Evaluating the effectiveness of various control and water treatment processes on the membrane integrity and toxin fate of cyanobacteria

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List of Abbreviations

AWQC	Australian Water Quality Centre
DAFF	Dissolved Air Flotation and Filtration
DOC	Dissolved Organic Carbon
EDTA	Ethylene-Diamine-Tetra-Acetic Acid
EOM	Extracellular Organic Matters
Fe	Iron
HPLC	High Performance Liquid Chromatography
MCs	Microcystins
Mn	Manganese
NOM	Natural Organic Matters
THM	Trihalomethanes
WHO	World Health Organisation
WSP	Waste Stabilization Ponds
WTPs	Water Treatment Plants
WWTP	Waste Water Treatment Plants

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Abstract

Cyanobacterial blooms could reduce the available volume of source water for use as drinking, sanitation and irrigation due to the associated toxins which could be severely harmful to humans and animals. Generally, the majority of cyanotoxins are intracellular in healthy populations but they could be released into the surrounding waters when the membranes are compromised by aging or chemical stress. However, conventional water treatment processes are not able to remove the dissolved toxins but only intracellular toxins in the intact cells. Although various chemical compounds have trialled for cyanobacterial bloom control or cyanobacterial cells/metabolites removal in water treatment processes, the effect of these treatments on the membrane integrity and toxin fate of cyanobacterial cells have not been systematically studied and compared. This study evaluated the effectiveness of copper sulphate ($CuSO_4$), chlorine, potassium permanganate ($KMnO_4$), hydrogen peroxide (H_2O_2) and ozone on the cell integrity, densities, toxin release and degradation of *Microcystis aeruginosa* cultured with ASM-1 medium. All of these technologies can compromise the cell membrane of cyanobacteria to varying degrees. Chlorine showed the strongest ability to impair the cell integrity with a majority ($\geq$ 88%) of the cells compromised within the first minute. Ozone dose of 6 mg L^{-1} also could induce 90% lysis of the cyanobacterial cells in 5 minutes and the cell lysis rate of $KMnO_4$ (10 mg L^{-1}) was 0.829 h^{-1}. $CuSO_4$ and H_2O_2 could not only destroy the viability of cyanobacterial cells but also showed algistatic potential over the 7 day treatment. All the chemicals expect $CuSO_4$ could remove the total toxins and chlorine was the most effective one with the fastest rate up to 2161 $M^{-1}s^{-1}$. Although the intracellular toxins were liberated due to cell lysis, there was no build-up of dissolved toxins detected during chlorine and H_2O_2 exposure which may due to the faster toxin oxidation rates than release rates. 1 and 3 mg L^{-1} $KMnO_4$ degraded both the intracellular and extracellular toxins with the cyanobacterial cells remaining intact while ozone induced significant increase of dissolved toxins. Wastewater reuse is important for irrigation; however, cyanobacterial blooms occurred frequently in the wastewater treatment systems with the ideal conditions for cyanobacterial growth. Tertiary treated effluent water was applied to investigate the cell lysis and toxin kinetics based on culture medium study. Similar impacts on the cyanobacterial cells were found using wastewater and medium but higher oxidant demand may be needed for wastewater treatment due to the higher concentrations of dissolved organic materials. In addition, the advantages and drawbacks of these chemicals on the downstream water quality were assessed to suggest the water authorities to choose the suitable option against cyanobacterial issues.