INVESTIGATION INTO ALTERNATIVE METHODS OF TREATING AN ALGAE CONTAMINATED WATER SUPPLY

Paper Presented by:

Paul Thompson

Authors:

Paul Thompson, *Manager, Process & Operations,*
Hunter Water Australia Pty Limited

Mike Brooks, *Senior Engineer Utilities,*
Armidale Dumaresq Council

3rd Annual WIOA NSW Water Industry Engineers & Operators Conference
Tamworth Regional Entertainment & Conference Centre
31 March to 2 April, 2009

INVESTIGATION INTO ALTERNATIVE METHODS OF TREATING AN ALGAE CONTAMINATED WATER SUPPLY

Paul Thompson, *Manager, Process & Operations,* Hunter Water Australia Pty Limited
Mike Brooks, *Senior Engineer Utilities,* Armidale Dumaresq Council.

ABSTRACT

Following on from a small scale investigation in June 1998, when water from Armidale was put through an offsite pilot plant, Hunter Water Australia (HWA) entered into an agreement with Armidale Dumaresq Council in September 1998 to determine the preferred long term treatment strategy for treating water from the Council's Malpas Reservoir. The supply from this reservoir is affected by algal blooms, especially during the summer, and the Council were looking for a treatment process that would effectively and reliably remove organic contaminants such as algal toxins and taste and odour compounds from the water.

After undertaking a process audit on the operation of the existing plant and reviewing the literature on possible alternative treatment processes, both in Australia and abroad, HWA installed a pilot plant at the Water Treatment Plant (WTP). This plant was designed to treat either filtered or settled water from the WTP. Ozone was added to these streams and the ozonated water was then passed through a biological activated filter (BAC). The water quality parameters resulting from the different processes were analysed and compared for effectiveness. As a result of these tests, coupled with an engineering, economic and risk evaluations of the alternatives, the construction of a secondary ozonation and BAC plant was recommended.

1.0 INTRODUCTION

For a number of years prior to 1998, the Armidale Water Treatment Plant (WTP) had been dealing with water contaminated with compounds caused by blue-green algae (cyanobacteria) that at times exceeded a million cells/ml. Although the processes used which included the application of algaecides, destratification and dosing with powdered activated carbon (PAC), were generally successful they were time consuming and expensive. Occasionally, when the algal count reached an exceptionally high level or for operational reasons treatment was less than optional, taste and odours were not totally controlled and customer complaints were received. As Armidale has a thriving tourist industry Council was concerned that a major breakthrough would lead to adverse publicity with the potential for a severe detrimental affect on the number of people visiting the region.

Armidale Dumaresq Council needed to find a long term solution that would deal with almost any eventuality, whilst reducing ongoing operational costs, lessening the workload on the plant operators and minimising the chance of any organic contaminants affecting the quality of the final product.

2.0 DISCUSSION

2.1 Review of Existing Plant Operations

As part of the project HWA undertook an in-depth analysis of the various treatment processes utilized at the WTP. Whilst this provided a vital background to the work undertaken on the pilot plant its prime purpose was to optimise the operation of the existing plant.

The rationale and findings of that investigation, which led to improvements in PAC, alum, polyelectrolyte and chlorine dosing as well as automation of filter backwashing and the provision of online instrumentation, are not included this paper.

2.2 Review of International Literature

A literature review was undertaken to access the latest information on organic contaminants, particularly cyanobacteria, algal toxins and taste and odour compounds. It was considered that this was the best way to provide a sound technical basis for subsequent work on the ozone/BAC investigation program.

The literature review revealed that the main methods used to remove taste and odour compounds from raw water are dosing with PAC, chemical dosing (for example potassium permanganate or chlorine) and ozonation. As noted the first method was already in use in Armidale and the second was considered impractical for a number of reasons. However, the review showed that the combination of ozonation and biological activated carbon (BAC) filtration is a relatively common process used in Europe and North America for the removal of natural organic material. Although the use of this process for removal of taste and odour and algal toxins is a relatively new application for this technology, there was evidence that geosmin and 2-methylisoborneol (MIB), both major components of taste and odour problems, could be successfully removed. All of the evidence indicated that the use of a pilot plant to treat Malpas water would provide the information required to make recommendations for a full scale plant.

2.3 Ozone BAC Process

Ozone BAC is a two stage process that consists of ozonation (injecting ozone into water and allowing it to stay in contact for a predetermined time), followed by filtration through a bed of biological activated carbon. If the process is retrofitted into an existing plant a pumping stage is required either before or after ozonation.

The primary reactions involved in the ozonation stage include the break down of complex organic carbon matter present in the water into simpler molecules that are readily biodegradable. This biodegradable matter supports the growth of micro-organisms in the granulated activated carbon (GAC) filters. The biological system established on the media converts the GAC filter media into a BAC filter that combines adsorption, filtration and biological action to remove contaminants.

2.4 Pilot Plant

The pilot plant used for the study included ozone generation equipment, an ozone contactor and three filter columns. The pilot plant was used to simulate and investigate two distinct process configurations as shown in figures 1(a) and 1(b) below. Although the main focus of the investigation was tertiary ozone BAC it also looked at results from a secondary ozone BAC process.

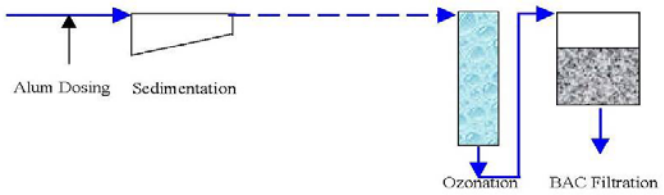

Figure 1: ***Secondary Ozone BAC process Configuration***

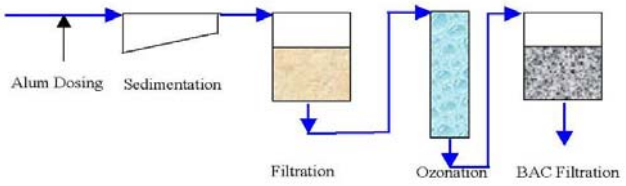

Figure 2: ***Tertiary Ozone BAC process Configuration***

Feed water for the pilot plant was sourced from the existing WTP either settled water (prior to filtration) or filtered water (post filtration) at a rate between 70 – 120L/hr for the whole plant.

Ozone was generated using a small-scale ozonator calibrated for a maximum output of 10 g/hr. The ozone was injected using a PVC injector driven by a feed pressure of 5 Bar and an outlet pressure of 1 Bar. The cylindrical ozone contactors, 150mm diameter and 4.5 metres long, were constructed from clear polycarbonate, with PVC end plates and O-ring seals. The ozone contact time was 4.5 minutes.

The ozonated water was then fed to three filter columns in parallel, each containing 2.0 metres of GAC. Filters 1 and 2 used a wood based PICABIOL GAC whilst filter 3 used James Cummings and Sons coal based GAC. The former has been used extensively for biological filtration with proven full scale applications, whilst the latter was chosen partly because a coal based product should have superior organic contaminant removal and partly to gain experience in a locally sourced product.

The pilot plant was contained within a standard 20 foot shipping container which consisted of the feed pumps, air preparation, ozone generator, ozone contactors and the BAC filters as shown in Figure 3.

Figure 3: ***Ozone Pilot Plant***

2.5 Investigation Program

An investigation program was developed jointly with Armidale Dumaresq Council to ensure that all of the project objectives would be met.

The pilot plant was operated between December 1998 and April 2000. Turbidity, head loss and ozone residual were monitored daily and recorded on the pilot plant log sheets.

Ozone was dosed at 1.5 – 1.7 mg/L and the filter columns were operated with an empty bed contact time (EBCT), a measure of the capacity of each filter, of 10 minutes for filter 1 and 15 minutes for filters 2 and 3.

Feed, ozonated and BAC filtered water samples from the pilot plant were tested for a number of organic contaminants. Jar tests were performed on some samples to determine the effect on post-treatment chlorine demand. Specific water quality parameters included: dissolved organic carbon (DOC) and total organic carbon (TOC); biodegradable dissolved organic carbon (BDOC); algal toxins (spiked saxitoxins); taste and odour compounds (spiked geosmin and MIB as well as natural geosmin levels); turbidity; true colour; metals; biomass balance and chlorine demand.

2.6 Summary of Results

Only the results from the secondary ozonation BAC process, i.e. using settled water as the feed, are discussed here as they became the key to the final design and present Armidale Dumaresq Council with the most cost efficient means of upgrading the WTP.

The ozone dose for the secondary process was 1.7 mg/l which resulted in an ozone residual of 0.11 mg/l at the contactor outlet, indicating complete oxidation of organic material. The disinfection residual-time product, CT was 0.45 mg.min/L.

Table 1: ***Average turbidity and colour of ozone treated water from the pilot plant***

Sample Point	Average Turbidity (NTU)	Average Colour (HU)
Feed Water (Settled)	1.14	19
Post Ozonation	0.87	11
F1 – PICABIOL (wood) EBCT = 10	0.18	1.6
F2 – PICABIOL (wood) EBCT = 15	0.16	1.4
F3 – JCS (coal) EBCT = 15 mins	0.13	1.2

The incoming settled water turbidity ranged between 0.5 and 2.6 NTU with ozone BAC filtration resulting in a final turbidity ranging from 0.13 to 0.27 NTU. The target maximum for the study was 0.3 NTU. The colour of the settled water ranged between 2 and 35 HU. The ozone BAC process proved to be very effective in reducing colour, consistently reducing the levels down to between 1.1 and 1.5 HU.

Metals: The ozone BAC process demonstrated very effective removal of aluminium and manganese. Incoming total aluminium levels of between 152µg/L and 85µg/L were reduced by ozonation at a C_t value of 0.45 mg.min/L by a significant amount (49%) to 61µg/L. BAC filtration resulted in a further 59% reduction to 25µg/L. Similarly manganese in a concentration of 39µg/L was reduced to 18µg/L and then to below 10µg/L by ozonation and BAC filtration. The water from filter 3 contained only 4µg/L total manganese.

Total Organic Carbon: The reduction in total organic carbon varied over the 15 month period of the investigation. The conclusion was that the initial higher TOC removal rate

was due to the adsorptive capacity of the GAC. However, when this was exhausted the coal based filter 3, with an EBCT of 15 minutes, still achieved a respectable 31% reduction rate.

MIB and Geosmin Removal: The performance of the pilot plant in removing taste and odour compounds was tested by spiking the feed water with MIB and geosmin. MIB was tested at three different levels, i.e., 230 ng/L, 550 ng/L and 1100 ng/L. Each MIB spiking trial was undertaken for a period of 24 hours and the results are shown below.

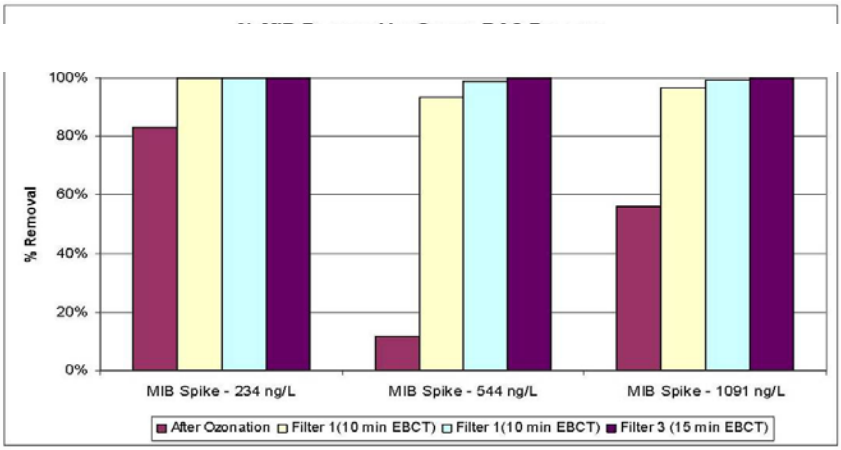

Figure 4: ***Percentage MIB removal by Ozone BAC process***

As can be seen ozone treatment by itself had little impact on MIB at the higher concentrations. However, the coal based GAC filter 3 was able to achieve 99.8% removal rates.

Similarly BAC filtration after ozonation was able to reduce spiked laboratory grade geosmin from up to 1039 ng/L down to 1 ng/L. Natural geosmin removal was investigated by treating Malpas Dam water containing high levels of natural geosmin. The water was settled in a 10,000 litre tank and then fed into the pilot plant. Using a much higher dose of ozone, 6.0 mg/L, then followed by deozonation to protect the filters, natural geosmin levels of 2600 ng/L were reduced to 2 ng/L.

Saxitoxin Removal: Saxitoxin is an intracellular neurotoxin found in several species of cyanobacteria that has been identified as having potentially adverse effects on human health. The destruction of saxitoxin by ozone was investigated by using a small scale bubble contactor and ozonator. This provided 94% destruction at higher levels of saxitoxin. A further test was carried out to determine the reduction in saxitoxin by BAC filtration alone. This was even more effective than ozone treatment achieving 100% reduction at all levels tested.

***Cryptosporidium*:** This is a parasitic protozoan that can cause serious public health events when an outbreak occurs in municipal water supplies. It is resistant to many methods of disinfection commonly used in water treatment. Using a CT value of 4 mg.min/L ozonation was found to achieve complete inactivation of 5000 oocysts/L of *Cryptosporidium*.

Chlorine Demand and By-products: The investigation showed that as well as the reduction or elimination of the main adverse parameters effecting the water treatment process there were other beneficial side effects. Chlorine jar tests were undertaken on Armidale filtered water and treated water from each of the BAC filters. These indicate

that ozone BAC treatment significantly reduced the normal system chlorine demand with filter 3 recording the highest reduction of between 20% and 50%. In addition by-products from disinfection, trihalomethanes, were reduced by 72% as compared to filtered water from the WTP.

2.7 Engineering and Economic Analysis

The report on the pilot plant work included an engineering feasibility and cost analysis based on the use of the tertiary treatment process. Capital cost estimates were provided for upgrading the PAC dosing facility and for the renovation of four of the plant's eight filters and the installation of all works necessary for the implementation of an ozone treatment plant. Operating cost of both options were estimated for varying periods and severity of algal blooms in the reservoir, and the net present value (NPVs) over a 20 year period assessed.

2.8 Recommendations and Further Actions

Based on the above analyses the report noted that there were considerable benefits in adopting ozone BAC to treat Malpas Dam water and that if implemented it would place Armidale as leaders in the provision of high quality water and in dealing with the water quality risks facing the community.

In February 2004 a risk workshop was held that included supervisors and operators from Armidale Dumaresq Council, a representative from HWA and water industry experts. This workshop compared the cost and benefits of the various treatment options presented in the report and concurred with the conclusion that treatment using ozone provided a clear advantage over enhanced PAC dosing while at the same time enhancing the reliability of the treatment process. However, evidence presented to the workshop showed that a secondary treatment process, passing settled water through the ozone plant and converting all of the filters to BAC filters, provided considerable cost savings over the tertiary process recommend by the report without having any adverse effect on final water quality. This was therefore the option selected.

Following the workshop HWA undertook a redesign of Armidale's existing sand filters and in 2006 they were replaced with GAC filters was undertaken by in-house resources. Then in 2007 contracts were let for the construction of an ozonation plant and for the replacement of the plant's existing PLC with a Siemens based PLC/SCADA system.

3.0 CONCLUSION

The investigation into possible options for treating toxins and taste and odour problems arising from algal blooms in Malpas Reservoir was extensive and thorough. The willingness of Armidale Dumaresq Council to be guided by the report and invest in modern technology to protect their water supply has led to the construction of an up-to-date facility that vastly improves the operator's ability to control problems as they arise. Although at the time this paper was submitted there was insufficient operational data to validate the results of the pilot plant investigation, it is anticipated that the facility will prove to be a valuable long term asset.