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WaterWorks
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WaterWorks welcomes the submission of articles relating to any operations area associated with the water industry. Articles can include brief accounts of one-off experiences or longer articles describing detailed studies or events. Submissions may be emailed to peter.mosse@gmail.com or info@wioa.org.au

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CERTIFICATION ON THE MOVE

George Wall

There have been a number of exciting recent developments in the operator certification and training spaces.

At their April 2016 meeting, the Water Industry Skills Taskforce (WIST), owner of the National Certification Framework for Operators within Drinking Water Treatment Systems, endorsed WIOA as the certifying body for operators for the next five years. This decision provides a degree of certainty to the industry, operators and WIOA alike, and allows us to concentrate on rolling out and promoting the benefits of the certification program nationally.

Another outcome from the WIST meeting was the confirmation of updates to the Certification Framework. Proposed changes, mainly as a result of implementation issues identified during the pilot projects in Queensland and New South Wales, were communicated to the industry in 2015, with comments sought from interested parties. After considering the feedback, the only significant structural change made to the Framework was the reduction of the system complexity rating from three levels to two: Low and High. This change removes many of the concerns raised by Regulators over the uncertainty of the relationship between the plant process and water quality issues. It is now a very simple process to determine the certification level required for a given treatment plant.

Also in April, a presentation ceremony was held at the WIOA New South Wales Operations conference in Newcastle, where the first seven New South Wales Operators were certified. Our congratulations are extended to the management teams and certified operators from Riverina Water County Council and Veolia Water, who took up the challenge to be the first in the state to voluntarily participate in the certification process. The presentation ceremony generated a great deal of interest from other employers in New South Wales, and WIOA looks forward to working with all the water enterprises in the coming months.

In addition to the national process, participation in the Victorian Certification Scheme is increasing steadily, with 61 operators currently certified by WIOA. Importantly, there are now 106 of the approximately 210 water treatment facilities in Victoria that have a certified operator employed by their controlling water business.

The recertification process has been completed for the four Victorian operators first certified in 2012. Having met all of the initial certification requirements, each of them has embarked on the Continuing Professional Development (CPD) journey, undertaking a range of activities designed to keep their skills current. WIOA has continued to work proactively with the water businesses employing certified operators to develop and implement a CPD scheme that is flexible, and that can be tailored to meet the needs of both individuals and employers.

I was extremely encouraged to listen to the conference paper delivered in Newcastle by Kathy Northcott from Veolia Water. Despite some initial fears of cost blowouts and a lack of operator time to participate fully, meeting the CPD requirements has actually benefited the business. Veolia Water has been able to develop a much more targeted development program for each individual operator, and there have been significant improvements in operator engagement and productivity – and at a lower overall cost to the organisation.

As joint signatories to the *Victorian Framework for Water Treatment Operator Competencies – Best Practice Guidelines*, the Victorian Department of Health and Human Services and the Victorian Water Industry Association have recently reconvened their implementation committee to undertake a review of the Guidelines.

Just like the national Framework, WIOA has identified a number of

OUR COVER

Our cover shot shows Burdekin Shire Council's Hayley Colls preparing a tap for water quality sampling in the Far North Queensland town of Ayr.

implementation issues with the Guidelines that require more clarification and direction. It is anticipated that the Guideline review and update process will be completed in late 2016.

There is also growing interest from the industry in a number of states to expand the certification process from drinking water into the wastewater management field. The Queensland Water Directorate (***qldwater***), through its Water Skills Partnership, is to be congratulated for ongoing leadership and commitment to skills development. The Water Skills Partnership Industry Leaders' Group identified in April 2014 that developing a Sewage Treatment Plant (STP) Operator Certification Framework was a priority. After convening a steering group, which included WIOA, to develop a draft STP Framework followed by consultation with the Queensland industry, the STP Operator Certification Framework was finalised in December 2015.

There are now plans to undertake a pilot program in the South East Queensland region to test the Framework, with WIOA undertaking the Certifying Body function. It is anticipated that the Framework will be suitable for implementation into other states, as well, and WIOA will report on the progress of the pilot in future publications.

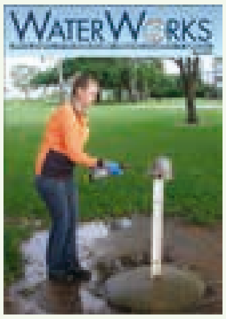
We see attaining Certified Operator status in either the water or wastewater fields as a real achievement, and something that must become part of the fabric of our industry in the future. It is envisaged that certification will help to reduce risk, greatly improve competency and portability of operator skills, and ensure the continual protection of public health and the environment for our communities.

Finally, in relation to training, in 2015 a high-level Australian Industry Skills Committee was created to take control of the management of all industry training packages. As part of the new structure, five Skills Service Organisations (SSOs) were established in January 2016, with each sector/training package assigned to one of them. The water industry, along with our National Water Training Package (NWP), now resides with the Australian Industry Standards SSO, along with 10 other sectors, such as gas, transport and logistics, corrections, aviation and electrotechnology, to name a few.

From Left - Phillip McAllister, George Wall, Dan Slocombe, Josh Tickell and Luke Prowse at the NSW Certification presentations.

The first meeting of the Water Industry Reference Committee (IRC), which comprised all of the organisations formerly on the GSA Water Industry Advisory Committee, was held in Melbourne in April. John Harris from Wannon Water in Victoria was elected Chair of the IRC, and George Wall from WIOA as Deputy Chair. We look forward to working with the new SSO to provide a National Water Training Package that is appropriate and suitable for our diverse industry, taking into account the scope of metropolitan, regional and remote water service provision responsibilities. One issue already earmarked as a priority project is to review the scope of units on offer at the diploma level of NWP, particularly in the networks space, to ensure that organisations can still access the range of units they need to make up a useful and valued qualification.

We welcome any queries, comments, ideas, suggestions or feedback on how we can further progress certification, training and our goal to improve the performance of all operational aspects of the Australian water industry. You can contact us on info@wioa.org.au.



We are excited to announce a new partnership between WIOA and Executive Media, who will be publishing *WaterWorks* in May and November annually. *WaterWorks* will be distributed to WIOA members as well as at WIOA conferences and events. It will also be distributed with *Future Water* each May. To ensure you continue to receive your copy, we recommend that you maintain your WIOA membership.

As part of this new partnership, *WaterWorks* will now include a limited number of sponsored articles and contributions, which will assist us to bring the latest news and cutting-edge insights into Australia's water industry to all WIOA members.

FROM IT OFFICER TO WATER OFFICER

Chris McCallum

Croydon is a remote former mining town located 600 km by road west of Cairns at the base of the Gulf of Carpentaria. It has a permanent population of fewer than 150 people, with tourist numbers almost doubling the population in the winter months. Historically, Croydon was one of Queensland's largest towns during the 1890s mining boom with more than 6000 inhabitants, but by the 1940s, it was a virtual ghost town.

Water is supplied from Lake Belmore. The lake, situated approximately 4 km from the town, was constructed in 1995. The lake is the largest body of fresh water in the region and boasts populations of Barramundi and Black Bream, making it a popular destination for locals and tourists alike. Prior to construction of the lake, people had windmills, wells and tanks. There was also a bore field, which had a poor yield and still supplies one family and part of the water for the recreation reserve.

On my first journey to Croydon, driving long hours away from the beautiful coastal rainforests and reefs of Cairns, and well beyond the picturesque Tablelands to an arid region with endless stretches of deteriorating, narrow, single-lane and sometimes gravel roads, I certainly had thoughts of, "What am I doing? Do I really want to uproot my family and come all the way out here?"

In April 2012, I was first employed by Croydon Shire Council as Information Technology Officer. Being a small council with limited staff, the scope of duties was quite broad, and included communication links and telemetry, and "other such duties as may be directed".

Little did I know that I would be entering the water industry at the deep end!

From IT to Water

When I first arrived, the telemetry radio system only had serial communications between PLCs, and did not allow remote access to the individual PLCs from the SCADA computer. One of my first IT tasks was to upgrade the telemetry control system to a Citect SCADA system with SMS alarm dial-out facility and remote access to the SCADA system via the internet.

Figure 1. Croydon in its prime

Figure 2. Water supply – now and then

Figure 3. A bit of a dirty water problem

Having done this, I soon found myself second on the list of pagers to receive alarms!

Before 2013 was over, the then Water Officer was injured and off work, and I found myself attending to most alarms. Along with our Town Maintenance Manager, we were having to both operate and repair various aspects of the plant. By January 2014, I was one of three people sharing the responsibility of water sampling, testing and recording. By February 2014, I was regularly doing testing and was made aware that the Clear Water Reservoir and reticulation system had poor chlorine residuals, despite the fact that it was being heavily dosed. Fortunately, our bacterial sampling was coming back from third-party testing okay, and continued to supply the town without any issue.

I guess this was what was meant by the "undertake projects, research and other such duties as directed" part of my IT contract.

I soon found that Croydon has a history of water quality issues, with water clarity and heavy metal concentrations being of concern. Limited staff training and poor resources have further exacerbated problems, not least of which was the transuding nozzle.

I did some digging through Council records. Back in 1999, the system failed to comply with guidelines, and reports identified that "dirty water was a problem Council would like to rectify". Subsequent development reports and growth estimates led to the system we have today being significantly oversized for its actual requirements. Census figures and growth forecasts were for a population of around 650 by now. The actual figure is fewer than 150 people. Storage tanks and pipelines are large; in fact, the Clear Water Reservoir can hold up to 20 days' supply in the wet season when demand is low.

The Water Treatment Plant (WTP) design is also similarly oversized, meaning that it only runs for short periods, leading to stagnation in the Clear Water Reservoir and subsequent degradation of chlorine residual. This is further compounded by the size of the reticulation pipework, which, with a 250 mm main from the Clear Water Reservoir to town, holds almost a day's worth of water in the pipe alone. The degradation of chlorine residual has historically been compounded by poor water quality caused by various process and operational failures.

It was alarming to find that even after the plant was installed between 2004 and 2010, there were serveral cases of *E. coli*, some at 80 CFU, and also some alarming levels of aluminium recorded in the water supply.

One of the tasks to keep the plant running was to add a chemical called "floc". I didn't really know how it was supposed to work, but I knew that it was called KlarAid and presumably made the water clearer. It didn't appear to be working too well, and I wasn't sure of the dose, so I just kept mixing it at the rate that I had been told worked.

In June 2014, I started a Certificate III in Water Operations and really became a Water Officer, with no prior experience or training.

I soon learnt that "flocculation" was a process occurring in the plant, and that our plant was a "direct filtration plant" with no dedicated flocculation tank. Previously, I had been told by various people around Croydon that the plant was designed to be a sewer plant, and "flocculation" sounded like a swear word to me.

Around July and August 2014, taking on board what I had been learning from my Certificate course, I decided that I needed to really take ownership of my WTP. It needed a good clean-up, and I needed to update and acquire some more testing equipment. I really delved into plant records to try to gain a better understanding of the plant's workings and history to help foresee problems that would likely reappear.

One of the most obviously important documents I had been seeking from the time I first entered the plant was an Operator's Manual. There was one, but the problem was that the treatment process did not entirely follow what the manual said.

I also discovered a long-disused portable flocculator, and understood the need for jar testing and turbidity testing. The portable flocculator had been misused; when I found it, the associated jars had what seemed to be about 2 cm deep of neat KlarAid (this must be the most viscous substance known to man) in a couple of them, and all 4 jars were very discoloured plastic.

I purchased new jars and other volumetric flasks, but although I knew approximately the kind of volumes (mg/L or ppm), I still didn't quite know where to start.

I needed some help!

Help

Consultants were engaged in 2014 to review the water supply system. They spent a busy week undertaking a limnological study of Lake Belmore, jar testing to optimise WTP performance, and testing alternative chemical combinations that might provide benefit to the process. They also inspected current infrastructure and the current PLC operating philosophy.

This was a great learning experience for me, and it quickly helped me to develop my knowledge and understanding of process requirements, as well as how the plant flows worked.

The consultants concluded that the WTP was basically sound in its physical configuration; however, other factors were found to contribute to reduced efficiency and process performance.

Figure 4. The WTP pressure filters

- The plant was running 25% above its maximum design flow, meaning that flocculation times were reduced, and the filters were operating above their design filtration rate.
- The backwash rise rates were also high, potentially leading to media loss.
- There was also an issue with build-up of trapped air in the pressure filters, reducing available flocculation space at the top of the filter bed, and therefore "flocculation" time.
- They considered that the floc would be forming after filtration or within the filter bed, but that it would be unable to coagulate to a size that the filter could remove.
- Filter media inspection was undertaken in Cell 6, and confirmed significant mudballing ranging in size from 2–5 mm up to 15–20 mm.

Multiple jar tests were undertaken to establish optimal doses.

The chemical dosing configuration at the time was KlarAid 1195P with prior chlorine oxidation. Jar testing showed that KlarAid could form acceptable floc sizes and produce a high quality water of an average of 0.25 NTU. The optimal dose was in the order of 6–12 ppm, which was higher than the 4 ppm being dosed at the plant at the time. The lab results, however, could not be replicated in the plant. In fact, treated water quality deteriorated, which prompted detailed investigation into the plant's physical capacity.

Tests on un-oxidised raw water did not achieve filtered water turbidities of less than 1.3 NTU, and even higher dose rates ranging from 8–16 ppm were required. From these findings, it was deemed essential to retain pre-chlorine dosing to oxidise soluble iron and manganese in the raw water, and to stimulate more efficient floc formation. The studies of the Lake Belmore water had confirmed the presence of significant levels of both iron and manganese.

Jar tests with a flocculation time of 15 minutes had been the starting point. When jar tests were repeated at shorter flocculation times more representative of detention times in the plant, similar performance was then observed in jar tests as was in the WTP itself. The KlarAid needed a minimum of 8 minutes to form a micro-pin floc, which was still too small for the filters to trap. As such, floc formation was now occurring within the bed and post-filtration, which led to worse treated water than previously encountered, despite initial tests indicating improved performance at higher dosages.

A revised chemical configuration was required in order to promote floc formation at a more rapid pace, and alum (Aluminium Sulphate), and ACH (Aluminium Chlorohydrate) were then tested, both alone and in conjunction with the KlarAid coagulant.

With the elevated pH of the raw water (7.7–8.0), the best dosing configuration was found to be ACH prior to the KlarAid.

But Wait, There's More

To address the issues of dirty water and post flocculation due to the poor coagulation in the plant, I embarked on a flushing program.

I worked away from the plant toward the extremes, drawing water through hydrants and increasing velocity using pumps into water trucks. I tested chlorine residuals after raising dosages at the plant to around 5 mg/L, and found that I could get chlorine residuals to the extremities of the reticulation, and laboratory results showed lowering Heterotrophic Plate Counts. These results were short-lived due to the high turbidity in the treated water and pipelines, and hence chlorine demand in the reticulation system was obvious.

After a couple of plant failures had lowered the Clear Water Reservoir, I started to see a relationship between the reservoir's levels and chlorine residuals. I found that by having a lower reservoir set point and more frequent top-ups, a better chlorine residual could be achieved.

Back to IT

The contractor also detected a major process control problem. The chemical dosing systems stopped working throughout the backwash sequence. This is a critical error in the control philosophy for the following reasons:

- Each filter is backwashed using water produced by the remaining filters, which stay online via a change in valve position.
- During this time, the filters providing the backwash water are not being dosed, despite being in normal operating mode, which requires coagulation in order to ensure that the filters are actually filtering.
- By the end of a backwash sequence, all six filters are full of raw, un-dosed water, meaning that when the plant returns to normal operation, the entire plant has to be flushed out once chemical dosing recommences, forcing untreated water (except for disinfection) into the Clear Water Reservoir until such time that the chemical dosing system has worked its way through the process and returned the filters to an operable state.

I was now back in more familiar territory. My improved understanding of automated systems and computer technology over past staff has been a big help in improving control logic and the functionality of the system, and its capacity to provide early warnings and alarms.

The PLC program was altered to ensure that chemical dosing occurred during backwash. ACH dosing was implemented, and I bought a more accurate turbidity meter to provide better monitoring data.

Figure 5. The culprit is finally exposed!

The plant flow was also slowed.

It was shortly after this that I found a major problem at the plant. Despite jar tests showing that the new chemical blend was achieving desired results in good time, I lowered the Clear Water Reservoir level to near empty, and ran fresh water from the plant. I then inspected the water in the tank. I could see floc floating in the water.

There is a section of clear pipework that backwash water flows through, and I observed a backwash cycle more closely than I ever had before. When the first cell backwashed, the water was dirtier than I had ever noticed it to be before, and the flocculation process was working to remove suspended particles better than I had seen before. However, it cleared toward the end of this cell and remained relatively clear through the second cell's cycle. It became dirty again on the remaining 4 cells, similar to what I had observed in the first cell's cycle.

I now had the answer to my turbidity and chlorine demand problem, as well as the explanation as to why the jar tests were not being well replicated in the plant tests. The second cell was short-circuiting, and I was prepared to bet that it had suffered from media loss through some sort of failure or excessive backwash rise rates.

The next day, I took the lid off Cell 2 and reached in with a length of tube to measure the filter sand depth. There was none! After shutting the plant down and draining it, there it was – the media transuding nozzle that had crippled the plant for years! One missing nozzle had led to a complete failure of the process.

A supply of filter media was obtained, emergency filter nozzle replacement surgery carried out, and the media replaced. With the improved process chemistry, and a filter with actual media in it, the plant now produces high quality water in the realms of 0.05–0.15 NTU, chlorine residuals remain for longer, and the chlorine dose required has dropped significantly.

My transition from IT Officer to Water Officer was complete, at least until next time.

The Author

Chris McCallum (chrismcc@outlook.com.au)
was IT and Water Officer with Croydon Shire Council in North Queensland, and is now working with Cassowary Coast Regional Council.

MEMBRANES AND ORGANIC POLYMER FLOCCULANTS?

Kathy Northcott

From time to time, water treatment operators are faced with the dilemma of whether or not to apply organic polymer flocculants (poly) to enhance primary coagulation upstream of polymer membrane filtration. In these situations, the feed water often contains high levels of total organic carbon (TOC) and/or colour. If inadequately treated, dissolved TOC compounds can carry through the treatment process and form possibly carcinogenic disinfection by-products (DBPs) in the presence of chemical disinfectants.

Flocculants are used in both conventional drinking water treatment, as well as various wastewater clarification processes. However, as a general rule, membrane manufacturers don't recommend the use of poly upstream of membrane filtration. The key reason cited is the risk of unacceptable levels of membrane fouling, particularly irreversible fouling.

Firsthand operational experience has shown that the risk of membrane fouling in the presence of anionic (negative) poly flocculants can be a very real problem for polymer membranes. A process upset in the washwater system clarifier (Figure 1) at the Castlemaine Water Treatment Plant (WTP) in 2004 resulted in inadequately clarified reclaimed washwater being returned to the head of the process for a short period. This reclaimed washwater contained a small amount of anionic poly, which caused significant increases in Trans-Membrane Pressure (TMP), and poor membrane recovery after backwash and chemical Clean In Place (CIP). The performance of the fouled membranes was eventually recovered; however, it took a targeted campaign of backwashing and chemical cleaning to do so.

That being said, the Castlemaine WTP has had anionic poly dosing in the washwater system for 14 years, and there has only been one membrane-fouling incident associated with the clarifier during that entire time.

So, are there any situations where it's okay to use poly in combination with membrane filtration in water treatment applications?

Figure 1. The advanced membrane filtration plant at Castlemaine WTP. The washwater clarifier is the circular tank at the front of the plant

In this review, I will look into some of the studies that have been undertaken to address this question, and I will attempt to draw out the key findings regarding the use of poly in combination with membranes, both for drinking water and recycled water applications.

Membrane Fouling Studies Relating to Use of Organic Polymer Flocculants

Studies That Suggest it IS Okay

A few studies have indicated a net benefit of using poly in pre-treatment for membrane systems. Howe and Clark (2006) found that the addition of a cationic (positive) flocculant at 1 mg/L as a coagulant aid for alum dosing reduced the fouling potential of various lake waters filtered through a polypropylene membrane.

In Coagulation/Flocculation-Microfiltration (CFM) treatment of an arsenic-contaminated groundwater, Han and co-workers (2002) showed that fouling reduction was achieved for a mixed cellulose acetate and cellulose nitrate ester membrane through the use of 0.3 mg/L cationic polyacrylamide as coagulant aid. In this study, the primary coagulants tested were ferric chloride and ferric sulphate.

Schimmoller and Lozier (2011) reported less frequent chemical cleaning and higher membrane permeability using a high molecular weight anionic poly at 0.2 mg/L in a Coagulation/Flocculation, Sedimentation, Microfiltration (CFSM) process. In this particular study, the investigation was carried out on a secondary-stage treated wastewater effluent.

Another wastewater filtration study investigated the use of cationic poly for laundry wastewater treatment in a CFSM process (Kim et al. 2014). Of seven different cationic flocculants tested, an epichlorohydrin and dimethylamine (epiDMA) poly returned the best results. This was based on settleability of flocs and lowest rate of fouling on a dead-end polyvinylidene fluoride (PVDF) membrane filtration process.

While a review of available literature was conducted on the use of coagulant aids in membrane bioreactors, it was found to be extremely difficult to draw any definitive conclusions on the impact on membrane fouling from the reported data. It is thought that the high levels of biomass and, in particular, the presence of naturally occurring Extra-cellular Polymeric Substances (EPS) play a dominant role in membrane fouling. From the available literature of flocculants in MBR systems, indications are that their use may offer some benefits. This is due to the improved settleability of floc, and the development of a more porous filter cake on the surface of the membranes.

Studies That Suggest it is NOT Okay

As the flocculant types, raw waters, process conditions and membrane materials reported in the aforementioned studies were all different, it is almost impossible to draw direct conclusions beyond the specific conditions for each study. This is because in each case, the role of poly flocculants in membrane fouling was not fully characterised.

One of the most relevant studies into the fouling potential of poly in membrane microfiltration was by Wang and co-workers (2013). In this study, the effects of three types of poly were tested against filtered water quality and membrane fouling using a hollow-fibre PVDF membrane under two different operation modes. These modes were classified as CFSM and CFM.

The flocculants were a positively charged cationic pDADMAC, a negatively charged anionic poly acrylic acid co-acrylamide (PACA), and a non-ionic PAM. The flocculants were used in combination with poly-aluminium chloride (PACl) as the primary coagulant. The raw water source was the Mississippi River in Minneapolis.

It was found that the use of all three types of poly increased the incidence of fouling in both CFM and CFSM modes, with the sole exception of the pDADMAC cationic (positive) poly used in CFSM mode. In particular, all poly greatly increased the risk of irreversible fouling in the CFM mode. The increased fouling caused by anionic (negative) and non-ionic poly in the CFSM mode was determined to be due to the residual free polymer in solution. In the CFM mode, the fouling was attributed to direct floc attachment on the membrane surface.

Similar membrane fouling issues were reported by a study on the use of anionic (negative) poly for treatment of a groundwater source at a French drinking water treatment plant (Darracq et al. 2015). In this study, the impact of different pre-treatment conditions, such as powdered activated carbon (PAC) addition, iron chloride coagulation, and anionic poly addition on ultrafiltration membrane fouling were tested. A key aspect of the investigation was the comparison of fouling rates on new and used polyethersulfone/polyvinylpyrrolidone (PES/PVP) membranes. For both new and used membranes, the presence of residual anionic poly after settling/clarification caused high levels of fouling on the membranes tested.

Key Parameters for Application of Poly in Membrane Filtration Pre-Treatment

So, what are the key parameters that determine the success or failure of the application of poly upstream of membrane filtration?

Operational Mode

This review has looked at a number of membrane pre-treatment and fouling studies, incorporating treatment both with and without sedimentation/clarification (Han et al. 2002; Kim et al. 2014; Darracq et al. 2015). Based on available data, the general theme appears to be that membrane fouling from poly is almost guaranteed without a settling/clarification step between chemical dosing and the feed to the membranes. This seems to be the case regardless of the type of poly used.

Cationic polymers have been reported to have the lowest fouling potential, if used in combination with settling/clarification. This is in contrast to studies on the use of anionic and nonionic polys, which are more frequently reported as having issues with residual polymer carryover.

Flocculant Dose Rate

Of the membrane-fouling studies reviewed, the general consensus amongst investigators is to use a low dose of poly (Kim et al. 2014; Han et al. 2002; Wang et al. 2013). The study by Wang and co-workers (2013) suggested that concentrations of nonionic and anionic poly should never exceed 0.5 mg/L. Additionally, the same study indicated that a high ratio of poly to inorganic coagulant increased overall floc size, whereas a lower ratio reduced the size and density of floc. This is an important finding in light of membrane manufacturer recommendations for operators to aim for a small "pin" floc in membrane feedwaters. A pin floc is considered to have a lower fouling potential over large, low-density floc.

In the laundry washwater treatment study by Kim and co-workers (2014), the optimal dose for cationic (positive) flocculants was recommended to be around 50% of the dose required to achieve charge neutralisation of particles in solution (equivalent to a zeta potential of zero).

Membrane and Poly Surface Charge

All polymer membranes have a natural surface charge (zeta potential), which varies with the solution pH that the membrane is in contact with (Figure 2). A membrane with a negative surface charge will tend to attract cationic (positive) polymers and repel anionic polymers to some extent.

A study by Wang and co-workers (2011) investigated the relationship between polymer charge and membrane surface charge on three different membrane types: PVDF, PES and polysulfone (PS). All three membrane types had a negative surface charge in the pH range of 4–10. This range covers almost all municipal water pre-treatment applications. As would be expected, when applied through the CFM mode of filtration (i.e. no settling), the positively charged cationic polymer caused the greatest fouling, and the negatively charged anionic polymer the least, with the nonionic polymer fouling potential somewhere between the two.

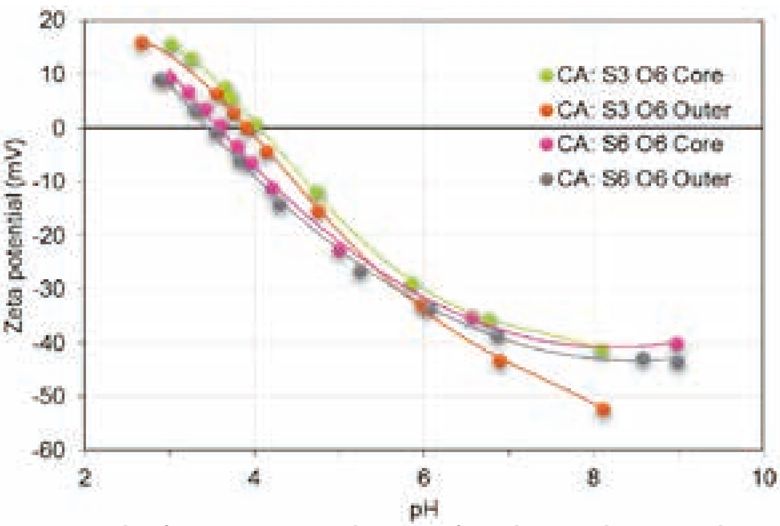


Figure 2. Example of variation in membrane surface charge relative to solution pH, for polypropylene membranes at Castlemaine WTP

Poly Molecular Weight

When it comes to flocculants for water treatment applications, there are literally hundreds to choose from, with varying charge densities and molecular weights. The study by Wang and co-workers (2011) looked into the impact of molecular weight (MW) of flocculants on membrane fouling potential. Increasing flocculant MW was found to have a strong correlation with the decreased permeability and increased TMP of membranes. So, amongst a group of flocculants with the same type of charge (cationic, nonionic or anionic), low MW products will tend to have lower fouling potential over those with a high MW.

Feedwater Chemistry – pH, Calcium

Solution pH is generally considered to be an important factor in membrane fouling, as it affects the surface charge of the membranes. However, in the study by Wang and co-workers (2011), the effect of feedwater pH on membrane fouling was found to have less of an impact than the characteristics of the poly (charge and MW). This was due to the fact that the membranes had a net negative surface charge in the pH range of 4–10, which covered all typical feedwater conditions.

However, pH becomes very important when managing chemical cleaning (CIP). In the case of the Castlemaine WTP, the membranes are polypropylene, and the CIPs involve a low pH acid clean followed by a high pH caustic clean. In particular, it becomes important that the pH of the acid clean is low enough to be in the range where the membrane surface charge switches from negative to positive, to facilitate repulsion of foulants.

The effect of fouling and cleaning on membranes is shown in Figure 3.

Calcium ions have been shown to have significant influence on membrane surface charge (Saravia et al. 2006), and can effectively neutralise charges to facilitate attraction of foulants to the membrane surface.

Concluding Remarks

In conclusion, if it becomes necessary to use polymer flocculants as pre-treatment to membrane filtration, it is important to do so cautiously. No two raw waters are the same, and it is highly recommended that a program of jar testing be performed to identify the most suitable poly type and the lowest effective dose. Types of poly include considerations such as molecular weight, charge (cationic, anionic, nonionic) and charge density, and they should be selected based on specific feedwater conditions.

General rules to follow when using poly are:

- The use of any polymer flocculants as pre-treatment in membrane plants without a settling/clarification step is inadvisable. One further thing to note is that whilst there were no references in this review relating to tertiary media filtration prior to membranes, this would likely reduce the risk of membrane fouling further.
- Keep the polymer dose as low as possible, and ensure that you have a high ratio of inorganic coagulant to poly dose.
- Manage the pH of CIPs to get the optimum cleaning efficiency and recovery of membranes, taking advantage of the membrane surface charge characteristics.
- Consider calcium levels in the raw water, and the type of pH adjustment chemicals used in the process, to keep calcium concentrations to a manageable level.

Whilst none of the above can guarantee a risk and stress free experience using poly in combination with membrane filtration processes, they do provide some options regarding how to manage and mitigate the risks of membrane fouling. A final comment is to always check with your membrane supplier about the implications of the use of poly in membrane pre-treatment on supplier membrane warranties. An improvement in feedwater pre-treatment may not be worth the risk of voiding a membrane warranty.

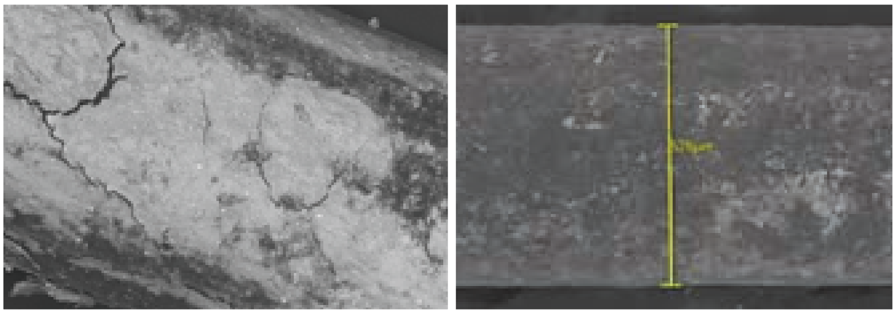


Figure 3. Scanning electron microscope images of membrane fibres taken from the Castlemaine WTP. The image on the left shows fouling after floods affected feedwater quality in 2011. The image on the right is after a targeted CIP cleaning campaign on the membranes

The Author
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CONTROL OF MANGANESE IN DRINKING WATER

Bruce Murray

Manganese (Mn) can cause water colour to range from straw-yellow through to black (Figure 1). In contrast, iron (Fe)-laden water is generally orange through to rust-brown. As a result of either iron or manganese being in the water, consumers may complain of dirty water, stained laundry and discoloured plumbing fixtures. Iron and manganese can also contribute to taste and odours, particularly if they lead to microbial growth that concentrates the metals in biofilms.

Iron and manganese problems are usually intensified by periods of warmer weather. This is primarily because dissolved oxygen concentrations are lower in warmer waters, and therefore less natural oxidation of soluble metals occurs. Increases in biological activity at warmer temperatures also contribute to anaerobic conditions favouring the release of soluble metals.

Both manganese and iron can be present in water in particulate and soluble (dissolved) forms, depending on the chemical oxidation state. They can also be bound up with organics in the water as complex compounds.

For effective treatment of manganese and iron, it is critical to know the levels of both particulate (oxidised) and soluble (reduced) metals. Manganese and iron in particulate form can generally be removed by coagulation, flocculation, clarification and filtration. To remove soluble manganese and iron requires an additional oxidation step by chemical dosing or aeration to convert it to the particulate form. Organically bound, soluble manganese is generally the most difficult to remove.

Analysis of Total and Soluble Metals

Soluble manganese and iron can be measured by filtering the sample through a membrane filter with a pore size of 0.45 µm (to remove the particulate manganese or iron), and then analysing the filtrate. The membrane filtration step should be applied as soon as possible after sampling (before sending the sample to the laboratory), as the soluble manganese and iron is likely to oxidise to particulate form quite rapidly.

Figure 1. Manganese stained bathroom fittings and black water high in manganese being flushed from a hydrant

Total manganese and iron can be measured by analysing the total unfiltered sample.

Particulate manganese and iron is then calculated as the difference between total and soluble levels.

Although the most common definition of "soluble" metal is that which passes through a 0.45 µm filter, some very fine particles can be smaller than 0.45 µm. Manganese particles are often in the range of 0.15 to 0.3 µm. If soluble manganese results remain higher than expected after oxidation, these fine particles may be present. In this case, to find out whether oxidation has been effective, you can either:

- pre-treat the sample by passing it through a 0.22 µm membrane filter; or
- optimise jar testing to coagulate, settle and filter to remove the fine manganese particles.

When working with a water supply system with manganese and iron problems, it is best if the testing can be done in-house. This allows the results to be obtained quickly and more accurately (no continued oxidation in transport to labs), thereby allowing for better management of the problem. It also has the potential to save money when a lot of samples and testing are required.

Most in-house testing uses a spectrophotometer to measure how much colour is formed when the necessary chemicals are added. When carrying out testing for manganese and iron, the following important actions need to be taken:

- **Filter the sample as soon as possible.** As soon as the sample comes into contact with air, natural oxidation will start to take place. This means that some of the soluble metal is converted to its particulate form and will therefore be removed when the sample is passed through the 0.45 µm filter. This will give a soluble metals result that is lower than what was actually in the sampled stream.
- **Follow the sample preparation procedure** for your spectrophotometer exactly.
- **Use a quality-control standard.** To be confident of your results, you can obtain manganese standards of, say, 0.1 mg/L and 1 mg/L, and run these through your testing process. Ideally, your results for these samples should be +/- 10% of the stated values. Standards can be obtained from commercial NATA accredited laboratories, or the various testing kit suppliers.

Organically Bound Manganese and Iron

There is no simple analysis method to determine whether manganese and iron are organically bound.

The level of natural organic matter (NOM) in the water, roughly indicated by "true" colour or better UV absorbance at 540 nm ($A_{54}0$), can give some indication of likely organic bonds. Jar testing can be used to determine how easily the manganese and iron will be oxidised by various chemical oxidants, followed by coagulation, settling and filtration.

Performance Targets

The 2011 Australian Drinking Water Guidelines (ADWG) set an aesthetic guideline limit of <0.1 mg/L (100 µg/L) for manganese, and a health guideline of <0.5 mg/L. Experience has shown that significant numbers of dirty water complaints are received when treated water manganese concentrations exceed 0.02 mg/L (20 µg/L), and for this reason, <0.02 mg/L is recommended as an industry best practice target for manganese levels in treated water. Some water treatment plants have set targets as low as <0.01 mg/L.

The ADWG aesthetic guideline for iron is <0.3 mg/L. There is currently no health guideline for iron in drinking water. Some water treatment plants target iron as low as <0.1 mg/L in treated water.

Removal of Manganese

To remove manganese and iron, they must both first be oxidised to particulate manganese and iron. Manganese usually requires chemical oxidation for effective removal. Where iron and manganese are present together in raw water, treatment generally focuses on manganese removal. Iron removal will generally be successful if manganese removal is successful. This section therefore focuses mainly on treatment of manganese.

1. Aeration

Aeration processes involve contacting water with air (or sometimes compressed oxygen) so that the oxygen in the air dissolves in the water. Once this has occurred, the oxygen can oxidise any dissolved iron or manganese in the water. This forms insoluble precipitates, which can be collected with other solids in the water during coagulation, flocculation, clarification and filtration. Aeration can be a very cost effective oxidation process if successful, because it can be done without chemical dosing and with minimal equipment. It is also a robust treatment process, requiring little adjustment when raw water quality changes.

Figure 2. An example of a tray aeration system

Oxidation by aeration can be a relatively slow process, and is also strongly pH dependent.

Fe^{2+} (ferrous), or soluble iron, can be oxidised to Fe^{3+} (ferric) within about 15 minutes at pH 7.5.

However, aeration alone usually cannot achieve effective oxidation of manganese, particularly at pH values of <9.5 and if manganese is organically bound.

Aeration is usually more effective for bore water because the manganese and iron are usually in their simplest inorganic forms without associated NOM competing for oxidation.

The efficiency of aeration for oxidation of manganese can be improved by raising pH. This is because manganese is less soluble in water at higher pH levels. Typically, a pH level above 9.5 is required to reach target metal concentrations.

Increased pH will, however, affect coagulation, and a switch to a coagulant such as ACH or PACl or ferric salts may be required. Alum generally works best in the pH range of 5.8 to 6.8, requiring pH reduction prior to coagulation, but this can be tricky.

Pre-lime and carbon dioxide (lime-CO_2) dosing systems are common; lime raises the pH for oxidation, and CO_2 lowers the pH for coagulation, without significantly decreasing the alkalinity. Acids should be used only with caution, and are not recommended as they will consume alkalinity and may cause metals to re-dissolve.

2. Potassium Permanganate Oxidation

Potassium Permanganate ($KMnO_4$) is a strong oxidant, and can oxidise both manganese and iron effectively.

When oxidising manganese and iron, $KMnO_4$ should be dosed carefully to avoid both underdosing and overdosing. Underdosing will result in incomplete oxidation of metals, while overdosing can add dissolved manganese to the water, and any unreacted $KMnO_4$ may result in "pink water".

In the absence of any organics, there is an exact amount of $KMnO_4$ necessary for the oxidation of iron (0.94 mg $KMnO_4$ for each mg of soluble Fe) and manganese (1.92 mg of $KMnO_4$ for each mg of soluble Mn); however, the actual dosing rates required are generally higher than these. So, for example, in practice, soluble manganese oxidation may require between 2 mg and 8 mg of $KMnO_4$ for each 1 mg of soluble Mn, depending on what else is in the water that reacts with the $KMnO_4$. Bore water is usually around the lower end, and surface water with colour – where all the dissolved manganese is organically complexed – will be at the higher end.

The permanganate oxidation reaction is optimal at a pH value of 8.5. Oxidation can be successful down to about 6.7, but longer contact time is usually required. At pH 8.5, oxidation of inorganic manganese can occur rapidly within about 3 minutes, while at a lower pH – and if there are significant organics present – oxidation may require more than 10 minutes.

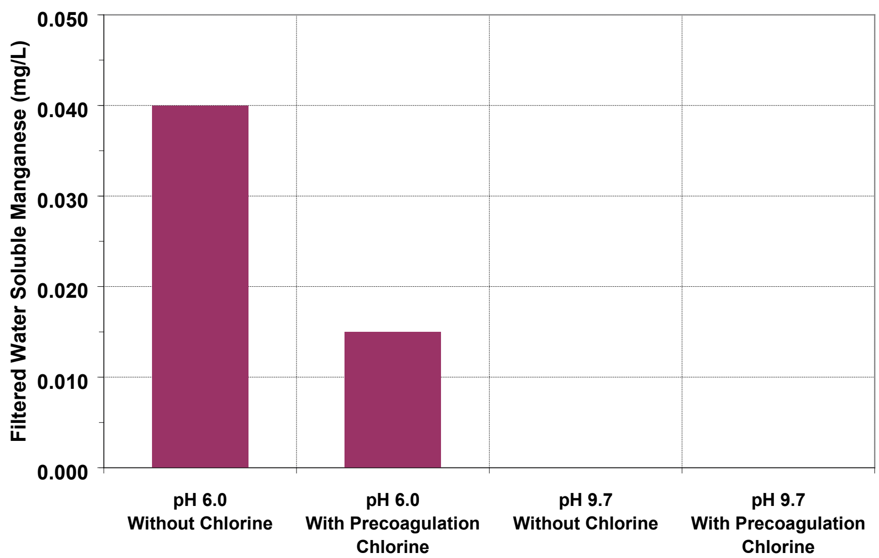


Figure 4. The effect of chlorine and pH on the removal of manganese from water

Jar testing is the best way to determine the necessary ratio, and these tests may need to be repeated regularly as the water quality changes. For example, during a particular event in one reservoir in Victoria, up to 3 jar tests were required each day to maintain the correct dose. Figure 3 shows a manganese jar test after oxidation. The jar on the far left is underdosed, and the jar on right is overdosed. The correct dose is probably somewhere between jar 2 and jar 3. Subsequent coagulation and settling then removed the oxidised particulate metals.

Jar testing water with low levels of manganese (say <0.2 mg/L) in the water can be quite frustrating. In this situation, it is sometimes better to slowly add low doses of $KMnO_4$ into the WTP itself and measure the soluble manganese in the filtered water. There is also a simple test that can help to determine if the dose is correct:

- Take a sample of the water coming out of one of the filters.
- If it has any pink tinge to it, the dose was too high.
- If it is clear, and after adding 1 or 2 mL of dilute $KMnO_4$ solution to the sample the water goes brown, the dose was not high enough.
- If it is clear, and after adding 1 or 2 mL of dilute $KMnO_4$ solution to the sample of water it goes pink, the dose was correct.

More details on manganese jar testing can be found in Murray and Mosse (2015) *Practical Guide to the Optimisation of Chemical Dosing, Coagulation, Flocculation and Clarification* (available from WIOA).

3. Chlorine Oxidation

Chlorine can effectively oxidise iron and manganese. It is a less powerful oxidant than $KMnO_4$, and so requires a longer contact time, typically 15 to 30 minutes. Disadvantages of dosing chlorine to an unfiltered water system include the formation of disinfection by-products, such as Trihalomethanes (THM) through reactions with NOM, and high chlorine demand of the raw water.

Just like with $KMnO_4$ dosing, the actual chlorine dosing ratios are higher due to organic material and microorganisms in the water. Basically, if a chlorine residual is present in the water after the oxidation point, then sufficient chlorine has been dosed. High pH also has a beneficial effect on oxidation (Figure 4).

Figure 3. Example of a manganese jar test

Figure 5. $KMnO_4$ coating of filter media

4. Coated Filter Media

Filter media coated with manganese dioxide (MnO_2) can be used to remove manganese from water. It is used in conjunction with chlorine dosing just prior to the filter, or with chlorinated backwash water. The solid MnO_2 coating on the media provides adsorption sites where dissolved manganese attaches and reacts with the catalytic action of chlorine to combine with the coating.

Because the process is self-perpetuating under the right conditions, coated media can be a cost effective method of manganese removal. Filter media can be purchased pre-coated (known as "greensand media"), or coated in situ with appropriate permanganate and chlorine dosing.

Filter media can be "coated" in three ways:

1. **Potassium Permanganate Soaking**
   Filters should be very clean before coating, or the MnO_2 will not properly attach to the media. The filter media surfaces then need to be soaked with sufficient chlorine to achieve a residual of around 2 mg/L after mixing (air scour) in the media. Then add sufficient $KMnO_4$ to achieve about 0.4% solution in the filter media volume, and drain the filter down so that the solution is within the media bed, and air scour the filter to mix it well. Leave for about 24 hours with periodic air scouring (2–3 times). Check the manganese coating on media by lab analysis. The aim is for 0.2 mg Mn/L/g media. Repeat the procedure if the coating is too low. The filters then need to be washed very thoroughly, and the discharge of the backwash water needs to be carefully managed because it contains manganese. The filters can then be operated with a dose of chlorine sufficient to result in at least 0.2 mg/L coming off the filter.
2. **Chlorine Predosing**
   If a filter is operated with chlorine predosing to achieve a free residual of at least 0.1 mg/L coming off the filter, a layer of MnO_2 will gradually build up on the surface of the filter, and will quite effectively remove manganese as long as the free chlorine residual is maintained.

To minimise formation of disinfection by-products, chlorine dosing must be done after coagulation, flocculation and clarification.

The efficiency of the filter-coated media process can be assessed using one existing filter, or in a pilot filter column to confirm selection and operating parameters required.

Many small councils and water utilities try to combine manganese oxidation across filters with primary disinfection. This does not work very well. It is better to separate the two functions. The first dosing of chlorine is for oxidation of manganese (prior to the filters); chlorine should then be dosed again under residual trim control as the water leaves the treatment plant for disinfection.

3. **Green Sand Filters**
   Green sand is a commercially available coated media product for manganese removal. There are several products on the market that are traditionally designed as a separate manganese removal filter in small WTPs, ideally after normal filtration. There have been numerous reported problems where filter media has been fully or partially replaced with greensand or similar media. The product is often much finer than conventional media, and can block normal filtration if not designed and tested properly.

Multiple Barrier Approach

WTPs that achieve the most successful manganese removal over a range of conditions usually employ a multiple barrier approach to manganese. The most common of these is to include aeration for destratification of the raw water storage (weir or dam) followed by $KMnO_4$ dosing at elevated pH, then coagulation and clarification followed by pre-filter chlorination and coated media filtration.

Monitoring and Testing

The efficiency of most of these methods described can be assessed using jar testing. The jar testing can be used to assess the following process steps:

- pH adjustment
- Aeration
- Oxidation using chlorine
- Oxidation using chlorine dioxide
- $KMnO_4$ at high pH.

Once implemented in the plant, it is important to establish how well the process is working. It is useful to construct a manganese profile for the plant. This can be done by measuring soluble and total manganese levels at the following points in the water treatment process:

- Raw water
- Clarified water
- Filtered water
- Final water.

Adjustments in the dose rate can be made based on the results.

Table 1. Advantages and disadvantages of the manganese removal processes

Process	Advantage	Disadvantage
Aeration	Easy to implement Inexpensive	Slow reaction time Oxidation-reduction potential may not be strong enough for manganese removal Elevated pH may be required
pH Adjustment	Easy to implement and control manganese removal Relatively inexpensive	Increased alkali handling and consumption Need for lowering pH before coagulation or else use of alternative coagulants
$KMnO_4$ Dosing	Strong oxidant Inexpensive Commonly used	Difficult to optimise $KMnO_4$ dose (depends on manganese level in raw water) Possible use of alternative coagulants Difficult to achieve manganese level in treated water <20 μg/L
Chlorination	Easy to implement	Requires high contact times DBPs can be a problem
Coated Filter Media	Efficient manganese removal Easy to implement and control manganese removal	Need to maintain coating and manganese input DBPs can be a problem
Chlorine Dioxide	Strong oxidant Efficient oxidation of organically complexed iron and manganese	More expensive Chlorite and chlorate ions formed
Ozonation	Very strong oxidant	Expensive Difficult to control dosage
Biological Process	Low operation and maintenance costs	Limited Australian experience Not sufficient removal for water with high manganese

Other Methods Not Commonly Used in Australia

Chlorine Dioxide and Ozone

Ozone and chlorine dioxide are strong oxidants that can be used to oxidise both manganese and iron. They are less common options, but chlorine dioxide has been used in the past at the Gold Coast and Toowoomba, and ozone is used for pre-treatment on the Sunshine Coast and at Orange (in addition to post-treatment for organic contaminant removal). Both ozone and chlorine dioxide are used to reduce taste and odour problems, and both are effective disinfectants. Both are less sensitive to pH, and both need to be generated on site.

Biological Processes

Manganese and iron consuming bacteria can be used in bioreactors. These bacteria consume the greatest quantity of dissolved metals when they are growing. Once the growth capacity is reached, metabolism of iron and manganese may slow or stop. Bioreactors may also struggle to process high metals loads. Bioreactors are not widely used in Australia for manganese and iron removal.

Biofilms in pipelines act as bioreactors, though with the biomass eventually sloughing off, dirty water will result. Cleaning of the pipes will lead to increased biological manganese removal as the biofilm is re-established.

Summary

Table 1 summarises the advantages and disadvantages of the various manganese removal processes.

A multiple-barrier approach, typically including pre-coagulation oxidation and the coated media process, is preferred.

The Author

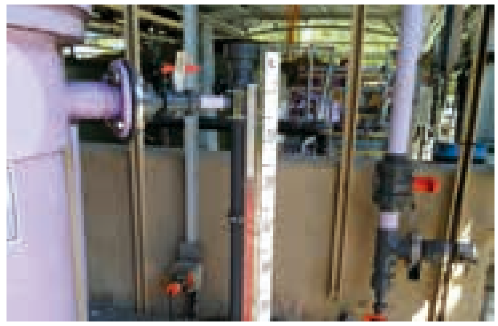
Bruce Murray (bruce@citywater.com.au) is the Managing Director of City Water Technology, a specialist water treatment company based in Sydney.

IMPROVING PLANT PROCESSES

For nearly 20 years, Control Components has worked closely with customers, both directly and through associates, to supply a range of flow, level and pressure instruments for process control and automation.

Through the combined experience and efforts of its staff, the company has earned a respected local reputation for brands, such as:

- Weka – magnetic level indicators
- Besta – Trimod electric and pneumatic level switches
- Gems Sensors – flow, level and pressure sensors
- McDonnell & Miller (Xylem) – flow switches
- ITT Neo-Dyn – industrial pressure switches
- Kari – cable float switches
- Eletta – flow sensors.



While, traditionally, the company's relationship with the water industry had been for basic process alarms (sump level, safety showers and pump flow), the upgrading of ineffective level gauges on chemical storage tanks to Weka visual level indicators has prompted more direct collaboration with water/wastewater sites.

During plant visits, we heard of the widespread desire to improve plant processes to reduce chemical and energy demands, running costs and, ultimately, to improve the quality of output.

Since its start in the late 1970s, Cerlic has encouraged user feedback in the development of its products (built-in, self-cleaning, standard) for success in both Europe and North America. Based on the results of successful trials and installations at Australian and New Zealand plants targeting suspended solids handling and dewatering optimisation, Control Components is proud to be the South Pacific partner of Cerlic.

HASSLE-FREE, CHEMICAL-FREE, POWER-FREE IRON REMOVAL

If you have ever had high levels of iron in your water, you know the real issues it causes on a number of levels. The general discolouration of clothes and bathroom amenities, the effect on drinking water, and the build-up in pipes that can eventually block are all issues that you should not have to put up with in the year 2016.

Filtration systems are the typical answer to iron in water, but generally these filters need power, require continual maintenance (often with many breakdowns), and rely on the addition of chemicals to remove the iron. In many situations where iron is present, businesses cannot, and do not, want to add harsh chemicals, nor do they have the resources for continual maintenance, and, for some, the access to consistent electricity supply is not an option.

Finally, there is a hassle-free, chemical-free, electricity- and operator-free, water-filtration system that will remove 100 per cent of the iron in water. Never has there been a system that works virtually anywhere, and still removes iron.

CEO of EcoCatalysts, Gary Murdoch-Brown, the distributor of this technology, explains, "The great thing about these filters is they are simple, remove 100 per cent of iron from water (plus a little manganese and other impurities), but generally your iron is gone without the chemical and electricity needs of other filters on the market".

Because of a unique automatic filtration technology, the system runs off the pressure of the water system that it is filtering. Then, via a backwashing and discharge cycle, the iron is flushed from the filtering system to a pit within a matter of minutes, and the filtering process begins again.

The beauty of an automatic filtration system is that no person or system is required, there are no valves or moving parts and, best of all, there are no running costs.

Peter Kirchmann from the Wujal Wujal Aboriginal Shire Council is just one happy customer of the Ecofinity Filter. "We have been using the Ecofinity Iron Removal Filter for six months now, with great success. All of our regular water testing results have come back with an iron reading of less than 0.1. We couldn't be happier with these results," he says.

"It's great that such technology can assist such remote communities, but also have the flexibility to assist in filtration in a city."

Murdoch-Brown says, "We are all about creating solutions for our customers, and the Ecofinity Filter is the most efficient, effective solution for what is, for many, a major issue."

Overall, the Ecofinity Filters seem to be an obvious choice in iron removal. To find out if this is a solution that could work for you, call 1800 244 009.

Ecofinity Iron Removal Filters

The ultimate chemical free, electricity free and operator free, water filtration system

Ecofinity Iron Removal Filter Benefits:

- Removes all Iron
- Automatic filtration, backwashing and discharge cycle
- No valves or moving parts
- No running costs
- Sized to treat from 20 KL to 4800 KL per day

"We have been using the Ecofinity Iron Removal Filter for six months now with great success. All of our regular water testing results have come back with an iron reading of less than 0.1. We couldn't be happier with these results"

Peter Kirchmann
Wujal Wujal Aboriginal Shire Council

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EcoCatalysts®

CHT BEZEMA: SOLUTIONS FOR THE ENTIRE pH RANGE

In general

Preventing iron and manganese oxidation is key to controlling iron- and manganese-based discolouration in water systems with high levels of dissolved metals across a wide pH range. CHT Iron Solution works to safely capture the available metals, such as iron and manganese, and to retain these in solutions so that discolouration of water does not occur. Subsequent precipitation of rust scale is then avoided, and the consequent blockage of dripper and pipes is effectively controlled.

Our expertise

With our innovative German-based chemistry concept, we can offer solutions for the entire pH range where the focus lies on the deposition inhibition of polyvalent metals, such as iron, and including alkaline earth metal carbonates, alkaline earth metal sulphates, alkaline earth metal oxalates, and silicates.

Customised solutions

With the combination of different chelating and dispersing components, the performance of our products can be adapted individually to customer demands. A detailed process analysis accompanied by analytical examinations of the processed water and of the deposits is the basis for successful control of water discoloration due to iron and manganese.

Mode of action

CHT Iron Solution uses biodegradable chelating agents with the synergetic effect of complementing chemistries. As well as chelating the free metal ions, there are additional polymers that can disperse macroscopic crystals and prevent the crystals from agglomerating. These polymers adsorb on submicroscopic crystals and modify their surface. This surface modification leads to amorphous "sludge", which can easily be filtered and rinsed out. If you want to know more, please ask.

Crystal modification with CHT Solutions

Without

With

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MANAGING YOUR WATER NETWORK PERFORMANCE

Since the Australian release of the Chloroclam® almost two years ago, many water authorities appreciate the ease of access to real-time chlorine data information. It is helping customers to better understand distribution network water age, make process decisions for re-chlorination and tackle nitrification issues.

Evoqua has also released the Hydraclam®. This device can measure high-resolution turbidity, conductivity, pressure, free or total chlorine and temperature. The Hydraclam has been successfully used in the United Kingdom for some years now. One of the benefits of this product is its ability to monitor water discolouration events and even predict when a water main may need flushing, swabbing or pigging.

The Hydraclam and Chloroclam are battery-powered data-logging sensors that are highly mobile and simple to deploy. No extra hot-tapping is required, as they use existing hydrant infrastructure to connect directly to the water main.

Australia is a big country with large geographical reticulation networks. The need to drive for hours to conduct water quality tests should be a thing of the past. Deploying a Chloroclam or Hydraclam will deliver next-to-real-time water quality data at your fingertips.

Meet us in Rockhampton (Booth 43) or call 1300 661 809

HYDRO'S PEOPLE ARE PUMP PEOPLE

Hydro Australia is a company that specialises in the repair, refurbishment and upgrading of high-energy pumps. Since its inception in 1998, it has grown considerably, and with the assistance of its parent company, it now forms a part of the largest independent pump company in the world.

'Independent' is an important word for Hydro, as it sees this as one of the strengths of the company. Being able to look at any make, or any model of pump, and give an unbiased assessment on the condition of that pump, has been at the core of the success the company has achieved.

Hydro is also a solutions-based company that looks for innovative ways to ensure that pump effficiency is at a maximum, and energy costs are at a minimum. Its philosophy is to use what's in the pump, and not replace it – yet it can still supply quality-engineered spare parts. Hydro looks to repair an impeller and not replace; it looks to save a shaft, and not sacrifice it.

Over many years, the company has been at the forefront of many sought-after engineering upgrades, including but not limited to: "A" Gap, "B" Gap modifications, and rotor centralisation.

Hydro is always looking for better ways to do things, better materials to extend the life of a pump, and better methods to ensure that the mean time between repairs (MTBR) is increased to above industry standard.

The company operates out of a first-class facility, and all of its people are pump people. It invests heavily in their training, and they are also able to operate unsupervised in Hydro's facility, or at yours.

SAVING ON ENERGY WITH AEROSTRIP® DIFFUSERS

The South Rockhampton Sewage Treatment Plant was recently upgraded, and now serves a population of more than 19,000 people. The price of electricity in Queensland rose more than 20 per cent in July 2013, and it's no mean feat to keep under the limit of 5–10 milligrams per litre of total nitrogen.

However, thanks to the upgrade of this treatment plant – which includes Aerostrip® Diffusers – the Rockhampton Regional Council has achieved a total nitrogen limit as low as 3.1 milligrams per litre, and aims to reduce electricity costs by up to 20 per cent.

"More than half of the energy used in a treatment plant such as ours is consumed in what is called the biological/aeration process.

"This is why we have upgraded the plant by retrofitting it with the highly efficient aeration system of Aerostrip® Diffusers," says Cr Greg Belz of Rockhampton Regional Council.

"We chose Hydroflux HUBER to install Aerostrips not only because they will cut our energy use while reducing our carbon footprint, but also because Hydroflux HUBER provided performance guarantees for the installation.

"These guarantees have been met and verified," says Cr Greg Belz.

BLACKWATER NO MORE

Stuart Doak

Residents in the Central Queensland towns of Blackwater (population 6000) and Bluff (population 380), approximately 200 km west of Rockhampton, have experienced poor water quality for a number of years. The water quality issues started with community-wide concerns about dirty, "black", odorous water (Figure 1). The problems were attributed to organics and manganese, which had accumulated in the source water. Blackwater sources its water from Bedford Weir, located on the Mackenzie River, and it is delivered through a 25 km long pipeline through three turkey nest dams. Bluff receives treated water from Blackwater through a 20 km long pipeline.

The key concerns for residents were:

- Discolouration of the water
- Unpalatable tastes and odours
- Stained washing
- Uncertainty around the short- and long-term health impacts of using and ingesting the water, especially for families with babies and young children.

Many families installed in-line filters, and it would seem that the majority of people in both towns stopped drinking the water, with the sales of bottled water skyrocketing for a prolonged period of time. There were also regular anecdotal reports from the community of increased cases of gastric and skin irritation problems; however, no connection to the dirty water was found.

In February 2013, Council held a public meeting in Blackwater to advise residents of what it would be doing to improve the water quality in Blackwater and Bluff. The identified actions are summarised below:

- To investigate whether the extraction point at Bedford Weir could be raised to access better quality water (not implemented due to cost).
- Changing the flow direction from the water reservoirs to town to minimise retention times in the network (implemented successfully).
- Trialling granulated activated carbon (GAC) on top of a sand-filter bed to adsorb tastes and odours, and improve filtration (trialled unsuccessfully – carbon was lost through the backwash process).

Figure 1. Typical water quality prior to improvement projects

- Removing and replacing aged sand media in the filters (implemented successfully).
- Improved notifications to customers (implemented successfully).
- Increased reticulation flushing program (implemented with some success).

In an attempt to manage the high manganese levels prior to it entering the plant, chlorine was dosed into the untreated water as it entered the plant. While this was successful in removing manganese, it also raised Trihalomethane (THM) levels, and therefore was discontinued.

The underlying problems with the water remained.

In January 2014, Council engaged a specialist water quality consultant to assist with addressing the ongoing water quality issues. They recommended the following:

- Increased monitoring to better define the problem
- Destratification of the raw water dam at the WTP to increase dissolved oxygen in the water
- Improved removal of manganese through additional pre-treatment oxidation and manganese oxide–coated media
- Removal of tastes and odours and potential algal toxins through powdered activated carbon dosing into a contact tank.

Council also engaged a contractor to clean out the two 10 ML Blackwater Treated Water Reservoirs, and to air scour a number of critical water mains within the Blackwater township.

As a result of further investigations, Council decided that, as well as the treatment plant not being equipped to remove the excessive manganese from the raw water, the reticulation system was in such poor condition that regular sloughing of the biofilm was also a source of the dirty water.

Council therefore adopted a comprehensive whole-of-system plan to address Blackwater's water problems. The plan included the following items:

- Upgrading the Blackwater WTP
- Scouring the reticulation systems in Blackwater and Bluff
- Cleaning the reservoirs and the raw water storage
- Employing a dedicated Project Manager to ensure completion of the works
- Employing a dedicated Communications Manager to liaise with the community.

Desludging the Raw Water Lagoon

In order to remove as much manganese-laden silt as possible from the bottom of the raw water lagoon, Council purchased a small floating dredge, appropriately called a Sludge Rat. The Sludge Rat took up residency at the Blackwater WTP raw water lagoon for a period of 3–4 months, and steadily removed the manganese-laden sludge from the base of the lagoon, depositing it into a pre-constructed settling pond with an overflow to another storage. After testing to determine that the supernatant was free from manganese, it was pumped back into the raw water lagoon. The dried sludge was removed to landfill.

WTP Upgrade

The Blackwater WTP was constructed in the 1970s as a conventional WTP. It was upgraded in the 1980s to a capacity of 12 ML/day, but was not equipped with any pre-treatment facilities that would remove manganese.

The upgrade works included:

- Construction of a ~500 kL concrete dosing and contact tank
- Refurbishment of the six filters and under-drains, including filter media replacement
- New and upgraded chemical dosing systems, including potassium permanganate, PAC, polymer and pre-filtration chlorine dosing
- Complete plant automation upgrade
- Valve and instrumentation upgrade.

Ice Pigging of the Reticulation System

After the unsuccessful air scouring program in 2014, Council investigated a new mains cleaning technology called "ice pigging". The technology, developed in the UK, had only been established in Australia for about two years. Ice pigging has a number of advantages over other conventional ways of cleaning water mains, such as:

- Nothing to get "stuck" in the main. If the "pig" gets stuck, it is just allowed to melt
- Uses minimal water and only minor flushing is required
- Domestic connections are generally not required to be isolated
- Very mobile operation, with vehicles easily parked in a suburban street and with minimal traffic management controls required
- Relatively quick with mains only needing to be isolated for no more than two hours
- No high pressures in pipeline.

The ice pigging process involves the injection of a thick ice slurry (made from a brine solution) into an isolated section of a main through a hydrant, and uses the mains pressure to force the ice through the main. The ice pig and the scoured material are then removed via a hydrant at the other end of the main. The waste material and the ice pig are collected in a tanker and discharged onto drying beds at the sewerage treatment plant. The potable water preceding the ice pig is dechlorinated and discharged into stormwater drainage. The main is then flushed and returned to service.

In a hot climate such as that of Central Queensland, there were some initial concerns about the high air and ground temperatures in Blackwater, but these proved to be unfounded.

An ice-making plant contained in two shipping containers was established on the WTP site (Figure 2). The plant was capable of producing 10 tonnes of brine slurry per day.

The ice pigging plant consisted of a semi trailer mounted ice delivery tank with slurry pumping equipment (Figure 3), and a utility with analysis equipment mounted on the tray.

Figure 2. An ice-making plant was established at the WTP

Figure 3. The ice pigging plant comprised a semi trailer-mounted ice delivery tank with slurry pump equipment

Figure 4. Samples of the effluent taken during an ice pigging operation

Regular samples were taken of the effluent discharging from the outlet hydrant, as the ice pig passed through the main (Figure 4).

The samples were then filtered, dried and weighed to obtain an estimate of material removed from the main. From some mains, it was determined that as much as 67 kg/km of sediment and biofilm was removed! Some other interesting statistics relating to the Blackwater ice pigging project are summarised in Table 1.

The cost of the ice pigging program for Blackwater was in the order of $4.70/m of main.

Table 1. Blackwater ice pigging project statistics

No of completed operations	126
Length of main cleaned	73 kmsw
Average distance cleaned per operation	580 m
Water used	~2,710 kL
Estimated water saved compared to swabbing	~6,250 kL *
Average disruption time per operation	< 2 hrs

** Estimate provided by the contractor*

Community Consultation

A vitally important part of the program was to keep the community informed throughout the lengthy project. This was done in several ways:

- Separate monthly public meetings in Blackwater and Bluff
- A project webpage with all information about the project, including water analysis results
- The Project Manager and Communications Manager visited concerned residents
- An Issues Register was published, listing every issue raised, along with the Council response
- Regular media releases
- Fact sheets were distributed covering issues such as elevated THMs and upcoming events, such as the ice pigging.

The success of the communication strategies can perhaps be gauged by the fact that the December meeting was attended by 65 annoyed residents, and by the following May meeting, only two interested residents attended. There was also an improvement in Facebook content relating to the project. Indeed, a former vocal complainant responded to a rare Facebook complaint, supporting Council and admonishing the complainant, such was the success of the communications exercise.

Blackwater All Clear!

The success of the project was not only the obvious improvement in the quality and appearance of the water, but also the turn-around of the community's attitude.

The Author
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TOILETS FOR SARIRI

Winner of the Hepburn Prize for the best paper overall at the 2015 WIOA Victorian Operations Conference

David Greaves

In Australia, we take for granted turning on a tap and receiving high-quality water, and even pushing a button on the toilet and not having to worry about what happens with our waste from that point on.

In 2008, Sariri village was hit by Cyclone Guba. Located near the Kokoda Trail, Sariri is home to around seven tribes of 300 inhabitants (which is expected to grow to 1000).

When the cyclone hit, the village was virtually erased from the map. The PNG Government and tribal chiefs agreed to move the village from its existing riverbank location to a safer site approximately 2 km inland. This move created issues around the most basic of water and sanitation needs.

Sariri Village is located on the north coast of PNG, with the nearest township being Popondetta (Figure 1). Once in Popondetta, the journey to Sariri is by 4WD and takes up to a full day, depending on conditions and river levels. The drive itself involves several river crossings and very poor 4WD tracks to a river staging point. From there, a canoe trip across the river and a 2.5 km jungle walk gets you to the village.

The Geelong Rotary Club approached Barwon Water with a vision for the village. There were a number of clear objectives.

- Plan a sewer system that could service the village
- Introduce an educational awareness program
- Provide funding for the project, and visit Sariri to plan and deliver the sewer project
- Prepare a blueprint for other villages to implement similar schemes.

Barwon Water conducted a workshop with more than 40 staff members (Figure 2) to look firstly at our ability to help, and, secondly, to come up with sanitation solutions. From this initial meeting, a small team worked on the many ideas that came from the workshop, and short-listed them based on sanitary risk mitigation, construction feasibility in a remote location, and usability.

The ideas and outcomes were defined by several constraints.

Figure 1. The location of Sariri village on the north coast of PNG

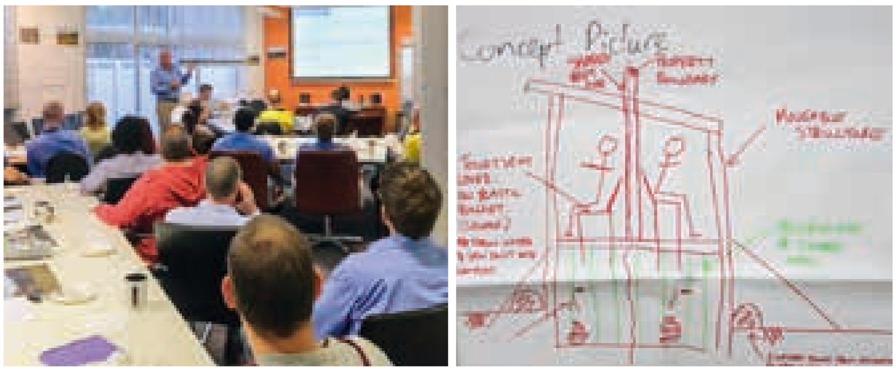

Figure 2. The initial Rotary workshop at Barwon Water offices

- Local custom did not allow for the handling of waste
- Groundwater was <1 m deep in places and 2 m maximum
- Town water was drawn from a groundwater well in the centre of the village
- The soils were permeable and sandy
- Resources were in short supply or non-existent, and everything needed to be made from timber, as a small portable saw mill was owned by the village
- Low skills-based labour.

The World Health Organization has produced "A Guide to the Development of On-site Sanitation" (WHO, 1992), which gives recommendations and design criteria for basic sanitation options. From our workshop outcomes and using this WHO guide, an options assessment was completed to validate the most appropriate final solution.

A composting toilet design that utilised wheelie bins was developed.

Design Calculations

Constraints:

- Unknown local volumes of waste
- Unknown number of people per family unit
- Unsure if toilet paper and sanitary pads are degradable.

Assumptions:

- Capacity of wheelie waste bin – 2/3 x 240 litre = 180 litres
- Some separation of urine from waste bin
- Based on WHO tables, sludge accumulation rate per person = 60 litres per person per year (L/p/yr)
- Factor up 50% for short-term storage – 60 x 1.5 = 90 L/p/yr
- Factor up 300% for organic covering (e.g. sawdust to aid odour and composting) 90 x 3 = 270 L/p/yr
- Volume sludge, say 5 people/family = 270 x 5 =1350 L/yr
- Empty every two months.

Figure 3. Test build and flat pack shipping trials

The Prototype Toilet

With the concept and calculations finalised, a detailed design was produced, and a prototype toilet was constructed to ensure that all objectives of the project had been met. It was also agreed that this prototype would be sent to PNG as a base model for other units to be copied from due to potential issues with absence of skill levels required to follow detailed plans.

For the construction, a partnership was formed between the Rotary Club, Barwon Water and Geelong Technical Education Centre (GTEC). Barwon Water supplied all the materials, while the staff and students in the building and carpentry sections of GTEC constructed the prototype (Figure 3).

Staff and students of GTEC suggested modifications during construction, which allowed for simplification and a reduction in materials. They also initiated the concept of modular design and flat packing (Figure 3). This had three significant benefits:

1. Ease of shipping the prototype to PNG
2. Allowed us to label and colour-code connection points and components
3. Allowed the villagers to build new toilets in simple sections or modules.

Finally, the GTEC students assembled and dismantled the final unit in a bush setting using techniques available to villagers to ensure that our design and construction methods were sound. It was then packed up and sent to PNG.

Sariri Village

The toilet and other items needed for the village were shipped to PNG in February 2015. From the Oro Bay Port, the contents of this shipping container were transported to the village over the course of a month (Figure 4). In June 2015, a team of six people (myself and five Rotarians) travelled to Sariri for a 14-day period to complete multiple projects, including construction of the flat pack toilets and the fabrication of a second unit built from resources available to the village.

Although originally designed to be installed at houses, the village decided that the first toilets would be built near the school. This allowed for the children to be taught about its use, care and composting, and allowed them to pass this information on to others in the village.

Once we had arrived at the village, it took several days for all of the components to make their way across the river to the construction site.

When all the components were on site, it took two days to construct the flat pack toilet.

As with a number of projects completed during this trip, improvisation was essential, as there were no stores, hardware or otherwise, within a day's travel. Several items went missing between the port and the village, and we also had to use some of the taps and PVC fittings from the toilet project to repair the water tank systems, which took priority.

Once the first toilet was complete, we travelled into the jungle and milled enough wood with the portable mill saw to construct a second toilet (boys and girls). All the work completed by GTEC in the prototype phase of the project paid off, as the second toilet was built in modules using the first as a template. This allowed the second toilet to be completed in two days once the wood arrived on site.

Figure 4. The flat pack toilet arriving in Sariri Village

The Author

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BUMP WASHING AT MYPONGA

James Laube

The Myponga Water Treatment Plant (WTP) is a Dissolved Air Flotation Filtration (DAFF) process that uses dissolved air to float floc particles to the surface. This forms a blanket of sludge or "float", on the surface of the water over the filter, which is periodically removed by performing a "decant" where the water level is raised to allow the float to flow to waste (Figure 1). The water below the float gravitates through a monomedia filter to remove remaining particulate matter.

The plant was built in 1993. During the initial years after the build, a process called "bump washing" was trialled to try to extend filter run times and improve the efficiency of the process. These involved taking the filter off-line and initiating a short backwash on the filter to try loosening the bed to lower headloss. This was considered a risky endeavour, as it introduced a high probability of contaminating the filtered water due to the fact that the air scour step was used to disturb the bed, but a full wash of the filter was not performed.

The Approach

In July 2011, the decision was made to reduce the size of the monomedia sand from 1.3 mm ES to 0.9 mm ES to improve turbidity removal of the filters, and to reduce the risk of *Cryptosporidium* breakthrough due to the source water being susceptible to contamination from local primary industry. The filter bed specifications are provided in Table 1.

This smaller sand media introduced a new issue, with the filter run times reducing due to increases in headloss. Filter run times dropped to 8–10 hours, and it became increasingly challenging to achieve water quality targets and prevent mudball formation. After discussions with other team members, and reviewing of past documents, it came to light that alterations made to the original concept design of the filter cells may have reduced the depth of the cells. This introduced the possibility that saturated air from the flotation stage was impregnating the bed and leading to a false increase in headloss caused by microscopic air bubbles and not turbidity.

Modification of the initial bump wash was conceived, and consisted of taking the offending filter off-line, opening the backwash inlet valve and introducing only low-rate backwash water at 9 m/hr for 60 seconds as a rinse to free any air bubbles trapped in the bed and lower the filter's headloss. Initial trials were conducted on filters 1 and 4, with headloss reaching 1.0 m at approximately 10 hours.

Figure 2 shows that during the initial bump wash trial, headloss dropped to 0.4 m, and the filter ran out to another 12 hours before headloss hit 1.79 m with a total run time of 21 hours. Visually, it was difficult to gauge if trapped air bubbles were released from the filter bed due to the scum float being in place; however, the extended run times (Figure 2) show a benefit to production.

Figure 1. Float removal on one of the DAFF cells at Myponga WTP

Table 1. Myponga WTP filter bed specifications

Layer	Depth (mm)	Size (mm)
Sand	960	0.9
Gravel	50	10-20
Gravel	50	5-10
Gravel	50	10-20

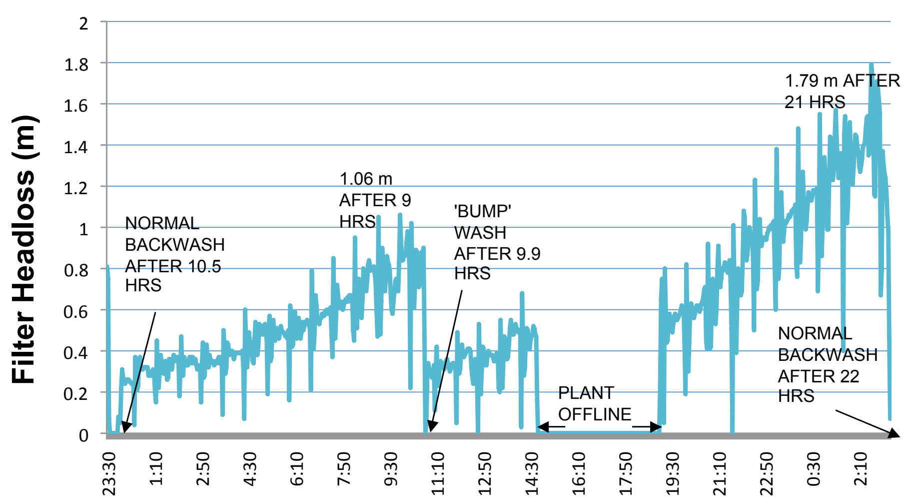

Figure 2. Filter 1 headloss trend during initial bump wash trials

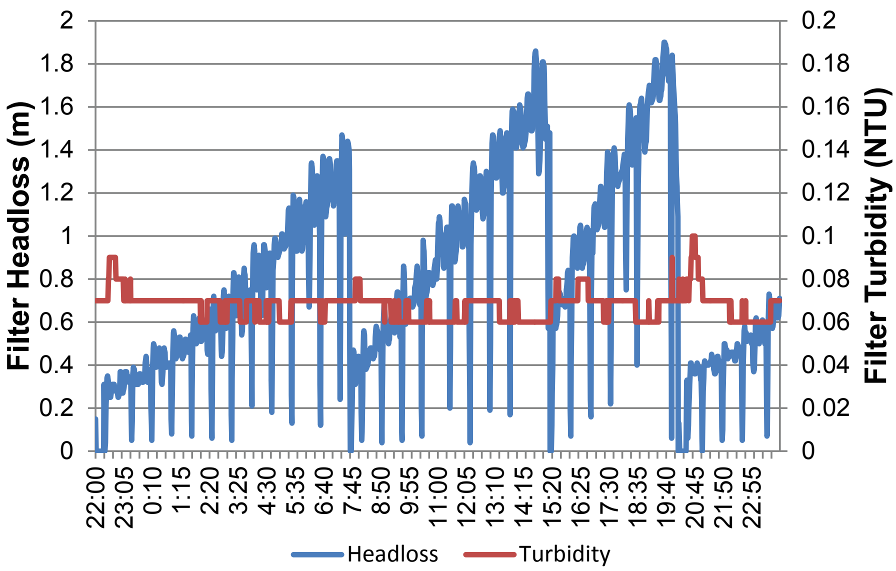

Figure 3. Filter 5 headloss and turbidity trend during the double bump wash trial, February 2013

Following the bump wash, a small ripening spike was seen; however, there was no increase in filter turbidity and no effect on the overall plant process. Further testing showed that another bump wash introduced at high headloss increased the run times by up to another 10 hours again, with no detrimental impact on water quality (Figure 3).

The trials showed huge improvements in filter run times, as well as a reduction in power consumption and water losses due to a reduction in the number of full backwashes required. To further validate this process, plans have been made to inspect the media in at least two filters, focusing on backwash regime review, solids retention profiles and media depths to measure for any movement of sand or damage to the support gravel.

Following the trials, permission was gained from management for the bump wash process to be automated into the process and performance of the plant monitored. Results varied due to the plant's operational hours, flows and shutdown times, but run times varied from 24 hours up to 40 hours, depending on flow through the plant. After a few months of fine tuning, trending indicated that two bump washes showed significant improvement. It was decided to limit the number of bump washes per filter run to two, after which a backwash would trigger at 1.7 m.

With this modification being so successful at Myponga, the data was shared with other Allwater plants supplying water to Adelaide, and is currently being trialled at a DAFF wastewater recycling plant in Adelaide, as well.

The Myponga WTP has just undergone a full control-system upgrade. This has included a flexible bump wash program to suit different strategies. Built into the upgrade are a number of other filtration improvements that will greatly increase the flexibility to optimise the operation of the plant, while ensuring reliable operation for many years to come.

The Author

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Editor's Comment

We are aware of bump washing being applied at other WTPs for a number of reasons with apparent success. Should others wish to consider introducing a similar step, careful trials should be conducted, and the filtration performance and integrity of the bed monitored. A short air scour at the start of the backwash could also be assessed.

Aussie Water Recognised Worldwide

Congratulations to Goulburn Valley Water (GVW) for winning the silver medal in the Municipal Water category at the Berkeley Springs (USA) International Water Tasting competition.

After the sample from GVW's Marysville Treatment Plant won WIOA's national taste test competition last year, we helped arrange entry of a sample into the international competition. The new Marysville Treatment Plant, commissioned in 2015, uses a microfiltration treatment process to treat drinking water supplied to the towns of Marysville and Buxton.

WIOA will enter an Australian representative into the competition again in 2017 with the aim of bringing home GOLD for Australia! To be in the running, make sure your water business enters a sample into one of the state based competitions and who knows, just like the GVW team, you could be recognised as having some of the best tasting water in the world.

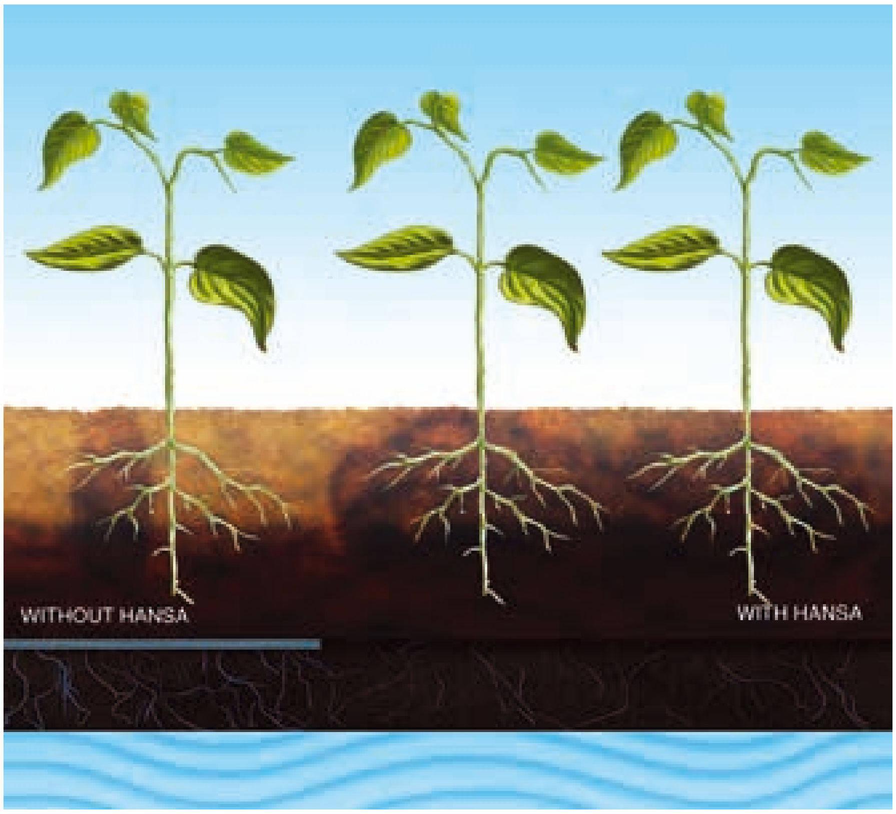
Berkeley Springs International Best Municipal Water in the World 2016

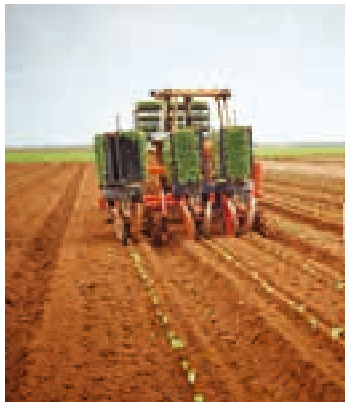
1st – Clearbrook, Abbotsford, British Columbia, Canada

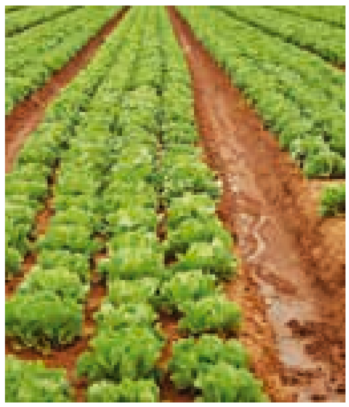
2nd – Marysville, Victoria, Australia

3rd – Independence, Missouri, USA

HANSA SOIL CONDITIONER







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