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UTILIZATION OF SUGARCANE BAGASSE IN THE PRODUCTION OF ACTIVATED CARBON FOR GROUNDWATER TREATMENT

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ABSTRACT

Malaysia takes a step forward to promote and support the development of sustainable and green technology by adopting and master the technology holistically. In this research, utilization of local agricultural waste which is sugarcane bagasse in producing of activated carbon (AC) for groundwater treatment was studied. The aim of this study is more towards environmental friendly solutions by transforming the unwanted waste to valuable materials and thus, improves and upgrades the technology. The AC was produced through the chemical activation process where the sugarcane bagasse is carbonized at the temperature of 500˚C for two hours after it was impregnated with sulphuric acid to activate a pore surface. In order to determine the most effective size of the produced activated carbon, sugarcane bagasse was divided into two types of particle sizes, powdered activated carbon (PAC) and granular activated carbon (GAC) where the size of particles is 63µm to 300µm and 2mm to 3.35mm respectively. The quality and efficiency of product are being tested and analyzed into three different phases, which is material preparation and analyzing, raw water testing parameter and effluent after treatment testing parameter. It was noted that, PAC has proven that it's the most suitable AC's product for groundwater treatment when it gave the highest percentage of removal for those parameters such as turbidity, color, total suspended solid, total coliform and heavy metal at optimum hydraulic retention time (hrt)of 30 minutes compared to the GAC.

Keyword: Utilization, Sugarcane Bagasse, Groundwater Treatment, Activated Carbon

1. INTRODUCTION

The previous researcher stated that activated carbon (AC) is a group of absorbing substances of crystalline form, which having large internal pore structures that make the carbon more absorbent. The term of activated carbon is come from the word *"carbon"* and *"active"* which carbon meant a raw material undergoes a carbonization process (burning in high temperature) while active meant a material in carbon condition undergoes an activation process to open a pore surface area as a maximum as can to increase adsorption rate of activated carbon.

In Malaysia, activated carbon had been produced from variable material such as a rubber wood sawdust and palm oil coconut shell. First and foremost, AC was used as an adsorbent to remove organic compounds and pollutant from liquid and gas streams. The increasing of environmental issues, especially in water and air purification gives a big impact to the worldwide country recently. As a consequence, more countries realize the need for activated carbon to comply with environmental regulation. These issues had brought to the growth of the activated carbon market in the last two decades in the most industrialized region and probably continue in the near future as more developing areas of the world will realize the importance of controlling the quality of water and air and reduces the pollution (A. H. Mahvi, 2008). Local agricultural waste is a potential resource of a raw material for the production of the AC. In this research, sugarcane bagasse was examined to produce an AC through the chemical activation process since it was an availability and inexpensive material with high carbon and low inorganic content. In hoped, the result obtained from this study will help produce a solution for groundwater treatment with a minimum cost and more effective way.

2. BACKGROUND OF ACTIVATED CARBON

The previous researcher, Nurul'ain Jabit, 2007 was stated that Activated Carbon (AC) as a solid,

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porous, black carbonaceous material and tasteless. It is a high degree of micro-porosity material with a surface area in excess of 500 m^2 for only one gram of AC (Figure 1). Through the sufficient activation process, either physical or chemical activation, the material will act as absorbent, which come solely from the high surface area thus give the better absorption performance. Besides, AC was the extensive use in the industrial sector for adsorption of pollutants from gaseous and liquid streams. As mentioned, there are two manufactured technique to produce activated carbon, Physical and Chemical activation. In physical activation, the AC will be produced using gasses with either Carbonization or Oxidation process or combination of both processes. In carbonization process, carbon content is heated up to 600-900 °C, in an atmosphere of inert gases such as argon or nitrogen. Meanwhile, in oxidation, the carbonized materials are exposes to oxidizing atmospheres such as oxygen, carbon dioxide or steam, at temperatures between 600-1200 °C (Tham Yee Jun et al., 2009).

Nevertheless, in the Chemical activation process, the raw material is impregnated with a certain chemical such as an acid, strong base or a salt before it being carbonized at low temperatures between 450 - 900°C. It was believed that, the chemical activation process is the most preferable technique compared to physical activation because offers a minimum time and low temperature for activating material. Alternatively, the AC can be created in a variety of different physical forms. Two of the most popular form is Powdered Activated Carbon (PAC) and Granular Activated Carbon (GAC). PAC is particularly a powder or fine granules with less than 1.0 mm size in average has a large surface area to the volume ratio. Generally, it was used in raw water intakes, rapid mix basins, clarifiers, and gravity filters. In contrast, GAC is relatively larger than the powdered version and, consequently, has a smaller surface area to the volume ratio. Traditionally, this substance is preferred in the adsorption of gases and vapors. Despite the fact that activated carbon may take many different physical forms, its application is still the same to remove pollutants and other contaminates.

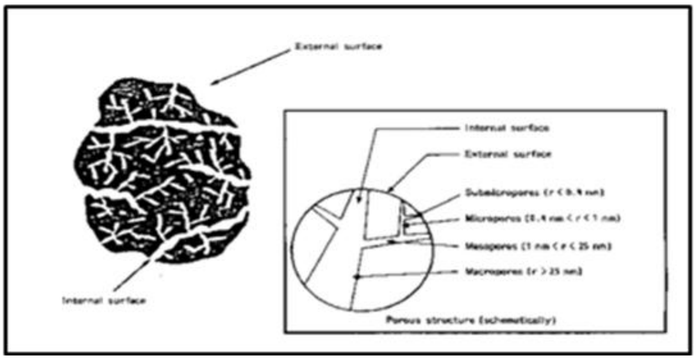

Figure 1. Schematic activated carbon model (Henning KD, Degel J. 1990)

3. ADSORPTION PROCESS OF ACTIVATED CARBON

Adsorption is the process by which AC removes substances from water which is refers to the diffusion of a gas or compound into the porous network where a chemical reaction or physical entrapment takes place. It is an important process that is utilized by environmental engineers in water and wastewater treatment. It is also known as a removal process where certain particles are bound to an adsorbent particle surface by either chemical or physical attraction. Activated carbon is an effective adsorbent material due to its large number of cavernous pores. Nursyaza Husna Bt. Shaharuddin proven that AC provide a large surface area approximately in ratio of 1 gram is equal to 100 m^2 to the size of the actual carbon particle and its visible exterior surface. Principally, AC adsorption proceeds through 3 basic steps which are substances adsorb to the exterior of the carbon granules, substances move into the carbon pores, and substances adsorb to the interior walls of the carbon.

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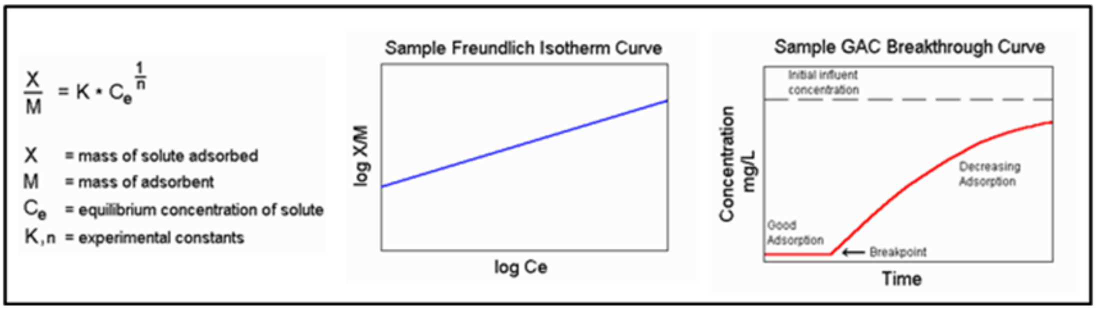

Figure 2. Relationship between adsorbent and time using Freundlich Equation (Mark P. Cal et al., 1994)

The efficiency of adsorption is actually decreasing over time, thus the activated carbon will need to be replaced or reactivated. In practical, the isotherms are used to predict how much solute can be absorbed by activated carbon. There are three most well known isotherms are the Freundlich, Langmuir and Linear. Freundlich isotherm is the most commonly used in environmental engineering as are empirical relations for absorption process (Mark P. Cal et al., 1994). Figure 2 above illustrate the Freundlich isotherm equation in general form, a sample breakthrough curve and the relationship between absorbent and time Freundlich equation. Each individual type of GAC has an own isotherm curve and breakpoint characteristics, which help to predict the adsorptive capacity of particular activated carbons. From this, a design estimate for adsorptive life is obtained and once the breakpoint has been reached a reactivation process becomes necessary.

4. PRODUCTION OF ACTIVATED CARBON USING LOCAL AGRICULTURAL WASTE

4.1. Sugarcane Bagasse

Sugarcane bagasse is a new alternative as a replacement to existing product of activated carbon. Bagasse pitch is a waste product from sugar refining industry. It is the name given to the residual cane pulp remaining after sugar has been extracted (Figure 3). Bagasse pitch is composed largely of cellulose, pentosan, and lignin. Previous researcher, Nasim Ahmad Khan (2004) studied on adsorption of Cd (II) and Pb(II) onto functionalized formic lignin from sugarcane bagasse. It was reported that the removal of Cd(II) and Zn(II) is found to increase as pH increases beyond 2 and at pH > 8.0 the uptake is 100%.

Besides, there is an evident that the sorption affinity of the derived activated carbon towards Cd(II) and Zn(II) is comparable or better than other available adsorbents. Consequently, the cost wise the activated carbon prepared to would be cheaper than the commercially available ones and that at an adsorbent dose of 0.8g / 50ml is sufficient to remove 80 – 100% Cr (VI) from aqueous solution having an initial metal concentration of 20mg/l at a pH value of 1, but the efficiency reduced sharply to 15% at pH 3.

Saifuddin M. Nomanbhay et al. 2005 was study the concentrate on the removal of hexavalent chromium from wastewater by adsorption. Removal of chromium (VI) from aqueous waste was investigated using adsorption based on bagasse and coconut jute. The effect of solution pH, Cr(VI) concentration, adsorbent dosage and contact time were studied in a batch experiment. Generally, the removal is most effective at low pH values and low Cr(VI) concentration. Activated coconut jute carbon was the most active among the four adsorbents studied. It was fairly stable even at higher pH. This was followed by activated bagasse carbon, raw bagasse and bagasse ash respectively. The maximum removal obtained was around 99.8 percent at pH 2. The data for all the adsorbents fit well to the Freundlich isotherm.

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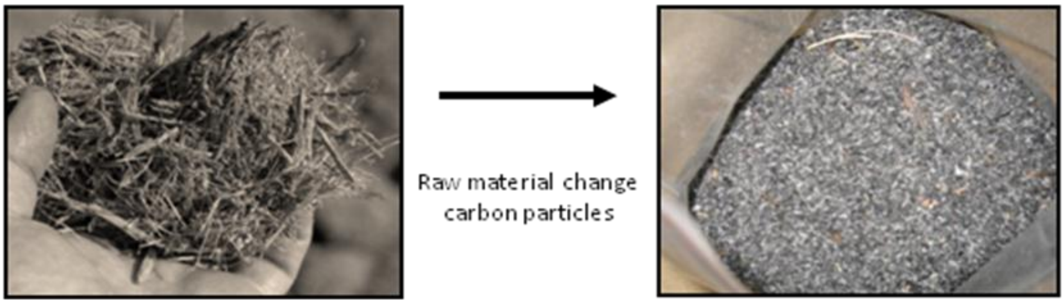

Figure 3. Sugarcane baggase (Cited from http://vivbizclub.com/blog/tag/sugar-cane-bagasse/)

5. GROUNDWATER

Groundwater is water that comes from the ground surface. Half of every person in the United States drinks groundwater every day. Groundwater commonly comes from rain, snow, sleet, and hail that soak into the ground. The water moves down into the ground caused by gravity, passing between particles of soil, sand, gravel, or rock until it reaches a depth where the ground is filled, or saturated, with water. Groundwater is divided into two different zone, which is saturated zone is where he area that is filled with water and the other is called the water table which lies at the top of the saturated zone.

Most groundwater is clean and safe, but groundwater can become polluted, or contaminated. In contrast, it can become polluted from leaky underground tanks that store gasoline, leaky landfills, or when people apply too much fertilizer or pesticides on their fields or lawns. Hence, when pollutants leak, spill, or trapped on the ground they can move through the soil. Drinking contaminated groundwater may have serious health effects to human. The contaminated of groundwater also harmed local flora and fauna. The untreated groundwater will expose to diseases such as hepatitis, cholera, typhoid and dysentery may be caused by contamination from septic tanks or sewage leaks that adsorb to groundwater.

6. RESEARCH METHODOLOGY

In this study, the activated carbon (AC) was produced through the chemical activation process which conducted into three phases which is material preparation and analyzing (phase 1), raw water testing parameter (phase 2) and testing of raw water through activated carbon filter media (phase 3).

6.1. Phase 1: Material Production and Analyzing

Raw material from agricultural waste sources, which is sugarcane bagasse was washed and cleaned with distilled water to remove substance and waste in the material. Sugarcane bagasse was obtained from Kampung Bukit Besar, Alor Setar Kedah. A production of activated carbon was referring to Environmental Standard MIL-STD 810F Method 501.4 (high temperature for both storage and operating). Then, raw materials were dried in a dry oven at 130ºc for drying process for 24 hours. After that, the dried materials were carbonized at the temperature of 500˚C for two hours after it was impregnated with 28 ml sulphuric for every 10 g activated carbon in the activation process. The purpose of the activation process is to open pore surface area of activated carbon.

The AC is divided into two different particle sizes, which are granular and powdered by sieve analysis testing by referring ASTM C136-06 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. The size of the GAC is 2mm to 3.35mm, while the PAC is between 63µm to 300µm. Different particle sizes of activated carbon were undergoing a porosity tests to determine a percentage of porosity value of each activated carbon. About 2.5 g of each activated carbon were used to conduct an adsorption tests and stirred it with 1000ml distilled water using a magnetic stirrer. A methylene blue in 3 g/l concentration was diluted to 10 mg /l by stirring and mixing 10 ml methylene blue solution with 2990 ml distilled water. The mixing solution in 5, 10,15,30,45 and 60 minutes was collected, and the result was analyzed using spectrophotometer HACH DR 5000.

6.2. Phase 2: Raw Water Testing

In this phase, water sample which is groundwater is collected from WASRA station at Universiti Malaysia Pahang (UMP) were undergoes a testing and analyzing process for six parameter which are turbidity, color, pH, total coliform, total

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suspended solid and heavy metal using specific apparatus.

6.3. Phase 3: Testing Of Raw Water through Activated Carbon Filter Media

Two filter models of both types of activated carbons were set up using a plastic container. One filter is denoted with PAC SB for powdered sugarcane bagasse activated carbon, and the other is denoted as GAC SB for Granular sugarcane bagasse activated carbon (Figure 4). The valve was installed to control flow rate of water. The model platform is installed at two different height, which is platform 1 (75 cm height) is for raw water container, and platform 2 (30 cm height) is for activated carbon filter. The polyvinylchloride pipe (PVC) with 15 mm diameter is used to convey the water flow. Every container was installing with 15 mm valve to control flow rate at the container at platform 1. Meanwhile, small size of copper valves was used at activated carbon filter to retain the water. The water treatment process was taken about 60 minutes. All filters are run at the same time. An effluent from each filter for every 15 minutes of retention time was collected until retention time of 60 minutes.

Figure 4. Activated carbon filter media models

7. RESULT AND ANALYSIS

7.1. Porosity Test

The fraction of pore space in the soil called porosity and measured in percentage (%). From the porosity testing result (Figure 5), the best porosity material of activated carbon produces is sugarcane bagasse in powdered condition (PAC SB). Below the bar chart that show a comparison of activated carbon with granular and powdered sizes. According to bar chart, the result shown that PAC sugarcane baggase has a highest percentage of porosity which is 84.38%), compare to activated carbon, GAC sugarcane baggase (64.29%). The highest value of porosity will effect to the adsorption of activated carbon. The increment of porosity value will increased the adsorption rate in raw water organic content and others parameters removal.

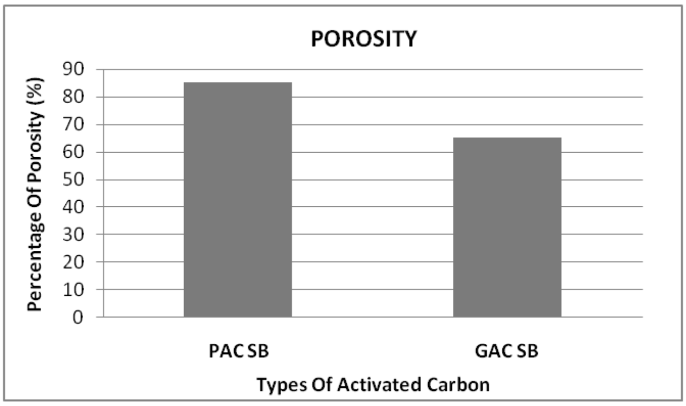

Figure 5. Porosity versus type of activated carbon

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7.2. Scanning Electron Microscope (SEM) test

In this test, the best surface area is sugarcane bagasse powdered activated carbon compared to granular form. It shows an image of powdered sugarcane bagasse activated carbon in 10 µm^2 scale (Figure 6). The image was captured the largest size of pore surface is 6.7 µm^2 and the smallest size is 2.7 µm^2. In contrast, for granular activated carbon, the largest size of pore is only 1.5 µm^2 whilst 1.0 µm^2 is the smallest one (Figure 7).

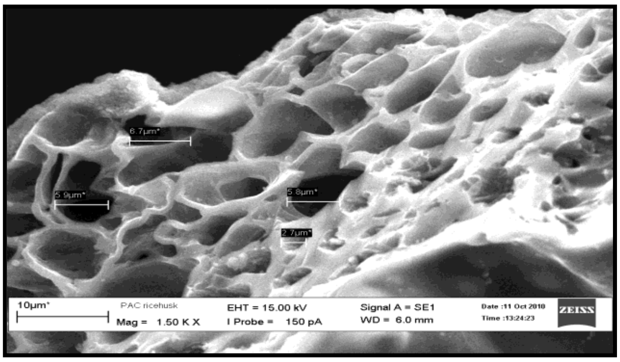

Figure 6. Treated Sugarcane bagasse activated carbon (Powdered @1500 magnification)

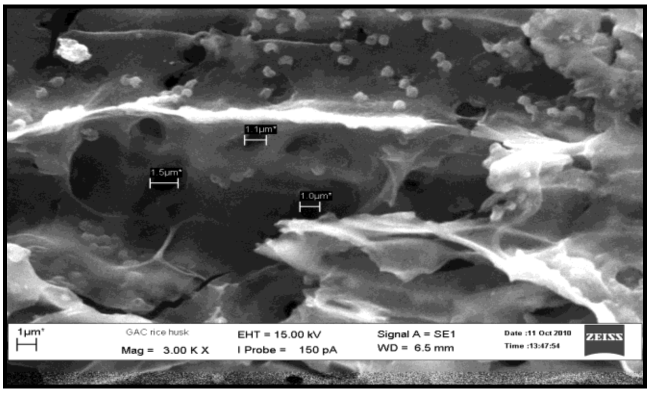

Figure 7. Treated Sugarcane bagasse activated carbon (Granular @1500 magnification)

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7.3. Turbidity Removal Test

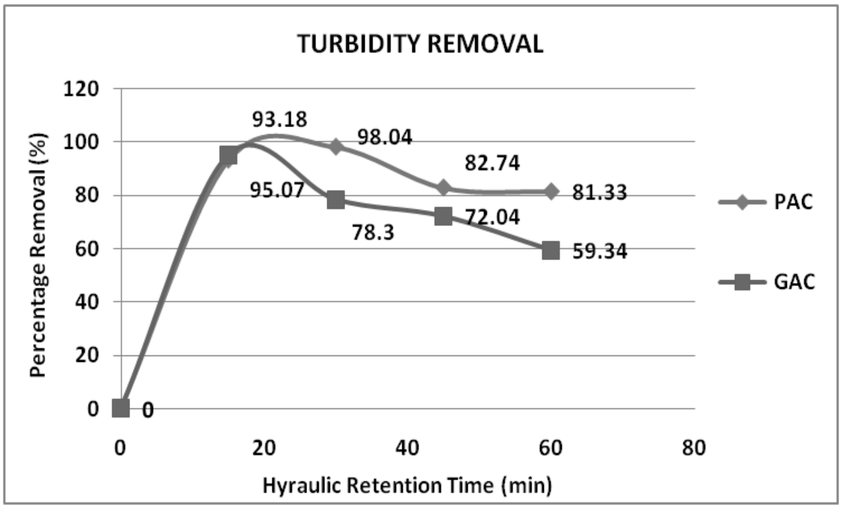

Figure 8. Percentage of turbidity removal for both powdered and granular sugarcane bagasse activated carbon

The graph above shows that turbidity removal of powdered sugarcane bagasse activated carbon (PAC) is higher compared to granular sugarcane bagasse activated carbon (GAC). At 30 minutes hydraulic retention time (HRT), PAC of give the highest removal value which is 98.04%. The HRT 30 minutes give the optimum effectiveness rate of activated carbon to absorb all organic content, pollutant and etc in the water. While, at 60 minutes of

HRT, both type of activated carbon was present the lowest percentage removal. Obviously, through observation the functionality of activated carbon is decreased at HRT 60 minutes and it can be assumed that the removal of turbidity decrease after the optimum retention time take place.

7.4. Color Removal Test

The color removal of powdered sugarcane bagasse activated carbon (PAC) is higher than granular sugarcane bagasse activated carbon (GAC). In Figure 9, the highest percentage value is recorded at 30 minutes HRT where 96.24% for PAC and 65.04% for GAC. At this HRT the activated carbon is effectively remove color impurities before it reduced at 60 minutes HRT.

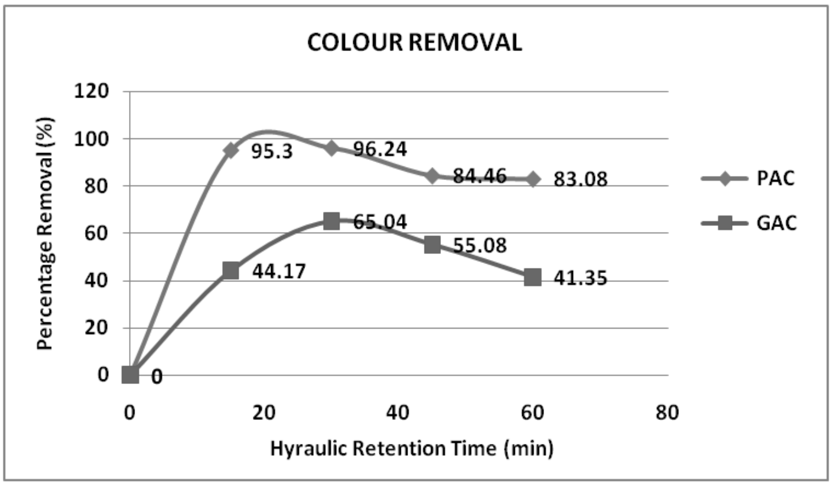

Figure 9. Percentage of colour removal for powdered and granular sugarcane bagasse activated carbon

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7.5. pH Test

As shown in Figure 10, at 30 minutes of HRT, the pH value for PAC AND GAC is 2.98 and 6.2 respectively. This shows that both of effluents are in the acidic region. Meanwhile, at the end of the experiment, both of the effluent are started to change their pH value nearly to 7. It can be said that the pH value of effluent after treatment processes have achieved less than pH 7 which is in acidic solution. From the previous research, it was proven that pH value at range 2-5 is the efficient pH value in water removal such as heavy metal and turbidity.

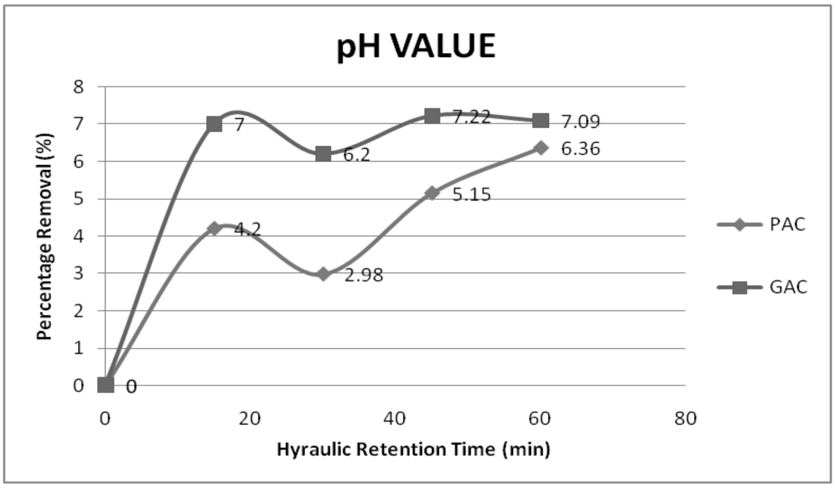

Figure 10. Comparison between percentage of pH value for powdered and granular sugarcane bagasse activated carbon

7.6. Total Suspended Solid Removal Test

The graph in Figure 11 shows that the total suspended solid (TSS) removal of powdered sugarcane bagasse activated carbon is higher compared to granular sugarcane bagasse activated carbon. For both activated carbons the highest removal is at 30 minutes of hydraulic retention time (HRT) which is 99.72% (PAC) and 99.32 % (GAC). But, the lowest removal is at 60 minutes of HRT where only 98.58% of PAC and 97.61% of GAC have been removed. At this time, the pore sizes of both activated carbons are decreased. Beside, a removal of total suspended solid is actually related to the colour removal. When removal colour of water increased, the removal of total suspended solid also increased.

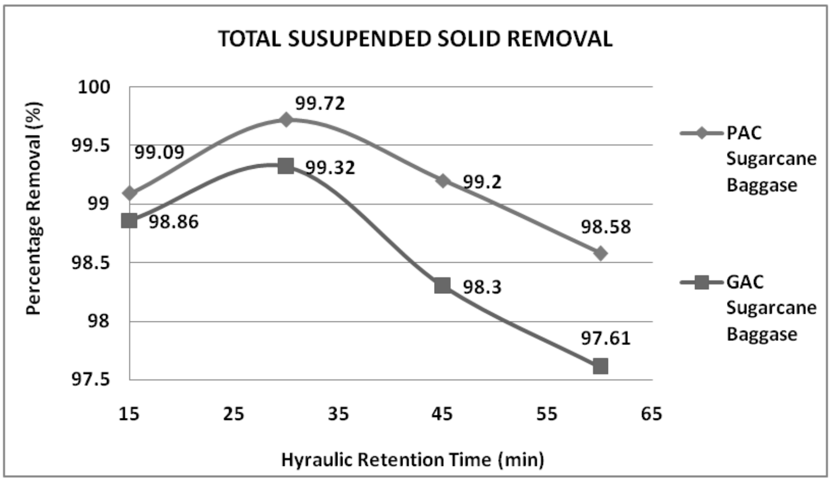

Figure 11. Comparison of total suspended solid removal percentage for powdered and granular sugarcane bagasse activated carbon

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7.7. Total Coliform Removal Test

According to Figure 12, show that the powdered sugarcane baggase activated carbon (PAC) achieved the highest percentage removal of total coliform compared to granular sugarcane bagasse activated carbon (GAC). From observation, it was noted that at 15 to 30 minutes of HRT, both types of activated carbon attain 100% percentage removal of total coliform. It started to gradually decrease at 35 minutes of HRT until the end of the experiment process which is 51.22% for PAC and 24.39% of GAC. Similar to the previous experiment tests, the highest percentage removal is also at HRT of 30 minutes.

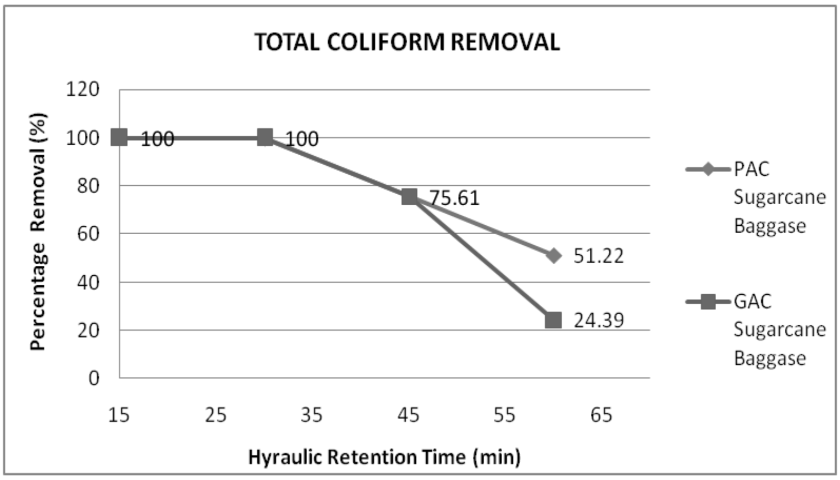

Figure 12. Comparison of total coliform percentage removal for powdered and granular sugarcane bagasse activated carbon

7.8. Heavy Metal Removal Test

Figure 13 shows that the higher percentage removal of ferum for both powdered sugarcane bagasse activated carbon (PAC) and granular sugarcane baggase activated carbon is at optimum HRT of 30 minutes. At this stage, the activated carbons are very efficient to remove ferum content in raw water sample. About 88.47% of ferum are being removed using powdered sugarcane baggase filter media but only 77.46% of ferum was removed using the other filter media. It most cases, PAC filter media give the higher percentage removal for all experimental testing conducted for groundwater treatment.

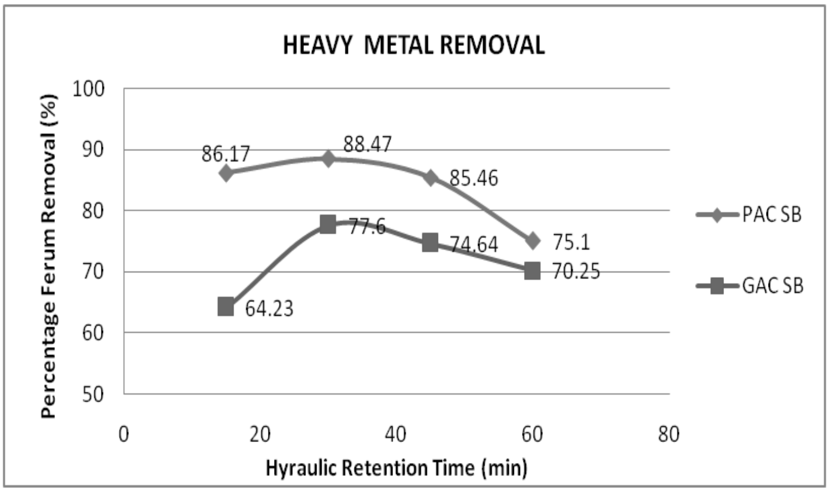

Figure 13. Percentage of ferum removal for powdered and granular sugarcane bagasse activated carbon

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8. CONCLUSION

Groundwater is natural water that contained a various unneeded substance that must be removing. The performance of activated carbon in water and wastewater removal has been proving by various previous studies.

According to the result from various parameters that has tested shown that powdered sugarcane bagasse activated carbon (PAC SB) is most effective term of parameters removal (%) such as turbidity, 98.82% , color, 96.99%, total coliform ,100% and total suspended solid,99.55% at optimum hydraulic retention time, 30 minutes. At the hydraulic retention time (hrt) at 30 minutes, the activated carbon shows the best and optimum contact time to remove organic content, contaminant, metal and others pollutant in the raw water.

This study also prove that the smaller particles of activated carbon is the most effective in water parameter removal. While, clearly stated that after the optimum retention time of 30 minutes, the percentage of removal for both types of activated carbon were decrease because the effeciency of its performance to adsorp is decrease caused by pore surface area are slightly closed. Therefore, it can be concluded that, the powder sugarcane bagasse activated carbon is a good adsorber and potentially being used for groundwater treatment compared to the granular.

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