Ozone and Biological Filtration for Algal Metabolite Removal in Australian Waters

Dr Craig Jakubowski, Dr Yaode Yan
Hunter Water Australia
Outline

- Treatment methods for removing algal metabolites
- Ozone and biological filtration for drinking water treatment in Australia
- Pilot plant case study
- Full-scale upgrade case study
Algal Metabolites

- Algal blooms are a common issue for surface waters in Australia and more prevalent in dryer warmer conditions

- Problem algal metabolites
  - Common taste and odour compounds, i.e., geosmin and 2-methylisoborneol (MIB)
  - Cyanotoxins, including saxitoxin
Treatment Methods

- Powdered activated carbon (PAC) – the most commonly used
Conventional Treatment - PAC

- Most common approach in Australia
- Not an operator’s best friend
- Dirty
- Manual handling
- Good for short events
- Costly for long duration events
- Effect of background NOM
Granular activated carbon (GAC)

- Effective, but adsorption capacity can be exhausted within weeks depending on background NOM concentrations
- However, GAC particles with honeycomb structures can be turned into biological activated carbon (BAC) for biological filtration
Advanced Treatment

- Ozone and BAC
- Advanced Oxidation Processes (AOPs) involving hydroxyl radicals, e.g.,
  - Ozone/H₂O₂
  - UV/H₂O₂
Mainly for algal metabolite removal
  - i.e., taste and odour, algal toxins
  - However, there has been increasing interest for use to enhance THM reductions

16 Ozone/BAC plants in operation for drinking water treatment
  - 14 use tertiary ozonation
  - Only 2 use intermediate ozonation

Designs are largely based on European design principles, in particular, France
HWA has undertaken numerous pilot scale studies of ozone and biological filtration, e.g.,

- Armidale WTP, Armidale Dumaresq Council, NSW
- Grahamstown WTP, Hunter Water Corporation, NSW
- Gold Coast City Council, Qld
- North Pine WTP, Brisbane Water, Qld
- Teddington WTP, Fraser Coast Regional Council, Qld
- Toowoomba Regional Council, Qld
- Huia WTP, Watercare, NZ
Pilot Plant Case Study – Armidale WTP

- 40 ML/d serving 25,000 people
- Conventional process with PAC (up to 80 mg/L)
- Algal blooms – twice/year, up to 6 months – some years more often than not
- *Anabaena circinalis* (now *Dolichospermum circinale*) up to 4 x 10^6 cells/mL
- Geosmin - 1,000 ng/L measured
- Consistent customer complaints
- Linkage of liver damage to a *Microcystis* bloom in the 1980s
Project Objectives

- Provide a robust barrier for taste and odours and cyanotoxins
- Barrier to be a continuous process
- Eliminate PAC dosing
- Reduce demands on operators, particularly time and OH&S
- Provide upgrade capacity for future growth in treated water consumption
Pilot Testing Findings

- Ct of 0.45 mg.min/L achieved 10 - 80% and 65% removal of spiked MIB and geosmin, respectively
  - Up to 1,000 ng/L MIB removed when combined with 15 min EBCT BAC
- Ozone reduced 2,700 ng/L naturally occurring geosmin to 70 ng/L with BAC filtration further reducing to 5 ng/L
- BAC alone with 15 min EBCT capable of removing up to 350 ng/L of MIB and geosmin and 15 µg/L saxitoxin
- Ct values of 2 and 3 mg.min/L were recommended for effective destruction of saxitoxin levels of 25 µg/L and 60 µg/L, respectively with no toxic by-products
Spiked MIB

Ozone Dosed at 1.5 mg/L, 4.5 min contact time, 0.1 mg/L residual
Naturally Occurring Geosmin - Ozonation

- Raw water with high natural levels of geosmin collected, coagulated and settled in 10 kL tank
- Dissolved geosmin > 2,500 ng/L
- 6 mg/L ozone dose and 5 minute contact time before deozonation with sodium thiosulphate

<table>
<thead>
<tr>
<th>Natural Geosmin (ng/L)</th>
<th>Ozonated (ng/L)</th>
<th>Filter 1 (Wood, 10min EBCT) (ng/L)</th>
<th>Filter 2 (Wood, 15min EBCT) (ng/L)</th>
<th>Filter 3 (Coal, 15min EBCT) (ng/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,740</td>
<td>69</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2,600</td>
<td>60</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>
Spiked Saxitoxin - Ozonation

Saxitoxin Destruction By Ozonation

Saxitoxin (ug/L)

Ct (mg.min/L)

Saxitoxin Spike Post Ozonation

Saxitoxin Spike  Post Ozonation
## Saxitoxin Removal – BAC Filtration

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Saxitoxin Spike Level (ng/L)</th>
<th>Filter 3 (15 min EBCT) (ng/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>8.2</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>30</td>
<td>9.1</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>45</td>
<td>16.1</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>60</td>
<td>14.4</td>
<td>&lt; 0.2</td>
</tr>
</tbody>
</table>
Other Pilot Plant Findings

- No significant difference in performance between coal and wood-based GAC
- 15 min EBCT BAC better than 10 mins
- No bromate formation issues
- Other Benefits
  - ~30% DOC removal
  - ~33% reduction in post-Cl₂ dosing and 72% reduction in THMs
WTP Process Flow Diagram

- Malpas Dam
- Inlet control valve
- Flocculators
- Static mixer
- Sedimentation tanks
- Settled water channel
- Filter inlet channel
- BAC filters
- Elevated backwash storage
- Ozone generator cooling
- Reticulation network
- Clear water storage
- Alum
- Polymer
- Contactor feed well
- Air scour
- Filtered water channel
- Ozone reactor
- Ozone destructor
- Static mixer
- Ozonated water pumps
- Ozone contactor
- Sidestream booster pumps
- Spent backwash water
- Sludge lagoons
- Chlorine
- Fluoride
- Soda ash
Ozone System

- 2 x ozone generation trains each featuring air compressor, dryer, ozone generator
- 2 x Wedeco SMA600S each producing 2.8 kgO$_3$/hr at 40 gO$_3$/Nm$^3$ at 70 Nm$^3$/hr. Equivalent to 3 mg/L at 22.5 ML/d.
- Statiflo DN600 inline static mixer and duty/standby GDS
- Wedeco thermal/catalytic ozone destructor
- 3 x ozonated water return pumps
BAC Upgrade

- Initial assessment of filters – media, structure and backwashing
- Filter floors, nozzles, air scour pattern and underdrains inspected prior to new media installation
- Same ES GAC as original sand
- EBCT at 22.5 ML/d = 10 mins
- EBCT at 14.9 ML/d (95th percentile) = 15 mins
Outcomes

- Commissioned in January 2009
- No customer complaints experienced during algal events
- Operators now on day-shift only. No longer require 24-hour manning of plant.
- Reduction in plant chlorine dosing requirements
- No cyanotoxin challenge to date
- PAC system mothballed and to be decommissioned
Summary

- Ozonation and biological filtration was found to be effective for algal metabolite removal.
- Pilot plant investigation has led to a successful upgrade of Armidale WTP.
- Important design parameters:
  - Ozonation: Ozone dose and contact time, or Ct
  - BAC: Empty bed contact time (EBCT)
Acknowledgements

- Armidale Dumaresq Council
- Colleagues at HWA