

# THE INFLUENCE OF CLEANSING AGENT AND SORBENT DOSAGE ON THE AESTHETIC QUALITY OF DRINKING WATER TREATED USING COCONUT SHELL-BASED ACTIVATED CARBON

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## Abstract

This study investigates the suitability of using commercial activated carbon developed from coconut shell in tap water filtration. Turbidity and metal content were analyzed with respect to the different cleansing agent and activated carbon dosage used in the filtration. The results showed that activated carbon cleansed using potassium hydroxide, zinc chloride or iron chloride, improved the taste of water. It was also found that as the dosage of activated carbon was increased, the taste enhanced and the metal content decreased suggesting the taste of water is inversely proportional to metal content of the water.

Keywords: activated carbon, drinking water, aesthetic quality, odor and taste, turbidity, metal content

## 1. Introduction

World Health Organisation defines safe drinking water as water that does not represent any significant risk to health over a lifetime of consumption including different sensitivities that may occur between life stages. It should also be suitable for all usual domestic purposes, including personal hygiene [1]. In addition, drinking water should contain no impurity that would offend the sense of sight, taste, or smell which reflect its aesthetic quality [2]. Due to the changing of aesthetic quality of water flowing through distribution pipes from treatment plants, most households in developing countries including Malaysia use water filters to treat tap water. Filter systems are relatively simple and effective ways to control variety of contaminants. These include mechanical filters, oxidizing filters, neutralizing filters and the subject of this study, activated carbon filters [3].

Activated carbon, a porous black carbonaceous solid, can remove most of the aesthetic problems since when water passes through it, chemicals or contaminants in the water are adsorbed by its surface and effectively removed from the water [4]. Since the surface area of activated carbon is large, it possesses high capacity for adsorbing chemicals from gases and liquids. Absorptive property of activated carbon that depends on its extensive internal pore structures can be improved by processing it in the absence of oxygen [5].

It is low cost if it is derived from biomass that is abundance in nature such as coconut and palm shells [6]. However, there is also concern over the use of activated carbon produced from biomass in treating drinking water since the biomass consists of inorganic elements and the incorporated chemicals such as KOH and  $ZnCl_2$  in the synthesis could leach out of the surface of the sorbent during its application in water treatment [7]. Though in small quantities, metal

presence could affect the color, taste and odor of drinking water and accumulation of metal in human body above allowable limits would present danger to their health. Hence, any materials used in the construction of drinking water treatment and distribution systems must not have adverse effect on the quality of water supply [8].

The selection of cleansing agent and magnitude of dosage are hypothetically crucial in preventing leaching of metal from prepared activated carbon. Therefore this study investigates the influence of types of cleansing agent and activated carbon dosage used for drinking water treatment on the aesthetic quality of drinking water: turbidity, odor and taste. In addition, metal content of the water is also determined to relate the changing in aesthetic quality with the type of metal presence.

## 2. Materials and Methods

### 2.1 Activated Carbon (AC) Preparation

AC (Acticon GAC B30) used in this study was coconut shell derivative and was obtained in bulk from the local industry. The inorganic content of GAC B30 was analyzed using X-Ray Fluorescence Spectrometer (MICRO ENERGY XRF, Shimadzu, Japan). Since the commercial AC was prepared in bulk, cleansing process is necessary before used in drinking water treatment filter. The three types of cleansing agent used in this study were Potassium Hydroxide (KOH), Iron Chloride ( $FeCl_3$ ) and Zinc Chloride ( $ZnCl_2$ ). The chemicals were chosen because they are commonly used for synthesis of activated carbon from biomass [9].

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The granular activated carbon was firstly rinsed for about 10 minutes under tap water to remove any fine particles from the surfaces and voids before oven-dried for about 2 hours. A portion of this AC was taken as GAC sample and the rest were further treated with cleansing agents by immersing the AC at room temperature (26 °C) into KOH (~85%), ZnCl<sub>2</sub> (≥98%), and FeCl<sub>3</sub> (≥98%) solutions of 25 %w/w (chemicals to AC) for 24 hours before rinsed and oven-dried to produce AC known as GAC-KOH, GAC- ZnCl<sub>2</sub> and GAC- FeCl<sub>3</sub>, respectively. All chemicals used were purchased from Merck (Germany).

## 2.2 Experimental Method

In order to study the effects of AC alone, water filter used in this study contained solely the AC prepared as described in Section 2.1. The AC was weighed to 200 g before placed in the cartridge that was purchased from local market and labeled as AC(2), ACK(2), ACZn(2) and ACFe(2) respectively for control AC (not cleansed), GAC-KOH, GAC- ZnCl<sub>2</sub> and GAC- FeCl<sub>3</sub>.

Tap water was flushed at constant flow rate of 30 L/h until the water does not vary by more than 1 °C over a period of one minute and does not exceed 26 °C. Then, 500 mL of the water was collected in a beaker before poured into the water filter. The filtrate was collected and analyzed for odor and taste, turbidity as well as metal content. A sample of tap water which acted as control was also collected and analyzed into another beaker without passing any materials.

After finding the best cleansing agent, the experiment was repeated using different dosage (100 g and 300 g) of AC treated using that particular agent to determine the effects of AC dosage. The number in the bracket of the label was changed to (1) and (3) to denote 100 g and 300 g of dosage.

## 2.3 Experimental Analysis

Initially, odor and taste examination was carried out according to Malaysian Standard 1583: Part 1 which requires three panelists. The panelists were required to participate in an initial sensitivity trial and were instructed to abstain from drinking beverages other than water, eating and smoking for a minimum period of 60 minutes before performing the odor and taste assessment. The use of perfumes or cosmetic preparations which include scented soap for hand washing was also not allowed during the assessment day. Each of them was then required to smell the water from at least not more than 5 cm distance before taking into their mouth whatever volume of water that is comfortable and to hold it for several seconds before discharging it without swallowing. The assessments were carried out in comparison to control where the panelists rated the water from 1 to 5 for poor to best accordingly.

The water was then further analyzed for the parameters that have been chosen in this study which are listed in Malaysian National Drinking Water Standard; turbidity from group 1, iron (Fe) from group 2 and zinc (Zn) from group 3. Turbidity was measured using Turbidimeter (Orion AQ3010, Thermo Scientific, USA) while Fe and Zn content were analyzed using Atomic Absorption Spectrophotometer (AA-7000, Shimadzu, USA).

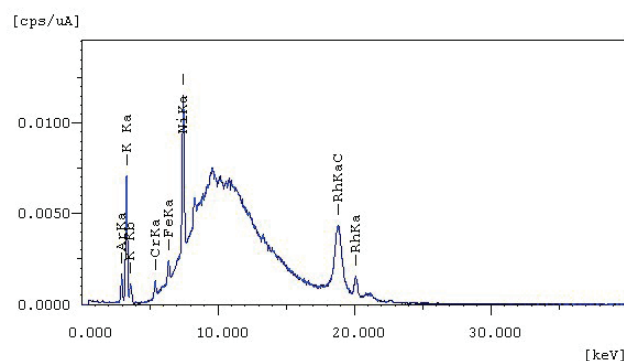
## 3. Results and Discussion

### 3.1 Properties of Activated Carbon and Initial Water Condition

The specification of AC used in this study is tabulated in Table 1 as provided by supplier while Fig. 1 shows the XRF spectra obtained for GAC B30. From the spectra, it can be found that the major inorganic components intrinsically present in the AC are potassium (K), nickel (Ni), chromium (Cr) and Iron (Fe). Table 2 shows the initial condition of water used before treatment.

**Table 1.** Properties of GAC B30

| Properties        | Value                          |
|-------------------|--------------------------------|
| Particle size     | 8 to 30 mesh (2.38 to 0.59 mm) |
| Moisture          | max. 5%                        |
| Ash               | max. 3%                        |
| Ball-pan hardness | min. 98%                       |
| Apparent density  | 450 – 520 kg/m <sup>3</sup>    |
| Surface area      | 1100-1250 m <sup>2</sup> /g    |
| Iodine number     | min. 1050                      |
| pH                | Alkaline                       |
| Arsenic           | <0.001 mg/kg                   |
| Lead              | <0.001 mg/kg                   |



**Figure 1.** XRF Spectra for GAC B30

**Table 2.** Properties of water used

| Properties   | Value             |
|--------------|-------------------|
| Temperature  | 25 °C             |
| Turbidity    | 0.774 – 1.601 NTU |
| Average Iron | 0.0818 ppm        |
| Average Zinc | 0.1083 ppm        |

### 3.2 The effects of types of cleansing agent

The odor test attained a unanimous finding from the panel where there was no unpleasant smell for all water samples treated using all types of water filter. This signifies that there is no susceptible odor compounds present above the detectable threshold. However, according to the Taste and Odor Wheel, some contaminants can also exist odorless which require further taste examination [10].

**Table 3.** Ranking of water treated using different water filters

| Water Filter | Panelist |   |   |
|--------------|----------|---|---|
|              | 1        | 2 | 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 |

Table 3 shows the ranking of the taste of water treated using four different water filters AC(2), ACK(2), ACFe(2) and ACZn(2) which were prepared using GAC, GAC-KOH, GAC-FeCl<sub>3</sub> and GAC-ZnCl<sub>2</sub>, correspondingly. As for the record, the taste of the water in this study was not so poor though rated as '1' but it was the least preferred by the panelists. Two of the panelists arranged their preference in increasing order of: control < AC(2) < ACFe(2) < ACZn(2) < ACK(2). However, disregarding the control sample, all of them agreed that the taste of water treated using ACK was the best while AC produced effluent of the least preferable.

The reduction in turbidity of water treated using the four water filters is shown in Fig. 2. As the cleansed AC was used in the filter, the capability of reducing water turbidity increased with ACFe(2) being the filter that reduced turbidity the most. This is mostly because the cleansing agent has removed fine particles trapped deep inside the pores of GAC and vacated more available surface for adsorption of contaminants that cause turbid color of water.

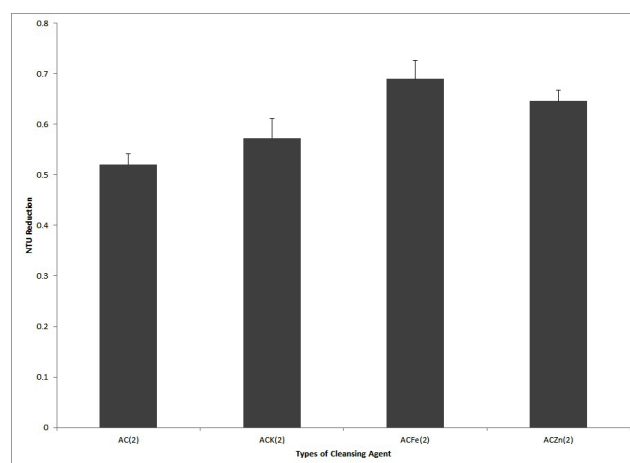
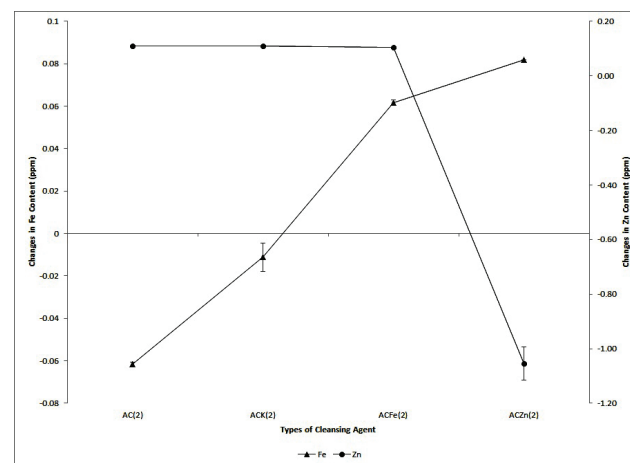
**Figure 2.** Turbidity reduction using different water filters**Figure 3.** Metal content changes using different water filters

Fig.3 displays the changes of Fe and Zn content in water after treated using different water filters. Positive values indicate that the metal content has reduced while the opposite is true for negative values. It can be seen that all water filters were able to remove Zn except for ACZn(2) where the content increased by 1.0538 ppm. This is due to residual of Zn ions on the surface of AC cleansed using ZnCl<sub>2</sub>. As for Fe content, only ACFe(2) and ACZn(2) water filters were able to reduce it though at lower extent. Overall, AC(2), ACK(2) and ACFe(2) showed higher capacity for Zn ions whereby ACZn(2) for Fe. Evidently, ACFe(2) is the only water filter that can reduce both Fe and Zn content in the water.

At this stage, it can be certainly decided that ACFe(2), compared to AC(2), ACK(2) and ACZn(2), is the best water filter which can result in water of no odor, good taste as well as lowest turbidity and metal content. Besides, the relationship between taste, turbidity and metal content can be determined as inversely proportional to each

other which means lower turbidity and metal content gives water of better taste.

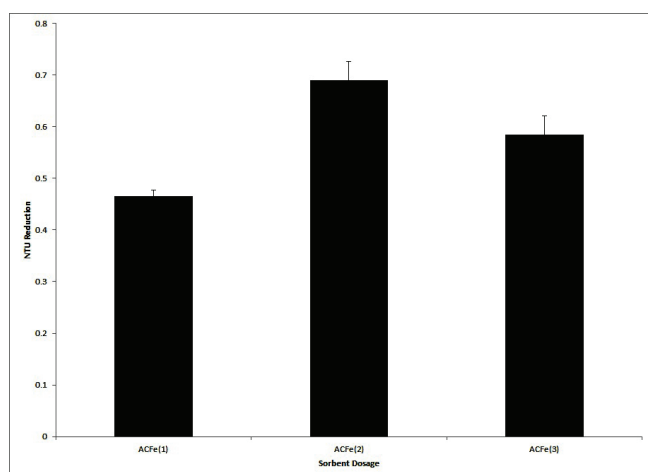
### 3.3 The effect of AC dosage

Henceforth, the discussion will focus on ACFe where the effect of AC dosage was studied. The experiments were repeated using 100 g and 300 g of GAC-FeCl<sub>3</sub> in the water filter. Table 4 shows the ranking of water filters ACFe(1), ACFe(2) and ACFe(3) in term of taste of water treated, by using 100 g, 200 g, and 300 g of GAC-FeCl<sub>3</sub> respectively. Again, panelist 2 and 3 arranged their preference similarly which was: ACFe(1)<ACFe(2)<ACFe(3). This contradicted to the preference arranged by panelist 1 where the arrangement is in reverse order.

This may be due to similar taste of water produced using the three different AC dosages. However, it can be said that out of majority, ACFe(3) gave better taste of water indicating that dosage has direct relationship with the improvement of water taste.

**Table 4.** Ranking of water treated using ACFe with different AC dosage

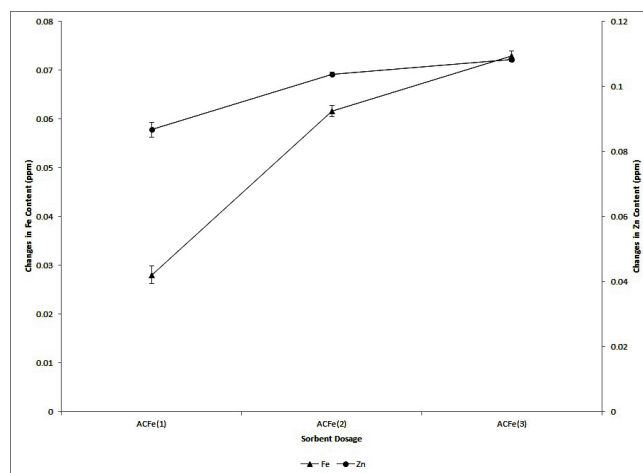
| Water Filter | Panelist |   |   |
|--------------|----------|---|---|
|              | 1        | 2 | 3 |
| ACFe(1)      | 3        | 1 | 1 |
| ACFe(2)      | 2        | 2 | 2 |
| ACFe(3)      | 1        | 3 | 3 |



**Figure 4.** Turbidity reduction using ACFe with different AC dosage

Fig. 4 presents the ability of ACFe(1), ACFe(2) and ACFe(3) in reducing turbidity of water at dosage of 100 g, 200 g and 300 g respectively where it can be seen that 200 g of GAC-FeCl<sub>3</sub> is the optimum dosage at the low flow rate of 30 L/h water. The ability

decreased as the dosage was increased from 200 g to 300 g mainly due to the contribution from the built up particles within the voids of AC as the dosage increased.



**Figure 5.** Metal content changes using ACFe with different AC dosage

The changes in Fe and Zn content in the water after treated using ACFe of different AC dosage are illustrated in Fig. 5. The figure shows that both metals can be adsorbed at higher degree as the dosage was increased because of the increase in available sites for metal adsorption. However, the capacity for Zn increased slightly (4%) compared to the capacity of the sites for Fe ions that increased 18% when dosage was increased from 200 g to 300 g. This shows the affinity of the AC towards Fe is higher compared to Zn.

As the previous section suggested that taste is inversely proportional to the magnitude of turbidity and metal contents (Fe and Zn), this section shows that turbidity does not have direct relationship with taste of water. Hence, only metal content affects the taste of water treated using AC.

### 3.4 The health effects of cleansing agent and sorbent dosage

Aesthetic of drinking water does not only affect the desire to consume the water but also the health of the consumer. It has been proven that odor and taste of water are related to the substance present which could be organic or inorganic [10]. This is the reason for most people in developing countries not to consume directly end-of-point water with low aesthetic quality. This study has found that all three cleansing agents used in post-treatment of activated carbon derived from coconut shell have a positive effect on improving the odor, taste and turbidity of water. Therefore, low cost water filter can be developed using these chemicals for the purpose of consumer demands and health.

However, there is concern over the presence of heavy metals above allowable limit in drinking water. Excess presence of Fe in the tap water can be attributed to the corrosion of water mains or the residual coagulant used in the treatment while Zn presents as a result of corrosion of pipes or fittings where both metals can induce astringent taste [2]. Based on Fig. 3, AC(2), ACK(2) and ACZn(2) resulted filtrate of increased metal content. The source of iron leach is the AC while zinc comes from the cleansing agent,  $\text{ZnCl}_2$ . Prolonged consumption of iron or zinc in water may cause severe health problems in human [11]. On the other hand,  $\text{FeCl}_3$  was able to prevent leaching of Fe, most probably because it removed weakly bonded Fe ions that were intrinsically present on the surface of the AC.

Moreover, turbidity is an important parameter because it reflects the intensity of particles present in the water. As mentioned in Section 3.3, turbidity could be increased in AC water filtration system because of the built up of smaller particles within the voids of AC bed due to attrition of AC. The production of water filter in bulk could result such circumstance where one of the ways to mitigate this is to rinse AC rigorously after placed in the cartridge.

Hence, the choice of dosage amount is paramount in strategizing quality control for a particular filter design because low quality water filter would affect the health of consumer for ingesting inorganic substance.

## 5. Conclusions

The demands and market growth of activated carbon (AC) in drinking water industry have been increasing over the recent years because of the unique properties and low investment cost compared to inorganic adsorbents like ceramics. However, there is also an increasing alarm over the use of activated carbon derived from biomass in treating drinking water since the biomass consists of inorganic elements that could leach out of the surface of the sorbent. It was hypothesized that type of cleansing agent and dosage of activated carbon in a water filter can affect the leaching and adsorption surrounding activated carbon particles which in turn, affect the aesthetic quality of the treated water. It was primarily found that all three cleansing agents used in this study improved the taste of treated water. However, in terms of turbidity and metal content (Fe and Zn), activated carbon cleansed using  $\text{FeCl}_3$  gave the optimal performance. Furthermore, dosage of activated carbon in water filter has also affected the taste, turbidity and metal contents of treated water where it was discovered that higher dosage of up to 300 g for 30 L/h water flow rate enhanced the taste of water alongside the reduction of metal contents. As a conclusion, selection of cleansing agent and carbon dosage in a water filter affects the aesthetic quality of water which is resembled by the odor and taste as well as turbidity and metal content. It must

be reminded here that though these parameters are not enough to validate the safety of drinking the water where further analysis of water is required; this study has presented an approach to relate several parameters that would be useful in designing low cost water filter.

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