DBP Formation Control by Modified Activated Carbons [Project #2998]

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OBJECTIVES:
The main objectives of this project were to (1) conduct a systematic investigation for developing a fundamental understanding of how activated carbons should be tailored for enhanced removal of dissolved organic matter (DOM) from natural waters; and (2) investigate the effectiveness of some carbon tailoring approaches for disinfection by-products (DBP) formation control at typical drinking water treatment conditions.

BACKGROUND:
Powdered or granular activated carbon adsorption has been widely used in drinking water treatment plants primarily for taste, odor, and synthetic organic contaminant (SOC) removal. However, carbon adsorption has not been widely used for controlling DOM due to the low equilibrium capacities and slow adsorption kinetics. The main reason for these drawbacks is that the majority of commercial activated carbons have been developed primarily to remove small molecular weight hydrophobic SOCs from water. As a result, many commercial carbons do not provide feasible engineering solutions for removing large molecular weight and heterogeneous mixtures of DBP precursors. This research was undertaken to develop a fundamental understanding of tailoring activated carbons for DBP control.

HIGHLIGHTS:
Detailed and accurate information should be obtained about the pore size distribution and pHpzc values of candidate granular activated carbons (GACs) to be evaluated for DBP precursor control. The conventional parameters such as Brunauer-Emmett-Teller equation (BET) surface area and total pore volume are not useful to evaluate a GAC for DOM removal. Among several candidates GACs, the carbons with large surface areas and pore volumes in pores >1 nm and basic pHpzc values should be selected for DBP precursor control. GACs with wider pore size distribution and higher pHpzc can be produced by extending steam treatment periods during carbon preparation. For the treated water examined in this study at Myrtle Beach Water Treatment Plant, after 18,000 bed volumes or approximately 4+ months of operation, the steam-treated GAC (HD-S45) at pH 5.5 had effluent THM and HAA₉ formations well below the regulatory limits.

Rapid small scale column tests (RSSCTs) should be combined with DBP testing to determine the feasibility of GAC adsorption for DBP control. Although batch isotherm measurement is a simple technique that can be used to screen various activated carbons for DOM removal, a dynamic RSSCT, despite its time consuming and costly experimental nature, should be performed to obtain relevant information about the feasibility of activated carbon adsorption for full-scale applications. The RSSCT should be combined with DBP testing because monitoring of total organic carbon (TOC) or UV₂₅₄ removal alone does not provide information about the effectiveness of GAC adsorption for DBP control.

APPROACH:
In the first phase of the project, the researchers examined adsorption of DOM before and after conventional
water treatment processes by modified activated carbons prepared using various modification techniques, and characterized DOM before and after adsorption in order to gain some insight to the removal of DOM by the modified activated carbons. For the second phase, the research team investigated the impact of activated carbon pore enlargement using steam treatment while maintaining basic surface characteristics on both DOM adsorption and DBP control. The last phase of the project consisted of an investigation into the effectiveness of iron-impregnated GACs for DOM adsorption and DBP control using both batch isotherms and RSSCTs.

RESULTS/FINDINGS:
The GACs with large surface areas and pore volumes in pores >1 nm and basic pH_{PZC} values should be selected for DBP precursor control. GACs with wider pore size distribution and higher pH_{PZC} can be produced by extending steam treatment periods during carbon preparation. The steam-treated GACs showed higher DOM uptakes compared with their precursors. High temperature treatment effectively regenerated these GACs.

Among several iron impregnation methods, the isotherm results showed that iron-impregnated carbons prepared with the ion exchange method enhanced DOM uptake at typical water treatment conditions. The advantage obtained during batch isotherm tests was not observed in RSSCTs. The lack of iron impact was attributed to the different adsorption patterns between the column and batch mode isotherm tests.

Although batch isotherm measurement is a simple technique that can be used to screen various activated carbons for DOM removal, a dynamic RSSCT, despite its longer and more costly experimental nature, should be performed to obtain relevant information about the feasibility of activated carbon adsorption for full-scale applications. The RSSCT should be combined with DBP testing to properly assess the effectiveness of GAC adsorption for DBP control.

Removal of high molecular weight components during conventional treatment processes and prior to GAC adsorption significantly increases the operational time of GAC filters for DBP control. Operating a GAC filter at a low pH value (e.g., 5.5 tested in this study) can further increase the DOM removal and DBP control. The effects of pH on DOM removal in both conventional treatment processes and subsequent GAC adsorption need to be optimized.

IMPACTS:
This project showed that the removal of DBP precursor by GAC adsorption can be significantly improved. GAC adsorption, using modified GACs, can provide another alternative to some water utilities for meeting the Stage 2 requirements of the Disinfectant/Disinfection By-Products Rule.

PARTICIPANTS:
Three water treatments plants in South Carolina participated in this project.