LESSONS LEARNED FROM 20 YEARS OF BAC FILTER OPERATIONS

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ABSTRACT

Biologically Activated Carbon (BAC) filters, combined with pre-ozonation is an effective process to remove organic contaminants from water. Whilst BAC filters are considered an advanced treatment technology, simple strategies can be used to optimise ozone-BAC filtration performance, and troubleshoot filters impacted by poor raw water quality or upstream process changes.

Veolia Australia-New Zealand (Veolia) operates three water treatment plants (WTPs) in central Victoria which all feature ozone-BAC for treatment of dissolved organics and taste and odour compounds under the AQUA 2000; a 25-year BOOT contract with Coliban Water.

Since operations commenced in 2002, the Veolia team has built a large knowledge-base on ozone-BAC operations. This paper presents and illustrates key messages for BAC management through real examples and lessons learned from over 20 years of continuous process optimisation at the AQUA 2000 sites. Particularly regarding the interaction of ozone-BAC feed water quality, BAC filter media age, and the importance of a good monitoring program on maintaining operational performance.

1.0 INTRODUCTION

Ozone-BAC is an effective process for removal of organic contaminants from water. BAC filters are essentially a form of granular media filtration, and to some degree are managed in a similar way (turbidity and headloss monitoring, backwashing and airscouring etc.). There are various strategies used to optimise ozone-BAC filtration performance, and troubleshoot filters impacted by poor raw water quality or upstream process changes.

Veolia Australia-New Zealand (Veolia) operates three water treatment plants (WTPs) in Central Victoria, all of which which feature pretreatment (coagulant and pH/alkalinity adjustment), membrane filtration, ozone-BAC and disinfection under the AQUA 2000; a 25-year BOOT contract with Coliban Water. The AQUA 2000 plants supply safe drinking water to the towns of Bendigo, Castlemaine and Kyneton, with a combined capacity of around 150 ML/d.

Since operations commenced in 2002, the Veolia team has collected a large body of knowledge on ozone-BAC operations. The discussion section of this paper gives a series of case studies that presents lessons of 20 years of continuous process optimisation at the AQUA 2000 sites.

2.0 METHODS

The following methods have been used in BAC filter operations at the AQUA 2000 sites:

- Source water (surface reservoir) monitoring is essential and includes routine inspections, reservoir sampling, depth profiling and continuous online monitoring. One-off weather events (e.g. floods), seasonal events (e.g. algal blooms, reservoir destratification) and impact of reservoir levels all play a significant role in raw water quality and hence BAC performance.

- Characterisation of raw water and ozone-BAC feed water quality, and how they relate to BAC performance. Routine sampling and testing of raw water for a range of physical and chemical water quality parameters is undertaken at the WTPs. Optimisation and online monitoring of upstream membrane and ozone process performance also provide insights for BAC operational management.
- Optimisation of BAC performance is achieved by monitoring of filter bed head loss, recovery after backwash, backwash troubleshooting. The AQUA 2000 plant SCADA control systems have been designed to continuously monitor, trend and facilitate reporting of critical BAC performance parameters such as filter flow rate, filtrate turbidity, filter head loss.
- All online BAC operational performance data can be compared with data on raw water and treated water quality, using online water quality databases.
- The Veolia team records regular maintenance activities. Records kept include filter media scrapes and replacements, backwash frequencies, backwash setpoints, and routine operator observations.
- BAC media condition and ageing profiles completed annually since 2012 to assess the physical and biological condition of the media. The combined monitoring and maintenance information enables better understanding of BAC ageing and performance.

3.0 DISCUSSION

Three case studies of how all the above-mentioned tools and techniques are brought together to manage and optimise BAC performance will be presented in this section. The case studies have arisen from operational challenges or events experienced by the AQUA 2000 team, and include:

1. Management of a T&O compound detection, 2-methylisoborneol (MIB), in the Castlemaine WTP raw water.
2. Installation of BAC covers to reduce risk of algae growth and contamination.
3. BAC process impact investigation after an ozone unit outage at the Kyneton WTP.

3.1 Case Study 1: Castlemaine MIB Detection

A T&O event at Castlemaine WTP occurred in April 2009 towards the end of the millennium drought. Low reservoir levels at the McCay storage reservoir, coupled with an onset of cooler weather and reservoir destratification resulted in high MIB detections in the raw water, thought to be linked to the bacteria *Actinomyces*. This bacteria is commonly found in reservoir sediments. Concentrations of MIB above the threshold for normal human detection (10 ng/L) were reported in the raw water over the course of 5 weeks, with a maximum reported concentration of 50 ng/L entering the WTP (Table 1).

Response and process investigations during the T&O event found that an additional 35 ng/L of MIB was being returned to the head of the plant via the supernatant return from the reclaimed wash water system. Despite these high MIB concentrations, the ozone-BAC process adequately removed MIB to maintain treated water MIB below the 10 ng/L process threshold throughout the event and no customer complaints were received.

Process modifications implemented to optimise MIB removal across plant during the event included:

- Changing the reservoir offtake level,
- Pretreatment coagulant (ACH) dosage increased to enhance coagulation of organic compounds and remove whole algae cells,
- Ozone residual set point increased for oxidation of MIB,
- Production rate decreased to allow for longer ozone-MIB contact time, and
- BAC empty bed contact time (EBCT), and BAC backwash frequency increased

(from 130 to 80 hours) to remove MIB more frequently.

MIB concentrations quickly reduced once filling operations commenced at McCay reservoir, emphasising the importance of maintaining the reservoir water level. Furthermore, the event triggered investigations into implementing a supernatant return to reservoir option for use during certain water quality events such as T&O. A laboratory BAC filter study was also conducted to simulate the effectiveness of topping up carbon to increase MIB adsorption in the full scale BAC filters. However a carbon top-up was not implemented in practice due to the short timeframe of the event and effectiveness of management implemented onsite.

Table 1: ***MIB Concentrations At and Removal Across Treatment Stages***

Castlemaine WTP Treatment Stage	**MIB (ng/L) 11/05/2009**	**MIB Removal (% of Post-CMF concentration)**
Raw Water (upon entry to WTP, before addition of reclaimed water)	32	-
Post-Microfiltration (CMF)	42	-
Post-Ozonation	17	59.52
Post-BAC	9	19.04
Post-Clear Water Storage (CWS)	9	-
Total MIB Removal (% of Post-CMF concentration)		78.56

3.2 Case Study 2: Algae Growth & BAC Cover Installation

During the early 2010's high BAC head losses at AQUA plants were observed to be gradually increasing in severity and frequency. High head losses were triggering backwashes prior to the filtration run time trigger, and caused increased backwash frequency and high wash water volumes. This led to increased load through the clarifier and sludge management system, excessive loss of biology in BAC filters (hence reduced biological capacity for removal of organics), reduced BAC filter capacity due to offline filters during backwashes, and ultimately increased operator intervention.

Visual observations indicated head losses were in part due to algae growth on the surface of BAC filters. The BAC filters are open to the atmosphere and received a lot of sunlight. Various strategies were trialled in an attempt to reduce algae growth, including hypochlorite soaks and pressure washing of filter walls and inlet channel.

The most effective method discovered was to install covers over the BAC filter beds. Shade sails were initially installed at Castlemaine in 2013, and by 2017 shade sails were installed at all 3 AQUA plants. Routine visual inspections noted less algae growth after shade cloth installation, and confirmed through reduction in BAC backwash frequency, reduction in operator intervention, and annual BAC media condition reporting.

Operability and functionality were key factors when designing and installing the BAC covers. The covers needed to allow visual observations to be carried out, and be removed for any required inspections or maintenance including annual media scrapes or replacement.

In 2021, the Kyneton BAC covers were modified from shade sails to fly screen style covers, due to the high winds experienced at the WTP and associated structural integrity and safety concerns from shade sail damage. The slip-in fly screens were designed to reduce drag and improve structural integrity, as well as continuing to provide sufficient shade coverage to inhibit algal growth and allow for easy access for cleaning and maintenance.

Figure 1: ***Bendigo WTP BACs - (L) 2011 bog ore prior to covers, (Top R) 2012 before covers, (Bottom R) 2016 during cover installation***

Figure 2: ***Kyneton BACs - (L) before covers, (R) slip-in fly screen covers***

3.3 Case Study 3: Kyneton Ozone Outage

There was an ozone process outage at the Kyneton WTP for 8 days in early 2014. Due to healthy BAC filters with good biofilm from ongoing BAC management practices, treated water quality targets were achieved and maintained throughout the ozone outage.

BAC media samples were collected immediately following reinstatement of the ozone unit (May 2014) and also 4 months later (September). When compared to the BAC ageing profile of the previous year (2013), May results indicated significant changes to manganese distribution throughout the carbon filter bed and increased bacterial growth, in particular iron and manganese oxidising bacteria. This suggested the BACs had good ability to retain iron and manganese in the biofilm and no breakthrough of these metals were detected in the treated water.

Results in September indicated an overall reduction of manganese in the media during the 4 months since ozone reinstatement (Figure 3), as well as reduced levels of bacterial counts overall (Figure 4). Organics removal across the BAC filters during both periods were similar (Table 2). It was noted that BAC head losses did not appear to be significantly affected throughout or in the months following the ozone outage, despite the significant redistribution of biology.

An outcome of the Kyneton ozone outage and investigations was the launch of a research program into how BAC filters capture and lock up iron and manganese through biological processes.

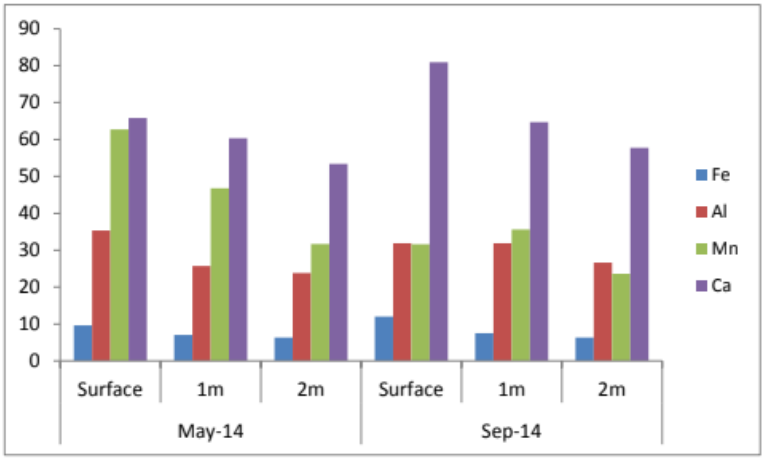

Figure 3: ***Kyneton BAC filter mineral content trends (mg/g BAC), May and September 2014***

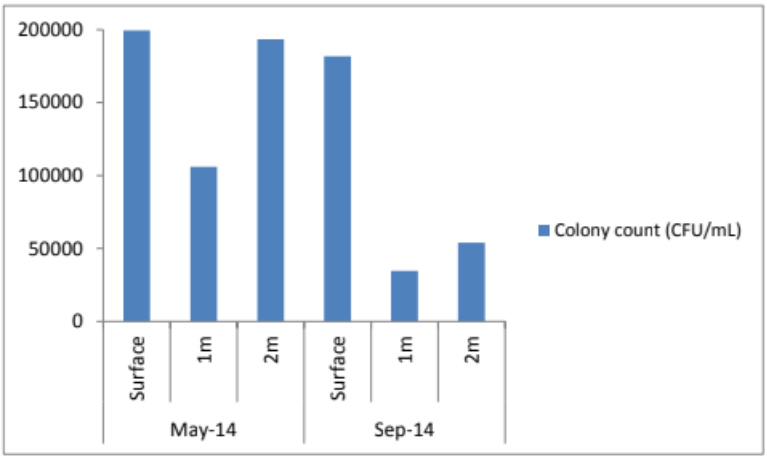

Figure 4: ***Kyneton BAC filter microbiological analysis (CFU/mL), May and September 2014***

Table 2: ***Organics treatment across BAC filter in May and September 2014***

	DOC Removal (mg/L)	BDOC Removal (mg/L)	AOC Removal (mg/L)

4.0 CONCLUSION

BAC condition monitoring and assessment is important for tracking the impact of feedwater and process conditions on the ageing characteristics and treatment performance of ozone-BAC systems. Good BAC process management requires a comprehensive system of performance monitoring, maintenance and record keeping, feedwater quality monitoring, BAC filter inspections, and BAC filter ageing profile studies.

It is important to note that source water characteristics and raw water quality is unique to each facility. Apply performance management and optimisation strategies only after you have fully investigated and understood your specific site conditions before choosing and implementing management strategies.

5.0 ACKNOWLEDGEMENTS

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6.0 REFERENCES

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