EVALUATING THE PERFORMANCE OF DIFFERENT POWDERED ACTIVATED CARBONS (PAC) FOR TASTE AND ODOUR REDUCTION

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ABSTRACT

A number (12) of powdered activated carbons (PAC) were jar tested in natural raw water containing a commercial spike of MIB and geosmin and their performance for reducing these compounds was evaluated. The PACs tested came from a variety of suppliers, raw materials, activation methods and countries including steam activated coal, wood and coconut; and chemically activated wood. Each of the carbons (except Acticarb PS1300) had the same iodine number (a measure of adsorption capacity) and were analysed under the same conditions including a 15 minute contact time. Of these carbons the Australian steam activated coal carbons, Acticarb PS1000 and PS1300 had the best removal efficiencies. The Acticarb PS1300 was the only carbon with a higher iodine number, however this increase in adsorptive capacity for iodine was not proportional to the increase in adsorption for MIB and geosmin. For all of the PACs tested, the geosmin was more easily reduced than the MIB. Contact time, raw water character and PAC character all influenced the PAC's ability to reduce MIB and geosmin.

1.0 INTRODUCTION

Powdered activated carbon (PAC) is a well documented treatment method for taste and odour reduction in drinking water. Activated carbon is similar to a sponge that can adsorb organics, including the taste and odour compounds MIB and geosmin. Many characteristics influence the adsorptive trends of activated carbon and not all carbons have the same affinity to taste and odour compounds. This study looked at a variety of PACs and determined that Acticarb PS1300 a coal based carbon from Australia had the best reduction of MIB and geosmin of the carbons tested.

2.0 CHARACTERISTICS OF ACTIVATED CARBON

Activated carbon is derived from a variety of sources such as coal, wood and coconut. The base raw material and the method of activation, are two of the influences on the surface chemistry and consequently the character of the PAC. To evaluate the adsorption capacity of PAC a number of parameters should be examined - Pore Structure – macropores, micropores and mesopores, Surface Area, Bulk Density, Particle Size, Raw Material, and Activation Process.

2.1 Pore structure

Activated carbon is made up of millions of microscopic pores that contribute to the carbon's adsorptive capacity. The raw material and activation process influences the pore structure of the carbon and therefore its efficiency in adsorbing different contaminants. Pore sizes are referred to in three sizes:

- macropores are the pores with a diameter of greater than 250 Angstroms and are capable of adsorbing the largest organic molecules.
- mesopores are pores that have diameters between 10 to 250 Angstroms and are distinguished by their ability to remove mid sized molecules.
- micropores are pores that have a diameter of less than 10 Angstroms and are

distinguished by their ability to remove small molecules.

Generally, in drinking water treatment, the best carbon for the adsorption of taste and odour compounds and algal toxins, is one with a bimodal pore distribution such as coal based carbon.

2.2 Surface Area

The primary goal when carbon is activated is to increase the surface area to allow adsorption of organic molecules. The surface area of a high quality powdered activated carbon, is very important as the larger the surface area, the greater the ability to adsorb organic contaminants, such as tastes, odours and toxins etc., from water supplies. For example, when a PAC with a 1000 m^2/g surface area is compared to a PAC with a 1500 m^2/g surface area, the carbon with a greater activity, has approximately a 50% larger surface area than the lower grade. This will directly influence the adsorption capacities of each of these carbons.

2.3 Bulk Density

The bulk density of powdered activated carbon, relates to the physical weight per volume of powder and is generally measured in milligrams/c.c. The bulk density of PAC is also important when comparing the speed of adsorption of carbons with similar specifications. PAC is dosed by weight so the lower density carbons will be added in greater volume. A higher volume of carbon will deliver to the water a greater surface area for adsorption of micro-pollutants. The higher surface area will usually deliver a higher adsorption rate and thus lower doses of PAC may be added to achieve the same result as for high doses of more dense grades.

2.4 Physical Size

The physical size of PAC is important, firstly for the ease of pumping with metering pumps, and secondly for the ease of mixing, wetting and distribution. The speed of adsorption is increased when the particle size is decreased.

2.5 Carbon Type (Raw Materials)

The source of the raw material is important when comparing activated carbons, as the source directly influences the suitability of the carbon to its proposed application. Carbon commonly comes from a variety of sources including coconut, coal, and wood. Coal and wood based carbons are predominantly microporous and mesoporous but with some macroporous character. This makes them ideal for the water industry where target micropollutants have a large range of molecule sizes from smaller taste and odour compounds to the larger algal toxins. Coconut carbons are predominantly microporous and therefore limited to the removal of smaller micropollutants and are prone to interference from the larger NOM molecules when surface blockages occur.

2.6 Activation Process

There are commonly two methods used for the activation of carbon – steam or chemical. Steam activation occurs in a furnace with temperatures of 800-1000ºC. Chemical activation involves a chemical dehydrating agent then activation at 400-600ºC. The degree of activation, is measured by the carbons specific surface area and adsorption capacity. Activation is a function of time spent in the activation furnace: the longer the time, the greater the activation.

3.0 HOW PAC IS USED AT WATER TREATMENT PLANTS

PAC typically arrives at the plant as a powder in either bulk bags (1 m^3) or paper bags (60L). It is also possible to receive powder in slurry form in 200L drums or 25L pails however this typically adds to transport costs.

The carbon bulk bag has a tie at the base of the bag for discharge of the powder. The bag is placed on a purpose built bulk bag discharge hopper that takes the powder from the bulk bag mixes it to a slurry and then doses it into the raw water source.

Some plants dose at the raw water main to gain the longest possible contact time between the carbon and the water, however care must be taken to ensure there is enough flow through the pipe to prevent the settling of PAC in the line. Some plants dose at the head of the plant just prior to coagulation, some just prior to filtration to ensure the majority of organics have been removed by coagulation and some install large contact tanks prior to the water treatment plant. PAC can enhance coagulation by providing a nucleus for floc during times of low turbidity. Studies have been conducted that show the size of floc influences the effectiveness of the PAC in removing target taste and odour compounds. To remove the powder, filtration is required.

4.0 TASTE AND ODOUR REDUCTION USING PAC

Taste and odour compounds MIB and geosmin are typically found in raw water sources as a result of algae blooms. They result in customer complaints of “musty” or “earthy” tasting water at levels of 10ng/L and above. As algae blooms can also be toxic, taste and odour is usually an immediate indicator of the PAC’s effectiveness of adsorbing algal metabolites.

To test the effectiveness of PAC in removing taste and odour from drinking water sources jar testing is conducted using the plants natural water and a variety of PACs. In this study 12 PACs were tested in 4 different natural water sources. The results are shown below.

5.0 STUDIES COMPLETED

5.1 Study One: Comparison of Raw Materials – Coal, Coconut and Wood

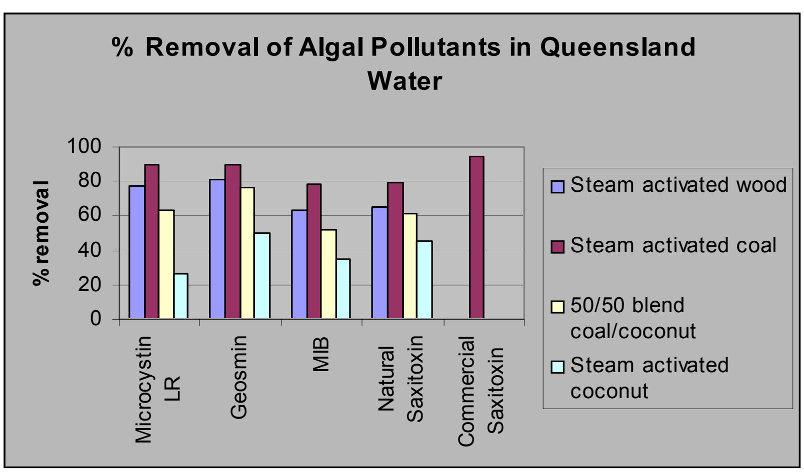

Figure 1: ***Removal of algal pollutants in a natural Queensland Water using 20 mg***

PAC/L for microcystin LR and saxitoxin removal, and 15 mg PAC/L for MIB and geosmin removal; all with 30 minute contact time.

This study used different raw material based carbons in the raw water of a Queensland water treatment plant containing low DOC (<4 mg/L) that had been artificially spiked with contaminants as shown. Each of the carbons has a similar iodine number (measure of adsorption capacity) and all were steam activated, yet there is a significant difference in performance when used to remove target contaminants in drinking water. Microcystin LR and saxitoxin results were conducted using 20mg of each PAC per litre of raw water, whereas the geosmin and MIB results show removal using 15 mgPAC/L.

5.2 Study Two: Comparison of Natural Water – High DOC and Low DOC

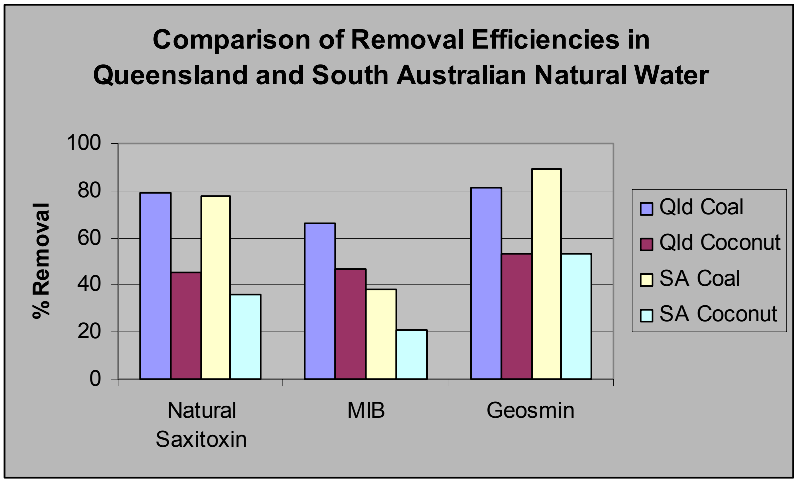

Figure 2: ***Comparison of removal of algal pollutants in natural Qld and South Australian waters using 15 mg PAC/L and 30 min contact time.***

In Figure 2 the removal efficiency of coal and coconut based carbons in two different natural waters is compared. The two natural waters chosen for this investigation were very different, however the most significant difference is that the South Australian natural water typically has a high DOC of 14 mg/L, whereas the Queensland natural water has a relatively low DOC concentration.

This figure shows that the steam activated coal based carbon is more efficient than steam activated coconut based PAC, in removing natural saxitoxin, MIB and geosmin in both high and low DOC waters. The higher DOC of the South Australian water appears to hinder the performance of the PAC in removing MIB, however there is little interference from DOC in the removal of natural saxitoxin and geosmin.

5.3 Study Three: Contact Time

Another significant factor to take into account with powdered activated carbon selection is available contact time. Different carbons adsorb at different speeds. Generally coal based carbons are faster than coconut carbons, as shown in Figure 3.

From this study it is evident that there is less contact time required for coal based carbons than coconut based carbons, however what if there is not a 30 minute contact time available? Full scale plant data using coal based PAC show that contact times as low as direct application of the PAC onto the sand filters (contact time of 5-10 minutes) can still remove most algal contaminants such as geosmin and cylindrospermopsin at dose rates as low as 5 mg PAC/L. To determine the best contact time to suit a particular plant, jar testing is recommended.

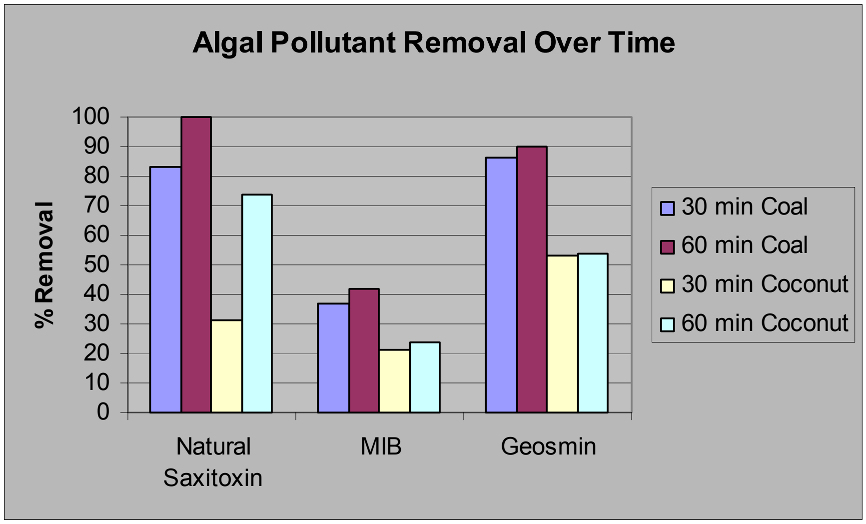

Figure 3: ***Algal pollutant removal using 15 mg PAC/L in South Australian natural water (DOC = 12-13 mg/L).***

5.4 Study 4: Comparison of Coal Based Carbons

Although the previous studies indicated that steam activated coal based carbons possess the best characteristics for taste and odour removal, steam activated coal with identical specifications but from different sources can demonstrate very different removal efficiencies as shown in Figure 4.

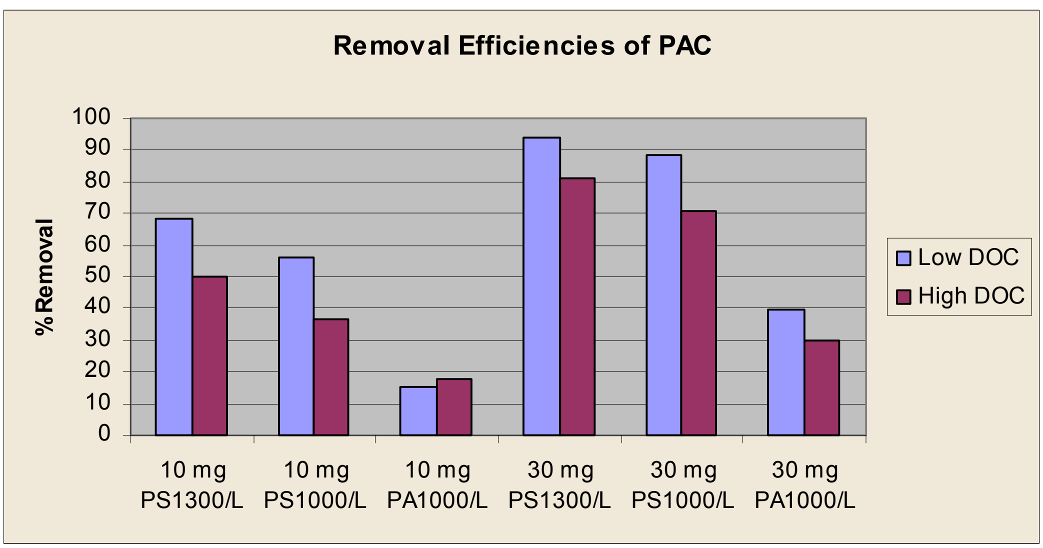

Figure 4: ***Removal of MIB and geosmin with 3 steam activated, coal based PACs in a high and a low DOC natural water.***

Table 1 below, shows the typical datasheet specifications for each of these carbon products, which have very similar characteristics yet very different MIB and geosmin removal capabilities.

Table 1: ***Typical datasheet specifications for 3 steam activated, coal based PACs***

	PS1300	PS1000	PA1000
Iodine Number	>1300	>1000	>1000
Moisture (% max.)	5	5	5
Apparent Density (g/mL)	0.25-0.35	0.35-0.45	0.35-0.45
Particle Size d50 (μm)	20-30	20-30	20-30
Raw Material	Coal	Coal	Coal
Activated Method	Steam	Steam	Steam
Country of Origin	Australia	Australia	China

5.5 Study 5: Comparison of Chemically Activated Wood and Steam Activated Coal

In this study a variety of chemically activated wood based carbons (both zinc chloride and phosphoric acid activated) were compared to steam activated coal based carbons for MIB and geosmin reduction. Chemically activated carbons are typically more hydrophilic than the coal based carbons due to the polar oxygen groups present on the surface of the carbon. This study compared this hydrophilic surface chemistry to the coal based carbons.

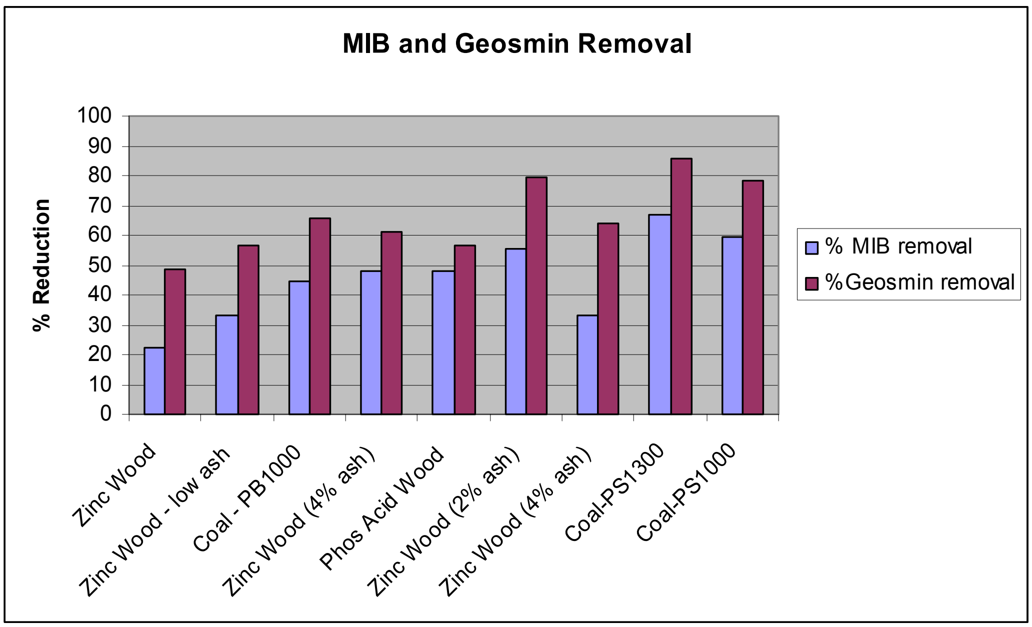

Figure 5: ***Reduction of MIB and Geosmin in natural water (>4mgDOC/L) using various PACs at 5.5mgPAC /L for a 15 minute contact time.***

All carbons had iodine numbers of approximately 1000 (except PS1300 which has a higher iodine number of 1300). There were different levels of ash (impurities) and for the chemically activated wood based carbons the low ash carbons performed slightly better than the higher ash wood based carbons. The PS1000 still out performed most of the chemically activated wood based carbons however the different carbons had different performance. One of the low ash, zinc chloride activated carbon had good reduction of MIB and geosmin, however the other did not, re-enforcing the need for jar testing when comparing carbon's performance.