DROUGHT-INDUCED TREATMENT CHALLENGES AT WHITE SWAN WATER TREATMENT PLANT

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71st Annual Water Industry Engineers and Operators' Conference
Bendigo Exhibition Centre
2 to 4 September, 2008

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ABSTRACT

Water storages have reached record low levels across the Ballarat region in summer 2007/2008, dropping below 10% in White Swan Reservoir. Resultant and unprecedented algal growth presented reservoir management and treatment challenges. Various powdered activation carbon varieties and doses were also trailed and achieved reasonable success at lowering filtered water 2-Methylisoborneol (MIB) and geosmin levels produced by the algae. Jar testing was successfully used to forecast that no significant changes in chemical dosing were required in moving to the bottom reservoir offtake. The Goldfields Superpipe has begun to augment Ballarat water supply as of late May 2008 as a drought-response measure. Jar testing again proved invaluable in assessing the treatment capacity and any changes required due to this complex new water source. Initial results show, the water appears treatable within the capacity of the existing White Swan Treatment Plant.

KEY WORDS

White Swan, PAC, Geosmin, MIB, *Phormidium*, Manganese, Superpipe, Jar Testing.

1.0 INTRODUCTION

1.1 Taste and Odour Compounds and Sources

Like much of Australia and in particular Victoria, water supply levels in Ballarat have been steadily declining over the last 10-20 years. This has brought about new challenges for drinking water treatment management during summer in early 2008 at the 65 ML/d White Swan Water Treatment Plant (WTP). United Water (UW) operates six WTPs in the Ballarat area and supplies potable water to the regional water authority, Central Highlands Water (CHW). Along with Lal Lal WTP and Ballarat West disinfection station, the White Swan supplies Ballarat, Ballan, and Creswick townships with a combined population of approximately 100,000. The White Swan reservoir is a 14 GL off-stream storage managed by CHW.

Taste and odour compounds, predominantly 2-Methylisoborneol (MIB), have been detected at White Swan in much high numbers than previously experienced, requiring unusually prolonged Powdered Activated Carbon (PAC) dosing. MIB causes a musty taste and odour, and the other taste and odour compound geosmin causes an earthy smell. The human detection threshold is generally accepted to be around 10 ng/L for combined geosmin and MIB (NHMRC & NRMMC 2003), necessitating significant treatment to manage water quality for the benefit of customers.

MIB and geosmin are typically excreted from various microorganisms living in water or sediment. Common varieties include the planktonic species *Anabaena*, *Pseudanabaena,* and the benthic cyanobacteria *Phormidium* or *Oscillatoria.* Taste and odour compounds can also be produced by *Actinomycete* bacteria in the shallow water sediments. The process can be accelerated by warm weather conditions, high organic carbon food sources and sunlight, explaining why algae often bloom in summer.

Identification of these organisms and confirmation of taste and odour production presents a challenge to water operations globally. MIB and geosmin producing organisms are prolific in many reservoirs throughout South Australia, e.g. the MIB-producer *Phormidium* was detected in 2000 in the shallow Upper Paskeville Reservoir on Yorke Peninsula (Baker *et al.*, 2001). MIB and geosmin have also been detected in many lakes in Southern USA for a number of years (Izaguirre *et al.*, 1982).

1.2 Powdered Activated Carbon Treatment

PAC has been used to removed taste and odour compounds globally since the mid 1970s, and was officially approved in Australia in 1983 (NHMRC & NRMMC, 2003). It is produced by heating carbon rich material such as coal, wood or coconut shells, to high temperatures in the presence of steam. The final product is a complex structure of carbon particles with very high surface area (order of 1000 m^2/g), differing pore sizes (diameter in the order of 15-30 μm), and charged surfaces to attract and physically entrap MIB and geosmin molecules. PAC is dosed as a slurry (typically 10-20%) into the raw water before the main treatment plant to give it time to mix (10-30 minutes typically required). PAC and trapped compounds then can be filtered out by conventional water treatment filters (e.g. Dissolved Air Flotation Filtration units at White Swan WTP). Different varieties of PAC are available in Australia and are generally coal-based, due to their higher quality structure and production.

1.3 Jar Testing

The effectiveness of different PAC varieties can be determined by Jar Testing. This involves adding different concentrations and varieties of carbon to samples of water and measuring the taste and odour either by external lab (MIB/geosmin) or smelled for quick operational results. Declining reservoir levels at White Swan have meant that water now has to be sourced from the lowest offtake. Due to the tendency for a reservoir to stratify and create layers of different chemistry, it was thought there may have been higher levels of manganese, iron, colour and turbidity in the raw water at this depth. A more sophisticated form of jar testing was therefore used to simulate the WTP on a lab scale. This involves adding various doses of the coagulant aluminium sulphate (alum) and coagulant aid (polymer) to 2 L vessels, stirring to simulate coagulation and flocculation, followed by settling and filtering through filter paper. By plotting key parameters versus dose rates, minimum doses to meet contractual limits can be estimated.

2.0 TASTE AND ODOUR PROBLEM IDENTIFICATION

There have been two taste and odour incidents previously since the WTP came online in 2000, which have involved low levels of predominantly geosmin and some MIB (10-15 ng/L total). CHW employed a temporary aeration installation in the reservoir from October 2007 in an effort to control manganese as the reservoir drew down. A permanent installation was commissioned on 2 January 2008 which provided a significant increase in aeration Shortly after this taste and odour was detected in the water supply and PAC dosing commenced. Levels of up to 70 ng/L MIB, and virtually undetectable geosmin, were recorded in the raw water. Microbiologists from United Water's Research and Development group set out to identify the source of the outbreak. Previously 10 mg/L was adequate at removing geosmin and MIB. Therefore 20 mg/L was utilised as an initial dose until test results were received. United Water's senior microbiologist, Dr Rasmussen, investigated historic algal counts to assess what may be the cause of the outbreak.

Likely candidates for potential MIB production were identified as *Pseudanabaena* or *Actinomycete* bacteria (due to unvegetated exposed banks and shallow water shorelines). In January a net tow of the reservoir was organised and samples analysed via Polymerase Chain Reaction (PCR) at the Australian Water Quality Centre (AWQC) to see whether any planktonic MIB-producing algae were currently present. The results were negative.

In the meantime, it was identified that an area around the reservoir had a particularly high concentration of MIB (300 ng/L). This was most likely due to it being partially blocked from the main water body having shallow sections providing adequate sunlight for benthic algae growth. Evidence of cyanobacteria matching the description of *Oscillatoria* or *Phormidium* was reported by the CHW reservoir keeper. Further investigative work was undertaken by taking soil sediment samples around the periphery of the reservoir, including the aforementioned area. These were analysed by AWQC in February. After several weeks of culture development and complex specialist analysis, it was found that snake-like cyanobacteria filaments were present, typical of *Phormidium, Pseudoanabena,* or *Oscillatoria*. Further analysis from a scum sample taken on the reservoir in March confirmed that *Phormidium* was dominant. The unprecedented growth of cyanobacteria of this nature is most likely due to the very low reservoir levels (bottomed out at 7% in April) leaving previously unexposed banks and shallow waters to sunlight leading to warmer waters and better growth conditions. The emergence of thin benthic mats at low levels in the reservoir compounded this effect further. More algae sampling was undertaken by UW prior to White Swan treating Goldfields Superpipe water and found that no significant quantities of MIB or geosmin-producers were present.

3.0 TASTE AND ODOUR REMOVAL RESULTS AND DISCUSSION

White Swan has 9-32 minutes contact time for PAC absorption. See Figure 6 for a history of PAC variety, dose rate, and performance over time when the WTP was online until 1 July.

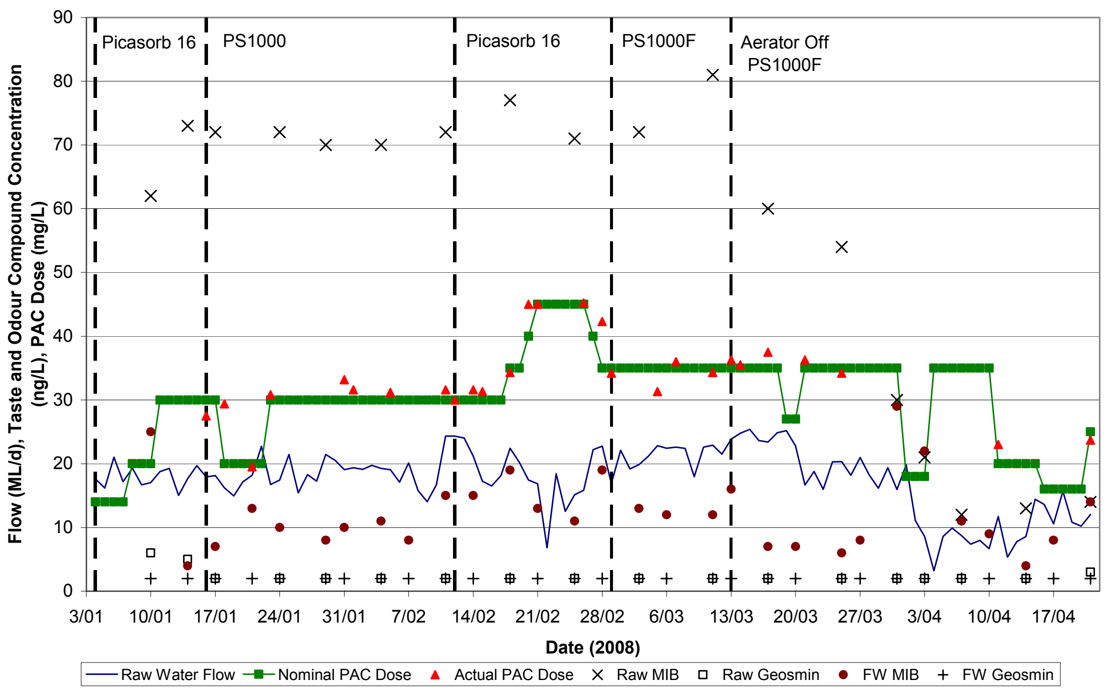

Figure 6: ***Powdered Activated Carbon dosing and MIB/geosmin removal performance.***

UW's Adelaide operations recently had success using the PS1000 for treatment of geosmin. Given the similar molecular size, it was thought that this would be adequate at capturing MIB and geosmin. However, throughout the process the results were mixed. MIB levels were able to be reduced by approximately 80%, but not below the 10 ng/L odour threshold. After the limited success of the PS1000, the remainder of Picasorb 16 originally available on site was trialled at a higher dose. This performed worse than the PS1000 at lower doses. A finer variety (half the effective pre size of PS1000), PS1000f was finally trialled to similar success to the PS1000. These are all coal-based varieties of slightly varying size and structures.

Due to the numerous PAC varieties available and recommended from Adelaide operations, several were jar tested; from Activated Carbon Technologies, the varieties PS1300, PS1000, and PS1000f; from Pica the variety Pica sorb 16. Dosed concentrations of 20, 30, and 40 mg/L were made up in fresh raw water samples in a glass jar. They were stirred thoroughly and smelled for odours. All samples contained strong odours at 20 mg/L. At 30 mg/L, some of the odour had dissipated from the PS1000f and Pica sorb 16. At 40 mg/L, all appreciable odour had been removed from each sample. As can be seen from Figure 6, results were moderately successful with the Pica sorb 16 and PS1000/PS1000f varieties in the 30-40 mg/L dose range. The PS1000f was deemed to be best for MIB removal and was used for the remainder of the period.

In March it was decided to turn off the aerators at the risk of stratification and release of manganese from the reservoir sediment during anaerobic conditions. This did not result in significant soluble manganese increases in the raw water and hence potassium permanganate dosing was not needed. Turning the aerators off resulted in a steady reduction of raw water MIB over a 3 week period. This was most likely due to the aerators previously stirring up MIB from the sediments to the nearby bottom offtake (the only one submerged at this time), which is only 3 metres from the reservoir floor.

4.0 MANAGING RESERVOIR LEVEL CHANGES

To forecast any major changes in chemical dosing (primarily alum) in changing to the bottom offtake, raw water samples were taken at depth using a pump hung off the boat on the reservoir. Various doses were trialled whilst keeping the coagulant aid dose constant at the concurrent WTP dose rate. See Figure 7 for results. The results showed that adequate colour and turbidity removal below compliance limits of 5 HU and 0.2 NTU, respectively, was possible at a minimum of approximately 50 mg/L alum. After the switchover on 4 March, however, a dose of approximately 75 mg/L was required to minimise particle counts (particle counts are a surrogate for detecting oocysts and cysts of pathogenic protozoa such as *Cryptosprodium* and *Giardia* at 3-12 μm).

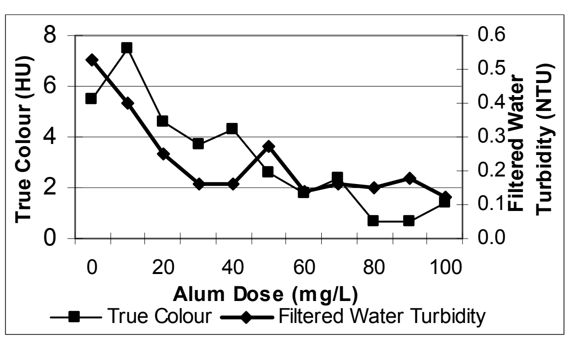

Figure 7: ***Jar test results offtake 4 (raw turbidity 4.2 NTU, colour 5.5 HU, UV_{254} 0.11 cm^{-1})***

5.0 INITIAL SUPERPIPE JAR TESTING RESULTS

Ballarat, Ballan, and Creswick's water supply would have come under serious pressure this summer if it was not for CHW's Superpipe coming online on 19 May. The pipe feeds water from any one of the following sources: Goulburn-Murray system (pumped out of the Western Waranga Channel at Colbinabbin), Lake Eppalock, and Sandhurst Reservoir (which will have predominantly either of the above waters in it). Extensive risk assessments were conducted by CHW and all stakeholders. United Water believed it critical to jar test these major two sources of water in advance to initially identify any major changes required in the treatment process. See Figure 8 for results. Again, coagulant aid polymer was kept constant. Table 1 shows the differences between the new Superpipe water sources and background White Swan raw water quality.

Table 1: ***Ranges of key water quality parameters with Superpipe (Jul 07 – Jun 08)***

Parameter	White Swan	Lake Eppalock	Waranga Channel
Turbidity (NTU)	0.5 – 20	4 – 40	24 – 62
Colour (HU)	5 – 14	20 – 45	10 – 35
pH	6.6 – 8.6	7.6 – 7.9	7.3 – 8.1
Alkalinity (mg/L as $CaCO_3$)	48 – 70	40 – 60	10 – 20
Manganese (total, mg/L)	0 – 0.21	0.2 – 1.1	0.008 – 0.016
EC (µS/cm^2)	240 – 330	540 – 1100	74 – 130

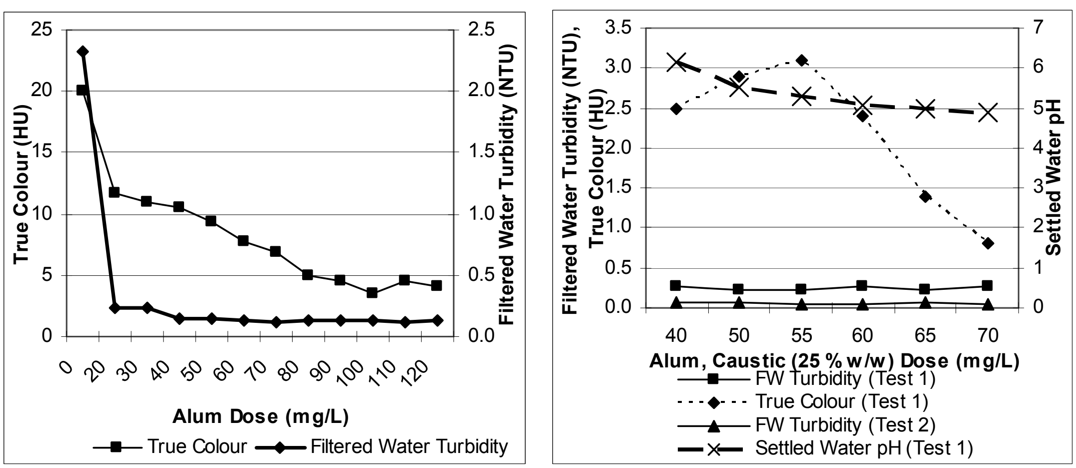

Figure 8: ***Jar test results of Lake Eppalock (left, raw turb. 7.1 NTU, colour q 20 HU, UV_{254} 0.22 cm^{-1}), Waranga Channel (right, raw turb. 27.4 NTU, colour 40 HU, UV_{254} 0.14 cm^{-1})***

The results showed that water from Lake Eppalock was readily treatable at similar alum dose rates to the current plant. The limiting factor was true colour removal, which required at least 80 mg/L. This was likely due to the relatively higher amounts of organic carbon than Waranga Chanel (c.f. UV_{254} absorbance of 0.22 versus 0.14 cm^{-1}, respectively). Initial tests on Waranga water revealed that although colour was easily removed (even though it was twice that of Lake Eppalock), turbidity removal to 0.2 NTU was not achievable at any dose rate tested. Inspection of the pH trend quickly showed that this was likely due to sharp drop in pH below the normal optimal range of 6.0 – 6.3 brought about by the very low buffering capacity of the water (c.f. alkalinity 17 versus 37 mg/L as $CaCO_3$ as with Lake Eppalock). Using the best dose rate of 50 mg/L alum from the first test, a second test at varying degrees of sodium hydroxide doses (using 25% w/w caustic soda) demonstrated that adequate turbidity removal could be achieved at any of the doses tested (lime is used at White Swan, with a dose equivalence of approx 1:1). This prompted operators to reinstate a pre-lime dosing point prior to alum dosing in order to optimise coagulation pH. A recently installed dosed water pH meter now also assists operators in providing real-time coagulation optimisation. Further jar testing of White Swan water with Superpipe water in it was carried out in June along with a test run of the WTP discharging filtered water back to the reservoir prior to the WTP's reinstatement and water being delivered to customers on 1 July. So far, water from the Superpipe has doubled the reservoir storage volume without short-circuiting to the offtake and operators have been able to successfully treat the water without the need of pre-coagulation lime.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The drought and subsequent low reservoir levels at White Swan have provided UW operations with many challenges in 2008. PAC was successful at removing 80% of the taste and odour compound MIB and all geosmin in filtered water samples. The source was most likely the cyanobacterium *Phormidium*. For summer 2008/2009 it is recommended that the aerators are turned on late September and kept on throughout summer to slow the growth of such bacteria through the warm months. Algal monitoring should also be initiated at this time to forecast any similar blooms. The Superpipe will increase reservoir levels to a more amenable state such that less banks are exposed and sunlight is attenuated. This is likely to result in less potential benthic cyanobacterial growth. Time will tell if the altered water input will favour the growth of *Phormidium* or other problematic cyanobacteria. This may be affected by the slow rate of fill in the reservoir, or the transfer of new algae and cyanobacteria from upstream sources.

Jar testing successfully demonstrated that present coagulant dose rates were suitable for treating water in the bottom layer of the reservoir, and the various Superpipe sources at this point in time. The lower alkalinity from Waranga will provide operators with challenges to closely monitor lime doses and pH response. Continual monitoring and communication protocols are needed to further solidify the treatment barrier.

7.0 ACKNOWLEDGEMENTS

The author wishes to thank Dr Paul Rasmussen for leading the microbiological investigations, Chris Perks (CHW) for boat trips on the reservoir, James Morrison for PAC jar testing results, and Jason Marnell for providing an 'enjoyable' PAC-batching opportunity.

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