Treatability of South African surface waters by activated carbon

KP Lobanga, J Haarhoff* and SJ van Staden
Department of Civil Engineering Science, University of Johannesburg, PO Box 524, Auckland Park, 2006, South Africa

ABSTRACT

Natural organic matter (NOM) in water resources for drinking purposes can be removed by different methods, including activated carbon adsorption. Due to the variability of NOM in natural waters, both in terms of its nature and its concentration, a study was undertaken to investigate NOM removal for a wide range of South African surface waters, sampled at different periods, by the use of granular activated carbon (GAC). NOM removal was assessed by measuring the ultraviolet (UV) absorbance at 3 wavelengths, namely, 254 nm (UV_{254}), 272 nm (UV_{272}) and 300 nm (UV_{300}). A comparison of data between the three wavelengths showed that any of the three wavelengths can be used to assess NOM removal by GAC, which is well described by the Freundlich equilibrium equation. A treatment target of 40% removal of initial UV_{254} absorbance was considered. It was observed that, although the GAC dosage was generally a function of the initial UV_{254} absorbance, differences existed between waters. This suggests that GAC usage rate is not only a function of the initial UV absorbance but also of the NOM composition, indicating a need for improved NOM characterisation. Comparison between the UV absorbance and dissolved organic carbon (DOC) data suggested that for some waters UV_{254} absorbance can be used as a rapid substitute for DOC. Finally, the high GAC dosage rates required for the target criterion revealed that the process is inadequate for use at the initial stage of raw water treatment; GAC adsorption should be used at later stages of drinking water treatment.

Keywords: activated carbon, adsorption, Freundlich isotherm, natural organic matter, surface water, ultraviolet absorbance

INTRODUCTION

Natural organic matter is a complex mixture of organic compounds such as humic and fulvic acids, proteins, amino acids and carbohydrates, resulting from the degradation of plants, animals and microorganisms (Cornelissen et al., 2008; Edzwald and Tobiason, 2010; García et al., 2011). Based on its origin, NOM can be placed in two categories, namely autochthonous organic matter (formed within the water body) and allochthonous organic matter (produced elsewhere and transported to the water body) (Edzwald and Tobiason, 2010). It can be further classified as either particulate organic matter (POM) or dissolved organic matter (DOM). NOM in water affects the organoleptic aspects of the drinking water, promotes bacterial regrowth in drinking water distribution systems and reacts with disinfectants and oxidants, producing disinfection by-products and other products (Van der Kooij, 1998; Batterman et al., 2000; Hallam et al., 2001; Melnick et al., 2007; Edzwald and Tobiason, 2010; Ødegaard et al., 2010). NOM in raw water can be removed by different methods including the use of activated carbon. Adsorption of DOM by the activated carbon is a function of the NOM composition (nature and concentration), pH of the water, water temperature, molecular size and concentrations of some ions, such as magnesium and calcium (Schreiber et al., 2005).

In drinking water treatment plants, adsorption by activated carbon is a well-established process. The activated carbon is used either as powder (powdered activated carbon – PAC) or as granules (granular activated carbon – GAC). The PAC is generally used at the beginning of the treatment process (at or just after coagulation), while the GAC is used at a later stage of the treatment (generally before disinfection) (Kristiana et al. 2011; Matilainen et al., 2006). PAC is added to the water as slurry, while the GAC is placed in filter beds.

The aim of this study was to investigate NOM removal for a large range of South African surface waters by the use of GAC. The removal was assessed by measuring the UV absorbance at 254 nm (UV_{254}), 272 nm (UV_{272}) and 300 nm (UV_{300}). For some waters, the DOC values were used and compared with the UV absorbance values.

MATERIALS AND METHODS

Source water

Eight surface waters were sampled. As shown in Fig. 1, the sampling sites were chosen from different geographic regions in South Africa in order to include differences in NOM composition. The surface waters were also chosen to account for the main surface water types of South Africa (Oberholster, 2010). The different categories of waters are summarised in Table 1. The raw waters were collected at 5 different times to capture the seasonal variations in NOM composition (Sharp et al., 2006; Uyak et al., 2008). The sampling was done during the following periods: Round 1 from February to April 2010; Rounds 2, 3 and 4 in July 2010, November 2010 and February 2011, respectively. Round 5 waters were sampled in May and June 2011. Raw waters were collected (using two 25 ℓ plastic containers) and stored at approximately 4°C, in the dark. Analysis of the samples was done within 2 months, during which there was no significant change in NOM concentration or composition (Haarhoff et al., 2013).

Granular activated carbon preparation

The activated carbon used was a product commercially available in South Africa and kindly provided by a local supplier.

This paper was originally presented at the 2012 Water Institute of Southern Africa (WISA) Biennial Conference, Cape Town, 6–10 May 2012.
* To whom all correspondence should be addressed.
☎ +27 11 559 2148; e-mail: jhaarhoff@uj.ac.za

http://dx.doi.org/10.4314/wsa.v39i3.6
Available on website http://www.wrc.org.za
ISSN 0378-4738 (Print) = Water SA Vol. 39 No 3 WISA 2012 Special Edition 2013
ISSN 1816-7950 (On-line) = Water SA Vol. 39 No 3 WISA 2012 Special Edition 2013