Efficacy of conventional drinking water treatment processes in removing problem-causing phytoplankton and associated organic compounds

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ABSTRACT

Seven phytoplankton groups were recorded in the source water supplied to South Africa's largest conventional drinking water treatment plant (DWTP). Two phytoplankton genera, *Anabaena* and *Ceratium* were identified as the problem-causing phytoplankton due to their ability to interfere with the water treatment process and negatively impact on water quality. The objectives of this study were to identify problem-causing phytoplankton genera and investigate the efficacy of unit processes in removing phytoplankton genera and associated organic compounds. Phytoplankton and organic compound data were obtained from four different sampling localities throughout the treatment plant and statistically analysed to evaluate the removal efficiencies of unit processes. The highest percentage removal for the Cyanophyceae average seasonal concentration (> 1 000 cells/mℓ) was recorded at 98%, while the highest percentage removal for the Dinophyceae average seasonal concentration (± 9 cells/mℓ) was recorded at 100%. *Microcystis* and *Anabaena* were removed by the processes of coagulation, flocculation and sedimentation (> 95%), while *Ceratium* cells were removed by sand filtration (> 80%). Ineffective removal of *Ceratium* by coagulation, flocculation and sedimentation (and subsequent penetration to the sand filtration step) will negatively impact on filter run times when these phytoplankton genera are present in high concentrations in the source water. Total photosynthetic pigments (TPP) were removed effectively by all the different water treatment processes. Not enough statistical evidence could be displayed to suggest effective removal of geosmin in this conventional water treatment plant. With good removal of intact cyanobacteria cells during coagulation, flocculation and sedimentation, geosmin concentrations in the final water could be kept to accepted organoleptic levels of 5–10 ng/ℓ in the final water. Optimising conventional drinking water treatment processes can effectively remove problem-causing phytoplankton as well as their associated organic compounds and thereby reduce the potential risk to drinking water consumers.

Keywords: coagulation, sand filtration, drinking water, *Ceratium*, *Anabaena*, *Microcystis*, geosmin

INTRODUCTION

Pollution and eutrophication lead to the presence of high concentrations of organic and inorganic compounds, which enhance phytoplankton (including Cyanophyceae) blooms and concomitantly decrease water quality (Venter et al., 2003; Heisler et al., 2008 and Li et al., 2011). The occurrence of these blooms in the source water for drinking water production is of critical importance to drinking water providers as phytoplankton can have both a physical impact (e.g. clogging of filters) and chemical impact (e.g. production of cyanotoxins, disinfection by-products and taste and odour compounds) on the treatment process (Du Preez et al., 2007; Merel et al., 2010).

Phytoplankton known to cause problems during drinking water treatment, include groups like Dinophyceae (*Ceratium hirundinella*), Cyanophyceae (*Microcystis aeruginosa*, *Anabaena circinalis*, *Oscillatoria simplicissma* and *Cylindrospermopsis*), Bacillariophyceae (*Aulacoseira granulata*) as well as the Chlorophcyeae (*Cladophora*). *Ceratium*, for example, is known to disrupt the coagulation, flocculation and sedimentation processes and clog sand filters as well as to produce taste and odour compounds (Swanepoel et al., 2008a). Cyanophyceae blooms add an additional dimension as the toxic strains of the different species can produce cyanotoxins that pose a health risk to the consumers of drinking water (Du Preez et al., 2007 and Newcombe, 2009). Furthermore, blooms with high cell numbers can have a significant effect on the formation of disinfection byproducts after oxidation with chlorine (Rositano et al., 2001; Rodríguez et al., 2007; Zamyadi et al., 2011 and Zamyadi et al., 2012a).

Removal of phytoplankton is a challenge during conventional water treatment as it is often inhibited by various factors such as: (i) the specific phytoplankton species present, (ii) the concentration of the phytoplankton in the source water, (iii) the optimisation (or lack thereof) of the coagulation, flocculation and sedimentation unit processes as well as (iv) the effectiveness of the sand filtration process. It is therefore important to monitor phytoplankton and their related organic compounds, not only in the source water, but also in the drinking water (Swanepoel et al., 2008a), and to get a clear understanding of the efficacy of conventional treatment processes (i.e. different unit processes) in removing phytoplankton and their related organic compounds from the source water. The objectives of this study were to (i) identify problem-causing phytoplankton

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