ELSEVIER

Desalination 176 (2005) 81–89

DESALINATION

www.elsevier.com/locate/desal

Modeling the treatment of drinking water to maximize dissolved organic matter removal and minimize disinfection by-product formation

J. van Leeuwen[a,d]*, R. Daly[a,b], M. Holmes[a,c]

[a]Co-operative Research Centre for Water Quality and Treatment, Australia
[b]Australian Water Quality Centre, SA Water, PMB3, Salisbury, South Australia
[c]United Water International Pty Ltd., P.O. Box 690, Modbury, SA 5092, Australia
[d]CSIRO Land and Water, PMB 2, Glen Osmond 5064, Australia

Received 19 October 2004; accepted 29 October 2004

Abstract

Surface waters used for drinking purposes can vary markedly in their organic and inorganic content. High levels of variation occur in a range of water quality parameters such as turbidity, alkalinity, colour, natural organic matter, algae and micro-organisms. The removal of organic matter using inorganic coagulants is impacted by the character and concentration of the organics and the turbidity and alkalinity of the raw water. Mathematical models that relate the character and concentration of dissolved organic matter in raw water to inorganic coagulant dosing that maximize removal of dissolved organic carbon (DOC) have been developed. These models were used to predict alum doses that were subsequently applied to treat waters from two Australian drinking water sources (Googong and Middle River reservoirs) under jar test conditions and in pilot plant trials. Percentage removals of DOC were ~50–60% with application of model predicted alum doses for maximizing removal of DOC when coagulation was performed at pH 6. Much higher coagulant dosing at similar pH resulted in comparatively minor additional removal of DOC. Trihalomethane formation potential (THMFP) under standard laboratory conditions was found to be proportional to the residual DOC concentrations and appeared to be linearly related. Formation of individual THMs was consistent in each water source but differed between the two sources.

Keywords: Enhanced coagulation; Modeling; NOM; DBP; THMFP

*Corresponding author. Present address:
Tel. +61 (8) 8303-8721; Fax +61 (8) 8303-8750;
email: john.vanleeuwen@CSIRO.au

Presented at the Seminar in Environmental Science and Technology: Evaluation of Alternative Water Treatment Systems for Obtaining Safe Water. Organized by the University of Salerno with support of NATO Science Programme. September 27, 2004, Fisciano (SA), Italy.

0011-9164/05/$– See front matter

doi:10.1016/j.desal.2004.10.024

1. Introduction

Water that is acceptable to consumers for drinking purposes should be safe, meaning it is free from pathogens and does not contain chemicals at concentrations that can cause harm. It should also be aesthetically pleasing having low colour and turbidity with no unpleasant taste or odours. In order to attain high quality drinking water a range of treatment technologies can be used including membrane filtration, coagulation/flocculation/sedimentation or dissolved air flotation/filtration, ozonation, activated carbon, ion-exchange resins and disinfection by chlorine or chloramine and UV irradiation.

The most common water treatment process involves the use of metal-based coagulants for removal of colour, turbidity and organic compounds. Dissolved organic matter (DOM) in raw water used for drinking purposes comprises a wide range of organic compounds, some of which are amenable to removal by coagulation using metal based coagulants while others are recalcitrant to removal. In addition to the type of DOM (measured as DOC) present in raw water, the amount of DOM removed by coagulation is determined by the dose and type of coagulant used and the pH at which coagulation occurs. For a given coagulant there is an optimum pH at which coagulation is most efficient for removal of organics. Natural DOC could be considered as comprising of two fractions in relation to a particular coagulant, that which can be removed (coagulable) and that which is recalcitrant to removal. Those that are able to be removed are predominantly high molecular weight hydrophobic compounds that tend to have higher UV (at 254 nm) absorbance and colour while those that are recalcitrant are smaller molecular weight hydrophilic compounds.

In water disinfected with chlorine, residual DOM can react to form disinfection by-products such as trihalomethanes (THM). Specified removal of organics to minimize disinfection by-products is a regulatory requirement in the USA, and water authorities in the USA, Britain and Europe are required to meet regulatory limits on disinfection by-products. In Australia, guidelines exist for levels of disinfection by-products in drinking water [1].

Modeling of water treatment processes have been described by Bazer-Bachi et al. [2], Ellis et al. [3], Girou et al. [4] and Ratnaweera and Blom [5]. These models are mostly based on relationships between raw and treated water quality and treatment conditions required to achieve a target water quality. Models and predictive tools for determination of the removal of organics from drinking water have been proposed by Edwards [6], Urfer et al. [7], Baxter et al. [8], Stanley et al. [9], van Leeuwen et al. [10,11] and Kastl et al. [12].

In this paper, mathematical models previously described [10,11,13] were applied for prediction of alum doses required to maximize removal of dissolved organic matter from two raw water sources, Middle River (South Australia) and Googong (Australian Capital Territory). Predicted alum doses were tested under jar test and pilot plant conditions. The formation potential of THMs from residual DOC and relative abundances of individual THMs are described.

2. Materials and methods

2.1. Samples

Raw water samples were collected from Middle River Reservoir, South Australia and from Googong Reservoir (ACT/New South Wales). At the time of sample collection, water from Googong Reservoir had a DOC concentration of ~6.5 mg/l, alkalinity (as $CaCO_3$) of 45 mg/l and turbidity of ~2 NTU. Middle River water had a DOC of ~12–14 mg/l, alkalinity ~15 mg/l and turbidity ~5 NTU.

2.2. Determination of water quality parameters

Colour: Colour (Col), in Hazen units (HU) was determined by measuring the absorbance at