WATER TREATMENT TROUBLE-SHOOTING AND INNOVATIVE SOLUTIONS

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ABSTRACT

Despite fundamental similarities in the core processes used in the water treatment industry, every water treatment plant has its own unique characteristics. Operating philosophies are developed to optimise performance of coagulation, flocculation, settling/floatation and filtration in any given facility. It is when the typical or average conditions and quality of raw water vary significantly, that the drive to innovate to improve process capacity becomes a 'must do' rather than a 'nice to do', and where ground can be broken in order to resolve problems and bridge the gap between the theories of plant design and operation, and the reality of making it work today. Successful resolution of issues arising due to changing environmental conditions, natural disasters or other influences beyond the control or scope of plant designers, constructors and operators requires a structured approach and attention to detail. Accurate jar testing procedures combined with thorough working knowledge of plant capacity are essential, the knowledge and ideas of a wide range of people needs to be combined and one needs to think outside the box to resolve situations that are themselves outside the box of standard operating conditions.

1.0 INTRODUCTION

The unique characteristics determining how a particular process is managed and operated begin with the raw water source, its variability and vulnerability to significant change caused by natural or man driven environmental conditions. Much of a supply's variability is beyond the control of the operator, and where natural disasters occur also beyond the control of managing bodies and environmental regulators and offices such as Department of Sustainability and Environment, EPA and the Catchment Management Authority.

Over the past 17 years, I have been privileged to have been a part of a number of teams that developed and implemented some remarkable innovations in water treatment plants generating successful outcomes where raw water supplies had been adversely impacted by environmental conditions.

From an emergency event in Yarrawonga in 2002 caused by draining of Lake Mulwala for remedial works on the dam wall where manganese levels up to 0.42mg/L were observed and later in a separate event at Springhurst we saw Mn as high as 1.2mg/L. To the 2003 & 2007 bushfires which after heavy rain led to mud slides in the catchments and raw water turbidities commonly over 1000ntu and up to 4000ntu in Wangaratta and Licola, Coongulla, and Maffra. Similar turbidities were seen in a dirty water event at Moe in 2007, caused by heavy rain in an unburnt catchment predominantly occupied with potato farms that had recently been ploughed leading to significant erosion.

Each event, location and plant configuration required a different solution and had different challenges to overcome in order to maintain treated water quality. Despite the configuration of the plant, the same approach to investigating the problem and identifying solutions was used. Along the way, beyond the response actions implemented, some fairly simple safeguards and monitoring tools were identified that can be used to prevent plant failures and provide early warnings for raw and treated water quality issues.

 

Figure 1: ***Bushfire impacted catchments, Mitchell and Macalister Rivers (Vic).***

2.0 DISCUSSION

2.1 Different Problems – Same Problem Solving Method – Different Solutions

Innovations developed to overcome deteriorated water supplies were as variable as the raw water supplies impacted, however all contained one crucial element, the jar test. Procedures were assessed and re-designed at each site due to the critical need for accurate mixing times, chemical addition timing, flocculation and clarification detention times. The jar tests had to mimic the plants actual holding periods.

To do this accurately, the procedure needs to consider the impacts of both fixed and variable parameters such as flow rate, pipe diameters, floc tank, clarifier volumes and distances between dosing points. All need to be assessed to generate a truly representative jar test that can be used as a foundation to make decisions on trouble shooting and designing alterations to processes.

Designing a jar test procedure is a process that should be done with care and attention to detail. Many facilities do not have a procedure for jar testing and where procedures do exist, they are somewhat generic across a utilities processes and do not necessarily accurately reflect what specific plants have to offer.

A critical aspect of interpreting jar test results from the laboratory, is that they rarely indicate exactly how a certain configuration will behave in the process. Design, flow rate, temperature, filter configuration are just a few physical aspects of a plant that the jar test cannot mimic perfectly. A good operator will pay close attention to jar test results and actual plant performance to bridge the gap between 'ideal' laboratory conditions and how the process behaves.

Once representative processes were developed it was time to gather a selection of treatment chemicals and rigorously examine the effectiveness of different configurations. Testing existing chemicals used on the site is about identifying the capacity of hardware to deliver the required dose rates. A common issue with dirty water events is capacity to maintain pH correction for the flocculation phase, where elevated dose rates of Alum cause reduction in pH to create unfavorable conditions for flocculation. Many systems have limited pre-pH correction and when faced with extreme dirty water events cannot provide sufficient buffering.

2.2 Manganese Removal – Yarrawonga & Springhurst

After testing all possible chemicals to oxidize Manganese from soluble state to solid state, it was determined that the plant did not have detention capacity to achieve the required reduction in manganese concentration.

There was not enough space to install temporary tanks to increase available oxidation time. After a long day jar testing, it appeared all avenues were exhausted, and we were destined to provide dirty water, stain sheets and cloths and risk biological non-compliance due to high chlorine demand from the oxidation of the manganese in the treated water.

Then the brainwave came, what if we combine the oxidation chemistry with some absorption chemistry? Chlorine and Activated Carbon? So as we departed the plant at around 10pm on Thursday night before the Queen's Birthday weekend and the annual Lawn Bowls classic (and after having to urgently replace several sets of bowling whites due to Manganese staining). It was an hour drive home plus a diversion to collect a PAC sample for tomorrows jar testing, and a long night thinking of how it could be implemented, if it could even work?

Meanwhile, operators across the authority were asked to check their plants for dosing pumps, poly tanks and mixers that were not in use in preparation, and the solution hadn't even been tested! The next morning was an early start and we had a team eager to start putting the solution into place. Before I'd completed the first jar test the team was installing a batch tank and mixer and asking what size dose pump they needed.

The first jar test was a success; it worked like magic, reducing treated water Mn to well below 0.1mg/L, and in most jar tests less than 0.01mg/L. As soon as I had dose rates and detention times required to determine dose point locations the team went into action running the pipes and tapping dose points before kicking it into action in the plant.

We managed to produce quality water, well within guideline limits and implemented some additional monitoring to ensure any hiccups were identified before they became an issue on final water quality.

After successful implementation of the manganese control method at Yarrawonga, a latter event at Springhurst employed the same chemistry. A recently installed aeration system at a balance tank on the raw water supply for Springhurst and modifications to enable pre pH correction installed to manage a pre-existing Iron issue failed to cope with the high levels of manganese.

The chemistry was later installed at Chiltern WTP to remove Iron from a highly contaminated bore source, producing quality water. Subsequently if the system was ever taken off line the residents began to complain of the change in taste, regardless if Iron was present or not. Where long detention times are not available for oxidation processes, it has been proven a viable option in preference to construction of oxidation tanks.

North East Water (NEW) have since adopted the use of Activated (DMI) sand media within some water supplies for Mn removal. Following similar principles, the filter media is activated and the source water minerals are oxidized via chlorination, and effectively removed through filtration. This process is also effective in removing Arsenic and Iron, which can be common in groundwater supplies.

2.3 Bushfires and Floods Lead to Dirty Water Response

Through bushfires and subsequent heavy rain events, dirty water of a different kind creates another range of issues to tackle. Not only does dirty water stretch the capacity of any plants chemical dosing system, and or require a different chemical configuration all together, when raw water quality exceeds 3% dry solids content, sludge production can be a major issue and limiting factor for overall plant capacity.

Following the 2003 bushfires in North East Victoria, a severe storm event with heavy rains came along impacting the Ovens River catchment and Wangaratta water supply; similarly this occurred in Gippsland in 2007 impacting Licola, Coongulla and Maffra, as well as East Gippsland where the Bairnsdale supply was impacted. A latter event at Moe where heavy rains in an unburnt catchment also led to extreme dirty water occurring.

The task was possibly most challenging at Wangaratta where two separate treatment plants, one up-flow clarifier-sand filter configuration and one direct filtration (DF) plant were joined together to treat the water twice, both plants ended up utilizing different chemistry configurations to get through.

Reconfiguration of the physical changes to the Wangaratta plant was masterminded by Rex Humphreys and Brian Scobie, who while I conducted jar tests on the dirty water as it approached the plant from samples collected up stream, Rex and Brian were busy organizing pipes, interconnections, and PLC-Citect control logic changes to enable the two plants to be run as one. The clarifier plant was intended to be the primary solids removal system with its sand filters bypassed, aiming to achieve settled water turbidities of 20-40ntu, before entering the direct filtration plant, where temporary chemical storages were required to run alternative chemistry to polish the primary treated water. Configurations of the two plants are outlined in Table 1.

Issues with maintaining flocculation pH as described above became apparent at Wangaratta, where mid-way through a 17 day long dirty water event it was identified that elevating the raw water pH prior to addition of flocculant improved process performance significantly. After confirming improved results via jar testing we set about implementing the new chemistry in practice. The decision was made at around 10pm, and implemented by 2am during the night shift with an additional pump being installed from the critical spares cupboard and operated manually.

Table 1: ***Chemical Configurations in the combined treatment plants.***

Plant	Pre- pH	Coagulant	Polymer	Post pH
Clarifier	Soda Ash	Alum	LT20	Soda Ash
Direct filtration		MegaPAC 23	LT20	Soda Ash

Testing of the settled water to establish a chemical dosing regime suitable for the DF plant was tricky, but once the water hit the plant became a matter of taking samples from the clarifier launder troughs for jar testing in the DF plant. Prior to modifying the chemistry in the DF plant all dose lines had to be flushed to avoid reaction between the normal chemical of choice, Alum and the Alumiuium Chlorohydrate (MegaPAC 23). The flow pacing of all DF plant dose pumps also had to be switched over to the Clarifier plants inlet flow meter requiring some urgent, tricky and reversible Citect programming.

Interestingly, North East Water have since frequently reverted to operating the configuration of the clarifier and DF plant in series. A number of fire and flood events over the past 10 years have resulted in river turbidity levels in the thousands, with this configuration being able to treat the water to acceptable risk levels (<0.3NTU). It is currently being proposed that NEW will operate in this configuration permanently to align with principles of multiple barriers, and enable increased flow capacity in normal conditions. At Licola, there were no existing configurations to test or modify, in fact there was no treatment plant as the town was supplied from a previously pristine alpine catchment and had a disinfection only hypochlorite dosing system.

The challenge at Licola was in some ways more complex, yet had to result in a simplified system, it would need to be operated by untrained staff as it was privately run, operated by the Lions Club.

The swimming pool was chosen as the most likely candidate to bypass water into and enable settling of sludge prior to distribution, and the water was only to be used for showers and toilets, while bottled water was supplied for drinking. The main focus of establishing a suitable chemical configuration was keeping it simple! Due to the key requirement being simplicity it was essential to develop a configuration that minimized the number of chemicals required so Alum was excluded due to the need for constant and accurate pH correction to maintain a suitable floc pH.

Similarly to Wangarattas DF plant, Poly-Aluminium Chloride was selected at Licola, PAC10 – LB – a product with low basicity meaning its impact on pH was minimal or non-existent. This chemical also proved to have a very wide operating range where good results were obtained in comparison to others.

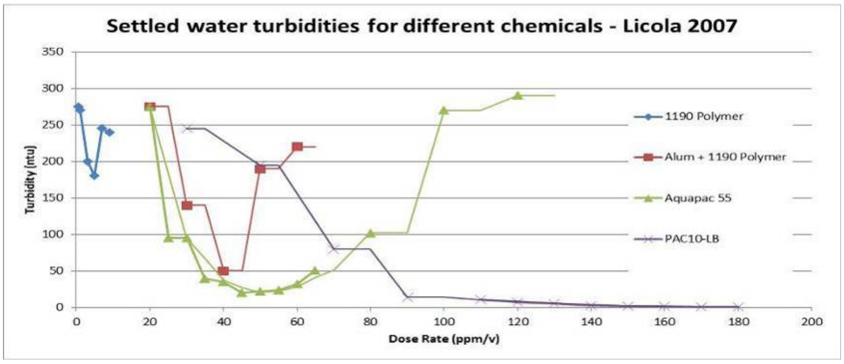

Figure 2: ***Settled water turbidity results for a range of chemicals tested at Licola***

Despite favorable results in the jar tests it was difficult to achieve the same floc formation in the real situation. Further jar tests indicated that the chemistry was strongly dependent on mixing to ensure the coagulant wasn't just swamped with solids rendering the active charges trapped inside. A rapid mixer was installed, this consisted of a 200L drum with rocks in the bottom half, the inlet was diverted to the bottom of the drum and disruption of flow and mixing achieved delivering results, where good sized floc particles were observable before the water left the drum to the floc tank/settling zone of the pool.

Downstream from Licola, both the Coongulla and Maffra Water treatment plants drew water from the Macalister River. Coongulla was ultimately taken off line as the offtake was inundated by mud and potable water had to be trucked in.

Figure 3: ***Coongulla raw water offtake buried in mud and debris.***

Chemistry configuration options were assessed and a temporary PAC dosing system installed at Maffra in case the dirty water breached the dam and continued downstream. The plant operators managed to get through the worst of it using the existing chemistry, although one of the PAC dosing pumps had to be used to boost pH correction requirements. A different challenge at Maffra was removal of sludge from the clarifier.

In jar tests of the water, up to 10% was observed as settled sludge, a percentage that the plants existing configuration could not maintain through an extended dirty water event. Ultimately several submersible pumps were placed in the clarifier and programmed to periodically extract sludge, the key selection criteria becoming head pressure capacity.

Figure 4: ***Jar tests on the Macalister River water Licola.***

3.0 CONCLUSION

A well-structured approach to investigation of solutions is essential to ensure quality is maintained and degraded raw water supplies can be managed. Issues presented in dirty water events extend well beyond making the chemistry work, and also require thought on sludge management, filtration capacity and adverse impacts on disinfection effectiveness. In overcoming such conditions a great deal can be learnt about plant design limitations, as well as some surprising learnings on what a plant can actually achieve if reconfigured successfully.

Managing a dirty water event also requires a high level of record keeping. Recording what has and hasn't been tested and what has and hasn't been successful is of key importance in maintaining continual improvement of process performance throughout an event. The transfer of knowledge gained in such events and/or routine optimisation work to future design and development is an area in need of improvement.

4.0 ACKNOWLEDGEMENTS

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