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FOREWORD

Research Report Title: Impacts of De-stratification on Reservoir NOM and its Removal by Water Treatment

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RMIT University
Curtin University
ACTEWAGL Corporation

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(1) Impact of De-stratification on the Treatability of Natural Organic Matter in Drinking Water Reservoirs-Field Studies.

(2) Impacts of De-stratification on NOM and its Treatability- Laboratory Studies.

Printed Thesis Reports : (1) Leon Linden (2) Yeow Soh CRC Water Quality and Treatment.

OBJECTIVES

The objectives of the project were to:

1) determine impacts of water storage in reservoirs on the character of NOM,
2) determine impacts of de-stratification of reservoir water on the character of NOM,
3) relate character changes or differences of NOM found in (1) and (2) above to the capacity of conventional water treatment (using the coagulant alum) to remove NOM from raw water,
4) model the NOM budget of the Myponga catchment-reservoir system.

BACKGROUND

Natural organic matter (NOM) in soils and in waters is a complex mixture of compounds varying in hydrophobic and hydrophilic character, molecular size, chemical structure and functionality. The character of the NOM varies for each water body depending on the transportation and degradation processes that lead to its formation. NOM present in drinking water is an important issue to the water industry as it is a precursor in the formation of disinfection by-products, exerts a chlorine demand and is a substrate for microbial growth in distribution systems. Maximising the removal of NOM from drinking water has become an increasingly important issue for water authorities.

Methods for controlling the biomass production in lakes and reservoirs (and autochthonous NOM) include limiting light intensity to the water body, bio-manipulation and artificial de-stratification. Artificial de-stratification can be achieved through mechanical mixers and direct air injection (aerators) and these result in the water column being de-stratified i.e. the mixing of the benthic/hypolimnion layers with those above them. Stratification of lakes and reservoirs occurs due to a combination of reduced mixing of surface layers and increased solar energy input leading to temperature and eventually oxygen gradients over the water column.

The detrimental impacts of stratification of reservoirs on overall water quality have been extensively reported. These impacts include the release of metals and nutrients from sediments under anoxic conditions and high phytoplankton biomass production, both conditions indicative of a eutrophic system.

The merits of using de-stratification to improve water quality have been reported in the scientific and technical literature. Breaking down the water column structure can reduce metal mobilisation and algal and cyanobacterial growth. This has been achieved through the use of mechanical mixers and aerators.

The cost of treating drinking water to minimise the residual concentration of NOM by conventional treatment is substantial, and especially for source water where the dissolved organic carbon (DOC) concentration is high. At the commencement of this project it was unknown what the impacts were of reservoir de-stratification on the concentration and character of NOM in reservoirs and on its treatability by conventional water treatment processing where a metal coagulant is applied.

HIGHLIGHTS

- The influence of riverine inflows and intrusions on reservoir hydrodynamics and the subsequent dilution and distribution of NOM was modelled. The feature of reservoir short-circuiting through cold, dense water flow along the benthic/hypolimnion to the reservoir off-take to the water treatment plant was described.
- Identification of a potential management strategy for water off-take at the reservoir during and after storm-events to maximise the quality of raw water supplied to a drinking water reservoir.
- Field studies using mesocosms and laboratory based studies were conducted to simulate stratified and de-stratified conditions of the Myponga Reservoir, South Australia. The results obtained indicate that artificial de-stratification of waters from this reservoir has a minor impact on the concentration and character of the DOC, and consequently on its treatability. Although the effects were statistically significant they are considered to be probably of minor

practical relevance. (Stratified water from the benthic was calculated to require 3.7% lower treatment costs based on alum treatment with pH control than surface and de--stratified waters). Similarly, small differences in DOC were found between simulated stratified and de-stratified waters, under laboratory conditions.

- Under laboratory conditions, the impacts of UVB, UVA and photosynthetic active radiation (PAR) were also assessed on Myponga waters. These investigations indicate that UVB exposure slightly lowered DOC while PAR slightly increased DOC in stratified and de-stratified waters. However, the UVB and UVA exposed waters showed no practically relevant difference in residual DOC after alum treatment (the coagulant recalcitrant fraction remained much the same in concentration), though the neutral and BDOC fractions increased. This increase is attributed to microbial growth leading to an increase of organics that are hydrophilic and more recalcitrant to removal using alum.
- The character of NOM (as DOC) impacted by stratification and de-stratification, before and after alum treatment was assessed using a range of techniques, including High Performance Size Exclusion Chromatography (HPSEC) – UV and DOC, ATR-FTIR, Rapid Fractionation, BDOC.
- Extracellular enzyme activities of bacteria in riverine and reservoir waters were studied. These enzyme activities are reflective of the types of organic polymers that are present in catchment and source waters of drinking water reservoirs and which might impact on water quality and its treatability. Highest activities were recorded in river samples. These enzyme activities seem to reflect the metabolically active, biochemically distinct fractions of the DOC rather than the more complex humified DOC that is the target of water treatment processes.

APPROACH

The project comprised two key components- a field based study where several drinking water reservoirs were investigated i.e. Googong Reservoir in Canberra, Wartook Reservoir in Victoria and Myponga Reservoir in South Australia. Of these, the Myponga Reservoir was studied in detail.

NOM transport in the Myponga catchment to the Myponga River was investigated as well as subsequent transport of NOM from the river to the Myponga Reservoir. From this investigation, models of the dynamics of DOC based on hydrodynamic models of the Myponga Reservoir were developed. NOM from the river and reservoir was assessed based on DOC concentration and character. A range of techniques were applied for characterisation of DOC, including HPSEC-UV/DOC, FTIR, BDOC and Rapid Fractionation. A mesocosm experiment was conducted at Myponga Reservoir to compared simulated stratification with the destratified reservoir.

Microbial enzymes were determined in river and reservoir waters and activities associated with particles, cell surface and in free suspension. Laboratory investigations were conducted on Myponga Reservoir waters at RMIT University. In simulations, the temperature, light and mixing conditions were controlled. Experiments were conducted to assess the impacts of UVA, UVB and PAR on DOC in terms of DOC concentration and character and treatability with alum.

RESULTS/FINDINGS

Prediction of DOC concentration dynamics in Myponga Reservoir during riverine intrusion, using the ELCOM model.

A model was developed that enables prediction of the movement and dilution of NOM in waters of the Myponga Reservoir during riverine inflow and is based on the hydrodynamic model ELCOM. Hydrology was found to be a major determinant of the concentration of dissolved and particulate organic carbon (DOC and POC) in Myponga River. The intrusion and mixing hydrodynamics determined the characteristics of DOC transport to the reservoir dam. The model may be applied to optimise the quality of water at the off-take to a drinking water reservoir, during and following a storm event in the catchment.

Assessment of Microbial Enzyme Activity for Characterisation of NOM in River and Reservoir Water Samples.

Microbial enzyme activity was investigated based on a hypothesis that the level of activity would reflect the concentration and character of the NOM. It is well recognised that microbial activity affects the character of NOM in soils and aquatic environments. Microbial activities were higher in river than reservoir water samples and appeared to reflect more the concentration and character of particulate NOM. Significant correlations between microbial enzyme parameters and simple characteristics (Colour, UVA, DOC, SUVA etc) of dissolved organic matter were not found.

Impact of De-stratification on the Character and Treatability of NOM

The benefits from artificial de-stratification of reservoirs on metal and nutrient immobilisation and control of algae and cyanobacteria are well established. However, the concurrent impacts of de-stratification on the character of NOM and its consequent treatability under conventional treatment processes were found to be minimal. The results from both field (mesocosms) and laboratory simulation studies were consistent in that the NOM character changes and removals associated with de-stratification were of minor practical significance. The range of NOM characterisation techniques applied in this project, including HPSEC-UV/DOC; FTIR, BDOC indicated similarity between waters that had been stratified and de-stratified. Exposure of stratified and de-stratified simulated Myponga waters to UVB and UVA light (equivalent to 90 days of sunlight) resulted in lowering of DOC concentrations in untreated and alum treated waters. In contrast, exposure to PAR resulted in no apparent reduction in DOC. Differences between stratified and de-stratified waters that had been similarly exposed to UVB, UVA and PAR showed no practically significant differences in DOC concentrations.

The results of this study indicate that although changes in DOC concentration and character in rivers and reservoir are likely to occur associated with climate change (e.g. higher levels of UV irradiation) the strategy of artificial de-stratification for water quality management is not likely to significantly alter the treatability (by conventional treatment) of NOM compared with stratified waters.

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The Cooperative Research Centre (CRC) for Water Quality and Treatment operated for 13 years as Australia's national drinking water research centre. It was established and supported under the Australian Government's Cooperative Research Centres Program.

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The research in this document was conducted during the term of the CRC for Water Quality and Treatment and the final report completed under the auspices of WQRA.

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