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OFFICIAL JOURNAL OF THE WATER INDUSTRY OPERATORS ASSOCIATION OF AUSTRALIA

May 2015

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

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OUR COVER

SA Water Central Region Water Treatment Coordinator, Nick Nedelkov, inspecting scaffolding prior to carrying out a filter inspection of the GAC filters at the Palmer Water Treatment Plant.

OHS. CLEAN UP YOUR ACT.

Peter Mosse

From the outset, I want to ensure readers that I take workplace health and safety very seriously. Indeed, those of you who have undertaken filter training with me can attest to the fact that I always check the safety features in place for entering a filter and often suggest improvements. Working safely is important. No-one wants to be injured or killed at work. Equally, no employer wants anyone to be injured or killed while working for them.

In the past few months I have been required to participate in two general safety inductions for two separate water utilities, as well as complete White Card, Confined Spaces and Working at Heights training.

As might be expected, the two inductions had many elements in common, however it is the delivery and the assessment that I want to consider here. One induction involved an online delivery with many PowerPoint-type screens. Each sub-section of the induction was followed by a "test". Incorrect answers were flagged and prompts for the correct answer provided.

The other induction involved being shown a PowerPoint presentation on a relatively small laptop in a lunchroom. The slides were cluttered and the font size and colours were difficult to read even at the distance of a lunchroom table. This induction also had a 10-page test. The answers were actually provided on the individual screens in red type (which was hard to read), while the answers to the "test" were to be filled in during the presentation, with multiple prompts from the presenter to fill in the red words for the answer to such-and-such a question.

What were the common features? Too much general information – and one would have to suggest irrelevant information, since the inductee would simply not retain the vast majority of it. Secondly, tests that could only be considered administrative, since they did not test any degree of recall or retention. In both of these cases I really can't remember much of the content of the induction or the answers to the questions. I still don't actually know what the take-home safety messages were. However, I imagine the companies concerned would feel they were "covered" and had met the requirements of "The Act" by having a record of me being inducted and being "tested".

The risk of requiring workers to submit to repeated inductions of this type is that they are simply ignored and/or taken superficially – and I have to admit I am guilty here. Take any flight on one of our domestic airlines and look around to see how many people are actually listening to the safety briefings that go on and on in the standard format.

All the formal training courses had an assessment component that in the case of the online course had to be completed in full before the certificate was awarded. The questions were banal and trivial. At one course the presenter actually told us not to worry too much about filling it in accurately… *just throw a few ticks around. It's just a requirement of Government that we have to do these…* Really!

And let's be honest about course content and duration. One of the courses I attended went for seven hours. It started 30 minutes late and conservatively we had 80 to 85 minutes of "taking breaks", including lunch. At a time when water utilities are being asked for fiscal responsibility, the OHS training bill could be reduced significantly.

As an alternative, why can't we establish inductions that actually provide the inductee with what is important to safety while working at that site/for the company? Perhaps there should just be a general safety induction that is carried out once. In my experience, they would all contain pretty much the same key points!

Let's not trivialise the testing or examination process. Does the information need to be tested? What do you want trainees to recall to ensure they are not injured or killed at work? Very often it comes down to some really simple principles. Reinforce those and only those. In most cases they will be shorter and testing should really only assess the key take-home messages, the ones that will actually stay in the forefront of the inductees' minds while working and help to ensure their safety. I really can't believe that it is important that workers know the name and date of the legislation or the difference between acts, regulations, codes and guidelines.

It appears that OHS legislation has spawned a new industry, that of OHS training. While it is necessary, water utilities must ensure that the OHS training their staff is completing or requiring others to undertake is totally relevant and represents value for money.

SAE SAVES $ AT STPS

Richard Brice

Are you getting value for money from your Sewage Treatment Plant (STP) aeration system?

The cost of aeration typically makes up 40 to 60 per cent of the overall power costs for the operation of an STP. Many aeration systems are inefficient due to old, poorly performing equipment, fouling of diffusers and/or poor control.

The Standard Aeration Efficiency (SAE) is a measure of the efficiency of delivery of oxygen into the system, based on the load that needs to be treated and the actual power consumption. That is, how much energy is necessary to dissolve a certain amount of oxygen? SAE is used for both mechanical surface aeration and diffused air aeration under standard conditions. Standard conditions refer to clean water at a temperature of 20°C and atmospheric pressure of 101.3 kPa with 0 mg/L of dissolved oxygen (DO).

A comparison of some common aeration system efficiencies is provided in Table 1.

Table 1. Comparison of standard aeration efficiencies for common aeration systems (Water Environment Federation).

Aerator Type	Standard Aeration Efficiency (kgO_2/kWh)
High-speed surface aerator	0.9-1.3
Low-speed surface aerator	1.5-2.1
Coarse bubble	0.6-1.5
Turbine or jets (fine bubble)	1.2-1.8
Fine bubble or fine pore	3.6-4.8

Suppliers of diffused aeration systems often quote SAE values of between 4–8 kgO_2/kWh. So there is some notable difference in what is claimed and what the Water Environment Federation states for actual systems.

Historically, the maintenance of aeration systems has been largely based on supplier recommendations or equipment guarantees. In many cases, maintenance has only been initiated reactively in response to a license non-compliance such as increased ammonia in the final effluent. Some utilities have incorporated it into asset management programming, but many do not.

SAE allows an easy comparison of the efficiency of all aeration systems (diffused aeration, in particular, due to the subsequent asset management practices that can be utilised to improve performance) from plant to plant and also within a plant over time. It is also a very good mechanism for identifying failing systems, as well as to provide triggers for replacement based on the potential savings of improving aeration performance.

Table 2 provides some figures for four different activated sludge STPs. The SAEs vary widely! Low or decreasing SAE can simply be equated to increased or increasing costs.

Table 2. Activated Sludge Treatment Plant Aeration Performance.

Treatment Plant	Rotorua	Colac	Plant Y	Plant Z
Process	MBR	SBR	MLE/SBR	MLE/SBR
Flow Treated (ML/d)	9	6	12	3
SAE (kgO_2/kWh)	4.5	2–3	1–2	2–2.5
Aeration OPEX costs ($/year)	To come	$250,000	$300,000	$200,000
Diffuser Maintenance	Annual cleaning 7-year replacement program	Failure to meet licence limits initiates manual diffuser clean and replacement if unsuccessful	None	None

For example, in Plant Y where the SAE is as low as 1 kgO_2/kWh and the aeration system OPEX is around $300,000 per year, there are clearly significant savings that can be made if the SAE could be increased to 4 kgO_2/kWh. Such an improvement in SAE is quite possible and would result in a saving of around $225,000 per year, a massive 75% reduction.

So what can we do? Save money of course!

By regularly determining SAE and power costs, changes can be tracked and act as a trigger for diffuser cleaning and/or replacement.

SAE can be determined at any STP by a process engineer, however, an online SAE calculator is now available. Installation of the full online calculator application would allow you to continuously determine SAE, monitor any long-term changes in aeration efficiency, monitor the effectiveness of any diffuser cleaning programs and also compare the efficiency of your plant with other utilities and plants.

So what do you do if the SAE is lower than the supplier says it should be, or lower than other similar plants?

There is a standard hierarchy of investigation.

1. Assess the performance of blowers by reviewing whether the blowers operate on the blower curves, and reviewing the age and maintenance procedures of the blowers.
2. Assess the performance of the diffusers. This is best done by cleaning the diffusers and then observing any improvement.
3. Assess the performance of the control system. This is mainly assessed by determining how well the DO set-point is maintained in the system.

Based on the SAE and the assessments described above, the cost of aeration can usually be reduced, without compromising treatment, by implementing one or more of the following actions:

- Periodic cleaning of diffusers to reduce "diffuser fouling";
- Improving blower turndown ratios (the ability of the blowers to run at both low and high speeds) to reduce over-aeration;
- Controlling aeration based on ammonia feedback from online ammonia probes

Figure 1. Rotorua Wastewater Treatment Plant – database display with sampling points.

to ensure that just the necessary amount of oxygen is added to the system;

- Implementing feed-forward control based on influent loads as determined by online sensors to ensure that just the necessary amount of oxygen is provided;
- Maintaining equipment (blowers, diffusers, control equipment);
- Replacing equipment.

SAE Calculator Case Studies

Rotorua STP

At Rotorua in New Zealand, the operators weren't sure how well the system was performing. They knew that best practice operation of diffused air systems required periodic cleaning of the diffusers and that ultimately replacement would be necessary; however, they didn't know when in both instances. Their program was an annual clean and a replacement every seven years based on the supplier's recommendations.

The SAE online calculator was installed on the web-based platform. Figure 1 shows part of the online calculator showing the plant, the sample sites and unit process details.

Figure 2 shows the SAE trend over a one-year period where the daily SAE is presented and a trend line overlays the daily data (to reduce the noise from the daily outputs). The SAE has dropped from 4.5 kgO_2/kWh to 4.3 kgO_2/kWh. The figure also shows a diffuser clean (highlighted in red – on 6 May 2013), which in this case appeared to do very little over a sustained period.

On the basis of this data, Rotorua will reduce the cleaning frequency. Since the SAE is quite good, there is no indication of the need to replace the diffusers at this stage. Ongoing monitoring will assist with this decision in the future.

Colac STP

Colac STP in Victoria experiences periodic and irregular process upsets when oxygen cannot be effectively delivered to the system. A DO of only 0.1–0.2 mg/L can be achieved with fully operational blowers. As a result ammonia removal is at times inhibited. The process update is due to high input of oil and grease from trade waste customers. It appears that the high oil and grease fouls the diffuser and results in under-aeration.

The diffusers were cleaned, however, improvement was short-lived so the diffusers were replaced. Under the current operation the diffusers have a low life experience. The SAE calculator has allowed Barwon Water to better manage the cleaning and replacement regimes. Barwon Water is also in the process of reducing the risks associated with the trade input through the installation of a pre-treatment system.

The SAE online calculator was seen as a way to monitor what was happening and provide an early warning system of fouling and possible nitrification inhibition.

The online calculator was installed and the SAE appears to be around 2.5–3 kgO_2/kWh. This suggests there are potential improvements in SAE after only six months' operation of the new diffusers. Currently the cause is being determined.

Plant Y

At Plant Y in Victoria, the existing aeration system was known to be inefficient. Water Company A wanted to know what the cost/benefit of replacing the diffusers and/or blowers was likely to be. A one-off SAE was determined using the calculator in single point average mode.

The SAE was found to be between 1 kgO_2/kWh and 1.5 kgO_2/kWh. This was used to demonstrate that immediate replacement of the complete aeration system would be cost-effective with a payback period of approximately two to three years.

Interestingly, treatment was not compromised at these low SAEs, but this was probably due to the excess blower capacity available, combined with poor control. For example, the control system resulted in a DO of up to 6 mg/L for extended periods.

Plant Z

At Plant Z in Victoria the existing aeration system was known to be inefficient. Water Company A was maintaining the diffusers but was having problems with the delivery pipework. The pipework was

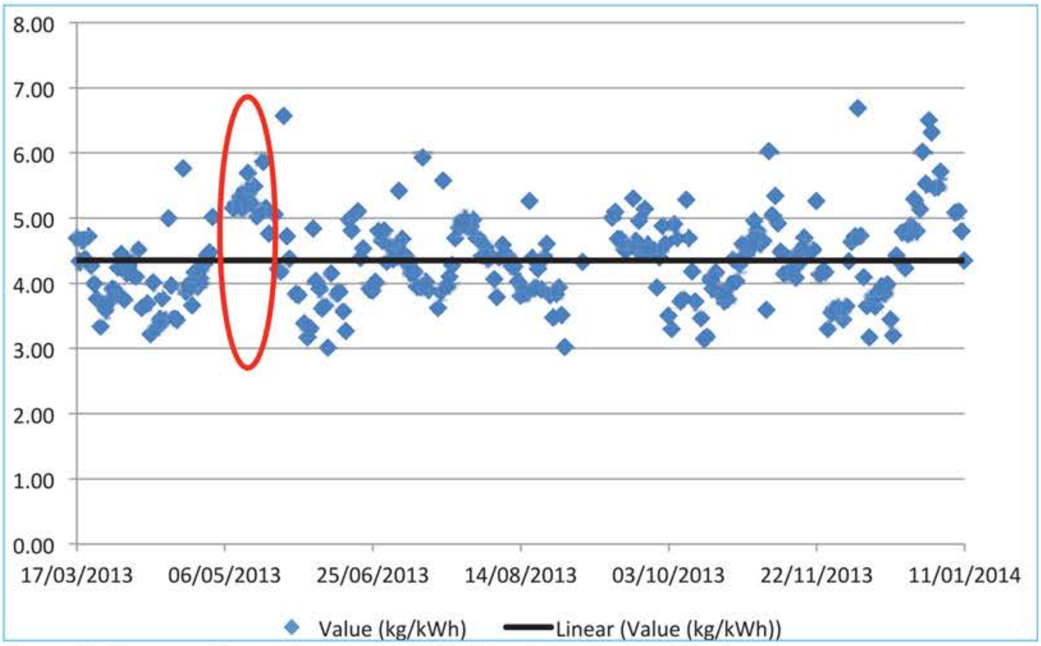

Figure 2. One-year time series trend of SAE (blue dots with trend line).

Figure 3. Air-delivery pipework in the reactor. The reactor had been emptied for cleaning and servicing.

in poor condition and Water Company A wanted to determine whether to replace the system with the same system or whether there was a more efficient system suitable.

A one-off SAE was determined using the calculator in single point average mode.

The SAE was found to be 2.5 kgO_2/kWh. Based on this relatively low figure, the control system, the blowers and diffusers were investigated as per the hierarchy described. The investigations showed:

- The blowers were new but poorly controlled (start and stops were poorly set up in the PLC);
- There was a very low diffuser density, with <5% coverage of the floor of the aeration tank;
- The delivery pipe size was adequate.

The recommendation was to immediately increase the diffuser density and replace the pipework with same-sized pipes. The final recommendation was to improve the control system.

Conclusion

The SAE calculator can be easily installed on any STP SCADA system, or even better as part of the online web based system. The calculator directly measures the aeration system performance and provides an evidence-based approach to operation, maintenance and replacement of aeration systems.

So why not save some money yourself? Remember aeration costs between 40 and 60 per cent of total plant costs. So a few per cent improvement in aeration efficiency translates to tens of thousands of dollars.

The Author

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Editor's Comment

It is a shame that the potential of modern SCADA systems is not fully utilised. The vast majority of SCADA systems simply log basic single parameter values such as DO, turbidity, temperature, level. There is so much more. The whole area of derived parameters needs to be implemented. Things like SAE in a STP or rate of headloss change in a WTP. It further seems an indictment on our plant designers and control system specifications that SAE is not a standard parameter at all STPs. The fact that it has the potential to save money and reduce license infringements makes it an obvious benefit to all STPs.

SEND IN THE DRONE

Alister Laidlaw

Winner of the Hepburn and Iwaki Prizes for the Best Paper Overall at the 2014 WIOA Victorian Operations Conference

North East Water covers an area of 20,000 square kilometres in north-east Victoria with 37 towns, 15 raw water reservoirs, 23 water treatment plants, 80 clear water storage tanks and 18 wastewater treatment plants.

Clear water storages have traditionally been inspected manually by an operator through a visual check and climbing the storage to check roof, gutter and hatch condition as well as look for any signs of potential ingress or contamination. Inspections of this type require working at heights training and working near water training. To reduce exposure of operators to these hazards, North East Water started using a drone in late 2013 for the primary purpose of inspecting clear water storages and water towers. The initial use of an inexpensive drone proved that the concept was effective and warranted further development.

A higher-quality quadcopter (four-bladed) drone (Figure 1) was selected to further develop the technology and inspections. The drone has four electric motors and an on-board computer with GPS, which allows for a flight time of up to 25 minutes. GPS is used to stabilise flight so the drone is able to hold its position with no input required from the operator. The drone can fly within an operating radius of 300 m and up to a regulated altitude of 120 m. The drone can be flown manually, or GPS waypoints can be programmed for automated flight, including take-off and landing.

The drone is controlled via a conventional twin stick controller with an integrated mount for a smart phone. The camera mounted underneath the drone is operated via an App on the smart phone, which provides live vision to the operator. The stable and predictable flight allows the operator to focus on framing and taking photos and video, rather than constantly focusing on the flight of the drone.

Figure 1. The quadcopter drone in flight during a clear water storage inspection.

Due to the electronics on board the drone, it cannot be flown in rain. While the drone uses GPS to stabilise flight, strong wind (approx. >20 km/h) can affect flight stability and reduce image quality.

North East Water's Water Quality Risk Management Plan requires that all drinking water storages must be inspected regularly. The use of the drone has reduced the need for operators to work at heights when climbing tanks and towers. The drone is also able to record images that an operator may not be able to see due to obstructions such as roof pitch, vents or solar panels.

North East Water used the drone to inspect a clear water storage after a storm event in April 2014. Figure 2 (far left) shows a photo taken by an operator from the ground indicating a potential roofing issue. The drone can be seen in the background.

The second photo in the sequence was taken by an operator from the top of the tank at the ladder access point. From this position no sign of damage is evident. The final photo in the sequence is an aerial photo taken by the drone that shows the roof was, in fact, missing a section of flashing. The missing flashing was nowhere to be seen on the ground. The roof was able to be repaired the following day to minimise any potential water quality impacts.

Figure 3 shows additional examples of clear water storage tank roofs with a range of problems highlighted.

The drone has not completely replaced human operator inspections. A full visual inspection is still carried out in parallel to the drone inspection at suitable intervals according to the risk. This includes physically opening hatches and looking inside the storage for light spots, which could indicate holes. However, it is hoped that as drone technology advances, North East Water will be able to replace, or at least reduce, operator inspections.

Health and Safety Considerations

While the use of a drone has had clear health and safety benefits through reducing

Figure 2. Photos of a damaged clear water storage roof, taken from the ground, the roof and the air.

Figure 3. Roof integrity problems "spotted" by the drone. The arrows indicate the problems.

Figure 4. Photo taken by the drone at Loombah Reservoir, Benalla, to determine the extent of a blue-green algae bloom.

the need to work at heights and near water, this new technology also introduces its own hazards. When spinning, the blades of the drone pose a cutting risk to the operator. The drone weighs over 1kg and can travel at speeds of up to 50 km/h, which could cause injury to an operator or bystander if a collision was to occur. Despite the drone having built-in safety features that reduce the likelihood of these hazards occurring, North East Water has developed safety protocols and implemented drone training.

Regulation of Drones

Aviation and privacy regulation in Australia is fast developing to address the rapidly growing use of drones. At present there are some grey areas and the regulation of drones could be considered to be open to interpretation, as it tends to lag behind the advances in drone technology.

The use of drones in Australia is regulated by the Civil Aviation Safety Authority (CASA). Under the *Civil Aviation Safety Regulations 1998*, an operator of a drone used for the purposes of 'air work' (i.e. aerial reconnaissance for a commercial use) must be licenced. Under the Regulations, a drone must only be flown under the following conditions:

- In uncontrolled airspace and not within 5.5 km of an airport or aerodrome;
- At a maximum operating height of 121.92 m;
- Under appropriate weather and daylight conditions;
- Away from populous areas;
- Within the pilot's line of site at all times.

The process to obtain a CASA licence to operate a drone can be relatively costly and time consuming. North East Water is currently investigating this process.

Privacy concerns are an aspect often associated with the use of drones. The *Information Privacy Act 2000* (Vic) is the key privacy legislation in Victoria. Under this Act, surveillance cannot be used to collect personal information about individuals and for the purpose of using or disclosing that information. North East Water has procedures in place to ensure that the use of the drone does not breach privacy law.

Other Applications

As well as for assessing the integrity of clear water storages, other applications where North East Water has used the drone include:

- Assessing the extent of a blue-green algal bloom in a reservoir (Figure 4);
- Assessing and recording dam spillway and wall conditions (Figure 4);
- Assessing aeration patterns in aerated lagoons (Figure 5);
- Recording progress of construction projects (Figure 6);
- Recording flow dynamics of wastewater treatment plants;
- Inspecting offtakes in reservoirs only accessible by boat;
- Inspecting decommissioned infrastructure;
- Providing high quality, current aerial photographs;
- As an education tool;
- 3D modelling.

The Author

Alister Laidlaw (alaidlaw@newater.com.au) is a Water Systems Coordinator with North East Water in Victoria.

Figure 5. Photo taken by the drone of a wastewater lagoon showing the diffuser aeration pattern.

Figure 6. Photo taken by the drone of a 520 ML off-river water storage under construction at Bright.

DO NOT LEARN THE HARD WAY!

Safe drinking water is a remarkable product that residents of developed countries too often take for granted. Consumers are able to do so at least partly because failures leading to adverse health impacts affecting them are so rare. However, the occurrence of outbreaks of waterborne disease keep happening in affluent nations and incidents of serious chemical contamination do occur.

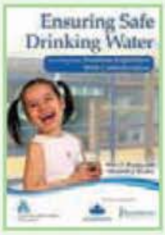
Steve and Elizabeth Hrudey have published a new book entitled *Ensuring Safe Drinking Water: Learning from Frontline Experience with Contamination.* In it they provide detailed analysis of what has happened in cases of drinking water failure in a manner that can be used for effective training of frontline water operators, managers, regulators and public health personnel about what has gone wrong.

A total of 16 major cases of drinking water disease outbreaks caused by microbial pathogen contamination, chemical contamination, or major close calls were assembled for this book. These are listed in the table below. As far as the accessible information allowed, each case study was written from the perspective of front-line personnel, about what they knew and when they knew it as an emerging story. Then, each case provides what really happened and what were the consequences. Each case also provides questions to ponder and a list of lessons that can be generalised, thereby maximising learning potential.

By documenting this contamination experience in a readily accessible manner, this book seeks to assist front-line personnel to be able to learn from the painful experience of others and thereby develop preventive measures in their own drinking water systems.

Ensuring Safe Drinking Water: Learning from Frontline Experience with Contamination is a must-read not only for the entire water industry but also Regulators, Equipment Manufacturers, Consultants and Politicians. Comprehension and application of practical information contained in this book will undoubtedly save lives in the future.

Ensuring Safe Drinking Water: Learning from Frontline Experience with Contamination



Authors:
Steve E Hrudey &
Elizabeth J Hrudey

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Note: This publication is also available from the Australian Water Association's Online Bookshop:
AWA Members $58;
Non-Members $73.
Go to www.awa.asn.au/Bookstore

See overleaf for a pullout poster: 10 Commandments For Safe Drinking Water.

Location	Year	Type of contamination	Health effects
Adliswil, Switzerland	2008	Mixed pathogens	180 cases
Alamosa, CO, USA	2008	*Salmonella*	1 death ~1,300 cases
Anytown, North America	2011	Process failure	Close call
Anytown, Australia	2011	Process failure	Close call
Brisbane, QLD, Aus	2009	Fluoride	Illness avoided
Burncrooks1, Scotland	1997	Diesel oil	Illness avoided
Burncrooks2, Scotland	2011	Aluminum	Illness avoided
Camelford, England	1988	Aluminum	Acute, chronic
Freuchie, Scotland	1995	*E. coli* O157:H7	765 cases
Milwaukee, MI, USA	1993	*Cryptosporidium*	50 deaths, 400,000 cases
Nokia, Finland	2007	Mixed pathogens	2 deaths, 8,450 cases
Northampton, England	2008	*Cryptosporidium*	422 cases
North Battleford, SK Canada	2001	*Cryptosporidium*	5,800–7,100 cases
Östersund, Sweden	2010	*Cryptosporidium*	27,000 cases
Stratford, ON, Canada	2005	Detergent	Illness avoided
Walkerton, ON, Canada	2000	*E. coli* O157:H7	7 deaths, 2,300 cases

10 COMMA
FOR SAFE DRI

STEVE E. HRUDEY & ELIZ
ENSURING SAFE DRINKING WATER - LEARNING FROM FRONTLINE EXPERI

1 NEVER SAY NEVER!
Contamination can strike any system. The test for you will be how quickly you recognize trouble and deal with it effectively.

2 DO NOT UNDERESTIMATE THE CAPACITY OF FAECAL (HUMAN OR ANIMAL) WASTE TO MAKE WATER UNSAFE.
Ample evidence proves how remarkably little faecal waste is needed to seriously contaminate drinking water.

3 LEARN FROM EXPERIENCE - DO NOT JUST SURVIVE IT.
Learn from your mistakes and from those around you.

4 MAKE SURE YOU UNDERSTAND WHY YOU MUST COMPLY WITH REGULATED REQUIREMENTS.
If you only do things because you are told to, you are well on your way to complacency and worse to come.

5 RECOGNIZE WHEN YOU DO NOT UNDERSTAND WHAT IS HAPPENING.
Admit it and seek help to understand.

6 TREAT WATER OPERATIONS LIKE DEFENSIVE DRIVING.
Expect mistakes by others.

ANDMENTS
NKING WATER

ABETH J. HRUDEY. 2014.
ENCE WITH CONTAMINATION.

7 Do not overlook the obvious.

If your plant is so poorly maintained or filthy that a reasonable person would not consider eating food there, you should not expect a rational person to have confidence in your ability to produce safe drinking water there.

8 Maintain healthy skepticism about the first explanations of what is wrong.

If things are going seriously wrong, an unfortunate coincidence involving independent but noncritical problems may lead your corrective efforts astray.

9 Do not let others (managers, politicians) be able to pin the blame on you.

If you know that improvements are needed, document those needs in detail and bring them to the attention of your immediate supervisor.

10 Take pride in the public health responsibility that you carry and maintain.

Our society generally takes drinking water for granted, but you must recognize and make sure your family and friends understand that all those involved in ensuring delivery of safe drinking water are in the front line of protecting public health.

WATER STORAGE TANK DESIGN: NOW AND FOR THE FUTURE

Dave Barry & Hannah Busch

For any new treated water storage tank design to remain 'fit for purpose', tank designers need to be fully conversant with upstream water treatment processes, as well as having a complete understanding of all the maintenance requirements and the downstream distribution system function.

Designers also need to consider the future. How will evolving environmental, OH&S and distribution requirements be met if a tank is only designed to meet today's standards and not those that will be in place in 20, 50 and 80 years' time? Tank design needs to incorporate some flexibility so they can be upgraded and adapted during their expected design life.

Access and Security

Access begins with the tank site and ease of movement for maintenance vehicles. Cranes and Elevated Work Platform (EWP) equipment will need a decent setdown area for outriggers as well as solid, level ground to move around on. The greater the space available, the easier it is to avoid underground pipework. Maintenance personnel also require close access to the main ladder for moving gear up and down to the roof platform area.

The tank site should be selected with consideration for future growth. The original structure may have fantastic access and tick all the boxes, but a second, future installation may not.

Figure 1. Restricted access for EWP equipment.

Figure 2. Security measures are easily bypassed.

Site security is often not adequately considered and needs to be factored into the initial design. Consumer confidence that water is safe and healthy to drink could be rapidly lost in the event of a water quality incident involving interference with water in a storage. Simple measures such as the elimination of structures that assist unauthorised climbing on the structure and installation of motion-detecting cameras need to be incorporated into the design.

Design considerations for site access and security include:

- Can the tank be fully accessed by an EWP, cranes and maintenance vehicles?
- Security fences and motion-detecting cameras should be set up to prevent and monitor public access around the whole tank site.
- Tower-type external ladder systems to access the tank roof should be built, instead of spiral staircases, which are easy to by-pass.

Platforms and Hatches

The most commonly used areas of a tank are the platform and entry hatch. The platform needs to meet a number of requirements. There should be sufficient space for storage of equipment, adequate guard railing for fall prevention, all surface areas to be self-draining (to prevent ponding, slip hazard and material corrosion) and it must be fully sealed to protect the water quality. The platform itself must be secure and of sound, robust construction.

Figure 3. Unsealed entry hatch area.

Many existing entry hatch covers have been slotted to allow for ladder stiles to extend through and in many cases the front edges have been removed to eliminate trip hazards. This misguided OH&S interpretation results in a significant contaminant entry point, as the hatch is not effectively sealed. When water quality is being compromised, often on a daily basis, and the entry hatch may only be accessed once a year, frequency must be the over-riding factor in deciding which issue is the more important one.

Some design considerations for platforms and hatches include:

- Ensuring that water can drain away from the platform and does not drain into the tank. Closely-fitted kick rails around the edges are the main culprit for debris accumulation and water ponding occurring;
- Having sufficient space for people and equipment to work safely;
- Fitting two hatches into a tank where possible: one roof-mounted for diver entry,

Figure 4. Good platform and hatch design.

with a vertical, uncaged ladder mounted below; and a second wall-mounted hatch at ground level to allow for a dry-tank, low-category confined space entry;

- Handrails to extend around the practical working area;
- Removing or relocating bird-roosting spots such as telemetry aerials and fixed, overhead safety systems.

Roofs

The primary function of a roof is to prevent contamination of the water supply. Many older tanks have had roofs retrofitted around existing fittings. The result is often a compromise and has not always been successful. Routine inspections have shown a number of recurring issues arising with both new and old roofing systems that all have the potential to allow contamination of the water supply they should be protecting.

- Non-draining surfaces and ponding behind fixtures such as vents, hatches and platforms;
- Ridge capping not correctly fitted, which allows for debris and stormwater entry;
- Guttering that cannot be cleaned safely, is unsealed or that allows backflow to occur during heavy rainfall events;
- Materials not compatible with humid environments, leading to structural failures.

So where can improvements be made in new designs?

- **Remove all gutters** This reduces tank maintenance and eliminates the risk of a gutter collapse and back flow.
- **Eliminate ponding** Roof fixtures such as platforms, hatches, ventilators or pipe penetrations should be installed so that water can pass around the fixtures.
- **Reduce ridge capping** This prevents build-up of contaminated materials underneath and limits the capping being "blown away" during storms.
- **Use appropriate materials** The humid area below the roof will accelerate corrosion of unprotected materials. This includes the 'fall protection' mesh, sometimes used during roof sheet installation, or the uncoated edges of rolled 'zincalume' type purlins. Many roof-fixing screws are also failing prematurely due to poor quality standards.

Figure 5. Collapsed roof gutter.

Figure 6. Debris build-up under roof flashing.

Tank Inlets and Outlets

The primary function of pipework is to deliver water into, or carry water away from, the tank. Effective delivery is a balance between blending the new water with the existing product to prevent short-circuiting without disturbing the residual sediments on the floor. Sediment should be allowed to settle within the tank, as it is more cost effective to clean a tank than the distribution system pipework.

Many positions for inlets have been tried over the years: through the roof, through the wall and set into the floor. Each has its own unique problems.

- Roof mounted inlets may result in ponding when roof drainage cannot flow around the penetration area and floor sediments can be re-suspended during filling if water levels become too low;
- Wall inlets generally force water across the floor to re-suspend sediments already settled out;
- An inlet coming through the floor will push water upwards, but blending is often limited.

Figure 7. Through the wall, external overflow.

A directional nozzle, fitted to wall or floor penetrations,

Figure 8. Directional nozzles give good results.

provides good water blending without stirring up sediment. Directional nozzles can also provide an effective separation of inlets and outlets that are close by, thereby reducing short-circuiting of the water.

Effective outlets should be raised up off the floor to avoid drawing sediments into the distribution system. They should also be screened to protect divers or robots, however, many screens are too large and cannot be cleaned internally (especially by robots). Safety screens should be made from non-corroding materials such as HDPE and be close-fitted to the penetration. Their holes should total no more than 120% of surface area of the pipe being covered, so that they do not allow sediments to collect on their external surfaces and then be drawn in when high flows occur.

The relative position of the inlet and outlet pipe should be planned to limit short-circuiting. By separating the inlet and outlet pipes and adding directional nozzles, short-circuiting can be reduced and mixing encouraged.

Internal Pipework and Fittings

Reducing the amount of exposed pipework within a tank, such as overflow and inlet risers, has a two-fold benefit:

- Firstly, less pipework reduces the chlorine demand due to corrosion (if uncoated ductile pipe is used);
- Secondly, there are fewer obstacles for divers (or robots) to navigate around when cleaning the internal areas.

Some internal pipe design considerations include:

- Minimising the amount of pipe within the tank to prevent corrosion;
- Protecting steel pipework with a coating or use HDPE/Poly/FRP for internals;
- Ensuring bolts are of a similar material or are insulated to prevent localised corrosion;
- Outlet screens should fit neatly over penetrations so that sediments cannot accumulate internally. Screens should also

Figure 9. An outlet area that cannot be cleaned.

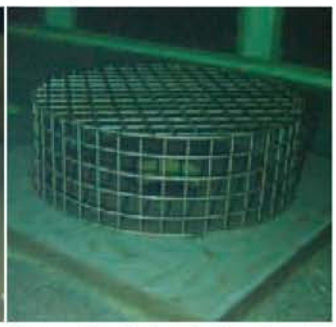

Figure 10. A closely fitted outlet screen.

Figure 11. Close inlet and outlet pipes encourage short-circuiting.

Figure 12. Internal pipework creates obstacles and problems for cleaning.

have a sealed base section up to 150 mm in height to prevent surrounding sediments being drawn into the penetration;

- Overflows can be a simple 'through wall' penetration with the riser external to the tank.

Internal fittings and fixtures should be kept to a minimum, or simplified if they do have to be installed. Tank-cleaning will likely be carried out by robots in the future, so let's make things achievable now instead of creating complications for the next generation of maintenance personnel. Roof support posts can be reduced in favour of larger roof-framing members, while post bases can be included into the sub-floor foundations and not be exposed above the floor level. Wall floor areas should have no steps or rounded edges, and floor seals should be neat and cleanable.

Conclusion

There are many aspects to tank design that need to be considered to protect public health and provide for effective future maintenance activities and growth. Drawing from field observations, many issues are recurring throughout the industry that could easily be solved during the design phase of a project.

A different view (other than cost cutting) should be taken when designing tanks that are 'fit for purpose' for the future. What are the future maintenance requirements, safety standards and water quality standards likely to be? Think upstream and downstream and maybe the next generation will remember us for something worthy, instead of being short-sighted and limiting our designing endeavours to cost alone.

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SAND AND SILT TRAP AT RAWSON WTP

Mark Walker
Winner of the Problems Accepted, Solution Supplied (PASS) Award 2012

At the Rawson WTP, raw water was harvested from a small stream that was subject to high levels of sand and silt, particularly during periods of high rainfall. The sand and silt gradually built up in raw water basin No 1 and eventually required removal by excavator and tip truck.

Although this problem did not directly impact on day-to-day operations, the cleaning process (Figure 1) was time consuming and costly and required the basin to be offline for 14–21 days. As there were two raw water storage basins this was not considered to be a huge issue, but with the decommissioning of raw water basin No 2 due to contamination and structural issues, outage of raw water basin No 1 wasn't an option any longer.

Figure 1. The accumulated silt and sand (top) and the slow cleaning process (bottom).

There had been several unsuccessful attempts to address the silting problem, the most recent being the introduction of a stainless steel wedge wire cylinder screen. This screen was fitted to the weir outlet and was effective in removing larger debris, including sticks and leaves, however, the fine sand and silt still passed through to raw water basin No1.

I had been thinking for a while about how to design a better system that was more efficient and less labour intensive.

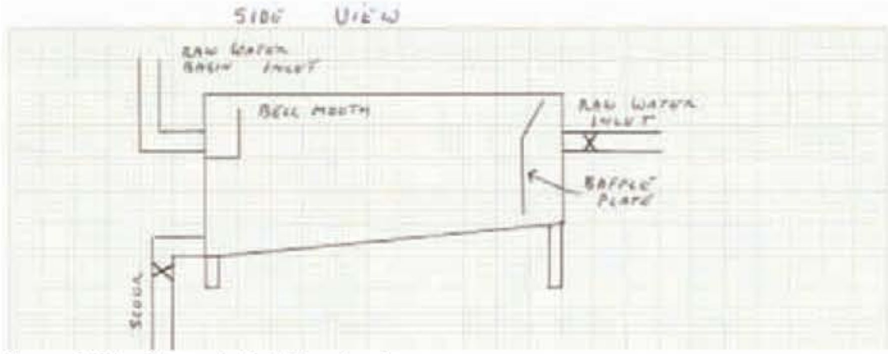

Figure 2. The first technical drawings!

Figure 3. The finished unit in place at raw water basin No 1.

Once I started some sketches, the design developed quite quickly (Figure 2).

After the initial concept design was worked through, I had a Gippsland Water engineer look over the plans, with my main concern being if it would still be effective at peak flows, which are approximately 12L/s. Once this was confirmed, a local engineering firm was engaged to construct the unit (Figure 3).

The raw water enters the sand trap, which has a baffle plate directing the flow down towards the base of the vessel. The sand and silt is heavy enough to settle on the bottom and accumulate, while the water level rises, spilling over the bell mouth outlet and entering the basin.

The sand trap needed to be cleaned out every couple of weeks, which wasn't a very user-friendly exercise. The new trap has a hopper style base that slopes towards the scour – all we have to do is reduce the inlet to approximately 2L/s and it basically cleans itself out.

Apart from the inconvenience of having the basin off-line, carting water and engaging contractors to clean it, the main benefit is the time and cost savings to the organisation. The trap works exceptionally well and is very easy to clean out.

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ULTRA AND MICROFILTRATION MEMBRANES DESIGN AND OPERATION

Rick Maffescioni

Capillary or hollow-fibre ultrafiltration (UF) and microfiltration (MF) membrane treatment processes effectively remove particles and microorganisms that are larger in size than the nominal pore size of a chosen fibre. The relationship between particle size and membrane pore size is shown in Figure 1.

Membranes are often used for treatment of surface water supplies to remove turbidity and colloidal materials. Membranes are also widely considered for effective removal of *Giardia*, *Cryptosporidium* (Figure 2) and a variety of water-borne viruses and bacteria.

In recycled water systems, membranes may be used in combination with other accredited virus removal processes, for example ultraviolet radiation and chlorine residual disinfection, to form part of a multi-barrier treatment process for production of Class A recycled water.

There are many different membrane materials and configurations. Typical hollow-fibre type membranes are manufactured from polymer molecular structure, which may include Polyethersulfone (PES), Polyvinylidene Fluoride (PVdF) and Polypropylene (PP), to name a few. Membrane material selection criteria may include their compatibility with different cleaning chemicals, tolerance to pH and temperature range, price/availability and their ability to be repaired or inspected if need be. PVdF type membranes are now more commonly used and priced accordingly.

Membrane manufacturers are continuously improving the technology. Membrane materials and the necessary cleaning chemicals are significant factors in fibre development. For example, oxidant-resistant fibres such as PVdF can be cleaned with low-cost chlorine-based chemicals that are relatively easy to dispose of and don't pose a significant threat to the environment.

Chemical cleaning of membranes typically involves acid and alkali chemicals. In general acid is used to remove inorganic chemical fouling, e.g. silicates and carbonates, while alkali and/or oxidants, in particular free chlorine, is used to remove biological or organic matter fouling.

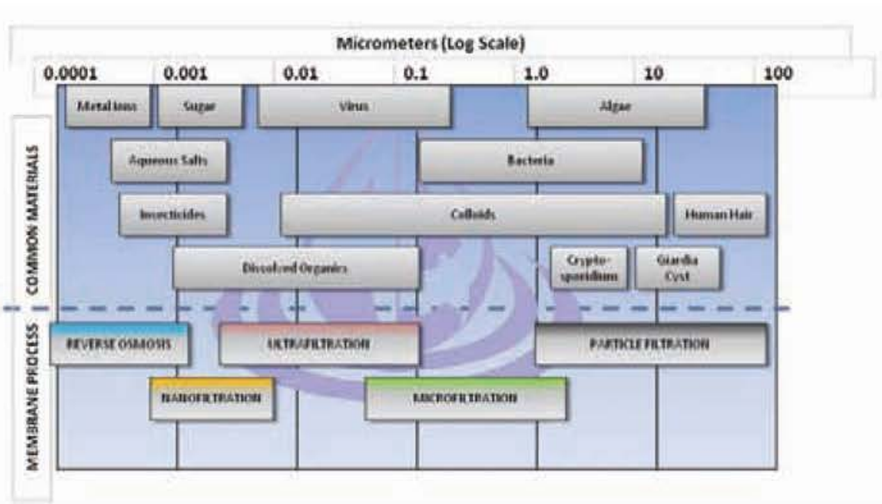

Figure 1. A filtration range chart showing the types of membranes and what they can typically remove.

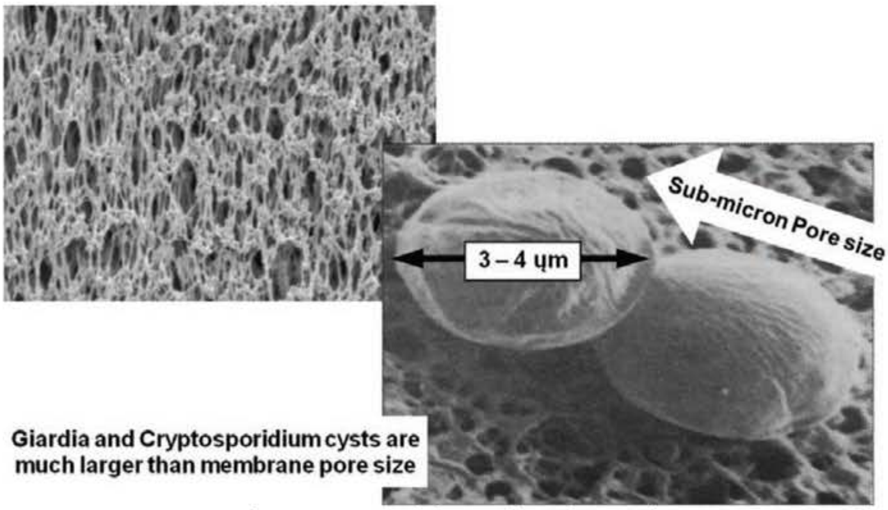

Figure 2. Protozoan pathogens are much larger than the membrane pore sizes and are removed by the membranes (*photo courtesy of Memcor Australia*).

Membrane systems can operate in either an inside-to-outside direction or an outside-to-inside direction. In inside-to-outside operation, the feedwater passes through the core of the fibre then permeates through to the outside. In outside-to-inside operation, the feedwater enters the fibre from the outside and permeates through the pore structure into the inside of the fibre. Outside-inside filtration path may allow for higher or larger solids loading because there are effectively bigger spaces around the outside of the fibre bundle.

There is sometimes a misconception that membrane treatment is highly technical and complicated. While this is true at design and implementation phase, it should not be the case at an operational level.

At the design level, the baseline design parameters are the key to long-term, cost-effective, reliable and simple operation. These include the careful selection of a conservative flux rate. The **flux rate** is Flowrate/Membrane Area and is expressed as $L/m^2/h$ (or LMH). The design flux

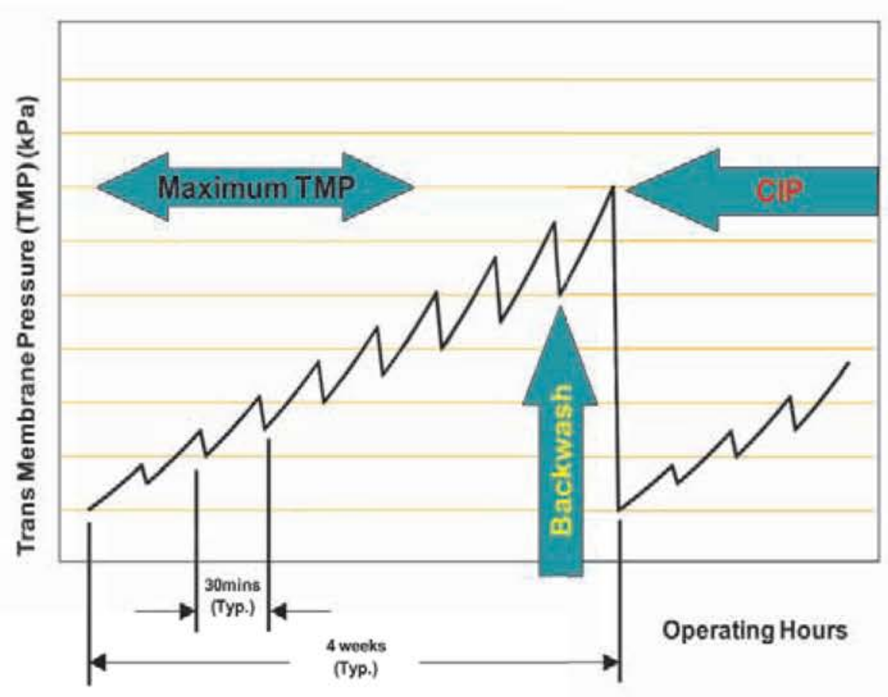

Figure 3. A generalised TMP trend showing the effect of backwashing and CIP on the TMP.

rate needs to take into consideration the influent temperature range and feedwater quality. Turbidity, the chemical nature of the suspended matter, insoluble metal ions such as iron and manganese, silica and true colour all impact on the operation of the membranes. In some cases, Fouling Indices such as the Silt Density Index (SDI) or Feed Fouling Index (FFI) can be used to simulate membrane performance on a given water supply. Determination of fouling indices involves filtering a feedwater sample through a specified filter paper over a given time/s against measured volume. This index may assist in sizing membrane area requirements. Essentially, the higher the index the more membrane area and/or the higher level of pre-treatment is required.

Pre-treatment design depends on feedwater quality and treated water objectives. The most common form of pre-treatment is simple coarse screening down to, say, 500 micron. Advanced pre-treatment to remove contaminants may include the addition of coagulant chemicals, or pre-oxidation, either directly into the membrane plant, or upstream of a more conventional clarification process. UF/MF is often specified for pre-treatment to Reverse Osmosis (RO) membrane systems.

Proper commissioning practices and a thorough hand-over combined with a fully instructive Operating Manual are critical for the reliable and easy operation of any treatment process. Membrane plants are no exception.

If the plant has been designed well it should be simple to operate, even with a variable feedwater quality, provided the plant flow with respect to water temperature, Trans Membrane Pressure (TMP) and chemical cleaning efficiency are carefully monitored. TMP is the pressure difference measured between the two sides of the membrane. As the membrane filters out particles and becomes progressively clogged, the TMP increases. Backwashing removes the filtered material and the TMP decreases. Periodically, clean in place (CIP) chemical cleans are used to further clean the membranes. Figure 3 shows a typical TMP trend over time, the effect of routine backwashing and the effect of CIP.

Water temperature is an important consideration in flow rate selection for membranes since it affects the viscosity of water (Table 1). As the temperature drops, the water molecules are more tightly bound and the viscosity increases. The flow rate needs to be decreased. The following example makes this clear.

If you typically run your plant at 5.0 L/sec @ 20°C, then when the water temperature falls to, say, 10°C, we would recommend you down-rate the plant as follows: 5.0/1.31 = 3.82 L/sec.

As with any automated process, the control system design and robustness is also a major factor in maintaining membrane performance and longevity. Control systems also require effective alarming when the system approaches or exceeds typical acceptable operating ranges.

Instrumentation and data logging is an important feature to be included in membrane plant monitoring. It is particularly important for troubleshooting event-triggered alarming and plant performance variations. Typically, SCADA software is connected to the plant control system, but often higher-resolution data loggers are used to conduct more detailed analysis including backwash profile and other cycle snapshots.

Membrane life expectancy is often 5 to 10 years, but is very much dependent on the feedwater quality, the volume treated and the routine maintenance and service regime. Shorter membrane life may result from cost-saving measures, particularly

Table 1. Effect of temperature on the viscosity of water.

Water Temperature (°C)	Dynamic Viscosity (mPa.s)	Water Temperature (°C)	Dynamic Viscosity (mPa.s)
9	1.34	20	1.00
10	1.31	21	0.98
11	1.27	22	0.95
12	1.23	23	0.93
13	1.20	24	0.91
14	1.17	25	0.89
15	1.14	26	0.87
16	1.11	27	0.85
17	1.08	28	0.83
18	1.05	29	0.81
19	1.03	30	0.79

during the design or implementation stage. An example is when systems are required to perform with inadequate pre-treatment, at higher flux rates with colder temperatures or with extended backwash and CIP intervals.

Membranes can become damaged. Once damaged, they can start allowing particles that would normally be filtered out, through the membrane into the final product. Clearly this is undesirable for effective pathogen removal. In most cases, integrity testing can be carried out automatically at a pre-determined time with appropriate reports and alarms.

Some membranes can be repaired to maintain integrity. This is usually done by placing a single membrane module in a purpose-built test rig, enabling impaired individual fibre/s to be identified and isolated. Membrane damage may not always be attributed to loss of fibre integrity. Irreversible fouling may also occur from physico-chemical characteristics of the water supply and, over time, a membrane may not fully recover from routine backwashing and chemical cleaning. The decision as to when to replace a membrane is dependent on the cost associated with keeping the membrane in service as opposed to the cost to replace it with a new membrane, or the potential risk associated with maintaining a reliable water supply when demand is highest.

In some cases, membrane manufacturers have developed a pressure decay test (PDT) and algorithm that calculates an indicative Log Reduction Value (LRV) equivalent. Some manufacturers also have pre-approved log removal credits for their membranes against particular contaminants. If the LRV falls below a target value despite backwashing and CIP, this can be taken as a trigger to replace the membranes.

Ultimately, plant performance and treated water quality will be dependent on the operator having the necessary training, experience, skill, relevant knowledge and competence to operate the plant, monitor, report and record critical data, and make judgements and act on day-to-day operational circumstances that may arise. However, having said this the labour resource needed to operate membrane plants should be less on a day-to-day basis than for conventional treatment processes.

In summary, UF/MF membrane technology is a cost-effective and simple treatment process with a continuously evolving fibre technology, efficiency and manufacturing improvements. Careful consideration into the initial design, integration and proper commissioning practices will benefit the overall performance, longevity and reliability of the membrane fibres.

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Editor's Comment

If you are in the position where you are operating a new membrane plant, it is worthwhile recording the initial permeability as soon after commissioning as possible. Permeability is the flux (L/m²/h) divided by the applied pressure and expressed at 20°C. It is also worth recording the initial TMP and the results of the initial integrity tests. With this information recorded at the plant, it is easier to determine the condition of the membranes at a later date.

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WATER **NETWORK** SOLUTIONS