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Technical Note

Application of biofiltration system on AOC removal: Column and field studies

C.C. Chien [a], C.M. Kao [a,*], C.W. Chen [b], C.D. Dong [b], C.Y. Wu [a]

[a] *Institute of Environmental Engineering, National Sun Yat-Sen University, Kaohsiung 804, Taiwan*
[b] *Department of Marine Environmental Engineering, National Kaohsiung Marine University Kaohsiung, Kaohsiung, Taiwan*

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Abstract

The Cheng-Ching Lake Water Treatment Plant (CCLWTP) is the main supplier of domestic water for the Greater Kaohsiung area, the second largest metropolis in Taiwan. Biological activated carbon (BAC) filtration is one of the major treatment processes in CCLWTP. The objectives of this study were to evaluate the effectiveness of BAC filtration on water treatment in the studied advanced water treatment plant and its capability on pollutants [e.g., AOC (assimilable organic carbon), bromide, bromate, iron] removal. In this study, water samples from each treatment process of CCLWTP were collected and analyzed periodically to assess the variations in concentrations of AOC and other water quality indicators after each treatment unit. Moreover, the efficiency of biofiltration process using granular activated carbon (GAC) and anthracite as the fillers was also evaluated through a column experiment. Results show that the removal efficiencies for AOC, bromide, bromate, and iron are 86% 100%, 17%, and 30% after the BAC filter bed, respectively. This indicates that BAC filtration plays an important role in pollutant removal. Results also show that AOC concentrations in raw water and effluent of the CCLWTP are approximately 143 and 16 μg acetate-C l^{-1}, respectively. This reveals that the treatment processes applied in CCLWTP is able to remove AOC effectively. Results of column study show that the AOC removal efficiencies in the GAC and anthracite columns are 60% and 17%, respectively. Microbial colonization on GAC and anthracite were detected via the observation of scanning electron microscopic images. The observed microorganisms included bacteria (rods, cocci, and filamentous bacteria), fungi, and protozoa. Results from this study provide us insight into the mechanisms of AOC removal by advanced water treatment processes. These findings would be helpful in designing a modified water treatment system for AOC removal and water quality improvement.

Keywords: Assimilable organic carbon (AOC); Biological activated carbon (BAC); Advanced water treatment system; Granular activated carbon (GAC); Biofiltration

1. Introduction

Activated carbon is an adsorbent derived from wood, bituminous coal, lignite, or other carbon-containing materials, and is the most widely utilized adsorbent for the treatment of water and wastewater. It is activated by a combustion process to increase its internal surface area. It is usually used in the form of granular activated carbon (GAC) and applied after sand filtration process in the water treatment plant. Moreover, biological activated carbon (BAC) filtration (biofiltration) has become one of the advanced treatment techniques applied in the water treatment plant. In general, BAC offers a large internal surface area for the adsorption of taste, odor, and color compounds, excess chlorine, toxic and mutagenic substances (e.g., bromide, chlorinated organic compounds, including trihalomethanes), trihalomethane precursors, pesticides, phenolic compounds, dyes, toxic metals, and substances that cause biological after growth (Zhao et al., 2006; Chien et al., 2007). After the biofiltration stage, a disinfection process is required to ensure the effluent meets the drinking

* Corresponding author. Tel.: +886 7 525 4413; fax: +886 7 525 4449.
E-mail address: jkao@mail.nsysu.edu.tw (C.M. Kao).

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water standards in the distribution system (Seredyńska-Sobecka et al., 2006). Because biofiltration is usually not capable of removing the biorefractory substances, pre-oxidation processes should be applied. Ozone is frequently used as the oxidant because ozonation increases the biodegradability of organic matters, and consequently, enhances the effectiveness of its removal during the subsequent biofiltration (Huang et al., 2002).

The Kaoping River located in southern Taiwan flows through the Kaoping metropolitan area, and empties into the South Taiwan Strait. It is 171 km long, drains a catchment of about 3257 km^2. The Kaoping River basin is the largest river basin in Taiwan. Based on the results from the pollutant sources investigation and water quality analysis, the Kaoping River is heavily polluted by domestic and livestock wastewaters. Cheng-Ching Lake Water Treatment Plant (CCLWTP) (the largest water treatment plant in southern Taiwan) is the main supplier of domestic water for the Greater Kaohsiung area, the second largest metropolis in Taiwan. Since the CCLWTP uses the Kaoping River water as the source water, the CCLWTP has encountered a challenge with regards to both technical and managerial requirements. Advanced water treatment system has been applied to the CCLWTP since 2004 to provide high quality drinking water to the residents in the Kaoping metropolitan area, and to meet the stringent drinking water standards. The current water treatment system of the CCLWTP contains the following processes: pumping station, preozonation process, sedimentation basin, pellet softening, rapid filter basin, ozonation process, and BAC filtration followed by chlorination.

Microbial growth in drinking water requires nutrients and carbon sources such as organic carbon, nitrogen, and phosphorus. Organic carbon, especially assimilable organic carbon (AOC) has been considered as the main control factor of the microbial growth in drinking water distribution systems (Chu and Lu, 2004). Recently, the appearance of AOC in the water treatment system and effluent of the treatment plant has brought more attention to the environmental engineers. AOC, which has been defined as a biological pollution, often causes the deterioration of the water quality due to the multiplication of heterotrophic bacteria inside the distribution and treatment systems (Lehtola, 2001; Al-Jasser, 2007; Srinivasan and Harrington, 2007).

The objectives of this study were to evaluate the role of BAC filtration in advanced water treatment plant and its capability on pollutants (AOC, bromide, bromate, and iron) removal. In this study, water samples from each treatment process of CCLWTP were collected and analyzed periodically for 24 months to assess the variations in pollutant concentrations after each treatment unit. Evaluate the application of sodium thiosulfate on AOC analysis. Moreover, the efficiency of biofiltration process using GAC and anthracite as the fillers was also evaluated via column experiments. The feasibility of anthracite for the filtration process was also assessed in the column study.

2. Materials and methods

2.1. Field study

In the CCLWTP, raw water is delivered to the system continuously at a rate of approximately 540 000 $m^3\ d^{-1}$. In the field-scale study, water samples were collected and analyzed from the influent and effluent of each treatment unit during the 24-month investigation period. Major water quality indicators [e.g., AOC, bromide, bromate, iron, turbidity, color, odor, pH, chloride, sulfate, fluoride, nitrate, nitrite, total dissolved solids (TDS), free residual chlorine, hardness, Mn, coliform group, total bacterial count (TBC), Methylene Blue Activated Substance (MBAS or anionic surfactant), phenol, cyanide were analyzed. The sampling processes and sample analyses were conducted in accordance with the methods described in Standard Methods (APHA, 2001) and Polanska et al. (2005). The treatment efficiency was determined using the averaged influent and effluent concentrations of the above major water quality parameters.

2.2. Column study

Column experiments were conducted to evaluate AOC removal efficiencies using GAC and anthracite as the fillers. Characteristics of the filter filling materials (GAC and anthracite) were showed on Table 1. The feasibility of using anthracite as in the biofiltration process was also assessed in the column study. Two columns, which had a diameter of 15 cm and a height of 200 cm with different filling materials, were used in the column test, and filling depth was 110 cm. Fig. 1 presents the components of the glass column filled with anthracite, sand, and stone. The GAC column used granular activated carbon as the media, which was filled up to 110 cm in height. The empty-bed contact time (EBCT) of the GAC column was approximately 6.6 min. The biological anthracite filtration (BAF) column was filled with 80 cm of anthracite, 20 cm of sand, and 10 cm of stone, with an EBCT of 6.6 min. The influent water used in the column test was from the ozonation unit and the filtration rate was 7.3 $m\ h^{-1}$ and loading rate of two columns with 55%. Columns were operated for one year, and scanning electron microscope (SEM) observations were conducted to evaluate the microbial colonization on the fillers at depths of 0, 5, and 40 cm from the bottom of the anthracite and GAC layers. In this study, coliform,

Table 1
Characteristics of the GAC and anthracite

Specification	GAC	Anthracite
Surface area ($m^2\ g^{-1}$)	1000	250
Moisture, weight (%)	2	2
Effective size (mm)	0.5–0.6	1–1.2
Uniformity coefficient	1.9	1.7
Ash weight (%)	6	2