WaterWorks

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Special Feature – A Review of Australian WTP Performance

WATERWORKS
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Contributions Wanted

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. These can be emailed to a member of the editorial committee or mailed to Peter Mosse, *WaterWorks* Editor, c/o WIOA, 22 Wyndham Street, Shepparton, Vic 3630.

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JSEWQA

Peter Mosse

WorkCover and other such schemes have done a good job. Operators are now well disciplined in the need for consideration of Occupational, Health & Safety (OH&S) requirements for their work and workplace.

Complete a JSEA/JSA, 'Dial Before You Dig', road traffic management, being sun-smart (long sleeves, sunscreen and hats) and numerous other work practices have all made it into the daily routine of a water industry operator. I must admit, I do have to smile sometimes when some of these same operators disappear every hour or so for a smoke… but hey, that can't be controlled. So we have indoctrinated our workforces to consider safety and this is regularly reinforced by television advertisements and threats of workplace inspectors appearing on job sites unannounced. And that's a good thing. No-one wants anyone to be injured or, even worse, killed performing their daily duties.

But what of water safety? What about the safety of those out there who rely on us to provide them with safe drinking water every time they turn on a tap? While we are alert to looking after individuals in the workplace, are we totally tuned in to the possibility that a water quality event might result in hundreds of consumers becoming ill, and possibly even cause some deaths?

Consider Milwaukee, USA (approximately 400,000 ill); Gideon, Missouri, USA (600 ill out of 1,100 people); Walkerton, Canada, (2,300 out of a population of 4,700); Galway, Ireland; Nokia, Finland; Pitsford, UK; and, most recently, Ostersund in Sweden, where 27,000 became ill and a boiled water alert has been in place for months. There are just too many examples of water events such as these occurring in our developed societies.

It is important before we do anything in a water supply system that we ask ourselves: "Could this have an impact on the safety of the drinking water?". Just like 'Dial Before You Dig'... "If I dig here am I going to shut down the communications system for a city?" Same concepts; however, one is more immediate, while the other unrolls gradually and with a slowly sickening sensation that the actions you did (or didn't) pause to think about, even very briefly, have resulted in widespread illness.

Positive Steps

But enough of the negative… let's be positive. Why can't we introduce a new discipline? We could simply add it on to what is already widely practiced and include consideration of the possible impacts of our action on water safety: a ***Job Safety Environment and Water Quality Assessment*** (JSEWQA). It even rolls off the tongue quite easily. And all it would take is the addition of a few extra sections to forms that already exist in most water utilities.

Some examples of how this could be used spring to mind quite readily. At the WTP, what is the consequence of stopping and starting the plant when you know the plant often stops with filters well towards the end of a filter run and heavily laden with floc? Studies have shown that start-up of filters poses an increased risk of exposing consumers to pathogens.

For the distribution system side, in exposing a water main for maintenance or repair, is there a risk of contaminating water? If yes, then consider the control measures – clean and disinfect backhoe buckets, make sure dedicated PPE and tools are used, disinfect the pipe fittings and so on. Most importantly, develop and implement a system to undertake all work in a manner that reduces the chance of contaminants entering the water supply. There are many other examples that could be provided but, hopefully, you get the point.

Are there any organisations out there that are already doing this? If so, congratulations on your foresight and for being so committed. We'd love to hear from you as to how you developed and implemented your system and how effective you think it has been.

As an industry we need to be proactive in developing and implementing systems to ensure that both our staff and consumers are protected at all times.

OUR COVER

Our cover shot shows Tamworth Regional Council staff members Mick Hearn and Jamie Hunt collecting a sample from the Intermittently Decanted Aerated Lagoons (IDALs) at the recently upgraded Westdale Wastewater Treatment Plant. Photo courtesy of Go Cross Media.

EDC STUDY AT WEST WODONGA

Peter Tolsher

Endocrine Disrupting Chemicals (EDCs) are chemicals that can disrupt the normal functioning of the endocrine (hormone control) system and damage the reproductive process. EDCs can be both natural and man-made. Researchers in the United States and Europe have demonstrated a number of effects from EDCs in wildlife populations; however, for most of the reported effects the evidence for a causal link is still weak.

In fish collected downstream from wastewater treatment plant (WWTP) outfalls in the United Kingdom, Europe, Asia and North America, intersex fish (male fish with eggs); altered hormone levels; imposex fish (females with male sex organs); reduced reproductive success; abnormal growth or reproductive development and altered mating behaviour have all been reported.

It was shown that some of these disruptive changes were associated with effluent from supposedly well-functioning sewage treatment works. The effects appeared to be mostly estrogenic and associated with an up-regulation of the vitellogenin gene in male fish. Vitellogenin is an egg-yolk protein and is normally only present in female fish. Under the influence of chemicals with estrogenic properties in the WWTP effluent, the male fish were found to be expressing female characteristics. Studies indicated the most potent components were estradiol (a natural hormone secreted by females) and ethinylestradiol (an active ingredient in the birth-control pill), found in sewage from high-density human populations.

These and other studies have also shown EDCs and other pharmaceuticals may not be fully removed by existing wastewater treatment technologies. The question is, what is the situation in Australia?

In Australia, treated effluent discharged from WWTPs can make a large contribution to the flows in rivers and creeks, particularly during periods of low rainfall (ranging up to 100% of the flow in many locations).

To obtain some information on Australian conditions, a collaborative study was conducted by the CSIRO and the US Geological Survey at the West Wodonga WWTP. This plant receives wastewater from the Wodonga Township, as well as several trade waste customers. The trade waste component comes from an abattoir and a pet food factory, both of which increase the potential for hormones to be present in the effluent. The West Wodonga WWTP has advanced secondary treatment by Biological Nutrient Removal using a five-stage Bardenpho process followed by UV disinfection. The plant receives 11ML/d and has a capacity of around 130,000 EP on a BOD basis. As the plant discharges treated effluent to the Murray River, it was an ideal site at which to undertake such a study.

Murray Rainbowfish

Zebrafish

The aim of the trial was to determine the amount of estrogens in the effluent and to monitor whether the survival and reproduction in fish is affected by EDCs present in the treated effluent from the West Wodonga plant. This would assist in assessing whether the treated effluent has any effect on the receiving waters of the Murray River. The trial focused on the estrogenic compounds and their effect on the reproductive system in a native fish species, the Murray Rainbowfish, and a standard fish test model used in the overseas studies, the Zebrafish.

The Mobile Fish Unit Trials

One-hundred-and-thirty of each adult male Murray Rainbowfish and Zebrafish were utilised in on-site experiments within a flow-through mobile exposure laboratory. These fish were used as they can be easily maintained under laboratory conditions, are found in South Australia, Victoria and New South Wales, and because the males and females are easily identified. Ten fish of each species were collected as initial controls. The remaining fish were exposed to reference water or dilutions of de-chlorinated WWTP effluent. The different exposures included 100% effluent, 100% river water, 50%: 50% (effluent: river water), 25%: 75% (effluent: river water) and 10%: 90% (effluent: river water) for up to 28 days (7, 14 and 28 days).

The laboratory was equipped to conduct on-site experiments under conditions of controlled temperature, lighting, feed, aeration and flow. All surfaces in contact with test solutions were glass, stainless steel or Teflon to minimise any contamination. The "reference" water was collected from upstream of the WWTP outflow and the "effluent" from the effluent channel (100%-effluent) into separate 200L stainless steel holding tanks. The flow rates ensured that retention time in the holding tanks did not exceed two hours. Throughout this experiment, fish were maintained at 24°C (+/-1) under flow-through conditions in the glass aquariums. A dissolved oxygen concentration of >85% was maintained throughout the experiment.

The fish were sacrificed at days 1, 7, 14 and 28 and samples of their liver, gonads (ovaries and testes), and blood/plasma were frozen to -80°C for analysis. The fish were then checked for gross abnormalities, intersex status and vitellogenin detection (mRNA and protein) using standard molecular techniques.

Effluent Testing

Effluent samples were collected every day to characterise the chemistry during the on-site fish exposure experiment in April–May, 2009. Basic water quality parameters (chemical oxygen demand, total suspended solids, ammonium and major ions) were analysed using standard techniques. The effluent and river water

An external view of the Mobile Fish Unit set-up.

samples were analysed for a range of EDCs, pharmaceuticals and consumer product chemicals.

Results

EDCs in the Effluent

Results of the analysis for EDCs in the treated effluent are shown in Table 1.

During the 28-day study, 17β-Estradiol, 17α-Ethinylestradiol, Bisphenol A, 4-Octylphenol and 4-Nonylphenoethoxylate were detected at concentrations of less than 1ng/L in the effluent samples. Estrone and 4-nonylphenol were detected in the effluent at maximum concentrations of 27ng/L and 1000ng/L respectively.

The relative potency compares how strong the EDC effect is relative to the Estradiol. So, for example, Nonylphenol is one-ten-thousandth as effective as Estradiol. The assessment is based on a laboratory test that measures the ability of the EDC to bind to biological receptors.

The WWTP effluent and Murray River reference water did not affect fish survival during the 28-day trial. The fish were under minor physiological stress, but we did not find intersex condition (male fish with eggs) in the male Murray Rainbowfish or Zebrafish exposed to the 100% effluent or the river water and their dilutions. The vitellogenin gene and protein in male fish exposed to the 100% effluent were also close to the background levels found in the river-water-exposed fish.

Based on the laboratory studies conducted with Murray Rainbowfish (Woods and Kumar, 2011), it has been established that vitellogenin production can be induced in male rainbowfish at concentrations of ~10 ng/L 17β-Estradiol. In light of these results, the absence of vitellogenin induction at both the mRNA and plasma protein level after 28 days of exposure to either the Wodonga WWTP effluent or the Murray River reference water suggests that these sources of water are not significantly estrogenic.

The estrogenic activity of the effluent was also low (between 2ng/L–6ng/L) during exposures, further confirming the low estrogenicity of the treated effluent from the Wodonga plant. The dilution of the Wodonga effluent in the Murray River is anticipated to be more than 90%

Table 1. Concentrations of EDC in the treated effluent from the West Wodonga WWTP.

Compound	Maximum Concentration in Treated Effluent	Relative Potency
17β-Estradiol	< 1ng/L	1
Estrone	27ng/L	0.22
17α-Ethynylestradiol	< 1ng/L	1.03
4-Nonylphenol	1000ng/L	0.0001
4-*t*-Octylphenol	<1ng/L	0.0004
Bisphenol A	<1ng/L	0.0001
4-Nonylphenolethoxylate	<1ng/L	0.000006
Total estrogenicity as 17β-Estradiol Equivalent (EEQ)	< 6ng/L	

17β-Estradiol is the natural estrogens secreted by females.
17α-Ethynylestradiol is the birth control pill.

The sample collection.

and at such dilutions there is no risk to the reproductive success of Rainbowfish downstream of this outfall.

Some of the key outcomes based on the multiple lines of evidence used in this study are as follows:

- Treated tertiary effluent from Wodonga WWTP was not acutely toxic to Murray Rainbowfish during 28 days of exposure;
- Estrogen receptors were not activated in male fish during the 7, 14 and 28 days' exposure to the 100% tertiary treated effluent;
- No intersex condition (i.e. presence of both male and female characteristics in an individual fish) was observed in sexually mature male fish exposed to the tertiary treated effluent over 28 days. Exposure to tertiary-treated effluent resulted in minor reproductive effects in Murray Rainbowfish and Zebrafish.
- Multiple lines of evidence suggested that the biological effects of the WWTP effluent at the study site were not significantly different from the Murray River reference water.
- The combination of a high level of treatment and high dilution of Wodonga WWTP effluent contributes to the control of any potential impacts on the environment.

This is a pleasing result, since at the outset of the work there was some nervousness about what the outcomes might be and what it might mean for North East Water and the ongoing operation of the plant.

Although results from this investigation at a tertiary WWTP suggest little impact, they cannot necessarily be extrapolated to other treatment plants in Australia.

The Author

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Reference

Woods M & Kumar A, 2011: Vitellogenin induction by 17β-estradiol and17α-ethynylestradiol in male Murray rainbowfish (*Melanotaenia fluviatilis*). *Environmental Toxicology and Chemistry*, 30: pp 2620–2627.

IS WTP PERFORMANCE IN AUSTRALIA GOOD ENOUGH?

Peter Mosse

***Editor's Note**: This paper was presented at the Victorian WIOA conference in September 2011. It was the sister paper to the one presented by Jason Colton about water quality in New Zealand (see WaterWorks November 2011, page 15). Since then the latest edition of the ADWG has been released. These set a target turbidity for water from individual filters of 0.2 NTU and a critical limit of 0.5 NTU. It seems timely to publish this paper with data from a number of plants highlighting the variable and sometimes very poor performance of many Australian WTPs.*

Background

Our primary responsibility in the water industry is to produce safe drinking water – water that doesn't make the consumer ill. Steve Hrudey, a Canadian researcher, concluded after studying waterborne disease outbreaks in the developed world that pathogens were the major risk and that all water treatment should be focussed on management of pathogens. For many years now *Cryptosporidium* has been the major pathogen of concern, responsible for the majority of water-borne illnesses.

The *Australian Drinking Water Guidelines* (ADWG) are just that – guidelines not regulations. While there are a number of *Safe Drinking Water Acts* (SDWAs) in different states, we have no real regulations in this country. Our ADWG and the various SDWAs promote a risk management framework, but provide no real guidance as to how to achieve adequate or best practice management. Risk management plans produced by utilities are only as good as the water quality and public health knowledge within the utility – and this is often lacking.

The Australian approach contrasts with regulations in countries such as the US and New Zealand. It is interesting that in the absence of our own regulations, a number of Australian utilities embrace US regulations (notably the ESWTR LT2 rule). This paper presents data from Australian plants and should be read in conjunction with the paper by Jason Colton describing the NZ system, its regulatory environment and the impacts this has had on water treatment and drinking water safety in that country.

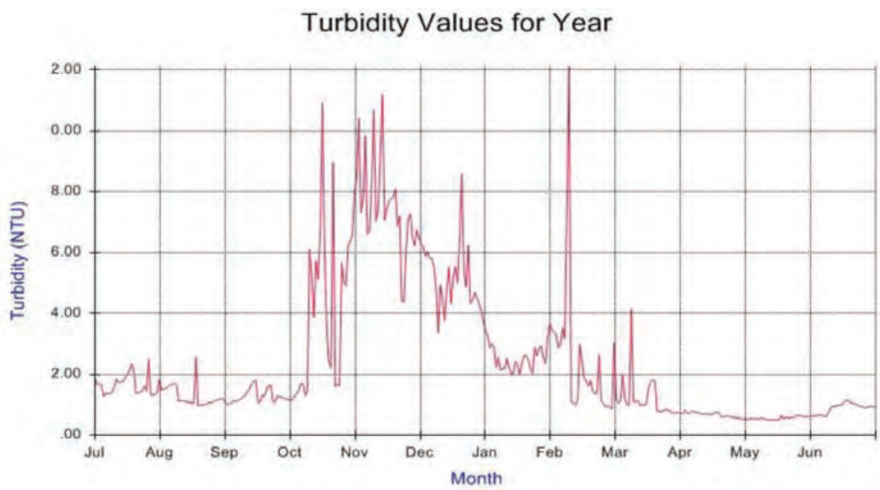


Figure 1. Raw water turbidity time series data for a 12-month period showing a lengthy period where the turbidity is elevated above the background level (the vertical scale is 0 to 12 NTU).

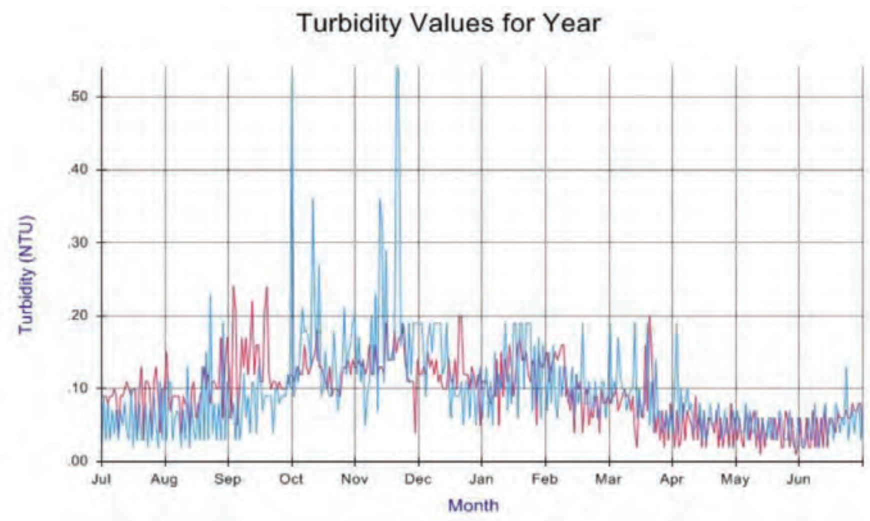


Figure 2. Filtered water turbidity for the same 12-month period as shown in Figure 1 (the vertical scale is 0 to 0.5 NTU).

Pathogens and Turbidity

We cannot measure pathogens online yet. Indeed, we cannot easily measure many of them regularly in samples. Our only real process monitoring parameter is turbidity, which can be measured online and provide instant feedback to facilitate immediate process control changes when required. Studies have shown that to achieve even reasonable removal of *Cryptosporidium* you need to achieve better than 0.2 NTU from every filter at all times. Even then, removal may be quite poor (<2 log). In general, the lower you get the turbidity below 0.2 NTU, the lower the risk to public health. In simple terms, turbidity equals pathogen risk. To minimise pathogen risk, minimise turbidity.

Most operators and operations management are familiar with standard monitoring of SCADA trends typically viewed over a few hours to a few days, however, most are not familiar with longer-term monitoring and the advantages such analysis offers. Time-series data should be collected to allow comparison of raw water turbidity, clarified water turbidity and filtered water turbidity over the same time period (Figures 1 and 2). At a minimum, the data should be analysed over a period of several months, however, at times analysis over periods as short as two weeks can be instructive. These time series can then be used to try to determine causes of any periods of poor filter performance and bring about improvements in the operation of the plant to prevent them recurring. Figure 1 shows data from a WTP where the raw water turbidity increased slightly

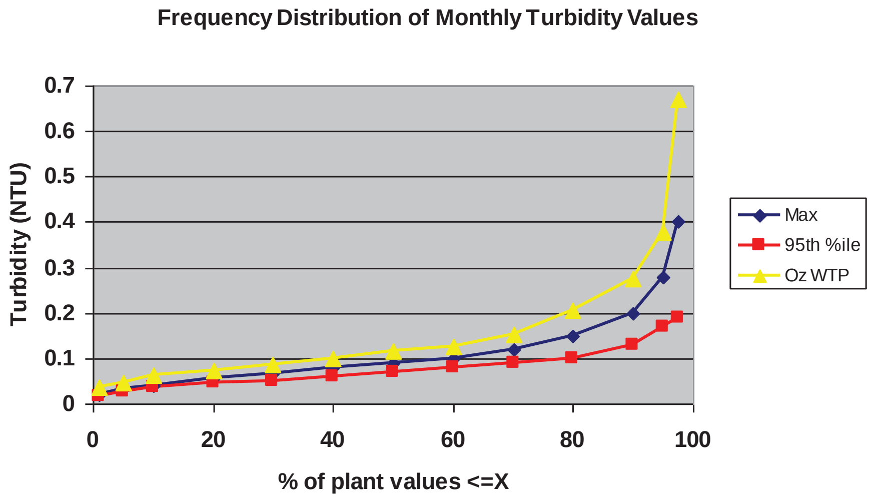


Figure 3. Cumulative frequency representation of an Australian WTP compared to US Partnership for Safe Water benchmark performance.

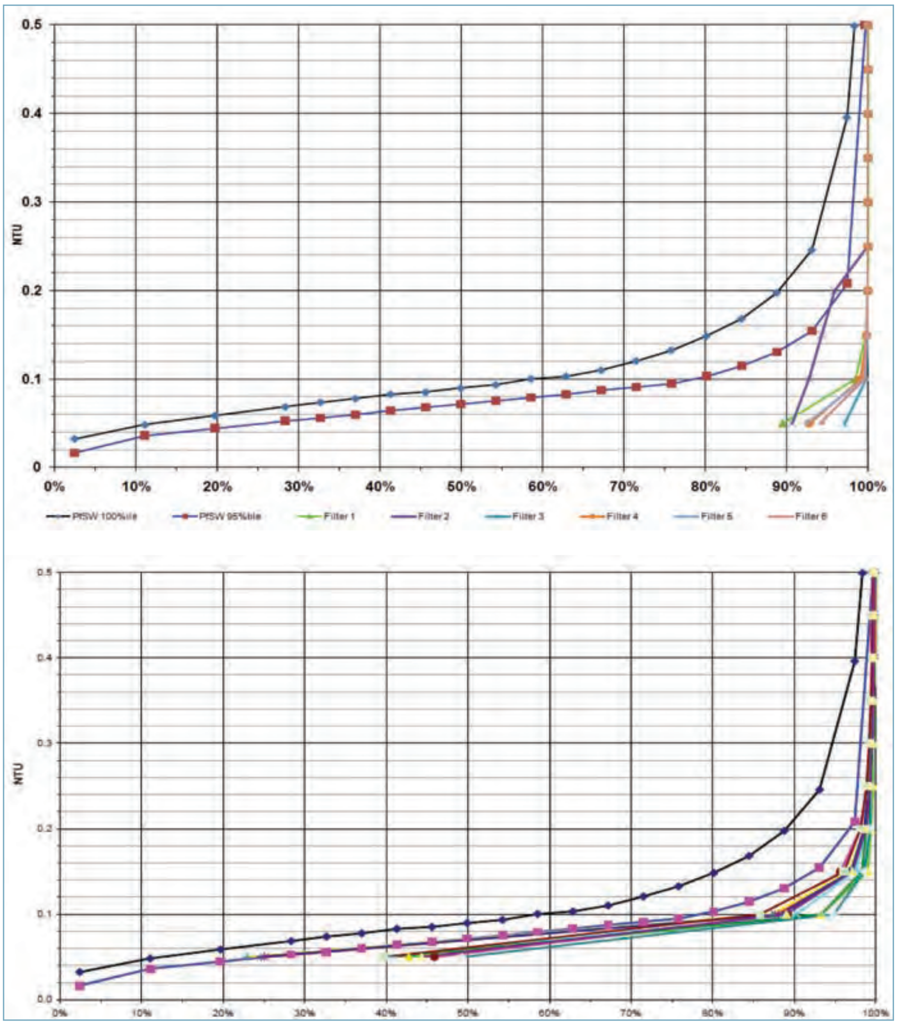


Figure 4. Two examples of very good performance, but in the top frame the data is good enough to show that one of the five filters is not performing as well as the others.

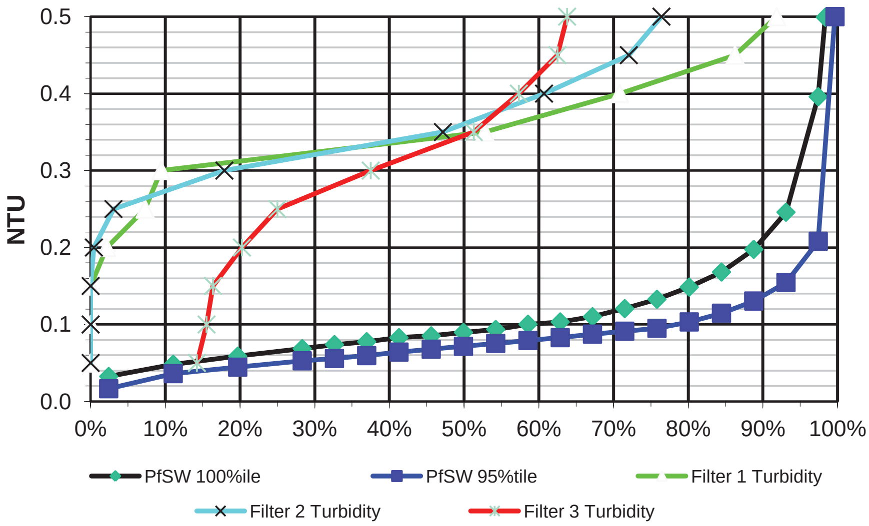


Figure 5. Very poor performance.

from around 2 NTU to around 8 NTU. Figure 2 shows the filtered water turbidity for the same period. Clearly the plant had trouble coping with the increase in raw water turbidity, even though it was quite small. The plant was a direct filtration plant and the data highlights some of the limitations of such plants, however, there is no real reason why a direct filtration plant should not be able to cope with a raw water turbidity event of this size. Clearly, such information can allow the utility responsible for the plant to focus on what needs to be done to prevent such deterioration of filter performance in the future.

A convenient way of representing plant performance that allows easy comparisons both between filters and plants is the cumulative frequency plot. This shows the percentage of time that a plant/filter is producing water less than a particular turbidity. Figure 3 shows an example. In Figure 3, the blue (middle) line is the 100th percentile line from the US Partnership for Safe Water (PfSW) data. This means all the participating US plants (over 400) were better than this line. The red (bottom) line is the 95th percentile. This means 95% of the participating plants were better than this. Clearly the Australian plant is not performing very well compared to this data. From the yellow (top) line it is possible to see that the Australian WTP is only achieving <0.1 NTU 40% of the time and <0.2 NTU (the new ADWG limit) 80% of the time. There is clearly room for improvement!

In simple terms, if the line is above the PfSW lines, plant performance is poor. If it is below the lines, performance is better. The lower the line the better. Figures 4 and 5 show examples of very good performance and very poor performance respectively.

Figure 6 shows time-series data for a large WTP where stable operation is never really achieved. Another way of interpreting the trend is to conclude that the ripening period is very long – several days!

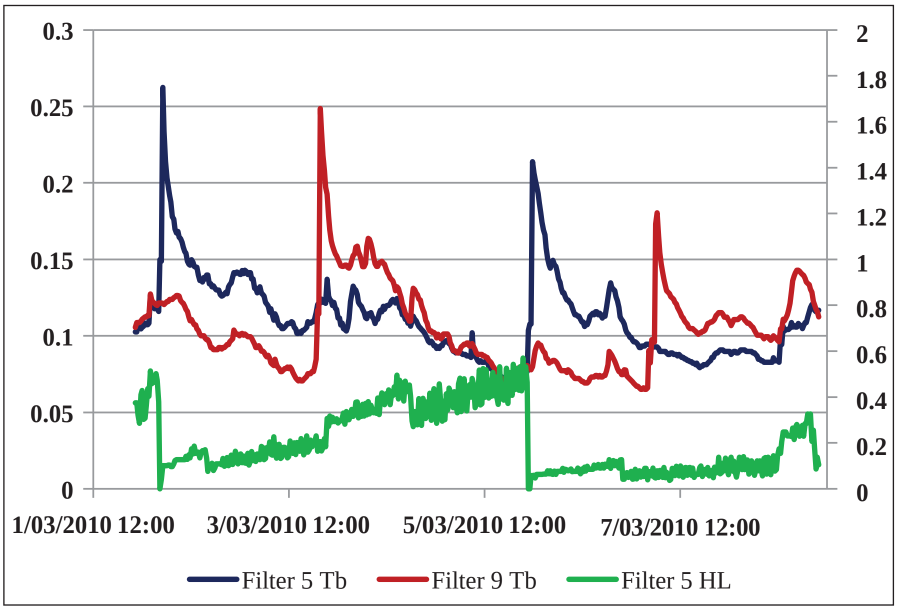


Figure 6. Time-series data over a 10-day period showing that the filters never actually achieve stable operation and the "ripening period" is very long. The red and blue lines are turbidity data for two filters and the green (bottom) line is the head loss data for one of those filters.

Some plants don't have turbidity meters, so no assessment of long-term filter performance or water safety can be made. Is it a case of "no-one is getting sick so the water must be good"?

Figure 7 (overleaf and page 13) shows some more examples of filter performance from Australian WTPs.

So, are we good enough? You decide.

The bottom line is all Australians deserve safe drinking water!

Is your plant performance good enough? Find out. An Excel-based software package that allows data analysis of this type (and more) has been distributed to all Victorian Water Utilities through the Victorian Department of Health and Water Services Association of Australia. It will also be available on the WIOA website for free download.

Peter Mosse (peter.mosse@gmail.com) is Editor, WIOA *WaterWorks* Journal.

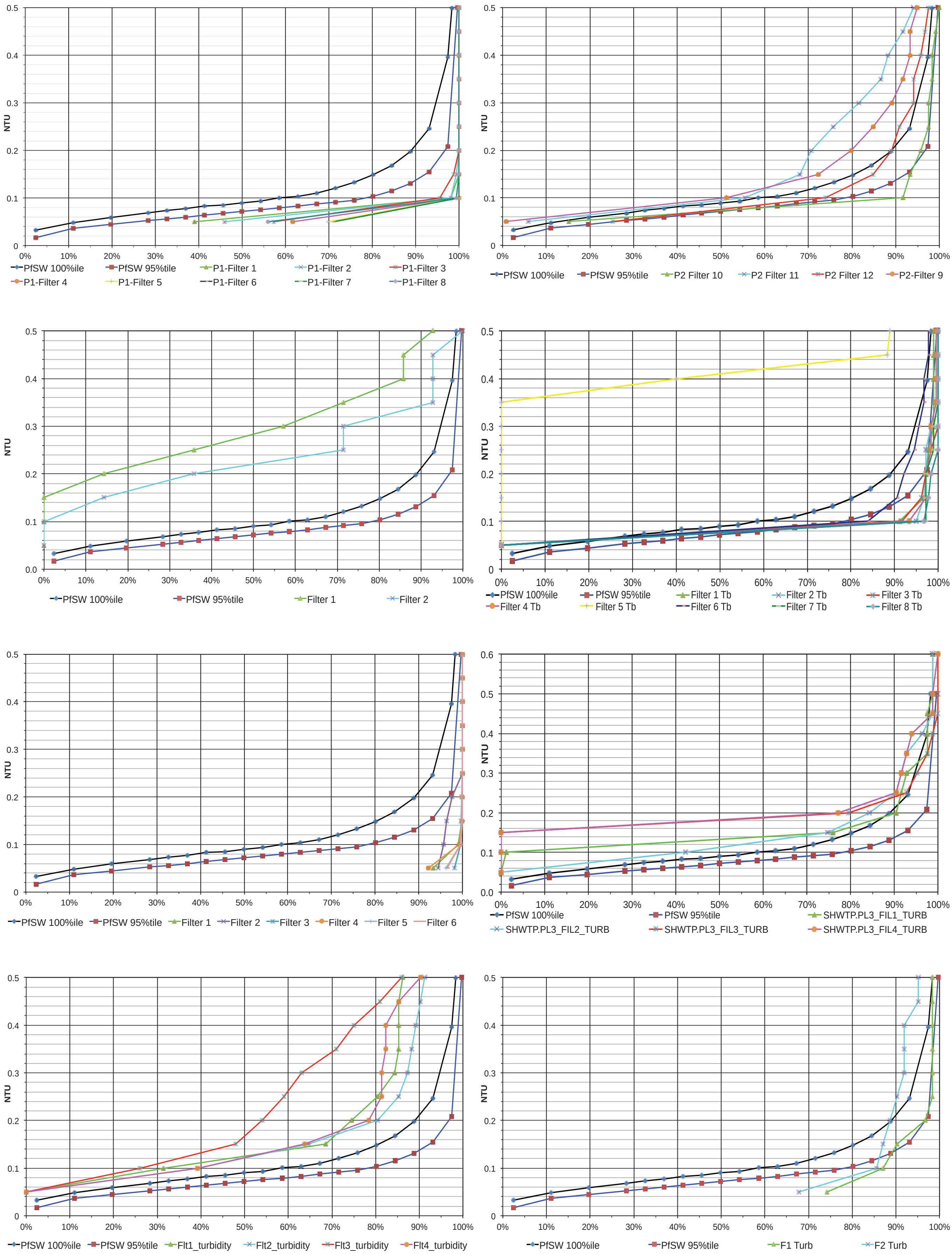
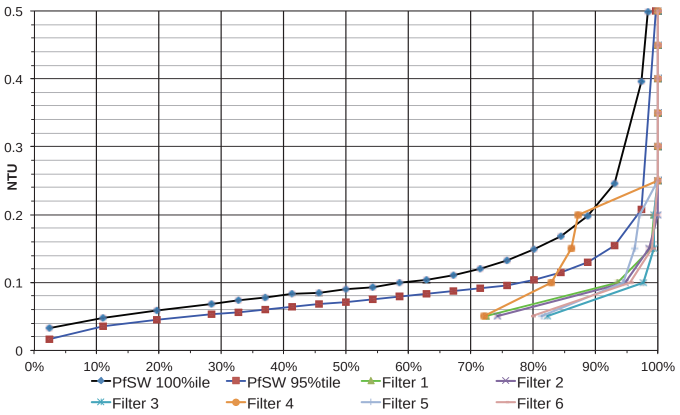
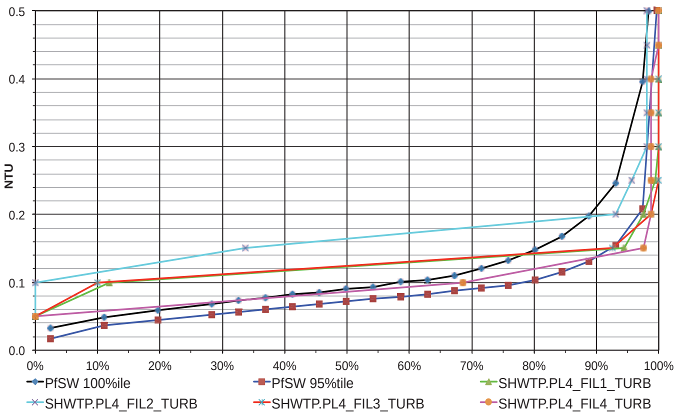
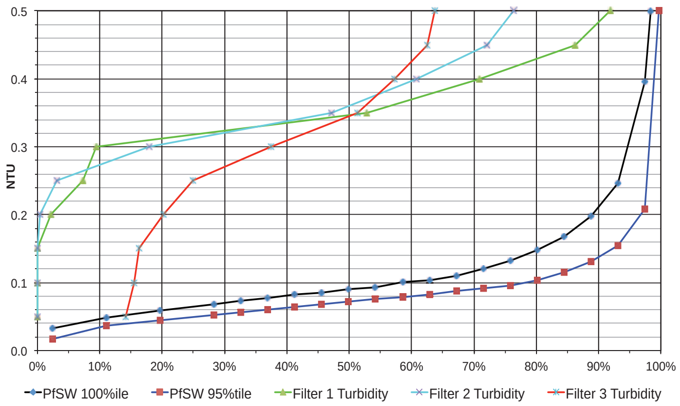
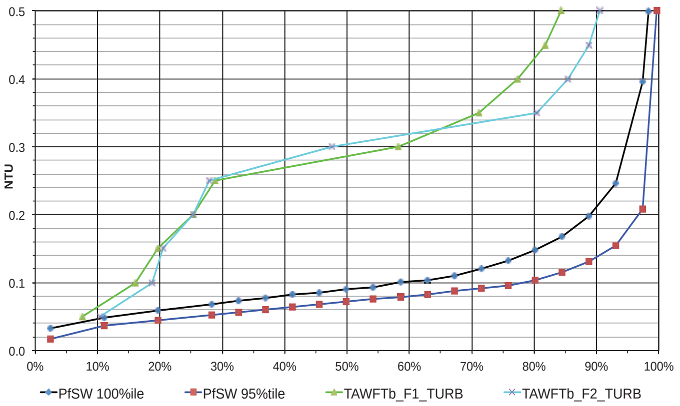


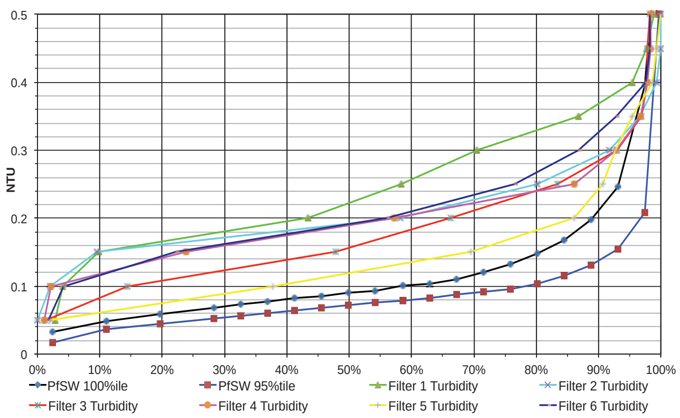
Figure 7 (above and opposite page). More examples of filter performances from 16 Australian WTPs, showing a range of performances from

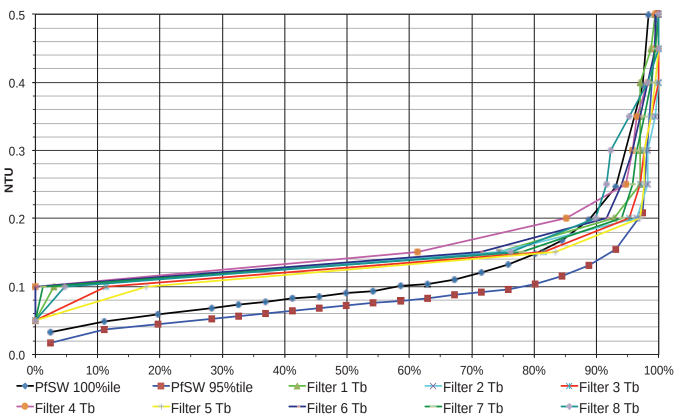


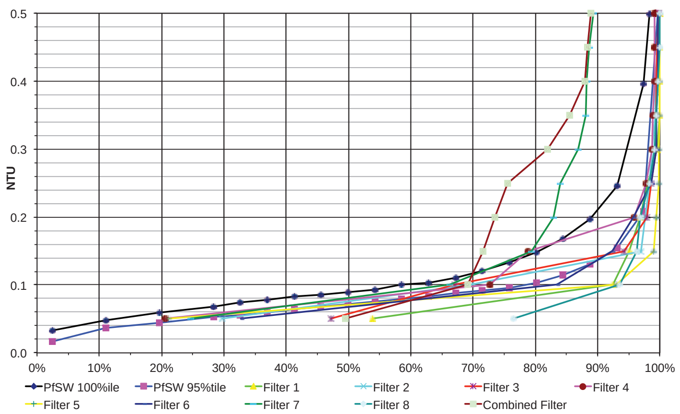


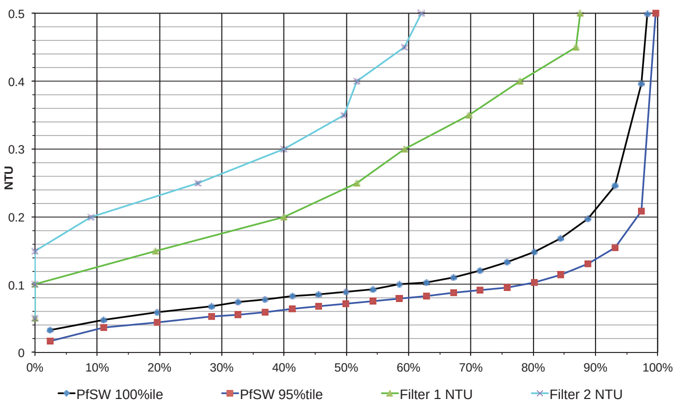












very good to very poor.

18 YEARS OF CLEANING TREATED WATER STORAGES

Dave Barry

Drinking water storage-tank cleaning is carried out to maintain water quality and to monitor the condition of the structure. The vacuuming of tanks began in the early 1990s, and it is difficult to 'pin down' where the original concept began. A need for new processes to overcome an ageing workforce, and the difficulties of placing personnel into confined spaces, drove the need to change from the traditional drain and sweep methods. Not having to isolate the tank for days has several other advantages, as pipe breaks are eliminated, consumers are not disadvantaged and reserves of water for fire-fighting services are maintained.

Diving into potable storage tanks has become an accepted maintenance discipline and the process quickly outgrew normal commercial diving practices. This is probably the only type of diving where the water is more at risk from a diver than a diver is at risk from the environment. Water quality is paramount, so innovations to equipment and a new set of safety rules had to be formulated to satisfy both OH&S and water consumer expectations. Safety has been based on holistic risk assessments and not existing practices, where many diving disciplines have remained unchanged since the 1950s.

Many water utilities now use the diver vacuuming method to clean their tanks, but few are aware of the actual 'nuts and bolts' of the process.

A diver vacuuming the floor of a treated water storage.

This paper will discuss the equipment used, the hazards encountered, vacuuming methods employed, wastewater disposal issues and the inspection opportunities that are available. After 18 years of reflections (and vacuuming), the author has decided it is time to offer the water industry a 'snapshot' of how this established process can be carried out safely and effectively, for both the water provider and the water consumer.

A Learning Process

The first task was learning all about storage tanks – new things to avoid or be aware of. Sharks, stone fish, boat propellers, strong currents and being too close to the gelignite when you 'pushed the plunger' had to be substituted for small access hatches, ladder cages, unscreened outlets and the many other tank-specific hazards that have become apparent over time.

A diver entering a ladder cage.

Most commercial diving equipment is also heavy and cumbersome, so lifting it all up onto a tank roof some 10 metres off the ground was a challenge. With the first tank it took around three hours to get all the gear set up on the roof, including the umbrella, chairs, thermos and newspaper – after the second job we started to modify and simplify in order to survive physically, as well as mentally!

So after we had a diver in the water, it was… what now? We began vacuuming the floor as if it was a swimming pool, with the diver standing in one spot and pushing a long handle attached to the vacuum head. Great progress was being made until the handle broke off one day and the diver decided to finish the job by holding onto the stub end – it was then discovered we could move around five times more quickly and the diver got to see a bit more of the scenery inside the tank. Cleaning times were reduced from three days to one day and we thought we "knew it all" after completing around 10 tanks. Now, with over 5,000 tanks under our belts, we are completing those initial three-day marathons in less than three hours.

There are three different vacuum heads in use, to cater for large and small tanks, thick and thin sediments, and the 'unexpected' fittings and fixtures within a tank that cleaning robots struggle with. The wheels are adjustable to allow for 'fine tuning' during cleaning – sticky sediments need the vacuum skirts to be rubbing on the floor and deeper, loose sediments require more clearance to suck up effectively. Each operator has his or her favourite settings for speed and efficiency, and more than one vacuum head is often used during a tank-cleaning operation.

Two different vacuum heads.

Many different types of suction hose have been tried (and discarded) as well, with crushing and buoyancy of the hose the main issues. The average-sized tank requires 40 to 60 metres of vacuum hose, with larger storages using 100 metres plus, so the equipment vehicles just kept on growing and growing over the years, along with the process knowledge.

Truck and lifting equipment.

The Right Mentality

It is important to be 'potable water dedicated' and have the mentality of "if we don't drink it, we don't dive in it". This includes the vehicles, all the external and internal equipment and the personnel. The water industry has spent much time and effort in separating water and sewer operations and this would all be for nought if someone knowingly (or unknowingly) contaminated our drinking water with waste substances. Drysuits and full face masks are a 'given' and there should be plenty of additional suits available onsite to allow for hot and cold weather conditions. Tanks fed from bores have been known to exceed 26°C in the middle of winter, so it is not always a 'thick in winter and thin in summer' dry suit policy.

There are no second chances with the pathogen control process. It has to be best practice in all things that we do, because disinfection can only reach the superficial areas of hoses, ropes, dive equipment and storage vehicles. There will always be residual water left in the vacuuming hoses when moving from tank to tank and from client to client, so strict hygiene practices and being particular about where the equipment and personnel have been, are the best options to maintaining water quality and consumer confidence.

Disinfection is used as a backup process on equipment, but total reliance on spraying down the diver with a disinfectant solution, and whatever bits and pieces of equipment that are within easy reach, is not an effective or failsafe means of pathogen control – it is merely 'ticking a box' and should not be relied upon as the water safety solution.

The Process

While divers are used to vacuum out tanks online, the process is an holistic combination of trained water quality technicians, height and safety personnel, and surface support operators who have the ability to perform difficult manual tasks in all sorts of weather and geographical environments in a safe and professional manner.

The oft-used saying, "We are divers, we are not too smart but we can lift heavy things" is not applicable in the tank-cleaning business. Like all skilled processes it takes several years to become safe and proficient. More tanks are cleaned by intelligent thinking than by pushing a vacuum head quickly around the floor.

Each tank has a different layout of posts, pipework and other internal fixtures that need to be considered when an effective vacuum pattern is decided upon. A good pattern creates efficiencies and ensures that no sediment is unnecessarily disturbed or left behind in the hard-to-access areas. Raised floor joints, pipework supports, post bases, ladder platforms and wall floor steps all need to be considered in the cleaning process. Anyone (even a machine) can do the easy bits, but when the vacuum head needs to be lifted over or shifted sideways, blockages cleared away and hoses manoeuvred within the tank, the human element is hard to beat.

Hoses come in two distinct types – hard hose and floating hose. Hard hose is the tougher working type that can withstand rougher handling without kinking or losing prime, but its weight means it would lie across the floor and disturb sediments. Floating hose is used for the last 20 metres of the system and allows effective vacuuming patterns to be used without disturbing the floor areas.

The same applies to the diver's airline. Heavy multiple component hose systems (umbilicals), as used in normal commercial diving situations, drag across the floor and disturb the sediments. They are also prone to retaining contaminants and are difficult to clean effectively. For this reason, a single floating airline with good secure connections has been employed to overcome the weight and pathogen problems. It is easy to deploy and retrieve, is simple to clean down with a disinfection wipe, and still satisfies the safety requirements of diving in a potable water storage tank.

Good suction is a cornerstone of the process and this can be achieved in three main ways:

1. Pumping over the top of the tank requires the tank to be at least 80% full for the pump to prime effectively. Using this method ensures that the diver can enter the tank and commence vacuuming straight away. This method is recommended when cleaning a tank for the first time, as scours may be screened, inaccessible or inoperable.
2. The scour can be utilised to create suction by placing a plug in the penetration and opening the external scour valve. Various sizes and shapes of scour plugs are carried to cater for most scenarios; however, the scour should be close to the diver's point of entry to

Pumping over the top of the tank.

Two different scour suction systems.

avoid disturbing the floor area sediments unnecessarily. Deeper tanks often have the water levels reduced to increase the diver's available working time, so the scour method is the only option when water levels are less than 80%.

3. On elevated tanks, with no scour access, a siphon can be created using both hard and soft hoses. This is preferable to hanging hard hoses long distances down to a pump for priming. The more heavy hose lowered over the side of a high tank, the greater the chance of a connection failing and causing an incident to the personnel working below. Lighter-weight, lay-flat hose can be used below the siphon point to run the wastewater away.

Wastewater Disposal

This can be the hidden component of the pricing process. All cleaning creates wastewater and volumes vary considerably depending on the sediment types and depth, internal fittings, tank layouts and how efficiently the vacuuming process is carried out. Wastewater can be disposed of in a variety of ways. In order of increasing cost, the most common are:

1. Irrigation onto the local ground, provided it is assessed as safe to the environment and neighbouring properties are not inconvenienced.
2. Containment in on-site coffer dams and being allowed to evaporate away.
3. Waste can be pumped directly to a sewer point if logistics allow.
4. Tankers can transport the wastewater to an approved disposal site. More than one tanker will be required for continuous vacuuming to be carried out. Wastewater is pumped directly into a stationary tanker, and this in turn is decanted into a travelling tanker. This system allows a 40-minute turnaround time to keep up with the vacuuming process. Longer distances will require a second travelling tanker to be employed.

Each option will have a cost involved, but the key to it all is to reduce the

Twin tankers, ready and waiting to remove the wastewater and sediment.

wastewater volumes by effective vacuuming processes and the experience of the operators involved. Reducing pumping flows is a false economy, as vacuuming times are merely increased and the sediments are not lifted cleanly off the floor.

A small coffer dam.

A Structured Inspection System

Vacuuming a tank presents the ideal opportunity to conduct a detailed inspection. The average cleaning time would be one to two hours, so all the team members (diver included) have time to 'look, listen and feel' the key inspection parameters. Removing the sediment means every section of the floor, lower wall areas and internal fixtures have been visually examined at one point or another. There is also no possibility of sediment covering up defects, or of it being disturbed by someone walking or swimming around in an 'inspection only' situation.

All the team members must be trained to a technician level and be aware of what to look for while on-site. The 'fresh eyes' approach can reveal evidence that would not always be noticed by the day-to-day operations staff. A structured inspection system will ensure consistent results and allow assets to be accurately compared with each other, allowing for long-term maintenance decisions to be achieved.

In Summary

The vacuuming of tanks using divers is much more than a diving operation. It is an integrated process involving a mixture of disciplines and technical skills, many of which have to be learned by repetition and trial and error. New safety perspectives had to be developed and tested; equipment had to be modified to overcome working at heights and avoiding water quality risks. Diving had to be re-learned, much the same as caving, and extreme depth diving demanded new techniques and equipment to be developed.

There is a certain amount of intellectual property involved as well, so it will be years until formal standards are documented and adopted for all to follow and use. Until then, the existing practitioners will continue to carry out this important maintenance procedure and, hopefully, all will contribute to our water being (a little bit) cleaner and safer for consumers.

The Author

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EMERGENCY EARTHQUAKE REPAIRS AT PINES WWTP, ROLLESTON, NEW ZEALAND

Stu Hildreth

On September 4, 2010 at 4:35am, a 7.1 magnitude earthquake struck the Canterbury area in New Zealand. The epicentre was 25km from the Rolleston township. On my arrival at the new Pines WWTP two hours after the quake, it was obvious that the plant was seriously damaged and would have to be taken out of operation for extensive repairs. Work started straight away with contractors pumping out the plant to allow repairs to be undertaken. We were also faced with power outages across the district, which meant we had to check other infrastructure and important sewer and water mains. And there were limited phone lines, which meant we had communication issues!

I went to the old Helpet Rolleston treatment plant to turn off the main pumps that pump to the new Pines plant. I opened up the splitter valve to divert the total flow into the old plant. Both plants have standby generators. Then I had to open up the valve to start filling up the redundant boat clarifier, as we were only operating one boat clarifier at the time. This would give us a day's grace to sort out what we were going to do in the next few days. The Helpet plant would go from receiving 300m^3 day to 1,100m^3 a day.

After discussing the repair priorities with the council engineers we got a pump installed in the clarifier so that when the launder pipe to the UV channel was fixed we could start on the two centre pivots and pump out the clarifier so further repairs could be conducted.

We had sucker trucks working all day Saturday and Sunday, pumping out the biotank and spreading the effluent onto the new paddocks, and the parts of paddocks that were not irrigated by our existing centre pivots. We had a total of 1,100m^3 to remove out of the two tanks. Also, we had to remove all the sprinkler heads from the centre pivots to allow us to pump out the effluent from the clarifier.

Emptying the contents of the biotank onto the paddocks.

The UV Disinfection System

One of our local contractors offered a small boat – it was just what we needed! I could start repairs on the 200m outlet pipe from the clarifier to the UV system. The damaged outlet allowed the biotank MLSS to enter and flood the UV channel. When the pipe was repaired pumping could start so we could use the centre pivots to empty the clarifier and the biotank.

The small boat being lifted into the biotank.

The broken UV outlet pipe.

The boat in use and the fixed pipe back in place.

The Clarifier and Biotank

There was damage to the centre drum and to the launder and scum baffle of the clarifier. This wasn`t going to be an easy fix. A new steel beam needed to be made and welded, plus the launder baffle would have to be removed, straightened and refitted. The drum was also out of shape and would take some time to repair. Two of the biotank concrete panels were broken in two; one had taken out an anoxic mixer, the other the recycle pump. I got on the phone to our local engineering company to come and check out the damage to the clarifier and launder, and to organise their staff to start on the repairs straight away.

Damage to the centre drum of the clarifier and launder.

Damaged zone panels. These panels weigh five tonnes each and just broke in half due to the force of the water.

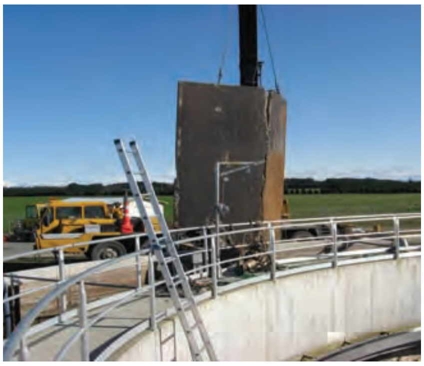
Diffusers damaged by the falling zone panels.

Repairing the clarifier centre drum.

We had no spares in New Zealand, so our contractor had to call Australia and order the parts that were needed. They arrived the next day from Sydney.

Once the biotank was empty we had the sides and floor water blasted so we could inspect all the diffusers. We also water-blasted the clarifier so we could inspect the bottom bearing on the clarifier centre drive gear box. This drives the scraper blades on the floor that move the sludge to the centre hopper.

After all the repairs had been finished in the clarifier and the scrapers had been rotated a few times and some minor adjustments made to the centre drum and the launder, we started to fill up the clarifier and biotank. This allowed us to check that the scum scrapers were working, and



Removing the damaged zone panels.

didn't get caught while travelling around the launder baffle. We filled the biotank, just covering the diffusers with a mixture of water and raw sewage, and started up the blowers to check to see if we had any leaks in the diffusers. This is normally done with fresh water, but it would have taken too long as we only have a 50mm water supply into the plant, and time was running out with the old plant starting to get overloaded.

On the seventh day (this is sounding almost biblical!) we started pumping raw sewage to the Pines WWTP. The flow to the Helpet plant was greatly reduced, so most of the flow from Rolleston would go to the Pines. When the biotank was full we had the normal white start-up foam. It took a few weeks for the clarifier to produce a clearer effluent, and time for the sludge to build up.

There was plenty of start-up foam!

All the contractors and staff worked 12 days straight to get the plant back into operation. Without their dedication, it would not have been back in operation in such a short time frame. In addition, there were no accidents, even with such long hours worked over this period.

The Author

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PROCESS OPTIMISATION AT HEALESVILLE WWTP

Richard Brice & David Diaz

Currently 93% of Yarra Valley Water's (YVW) customers' sewage is treated by Melbourne Water at either the Western or Eastern Sewage Treatment Plants. The remaining 7% of flows is treated at localised treatment plants situated to the north and north-east of Melbourne.

YVW operates nine treatment plants with varying levels of effluent quality produced at each site. The effluent produced at most plants is discharged to nearby waterways, with the remainder reused by nearby irrigation systems and/or dual pipe reticulation customers.

Five treatment plants, Healesville, Brushy Creek, Whittlesea, Upper Yarra and Lilydale, were identified as having particular process issues (see Table 1).

Historically the plants have been operated to achieve compliance with regulations and treatment quality standards set by EPA (and Department of Health for recycled water plants). YVW wanted to maintain and improve compliance but also wanted to explore impacts of future growth on the plants and any potential for savings in operation costs.

The YVW Planning Division had identified a number of capital projects that will be required for each plant, and their impacts on plant performance were unknown. There was also a requirement to determine the root cause of high operation costs at some of the plants.

A project was therefore developed to examine the current efficiency of the plants and to develop options for plant improvement.

For each of the plants a BioWin model was developed to ensure an accurate representation of operational characteristics. The benefit of developing the model to this extent was that it allowed testing of operator driven options for improving plant performance without running the risk of trialling this in the full scale plant and risking plant failures.

The following account is of the study and outcomes at the Healesville WWTP.

Healesville WWTP Case Study

Aerial view of the Brushy Creek WWTP in Victoria.

Healesville is a small town (population approximately 7,500) situated in the Yarra Ranges approximately 50km north-east of Melbourne. Large numbers of people visit the area, particularly during weekends, to attend race meetings and events at local wineries as well as the associated industrial inputs. These event weekends cause irregular short-term peak loads at the WWTP.

There are also two significant trade dischargers into the system, a winery and a brewery.

The Healesville WWTP consists of fine 3mm screens, an oxidation ditch with surface aeration, secondary clarification,

Table 1. YVW Problem Treatment Plant Summaries.

Treatment Plant	ADF (ML/d)*	Identified Process Issues
Lilydale	5.0	Primary treatment includes a pre fermenter with no solids/liquids separation resulting in high MLSS in the reactor Comparatively high chemical consumption Solids limitation on clarifiers due to high MLSS concentrations and high peak flows resulting in solids carry over Poor filter performance due to solids carry over Problems with backwash returns. The backwash water was returned to the end of the reactor exacerbating solids limitation on the clarifiers causing solids carry over and then resulting in extra backwashes.
Healesville	1.4	Poor effluent quality (ammonia/TN) Trade waste inputs, resulting in periodic high COD based peak load events periodically Large social events causing short term peak loads. Often due to race meetings and events at wineries A plant upgrade was planned to replace the existing plant.
Upper Yarra	2.0	Discharge license breaches for ammonia and suspended solids Potentially long sludge age resulting in excess MLSS leading to solids carry over during decant Decanter rubber seals split leading to excess maintenance and process risks due to decanters (and hence SBR tank(s)) being out of service.
Whittlesea	0.7	Excess chemical dose Sludge management systems not well understood (and issues with positioning of the sludge processing system on site) Discharge to land, but plant operated for full N and P removal. Therefore the costs and operational difficulties associated with nutrient removal are incurred without the need for these costs.
Brushy Creek	10	Population growth Cyclic aeration control poor and requires significant operator input/expertise Poor effluent quality Uncertainty over plant capacity Poor understanding of chemical dosing.

** Average Daily Flow as at 28/09/11*

Table 2. Notification Limits at Healesville WWTP.

Treatment Plant	BOD_5 (mg/L)	Suspended Solids (mg/L)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Ammonia (mg/L)	*E. coli* (orgs/100 ml)	pH
Healesville	20	20	2	20	5	500	6-9

upward flow pebble bed filters, UV disinfection and Alum and caustic soda dosing with final discharge to water. Waste solids are stored with periodic aeration in a WAS holding tank. Liquid is periodically decanted and returned to the inlet works. Thickened sludge is removed from site. Alum (300L/d) was dosed into the influent stream for P removal. The notification limits for the plant are presented in Table 2.

Effluent ammonia measurements ranged from 0 to over 5mg/L and effluent nitrate ranged from 5–15mg/L. Attempting to solve these problems was taking up a considerable amount of the operator's time. In an attempt to solve the issues with the nitrogen (ammonia and TN), YVW installed two spare 150kL reactors alongside the existing oxidation ditch to provide extra aerated volume. Flows are pumped to the side stream reactors from the oxidation ditch at a constant rate throughout the day.

Aeration is provided by two 18.5kW surface aerators situated in the main oxidation ditch and two 7.5kW blowers provide aeration in the side stream reactors. The oxidation ditch surface aerators were controlled by DO concentration measured in two places within the oxidation ditch. The DO probes were placed downstream of the two surface aerators and the aeration was controlled by averaging the readings from the two DO probes. The surface aerators were simply turned on and off based on this signal. The side stream reactors were fully aerated, there being no differential control of the blowers.

The following options were investigated using the calibrated BioWin models:

1. Altering the position of the inlet and outlet from the oxidation ditch;
2. Review of RAS flow rates;
3. Running the side stream tanks in air-off mode;
4. Ammonia-based control.

Altering the Position of the Inlet and Outlet from the Oxidation Ditch

Purpose:

- To allow improved denitrification by forcing influent into the anoxic areas of the oxidation ditch;

Outcome:

- The model showed no improvement in effluent quality or process stability. This is probably due to the high liquid velocity in the oxidation ditch. High velocities are used in oxidation ditches to simulate a high internal recycle and to ensure that the system is completely mixed right around the reactor.

Review of RAS Rates

Purpose:

- Increasing the RAS flow will allow greater consistency of effluent quality and better control.

Outcome:

- The model showed no improvement in effluent quality or process stability;
- Once again it was thought that due to the high internal recycle in the oxidation ditch, the effect of the extra RAS then became minimal.

Running the Side Stream Tanks in Air-Off Mode

Purpose:

- Despite high effluent ammonia concentrations being the main problem on-site, it was felt that the system was not efficiently using carbon. Carbon in sewage is made up of various fractions, readily degradable, slowly degradable and non degradable. These fractions can be either soluble or as fine solids suspended as a colloid. Biomass requires oxygen to utilise this carbon and produce more biomass and CO_2. Oxygen can come from air (via surface aerators or blowers for example) or other forms such as nitrate or nitrite. As such, within a treatment plant TKN/ammonia is converted to nitrite/nitrate and the system uses carbon to denitrify the nitrite/nitrate to convert this to nitrogen gas. Therefore, the less carbon that is used during aeration (particularly the readily degradable forms), the more carbon is available for denitrification (and phosphorus removal). By reducing the amount of carbon oxidised during aeration, the total air input required to operate the whole treatment system can be reduced. Reduced aeration means reduced power and, therefore, reduced power costs.
- The idea here was that turning the side stream tank aeration off would result in more efficient use of carbon and reduce the aeration demand. The reduced aeration in the tanks could also allow increased enhanced biological phosphorus removal resulting in a reduced amount of Alum that would need to be dosed.

Outcome:

- The model showed significant improvement in process performance and stability, with low ammonia and TN;
- This option was recommended.

Ammonia-Based Control

Purpose:

- Dissolved Oxygen (DO) probes are used to control addition of air; they do not provide direct measurement of a license parameter. In other words, DO probes measure oxygen concentration in solution, whereas license limits specify limits for BOD, TSS and ammonia which DO probes do not measure. DO probes are a traditional measure for oxygen input to ensure that the aeration system is working effectively.
- An alternative to this conventional approach is to directly measure a license-based parameter within the system and alter the plant control based on this parameter. The selection of this parameter then becomes the key for the operation of the process. BOD/TSS probes would provide a direct measurement of an effluent parameter, however, the system can be effectively removing both BOD and TSS without nitrifying. As such, low ammonia concentrations in the effluent are most likely to be matched with low BOD in the effluent and, assuming there is no solids carryover, low TSS (note that high TSS would most likely be matched with a higher BOD). Therefore, monitoring ammonia effectively monitors many aspects of plant performance. Nitrate probes provide an indication of denitrification efficiency and can also be used to alter recycles (and carbon dosing if this is used).
- In this case it was decided to use an ammonia probe with nitrate and DO probes providing back up information. Once the operators had confidence in using the probes, the decision was made to install the controlling probe on the discharge from the oxidation ditch to the clarifiers. This site was chosen because it was near the parameter being controlled,

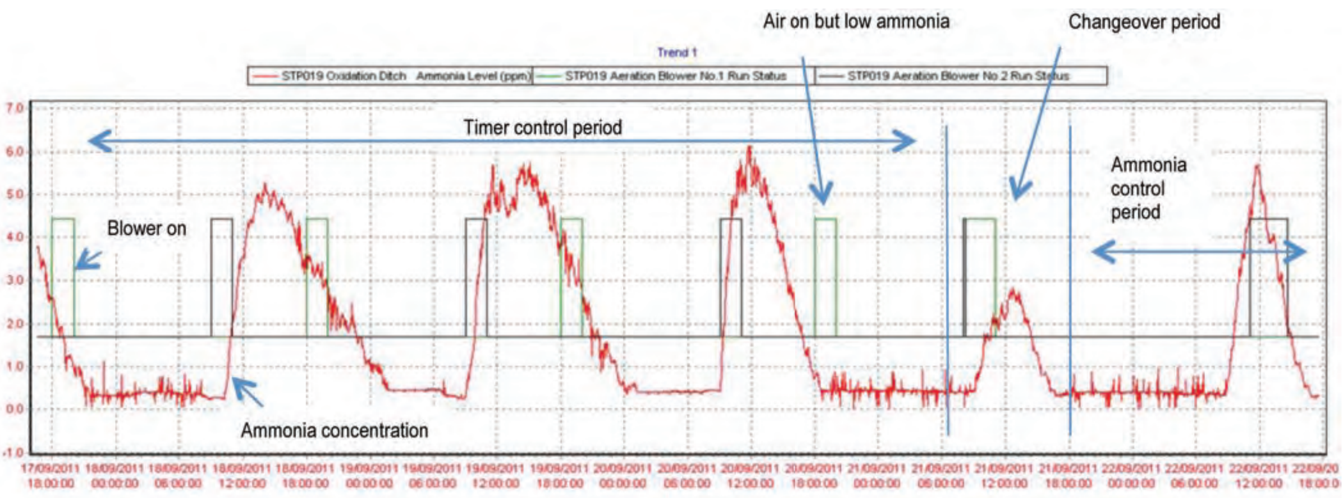

Figure 1. Trend showing ammonia concentration (red) and blower operation (black).

namely aeration. An alternative site for the probe in the clarifier effluent was less suitable because the retention time in the clarifier would have provided too much smoothing of data and increased the delay time, making control difficult.

- The BioWin model was used to simulate the side stream tanks being operated in air-off mode **and** utilising the ammonia probe installed within the reactor. The control was based on using set points for ammonia (high and low) to start and stop the aeration in the side stream tanks. As such, if this worked in the simulation model it would clearly be practical and simple to make changes in the full scale on the operating plant.

Outcome:

- The model showed significant improvement in process performance and stability, with low ammonia and TN;
- This option was recommended.

Full-Scale Plant Alterations

Initially operations staff were most comfortable operating the system based on DO and using timers to control aeration input. The plant operation was altered to provide aeration of the side stream tanks during peak load periods from 9am–noon daily, based on the operator's advice. Once this was proven to operate effectively, the control of the system was altered to be based on ammonia concentration within the oxidation ditch as recommended from the BioWin model. This has simplified operation of the plant and reduced the time operators need to spend at the plant to ensure license requirements are met.

There has also been a reduction in power consumption and Alum dose (down to approximately 75L/d). This is due to the reduced aeration demand as less carbon is removed during aeration resulting in more carbon available for denitrification and phosphorus release. The resultant Enhanced Biological Phosphorus Removal means less Alum is required for phosphorous removal.

Figure 1 presents the aeration profile before and after the implementation of the side stream aeration being altered from a time-based control to an ammonia-based control. As can be seen there were times of very low ammonia where the aeration is on and times where elevated ammonia concentrations are seen and the aeration is not "called up". The side stream aeration is turned on when the ammonia concentration reaches 4mg/L and off when the concentration reaches 2mg/L. The ammonia control has resulted in a significant reduction in aeration input, and ensured that aeration input is when it is actually required based on the defined measurable parameter ammonia.

Since the modelling study, flows (and loads) have increased from approximately 1MLD to 1.4MLD. Despite the increased flow, the effluent quality has improved due to increased knowledge and control over this period. Table 3 presents the actual results from the plant before and after the changed control regime. Of particular note is the reduction in Alum dose from 300L/d to 75L/d. Note that while all other parameters have decreased, phosphorus concentration in the effluent has increased due to reduction in Alum dose, despite conditions being more favourable for Enhanced Biological Phosphorus Removal. There appears to be return of stored phosphorus from the sludge holding tank. This will be investigated as the optimisation project continues. Similar outcomes have been achieved at the other plants in the studies and has resulted in a total saving of approximately $126,000 per annum for Alum and $103,000 per annum for caustic.

Future Instrumental Control

As presented for Healesville, significant savings can be made with the addition of an ammonia-based control algorithm. The next stage of the optimisation would be to install a forward feed control system utilising an s::can and ammonia analyser on the inlet. This would provide a direct measurement of carbon fractionation and nitrogen load (although some estimate of ammonia to TKN ratio would most likely be required) and a mass input of air required can be calculated, which can be used to control the aeration input from the surface aerators and/or the side stream reactors. In a conventional activated sludge system this can also be used to control recycles within the plant, and carbon dosing for denitrification where installed.

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Table 3. Comparison of quality prior to and after optimisation.

Parameter	Median (prior to optimisation)	Median (after operational control changes made)
BOD_5 (mg/L)	2	1
TSS (mg/L)	3	1
Ammonia (mg/L)	1.3	0.7
TN (mg/L)	7	6
TP (mg/L)	0.2	0.7
Alum (L/d)	300	75


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