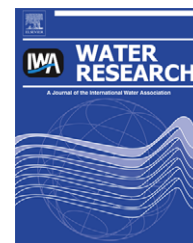


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Comparison of NOM character in selected Australian and Norwegian drinking waters

Rolando Fabris^{a,*}, Christopher W.K. Chow^a, Mary Drikas^a, Bjørnar Eikebrokk^b

^aCRC for Water Quality and Treatment, Australian Water Quality Centre, South Australian Water Corporation, PMB 3, Salisbury, South Australia 5108, Australia

^bSINTEF, Department of Water and Wastewater, N-7465 Trondheim, Norway

ARTICLE INFO

Article history:

Received 27 February 2008

Received in revised form

19 June 2008

Accepted 19 June 2008

Available online 29 June 2008

Keywords:

NOM

DBPs

Norway

Australia

Drinking water

ABSTRACT

Observations from many countries around the world during the past 10–20 years indicate increasing natural organic matter (NOM) concentration levels in water sources, due to issues such as global warming, changes in soil acidification, increased drought severity and more intensive rain events. In addition to the trend towards increasing NOM concentration, the character of NOM can vary with source and time (season). The great seasonal variability and the trend towards elevated NOM concentration levels impose challenges to the water industry and the water treatment facilities in terms of operational optimisation and proper process control. The aim of this investigation was to compare selected raw and conventionally treated drinking water sources from different hemispheres with regard to NOM character which may lead to better understanding of the impact of source water on water treatment. Results from the analyses of selected Norwegian and Australian water samples showed that Norwegian NOM exhibited greater humic nature, indicating a stronger bias of allochthonous versus autochthonous organic origin. Similarly, Norwegian source waters had higher average molecular weights than Australian waters. Following coagulation treatment, the organic character of the recalcitrant NOM in both countries was similar. Differences in organic character of these source waters after treatment were found to be related to treatment practice rather than origin of the source water. The characterisation techniques employed also enabled identification of the coagulation processes which were not necessarily optimised for dissolved organic carbon (DOC) removal.

The reactivity with chlorine as well as trihalomethane formation potential (THMFP) of the treated waters showed differences in behaviour between Norwegian and Australian sources that appeared to be related to residual higher molecular weight organic material. By evaluation of changes in specific molecular weight regions and disinfection parameters before and after treatment, correlations were found that relate treatment strategy to chlorine demand and DBP formation.

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1. Introduction

The relevance of natural organic matter (NOM) to water treatment operators is significant. Some components can

cause colouration of the water, it can include compounds that cause unpleasant taste and odours and it can act as a substrate for microbial growth. In addition, NOM may control coagulant and disinfectant demand; it may foul

* Corresponding author. Tel.: +61 8 8259 0314; fax: +61 8 8259 0228.

E-mail address: rolando.fabris@sawater.com.au (R. Fabris).

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doi:10.1016/j.watres.2008.06.023

membranes, block activated carbon pores and compete with taste and odour compounds for available adsorption sites, reducing adsorption efficiency. NOM that is not removed by the treatment process applied can, upon subsequent disinfection, react to form by-products such as trihalomethanes (THMs). Disinfection by-products (DBPs) can be of health concern and their minimisation in water can be achieved by maximising the efficiency of the treatment process for removal of their precursors (Kavanaugh, 1978). Aquatic NOM can be classified roughly into two groups: (a) non-humic solutes, consisting of compounds belonging to the well-known classes of organic substances such as amino acids, hydrocarbons, carbohydrates, fats, waxes, resins, low-molecular acids, etc., and (b) very complicated heterogeneous humic solutes. These two groups are not entirely distinguishable from each other, because some natural non-humic solutes, such as carbohydrates, can be an integral part in the structural composition constructing humic solutes; however, for the purposes of characterisation it is often necessary to identify reactive or non-reactive functional components from the heterogeneous mixture.

NOM may have distinctive characteristics associated with its origin (e.g. vegetation, soil, wastewater). For example, dissolved organic carbon (DOC) from aquatic algae has a relatively large nitrogen content and low aromatic carbon and phenolic contents. On the other hand, terrestrially derived DOC has relatively low nitrogen content but large amounts of aromatic carbon and phenolic compounds. Thus the aromatic content, which is believed to be a major reactive component, varies with different sources. The contribution of each carbon source is seasonally dependent as well, and the hydrological and biogeochemical processes involved can alter the chemical composition and physical structures of the NOM. The specific UV absorbance (SUVA defined as UV absorbance/DOC) seems well correlated to the aromatic content of NOM. Thus, SUVA is a valuable parameter when evaluating NOM reactivity and treatability (Archer and Singer, 2006).

Traditionally, the treatment of water for potable use has been accomplished by the use of conventional coagulation/flocculation using inorganic coagulants. As a result of the great impact of NOM on water quality and supply, optimisation of water treatment processes for NOM removal (i.e. enhanced coagulation using elevated coagulant doses and strict pH control) has been more common. Another shift has been evident recently in both research and water treatment practices away from chemical based treatments on both environmental and health grounds. The increasing usage of adsorbents such as ion-exchange resins and activated carbon as well as membrane filtration technologies is evident throughout the world as examples of this trend (Boller, 1994).

Physical and chemical fractionation of aquatic NOM at specific pH can be used to classify organic solutes into broadly defined hydrophobic and hydrophilic fractions (Ma et al., 2001; Leenheer, 2004). The different NOM fractions exhibit different properties in terms of treatability by coagulation, coagulant demand, chlorine and ozone reactivity and by-product formation potential. The high-molecular weight hydrophobic fractions can be efficiently removed by coagulation, and the hydrophobic content controls the coagulant demand due to

the fact that this fraction contains the majority of charge (carboxylic acidity). On the other hand, the lower molecular weight hydrophilic fraction is considered least amenable to removal by coagulation, attributed to a negligible charge density. Thus the hydrophilic fraction can be applied as an indicator of the achievable DOC residual after coagulation (Sharp et al., 2006; Henderson et al., 2006).

Observations from North America and Northern Europe (Sweden, Norway, Germany and Britain) during the past 10–20 years indicate increasing NOM concentration in water sources, likely due to global warming and more intensive rain events (Forsberg, 1992; Wilson, 2001; Eikebrokk et al., 2004; Korth et al., 2004). Other drivers, such as declining acid deposition, increased severity of drought events and local effect of land use have also shown trending towards increased DOC concentration in natural water sources, with no recorded evidence of decreases (Worrall et al., 2004; Evans et al., 2005). In addition, NOM composition and properties and thereby the treatability of NOM, vary with place (location) and time (season). The great seasonal variability and the trend towards elevated NOM concentration levels impose challenges to the water industry and the water treatment facilities in terms of operational optimisation and proper process control. Although a number of different technologies are available for NOM removal today, the coagulation-based treatment processes (i.e. enhanced coagulation) still dominate in most countries.

Because of the negative aspects of NOM and the fact that NOM tends to control coagulation and coagulation performance, it is important to optimise coagulation processes with respect to NOM removal. For this purpose, linking NOM characterisation to treatability is an important issue, particularly by including simple characterisation methods that can be used as optimisation tools at water treatment facilities (Chow et al., 2006).

The aim of this investigation was to compare selected raw and conventionally treated drinking water sources from different hemispheres (i.e. Norway and Australia) with regard to NOM character to obtain a better understanding of the impact of source water on water treatment.

2. Materials and methods

2.1. Norwegian source waters

All Norwegian source waters are natural lakes within coniferous forested catchments. Bedrock within the catchment areas can be primarily identified as granitic. The sources can be classified as low turbidity, soft and humic surface waters (Table 1). All locations normally have snow, and the lakes have ice cover between October/November and April/May. The Skullerud water treatment plant (WTP) sources water from Lake Elvåga, a natural lake 10 km east of Oslo in the south-east part of Norway. Alum is used for coagulation prior to direct filtration in three media filters with lime and carbon dioxide used for pH and corrosion control. Stjørdal WTP is located in central Norway (32 km east of Trondheim), and is supplied by Lake Lauvvatnet. Poly aluminium chloride is used for coagulation prior to flotation–filtration. Lime and CO₂ is applied for pH

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