Performance of Activated Carbon in Water Filters

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Abstract

The purpose of the present paper is to study the performance of activated carbon in water filtering system. Activated carbon is commonly used in water treatment to remove water contaminants from tap water and well water. Activated carbon is used in home water filtering system due to its excellent adsorption capacity. In this research, two types of granular activated carbon are used; one granular activated carbon-A (GAC-A) and the other granular activated carbon-B (GAC-B) to study their performance in the filters. Ultraviolet radiation system is used to purify water without leaving any harmful chemicals. Prototype is being made by using activated carbon and ultraviolet radiation system for water treatment. Surface area and porosity analysis is done on two activated carbons. Scanning electron microscopy (SEM) is used to obtain the magnified image of GAC-A and GAC-B for comparison between the surface morphology. Two types of water samples, the tap water and well water, are analyzed before and after the water treatment. The water samples were analyzed using pH test, turbidity test, total suspended solid examination, biochemical oxygen demand (BOD) test and chemical oxygen demand (COD) test. The results obtained from the water analysis shows that the GAC-A performs better than GAC-B in reducing turbidity, total suspended solid, BOD and COD. However the ultraviolet radiation reduced the BOD and COD of the water.

Keywords: Activated carbon; Water filter; Ultraviolet radiation.

1. Introduction

Water is essential for human; it comprises around 60% of the weight of human and it losses through various metabolic and excretory processes must be balanced by an adequate intake. Water may contain contaminants which can affect health and quality of life. Water intended for human consumption must be free from organisms and form concentrations of chemical substances that may be hazard to health [1]. The water we drink daily must be free from any

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pollution. There are two types of drinking waters including pure water and safe water. It is important to distinguish between these two types of drinking waters. Pure water may be defined as water that is free of extraneous substances whether harmless or not [2]. However, in a practical standpoint, pure water is hard to produce, even by the current sophisticated equipments. On the other hand, safe water is water that is not likely to cause undesirable or adverse effects [2]. Safe water may contain some contaminants but these contaminants will not cause any risks or health effects on human. The contaminants must be at an acceptable range. For example, chlorination is used to disinfect water. However, this process introduces trihalomethanes (THM) into the finished product. THM pose potential health risks [3]. Long-term drinking of chlorinated water appears to increase a risk of developing bladder cancer as much as 80%, according to a study published in the journal of the National Cancer Institute (St. Paul Dispatch & Pioneer Press, 1987). In 2006, the department of environment in united state (DOE) registered 18,956 water pollution point sources comprising mainly sewage treatment plants (9,060: 47.79% inclusive of 601 network pump stations), manufacturing industries (8,543: 45.07%), animal farms (869: 4.58%) and agro-based industries (484: 2.55%) [5]. Pollution from these sources indirectly affects human drinking water. As the population of the world increases and demands for using safe water enhances more than ever before, it is will be great concern in the near future on the water treatment facilities to be more effective. On the other hand, the water supplies to household still threatened contaminants like chemicals and microorganisms. Health problems of the world also increased due to the contaminants in the drinking water. The drinking water contaminants are seldom high enough to cause immediate health effects. Drinking water contaminants are more likely to cause chronic health effects. Usually, chronic health effects happen when a human is repeated expose to small amounts of chemical in the drinking water. Examples of chronic health effects are cancer, liver and kidney damage. Drinking water contaminants which may lead to health effects divided into five groups including microorganisms, disinfectants, disinfection by-products, inorganic chemicals, and organic chemicals.

Activated carbon has been used as water filtering medium for purification of drinking water for many years. It is widely used for the removal contaminants in water due to their high capacity for adsorption of such compound, arising from their large surface area and porosity. Activated carbons have varied surface characteristics and pore sizes distribution, these characteristic of activated carbon play an important role in adsorption of contaminants in water [10]. These contaminants produce bad tastes and odors, and also may constitute a source of infection. Activated carbon can remove the total suspended solids (TSS) and the biological oxygen demand (BOD) effectively over 99%, to 1 mg/l and also improve the tastes and odors of the drinking water [11]. This is the reason for the use of activated carbon as major filter medium in most of the home water filtration system. The ability of activated carbons to absorb various contaminants from drinking water is recognized. Absorptive properties can be explained by transport pores and adsorption pores of the activated carbon. Adsorption of activated carbon takes place within the porous network of the particles. Activated carbon adsorption proceeds through three basic steps: (1) Substances adsorb to the exterior of the carbon granules; (2) substances move into the carbon pores; (3) substances absorb to the interior walls of the carbon [4]. Activated carbon is surrounded with transport

pores which are the macropores on the exterior or surface of the carbon. Whereas, mesopores of the activated carbon are capillary branches off from the macropores toward the micropores. The macropores serve to trap absorbate materials from the external surface. Mesopores serve carry the absorbate materials to the interior of the particles where the finer pores or micropores will trap the absorbate onto the interior walls of the activated carbon. The pore sizes are defined as (1) macropores bigger than 25 nm, (2) mesopores with a size more than 1 nm and less than 25 nm, and (3) micropores with a size less than 1 nm [12]. Fig.1 illustrates the absorption mechanism of activated carbon. Pores (macropores and micropores) on activated carbon use to trap different sizes of contaminants. Macropores are used to trap larger contaminants and micropores are used to trap the smaller molecules. The amount and distribution of pores will affect the efficiency of the absorption in activated carbon.

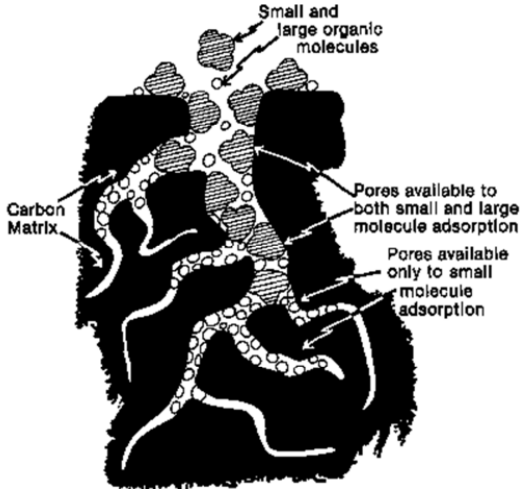

Fig.1. Molecular screening in the micropores of an activated carbon.

Adsorption can be defined, though, the process of accumulating substances that are in solution on a surface interface. The accumulation of material can be described as adsorption isotherm, which is used to define the mass of material adsorbed per unit mass of adsorbing material [12]. Freundlich isotherm is the most common adsorption isotherm used for activated carbon. The Freundlich isotherm is defined as follows:

$$= - = \quad ^{-} \tag{1}$$

Where q_e is mass of material adsorbed (x) per unit mass of the absorbent (m) at equilibrium, K_f is Freundlich capacity factor, C_e is equilibrium concentration of the absorbate in liquid phase after adsorption (mg/L) and $1/n$ is Freundlich intensity parameter. The coefficients in the Freundlich isotherm can be determined by the linearization of the Freundlich isotherm equation and plotting log (x/m) versus $log\ C_e$. The Freundlich isotherm equation can be written in a logarithm form:

$$\log - = \log \quad + - \log \tag{2}$$

The two graphs shown in Fig.2 illustrate a general Freundlich isotherm equation and a sample breakthrough curve. These help to predict the adsorptive capacity of particular

activated carbons and give a design estimate for adsorptive life. Once the activated carbons reached the breakpoint the reactivation or replacement is needed.

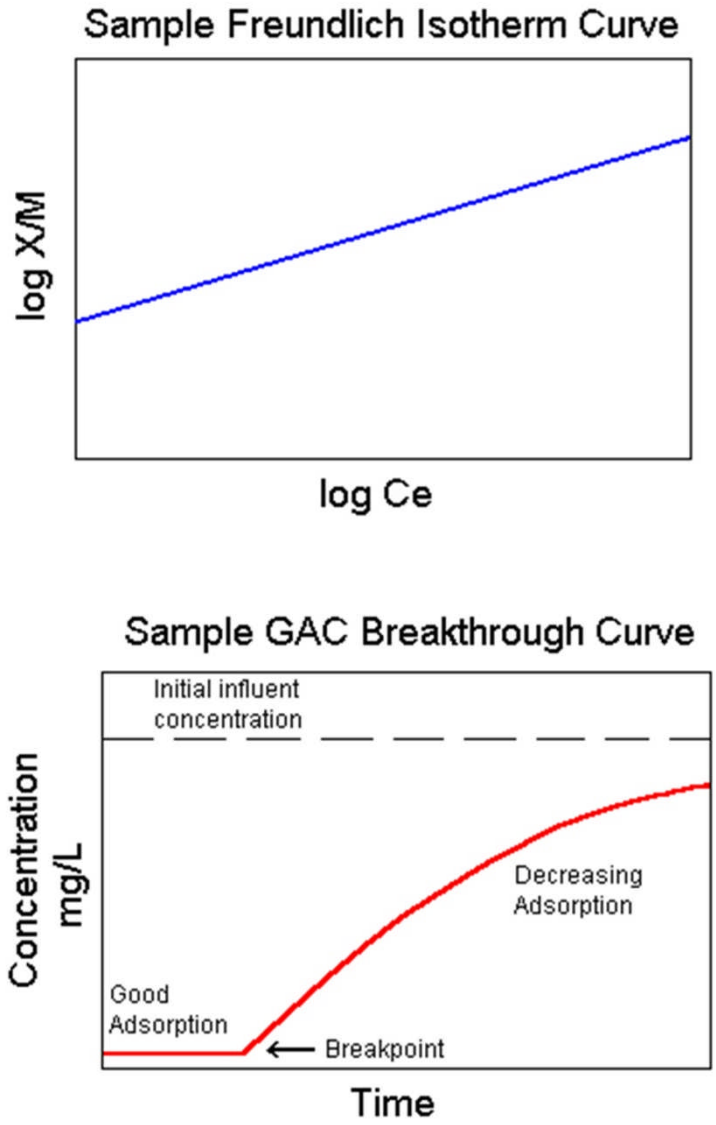

Fig.2. Graph illustrate Freundlich isotherm equation and sample breakthrough curve [13].

The first theoretical equation relating the quantity of absorbed gas to the equilibrium pressure of the gas was proposed by Langmuir [14]. The Langmuir equation is more applicable to chemical adsorption (chemisorptions), where chemisorbed monolayer is formed, but it is also often applied to physical adsorption (physisorption) isotherm [15]. This type of isotherm is usually observed with microporous adsorbents, that is, activated carbon, due to high adsorption potential. A convenient form of the Langmuir equation is

$$\frac{P}{W} = \frac{1}{KW_m} + \frac{P}{W_m} \quad (3)$$

where P is adsorbate equilibrium pressure, W is adsorbed weight, W_m is monolayer weights and K is a constant. A plot of P/W versus P should give a straight line with $1/W_m$ as the slope and intercept $1/KW_m$ from which both K and W_m can be calculated. After obtained the value of W_m, the sample surface area S_t can be then calculated from equation:

$$= \quad = \frac{\quad}{\quad} \tag{4}$$

Where Ax is cross section area, is molecular weight of absorbate and is Avogadro number. Brunauer, Emmett and Teller (BET), in 1938, extended Langmuir isotherm to multilayer adsorption called BET isotherm. The BET isotherm assumes that the uppermost molecules in adsorbed stacks are in dynamic equilibrium with the vapour [15]. This means that where the surface is covered with only one layer of absorbate, equilibrium exists between the layer and the vapour; where two layers are absorbed, the upper layer is in equilibrium with the vapour, and so forth. Since the equilibrium is dynamic, the actual location of the surface sites covered by one, two or more layers may vary but the number of molecules in each layer will remain constant. A convenient form of the BET equation is

$$\frac{\quad}{[(\quad)\quad]} = \frac{\quad}{\quad} + \frac{\quad}{\quad} - \quad \tag{5}$$

where P is adsorbate equilibrium pressure, P_0 is saturation pressure, W is adsorbed weight, Wm is monolayer weights and C is BET constant. The plot of $1/W\ [(P/P_0)-1]$ versus P/P_0 shows a straight line usually in the range $0.05 \leq P/P_0 \leq 0.35$. The slope, s and the intercept, i of the BET plot are, respectively,

$$= \frac{\quad}{\quad} \tag{6}$$

$$= \frac{\quad}{\quad} \tag{7}$$

Solving the slope, s and the intercept, i for weight adsorbed in a monolayer, W_m, gives

$$= \frac{\quad}{\quad} \tag{8}$$

And the solution for C, the BET constant, gives

$$= - + 1 \tag{9}$$

The total surface area can be calculated from the equation

$$= \frac{\quad}{\quad} \tag{10}$$

where A_x is cross sectional absorbate area. The factors affecting adsorption include: (a) the physical and chemical characteristics of the absorbent, that is, surface area, pore size and chemical composition; (b) the physical and chemical characteristics of the adsorbate, that is, molecular size, molecular polarity, chemical composition and the concentration of the adsorbate in the liquid phase (solution); (c) the characteristic of the liquid phase, that is, pH and temperature and (d) the residence time of the system. However, there are some parameters, which can be used to improve physical adsorption. The parameters are increasing the adsorbate concentration, increase the adsorbate area, select the best adsorbent for the specific application, remove contaminants before adsorption, reduce the adsorption temperature, increase the adsorption contact time and frequently replace or regenerate the absorbent. Other than activated carbon, ultraviolet radiation system is one of the most effective ways of ensuring the treated drinking water is microbially safe. Ultraviolet light at a wavelength of 254 nm inactivates bacteria. Energy dose of 20-40 mw/s is normally applied to kill bacteria [9]. So, ultraviolet radiation is extremely effective and is able to kill almost all known microorganisms found in water. An ultraviolet lamp is housed in a transparent quartz sleeve. The water enters one end of the unit and flows around the protected lamp ensuring adequate exposure. The greater the volume of water required, the larger the lamp is used to

ensure an adequate exposure time. Besides that, the lamp is housed in a metal box with a warning light and also an audible warning signal to indicate the lamp failure. The lamp life is around one year if the lamp runs continuous basis using either 18 or 35 Watts. In terms of running costs it is equivalent to having a 100 W light bulb on for five to eight hours each day. Ultraviolet radiation is not suitable for water with high levels of suspended solids, turbidity, colour, or soluble organic matter. These materials can react with ultraviolet radiation, and reduce disinfection performance. Turbidity makes it difficult for radiation to penetrate water. In additional, ultraviolet light is not effective against any non-living contaminants, lead, asbestos and chlorine.

In the present study, the performance of activated carbon is determined by analysing the water samples which had been treated by activated carbon. Water analysis was performed using physical and chemical analyses.

2. Results and discussion

2.1. Sample preparation

In this research, two types of water sources, tap water and well water, were analyzed and treated by activated carbon. According to standard method for the examination water and wastewater-9060A entitled sample collection, samples were collected in nonreactive borosilicate plastic bottles that had been cleansed and rinsed carefully, given a rinse with deionized or distilled water and sterilized. The samples were collected using 1.5 liters plastic drinking bottle. Ten bottles were collected for tap water and well water. Besides that, two different types of activated carbon, granular activated carbon-A (GAC-A) and granular activated carbon-B (GAC-B), were analyzed. The irregular channels and pores in the activated carbon, resulting in a very large surface-area-per-mass ratio. This large surface area gives activated carbon its effectiveness as an adsorbing agent.

2.2. Water analysis

2.2.1. pH

The hydrogen-ion concentration is an important quality parameter in drinking water. The usual means of expressing the hydrogen-ion concentration is as pH, which is defined as the negative logarithm of the hydrogen-ion concentration.

$$= -\log \quad [\quad] \tag{11}$$

The concentration range suitable for human is typically from 6.5 to 8.5. Low pH water may corrode the distribution pipes in potable water plants. The pipes corrosion may release metal ions like lead into the treated drinking water. Ingestion of heavy metals may pose substantial health risks to humans [6]. The pH of water specimens were tested by using digital pH meter. pH meter accurate and reproducible to 0.1 pH unit with a range of 0 to 14 and equipped with a

temperature-compensation adjustment was used for the pH analysis. The digital pH meter that was used in this analysis is Orion pH meter model 420.

2.2.2. Turbidity

Turbidity is a measure of the light-transmitting properties of water. It is another test used to indicate the quality of drinking water with respect to colloidal and residual suspended matter. Increases in turbidity are often accompanied with increases in pathogen numbers, including cysts or oocyst [7]. The measurement of turbidity is based on comparison of the intensity of light scattered by a sample to the light scattered by a reference suspension under the same conditions. The result of turbidity measurements are reported as nephelometric turbidity units (NTU). Colloidal matter will scatter or absorb light and thus prevent its transmission. It should be noted that the presence of air bubbles in the sample will cause erroneous turbidity readings. According to standard method for the examination water and wastewater-2130 entitled turbidity [16], the turbidity of water specimens were tested by using electronic nephelometer. The sample cell or tube which was used to store the water sample should be clear, colorless glass or plastic. The cell or tube must be cleared both inside and outside, and discard if scratched or etched. Dirt or finger print may affect the result. The nephelometer that was used in this turbidity analysis is Hanna Instrument microprocessor turbidity meter.

2.2.3. Total suspended solid

Suspended solids provide adsorption sites for biological and chemical agents. These adsorption sites provide a protective barrier for attached microorganisms against the chemical action of chlorine disinfectants [6]. Total suspended solid test is used to measure the residue remaining after a drinking water has been evaporated and dried at a specific temperature (103 to 105 °C). A pre-weighed filter is used to separate the total suspended solid from the sample water, the total suspended solids test is somewhat arbitrary, depending on the pore size of the filter paper used for the test. Filters with nominal pore sizes varying from 0.45 µm to about 2.0 µm have been used for the total suspended solids test. More total suspended solids will be measured as the pore size of the filter used is reduced. Thus, it is important to note the pore size of the filter paper used, when comparing reported total suspended solids values. Total suspended solid is determined by using the following formula [8]:

$$(\qquad) = \frac{\qquad\qquad}{\qquad\qquad} \times 1000 \tag{12}$$

2.2.4. Biochemical oxygen demands (BOD)

Biochemical oxygen demand is the parameter of organic pollution applied for water. Biochemical oxygen demand is a test used to measure the amount of oxygen consumed by the organisms during a specified period of time [6]. The most widely used biochemical oxygen demand test is 5-day BOD (BOD_5). This determination involves the measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter. In standard BOD test, a 300 ml BOD bottle was used and the sample was incubated at 20 °C

for 5 days. Light must be excluded from the incubator to prevent algal growth that may produce oxygen in the bottle and directly affect the Dissolved oxygen (DO) value of the test after 5 days. The dissolved oxygen was measured by HANNA Instruments H12400 Logging DO Meter. The BOD test was carried out by diluting the sample with de-ionized water saturated with oxygen, inoculating it with a fixed aliquot of seed, measuring the dissolved oxygen and sealing the sample (to prevent further oxygen dissolving in). The sample was kept at 20°C in the dark to prevent photosynthesis (and thereby the addition of oxygen) for five days, and the dissolved oxygen was then measured again. The difference between the final DO and initial DO is the BOD. The apparent BOD for the control was subtracted from the control result to provide the corrected value. Before starting the BOD test, the reagent called dilution water was prepared from two days before the test. Reagents prepared in advanced but discard if there was any sign of precipitation or biological growth in the stock bottles. To prepare the dilution water, there were several buffer solution needed, which were phosphate buffer solution, magnesium sulfate solution, calcium chloride solution, ferric chloride solution.

Initially, 8.5 g KH_2PO_4, 21.75 g K_2HPO_4, 33.4 g $Na_2HPO_4 \cdot 7H_2O$, and 1.7 g NH_4CI were dissolved in about 500 ml distilled water and dilute to 1L in order to prepare phosphate buffer solution. The pH should be 7.2 without further adjustment. For magnesium sulfate solution, 22.5 g $MgSO_4 \cdot 7H_2O$ was dissolved in distilled water and dilute to 1L. Similarly procedure was done to prepare calcium chloride solution and ferric chloride solution with 27.5g $CaCI_2$ and 0.25 g $FeCI \cdot 6H_2O$ each. As for further pH adjustment, the acid and alkali solutions of 1L were prepared just in case for neutralization of caustic or acidic waste samples. For acid solution preparation, 28 ml concentrated sulfuric acid added to distilled water slowly and while stirring, followed by diluted the solution to 1L. For alkali solution preparation, 40 g sodium hydroxide dissolved in distilled water and diluted to 1L. Afterwards, 1ml each of phosphate buffer, magnesium sulfate, calcium chloride, ferric chloride solution was added into 1L volumetric flask followed by added distilled water to 1L in order to prepare the dilution water. The dilution water was left it for two days with the sufficient oxygen gas supplied in order to maintain the saturated oxygen content in the dilution water, also known as BOD nutrient.

To start the BOD test, 1ml of water sample was added into a 500ml beaker and dilution water prepared before the test was added into the beaker until a volume of 300ml. The pH value of the solution was adjusted from 6.5 to 7.5 by adding the acid or alkali drops. Moreover than that, 300ml dilution water was prepared as the control of the test. Then, all the prepared samples and control were put in 300ml incubation bottles. The initial DO for each samples was measured by using the Dissolved Oxygen Meter before put all the bottles in BOD incubator for 5 days and the temperature of 20 °C was set. Lastly, the final DO value was measured after 5 days. The BOD_5 can be calculated according to the formula:

$$BOD_5\,(mg/l) = (D_1 - D_2)/P \quad (13)$$

where D_1 is equal to D_0 value in initial sample, D_2 is D_0 value in final sample and P is decimal volumetric fraction of sample.

2.2.5. Chemical oxygen demands (COD)

Chemical oxygen demand (COD) often is used as a measurement of pollutants in water. COD is defined as the amount of a specified oxidant that reacts with the sample under controlled conditions. The quality of oxidant consumed is expressed in terms of its oxygen equivalence. Both organic and inorganic components of a sample are subjected to oxidation, but in most cases the organic component predominates and is of greater interest. This COD test method followed the standard method for the examination water and wastewater-5220D entitled chemical oxygen demand-closed reflux, colorimetric method [16]. First of all we prepared the COD reagent, the 4.9036g of K_2CrO_7, 0.10g of $HgSO_4$, 0.08g of Ag_2SO_4, and 50ml of concentrated sulfuric acid and 100ml of distilled water were mixed. Then, the solution was mixed using magnetic stirrer in order to make sure the solution was homogenous. The reagent was prepared for several times. The prepared COD reagent was stored in the dark room where to prevent the direct UV exposure on it. For the COD test, 3 ml of the COD reagent poured into a vial tube and then followed by 2 ml of the sample leachate added into it. The sample was placed into a heater, named COD reflux HACH/ DR200 at a temperature of 150 °C and then heated for a period of two hours. After the timer of two hours expired, the vial sample was taken out from the heater and let it to cool down to the room temperature in which it was usually last about 20 to 30 minutes. The measurement of the COD value was determined using spectrophotometer HACH/DR 5000 machine.

2.3. Activated carbon analysis

2.3.1. Surface area and porosity

Surface area and porosity of two different types of activated carbon, granular activated carbon-A (GAC-A) and granular activated carbon-B (GAC-B), were analyzed using Micromeritics ASAP 2010 machine. The Micromeritics ASAP 2010 (accelerated surface area and porosimetry system) provides versatility in gas selection and high vacuum for high resolution low surface area measurement. It utilizes the principle of physical adsorption to obtain adsorption and desorption isotherms and information about the surface area and porosity of activated carbon. Nitrogen gas was used as standard gas to perform surface area analysis. These two types of activated carbon were analyzed by Micromeritics ASAP 2010 to determine (1) BET surface area (m^2/g), (2) Langmuir surface area (m^2/g), micropore area (m^2/g) and average pore diameter (A).

2.3.2. Surface morphology

The scanning electron microscopy (SEM) was used to obtain the magnified image of granular activated carbon-A (GAC-A) and granular activated carbon-B (GAC-B). The visual of the image can show the condition of activated carbon.

2.4. Design concept

The purpose of this design is to determine the performance of granular activated carbon-A (GAC-A) and granular activated carbon-B (GAC-B). Prototypes of water filter were made for this contribution. The prototypes were then filling up with the two different types of activated carbon that is GAC-A and GAC-B. Other than activated carbon, the materials need for the prototype water filters were 1.5 liter plastic drinking water bottle and glass wool. The 1.5 liter plastic drinking water bottle was used as the housing for activated carbon and glass wood. Glass wool was used as a pre-filter to eliminate soil of the untreated water because soil in the water may clog the activated carbon and reducing the adsorption capacity of the activated carbon. Besides that, glass wool also was used at the exit of the treated water to prevent the activated carbon discharge from the 1.5 liter plastic drinking water. Firstly, the 1.5 liter plastic drinking water bottle was washed to ensure it is clean from any contaminants and bacteria. After that, the 1.5 liter plastic drinking water bottle was rinsed a few times by using distilled water to ensure the bottle is free from washing detergent. Next, the 1.5 liter plastic bottle was filled up with glass wool as base, 200g activated carbon (GAC-A or GAC-B) and glass wool again as pre-filter. The structure of the prototypes is shown below (Fig.3).

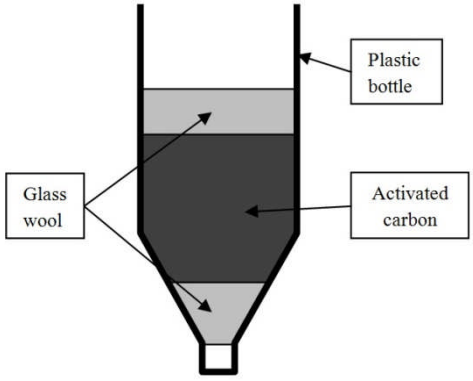

Fig.3. Design concept for the activated carbon water filter.

For the water treatment process, 3 liters of untreated water (tap water or well water) were treated in two of the activated carbon-water filters (GAC-A and GAC-B). After the activated carbon treatment, 1.5 liter of the treated water was taken out for ultraviolet disinfection treatment. Fig.4 shows ultraviolet disinfection treatment process.

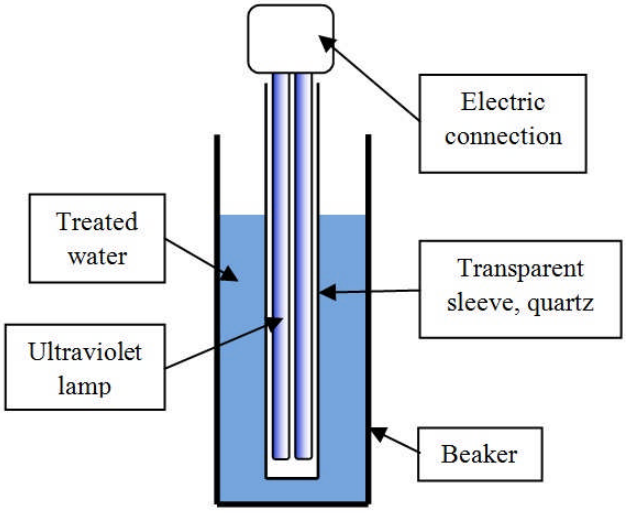

Fig.4. Design concept for the ultraviolet disinfection treatment.

After the ultraviolet disinfection treatment, all treated water samples (with or without ultraviolet disinfection treatment) were analyzed, allowing us to measure the performance of the activated carbon by comparing the water analysis results. Besides that, we also can compare the water analysis results between the water with and without ultraviolet disinfection treatment.

3. Results and discussions

3.1. Activated carbon analysis

3.1.1. Surface area and porosity

Two of activated carbons were analyzed using accelerated surface area and porosimetry system (ASAP). The result is shown in Table 1. From Table 1, GAC-A shows that it has slightly larger BET surface area (791.56m^2/g) as compare to GAC-B (781.4958m^2/g). BET surface area is the summation of the external surface area and micropore area. The external surface area of GAC-A is 13.9512m^2/g larger than GAC-B. But the micropore area of GAC-A is 3.8869m^2/g smaller than GAC-B. Whereas, the average pore diameter of GAC-A is 22.6389 A which is 1.1566 A bigger than GAC-B.

Table 1. Results of surface area and porosity analysis

Sample	BET Surface Area (m^2/g)	External Surface Area (m^2/g)	Micropore Area (m^2/g)	Average Pore Diameter (Å)
GAC-A	791.5600	190.4892	601.0709	22.6389
GAC-B	781.4958	176.5380	604.9578	21.4823

3.1.2. Surface morphography

Two types of activated carbon were visually investigated through scanning electron microscopy. The images showed the surface condition of the activated carbon. From Fig.5 (a), it can be inferred that the size of granular activated carbon-A (GAC-A) is roughly 1.5 mm. In Fig.5 (b), the size of granular activated carbon-B (GAC-B) shows it would be about 2.3 mm. It is obvious that the size of GAC-B is bigger than GAC-A. However, we can easily see the difference of pores distribution on the surface of GAC-A and GAC-B. Fig.6 shows SEM image of GAC-A and Fig.7 shows SEM image of GAC-B. As it is seen from Fig.6, the pores were distributed randomly on the surface of GAC-A. Fig.7 shows that the GAC-B does not have that much pores as revealed in GAC-A, giving better condition for the water filtering systems.

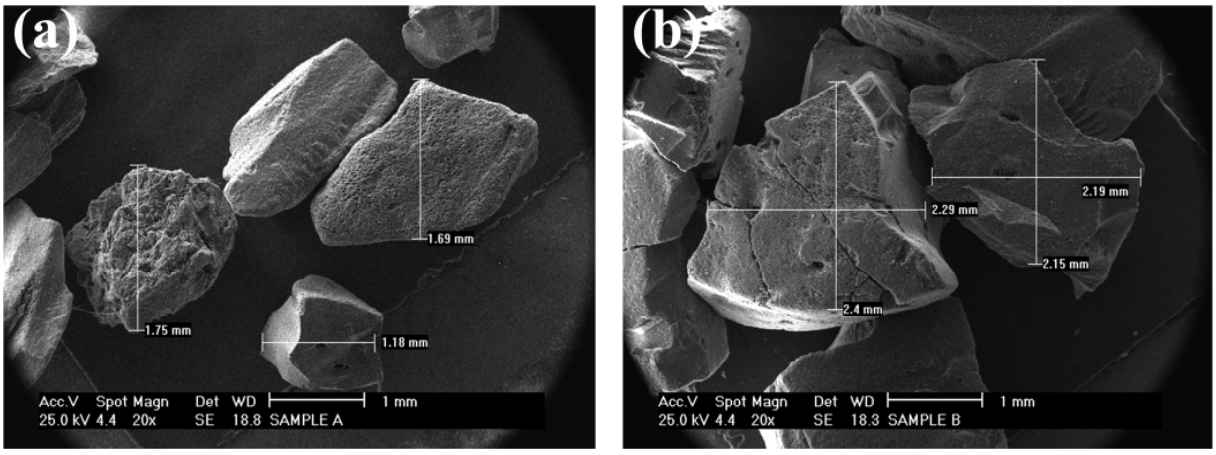

Fig.5. SEM images of (a) GAC-A and (b) GAC-B.

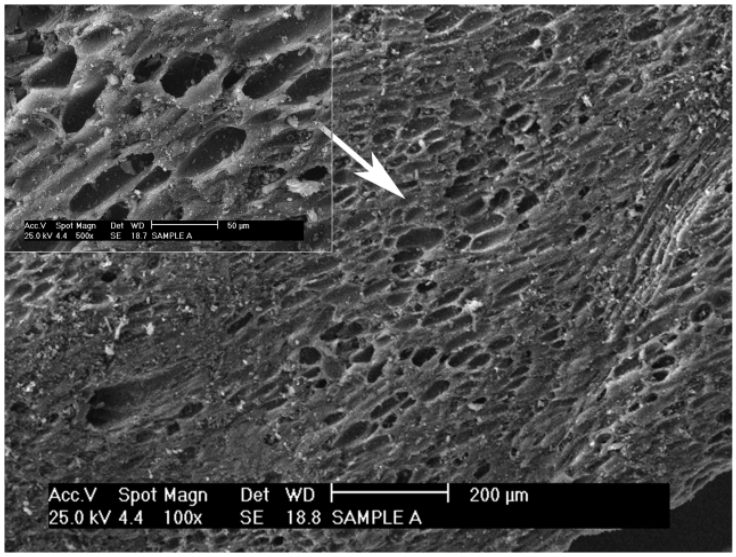

Fig.6. SEM image of GAC-A in the filter system.

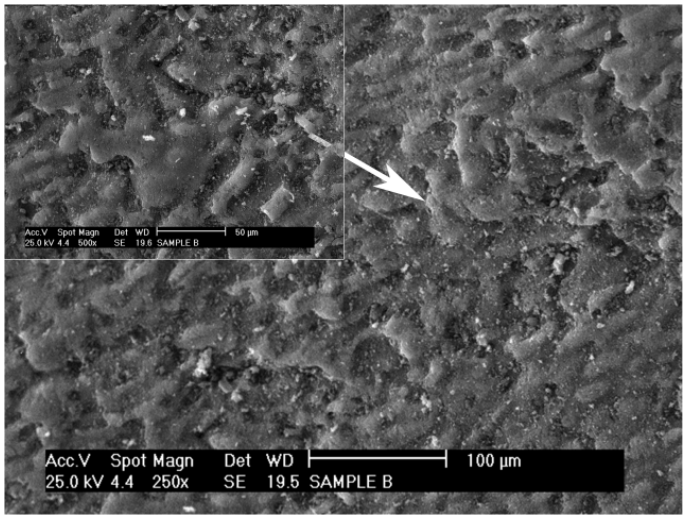

Fig.7. SEM image of GAC-B in the filter system.

3.2. Water analysis

3.2.1. pH

pH is an important quality parameter in drinking water. The concentration range suitable for human is typically from 6.5 to 8.5. From Table 2, the pH of untreated well water is 6.12; this is lower than the range that suitable for human. Low pH is acidic and may post substantial health risks to humans. Whereas, pH of the tap water is 7.13 and it is within the range that suitable for human. Granular activated carbon is very effective in balancing the pH of water. From Fig.8, granular activated carbon-A (GAC-A) increase the pH of tap water and well water to approximate pH 8 which is slightly alkaline. Alkaline water helps to neutralize acids and remove toxins from the body. However, granular activated carbon-B (GAC-B) also balanced the pH of well water from pH 6.12 to pH 7.1.

Table 2. pH of different types of water.

Replication / Type of water	1	2	3	4	5	Average
Tap water	7.12	7.13	7.14	7.14	7.13	7.13
Tap water GAC-A	8.23	8.21	8.22	8.22	8.22	8.22
Tap water GAC-A + UV	7.97	7.99	7.98	7.98	7.99	7.98
Tap water GAC-B	7.24	7.24	7.23	7.24	7.24	7.24
Tap water GAC-B + UV	7.3	7.29	7.3	7.29	7.3	7.30
Well water	6.11	6.11	6.12	6.12	6.14	6.12
Well water GAC-A	7.82	7.82	7.82	7.82	7.81	7.82
Well water GAC-A + UV	8.05	8.09	8.08	8.09	8.08	8.08
Well water GAC-B	7.07	7.1	7.12	7.1	7.12	7.10
Well water GAC-B + UV	7.23	7.23	7.22	7.2	7.21	7.22

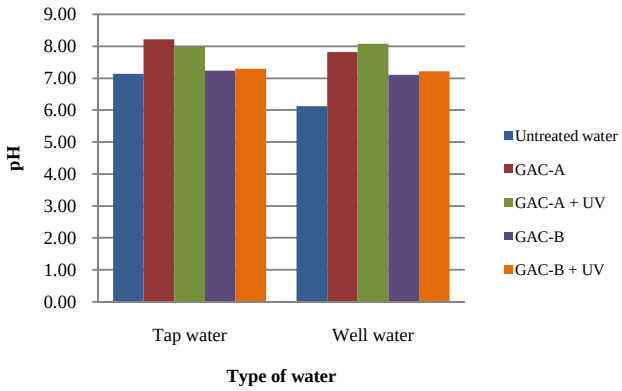

Fig.8. Graph of pH versus type of water

3.2.2. Turbidity

Turbidity of water is a test to indicate the quality of drinking water with respect to colloidal and residual suspended matter. Initially, the turbidity of tap water and well water are tested to take initial reading. The turbidity of tap water and well water are 0.79 NTU and 1.06 NTU respectively. Well water shows higher nephelometric turbidity units (NTU) as compare to tap water. After the tap water and well water underwent granular activated carbon and UV treatment, the turbidity tests were done again on each sample. The results are shown in Table 3. From Fig.9, the graph shown GAC-A could reduce the turbidity of tap water and well water to lower reading as compare to GAC-B. The granular activated carbon is very effective in reducing the turbidity reading. UV disinfection treatment did not affect the turbidity results.

Table 3. Turbidity of different type of water.

Replication / Type of water	1	2	3	4	5	Average
Tap water	0.8	0.79	0.78	0.79	0.77	0.79
Tap water GAC-A	0.22	0.23	0.23	0.24	0.22	0.23
Tap water GAC-A + UV	0.22	0.21	0.21	0.22	0.22	0.22
Tap water GAC-B	0.4	0.39	0.41	0.42	0.41	0.41
Tap water GAC-B + UV	0.37	0.37	0.38	0.36	0.36	0.37
Well water	1.09	1.05	1.05	1.05	1.07	1.06
Well water GAC-A	0.33	0.34	0.32	0.33	0.33	0.33
Well water GAC-A + UV	0.33	0.32	0.31	0.31	0.32	0.32
Well water GAC-B	0.34	0.36	0.35	0.37	0.36	0.36
Well water GAC-B + UV	0.41	0.42	0.39	0.38	0.39	0.40

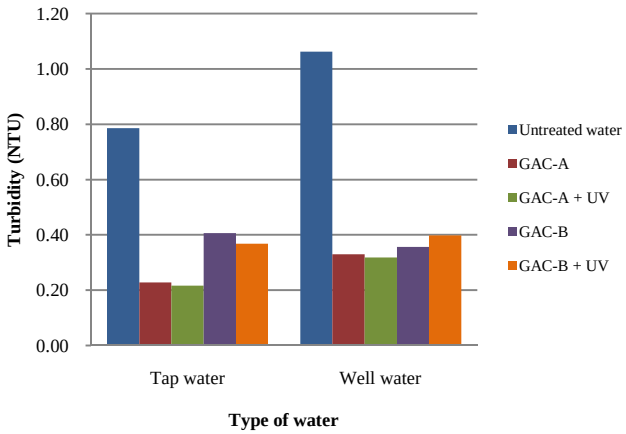

Fig.9. Graph of turbidity versus type of water

3.2.3. Total suspended solid

Total suspended solid is a test to measure the residue remaining after the water evaporated and dried at a specific temperature (103 to 105 °C). The total suspended solid of tap water and well water were tested before the water treatment. From Table 4, tap water showed 7mg/l and well water showed 10mg/l. However, the total suspended solid of tap water and well water can be removed by the activated carbon. Activated carbon which has large surface area and porosity can be used to trap the water contaminants. From Fig.10, the total suspended solid test results showed that GAC-A could reduce the TSS to lower value as compare to GAC-B. The total suspended solid of tap water and well water is reduced to 1mg/l after treated by GAC-A.

Table 4. Total suspended solid of different type of water.

Type of water	TSS (mg/l)
Tap water	7
Tap water GAC-A	1
Tap water GAC-A + UV	1
Tap water GAC-B	3
Tap water GAC-B + UV	2
Well water	10
Well water GAC-A	1
Well water GAC-A + UV	2
Well water GAC-B	3
Well water GAC-B + UV	4

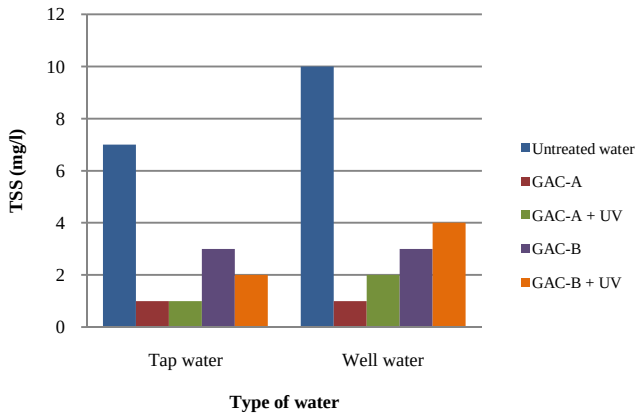

Fig.10. Graph of total suspended solid versus type of water.

3.2.4. Chemical oxygen demand (COD)

Chemical oxygen demand (COD) is defined as the amount of a specified oxidant that reacts with the water sample under controlled condition. Both organic and inorganic components of a water sample are subjected to oxidation. From Table 5, the untreated tap water showed 258 mg/l and the untreated well water showed 18 mg/l. This can conclude that tap water is much more polluted than well water. From Fig.11, the COD of the tap water and well water which were being treated with GAC-A dropped to 5 mg/l and 4 mg/l, respectively. For the tap water and well water treated with GAC-A, followed by UV disinfection treatment, the COD further decreased to 1 mg/l and 0 mg/l, respectively. For the tap water and well water treated with GAC-B, the COD dropped to 9mg/l and 10mg/l. The tap water and well water treated with GAC-B, followed by UV disinfection treatment, the COD decreased to 1 mg/l and 1 mg/l, respectively. From these statement, GAC-A showed better reduction of COD as compare to GAC-B. However, UV disinfection treatment will further reduce the COD to 0 or 1 mg/l.

Table 5. Chemical oxygen demand of different type of water.

Type of water	COD (mg/l)
Tap water	258
Tap water GAC-A	5
Tap water GAC-A + UV	1
Tap water GAC-B	9
Tap water GAC-B + UV	1
Well water	18
Well water GAC-A	4
Well water GAC-A + UV	0
Well water GAC-B	10
Well water GAC-B + UV	1

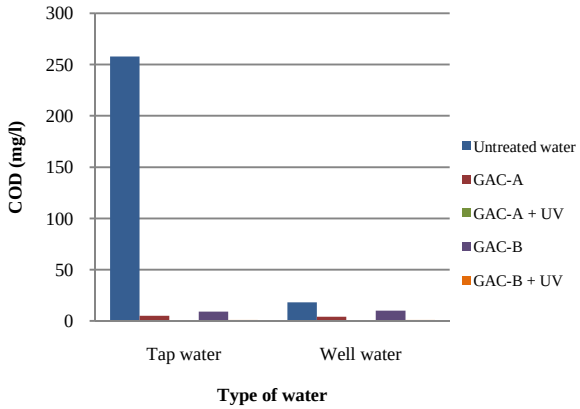

Fig.11. Graph of chemical oxygen demand versus type of water.

3.2.5. Biohemical oxygen demand (BOD)

Biochemical oxygen demand (BOD) is the parameter of organic pollution applied for water. Biochemical oxygen demand is a test used to measure the amount of oxygen consumed by the organisms during a specified period of time. From Table 6, the untreated tap water showed 26.145 mg/l in BOD and the untreated well water showed 20.09 mg/l in BOD. This is also to confirm that tap water is much more polluted than the well water. As it can be seen in Fig.12, the BOD of the tap water and well water treated with GAC-A, dropped to 5.53 mg/l and 6.09 mg/l, respectively. The tap water and well water treated with GAC-A, followed by UV disinfection treatment, the BOD further decreased to 4.725 mg/l and 4.445 mg/l, respectively. From Fig.12 it can be said that GAC-A could reduce the BOD effectively as compare to GAC-B. However, the BOD of tap water and well water treated with activated carbon could be further reduced by UV disinfection treatment.

Table 6. Biochemical oxygen demand of different type of water.

Type of water	BOD (mg/l)
Tap water	26.145
Tap water GAC-A	5.53
Tap water GAC-A + UV	4.725
Tap water GAC-B	16.415
Tap water GAC-B + UV	12.075
Well water	20.09
Well water GAC-A	6.09
Well water GAC-A + UV	4.445
Well water GAC-B	13.475
Well water GAC-B + UV	10.43

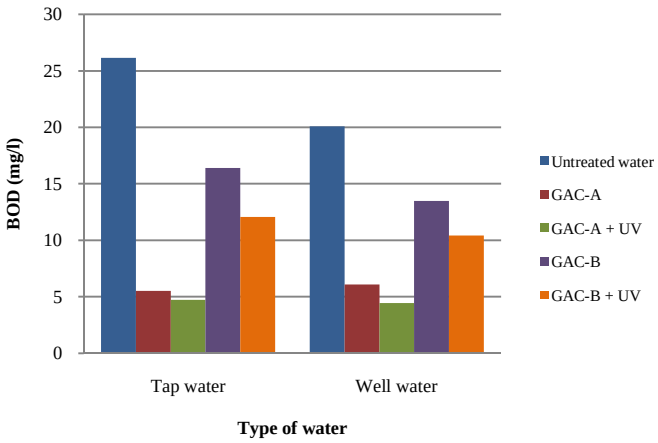

Fig.12. Graph of biochemical oxygen demand versus type of water.

4. Conclusions

Activated carbon is used in water filtering systems due to its excellent adsorption capacity. The pores of activated carbon trapped and locked water contaminants during the water filtering process. However, different activated carbons have different surface area and porosity. Based on the result, granular activated carbon-A (GAC-A) showed it has larger BET surface area as compare to granular activated carbon-B (GAC-B). However, this statement can be proven by comparing the scanning electron microscopy of GAC-A and GAC-B. The pores distribution of GAC-A can be clearly seen on its surface. The performance of activated carbon can be determined by analysis of the water treated by activated carbon. In the physical assessment analysis, GAC-A showed good result in balancing the pH of tap water and well water. Besides that, GAC-A showed a reduction in the turbidity of water as compared to GAC-B. Furthermore, the GAC-A eliminate the total suspended solid of water effectively when compare with GAC-B. The GAC-A successfully reduced the chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of tap water and well water to lower reading.

Ultraviolet radiation was not suitable for water with high levels of suspended solid and turbidity. This statement is proved by the result of physical assessment analysis of the water. From the result, the UV disinfection treatment did not affect the pH, turbidity and total suspended solid of the water. But, the UV disinfection treatment showed a good result in chemical assessment analysis. It is very effective in reducing the chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Finally it was shown that granular activated carbon-A (GAC-A) is much effective than granular activated carbon-B (GAC-B) in eliminating the contaminants in water.

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