Effectiveness of powdered activated carbon from fruit waste in removing heavy metals in groundwater

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Abstract. This study was conducted to measure and compare the existing concentration of heavy metals in groundwater at riverbank. This study was also carried out to determine the effectiveness of activated durian rind which serves as powdered activated carbon (PAC) as an adsorption agent to remove heavy metals such as iron (Fe) and manganese (Mn) in groundwater. The initial concentration of Fe and Mn from all groundwater samples have exceeded the allowable standard. The process of removing iron and manganese was done by using 0.1g, 0.2g, 0.3g and 0.4g of activated durian rind. The results has shown a promising success with the percentage of removal with activate d durian rind for iron ranging from 93.06% to 98.39%, while removal percentage for manganese ranging from 93.42% to 98.57%.

1. Introduction
Water is known as the most vital for life's source. It comes from river, lakes, ocean and groundwater. Groundwater was also an important source for maintaining the sustainability of living things. Most of the major source of groundwater contamination was caused by human activity such as uncontrolled waste disposal, oil release or spills and hazardous chemicals, and increasing use of fertilizers and pesticides [1]. In addition, iron and manganese are naturally available in the Earth's crust and can be dissolved in groundwater by natural processes. Groundwater will leach through the soil and rock and dissolve mineral containing manganese and iron [2]. If it is too high, this trace element concentration can actually affect groundwater quality. Dissolved iron and manganese-exposed to air it becomes insoluble and generates colored brown-red water, decreasing the value of the water itself. Therefore, to obtain clean groundwater resources it was compulsory to treat it properly for human consumption.

As the conventional groundwater treatment may prove to be costly, there is a need to look for an alternative treatment in metal removal such as Powdered Activated Carbon (PAC) to overcome the uses of dangerous chemical and costly technologies in water treatment especially for heavy metals [3]. PAC commonly used as an adsorbent in the water treatment process. It was a highly porous material and provides a large surface area that easily absorbs any kind of contamination that occurs in waters [4]. PAC can also be made from any biomass products that contain high carbon such as banana peels [5, 6], orange peels [7, 8] and sugarcane pith [9]. The focus in these studies was to investigate the effectiveness of new material based on agricultural waste for metal removal in water and wastewater.
Due to the high consumption of durian especially in Malaysia, its rind considered as waste because the inside is the only part that is edible. There are enormous amount of fruit and vegetables waste that is produced daily all over the world with significant amount of losses and negative impacts in multiple economic sectors [10, 11]. As the durian rind has become part of the cause for environmental pollution, converting the rind into activated carbon can be considered as an alternative way to reduce the waste effectively. Therefore, the specific objectives of this study are to identify the concentration of iron and manganese in groundwater, to determine the effectiveness of powdered activated carbon by using durian rind in removing iron and manganese in groundwater.

2. Methodology

The main purpose of this study is to investigate the effectiveness of natural organic material such as durian rind to remove and reduce the heavy metal presence in groundwater. This study includes undertaking a site visit to get the samples into the laboratory work such as measuring the amount of iron and manganese in the groundwater. Groundwater samples were collected in Perkampungan Orang Asli Jenderam Hilir, Dengkil, Selangor. Samples was acquired from two different wells and pumped by using diesel engine pump attached with Teflon tubing and then transfer the sample into the bottle for further experimentation in the laboratory. The samples were ensures to remain cool in the ice shipping box until received by laboratory personnel.

2.1. Study area

Groundwater samples were collected from monitoring wells in Kampung Jenderam Hilir, Dengkil, Selangor. The study area is situated in Sungai Langat's downstream and the nearest city in this study area is Dengkil Town, which is situated between Cyberjaya and Salak Tinggi in Selangor district of Sepang as indicates in figure 1. Dengkil has also been influenced by the development of Putrajaya and Kuala Lumpur for many years. This area was also chosen due to its high water demand. Based on Water Evaluation and Planning (WEAP) system investigated by [12] for Langat Catchment, the result shows that the total water demand up to year 2010 was 101.1 million cubic meter as the population growth rate increasing from 2.2% to 7% for the period 2001-2014.

![Figure 1. Location of study area.](image)
2.2. Determination of Fe
10 ml of groundwater sample was filled in a clean square sample cell. Then, Powder Pillow FerroVer Iron Reagent was added to the sample cell and was swirled to mix it thoroughly. The groundwater sample changed to orange colour due to the presence of iron in the groundwater sample. The solution for a reaction was within three minutes. The spectrophotometer was set to 265 Iron, FerroVer. Next, the blank sample was prepared into the spectrophotometer machine with a new batch 10 ml of groundwater sample in the sample cell. The square sample was properly wiped with a tissue before it was placed into the cell holder of the spectrophotometer as a precaution step. The spectrophotometer reading showed 0.0 mg/L after pressing the zero button. The blank sample was taken out from the spectrophotometer, and the groundwater sample that contain FerroVer Iron Reagent Powder Pillow after 3 minutes of reaction, was placed into the cell holder of the spectrophotometer machine and was measured.

2.3. Determination of Mn
Deionized water and ground water sample was filled into a separate square sample about 10 ml each. Next, Ascorbic Acid Powder Pillow was added into each square sample. Then, each of the sample cell was filled with a 12 drops of Alkaline-Cyanide Reagent solution. Mix well each cell by gently swirled it. A cloudy solution formed. Each sample cell was added with 12 drops of PAN Indicator Solution, 0.1 % then swirled again to mix well the solution. The orange color was formed to indicate the presence of manganese in the water sample. One of the sample was rested for 2 minutes. The square sample was properly wiped with a tissue before it was placed into the cell holder of the spectrophotometer as a precaution step. The spectrophotometer was set by program 290 Manganese, LR PAN then the blank sample was placed into the spectrophotometer. The spectrophotometer reading showed 0.0 mg/L after pressing the zero button. Next, the sample that added with 12 drops of Alkaline-Cyanide Reagent was inserted after the blank sample was taken out, then read button was pressed until the result displayed on the screen.

2.4. Activation of durian rind
Before the durian rind was used, it was washed thoroughly with water and dried in the oven for 24 hours at 105°C to remove moisture inside the durian rind. The dried durian rind then was blended to increase the composting rate because the particle size of the materials impacts the microorganism's decomposition [13]. Then, it was further heated for thermal activation (carbonization) for 1 hour in a muffle furnace at 550°C to transform the watermelon rind into activated carbon.

To determine the effectiveness of manganese and iron removal, 100 ml of groundwater sample was prepared. Then, the activated durian rind was added in the water sample. The efficiency was measured by using different amount of activated durian rind, using weight of 0.1g, 0.2g, 0.3g and 0.4g each to be mixed with the sample. Then, the mixture was placed to the mechanical orbital shaker at 150 rpm for 30 minutes. Each sample was filtered using filter papers. The concentration of iron and manganese after the filtration was measured and the percentage of removal was calculated using equation (1).

\[
\% \text{ metal removal} = \left( P_o - P_f \right) \div P_o \times 100
\]

Where:  
\( P_o \) = Initial concentration of metal (mg/L)  
\( P_f \) = Final concentration of metal (mg/L)
3. Results and discussion

Based on the tests done in laboratory, the results are tabulated in table 1.

Table 1. Results of laboratory testing for initial content of Fe and Mn in groundwater samples.

| Source | Sample | Fe (mg/L) | Mn (mg/L) |
|--------|--------|-----------|-----------|
| MW1    | 1      | 4.710     | 0.632     |
|        | 2      | 4.565     | 0.705     |
|        | 3      | 4.855     | 0.766     |
|        | Average| 4.710     | 0.701     |
| MW2    | 1      | 5.140     | 0.682     |
|        | 2      | 6.255     | 0.748     |
|        | 3      | 5.430     | 0.806     |
|        | Average| 5.608     | 0.745     |

Table 1 shows the initial content of iron and manganese from Monitoring Well 1 (MW1) and Monitoring Well 2 (MW2) at the riverbank filtration site. Based on the results, the mean for initial concentration of iron and manganese for MW1 is 4.710 mg/l and 0.701 mg/l respectively. For Monitoring Well 2 (MW2), the mean for initial concentration of iron and manganese is 5.608 mg/l and 0.745 mg/l respectively. It can be seen that the existing concentration of iron in sample from both monitoring wells were high and have exceeded allowable Malaysian water standard, which is 1.0 mg/L. While the concentration of manganese in sample from both monitoring well also exceeded allowable water standard which is 0.3 mg/L.

After the initial content of iron and manganese have been determined, the removal procedure using specified weight of activated durian rind was carried out. The weights of activated durian rind used were from 0.1g to 0.4g. The results of the removal efficiency are presented in table 2.

Table 2. Results of laboratory testing for removal of Fe and Mn in groundwater samples.

| Well   | Weight of activated durian rind (g) | Initial content | After | % of Removal |
|--------|-----------------------------------|-----------------|-------|--------------|
|        |                                   | Fe (mg/l)       | Mn (mg/l) | Fe (mg/l) | Mn (mg/l) | Fe (mg/l) | Mn (mg/l) |
| MW1    | 0.1                                | 4.710           | 0.701   | 0.219     | 0.032     | 95.35     | 95.44     |
|        | 0.2                                | 4.710           | 0.701   | 0.183     | 0.019     | 96.11     | 97.29     |
|        | 0.3                                | 4.710           | 0.701   | 0.148     | 0.015     | 96.86     | 97.86     |
|        | 0.4                                | 4.710           | 0.701   | 0.076     | 0.010     | 98.39     | 98.57     |
| MW2    | 0.1                                | 5.608           | 0.745   | 0.389     | 0.049     | 93.06     | 93.42     |
|        | 0.2                                | 5.608           | 0.745   | 0.340     | 0.045     | 93.94     | 93.96     |
|        | 0.3                                | 5.608           | 0.745   | 0.284     | 0.035     | 94.94     | 95.30     |
|        | 0.4                                | 5.608           | 0.745   | 0.236     | 0.029     | 95.79     | 96.11     |

Based on figure 2, the percentage of iron removal by using 0.1g to 0.4g activated durian rind for MW1 were 95.35%, 96.11%, 96.86% and 98.39%. Meanwhile, by using similar weights of 0.1g to 0.4g of activated durian rind for MW2, the percentage of removal were 93.06%, 93.94%, 94.94% and 95.79%.
While for manganese concentration removal for MW1, by using 0.1g to 0.4g of activated durian rind, it can remove up to 95.44%, 97.29%, 97.86% and 98.57%. Removal efficiency for sample from MW2, by using 0.1g to 0.4g of activated durian rind, the percentage is 93.42%, 93.96%, 95.30% and 96.11% respectively.

The overall results have shown that the trend of removal is increasing according to the increase of weight of activated durian rind as shown in figure 2 and 3. This has made possible due to the increased surface area for adsorption process. Using a minimum weight of 0.1g, it already able to remove both iron and manganese in the sample by more than 90%. This clearly shows that the activated durian rind is effective to remove heavy metals in groundwater and the use for larger scale of groundwater treatment could be valuable for long term cost benefit.

**Figure 2.** Percentage of iron removal against weight of activated durian rind.

**Figure 3.** Percentage of manganese removal against weight of activated durian rind.

### 4. Conclusion

This study has able to present that the existing amount of iron and manganese in groundwater is considerably high and exceeded the drinking water quality standard. The conversion of durian rinds as powdered activated carbon (PAC) also proven to be effective in removing iron and manganese in groundwater. When the amount of activated durian rind used were increased, it also increases the removal percentage of iron ranging from 93.06% to 98.39%, while removal percentage for manganese
ranging from 93.42% to 98.57%. This results has shown a highly significant success rate and therefore, it can be inferred that durian rind can be used as low-cost adsorbents, resulting in environmental benefits such as minimizing waste material from fruits and may add to further groundwater treatment monetary values.

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