organic wastes of coconut shell, rice straw, and bamboo via a liquid-phase exfoliation (Murat *et al*. 2012; Hernandez 2008) using a self-custom made ultrasonication device. Each of the MSC is used to test Fe filtration of Mataram canal water by comparing the Fe content in the filtered water samples based on atomic absorption spectroscopy (AAS).

METHODE

Materials used in this study are distilled water, detergent, coconut shell, bamboo, rice straw, and water samples from Mataram canal. The tools used in the study are a digital scale, lighters, knives, pipettes, cylinder and rectangular jars, chopsticks, measuring cups, paper filters, a blender, beaker glasses, aluminum foils, labels, and a hairdryer.

Left-over or wastes of coconut shell, bamboo, and rice straw materials are gathered. Then, the materials are burnt separately. The charcoal produced after burning from each material is collected and ground to become powder.

The self-custom made ultrasonication apparatus consists of piezoelectric as probes (top left of Figure 1), an audio generator (Csi/SPECO SS-1) and an amplifier (Uchida TA-2MS) [top right of Figure 1]. The audio generator is set at a frequency of 30 kHz and boosted with the amplifier. The piezoelectric probes which are connected to the audio generator are inserted into a designated solution. Hence, the ultrasonication process of the solution may be conducted in a certain time interval.

Figure 1. Equipment utilized in the study. Piezoelectric probes (top left), sonication apparatus (top right), a blender (bottom left), and a water filtration system (bottom right).

The powder of each material is produced by mixing 20 grams of ground charcoal of each respective material with 2 mL of commercial detergent in 100 mL of distilled water and then blended for 20 minutes (bottom left of Figure 1). The mixture is then ultrasonicated for 4 hours using the above piezoelectric-based ultrasound apparatus. Finally, the mixture is left alone for 3 days to equilibrate. After being left for 3 days, the sediment that occurs on the bottom of the mixture container is separated from the liquid and then heated for 30 minutes until dry (top left of Figure 2). This is the SMC powder that is used for the filtration system (top right of Figure 2).

The simple filtration apparatus is constructed as follows. A pair of chopsticks is cut into 2 parts, then glued onto both sides of the circular jar. A sheet of filtration paper is placed on the circular locking system and then put on top of the circular jar. Once attached, the circular jar is positioned upside down onto the top of the rectangular jar as observed in bottom-right of Figure 1.

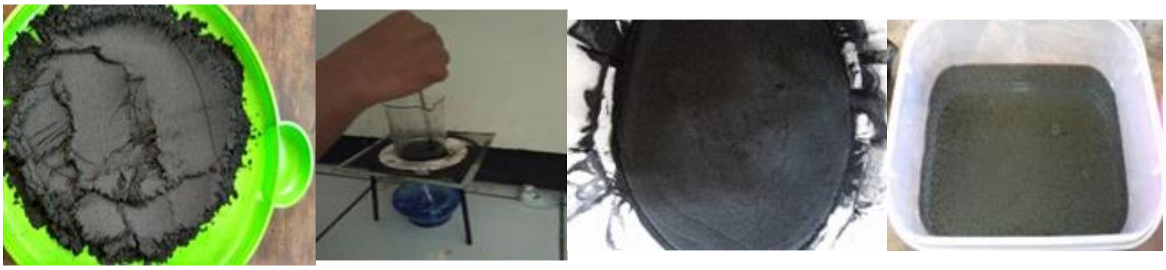

Figure 2. Treatments of the carbon materials. Heating the sediment obtained after ultrasonication (top left), the SMC material obtained after the heating process (top right), The SMC material dissolved in distilled water (bottom left), and the SMC as a filtration material on the filtration paper (bottom right).

The filtration material is made as follows. 1 gram of the SMC powder is prepared and then dissolved in 100 mL distilled water, and finally stirred thoroughly (bottom left of Figure 2). The mixture is poured into the filtration system such that water residues drop to the bottom of the rectangular jar. The SMC powder trapped on top of the filtration paper is dried using a hairdryer (bottom right of Figure 2).

Finally, the filtration process of the Mataram canal water sample is given as follows. An amount of 250 mL of Mataram canal water is prepared. The Mataram canal water sample is poured into the filtration system. The water obtained inside the rectangular jar is the result of the filtration process. Finally, AAS tests are performed for Fe content upon the filtrated water samples.

RESULTS AND DISCUSSION

Synthesis of SMC powder in this study utilizes leftovers or wastes from carbon sources, namely coconut shell, bamboo, and rice straw. The liquid-phase exfoliation via ultrasonication assisted by a commercial detergent is used to synthesis each of the SMC material. The self-custom-made filtration system consists of paper filter which is embedded with each solidified SMC material made from coconut shell, bamboo, and rice straw.

As mentioned above, the filtration material is observed in the bottom-right of Figure 2. Magnification of the filtration materials before and after being utilized as filters via an optical microscope may be observed in Figure 3. Figure 3a) an 3b) are magnifications of the initial filtration paper and the embedded SMC powder onto the filtration paper, respectively, whereas Figure 3c) and 3d) are magnifications of filtration paper and SMC powder on a filtration paper after being used to filter Fe content of Mataram canal water sample, respectively. The Filter paper is made up of long thread-shaped cylinder materials that have a size of approximately 0.2 micron and seem to have random arrangements. After being used to filter a sample of Mataram canal water, brown-yellowish materials occur on the filtration paper where the sizes of these materials varies but mostly larger than the gaps between the filter paper cylindrical threads.

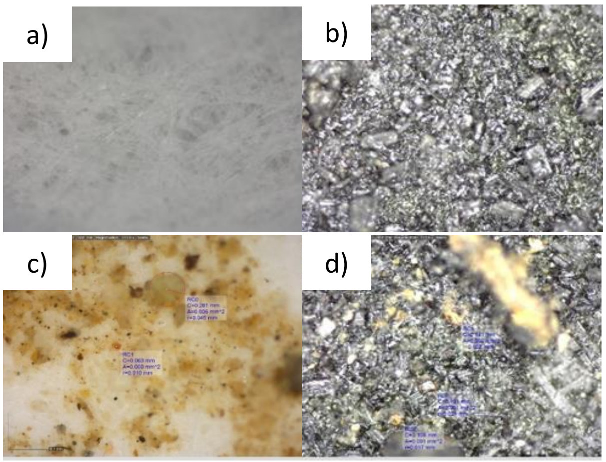

Figure 3. Optical microscope images of a filter paper (a), a filter paper with SMC material (b), the filter paper (c), and filter paper with SMC material (d) after being used for filtering the Mataram canal water samples.

The SMC powder is embedded on top of the filter paper (Figure 3b). The SMC material may be observed to spread evenly in covering the surface of the filter paper. After being used to filter the water sample, the brown-yellowish materials are seen again, but this time scattered in smaller areas. Comparing Figure 3c) and 3d), one may observed that the material trapped by the filter paper seems to consist liquid and solid materials, however adding SMC material on the filter paper absorbs the liquid material such that only the solid material remains trapped between the SMC materials.

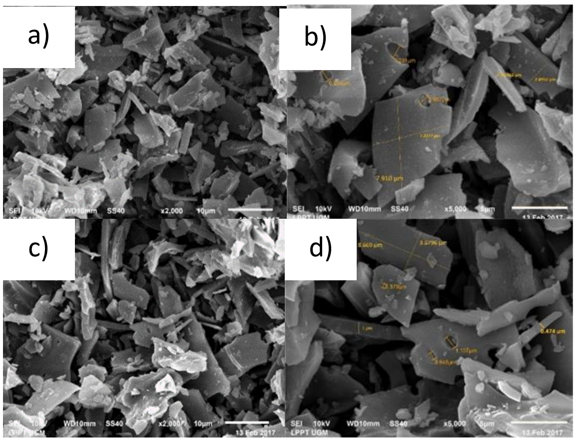

Figure 4. SEM results of SMC materials from coconut shell and bamboo with magnifications of 2000X (a,c) and 5000X (b,d), respectively.

Figure 4(a) and (b) are the SEM results of SMC material from bamboo with magnifications of 2000X and 5000X, respectively, while Figure 4 (c) and (d) are the SEM results of SMC material from coconut shell with the same magnifications. From Figure 4(a) and (c), we can see the distribution of the SMC materials. It appears that the sizes of SMC materials vary; some are small and some are large in sub-micron scales. Smaller SMCs are generated more rather than large sizes, where small materials are shaped like small cubes and large materials are shaped like sheets of broken glass with firm edges. There is no significant difference in shape between SMC materials from bamboo and coconut shell; however the rough number of smaller materials produced is different.

Figure 4(b) and (d) may give some insights concerning the sizes of the SMC materials. From Figure 4(b) it can be seen that the SMC material from bamboo has length and width of about 7 μm, and a thickness of about 0.6 μm. Pores are also observed in the SMC material from bamboo material with a diameter of around 1 μm. These pores show that bamboo may be used as an effective filtration material which may selectively trap solidified particles larger than the aforementioned diameter. Figure 4(d) shows the SMC material from coconut shell with a length of about 8 μm, a width of about 3 μm, and a thickness of about 1 μm.

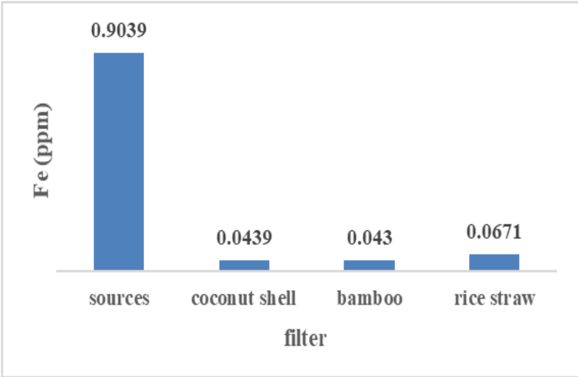

Figure 5. Fe filtration result using AAS.

Finally, the result of the Fe filtration using AAS is given in Figure 5. Based on the graph, it can be seen that the Fe content in the Mataram canal water sample before filtration is 0.9039 ppm. After filtration by SMC materials from coconut shell, bamboo, and rice straw the Fe content in the water sample becomes 0.0439 ppm, 0.043 ppm, and 0.0671 ppm, respectively, or decrease to 95.14%, 95.24%, and 92.57%, respectively. From the above data, it can be seen that the best material for filtrating Fe in the Mataram canal water is SMC material from bamboo. This is indicated by the level of Fe that decreased by 95.24%.

It is no surprise that coconut shell, bamboo, and rice straw have been used to produce activated carbon for various purposes, such as removal of Cr (IV) from wastewater using activated carbon from coconut shell (Babel & Kurniawan 2004; Kobya 2004), absorption of methylene blue onto bamboo-based activated carbon (Hameed *et al.* 2007), removal of nitrate nitrogen from drinking water using bamboo powder charcoal (Mizuta *et al.* 2004), adsorption of fluoride in aqueous solutions using activated carbon from pyrolysis of rice straw (Daifullah *et al.* 2007), and removal of 3-chloropenol from water using rice straw carbon (Wang *et al.* 2007). These materials have a long history in being used as alternative materials for cleaning and absorbing aqueous solutions. In fact, comparing the performance of the three materials has been done especially for removing methylene blue (Kannan & Sundaram 2001). On the other hand, filtration of iron (II) has also been conducted using activated carbon from olive stone waste (Alslaibi *et al.* 2013).

Now we analyze the MSC materials obtained in this study. It may be observed that the size of the original filter paper thread material is smaller SMC materials, i.e.: 0.2 micron compared to 3 to 8 microns, respectively. This means that the thread materials may hold the SMC materials above the filter paper. The surface of the original filter paper seems to be smooth but after the addition of the SMC materials the surface becomes coarse. In this study, we only manage to conduct SEM images for coconut shell and bamboo materials. The surface morphologies of both SMC materials seems to be similar and consisting of pores. However, the volume sizes of the SMC materials are different where bamboo are larger than coconut shell.

CONCLUSION

SMC materials from various carbon materials, i.e.: bamboo, coconut shell, and rice straw have been produced and compared. The method of synthesizing the SMC materials is liquid-phase exfoliation via self-custom made ultrasound generator assisted by surfactant contained in commercial detergent. The SMC materials are used as a filtration system combined with filtering paper to trap Fe metal contained in Mataram canal water samples. The sizes of these SMC materials are around 0.5 μm to 10 μm which confirm the exfoliation to sub-micron scales. The best SMC material for Fe filtration is from bamboo with Fe filtration ability up to 95% based on the AAS results.

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