

The Performance of Coconut Shell-based Activated Carbon (CSAC) in Treating Drinking Water

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Abstract—The demand and market growth of activated carbon (AC) in drinking water treatment have been increasing over the recent years. This is because of the better properties and relatively lower cost of AC compared to inorganic adsorbents like ceramics. However, there have been limited studies on the effects of AC preparation including type of cleansing agent on the adsorption of metal and the turbidity of treated tap water. Therefore, this research investigated the effect of types of cleansing agent and sorbent dosage on turbidity reduction and metal removal in drinking water treatment. The analysis showed that 200 g dosage of AC that has been cleansed with FeCl_3 has the turbidity and metal removal improved the most. For aesthetic value of drinking water though, filtration by using AC cleansed with KOH gave better taste and increasing the sorbent dosage up to 300 g increased this performance.

Keywords: activated carbon, coconut shell, cleansing agents, carbon dosage, drinking water

I. INTRODUCTION

SAFE drinking water is defined as the water that does not represent any significant risk to health over a lifetime and is suitable for all common domestic purposes, including personal hygiene [1]. It should contain no impurity that would offend the senses of sight, taste, or smell which reflect its aesthetic value [2]. In some countries, water filter is used to treat water before drinking even though the water is potable standard because of the changing aesthetic value of water flowing in the distribution pipes.

There are many types of water filter, and activated carbon is one of the materials used to remove most of these problems where contaminants are adsorbed when water flows through the voids in the bed of this material [3]. Activated carbon is a porous and black carbonaceous solid processed in the absence of oxygen in order to increase the number of pores [4].

When water passes over the activated carbon, any chemicals or contaminants in the water are bonded at a molecular level to the carbon, effectively removing them from the water [5]. The materials used in the construction of drinking water treatment and distribution systems must not affect negatively the quality of water that is supplied to the customer [6]. In this present study, the post-preparation and dosage of activated carbon used for drinking water treatment were investigated for their effects on the treated water such as turbidity, metal content and aesthetic value of the water. Thus, it verified the suitability of coconut shell-based activated carbon for safe use in drinking water treatment.

The parameters that have been chosen in this scope of studies as listed in Malaysian National Drinking Water Standard are turbidity from Group 1, iron (Fe) from Group 2 and zinc (Zn) from Group 3. Since the commercial AC used in this research had been prepared in a bulk amount, further process needs to be done before it can be used in water treatment filter. Three types of cleansing agents were used in this study were Potassium Hydroxide (KOH), Iron (III) Chloride (FeCl_3) and Zinc Chloride (ZnCl_2) which are usually used for impregnation of the raw material before carbonization of activated carbon. For the dosage of sorbent, 100g, 200g and 300g were used where 300g is the maximum capacity of the AC in the filter cartridge.

II. MATERIALS AND METHODS

2.1 Sample Preparation

A sample of tap water which acted as control water was collected into a beaker after it passed through the column with a continuous flow. The tap was flushed until the temperature of the flowing water does not vary by more than 1°C over a period of 1 min and did not exceed 25°C . Preparation of control water was carried out on the same day of assessment day.

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The virgin granular activated carbon (GAC) was rinsed for about 10 minutes with tap water to remove any fine particles from their surface and then heated in the oven for about 2 hours for hygienic purposes. Different amount of GAC to be filled into filter cartridge were 100g, 200g and 300g. For post-preparation purposes, GAC was immersed in Zinc Chloride (ZnCl_2), Potassium Hydroxide (KOH) and Ferric Chloride (FeCl_3) solutions at 1:10 ratio before rinsed with distilled water and oven-dried. All chemicals used were analytical grade and purchased from Merck (Germany). Table 1 shows the experimental matrix of this experiment.

Experiment	Manipulated variable	Fixed variable	Labeling of the activated carbons
Effect of cleansing agent	Normal, KOH, FeCl_3 , ZnCl_2	200g (Dosage)	AC(2), ACK(2), ACFe(2), ACZn(2)
Effect of sorbent dosage	100g, 200g, 300g	FeCl_3 (Cleansing agent)	ACFe(1), ACFe(2), ACFe(3)

2.2 Experimental Setup & Method

An AC water filter consists of a filter cartridge that may contain AC powder, granules, solid block and paper membrane or wound spool made of carbon-impregnated cotton cord or foam [7]. In this experiment, the AC used was in granular form ranging from 0.59 to 2.38 mm particle size and the type of filtration used was pour-through-filter which is the simplest and portable since no installation was required. The filter was held over a container and tap water was poured in at 30 mL/s.

Water samples were collected from the filter effluent to evaluate the parameters to be studied. Three parallel samples, each with a volume 500 mL, were analysed by using different assessment method depending on the parameters to be checked.

For odour and taste, three panelists that passed the panelists requirement test assessed the treated test water and compared with control water to detect any presence of discernible taste. Each panelist was instructed to take into the mouth whatever volume of water was comfortable and to hold it in the mouth for several seconds before discharging it without swallowing for taste assessment. Besides, turbidity meter was used to determine increase or decrease in turbidity of the water sample as compared to control water. In addition, inorganic substances extraction was determined by using fire atomic absorption spectrophotometry (FAAS).

III. RESULTS AND DISCUSSION

3.1 The Effect of Types of Cleansing Agent

Figure 1 shows the relationship between the Nephelometric Turbidity Unit (NTU) reductions and AC cleansed with different types of cleansing agent. It can be observed that all AC cleansed using the cleansing agents reduced the turbidity of water. The NTU reduction is increasing in the order of $\text{AC}(2) < \text{ACK}(2) < \text{ACZn}(2) < \text{ACFe}(2)$. The turbidity reduced as more particles in the water were being adsorbed by the activated carbon. This showed that the adsorption of particles on the surface of ACFe(2) was more than using AC(2).

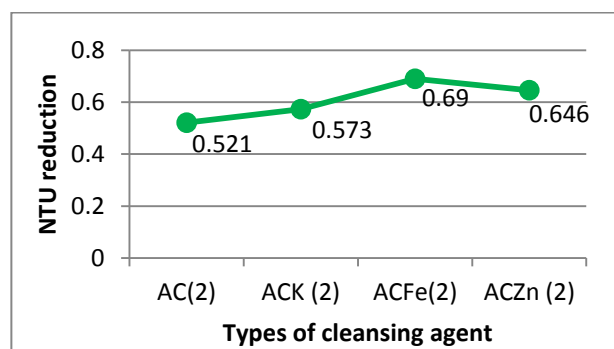


Figure 1 NTU reduction by using different type of cleansing agents.

Adsorption occurs when the attractive forces at the carbon surface overcome the attractive forces of the liquid. The reason is when water passes over the AC, any chemicals or contaminants in the water are bonded at molecular level to the carbon, thus effectively remove them from water [3]. The result is also expected because FeCl_3 is a good coagulant agent [8].

Figure 2 shows the changes in metals content (Zn and Fe) of water when treated using AC cleansed by different cleansing agents. The graph shows that AC(2), ACK(2) and ACFe(2) resulted positive changes which reflect that the ability of reducing the Zn content can be achieved by AC cleansed using any of the chemicals except ZnCl_2 . This is because ACZn(2) gave negative change in Zn content which means the Zn content was increased after the treatment. This indicated that there was leach of Zn from ACZn(2) which was due to inadequate removal of ZnCl_2 residues during cleansing process [9]. As the GAC (before cleansed) used did not contain traces amount of Zn, it was evident that the Zn ion leached was from the AC

(after cleansed). Therefore, it is accepted that AC(2), ACK(2) and ACFe(2) were good in removing Zn.

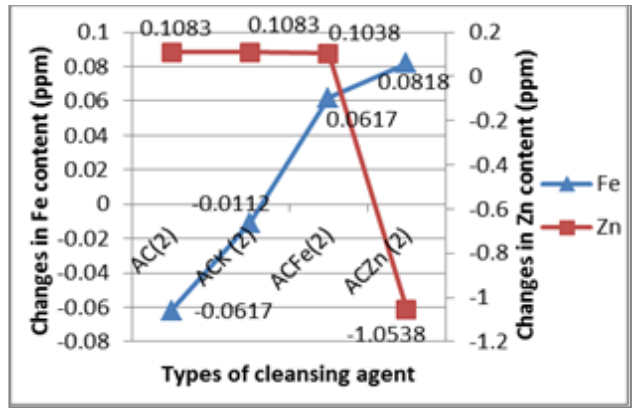


Figure 2 Changes in metals content by using different types of cleansing agent

For Fe content, only ACFe(2) and ACZn(2) could reduce the content of Fe in water with more Fe been removed by using ACZn(2). Fe from the tap water displaced the Zn adsorbed by AC during cleansing process with ZnCl₂. That was because Fe had higher affinity to be adsorbed on the surface of ACZn(2) than on ACFe(2) [10]. This could also be related to the leach of Zn from ACZn(2) from previous discussion of Zn content where the Zn adsorbed on ACZn(2) was displaced by Fe from water.

Both AC(2) and ACK(2) gave negative changes of Fe content which showed that Fe was leached from the AC. Since the AC used contained Fe, the leached Fe from both AC(2) and ACK(2) might be due to inadequate removal of Fe from the surface of AC during cleansing process. The larger amount of Fe leaching from AC(2) as compared to Fe leaching from ACK(2) showed that the bonding of Fe with the AC before treated using KOH was initially weak and cleansing the AC with KOH had removed the Fe which reduced Fe content in the AC. Hence, it could be proven that ACZn(2) adsorbed more Fe than by using AC(2), ACK(2) and ACFe(2).

The optimal cleansing agent could be found by relating types of cleansing agent used with changes in Zn content and NTU reduction in the water as shown in Figure 3. The reason of comparing with changes in Zn content instead of changes in Fe content was that the amount of Zn reduced by the AC was more than reduction of Fe when the same type of AC was used. From Figure 3, since the Zn content from all three AC gave the same amount of reduction, the comparison was narrowed down to the types of cleansing agent that could reduce the turbidity the most. The most preferable types of cleansing agent increased in the manner of AC(2)<ACK(2)<ACFe(2). Thus, it could be verified that FeCl₃ was the optimal cleansing agent which could remove both turbidity and Zn content.

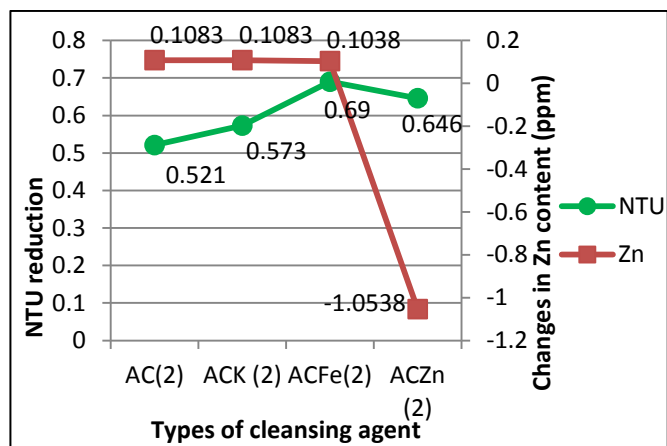


Figure 3 NTU reduction and changes in Zn content by using different types of cleansing agent

3.2 The Effect of AC Dosage

Figure 4 gives the relationship between NTU reductions with different dosage of AC. The turbidity reduction increased in the manner of ACFe(1)<ACFe(3)<ACFe(2). It showed that ACFe(2) reduced the turbidity the most because it had more exposed active sites or higher surface area for adsorption of the particles in the water to take place as compared to ACFe(1). Hence, increase in dosage of activated carbon increased the surface area and active site for adsorption process to take place [11]. Furthermore, the turbidity reduction was also higher compared to ACFe(3). This indicated that increase in dosage of AC after 200g lowered the reduction of turbidity. This might be due to increase in attrition of particles that has resulted more fine powders at higher dosage. Therefore, it could be accepted that 200g was the best dosage for turbidity removal for 30 mL/s of flow rate

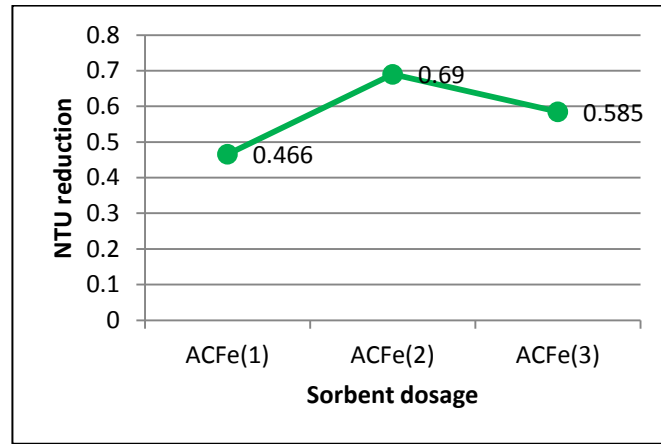


Figure 4 NTU reduction by using different dosage of AC

Figure 5 shows the changes in metals content (Zn and Fe) of water when treated using different dosage of AC. For Zn content, it indicated that all dosage of AC did reduce the Zn. The increasing removal of Zn was in the order of $ACFe(1) < ACFe(2) < ACFe(3)$. This was because ACFe(3) had more contact surface area as compared to ACFe(1). Hence, more Zn could be adsorbed. The immense surface area of AC formed during activation process gave AC an extremely adsorptive property [12]. Therefore, it could be said that increase in the dosage of AC also increased in the surface contact area for metal adsorption process to take place.

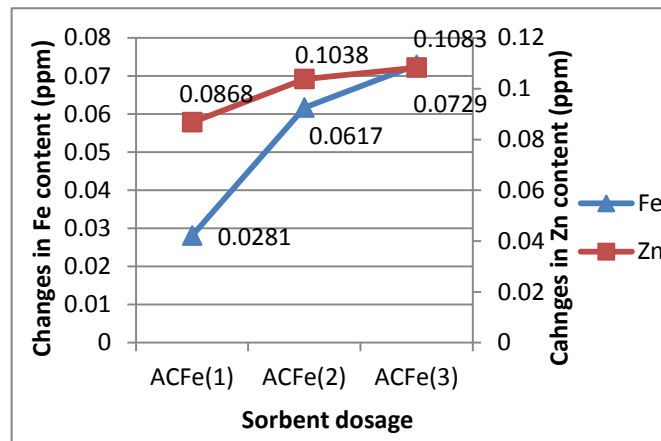


Figure 5 Changes in metals content by using different dosage of AC.

The increasing Fe removal was in increasing order of $ACFe(1) < ACFe(2) < ACFe(3)$. The result was similar which showed that ACFe(3) could reduce Fe content the most. The difference was that, increasing dosage of sorbent gave better and constant removal of Fe. Since ACFe(3) showed the most reduction of metal, it could be proven that ACFe(3) was the best to be used for metal removal because it could remove both Zn and Fe.

The optimal sorbent dosage was found by relating sorbent dosage with the amount of Fe removed and NTU reduction of the water (Figure 6.). The reason for comparing NTU reduction with Fe removal instead of Zn removal was that the Fe removal for different dosage gave constant reduction of Fe as compared to reduction of Zn using different dosage of AC. For ACFe(1), it did reduce the turbidity and Fe content. However, the reduction of both turbidity and Fe was the lowest value as compared to ACFe(2) and ACFe(3). Therefore, ACFe(1) could not be considered as the optimal sorbent dosage. Meanwhile, both ACFe(2) and ACFe(3) reduced the turbidity and Fe. In terms of turbidity, ACFe(2) could reduce more NTU as compared to ACFe(3), while in terms of Fe removal, ACFe(3) could remove more Fe as compared to ACFe(2). Based on the graph, ACFe(2) gave more consistency in the reduction of both NTU and Fe. Therefore, ACFe(2) could be regarded as the optimal sorbent dosage.

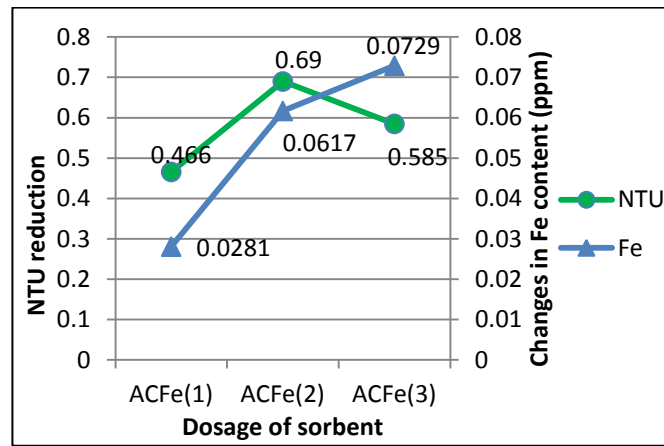


Figure 6 NTU reduction and changes in Fe content with by using different dosage of AC

3.3 The Aesthetic Value of the Drinking Water

All water samples had passed the odor test where no substantial color and odor can be detected by any of the panelists. The discussion is now focused on taste test of water samples. Table 2 shows the aesthetic values of drinking water as evaluated by different panels for cleansing agent. The range of their preference was valued from 1 to 5 which were from good to very good as compared to control.

Table 2 The preference of panels for different types of cleansing agent.

Sample	Panel 1	Panel 2	Panel 3
Control	1	1	1
AC(2)	2	2	2
ACK (2)	5	5	5
ACFe(2)	3	4	4
ACZn(2)	4	3	3

Two out of three panelists stated that their preference in terms of cleansing agent was in increasing order of AC(2)<ACFe(2)<ACZn(2)<ACK(2). However, all of them agreed that the taste of water treated using ACK(2) had superior taste. Figure 7 shows the rating of panel preference as evaluated for water treated using three types of cleansing agent and the turbidity of the treated water. Turbidity of water treated using ACK(2), ACFe(2), and ACZn(2) were 0.676, 0.559, 0.603 NTU respectively while AC(2) produced water of 1.08 NTU. This shows AC(2) did not reduce much turbidity as compared to control that had turbidity of 1.249 NTU. However, the water filtered with ACK(2) was preferred the most because of the alkalinity of the treated water. KOH was a basic solution meanwhile FeCl₃ and ZnCl₂ were Lewis acid. Thus, it could be accepted that the pH of the water could affect the aesthetic value of the drinking water.

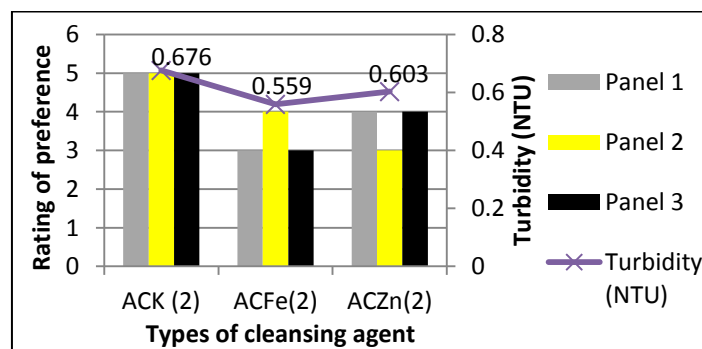


Figure 7 Rating of preference based on the turbidity of water with different types of cleansing agent used

Table 3 shows the aesthetic values of drinking water as evaluated by different panelists for different sorbent dosage. The range of their preference was from 1 to 3 which were ranged from good to very good. Two out of three panelists stated that their preference on the taste of water increased as the dosage of sorbent increased. Their preference increased in the increasing manner of ACFe(1)<ACFe(2)<ACFe(3).

Table 3 The preference of panels for different dosage of activated carbon.

Sample	Panel 1	Panel 2	Panel 3
ACFe(1)	3	1	1
ACFe(2)	2	2	2
ACFe(3)	1	3	3

From Figure 8, the metal content for Fe in the water was decreasing in the manner of ACFe(1)<ACFe(2)<ACFE(3). This indicates that the more dosage of sorbent, the more Fe metals could be removed and the better the taste of the water. Therefore, water filtered with sorbent dosage of 300g was the most preferable.

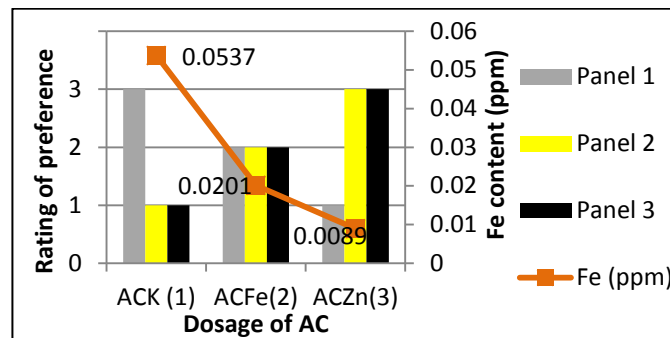


Figure 8 Rating of preference based on the Fe content with sorbent dosage

IV. CONCLUSION

The performance of CSAC in water filter has been studied focusing on the effects of cleansing agents and carbon dosage on the turbidity and metal content reduction as well as aesthetic quality of drinking water. It has been found that FeCl₃ was the best cleansing agent to reduce turbidity and metal content. In addition, increasing amount of carbon dosage more than 200 g for 30 mL/s water flow rate would not increase the ability of the CSAC to reduce turbidity due to the attrition rate but it could reduce further metal content for total surface area has been increased. For aesthetic value of water, KOH was the most preferred cleansing agent to be used in post-treatment of CSAC because of the improved taste besides the conserved drinking water characteristics that are odorless and colorless. Increasing carbon dosage in the filter could improve the aesthetic quality of the water due to the increased ability of reducing metal content. It can be concluded that the performance of CSAC can be increased by using suitable cleansing agent and optimal carbon dosage in the filter. Further studies are required to validate the safety of such improvement especially when CSAC is to be used in bulk.

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