Peat swamp groundwater treatment: efficiency of mixed citrus peel and kernel activated carbon layer

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Abstract. One of the natural water resources is groundwater. Groundwater is another alternative to meet the increasing water demand in Malaysia. Then, the decrease in supplying raw groundwater which may due to depletion of groundwater and hence it is important to maintain the availability of water supply locally and even establish new water source such as from peat swamp to overcome future water crisis. Activated carbon is famous for its characteristic in eliminating various organic contaminants. In this investigation, low cost mixed activated carbon of food waste (citrus peel) and agricultural waste (palm kernel shell) are used as adsorbents in biological sand filter to treat peat swamp groundwater whereby the overall aim of study to evaluate the performance of mixed activated carbon layer of citrus peel and kernel in biological sand filter for peat swamp groundwater treatment. The mixed activated carbon with 1:1 ratio is filled into the biological sand filter. The efficiency of the mixed activated carbon layered biological sand water treatment system is evaluated using parameters pH, Turbidity, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS) and E. coli and removal of heavy metal ions of peat swamp groundwater. All these parameters follow the Standard Methods for Examination of Water and Wastewater 2005. The implementation of investigation improved the water quality of the peat swamp groundwater, the water treatment technology using combination of activated carbon and biosand filter, human living standards by providing safe and clean water supply.

1. Introduction
Water is very important for an individual as every person needs water for consumption and daily activities such as cooking and washing. The universal water demand is predicted to increase 55% by 2050 which is predominantly affected by increase of population growth, daily consumption, urbanization, trade globalization, and energy and food security policies [1]. As the population growth and economic activities increases, the demand for fresh clean water also increases. Groundwater is another alternative to meet the increasing water demand in Malaysia. From the National Water Services Commission, the supply of raw groundwater in Malaysia increases from total of 223 MLD in 2011 to 252 MLD in 2015 [2]. Peat swamp groundwater have low gradients, high water tables and huge interdependence between hydrology and vegetation [3] which makes it a favourable new water source. Biosand filter or biological sand filter is an advance centralized or semi-centralized water purification system. The first biosand filter tested in the field in Nicaragua differentiate slightly in
design compared to the filter used today [4]. The layers of sand and gravel in biosand filter treat water by capturing physically sediments, pathogens and other contaminants in the water using absorption mechanism. Biological sand filter with developed biota able to remove microorganisms such as Giardia and Cryptosporidium present in water [5]. Sorption involves both process which is absorption and adsorption. Absorption means to be assimilated into something whereas adsorption means to gather on a surface [6]. Activated carbon is famous for its characteristic in eliminating various organic contaminants [7]. This is due to the good adsorption mechanism which are affected by the size of the activated carbon. Then, citrus peel and kernel activated carbon are chosen as one of the filtrates other than sand and gravel in the biosand filter.

Activated carbon is used to define carbon-based materials which have highly porous adsorptive medium due to its well composed internal pore structure [8]. Besides, activated carbon has great adsorption properties for an extensive range of organic compounds and therefore can be used to build an effective sorption barrier which suitable and helpful in treating contaminated water [9]. The usage of wastes such as citrus peel and kernel as the source of activated carbon can help reduce cost and waste produced besides increasing the activated carbon availability in the market. Therefore, conversion of these waste into activated carbon would boost economic value, help cut down the waste disposal cost and contribute a possible cheap substitute to the existing activated carbons [10]. This study executed to reach the following objectives whereby to examine the efficiency of peat swamp groundwater treatment via mixed activated carbon layer in biological sand filter to obtain neutral water from acidic water and to evaluate the efficiency of activated carbon in removing pathogen and chemical contents to provide safe and clean water.

2. Experimental

In this study, the concern and focus were on the peat swamp groundwater and performance of the mixed activated carbons. The groundwater sample was collected at house near the peat swamp area at Kampung Chenderawasih, Pekan, Pahang as study area and the peat swamp groundwater was pumped out into water containers. Then, the sample was brought back to Universiti Malaysia Pahang (UMP) and was analysed at environmental laboratory of Faculty of Civil Engineering and Earth Resources (FKASA).

2.1. Production of activated carbon

The food waste (citrus peel) and agriculture waste (kernel shell) were obtained from local fruit market, fruits stall and palm oil mill. The waste was washed with tap water to eliminate dust and other residues. After that, the processed waste was put in the oven to dry at 105°C for 24 hours. The dried waste was washed again using distilled water to remove impurities present in it. The dried waste was dried again at 105°C for 12 hours in order to remove additional moisture in it [11]. The sample was crushed into small pieces and put in crucible for weighing. Concentrated sulphuric acid of 18N was then added in the weight over volume ratio of 1:2 into the crucible [12]. The samples were heated in the furnace and temperature was maintained at 500°C for 0.75 hour [13]. The chemically activated carbon was then transferred to a beaker and cooled to room temperature. The activated carbon was washed with distilled water several times to remove acid content in it [14]. The activated carbon then tested with pH meter to get 6.5 to 7 pH value. Finally, the samples were dried in oven at 100°C for 24 hours to remove moisture in it [15]. The samples were then crushed, milled and screen sieved to 1 to 2 millimetres [16].

2.2. Construction of biological sand filter with mixed activated carbon

In this research, the biological sand filter components were added with a layer of activated carbons. The biological sand filter was modified. The biosand filter was made up of polyvinyl chloride (PVC) pipe with an outlet tube to allow the treated water to flow out. The biosand filter was filled with gravel, sand and activated carbon. The size of gravel was in the range of 3.35 millimeters to 6.30
millimeters while the first sand layer was in the range of 1.18 millimeters to 3.35 millimeters followed by fine sand of grain size less than 1.15 millimeters. The activated carbons were less than 2-millimetre grain size. The biosand filter also includes the diffuser plate and the filter lid. The biofilm layer will be produced after the biological sand filter was matured.

The size of the biological sand filter wall shown in figure 1 was proposed to be 50 centimeters in height and 8 centimeters in diameter. The gravel layer was 3 centimeters height, followed by first sand layer of 3 centimeters and second layer of sand of 20 centimeters. The activated carbons were proposed to be in 7 centimeters high and the standing water on top was fixed to 7 centimeters. The outlet tube was selected to be 50 centimeters long so that it can reach further. All the sizes and height were adapted from the biosand filter construction manual of Centre for Affordable Water and Sanitation Technology (CAWST) [17].

![Figure 1. Schematic diagram of biological sand filter with activated carbon layer.](image)

2.3. Analysis of Data

In this research, the data and results of treated water using slow sand filter is compared with the data and results of biological sand filter with mixed activated carbon layer. The National Water Quality Standards for Malaysia is (NWQSM) also used to establish the quality of the treated water with the list of standard method used according to the parameters shown in table 1.

| Types of parameter | Testing Methods |
|--------------------|-----------------|
| pH                 | APHA 4500-H+-B(c)# Electrometric method |
| Turbidity          | APHA 2130 Nephelometric method |
| Colour             | APHA Platinum Cobalt Standard Method |
| BOD                | APHA 5210 B# Axide Modification Method |
| COD                | APHA 5220 B# Open Reflux Method |
| TSS                | APHA 2540 D Filtration Method |
| Heavy Metals       | Analyst 200 User Guide Linear Calibration Method |

#: Standard Methods for Examination of Water and Wastewater, APHA (2005)
3. Result and discussion
The average pH concentration for the ten different water samples taken from Kampung Chenderawasih is 3.864. The average pH concentration of samples filtered using pre-treatment column, normal biological sand filter and activated carbon layered biosand filter (BAC) are 5.99, 6.575 and 6.26 respectively. The water samples’ pH concentrations are tabulated and a graph of comparison between different types of sample are drawn as shown in figure 2. The water samples’ pH concentration increases from average of 3.86 to an average of 6.26 after filtered using activated carbon layered biological sand filter. This indicates that the water filtered is in the range of 6 – 7 pH value which is approximately neutral. The pH concentrations of water filtered using BAC satisfied the National Water Quality Standards for Malaysia for class IIA which is in the range of 6 – 9 and within the Recommended Raw Water Quality which is between pH of 5.5 - 9. However, the water filtered using BAC does not meet the Drinking Water Quality Standards which is in the range of 6.5 – 9.0. This may due to the excess acid left in mixed activated carbon in the biological sand filter.

![Figure 2. Graph of comparison of pH concentration of different samples.](image)

The average turbidity concentration for the ten different water samples taken from Kampung Chenderawasih is 62.39 NTU. The turbidity concentration of samples filtered using pre-treatment column, normal biological sand filter and activated carbon layered biosand filter are 30.74 NTU, 17.36 NTU and 11.65 NTU respectively. The water samples’ turbidity concentration decreases from average of 62.39 NTU to an average of 11.65 NTU after filtered using activated carbon layered biological sand filter. The turbidity concentrations of water filtered using BAC satisfied the National Water Quality Standards for Malaysia for class IIA which is less than 50 NTU. However, the water filtered using BAC does not meet the Drinking Water Quality Standards which is less than 5 NTU. The high turbidity value may due to the residual particles in the sand and activated carbon layer that are not rinsed completely during the preparation stage [18]. From the figure 3, the normal biological sand filter (Control) and the activated carbon layered biological sand filter (BAC) shows reduction efficiency on turbidity concentration of 43.53 % and 62.10 % respectively. It is shown that the BAC filter has higher reduction efficiency on turbidity concentration compared to the Control filter.
The average biochemical oxygen demand (BOD) concentration for the ten different water samples taken from Kampung Chenderawasih is 12.6 mg/L. The BOD concentration of samples filtered using pre-treatment column, normal biological sand filter and activated carbon layered biosand filter are 6.44 mg/L, 3.62 mg/L and 2.69 mg/L respectively. The water samples’ BOD concentration decreases from average of 12.6 mg/L to an average of 2.69 mg/L after filtered using activated carbon layered biological sand filter. This shows a significant difference in BOD values for the water samples filtered using normal biological sand filter compared to activated carbon layered biological sand filter. The BOD concentrations of water samples filtered using BAC satisfied the National Water Quality Standards for Malaysia for class IIA which is less than 3 mg/L and within the Recommended Raw Water Quality which is less than 6 mg/L. However, the water filtered using BAC does not meet the Drinking Water Quality Standards which is 0 mg/L.

The high values of BOD concentrations in treated water samples using BAC filter may due to the bioactivity of the biofilm in the BAC column. The changes of dissolved oxygen of the water samples shows the activity at the biofilm. Lower bioactivity of biofilm may able to reduce more organic substrate which give higher removal efficiency of BOD concentration [19]. From the figure 4, the normal biological sand filter (Control) and the activated carbon layered biological sand filter (BAC) shows reduction efficiency on biochemical oxygen demand concentration of 43.85 % and 58.26 % respectively. It is shown that the BAC filter has higher reduction efficiency on biochemical oxygen demand concentration compared to the Control filter.
The average chemical oxygen demand (COD) concentration for the ten different water samples taken from Kampung Chenderawasih is 115.1 mg/L. The COD concentration of samples filtered using pre-treatment column, normal biological sand filter and activated carbon layered biosand filter are 93.5 mg/L, 33.7 mg/L and 23.67 mg/L respectively. The water samples’ COD concentration decreases from an average of 115.1 mg/L to an average of 23.67 mg/L after filtered using activated carbon layered biological sand filter. This shows a significant difference in COD values for the water samples filtered using normal biological sand filter compared to activated carbon layered biological sand filter. The COD concentrations of water samples filtered using BAC satisfied the National Water Quality Standards for Malaysia for class IIA which is less than 25 mg/L. However, the water filtered using BAC does not meet the Recommended Raw Water Quality which is less than 10 mg/L and the Drinking Water Quality Standards which is 0 mg/L. The high concentration of COD in the water samples after BAC filtration may indicate that the pores of the activated carbon are full of particles which slows the adsorption capacity of the mixed activated carbon layer in the BAC filter [20].

From the figure 5, the normal biological sand filter (Control) and the activated carbon layered biological sand filter (BAC) shows reduction efficiency on chemical oxygen demand concentration of 63.96 % and 74.68 % respectively. It is shown that the BAC filter has higher reduction efficiency on chemical oxygen demand concentration compared to the Control filter.

Figure 4. Graph of Reduction Efficiency of Water Filters on BOD concentration.

Figure 5. Graph of Reduction Efficiency of Water Filters on COD concentration.
The average total suspended solids (TSS) concentration for the ten different water samples taken from Kampung Chenderawasih is 5 mg/L. The TSS concentration of samples filtered using pre-treatment column, normal biological sand filter and activated carbon layered biosand filter are 0.0016 mg/L, 0.0006 mg/L and 0.0003 mg/L respectively. The water samples’ TSS concentration decreases from average of 5 mg/L to an average of 0.0003 mg/L after filtered using activated carbon layered biological sand filter. This shows a significant difference in TSS values for the water samples filtered using normal biological sand filter compared to activated carbon layered biological sand filter. The TSS concentrations of water samples filtered using BAC satisfied the National Water Quality Standards for Malaysia for class I which is less than 25 mg/L. However, the Drinking Water Quality Standards does not have the requirements for total suspended solids.

From the figure 6, the normal biological sand filter (Control) and the activated carbon layered biological sand filter (BAC) shows reduction efficiency on total suspended solids concentration of 62.50 % and 81.25 % respectively. It is shown that the BAC filter has higher reduction efficiency on total suspended solids concentration compared to the Control filter. This may due to high adsorption capabilities of the mixed activated carbon layer in the BAC filter [21].

![Graph of Reduction Efficiency of Water Filters on TSS concentration](image)

**Figure 6.** Graph of Reduction Efficiency of Water Filters on TSS concentration.

The average E. Coli bacteria concentration for the ten different water samples taken from Kampung Chenderawasih is more than 2419.6 MPN/100mL. The E. coli bacteria concentration of samples filtered using pre-treatment column, normal biological sand filter and activated carbon layered biosand filter are 13.54 MPN/100mL, 1 MPN/100mL and 0 MPN/100mL respectively. The water samples’ E. coli bacteria concentration decreases from average of more than 2419.6 MPN/100mL to an average of 0 MPN/100mL after filtered using activated carbon layered biological sand filter. This shows a significant difference in E. coli bacteria values for the water samples filtered using normal biological sand filter compared to activated carbon layered biological sand filter. The E. coli bacteria concentrations of water samples filtered using BAC satisfied the National Water Quality Standards for Malaysia for class I which is less than 10 MPN/100mL.

From the figure 7, the normal biological sand filter (Control) and the activated carbon layered biological sand filter (BAC) shows reduction efficiency on E. Coli bacteria concentration of 92.61 % and 100 % respectively. It is shown that the BAC filter has higher reduction efficiency on E. Coli bacteria concentration compared to the Control filter.
The average iron ions concentration for the ten different water samples taken from Kampung Chenderawasih is 8.283 mg/L. The iron ions concentration of samples filtered using pre-treatment column, normal biological sand filter and activated carbon layered biosand filter are 4.676 mg/L, 1.912 mg/L and 1.682 mg/L respectively. The water samples’ iron ions concentration decreases from average of more than 8.283 mg/L to an average of 1.682 mg/L after filtered using activated carbon layered biological sand filter. This shows a significant difference in iron ions values for the water samples filtered using normal biological sand filter compared to activated carbon layered biological sand filter. The iron ions concentrations of water samples filtered using BAC satisfied the National Water Quality Standards for Malaysia for class II which is 1 mg/L.

From the figure 8, the normal biological sand filter (Control) and the activated carbon layered biological sand filter (BAC) shows reduction efficiency on iron ions concentration of 59.12 % and 64.03 % respectively. It is shown that the BAC filter has higher reduction efficiency on iron ions concentration compared to the Control filter.

4. Conclusion
The result shows that water treated using biological sand filter with activated carbon layer have lower turbidity, coliform and heavy metals values compared to water before treatment and water treated
using the normal biological sand filter. The activated carbon layered biological sand filter shows higher reduction efficiency compared to normal biological sand filter. All parameters after the groundwater treatment using activated carbon layered biological sand filter are within the class IIA in National Water Quality Standards of Malaysia. Thus, the combination of activated carbon in biological sand filter is efficient in obtaining neutral water from acidic water. The activated carbon in biological sand filter also can eliminate and reduce pathogen and contaminants present in water to provide safe and clean water.

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