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Comparison between activated carbon and sand filtration method for water quality enhancement: A case study

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Abstract. Urbanization is regarded as the development of a country, and this process brings modernization of society with a positive impact. Nowadays, housing developments need to include green spaces towards a sustainable lifestyle. Thus, some of the developers choose to build projects near the existing recreational area or surface water environments. Hence, the transformation and expansion of residential and economic activities near waterbodies such as lakes and rivers have lowered the quality of this surface water system. Moreover, severe environmental pollution has been worsened especially in surface water located in urban areas. This study aims to determine the water quality status of Metropolitan Lake, Kuala Lumpur before and after the treatment of activated carbon and sand filtration method. Here, physical and chemical characteristics were conducted for in-situ and laboratory analysis. Temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS) and turbidity of water samples were taken in-situ. Meanwhile, parameters of biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, total suspended solids (TSS), ammonia nitrogen (NH_3-N) were determined in the laboratory. Before the treatment process, the classification of water quality index (WQI) for the sample of Metropolitan Lake, Kuala Lumpur was in class IV. However, after the two treatments of activated carbon and sand filtration, the water class of WQI has improved to class II. Thus, it is important to enhance the water quality through pre-treatment on the surface water system as this source of water is vital for water security and ecosystem surroundings.

1. Introduction
Water is in a fluid state at a normal temperature and exists in gas or solids under specific conditions. Living organism depends on water to survive. This fundamental element is used in daily activities such as water consumption for washing and cleaning, recreational activity, control and supply, route and medium for transportation [1].

The South China Sea surrounds Malaysia, and there are around 150 of streams and tributary flows in the peninsula, including Sabah and Sarawak [2]. This river and lakes are vital surface water resources for the intake of water supply to the citizens of Malaysia. As a developing country, Malaysia has rapid growth in economic sectors, and this positive impact creates a high demand for job creation. Thus, more infrastructure has been developed to accommodate the increasing population, mainly in the big city and urban areas [2]. However, along the industrial advancements critical issues of environmental pollution become more obvious [3]. Most of this pollution has affected the quality of water in the lakes as it is known to be a large water body that is bounded by land and involves different aquatic lives and freshwater ecosystems. This complex ecology in lakes is distinctive and needs to be conserved for long-term resources [4].

Metropolitan Lake is situated in Kuala Lumpur, the capital city of Malaysia. It is a human-made lake and is among the largest recreational areas in Selayang and Batu Caves district in Kuala Lumpur. The lake area is surrounded by 95-hectare of land and consists of the 57-hectare of lake's water for fishing or recreational activities. Figure 1 shows that the Metropolitan Lake area is surrounded by urban infrastructure, buildings, and roads. Urbanization encompassing the Metropolitan Lake mainly centred by the economic activities and rapid growth of population. The recreational area is known to be a popular place for outdoor events.

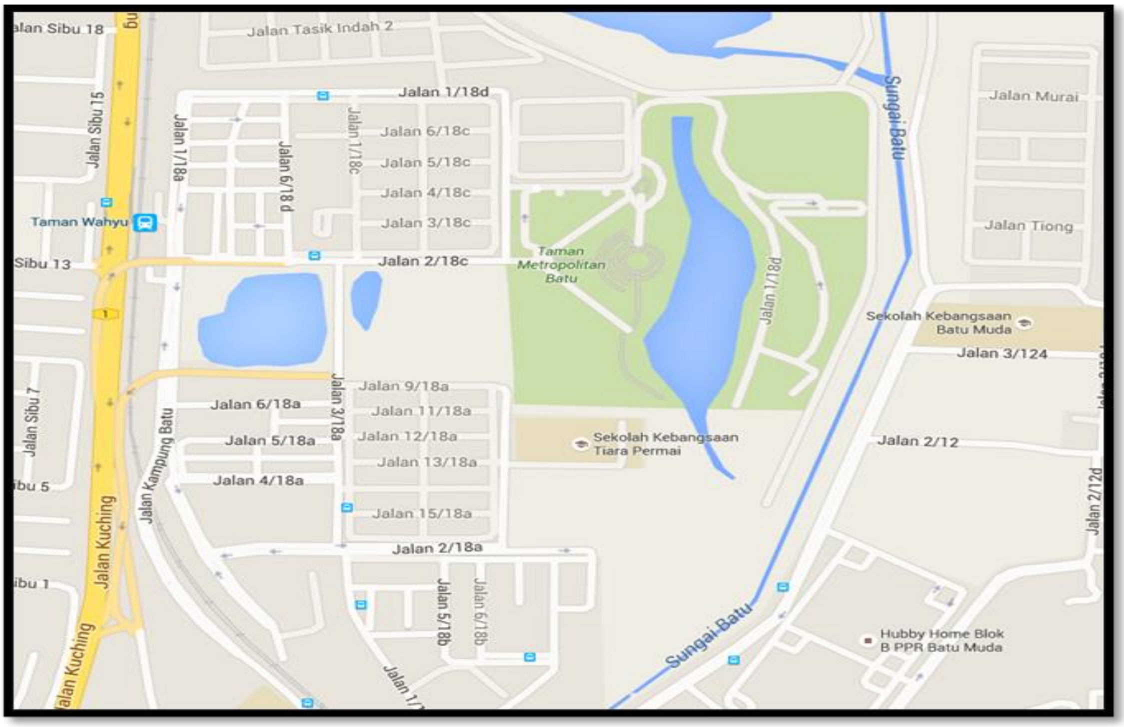

Figure 1. Location of Metropolitan Lake [5].

According to literature [6], water is a critical resource that is easily abused and polluted. The main factors of pollution sources came from land development, industrial or agricultural activities, and mishandling of waste [6]. The contaminants from these sources were directly discharged and deteriorated the quality of the surface water system. Loss of vegetation caused by development and soil erosion prompt the sedimentation, which depleted the oxygen in the water and changed the water characteristics [3]. Based on this situation, it is important to assess the water quality for this surface water system. Thus, by monitoring the condition of the rivers and lakes, mitigation measures can be proposed to improve and rehabilitate the water quality of the surface water body so that it can be able to function as a safe recreational park and resources for drinking water purposes.

2. Material and methods

2.1 Sampling location
A site visit was conducted to view the actual situation of Metropolitan Lake, Kuala Lumpur and to collect water samples. The sampling was done in triplicate near the inlet location of the lake. An average reading of water quality was calculated based on the results obtained. The samples were taken in March 2016, and September 2016 as March 2016 was considered to be a dry month in contrast to September 2016 (wet month). The data was analyzed for in-situ and laboratory tests to determine the existing water quality (WQI) of the water condition in Metropolitan Lake, Kuala Lumpur. From the data attained suitable water treatment for this research was proposed. The samples were collected in the samples bottles and preserved in 4°C [7] in the refrigerator in the Environmental Laboratory, Faculty of Civil Engineering, UiTM, Shah Alam, Selangor.

2.2 In-situ test
The physical characteristics of the lake's water were measured in-situ using handheld multiparameter instrument with digital sensors (HORIBA) [8]. Here, the parameters of turbidity, temperature, total dissolved solids (TSS), pH and dissolved oxygen (DO) were determined [7].

2.3 Laboratory test
For the laboratory test, parameters involved were biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphorus and ammonia nitrogen. The laboratory analysis for COD was done using a spectrophotometer for phosphorus and ammonia nitrogen [7].

2.4 Filtration apparatus for sand
The filtration apparatus employed in this investigation consists of 1.5 L container for sand filtration. The container was filled with graded sand (ASTM C778). An amount of 300 g of graded sand was washed through with water and allowed to be dried. The crushed rock was weighted for 300 g and placed into the same container. Then, the graded sand was layered under the crushed rocks.

2.5 Activated carbon preparation and filtration process
The second filtration apparatus used for the experiment was activated carbon from coconut shell. First, the coconut shell was cut into small pieces, washed with water to remove unwanted particles on the surface of the coconut shell. Then, it was dried in the sunlight for about 15 to 20 days. Dried materials of this coconut shell were heated in a furnace at a temperature of 150°C for 24 hours to eliminate the moisture and volatile impurities. After that, it was crushed with a crusher and sieved with a size range of 300-700 μm.

Chemical activation of the powdered precursor was done with zinc chloride ($ZnCl_2$) as an activating agent. The slurry form of powder precursor was correctly mixed and kept for 24 hours for proper soaking of zinc chloride ($ZnCl_2$) in the ratio of 1: 6 [9]. Zinc chloride ($ZnCl_2$) was used as this chemical acts as dehydration reagent to lower the carbonization temperature during the process of chemical activation and limits the formation of tar as well as encourages burning of carbon [9].

For the preparation of activated carbon, the material soaking with $ZnCl_2$ was heated inside the furnace at a temperature rate of 10°C min^{-1} to the final carbonization temperature of 650°C under the nitrogen flow rate of 120 cm^3. min^{-1} [9]. Besides that, the material was kept inside the furnace for about an hour at 650°C. Here, the elevated temperature will have resulted in the development of pores and channels in the matrix of activated carbon. Thus, it is important to choose the temperature below the boiling point of $ZnCl_2$ (732°C). Later, the material was cooled under the constant flow of nitrogen gas until it was completely cooled. After that, the dried material was washed with hydrochloric acid (HCl) for 2 to 3 times and then washed with warm distilled water to eliminate the residual organic and mineral matter. Then, it was finally washed with cold water. Finally, the sample was dried for one day at temperature

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100°C inside the oven and packed in an airtight container [9]. Further, the water sample would undergo treatment under filtration apparatus, which contained the prepared activated carbon.

3. Results and discussion

3.1 Results analysis

Table 1 shows the physical parameters of turbidity, temperature, total dissolved solids, dissolved oxygen, and pH for the raw water sample from Metropolitan Lake, Kuala Lumpur (in average values for March and September 2016). The turbidity of the raw sample is at 117 NTU with a temperature of 30.56ºC. The total dissolved solids were 97 mg/L with a high concentration of dissolved oxygen (9.43 mg/L). The pH for the raw samples was alkaline in the value of 8.08.

Table 1. In-situ test for raw water samples from Metropolitan Lake, Kuala Lumpur.

Parameter	Raw sample
Turbidity (NTU)	117
Temperature (ºC)	30.56
TDS (mg/L)	97
DO (mg/L)	9.43
pH	8.08

Table 2 shows the results of raw water samples compared with samples after the treatment with sand and activated carbon filtration (in average values for March and September 2016). The turbidity result of 117 NTU has later decreased after sand filtration treatment to 56.4 NTU and after activated carbon filtration to 57.2 NTU. The removal percentages for both filtration processes were 51.80% and 51.10%, respectively. The filtration method (sand and activated) has been proved able to reduce the turbidity from the water sample and improve the quality of water since the process isolated and removed the remaining solid particles and flocs from the water [10].

A BOD_5 of 8.96 mg/L has been observed for the raw sample as shown in table 2. Consequently, after the treatment with sand filtration, the BOD_5 has been dropped to 7.50 mg/L with a removal percentage of 16.29%. Later, the BOD_5 value was further decreased to 6.18 mg/L with reduction percentage of 31.03% following the filtration with activated carbon.

The results from table 2 show that the COD of raw sample is 47 mg/L which then decreased to 33 mg/L after sand filtration with removal percentage of 29.79%. Furthermore, with the implementation of activated carbon filtration, the result of COD has significantly dropped to 17 mg/L with removal percentage of 63.83%, respectively. This is a good indicator as a low COD value shows that the standard of water quality has improved. According to a previous work [11], crushed rock is stated to be the best type of sand filtration since it has a limited chance of being contaminated with organic material and pathogens. Moreover, the crushed rock produced sand grains that have rough edges, course, and non-uniform in size.

Next, the pH is slightly maintained within the range of neutral pH. However, for ammonia nitrogen (NH_3-N), the value of the raw sample was the same even though being treated in sand filtration. The low reduction was also detected in activated carbon filtration of 0.24 mg/L with a minor removal percentage of 7.69%. Overall, the filtration with activated carbon has displayed good achievement in reducing the contaminants from the raw water samples from Metropolitan Lake, Kuala Lumpur.

Table 2. Comparison of raw water samples with the treatment of sand and activated carbon filtration.

Parameter	Raw sample	Sand Filtration sample	Percentage removal (sand) (%)	Activated carbon filtration sample	Percentage removal (AC) (%)
Turbidity (NTU)	117	56.4	51.80	57.2	51.10
BOD_5	8.96	7.50	16.29	6.18	31.03
COD	47.0	33.0	29.79	17.0	63.83
NH_3-N	0.26	0.26	0	0.24	7.69

From this research, the current water quality (WQI = 41.50) in Metropolitan Lake is considered as polluted based on the raw water samples taken before the treatment (refer figure 2). This may be due to the development of housing areas near the Metropolitan Lake. The classification of water classes based on the WQI from the Department of Environment, Malaysia for this lake is class IV (Irrigation) [12].

Furthermore, the commercial centre near Metropolitan Lake has not been equipped with a proper disposal system for the wastewater such as oil and grease. Thus, this effluent had gone directly to the lake without being treated. This situation caused a significant reduction of WQI. As for that, mitigation measures for sustainable management are vital to improve the current condition. The investigation using sand filtration and activated carbon filtration has been carried out and proved to be reliable in increasing the water quality of water in Metropolitan Lake.

It has been observed that, after the sample has been treated with sand and activated carbon filtration, the WQI has increased and the index range based on the WQI has changed from polluted to slightly polluted [12]. Figure 2 shows the comparison of WQI in water samples before and after the treatment of sand filtration and activated carbon filtration. The WQI of the samples has increased to 63.96 compared to the initial value of 41.5. Furthermore, a significant increase has been observed for the WQI of the sample after being treated with activated carbon that is 78.29. This demonstrated that the water quality of the sample treated by activated carbon filtration has substantially improved. Thus, the classification of the previous WQI has changed from class IV to class II. The results show that it is important to have a pre-treatment before the water can be discharged to the lake.

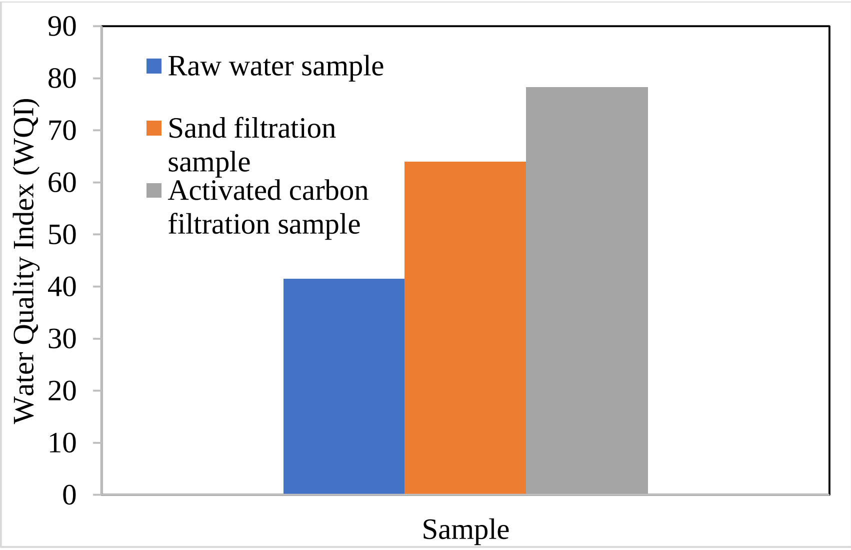

Figure 2. WQI in water samples before and after the treatment of sand filtration and activated carbon filtration.

Coconut shell has been chosen as the raw material for the preparation of activated carbon in this investigation because it is easy to find and the microporous structure of coconut shell is more effective than other materials [9]. It has been showed that the adsorption of gas and removal of colour and odour could be readily determined by using coconut shell activated carbon (AC) [9]. The activated carbon has a high fixed carbon and low ash content [9]. It is proved that the activated carbon could be utilized as an adsorbent to remove major contaminants from wastewater. The adsorption capacity of the activated carbon is highly reactive and can reduce the pollutants considerably. The use of the coconut shell from waste is also beneficial in terms of green technology as this waste material can be recycled. The suitability of coconut shell demonstrated that activated carbon made of this carbonaceous material could act as an adsorbent to decrease the pollutants in water.

The activated carbon has a porous structure, and this feature can easily capture contaminants by physical adsorption. Further research on activated carbon can be created from many carbonaceous raw materials such as coal, lignite, wood and some agricultural product (rice husk, nutshell, coconut shell, nut, sugarcane bagasse, tamarind, sawdust and industrial waste items) [13, 14, 15].

Finally, the activated carbon filtration is more efficient compared to the sand filtration. The treatment can increase the WQI and reduce the parameters of water samples such as turbidity, BOD, and COD effectively better than sand filtration. Activated carbon is a convenient method of filtration, inexpensive and efficient based on the carbon production process using local agricultural waste [13, 16].

4. Conclusion

It can be deduced that the classification of water samples for Metropolitan Lake was in class IV, and it showed that human activities have polluted the water. The current problem has been overcome with two treatments proposed, either using activated carbon or sand filtration. After the application of these methods, the water quality of this lake has been improved. The water sample of this lake has upgraded from class IV to class II.

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