WATER WORKS

OFFICIAL JOURNAL OF THE WATER INDUSTRY OPERATORS ASSOCIATION

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HAVE YOU CHECKED *YOUR* PLENUM SPACE LATELY???

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WOULDN'T IT BE NICE

INSTRUMENTAL CONTROL AND HIGH LEVEL OPERATIONAL REPORTING

Peter Mosse

In early February this year I visited Chris Laidlow and Jason Colton in Wellington New Zealand. Chris is the Water Supply Manager for Greater Wellington Regional Council (GWRC) and Jason is the director of $h_2$ope, a small NZ company specialising in process engineering for the water industry. I was aware that Jason and Chris had developed a feed forward coagulant dosing control system for both turbidity and organics (dissolved organic carbon) removal in water treatment.

The Com::pass system as it is called, is based on data collected by an S::CAN Spectrolyser (Figure 1), an instrument that continually measures the UV Vis absorption spectrum of water. The Com::pass system completely controls the dosing of coagulant at the Wainuoimata WTP in response to changes in raw water turbidity and organic content. The plant was originally commissioned in 1995 using a streaming current meter (SCM) to control the coagulant dose. Com::pass was installed just under four years ago and the plant has run using this control system since then. Com::pass has also been used on another of the GWRC plants for the last two years.

Figure 1. The spectrolyser that collects the data is indicated by an arrow.

Excellent coagulation requires fine control of pH. For this reason coagulation pH is monitored using three pH meters (Figure 2).

Figure 2. Coagulation pH is critical for good coagulation and flocculation. Here 3 pH meters provide "triple validated" pH control of the coagulant pH. This type of monitoring while very rare in Australia is quite common in the UK and continent.

GWRC have also developed an impressive array of operations monthly reports based on their SCADA system. As well as the usual primary measures of turbidity, chlorine residual, and pH they have developed a range of secondary or derived trends. These include unit costs of production based on chemical costs and power costs. They have collected sufficient data over the years to be able to predict the costs of production based on the raw water quality as measured by the Spectrolyser. The information is so well established that they have been able to alarm treatment costs. If the costs are increasing, an alarm is activated and operators are alerted to the fact that the cost is increasing beyond the maximum allowable and they should identify the cause. As they have these sensors in each raw water source they utilise, they know the unit costs of production from their alternative raw water sources and will alter ratio's of water drawn from each source or shut down one source and activate another based on their SCADA monitoring

Monthly reports include time series graphs of turbidity for individual filters and chlorine residuals. Frequency graphs are provided for both 3 minute and 30 minute chlorine. These graphs make it immediately apparent how well the filters have been performing against the target objective of 0.1 NTU and whether the disinfection system has worked reliably for the month or whether there have been periods of low or poor chlorine dosing. This reporting is effectively compulsory because the Department of Health in New Zealand has

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OUR COVER

An artistic shot showing sand in the plenum space. A pretty photograph but not a pretty sight for the operators of the filters.

INTERVIEW: DAVE BARRY OF AQUALIFT

How did you get started in reservoir cleaning?

It was just another job really. Brad Gannon from Beaudesert Shire Council was cleaning his pool one Sunday morning and wondered if it was possible to vacuum out a tank. Their tanks were stand alone, so any cleaning involved a complete shut down and no water for the residents. That's generally when a fire happens as well, so any way of doing it online was attractive.

Brad gave me a call, we visited the local pool shop, bought some pool type cleaning gear and gave it a go. The trial went OK, but it was slow due to the size and type of the plastic vacuum head. He suggested a price that they could clean a tank manually for and said I had the job if I matched it…. then it became a challenge!

I went away for about six months and thought about it, on and off, found the ideal SS vacuum head in WA (where they used such things for vacuuming out the ponds in crocodile farms), thought that using a dry suit may seem attractive to the consumers who had to drink the water afterwards and then basically flipped a coin as to whether I would gamble about outlaying $8000.00 in equipment costs to

earn $2500.00 - that's what made it all so attractive!!

Then a continuing string of luck came along that got it over the line, so I cannot claim much credit for it in the end.

Optus (sorry Telstra, but you missed out here!) gave me three serious paying dive jobs, laying cables in Northern NSW rivers – that solved the cash flow issues.

Once you got the idea, how did you get into the Water Industry and get it accepted?

We cleaned the two Beaudesert tanks, took some good photos, and then Brad gave a paper on the process at a WITA conference in Hervey Bay and won Operator of the Year award…..we were up and running! His boss then gave the same paper at an AWA conference in Stanthorpe and we were sprinting, not running!

The Queensland Department of Primary Industries got in on the act and made a movie about it which became a best seller. I think their movies to date had only sold about 20 copies each, being about bacterial slime and other attractive titles, but I bought around 300 of this one and sent it out to every Council listed in Yellow Pages that I could find. Slowly we got all the hard and impossible tanks to clean around the country - in two years we had cleaned a hundred tanks and thought we knew it all!!

What was your biggest success?

There are two successes that come to mind – one of a practical nature and the other more of an achievement for our process. After cleaning about ten tanks, with the diver standing in one spot at a time and pushing the vacuum head around on a long handle (remember we were underwater pool cleaners then!)… the handle broke off!! I thought..."now we are in trouble, but I will push it along using the handle stub to finish the job". We found out we could travel around four times faster and easier – so if innovation can come out of adversity, this was the BIG ONE!

As for the achievement one: we were working away in a small country town one Sunday morning, minding our own business, when this guy, dressed for golf, strode up and confronted us…"What are you blokes up to?" "Not stealing water are you?" So I told him we were vacuuming out the tanks around the place and giving them a thorough inspection for water quality issues and everything else we could think of at the time. "Any way, who are you?" "I'm the Mayor he said, I live just down the road, and people have been stealing water around these parts lately". Then he asked what the condition of the tanks were like, seeing as he was drinking the stuff himself. So...I told him – "a bit like in a third World country" and proceeded to show him the swallows flying in and out of the tank and the security gate hanging off its hinges and all the other things that were pretty obvious (to us anyway)! He was late for golf, but did mention he would talk to the General Manager about it on Monday. I told the

Editorial continued from previous page

strict requirements for the performance of these filtration and disinfection control points and clear limits that constitute a transgression. For example, for plants claiming the highest level of protozoan management, the water from individual filters must have a turbidity of <0.1 NTU 95% of time, <0.3 NTU 99% time and must not exceed 0.5 NTU for any 3 minute period. For treatment plants claiming lower log removal of protozoan pathogens, the requirements are slightly less demanding although the target turbidity is still very low at 0.15 NTU.

Since a restructure of the Council Water Supply division in1997, GWRC have been able to substantially reduce operational costs and part of this has involved the Com::pass system. These costs have not even paralleled the CPI increases over the last 10 years. The restructure did not include cutting staff and there has been no reduction in service levels. They have also improved their Ministry of Health ratings over this period. Pretty impressive really! Made me think isn't this what all water treatment operations should be like. It's not hard, it just requires commitment to what we are about i.e. producing safe drinking water. But interestingly GWRC has been able to demonstrate very large savings doing it.

So the Kiwis have thrown down the gauntlet. Jason and Chris are a formidable team but there is no reason we cannot do this in Australia also.

I am sure that Jason and Chris would welcome anyone from Australia seriously wishing to move their water utility along the same lines. Contact WIOA if you would like to follow this up.

boys that I thought the 'messenger would be shot for this one', and this would be our last time working in the Mayors town and surrounding area! Two months later we received a call from the water supervisor asking if we could assist them in fixing EVERYTHING listed in our reports! All our reports had been tabled in Council, put on their web site, and they had $70K a year to spend for however long it took to fix everything! All due to the Mayor being late for golf (and us working on a Sunday). I haven't met a Mayor since, but we still work on Sundays and live in hope!

Then Sydney Water finally returned my constant phone calls and passed me onto Max Harry. Max used to handle all the crank calls apparently! He arranged a meeting with some of his corporate clients and told me I had 20 minutes to make or break. So…I brought along $30.00 worth of chocolate biscuits, and it was a 'done deal'. Oh, they must have liked the talk as well, because we were in the door with the big guys and have never really looked back. Sydney Water also had a video production unit, so another movie was made, hundreds of copies were bought and sent out, this time into Victoria, SA and WA – there was no turning back from that point on.

What has been your worst job?

We have found lots of pretty ordinary things in tanks to date, but the dead dog sort of sticks with me. It was floating on the surface, around 4 to 6 weeks old, so I decided to get it out somehow. Wrapped it in a tarp, got my shoulder under it and carried it up the ladder. That was OK, because I still had my full face mask on and couldn't smell anything. The guys up the top who were helping (and vomiting at the same time) should have been a 'give away'. When I lifted my mask off, (which was covered in 'dog bits'), I just about dropped back down the ladder!

The local supervisor told me later (after the tank was drained and sterilized), that he thought his wife had bought a new brand of coffee, because his morning cuppa had tasted a bit different for the last week! 'Hair of the dog' took on a whole new meaning!!

What has been your philosophy as you have developed the business?

This probably defies all those 'self help' and management books out there, but I have just continued to 'make it up as I went along'. I have never been in a hurry to make a profit out of it all, but rather to make life easier out on the job. Better equipment and more resources (which makes you sleep better at night, knowing things are backed up and equipment is duplicated).

Over the years I have had some great mentors and also many great employees who have not been afraid to put in their ideas. My job has just been to make it all work out and to keep on trying new things. I have a shed full of failed equipment and a memory full of things that were pretty stupid in hindsight, but we also came up with some classics along the way. We began using KY lube on our dry suit seals way before it was accepted practice…..and don't ask me where THAT idea came from! But it is tax deductable and not everyone has a plausible excuse to carry around over 40 tubes of the stuff in the truck at any one time!

What are your thoughts on how we can raise awareness in the OZ water industry, of the poor state of storages and what needs to be done?

Any one reading this magazine has contributed for a start. Education, through formal training, attending conferences and in-house seminars are all good. Many of us know an awful lot about one little thing, and not much about the other co-dependant things. It is important to learn as much as possible about not just our own field of influence, but how it can effect (and enhance) other related subjects.

But there is one thing that not everyone seems to be comfortable with, and that is 'asking the hard questions'. Unless more people continue to ask the hard questions, we will remain complacent and continue to 'do things as they have always been done". This is often to avoid offending another person or upsetting an established process, but everyone who holds a job in this industry has an obligation to 'do the best for the Industry' and not what is sometimes best for themselves.

Where to in the future for Dave Barry and Aqualift?

Don't give up, keep on going till one of my guys does the decent thing and 'puts me down' (painlessly I hope). Continue to ask the hard questions, mentor the younger generation in return for the mentoring I received over the years and finally to continue to expand Aqualift, not in a financial sense, but rather in a way to remain relevant within the industry as it grows and changes.

In seventeen years, it is less about diving and more about 'problem identified, solution supplied'. That little mission statement hit me the other day and I thought …"that's nailed it"…but the acronym leaves a bit to be desired hey??

PIPES, MATERIALS AND FAILURES

Greg Moore

Pipes in the Australian Water Industry are estimated to have a replacement cost of around $35 billion and the fact is that many are reaching the end of their useable life. The total length of pipelines in use in Australia has been estimated at more than 139,000 kilometres. Figure 1 shows the typical lengths of pipe laid each year between 1875 and 2002. Most development occurred between the mid 1950s and the mid 1970s where large numbers of pipes were laid to accommodate the major expansion of population in the major cities fuelled by immigration and post World War II development.

Due to the ravages of corrosion, many pipes have already been replaced with alternative "non-corroding" materials, but corrosion of some traditional pipe materials is an ongoing issue for all water agencies.

Figure 2 shows the types of pipes of different materials for one large Australian water utility. However pipeline material do vary between water utilities. This is primarily due to water quality. Asbestos Cement (AC) pipes were not generally used where water was soft, such as in Melbourne or Sydney. In these systems the AC component was replaced by grey cast and ductile cast iron pipes which therefore make up the largest percentage of pipes in these water reticulation systems.

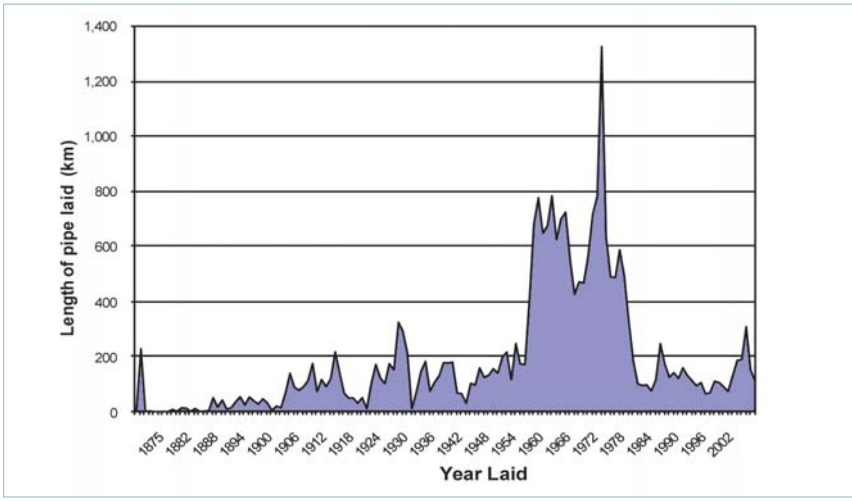

Figure 1. Lengths of pipe laid by one large Australian water utility each year between 1875 and 2002.

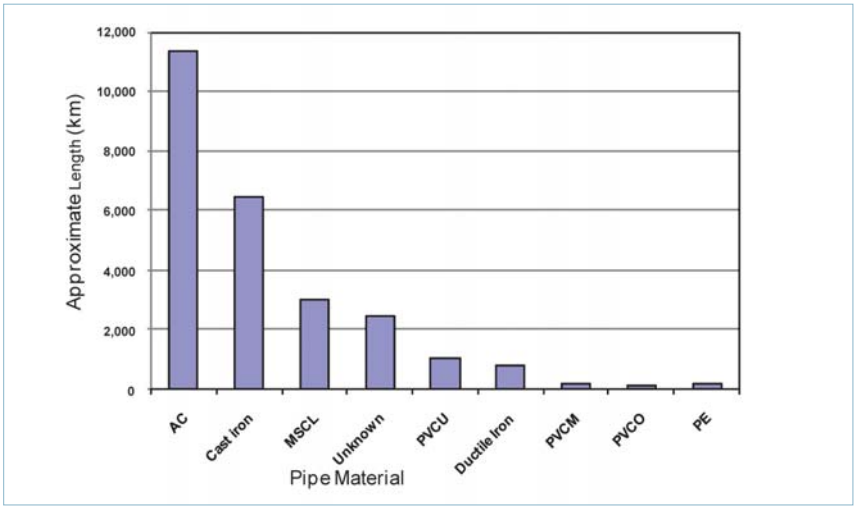

Figure 2 Lengths of different pipe types for one large Australian water utility.

Pipes and Pipeline Failures

Pipes don't last forever and pipeline failures are a fact of life for water utilities. Figure 3 shows the number of pipeline breaks per 100km for a number of Australian capital city water utilities. The graph clearly shows the significant differences between utilities.

Nationally, the average rate of breaks of all major water agencies is 28 per 100km. This means that for the 139,000km of mains in 2007/2008 there were a staggering 38,900 breaks. This equates to one every 13.5 minutes.

In the past, pipelines were run to failure, the point at which the number of failures in a pipe becomes unacceptable. While this is still often the case for small mains, for large mains there is now greater emphasis on undertaking pipeline condition assessment to predict failures and to replace the pipeline before any failures have occurred.

Metal Pipes

Cast Iron Pipes

Cast iron pipes are the most common type of pipes in most distribution systems. Cast iron pipes were the first

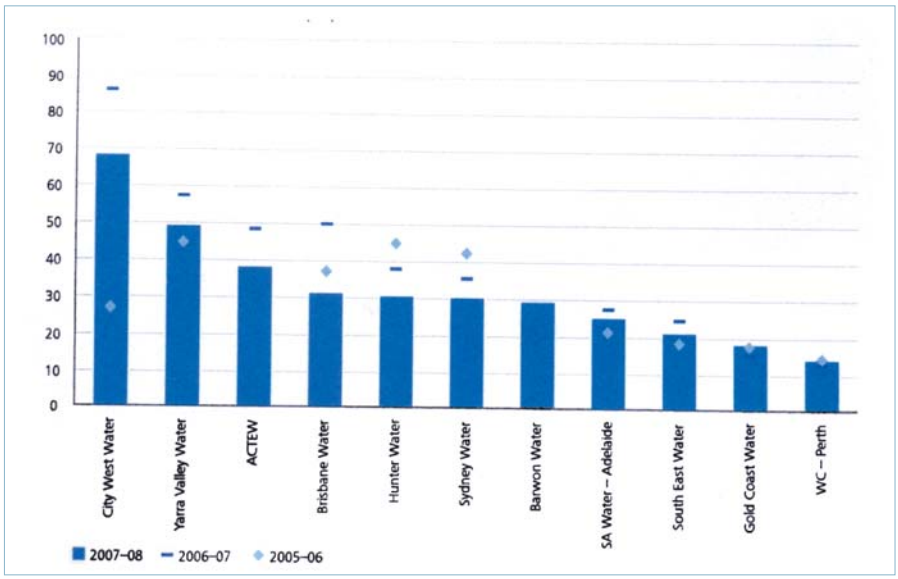

Figure 3. Watermain breaks per 100 km for mains in 2007–2008.

metal pipes used for water supply. The earliest cast iron pipes were produced in Europe and all of the early cast iron pipes used in Australia were imported. In the late 1800's, many foundries started to produce cast iron pipes in Australia. These were supplied to local markets and in the absence of any standards, were often made to local requirements. It was not until 1903 that cast iron pipes were standardised in the UK. Typically the pipes were thick walled grey cast iron with an internal lining and external coating of Trinidad tar or bitumen. The internal and external coatings served as corrosion barriers. The deficiencies of this basic corrosion protection soon showed up internally where the coating broke down resulting in extensive internal corrosion (Figure 1). Many of these pipes in Australia were then cement lined in situ. This overcame the majority of the internal corrosion problem. Cement mortar lining has proven to be a very effective lining for prevention of internal corrosion. The cement layer provides both a physical barrier to the water and also provides a high pH environment at the cast iron surface. External corrosion is by far the most prevalent form of failure of cast iron pipe (Figure 2) due mainly to corrosive soils. The thick walls of the early cast iron pipes made some allowance for this external corrosion. Some of these pipes with only the original bitumen external coating are still in use today after 100+ years of service but generally only in areas of low soil corrosivity. The earliest cast iron pipes

were manufactured in sand moulds. As a result of the manufacturing process, a layer of silica formed on the surface of the pipe. This layer provided some protection against corrosion. With the introduction of spun cast iron pipes in 1929 produced in a steel mould, the silica layer was not formed. The new process allowed the formation of pipes with a thinner wall but without the protective silica layer. As a result these pipes were in some ways more prone to corrosion than the pipes produced using the original methods.

Figure 1. Internal Corrosion of an unlined cast iron pipe.

Figure 2. External Corrosion of a cast iron pipe.

Steel Pipes

Steel pipe was first introduced in Australia in 1885. It was sometimes incorrectly referred to as wrought iron pipe. At this time, welding of steel had not been invented so the steel pipes were either riveted (Figure 3) or joined using an innovative locking technique using longitudinal bars (Figure 4). Not surprisingly this Australian invention was known as locking bar pipe and was used extensively from 1895 – 1925. The most famous pipeline constructed using this pipe was the Perth to Coolgardie pipe line. The pipeline was constructed in 1898 – 1902 and was 560 km long. However like the early cast iron pipes, both internal and external corrosion protection was limited to either a tar or bitumen coating.

Figure 3. Riveted steel pipe.

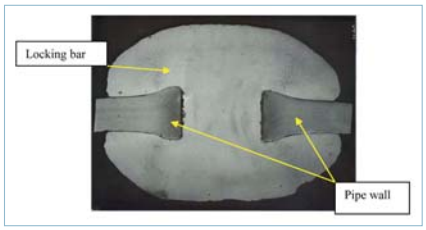

Figure 4. Cross section of locking bar joint. The two edges of the pipe barrel are formed into a dovetail shape which fits into a grooved metal bar which is then rolled down over the dovetailed ends to lock the the pipe together.

These pipes were usually larger diameter and in most cases were lined in situ with a cement mortar lining that overcame the internal corrosion issues. External corrosion protection was provided by a layer of hessian reinforced coal tar or bitumen. Inevitably this failed.

The different mechanical properties of the steel compared to cast iron generally resulted in the formation of leaks which in many cases could be effectively repaired. This was in contrast to grey cast iron pipe that generally fails catastrophically.

More Recent Metal Pipes

Ductile Iron (DI)

Ductile cast iron pipes were first introduced into Australia in 1973. The mechanical properties of this material with higher tensile strength and ductility compared to grey cast iron meant that the wall thickness was able to be reduced for equivalent pressure ratings. It was recognised that external corrosion prevention required enhancement and at this time the use of loose fit polyethylene sleeve became more wide spread to provide protection. This technique has in most cases provided very good performance but like all techniques has its limitations. Where problems have been experienced, these have been related to

galvanic corrosion of the ductile iron due to the use of un-insulated copper water services, poor installation or being used in situations where this form of protection is inappropriate, for example anaerobic saline ground conditions. Internal corrosion protection is provided by a cement mortar lining (DICL). The lining is added at the time of manufacture resulting in a dense high quality lining with excellent resistance to corrosion.

Steel

While steel has been used for over 100 years, today's steel pipe has had many improvements in corrosion protection resulting in a high performance product. Fully welded steel pipe externally coated with fusion bonded polyethylene and centrifugally lined with cement mortar lining can provide a 100 year life demanded by the industry. Some manufacturers have recently promoted epoxy or other organic linings as an alternative to cement mortar lining but these are unlikely to provide the long term performance required by the Water Industry. Prior to the introduction of fusion bonded polyethylene external coatings, coatings of reinforced coal tar enamel were widely used. While this provided improvements over the very early tar and bitumen coatings it was susceptible to deterioration, particularly due to soil stresses which resulted in splitting of the coatings and subsequent exposure of the steel to soil corrosion (Figure 5).

Figure 5. Splitting of coal tar enamel external coating due to soil stress.

External corrosion of steel pipes is also the major cause of pipeline failure; however welded steel pipes and their jointing technology are also suitable to the application of cathodic protection (CP). This has allowed CP to be retrofitted to these pipes and has been very successful in extending the life of these pipes. The use of CP has not been effective on the very early steel pipes which were lead jointed. The lead created high resistance joints and prevented sufficient electrical continuity.

Non Metal Pipes

Wood

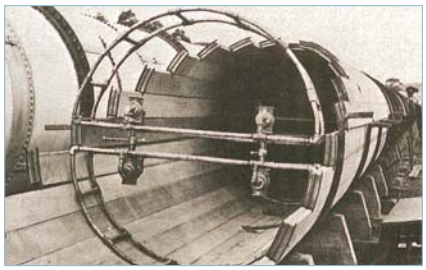

Figure 6. Construction of an early wood stave pipe.

The first pipes used in ancient times were made of clay or wood and are only of historical interest as none of these are in current use. Some pipes used in Australia were however of wood construction known as wood stave pipes where slats of timber

were fashioned into a pipe, not unlike a wine barrel but continuous in nature (Figure 6). These wood stave pipes were used by many water agencies but they generally only provided a short life due to internal rotting of the timber. Steel reinforced concrete pipes were also used by some agencies but these were generally relatively low pressure and were not widely adopted by the major water agencies.

Asbestos Cement (AC)

The first AC pipes were manufactured in 1916 in Italy. Manufacture commenced in Australia in 1926 and continued up until 1986 when manufacture ceased due to the health and safety issues associated with use of asbestos. AC pipes were one of the first composite pipes being composed of approximately 10-15% asbestos fibres in a matrix of Portland cement. Some also had a small amount of finely ground silica added. AC pipes were used extensively in Australia except where the water was soft with a low pH. However in some situations, bitumen coating of the AC was available to provide additional protection in situations where there was soft or aggressive water. In harder water, AC pipes were promoted as having exceptionally long life and as such, large quantities were used. In some utilities AC pipe makes up more than 50% of pipeline assets.

AC pipes do not corrode in the way that steel and cast iron pipes rust, but instead it undergoes chemical conversion of the cement binder. There is often no discernable change to the dimensions as a result of this change, but the loss of binder or its replacement by a weaker product forms a weak material that when damp has mechanical properties that have been called (unfavourably) by water maintenance servicemen as wet cardboard.

Originally it was thought that AC pipes would not corrode and life expectancies of the order of 80-100 years were regularly quoted. This was found not to be the case where the pipes were buried in aggressive soils or where they conveyed aggressive water.

AC pipe deterioration can occur at both the internal and external surfaces of a pipe. The resulting loss of strength begins to compromise the structural integrity of the pipe making it progressively more susceptible to failure due to internal pressure loads.

The common method used to assess the depth of deterioration or degradation of an AC pipe wall is by staining with phenolphthalein indicator. Phenolphthalein is a weak acid indicator that changes to a progressively deeper magenta colour from a pH of 8.3 to 10.0. This colour change can be used to highlight the difference between the alkaline areas where the cement matrix is sound and the lower pH areas where the $Ca(OH)_2$ has been leached away (Figure 7).

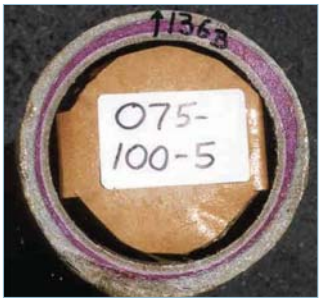

Figure 7. Cross section of AC pipe showing internal and external deterioration. Undeteriorated portions of AC are coloured magenta (Courtesy Opus International Consultants).

Plastic Pipes

In smaller sizes these pipe materials are also more economical than traditional metallic pipes. As such the industry has seen rapid growth in the use of these materials.

The two most common types of material used in Australia are Polyvinyl Chloride (PVC) and Polyethylene (PE). They are generally cheaper than traditional metal pipes and don't corrode in the traditional sense. However plastic pipes have their own limitations and can fail for reasons not related to corrosion. While the failure rates of plastic pipes are generally much lower than other traditional pipe materials, there is often considerable focus on plastic pipeline failures and subsequent concerns about their long term performance.

Plastic pipes are made of a visco elastic material. This means that when the material is placed under constant stress, the material creeps and in the long term the stresses required to cause a pressure rupture are less than those when the pressure was initially applied. This change in the rupture stresses can be related to ageing effects such as heat or UV, but in a buried pipe these effects are not relevant and changes to the rupture stress will occur very slowly under constant stress. All plastic pipe standards use a figure of 50 years to determine the design wall thickness of the pipes to account for visco elastic creep. This has created a lot of confusion in the industry as this has regularly been interpreted as the pipes only have a design life of 50 years, after which they will start to fail. This assumption is incorrect. There are high expectations on the long term performance of these plastic pipes and there are many examples of this but also some examples of plastic pipe failure. Plastic pipeline failure can be complex but the fundamental cause is its resistance to slow crack growth and subsequent rapid crack propagation resulting in brittle cracking (Figure 8). It is these aspects along with a desire to reduce the amount of material in the pipe that have driven the development of different PVC and PE materials with ever increasing resistance to slow crack growth.

Figure 8. A longitudinal crack in a PVC-U sewer pressure main.

Polyvinyl Chloride (PVC)

PVC pipes were first produced in Germany in 1934 but it took until 1960's for manufacture to start in Australia. This material was used widely in the rural and irrigation industries but it wasn't until the 1980's that major water agencies in Australia started to use this material for pressure pipes. The original PVC material was more correctly known as uplasticised PVC or PVC-U. In the last 10 years variations of the PVC have become available and include modified PVC (PVC-M) and molecular oriented PVC (PVC-O). Both these materials have improved physical properties compared to the original PVC-U. This has allowed the plastic pipe industry to produce pipes with lower wall thickness for equivalent pressure ratings (Figure 9) and improved resistance to slow crack growth. PVC pipes for pressure applications are joined by rubber ring joints and these generally have provided a good leak free service life.

Figure 9. Different types of PVC have different wall thickness for equivalent size and pressure ratings.

Polyethylene (PE)

Polyethylene pipes were first used in the early 1950's in Europe and the USA. Some pipe was produced in Australia in the late 1950's but it wasn't until the 1960's when it started to be produced more widely. Since its introduction there have been significant changes to the polyethylene resins. Early PE material was classified as PE 32 which meant it had a long term minimum required strength of 3.2MPa. The standard material that is produced and used by the water industry today is PE100 with a long term minimum strength of 10MPa. These significant changes to the strength have also resulted in a product which has very high resistance to slow crack growth. This makes it an ideal material for pipeline renovation. The PE is pulled through existing pipe materials without the need to fully dig up or create a new trench. PE pipe can also be produced in long lengths with minimal joints all of which can also help to provide a long service life. Current generation PE pipe has excellent resistance to slow crack growth and failures of the type shown in Figure 10 are rare. One draw back with PE as a pipe material is its need to be welded. While this also has some benefits in terms of the pipeline design, the welding process requires considerable quality control and experience to produce good welds. To date, joint failure in PE pipe systems is the area where most problems have occurred. A number of water agencies are now specifying PE for all applications and the challenges for these water agencies will be to introduce appropriate requirements for quality control of joint welding.

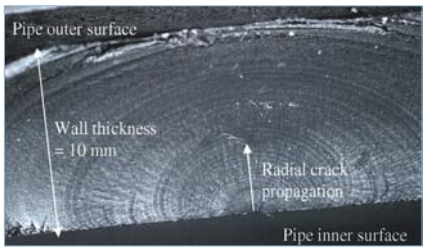

Figure 10. Slow crack growth in PE pipe material.

Other Plastics (ABS, Glass Reinforced Plastic (GRP))

Glass reinforced plastic pipes, also often referred to as fibreglass pipes are used in limited applications where high corrosion resistance is required, particularly in the larger pipe diameters. These have found more favour in the chemical industry and in seawater applications and with few exceptions have not been used in many water reticulation schemes. Similarly Acrylonitrile Butadiene Styrene (ABS) has not generally been used as a mainstream water reticulation pipeline but is widely used for process pipework in water and wastewater treatment plants.

Acknowledgments

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The Author

Greg Moore (geemoore@iprimus.com.au) is the Principal of Moore Materials Technology Pty Ltd in Adelaide. He specialises in failure analysis of plastic and other non ferrous pipes, assessment of protective coatings, soil corrosivity, corrosion of stainless steels and other materials used in the water and waste water industry.

WATER SAFETY vs OCCUPATIONAL SAFETY

Dave Barry and Peter Mosse

Most things in life require a balance. The Water Industry in Australia is facing a conflict in maintaining an appropriate balance in the area of occupational safety. It is something that is very easy to overlook while things 'appear to be functioning' satisfactorily. A lot has been said lately about producing safe drinking water, water that doesn't make the customer ill. We have the *Australian Drinking Water Guidelines, Safe Drinking Water Regulations* and other management systems to provide guidance and direction. There are processes and technologies in place and a substantial infrastructure to deliver safe drinking water to our consumers. But is it enough?

To operate this infrastructure, we require personnel who can carry out their roles safely and with confidence. Without OHS, personnel working in the many diverse fields that make up the water industry would be placed at risk, and the water supply utilities could be subject to very substantial legal liabilities.

But this is where the balance becomes 'blurred'. OHS only extends to the personnel involved in the production and distribution of water. OHS and its significant penalties for non-compliance have stopped short of managing the health and safety of the consumers. This is a shame when you consider the advances made to the safety of our work force in the last generation.

In an OHS situation, a 'near miss' report will lead to a coordinated effort to examine, analyze and correct the situation. This is because the reporting mechanisms are very simple and can be instigated by any member of staff notifying the Health and Safety officer of unsafe practices. Indeed members of the general public can pick up the phone and call Work Cover.

In contrast, the protections put in place to look after the water consumers are very poor, in terms of legislative requirements and enforcements. How simple is it to report a 'near miss' in a water quality situation? The evidence is not always obvious to the general public or to the naked eye without scientific testing. Auditing of records and extensive follow up is often required before an incident can be identified and appropriate action taken.

Figure 1. One of the elevated storages.

The process required to instigate an action is far harder and therefore likely to be ignored, unless something of a catastrophic nature occurs.

All of the above is leading up to a very important point. Some OHS practices are placing water quality at risk on a daily basis. There are many examples of operators being restricted from carrying out necessary procedures in the name of OHS, without alternatives being given, to allow these necessary procedures to be carried out as required. We will provide two examples.

Figure 2. The access hatchway surrounded by piles of bird droppings.

Treated Water Storages

Elevated storage tanks (Figure 1) are a good example of neglect. OHS departments restrict access to these structures. Most personnel are not comfortable or competent to climb anything more than a basic, low ladder system. Consequently high, restricted areas are often left unattended or unchecked. Without checking, water utilities do not really know what is happening to the water in these storages. Somehow the restrictions placed by OHS must be replaced by a system to allow regular inspection and correction of any problems. Ignoring this requirement puts many members of the public at risk compared with one or two utility staff. Two case studies are presented here and the fact that these cases are typical is rather scary for anyone consuming water from a distribution system.

Case 1

An elevated tank supplying a town of over 2000 was deemed unsafe to climb by the water utility OHS department as part of a general audit done on similar types of tanks. This tank design relies on roof mounted drains to prevent storm water from collecting and draining back into the access hatches. The situation was further complicated by significant bird activity and large amounts of faeces that had collected on the roof area (Figure 2). When the tank was finally accessed safely by trained personnel, a thick, smelly, green, soupy material was found to be draining directly into the stored water (Figure 3). This mixture of dirt, bird faeces and storm water had blocked the roof drains due to a lack of regular inspections and maintenance! The irony of this tank was that the internal ladders had been designed to meet AS1657-1992 (Fixed platforms, walkways, stairways and ladders) and yet there was no safe access to the roof and the hatches.

Figure 3. Ponded green water with easy access to the hatches.

Figure 4. Feathers on the surface of the water. Clear proof of contamination.

Case 2

An elevated tank situated inside the main depot of a water utility where at least 50 personnel were had been left unattended due to OHS restrictions. It was an obvious habitat for pigeons that were frequently observed flying around and roosting on the tank. This bird activity led to an accumulation of faeces across the roof and around the entry hatch area, due to a lack of regular maintenance. When the hatch was opened, the surface of the water was covered in feathers (Figure 4) that had blown into the tank past the unsealed entry hatch frame.

The importance of preventing entry of bird faeces to treated water storages is provided by the case of a waterborne disease outbreak in Gideon Missouri in 1993. In an attempt to address customer complaints relating to the taste and odour of the water, the local council undertook an extensive flushing program to clean out the system. This led to a rapid turnover of water from the municipal storage tanks. Shortly after this, people in the town started to become ill. The end result was that of a population of 1100 people, 600 became ill and 7 died! Sediment from the tank was found to be contaminated with Salmonella. Inspection of the tank revealed a bird roosting site over the roof of the tank, bird droppings on the roof and feathers on the surface of the water, pretty much what you can see in Figures 2 and 4.

Clearly those towns in the case studies above are at a high risk of seeing Gideon repeated in them.

To protect public health, a balance is required between allowing access and inspection and protecting the worker.

Media Filters

Media filters (sand and filter coal) are the only barrier to the pathogens *Giardia* and *Cryptosporidium* in a conventional water treatment system. Many people erroneously think that as long as the chlorine system is working, everything is fine. The problem is that chlorine does not kill *Cryptosporidium* or *Giardia* at the levels we can use in the water industry. So if the filter doesn't take them out, the chlorine won't touch them and they will be free to pass out into the distribution and possibly into someone's glass of water.

Let's consider some figures. In an analysis of 61 published reports of waterborne disease outbreaks, Risebro *et al* (2007) found that:

- 41 were due to more than 1 cause
- 34/61 were due to two events notably source water contamination and treatment system failures occurring together
- 23/61 were due to contamination of drinking water with protozoa where there had been a failure of treatment
- 90% of the identified failures of treatment were filter failures, many of which were chronic failures.

An important part of ensuring that media filters are operating correctly is to inspect the filter bed inside the filter cell. This should be carried out at least once per year. But once again many OHS departments in water utilities are making it increasingly difficult for operators to enter filters to carry out these inspections. Some allow entries but only if the treatment plant is shut down. Unfortunately the plant needs to be running to allow full critical observation of backwashes and then inspection of the media.

Figure 5. A filter with a relatively high risk of injury during entry. Fall arrest would be appropriate here.

Figure 6. A safe easy filter to enter. Fall arrest would not be necessary here.

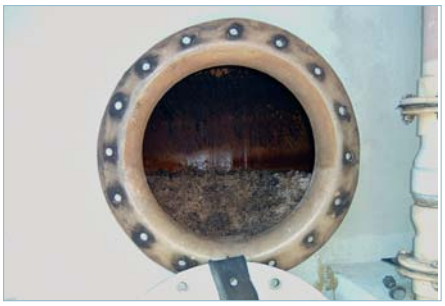

Figure 7. A fully enclosed filter. Actual entry to the filter would require full consideration of confined space entry however simple inspection of the surface of the media is simple and safe.

There is no single procedure for entry to a filter since they are all quite different (Figures 5 and 6) but all open filters can be entered quite safely. Mosse and Murray (2009) provide an example risk assessment and generic filter entry procedure. This can be taken as a basis for site specific entry procedures to be developed. Enclosed filters such as the one shown in Figure 7 do pose some difficulties but inspections are always possible.

The major issue with filters is to ensure access is made as safe as possible. The highest risk is climbing over a rail where no "gateway is provided. Simple gate systems can be easily retrofitted or included at the time of construction (Figures 8 and 9).

Again, to protect public health, a balance is required between allowing access and inspection and protecting the worker.

Figure 8. A simple "trombone slide" entry gateway has been cut in the rails surrounding a filter

Figure 9. A purpose built filter access point.

Conclusions

At present the formal aspects of OHS as practiced in the water industry are aimed at protecting the worker and rightly so. BUT they are not similarly aimed at protecting consumers from debilitating gastrointestinal illness. WRONG. The balance is just not right. The imbalance needs to be addressed urgently if we are to avoid an event such as Gideon, Missouri or a Galway Ireland where out of a population of 72,000, 250 became ill or Milwaukee where in 1993 over 400,000 became ill with Cryptosporidiosis and over 100 died.

In the words of an old folk song "when will they ever learn"? All we can do is try to draw attention to the problems. Those of you in the water industry with responsibilities take over from there. If you need some incentive, think about how you would feel if you found yourself in the position of watching an event like Gideon Missouri unfold in a town or city you have responsibility for. This and the photos we include above are the reality. In the words of Steve Hrudey

"If after reading about all of the other factors that have gone wrong to cause outbreaks in 15 different affluent nations you are truly certain that none of this could ever happen to you, then congratulations. To be justified in being certain, you must know your system very well and you must understand all of the ways that things can go wrong. You must have effective and well-practiced plans in place for dealing with the many problems, large and small, that can happen if you are to be truly confident about avoiding a Walkerton style disaster. However we suspect that those of you most likely to avoid encountering such problems will be those who are willing to believe that Walkerton style problems could happen. The choice seems clear: unwarranted peace of mind or nervous confidence underlying the vigilance necessary to forestall appearance before a Walkerton like Inquiry."

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MEASURING pH PROBLEMS OVERCOME

Wayne Shaw

The problem arose when I received notification of a high aluminium residual in a routine reticulation system sample. This was not what I wanted to see and of course I had to question the test result.

My reason for this was that I ran the plant at a coagulation pH of 6.0, which is the pH I understand to be the point of least solubility of aluminium into the water. My online pH meter was telling me that this pH was indeed 6.0 +/- 0.2. I trusted the online instrument, as it was not very old, routinely calibrated and kept clean. I decided to check a sample of the coagulated water with my portable pH meter, which again is routinely calibrated and kept clean. For the record I use Schott full glass probes on the portable meters. The check with the portable unit came back with a pH of around 5.3. My immediate reaction was to clean and recalibrate the portable unit but alas the same reading resulted.

Figure 1. Stilling vessel.

What to do?

I still had one of the old comparators and so decided to use it to do another check. Admittedly the reagents are like me getting a bit long in the tooth, but still indicated a reading in the same 5.3 area using Bromo Cresol Purple reagent tablets.

This led me to getting in touch with my instrumentation technician and asking if he would mind coming in and carrying out another full calibration and clean of the online instrument. This he did as well as replacing the tip and electrolyte. After all this, the same reading of around pH 6.0 was obtained. He then did a calibration of the portable unit to check my earlier calibration and checked the water with it. The result was again around pH 5.3.

At this time another instrument technician was consulted and his thoughts were that the flow through the inline unit was too fast for the probe to react and so couldn't give a reliable reading. The flow rate was reduced, and even at a very low flow the readings were still hit and miss. It was important to be able to keep the flow rate up to keep the loop times close to keep better control over the dosing.

The probe was taken out of the inline fitting and placed in a small bucket which had an overflow hole cut in it so as to act like a reservoir, and the coagulated water flow was directed into the bucket. This simple change proved to be the solution. Even at the normal flow rate, the increased area for the water to travel around had the inline instrument reading close enough to the portable unit.

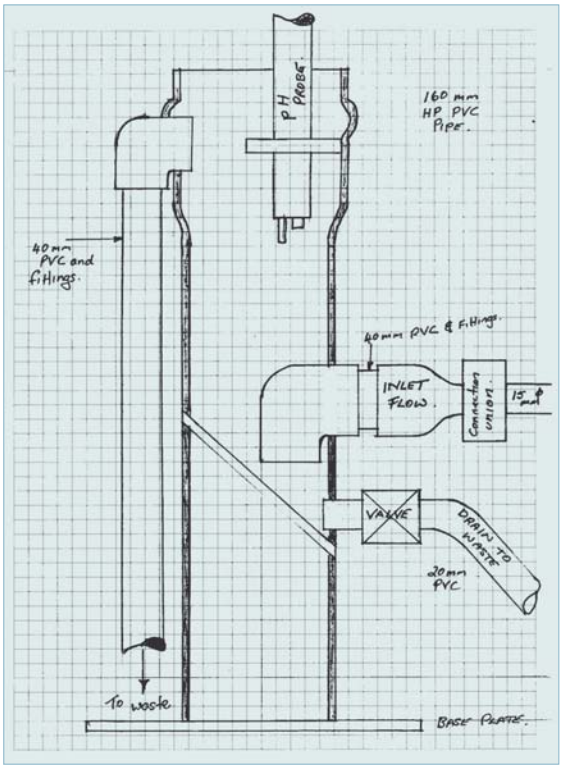

Figure 2. A "technical drawing" of the stilling vessel.

So we set about designing and building what we called a stilling vessel and then installing it in the system. The flow rate through the vessel is in the region of 5 L/min and to date the in line coagulation pH instrument is performing beautifully. I am lucky to have two portable pH meters and one of those is also in the vessel and is checked every morning as a check on the system performance. It is working well here.

Our vessel is basically a piece of 150mm high pressure PVC water pipe 680mm high. The pipe was cut such that a sloping floor could be plastic welded in place to allow for fast efficient draining to remove the sludge that builds up in the vessel over time. The inlet into the vessel is via a 15mm PVC pipe increased to 40mm and directed to the bottom of the vessel to reduce the velocity but keeping the water mixing in the vessel to reduce dead areas. The outlet / overflow is 40mm PVC and is through the wall and welded in place. The support to house the pH probe is a piece of 6mm thick PVC sheet shaped and welded into the pipe at about the centerline of the overflow. The stilling vessel is shown in Figure 1.

A drawing with pipe dimensions of the assembly is shown in Figure 2.

Acknowledgments

Thanks to Duane Kelly for his help in designing and installing the stilling vessel and to Gippsland Water management for allowing operators to try out "crazy" ideas.

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FILTER HEAD LOSS PROFILES

Peter Mosse

Media filters are designed to trap floc particles left over after the clarification process in the spaces between the grains of media. In rapid gravity filters, the aim is to get penetration of floc into the whole depth of the filter coal layer of a dual media filter. As the spaces become filled, the head loss increases, the water is held up by the blockage leading to a lower pressure at the bottom of the filter than at the start of the run. (The pressure at the top will remain the same). Sometimes filter run times are shorter than required. Sometimes this is due to blinding of the filters at the surface or in the first 100 mm or so of the filter bed. In determining the cause of the problem it is useful to construct a filter head loss profile. There are a number of ways to do this.

On the odd occasion that SA Water has been faced with the development of head loss problems with its media filters they have used the technique described below to identify the specific portion of the filter that appeared to be the cause of excessive head loss. The technique represents a practical method of monitoring the hydraulic gradient of an operating filter during the course of a filter run.

The technique involves the installation of a number of open-ended tubes to various depths into the filter bed (Figure 1).

Figure 1. A set of head loss tubes permanently installed in a filter at Mt Pleasant WTP.

The end of the highest tube should be immediately below the top of the filter bed, while the lowest should be as near as practical to the filter floor. There would normally be 3 to 5 intermediate tubes, with some being located just below any theoretical interface between different filter media. The tube bundle can be dug into the filter bed while it is drained. Alternatively it may be sufficient to lower a pre-cut tube assembly as far as the gravel layer during a backwash (when the bed is fully fluidised), and subsequently only directly measure the pressure profile above the gravel layer. This would still allow head loss development in the gravel layer to be inferred (as the difference between the total filter head loss and the measured head loss at the gravel surface.)

As a filter run proceeds, the water level in each tube will drop and this drop in level needs to be measured. This is best achieved using a noise emitting water level sensor attached to a tape measure. Such devices are commercially available (Figure 2).

Figure 2. Examples of water level measuring equipment (photo supplied by Geotechnical Systems Australia Pty Ltd.

As a flow is established through the filter, the water level in each tube will drop to below the water level in the filter. The distance dropped in each tube represents the pressure drop below the no flow hydraulic gradient at that particular point in the filter bed. These measurements can be presented graphically in what is known as a Michau diagram.

The diagrams below represent two instances where SA Water has used this particular technique to good effect. Figure

3 represents the measurements taken at a new Adelaide metropolitan WTP some years ago, where it was identified that the rapid development of excessive head loss (where the line dives to the left) was predominantly occurring at the interface between the anthracite and sand layers. This indicated that the filter media chosen was not correctly matched, and resulted in the media being replaced.

Figure 4 represents the situation that developed at a country WTP where nozzles with very fine slots were used in dual media filters. These filters initially operated without problems, but gradually developed difficulties with excessive head loss. Filter bed head loss measurements indicated that this head loss was developing at the very bottom of the filter (the line dives to the left through the gravel and at the bottom of the filter), indicating that the problem was with the nozzles. The nozzles were changed to nozzles with coarser slots. This change fixed the problem. The very fine slots of the original nozzles had become partially blocked by a combination of biofilm material and very fine sand particles.

There is another way to prepare a head loss profile. The asset management team might not like it but holes can be drilled through the filter wall at specific depths and vertical clear plastic tubes attached to the outside wall of the filter. In some well designed plants these head loss profile systems can be provided for during construction Figure 5.

Figure 6 shows an example of such tubes in a pilot plant filter.

The level of the water can easily be measured using a tape measure and the head loss profile produced. It is also interesting to watch the changing levels as the filter run progresses.

The system described by SA Water is easy to set up. To really know your filters, some knowledge of the head loss profile can be very useful when things start going wrong. Why not set one up and try it!

Acknowledgments

The author would like to thank Werner Mobius of SA Water for information on the system used by SA Water.

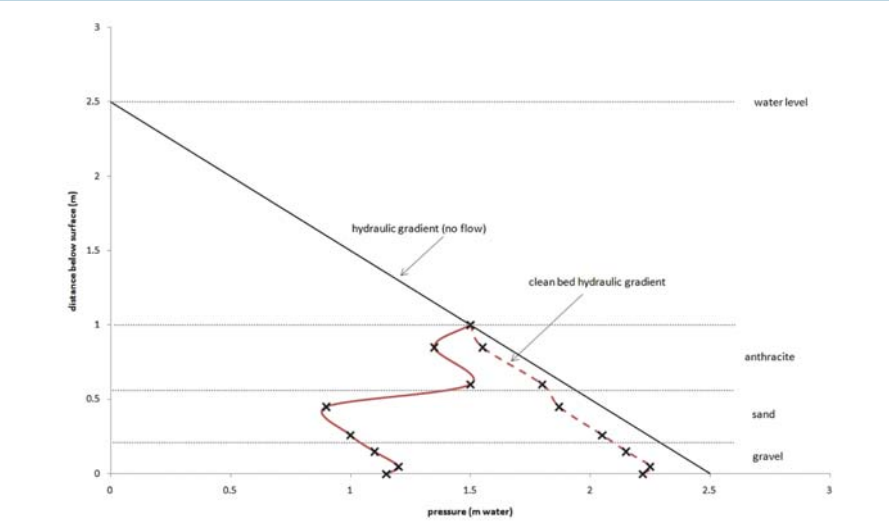

Figure 3. Typical hydraulic gradient resulting from high head loss at a filter media interface.

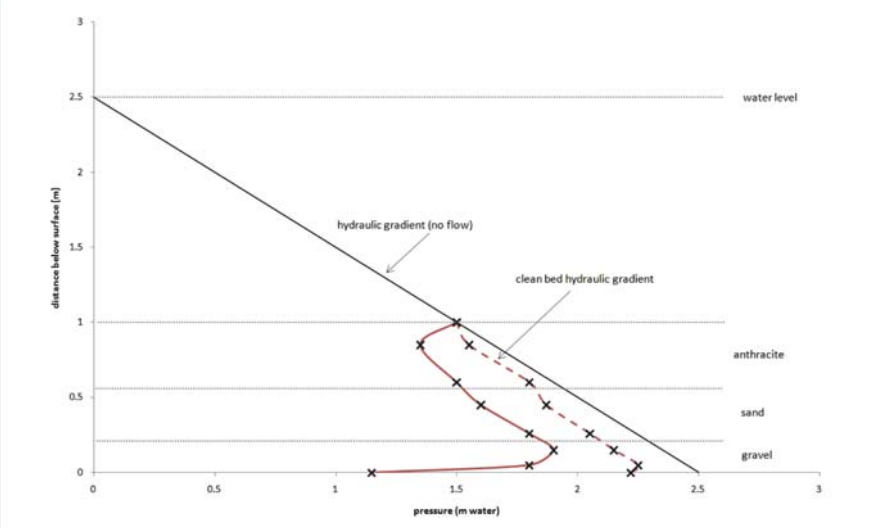

Figure 4. Typical hydraulic gradient resulting from blocking filter nozzles.

Figure 5. Headloss fittings in the wall of the filter gallery. The flexible tubing is disconnected.

Figure 6. Example of flexible head loss profile tubes fitted directly into a pilot plant filter.

LESSONS FOR OPERATORS

VICTORIAN SAFE DRINKING WATER ACT AUDITS

David Sheehan & Leanne Wells

Victoria's *Safe Drinking Water Act 2003* (SDWA) requires that state's water businesses to prepare and implement risk management plans (RMPs) for the drinking water supplies they manage. An integral part of the SDWA is the implementation and independent audit of the RMPs. The auditors need to be approved by the Department of Health.

The first round of audits was held in 2008, and a second round was held in 2009.

There are important lessons in the findings of the audits which can help water treatment operators and other operational staff improve the way that they manage drinking water quality.

First Round of Audits

These were undertaken between May and September 2008, covering the period 1st January 2006 to 30th December 2007. Of the 25 audits conducted, 15 were found to be compliant with the requirements of the SDWA, while for the other 10 a number of non compliances were identified (Figure 1).

A summary of the major findings from the first audits are presented in Table 1.

Non-compliances were classified as critical, major and minor, depending on whether the non compliance was likely to be a critical, major or minor risk to public health. No water business recorded a critical non-compliance, and only one water business was found to have major non-compliances.

Second Round of Audits

In response to 10 audits returning a result of non-compliance in the first round of audits, a second round of audits was held between June and December 2009, covering the period from 1st January 2009 to the date of the audit.

This time, 23 of the 25 audits were compliant. Two returned a non-compliant result (Figure 2). This was a significant improvement on the 2008 round of audits, and demonstrated the commitment of water businesses to improve their risk management practices.

Figure 1. Results of 2008 audits.

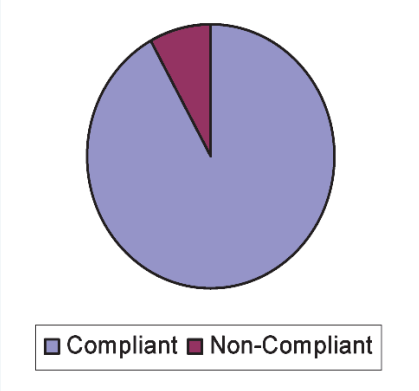

Figure 2. Results of 2009 audits.

The two water businesses that returned non-compliant audit results had findings of minor non-compliance. In general, the findings of minor non-compliance related to:

- Not all actions/documentation had been recorded as required by the water business' RMP.
- The frequency of recorded results did not agree with the RMP.

The auditors noted a number of opportunities for improvement. These are summarised in Table 2.

These opportunities for improvement indicate that there are still issues related to the implementation of the RMPs.

Implications for Operators

RMPs are not intended to be static documents that reside in the head office and bear no relationship to the daily work practices of operational staff. Ideally RMPs should either reflect or direct the daily activities of operational staff.

A significant issue that was identified in both rounds of audits was that in many instances the practices that were being undertaken in the field did not match the requirements or content of the RMP. This may indicate that:

- operational staff were unaware of the requirements of the RMP
- the plan did not match the current work practices in the field
- operational staff were not following the requirements of the RMP.

In the Department's experience, successful RMPs are developed in consultation with operational staff. The plans should reflect the day-to-day activity of operational staff. Quoting a prominent Australian water quality expert, *risk management should not be additional work, it should be the work.*

A RMP should not be a separate document to the one that dictates daily work practice. The daily work practice should be incorporated into the RMP (unless the daily work practice is not compatible with the production of safe drinking water in which case the RMP needs to be updated).

Table 1. Summary of major findings from the first round of audits.

- RMPs did not meet the requirements of the Act
- Lack of evidence that all the risks that had to be addressed by the RMP had actually been addressed
- Lack of evidence that the RMPs had been implemented in the field
- Instruments at water treatment plants (WTPs) not calibrated or maintained, or no records available to show calibration and maintenance had been undertaken
- Current treatment processes not sufficient to manage the identified risks

Table 2. Summary of opportunities for improvement from second round of audits

- WTP operators should complete visual inspection reports to show they have inspected for any potential water quality issues e.g. blue green algal blooms, security of storage.
- Records or results not recorded or not recorded at the interval stated in the RMP.
- Expired pH buffers and test chemicals still available for use.
- Instrument calibration procedures should be reviewed to include tolerance levels
- Acceptable differences between online and laboratory instruments need to be developed, and need to define the action to be taken when instruments are found to be outside limits. (Instruments which are not calibrated are likely to give incorrect readings, and therefore lead to the under or over dosing of treatment chemicals or an incorrect belief that treated water quality is within specification.)
- Calibration records could be made available to WTP operators to allow trending and performance analysis
- Actual values to be recorded rather than a tick a box for pass or fail
- Lack of records that deal with drift between calibrations.
- Need to ensure chemical deliveries comply with product specifications required by water business
- Water suppliers need to improve communication with water storage managers and to ensure sufficient monitoring is in place to minimise risks to drinking water supplies.

One of the often-noted criticisms of RMPs is that they are ultimately all about filling in paperwork and not about getting the job done. In the case of poorly conceived plans, this is likely to be case. Any RMP that is primarily about record keeping should be reviewed. Clearly there is a certain amount of record keeping that is necessary under a risk management approach, in order to demonstrate to senior staff and auditors that the plan is being implemented, but records should serve a more important function than this. Properly used records alert operators to problems and emerging trends, and also provide valuable information to justify plant or equipment upgrades.

Ultimately, good RMPs should allow for the early identification of potential issues that may affect drinking water quality, and assist, rather than be a hindrance, to the day-to-day activity of operational staff. The purpose of the audit process is partly about identifying where plans do not meet the requirements of the SDWA, but it is primarily about identifying opportunities to improve practices to ensure that safe drinking water is supplied to the public.

Where to Next

In order to ensure that RMPs continue to comply with the SDWA, further rounds of audits will be held, with the next full round of audits scheduled for the second half of 2011.

With upcoming changes to the Australian Drinking Water Guidelines and the ongoing development of a range of tools to assist water businesses to improve their risk management practices, the Department of Health will continue to work with businesses on improved risk management.

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Editor's Comments

Despite many WTPs passing SDWA or HACCP or ISO audits we often find the practices at treatment plants do not match the plans and often operators really are unaware of them. In the worst situations, control point summaries displayed at treatment plants bear no relationship to alarm limits in the PLC control system.

Operators have a key role in making the RMP reflect true practice. If you don't know all the details of your RMP, find out. If what you do doesn't match the plan, say where it is different, why it is different and change it. Alternatively if the RMP is correct, then you must change what you do. It is up to management to explain to you why the changes are necessary and must be implemented. If when you implement the changes, it just doesn't work then make this clear and again change the plan. The plan is there to be changed so that it faithfully represents what is done.

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