THE EFFECTS OF DISSOLVED OXYGEN DURING THE REACTIVATION OF GRANULAR ACTIVATED CARBON

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Introduction

An intriguing possibility for changing the features of activated carbon could be as simple as changing a characteristic of the water used to produce the steam, for activation and reactivation. The proposed component to be changed is the dissolved oxygen concentration. As stated above, the oxygen functional groups dominate the surface chemistry of activated carbon. Therefore, changing the concentration of oxygen functional groups or the type of oxygen functional group found on the activated carbon's surface could influence the efficiency by which the activated carbon sorbs compounds. The ability to easily change the surface chemistry would allow for more flexibility in the way activated carbon is produced or reactivated. Moreover, this could also be considered a fundamental change in the way activated carbon is generated. Until now, an idea such as this has yet to be presented in the literature. One could envision this as being a simplistic method for altering activated carbon production at an industrial level without the need to make costly changes to existing infrastructure.

Methods

Thermal reactivations focused on the variation of the dissolved oxygen content in the water that was used to make steam. The concentration levels examined of dissolved oxygen were approximately <4.5 mg/L, 6.0-8.0 mg/L, and 12.0 -14.0 mg/L. These levels were attained, as previously stated, by using nitrogen, air or oxygen to pressurize the stainless steel vessel containing nanopure water. Nitrogen gas was used to reach the low concentration level (4.4mg/L) of dissolved oxygen, air was used to attain the middle value range (7.9 mg/L), and oxygen gas was used when attaining the higher end of the values (12 mg/L) used in this study. Those three distinct DO concentrations were used for three reactivation protocols (low temperature reactivation, steam-curing, and steam pyrolysis). Steam (oxidation) and nitrogen (pyrolysis) gas flow rates were the same for all reactivation protocols. The first protocol was to thermally reactivate the spent GAC at 375 ˚C for one hour under a steam flow rate of 1.0 mL/min. The second protocol was the same as the first, with an additional step. In this added step, the temperature was ramped from 375 ˚C to 850 ˚C under a constant flow of nitrogen gas, while the steam was turned off. This is the protocol Mazyck and Cannon [1] developed in response to calcium catalysis called the steam curing protocol. The third protocol was an attempt to design a protocol that is similar to the conventional methods of industry, with respect to reactivation time and temperature, while trying to attain similar characteristics as

the one designed by Mazyck. The protocol called for a reactivation temperature of 750 ˚C for fifteen minutes of steam followed by fifteen minutes under nitrogen gas at the same temperature. This protocol was named the steam pyrolysis reactivation (SPR). The three reactivation protocols are summarized in Table 1.

Table 1 **Reactivation Protocols and notation.**

Reactivation Protocol	Description	Notation (relative to DO)
1. Low temperature reactivation	Temp: 375˚C; Time: 60 min. Oxidant: Steam (variable DO) Pyrolysis: none	1N= low DO 1A= medium DO 1OX= high DO
2. Steam Curing Protocol	2 parts: 1. Temp: 375˚C for 60 min. steam oxidant (variable DO) 2. Immediately ramped to 850˚C under pyrolytic conditions (nitrogen gas)	2N= low DO 2A= medium DO 2OX= high DO
3. SPR	2 parts: 1. Temp: 375˚C for 15 min. under steam oxidant (variable DO) 2. Temp: 750˚C for 15 min. under pyrolytic conditions (nitrogen gas)	3N= low DO 3A= medium DO 3OX= high DO

The aim of producing these nine reactivated carbons was to discern if a difference, with respect to surface chemistry and pore size distribution, in the resulting carbons, within each protocol existed. Because only the dissolved oxygen was changed within each protocol, this could present the dissolved oxygen content as being an important factor to address when considering reactivation.

Taste and odors in the raw water supply can be an annoyance to people. This is due to their low odor threshold concentration (OTC), which is in the nanogram per liter range [2,3]. The low concentration allows these compounds to evade capture by conventional water treatment [4]. The odor threshold concentration is defined as the lowest concentration that a compound, in this case MIB, is found to be perceptible to humans. The OTC for MIB has been found to be in the range of 6-10 ng/L [2]. The focus of this work was not on creating or tailoring a carbon for the best removal of a contaminant; however, it was a test that could show variations in carbons made with different DO

concentrations. RSSCT's were run in order to test the set of carbons on their performance capabilities.

4.5.1 Low Temperature Reactivated Carbons

The motivation for this protocol was that most oxygen functional groups remain on the carbon surface at low temperatures. The 1N produced nearly 8500 bed volumes when it finally broke through the OTC. This amount, when compared to the 1A (4000 bed volumes) and 1OX (Figure 1) (3000 bed volumes), is substantially more than the 1A processed and more than three times as many as the 1OX. The carbon produced with the lowest DO steam performed the best, followed by the carbon produced with the middle range DO concentration, and lastly the carbon produced from the highest DO steam. This trend in MIB removal can be related to the amount of oxygen functional groups on the carbons surface; however, it is unclear at the present time what impact the different DOs had on pore size distribution.

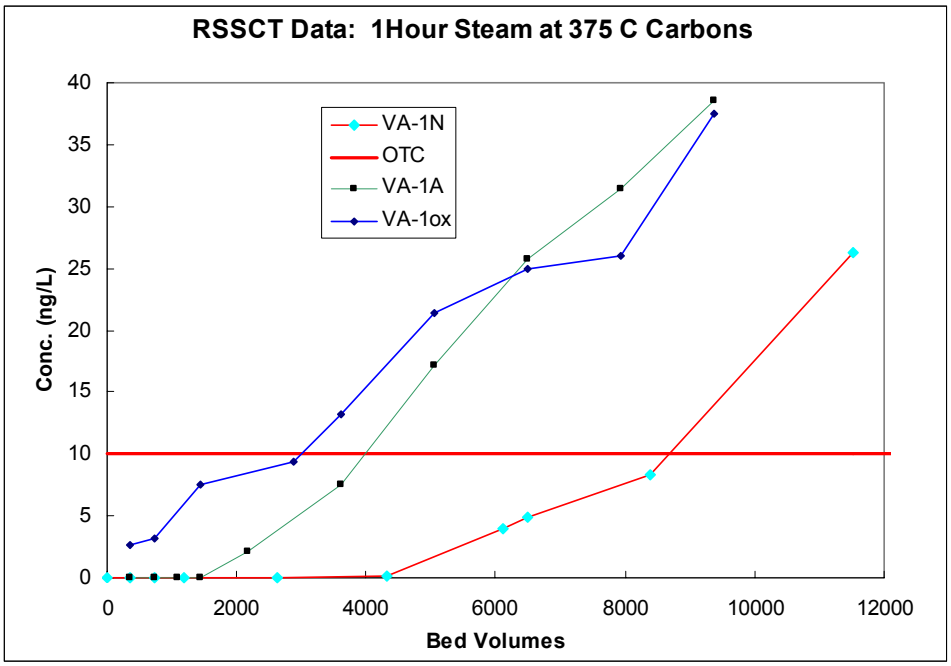

Figure 1 RSSCT data for carbons produced via low temperature reactivation protocol.

4.5.2 Steam-Curing Protocol

This is the protocol Mazyck and Cannon [5] devised to overcome calcium catalysis. The carbons, subsequently produced by Mazyck, proved to have a superior removal of MIB when compared with conventionally reactivated carbon. The RSSCT column run again showed the same trend: the 2OX or high DO carbon processed the lowest amount of bed volumes (7000 bed volumes) before

OTC breakthrough. The 2A was next at approximately 7500 bed volumes followed by the 2N carbon, which broke through at 8300 bed volumes.

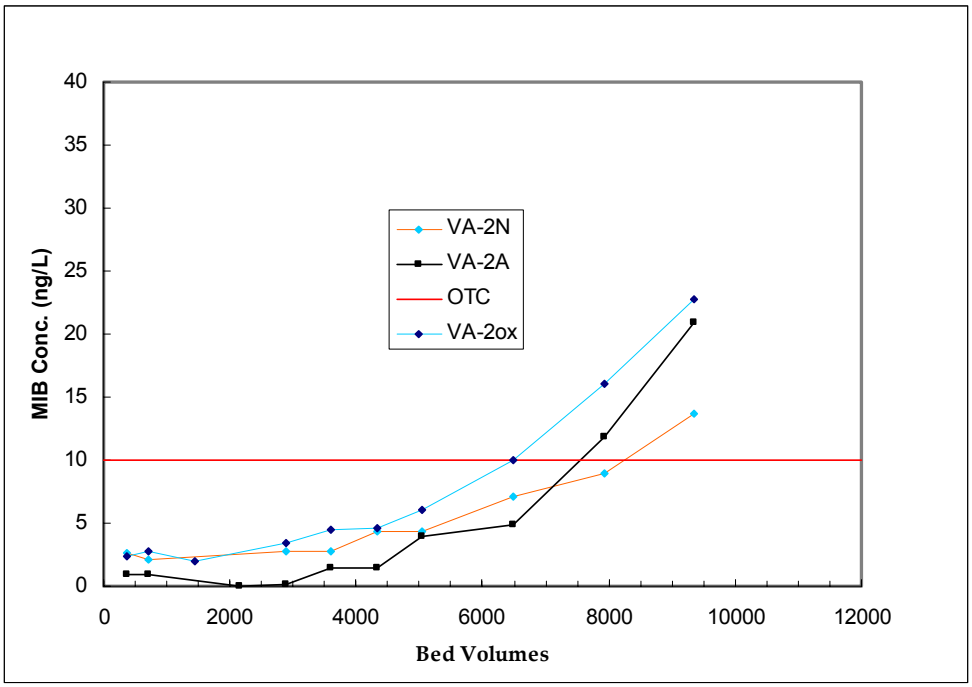

Figure 2 RSSCT data for carbons produced via Steam-Curing reactivation protocol.

Steam Pyrolysis Protocol

The steam pyrolysis reactivation procedure was found it to perform well for MIB removal. Again, the 3N performed the best followed by 3A and lastly 3OX (Figure 3). The difference in bed volumes processed, in this case, were apparent but not as pronounced as in the low temperature protocol. This followed the trend in performance of the lower the dissolved oxygen content in the water used to produce the steam for reactivation, the better MIB removal one observes.

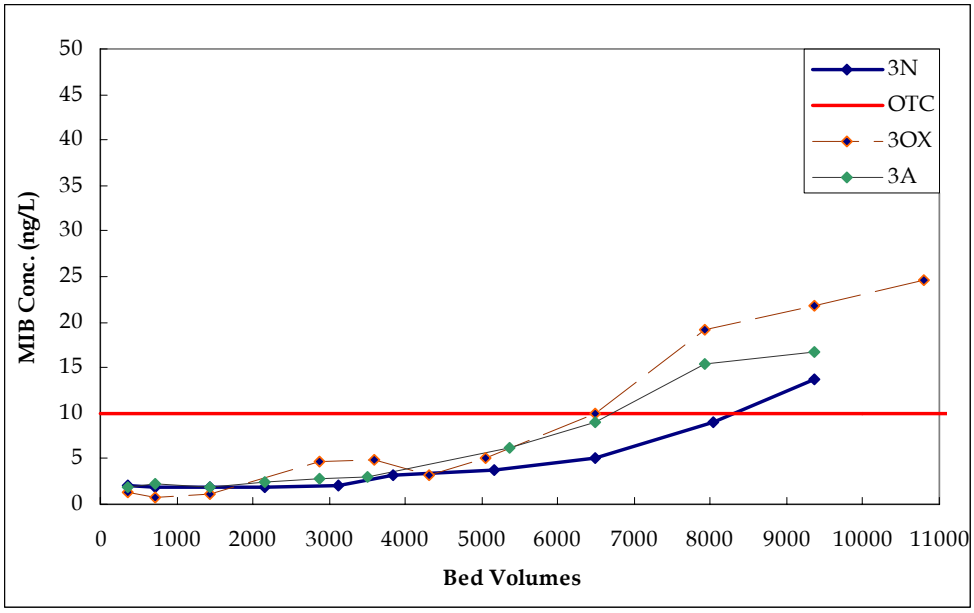

Figure 3 RSSCT data for carbons produced via Steam-Curing reactivation protocol.

The RSSCT data for all three protocols produced similar trends. The overall trend found was that the greater the concentration of DO in the water used to produce steam for the reactivation process, the fewer bed volumes the corresponding carbon would process, with respect to MIB. This trend is echoed by Figure 4.

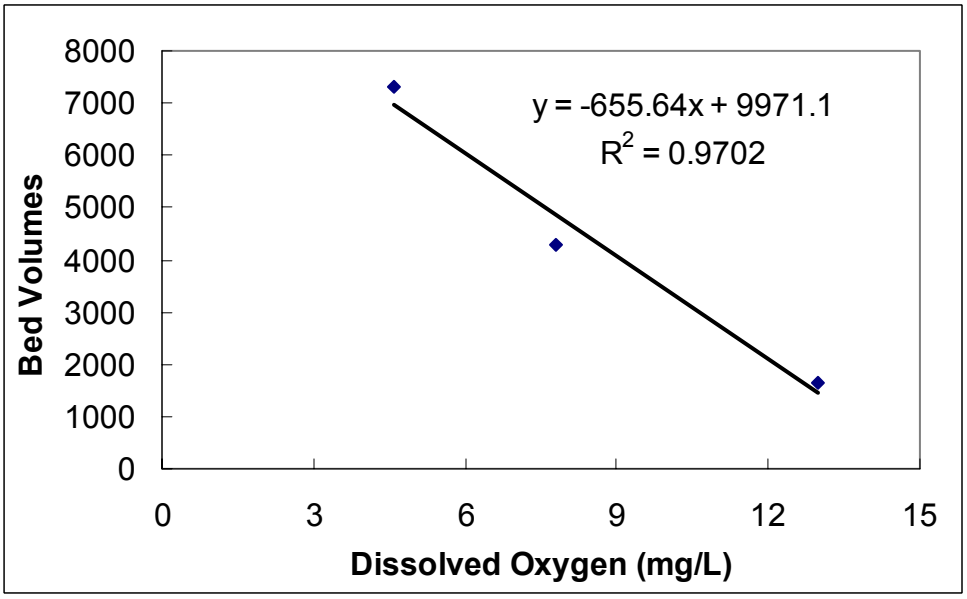

Figure 4 Dissolved oxygen and bed volumes processed.

The correlation between the bed volumes processed and dissolved oxygen was a 0.9702.

Conclusion

The RSSCT data showed that regardless of the protocol used performance of the carbon, for removing MIB, was dependent on the dissolved oxygen content of the steam used to create the carbon. This is an profoundly simple process that could have enormous implications in the production and reactivation of GAC. It is currently unclear whether the effects can be attributed to physical characteristics or surface functional groups. The answer could be related to the pore size distributions if it is a physical phenomenon or acidic/basic functional groups on the basal plane edges and pore openings. Future work is necessary to elucidate the affects of dissolved oxygen concentration and its influence on reactivated GAC.

References

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