WaterWorks

OFFICIAL JOURNAL OF THE WATER INDUSTRY OPERATORS ASSOCIATION OF AUSTRALIA

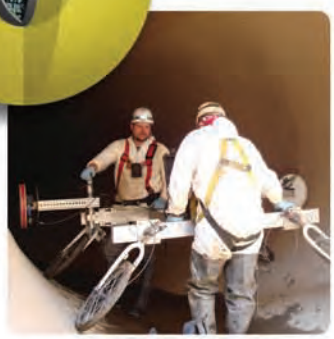
May 2011

New Minimum Requirements for Victorian Water Operators

aqua™ Environmental
A Pure Technologies Company

Aqua Environmental is a Pure Technologies Ltd. Company – a world leader in the development and application of innovative technologies for inspection, monitoring, assessment and management of pipeline infrastructure.

Services for water and/or wastewater pipelines include:



Top: Data Acquisition Unit
Above: Smartball Deployment
Top Right: P-Wave
Right: PureRobotics
Bottom: PipeDiver

Inspection:

SmartBall®	Leak and air pocket detection; Pipe wall assessment
PureRobotics®	Long-range wet or dry pipeline inspection systems
Sahara®	Leak detection, CCTV inspection & wall thickness assessment
PipeDiver™	Evaluation of pipelines; Metallic pipe wall assessment
P-Wave®	Evaluation of PCCP

Monitoring:

SoundPrint® AFO	Acoustic fiber optic technology detects and locates wire failures in pipelines

Assessment:

Aqua Environmental	High quality acoustic leak detection services for reticulation water mains
Jason Consultants	Specialised in the application of trenchless technologies with a focus on skilled condition assessment for water and wastewater pipelines
Openaka	Decision support services for assessing, repairing, and monitoring pipelines

Australia:
Aqua Environmental
3/1 Gordon Street
Camperdown, NSW
Australia
Telephone: 1800 264 262

www.aquaenvironmental.com

Head Office:
Pure Technologies Ltd.
3rd Floor, 705 - 11 Avenue SW
Calgary, Alberta Canada T2R 0E3
Telephone: +1.403.266.6794
Fax: +1.403.266.6570

www.puretechltd.com

WATERWORKS
OFFICIAL JOURNAL OF THE WATER INDUSTRY OPERATORS ASSOCIATION OF AUSTRALIA

Editorial Committee

Peter Mosse, Editor
peter.mosse@gmail.com

George Wall
george@wioa.org.au

Direct mail to:
Peter Mosse
WaterWorks Editor
c/o WIOA, 22 Wyndham Street
Shepparton, Vic 3630

Advertising & Production

Australian Water Association (AWA)
Publications, Level 6, 655 Pacific Highway,
PO Box 222, St Leonards, NSW 1590

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.

CONTENTS

Dear Editor,

I enjoyed your article on profiling filter head losses in the June 2010 edition of *WaterWorks*.

Over the years we've had the need to inspect and assess filters, and have developed a method to determine the depths of filter media. As you would well know, sometimes the depth of filter media layers aren't what the design specs say they are! Or often some media has been lost after years of operation… Therefore, it is very important for anyone carrying out a full filter inspection to determine the depth of each media type within the filter.

This can be done relatively easily using a section of DN 50 clear plastic tube, about 2m long. We have found that the easiest way to sample the media is to turn the backwash pump on and, just as you see the water at the top of the media, plunge the sample tube down through the media until you hit "rock bottom" (i.e. the gravel layer). The media at this stage is partly fluidised and the sample tube can be easily pushed down. If you try to push the tube through the media after it has drained and is "dry", it won't work; there is just too much resistance to allow travel of the plastic tube through the media bed.

When you feel the gravel, you then place your hand over the top and gently lift the tube out. Water will slowly drain out of the bottom of the tube and you will have captured all of the media inside. You have to be careful withdrawing the tube so that no media escapes out of the bottom.

Good separation of filter coal and sand after nine months of operation at Pyramid Hill WTP.

After a couple of attempts, you will develop a satisfactory technique!

A variation of the device uses a golf-ball (or similar) fastened to one end of a drawstring to act as a stopper on the end of the tube. The string, which is inserted down inside the tube, is pulled tight to seal the golf-ball onto the bottom of the tube to prevent any media loss when it is withdrawn. However, we have found that the method works just as well without the golf ball and drawstring.

Lay the tube down flat, and you can then measure the depth of the sand and filter coal layers. If you are using a tube that is not transparent, you will need to gently tap one end of the tube so that the media can be dislodged from inside onto the ground or some other flat surface, where you can then measure the depth of each media layer – *but beware, the measurements won't be as accurate*. By far the best way is to use a clear tube.

The photograph (below left) shows a core of dual-media filter media taken from the Pyramid Hill WTP nine months after we converted it from mono-media (sand) operation. The media-depth measuring device we used in this instance is the length of light-blue plastic pipe lying above the media sample. There was no significant loss of media after this period and the interface between the two media layers was very sharp, with little intermingling.

Once you know the "true" depth and profile of the filter media, interpreting the headloss profile by the method described in *WaterWorks* will be easier and, importantly, more reliable. Without knowing the actual filter media profile, you are really only guessing the depth of each type of media and where the media interfaces are located within the filter.

I hope this is helpful.

Cheers and best wishes to all at WIOA.

Peter Gebbie

Principal Process Engineer and Team Leader

Process Design Team

Water Group, SMEC Australia Pty. Ltd.

OUR COVER

Our cover photograph shows Mr George Wall, Executive Officer of the Water Industry Operators Association of Australia (WIOA), holding a copy of the recently released Victorian Framework for Water Treatment Operator Competencies, which WIOA played a major role in developing.

DIVERS REPAIR SUBMERSIBLE MIXER AT WWTP

Lester Little

The Selfs Point WWTP (see Figure 1) was upgraded to biological nutrient removal between 1996 and 1997. The upgrade incorporated the Danish triple ditch Bio-Denipho process with the existing biological tricking filters.

Figure 1. An aerial view of Selfs Point WWTP, with triple aeration tanks at the top left-hand-side of the plant.

Each aeration tank has two maxi rotors to maintain sufficient DO levels. There are also three submersible Flygt mixers for the anoxic stage of the process to keep the activated sludge moving within each ditch.

In May 2010, plant operators noticed that one of the supporting brackets that the mixer attaches to was on an incline. After an inspection was carried out, it was found the bottom support bracket had broken. After detailed discussions with Southern Water's senior project engineer, John Sandel, it was decided to look at options to complete this repair task. All three aeration tanks are interconnected, so it was not possible to isolate any tanks to take them offline to complete the task of draining and replacing the bracket.

If we had had to take all three aeration tanks offline we would have had to:

1. Seek approval from the EPA (given the likelihood to exceed the plant licence for an extended period) to divert all flow away from the aeration tanks and utilise the trickling filters to treat the entire incoming sewage while this work was being carried out.
2. Removing the existing bio-mass in the aeration tanks, which may have had potential odour issues.
3. Take approximately 12 weeks to build up the bio-mass in the anaerobic and aeration tanks following recommissioning, in order for final effluent quality to achieve licence compliance.

John Sandel suggested the works could be undertaken by a commercial diver to avoid having to drain the aeration tanks. The first trial to see if this was possible was to install a length of 300mm pipe over the location of the bracket and then flush potable water inside the pipe to see if it would disperse the sludge leaving a clear liquor. This trial proved very successful, and it was predicted that the same approach could be undertaken with a much larger (approximately 2.5m diameter) tank, as shown in Figure 2, in which a commercial diver could undertake the repairs necessary.

The next step was to have a commercial camera inspection to see what condition the bolts were in. The camera inspection showed that they were stainless steel bolts and in good condition.

We then proceeded and purchased a specially made plastic tank manufactured

Figure 2. Clear water in the tank before the diver enters.

with open ends and with ballast on the bottom to stabilise the tank. We located it in the aeration tank over the bracket on the bottom and secured the tank in place. By flushing potable water inside the plastic tank using a hose and also installing a small submersible pump, we were able to remove the majority of sludge and keep a clear liquid inside. The diver was able to enter the tank (see Figure 3) using a hooker line and locate the bracket.

Figure 3. The diver entering the aeration tank.

Once the bracket was located and removed (Figures 4 and 5) we had an engineering company on standby to make up new brackets for installation. As the bracket in one tank had already broken, it was decided to repair the other two brackets supporting the mixers in the remaining aeration tanks using the same approach.

After much planning and investigative work, the diving and maintenance carried out on the three aeration tanks to replace the mixer support brackets took a total of three days to complete, which was a rewarding result. While the work was carried out, the plant continued to meet all licence limits on our final effluent discharge.

The estimated cost just for dewatering the three aerations tanks, anaerobic tank and clarifiers was $34,000 alone, over a period of four to six weeks. The repair costs would have been on top of this.

Figure 4. One of the old support brackets.

Figure 5. A worn support pin.

The total repair costs for undertaking the project as described, while keeping the plant operational, was $31,300.

Overall it was a positive outcome to be able to carry out this task without taking the aeration tanks offline, when initially it was thought we would have to drain these tanks. Continuing to meet the plant licence limits during the repair project was the major benefit for undertaking the project in this way.

The Author

Lester Little (Lester.Little@southernwatertas.com.au) is Coordinator Central Wastewater for Southern Water in Tasmania.

PFS REDUCES ALUMINIUM IN RAWSON WATER

Mark Walker

Rawson is situated high in the foothills of the Great Dividing Range in Victoria. Water was originally sourced from high up on Mt Erica and stored in open basins. Later, disinfection was added and, finally, in late 2006 the Rawson WTP (see Figure 1) was commissioned.

Since then the plant has reliably operated to meet the Victorian Safe Drinking Water Act (SDWA) water quality parameters, with the exception of an occasional non-compliance with acid-soluble residual aluminium (greater than 0.20mg/L) in some parts of the reticulation system. There has also been an issue with relatively high pH throughout the system. The 300mm trunk distribution main is concrete-lined, which contributes to an increase in pH. Values greater than 9 have previously been detected.

The coagulant used at Rawson WTP is PACl (Poly Aluminium Chloride), which is an aluminium-based coagulant. At Rawson the PACl forms the best floc at a pH of 8. The high coagulation pH contributed to the elevated soluble aluminium residual and these residuals

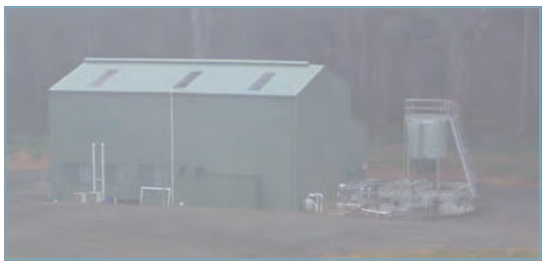


Figure 1. Rawson WTP enshrouded in fog.

sometimes led to a non-compliant sample in the reticulation system.

After the last non-compliant result it was decided to undertake some lab testing with a different coagulant that would not lead to any possible high aluminium residuals. We chose Polymerised Ferric Sulphate (PFS) as it is an iron-based coagulant and has a broad coagulation pH range, typically between 5 and 8.5. After bench trials it was found that the optimum coagulation occurred at pH 5.6 with 99% iron removal. All the other usual water quality parameters indicated that PFS should work in the plant. *No Aluminium = No SDWA Compliance Failures.*

To trial this change in coagulant dosing on a full plant scale we first had to separate the duty standby PACl dosing system, to enable us to trial the PFS with the ability to switch back to PACl at any time. We utilised duty pump Number 1 as the PFS dosing pump and duty pump Number 2 as the PACl dosing pump.

We began the trial on July 15, 2010. At the start of the trial, our Field Operations team pigged the 300mm main from the Rawson WTP to Parkers Corner, where the pipe reduces to 150mm then into 100mm. This large section was pigged due to being too large to flush. Known low-flow areas and dead ends in the reticulation system were flushed. We then completely drained the plant and the sludge handling system, to avoid mixing newly dosed low-pH water with the original high-pH water, and ensured that any undissolved aluminium already in the treated water did not become soluble and contribute to further exceedences in aluminium residual. On completion of these works we were able to start the plant using PFS, and dose rates were determined based on successful jar testing in the lab.

When using PFS the water treatment plant performed really well, and it was

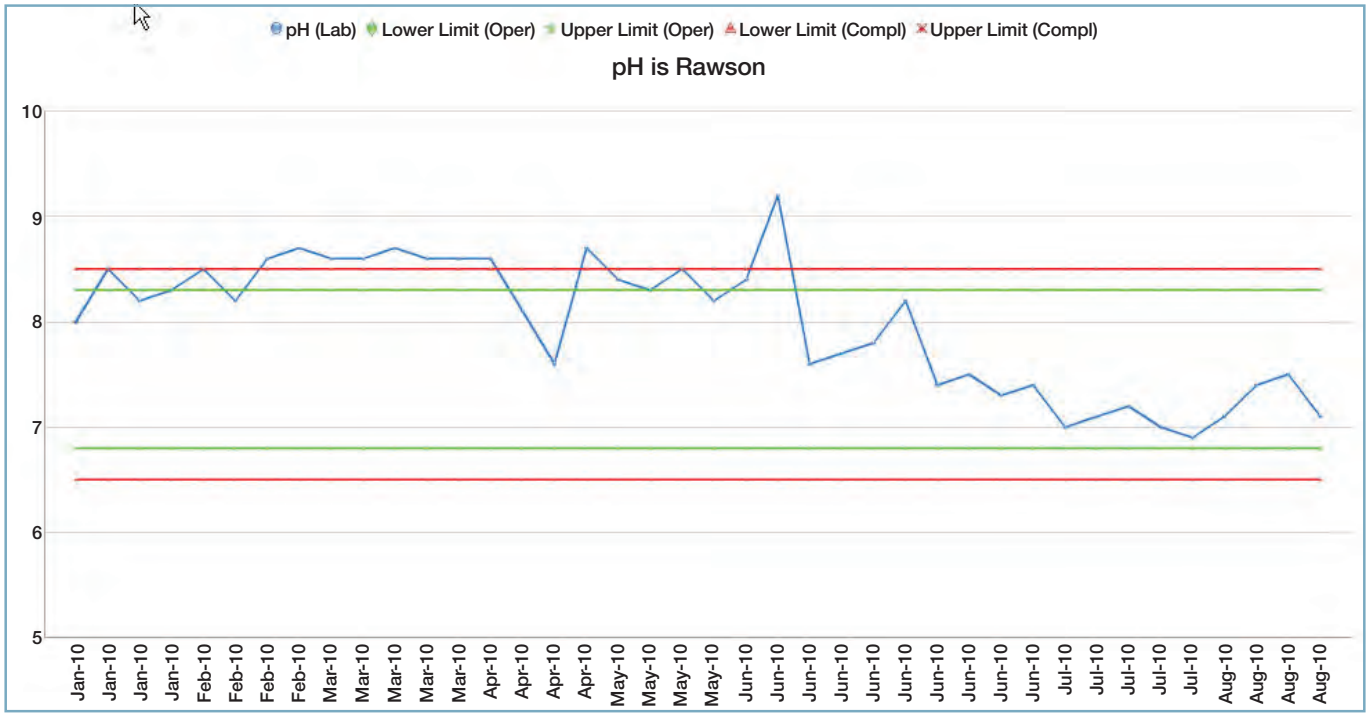


Figure 2. pH in the Rawson system.

very easy to control the treatment process. Aluminium residuals are now consistently well below SDWA requirements and a secondary benefit is that we have successfully lowered the pH right through the reticulation system, bringing it in line with guideline values.

Figures 2 and 3 illustrate the reduction in both reticulation pH and acid-soluble aluminium.

Converting from PACl to PFS dosing at the Rawson WTP has been a success in respect to treated water quality, eliminating two water quality issues that were constantly an operational headache for our Water Treatment Group. The only drawback of converting to PFS has been a 30% increase in sludge production, but this does not cause any operational problems and outweighs the issue of dealing with SDWA non-compliance issues, which have been eliminated for good (we hope).

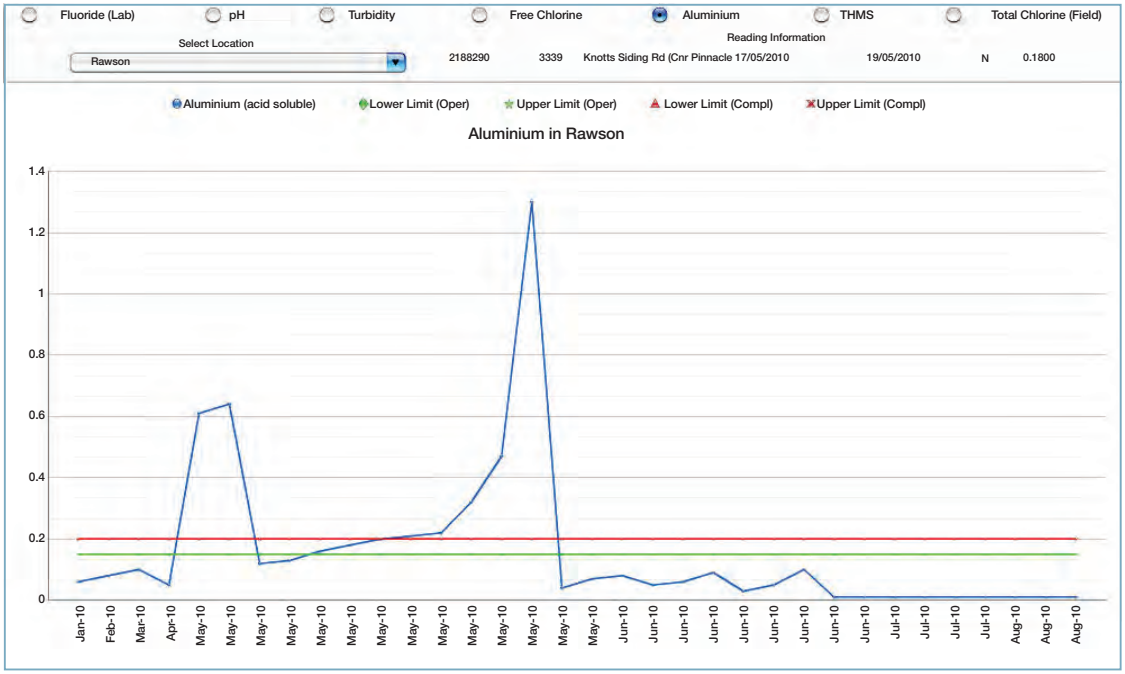


Figure 3. Aluminium residuals in the Rawson system.

The Author

Mark Walker (mark.walker@gippswater.com.au) is a Water Treatment Technician with Gippsland Water in Victoria.

UV DISINFECTION & VALIDATION

Graham Smith

Ultraviolet (UV) radiation is being used increasingly to provide an additional barrier to the passage of pathogens in both water and wastewater treatment plants. While chlorine has been the disinfectant of choice since the early 1900s, the recognition of the protozoan pathogens *Cryptosporidium* and *Giardia* as possible contaminants of both water and wastewater has rewritten the rule books. *Cryptosporidium* and *Giardia* are not controlled by chlorine at the doses that are typically able to be used in the water industry. They are, however, killed efficiently by UV; however, UV systems have to be carefully specified to ensure the final barrier is effective. Put simply, there needs to be enough UV energy to kill the "bugs". There is a confusing array of terms and advertising blurb, so this article is about trying to explain them and allow water utilities to be better informed when considering installation of UV systems.

What is UV Disinfection?

UV light is a component of sunlight. It falls in the region between visible light and X-rays in the electromagnetic spectrum between 100nm and 400nm in wavelength (see Figure 1). UV light in itself can be categorised into four separate regions:

- Far UV (or "vacuum") 100nm–200nm;
- UVC 200nm–280nm;
- UVB 280nm–315nm;
- UVA 315nm–400nm.

UVB and UVC are the most important for disinfection, as they have higher germicidal properties. These regions are, however, significantly filtered out by the Earth's atmosphere.

UV light "disinfects" by penetrating inside the cells of microorganisms and damaging their DNA molecules. In doing so, the microorganism is unable to reproduce, thereby rendering it inactive and no longer pathogenic. But what does inactivation reallly mean? Does it mean that every single pathogen that ever passes through the UV system will be inactivated? In reality, this is impossible. Indeed, this is impossible regardless of what disinfection method is used, whether it be UV, chlorine or anything else.

What is possible is that the pathogen of interest is reduced by a predictable amount. This amount is referred to as a "log reduction" (as in "Logarithmic" reduction). A 1-log reduction will see the pathogen of interest reduced by 90% from the influent level. A 2-log reduction will see a 99% reduction, and a 3-log reduction will see 99.9% removed. Scientists have calculated the amount of UV exposure required to inactivate a whole range of different pathogens by various log reductions.

For disinfection of water or wastewater, the UV light is generated by a UV lamp. These lamps contain a small amount of mercury. Because of the mercury, UV lamps should never be disposed of in general waste. They must be disposed of as a hazardous material or, even better, recycled so the mercury can be recovered. Most reputable UV lamp and system suppliers will take the "spent" lamps and dispose of them responsibly after servicing the UV system. It is worth asking the service engineer who services your system how they dispose of the lamps. If a satisfactory response is not gained, consideration might be given to who you engage to perform the service in future.

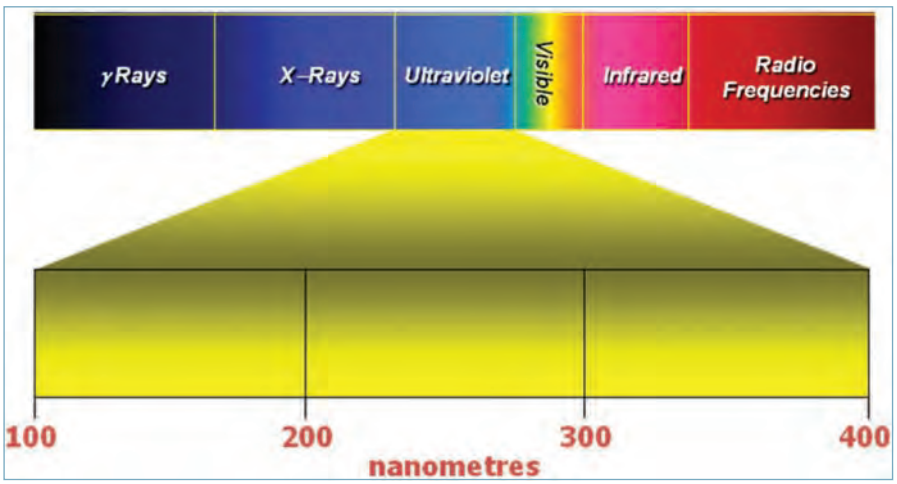


Figure 1. The electromagnetic spectrum.

When electricity is applied to the lamp, the mercury is "excited" and emits UV light. The exact wavelengths emitted depend on the vacuum pressure within the lamp tube itself.

- "Low Pressure" (LP) UV lamps are evacuated to relatively "low" pressures (between 1-10 Pa) and emit germicidal (i.e. UVC) light at a single UVC wavelength of approximately 254nm.
- "Medium Pressure" (MP) lamps are evacuated to what is termed "medium" pressure and emit a broader spectrum of UV light with higher intensities between around 254nm–265nm.

Low-pressure and so called "Amalgam" lamps are about twice as efficient at converting electrical energy into UVC light compared to medium-pressure lamps. However, medium-pressure lamps emit far more UVC energy per lamp than do low-pressure or amalgam lamps. Both low-pressure and medium-pressure lamps are germicidally effective. Table 1 provides a summary of some of the characteristics of the different lamps.

As with normal house lights some lamps are brighter than others. The energy produced by the lamps is measured in mJ/cm^2. This is the amount of UV energy measured in millijoules falling on one square centimetre of surface.

There are a variety of considerations to be taken into account when choosing which of these lamps should be used for a given application.

Selecting a UV System

There are three key parameters that need to be considered when selecting a UV system for disinfection of water or wastewater:

1. Water Quality

The nature and quality of the water to be disinfected is critical, not only in selecting an appropriate UV system, but

Table 1. Comparison of the characteristics of different UV lamps.

Trait	Medium Pressure (MP)	Low Pressure (LP) &/or Amalgam (Low Pressure High Output – LPHO)	Comments
Lamp	Evacuated to medium vacuum pressure	Evacuated to low vacuum pressure	Hence their names – this has nothing to do with the water pressure.
Wavelength range (NB: UVC light has the highest germicidal properties and occurs approximately between 200nm–300nm)	Approximately 200nm–300nm (majority of output is between approximately 240nm–280nm)	Monochromatic at 254nm	While all pathogens' DNA is denatured to some extent at 254nm, their DNA absorbs more broadly across much of the MP UV range. As such, pathogen DNA may be more broadly denatured by MP. This may explain why some studies have shown pathogens are less likely to repair their DNA damage (and therefore survive) after treatment by MP UV.
Input power	Typically 3000W–7000W	LP typically 50W–150W LPHO typically 150W–500W	So, many more LP/LPHO lamps are required to emit the same amount of UVC energy as MP lamps.
Efficiency (conversion of electrical energy to UVC energy)	Approximately 18%	Approximately 35%	So, approximately twice as much electrical energy required by MP lamps to emit the same UV energy as LP/LPHO lamps
Upshot of input power/efficiency	1 lamp	Equals approximately 10 LP lamps Equals approximately 3–4 LPHO lamps	
Lamp life	Typically 8000 hrs	Typically 12000–16000 hrs	
Working temperature of lamp	Many hundreds of degrees C	Less than 100°C	MP systems must constantly have water passing through them to keep the lamps cool. In some circumstances it may be possible for single-lamp LPHO systems (or multi-lamp LP systems) to cope with static water in the chamber for an extended period without over-heating.
Effect of water temperature on UVC output	None. Constant UV output independent of water temperature	LP – bell curve of UVC output (i.e. lower UVC output at lower and higher temperatures, centred around a peak at about 20°C LPHO – some susceptibility to water temperature, but not as dramatic as LP.	
Configuration	Chamber only	Channel or chamber	
Relative lamp price (approximate per lamp)	"100"	"50"	While the price of LP & LPHO lamps is about 50% of MP, the number of extra lamps and labour costs of changing them will usually make MP systems much less expensive to maintain in terms of parts and labour.
Relative running (power) costs – approximate	"100"	"50"	LP & LPHO consume about 50% of power compared to MP systems. This holds, regardless of the number of lamps per system.
Relative cost of ownership summary	– Higher capital costs – Higher cost per lamp – Higher power costs – Lower maintenance/ labour costs	– Lower capital costs – Lower cost per lamp – Lower power costs – Higher maintenance/ labour costs	As a general rule, the larger the system: – Less capital cost difference between LP/LPHO & MP systems. – Lamp and labour costs will increasingly be more expensive for LP/LPHO than MP. – Power costs will increasingly become more expensive for MP than LP/LPHO.

also in deciding if UV disinfection is even possible. Of all water quality parameters, Ultraviolet Transmissivity (UVT) is the most important. This is because the UVT of the water will determine how well the UV light will penetrate the water in order to activate the pathogens. The UVT is measured in a simple laboratory test that determines the amount of UV light at 254nm passing through the sample.

BOD, COD, turbidity, suspended solids (TSS) and dissolved solids (TDS) all affect how UV light can pass through water. Turbidity and TSS are the most limiting factors. TSS above 20mg/L can result in a phenomenon known as "shielding", whereby the pathogens are "shielded" from the UV light and not harmed. Any turbidity in the water also reduces the UVT.

2. Water Flow Rate

A key factor in determining how effective UVC light will be in deactivating a given pathogen is the time that the pathogen is exposed to the UV light (exposure time). The longer the exposure time, the more effective the UV will be at inactivating the pathogen. Therefore, it stands to reason that the slower the flow rate of the water through the UV system, the longer the UV exposure time and vice versa.

Both the instantaneous maximum and minimum flow rates are important because many UV systems have the ability to adjust the power output of the lamps in relation to changes in flow. Daily and hourly flow rates are not suitable as they can mask important "peaks and troughs" in the instantaneous flow rate, thereby resulting in spurious calculations of the true UV exposure time during these peaks and troughs.

3. Pathogen(s) to be inactivated

Different pathogens require different amounts of UV energy to inactivate them. Therefore for any UV system, it must be clear which pathogens are to be inactivated. Table 2, taken from the USEPA *UV Disinfection Guidance Manual* (*UVDGM*), shows the UV dose required to achieve different log removals of pathogens.

For example to achieve 99% removal (log 2) removal of *Cryptosporidium* requires 5.8 mJ/cm^2. To achieve 4-log removal (99.99% removal) requires 22 mJ/cm^2. It is important to note that the relationship between the dose and the log removal, the so called dose response, is not linear. It takes a very much higher dose to achieve log-4 removal compared to log-2 removal.

UV Intensity and UV Dose

UV dose is measured in millijoules seconds per cm^2 (mJ/cm^2) and is calculated using the following parameters:

- UV Intensity (I), measured in milliwatts per cm^2 (mW/cm^2);
- UV Transmittance (UVT) (%);
- Exposure time (t) (seconds).

The relationship between these parameters can be described by the following simplified equation:

UV dose = (I/UVT) x t

The important thing to understand from this relationship is that UV Intensity and UV dose are two different things. UV Intensity measures the "amount" of UV energy actually penetrating through the water being treated. UV dose is the amount of UV energy penetrating the water, multiplied by the amount of time the water is exposed to this energy. It is the UV dose that determines the log reduction of a pathogen.

UV dose is usually quoted as either the "average" dose or Reduction Equivalent Dose (RED). The average dose implies that some of the water being treated will receive the prescribed dose, some will receive more than the prescribed dose, but, importantly, some water will receive less than the prescribed dose. If some water receives less than the prescribed dose, then the prescribed log reduction may not be achieved. This concern has led to the adoption of the RED concept. In essence, RED suggests that all the water passing through the UV system will receive at least the prescribed dose, thereby ensuring the prescribed log reduction targets are achieved. RED is the concept on which UV systems are validated.

Table 2. UV dose requirements in mJ/cm^2 to achieve stated log reductions for some typical water-borne pathogens.

Target Pathogens	Log Inactivation							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

Table 3. Comparison of key aspects of the USEPA *UVDGM* & German DVGW validation protocols.

	USEPA *UVDGM*	DVGW
Who is permitted to carry out the UV system validation?	Anyone who can prove that the validation protocol outlined in the *UVDGM* has been followed.	Only a DVGW certified facility.
What is the result of the validation procedure?	A detailed report proving the *UVDGM* protocol has been followed.	Certification of the validated UV system.
What UV dose is required to achieve validation?	As much as is required to inactivate a given pathogen by a specified log reduction. (See Table 1.)	40mj/cm^2 RED. This is based on the principal that almost all common water-borne pathogens will experience at least a 4-log reduction at this dose. DVGW don't care about the pathogen or the log reduction, they believe a UV dose of 40 mj/cm^2 is enough to inactivate most "bugs" by 4 log, and so they only require the UV system to deliver this dose.

How are UV Systems Validated?

Clearly it is important to be sure that a particular UV disinfection system actually achieves the log removal it is supposed to. Validating the performance of each and every UV system *in situ* is impractical, therefore another system is necessary. Over the years, there have been many systems developed. The one that has come to be accepted by the international community as the most appropriate is that which verifies system performance by "first principles" – the so called "biodosimetric" approach. This validation system uses actual pathogens to test the log reduction achieved by a given UV system in the following steps.

1. The pathogen of interest is cultured under controlled and reproducible laboratory conditions.
2. The pathogens are exposed to UV light under controlled laboratory conditions.
3. The culture is then exposed to a known UV intensity, of known wavelength, for a fixed period of time, thereby delivering a known UV dose to a known area of the presentation plate – hence dose and intensity are measured per cm^2 (area) rather than cm^3 (volume). The apparatus used to perform this test is called a Collimated Beam apparatus.
4. The exposed area of the plate is re-cultured to quantify the survival of the pathogen.
5. This procedure is replicated many times at systematically increasing doses in order to build a Dose Response Curve. This curve enables the log survival (and by inference, log reduction) for the pathogen of interest to be determined for any given UV dose. This entire procedure is then replicated at every UVT level across the required UVT range.
6. After the various Dose Response Curves have been constructed in the laboratory, these then need to be applied to test an actual UV disinfection system in order that it might be validated. The pathogens used to test the UV system are cultured (albeit in much higher volumes) under exactly the same conditions as used in the laboratory.
7. A sample of the water is taken at the inlet to and exit from the UV system and re-cultured to determine how many pathogens have survived.
8. The observed log survival of the pathogen is then compared to the pathogen's Dose Response Curve (see Step 5) and the actual UV dose delivered read off from the curve. This dose is termed the Reduction Equivalent Dose – RED.

A large "in-channel" UV system.

Who Determines the Rules for UV System Validation?

It all sounds relatively simple and sensible to this point, however, there are a number of different validation systems. The internationally recognised validation protocols for drinking water are:

- O-Norm (Austrian)
- DVGW (German)
- USEPA (USA – as per the *UV Disinfection Guidance Manual – UVDGM*)

(Interestingly, there is as yet no internationally recognised validation protocol for wastewater.)

Of these protocols, the USEPA and DVGW are the clear leaders. In general, Australian state health authorities will accept UV systems validated against an internationally accepted validation protocol, which includes either of these two protocols. Table 3 compares these two validation protocols. It is important to recognise that this table is not intended to be exhaustive, but rather it is intended to compare some of the most fundamental aspects of the two protocols.

Currently, the only internationally recognised water reuse validation protocol is:

USEPA – National Water Reuse Institute (NWRI)

This validation protocol is administered in a similar way to the UVDGM protocol for drinking water. The main difference is that the dose required to meet the validation standard is affected by the nature of the pre-treatment of the water upstream of the UV system. This introduces the concept of "log credits". This concept is best illustrated by way of the following example.

Two smaller "in-pipe" UV systems.

Let's assume that a pathogen requires a 7-log reduction on its passage through a water reuse disinfection system. The filter system in use upstream of the UV system has been validated to provide a 3-log reduction in the pathogen (i.e. it provides a "3-log credit"), therefore the UV system is required to provide only a 4-log reduction to achieve the 7-log target. The filter system would have been validated in some way similar to the biodosimetric method described above described for the UV system.

Various filter media perform better than others when it comes to providing log credits. In general media filters are less efficient than membrane filters, which are in turn less efficient than, say Reverse Osmosis (RO).

So, in summary, to have a UV system work for you, you need to know the following:

1. The minimum UVT of the water.
2. The peak, instantaneous maximum flow rate of the water passing through the UV system.
3. The log reduction requirement with respect to the pathogen(s) of interest.

The consequence of overestimating the minimum UVT or underestimating the instantaneous maximum flow, while making the system cheaper, will be failed UV disinfection that is not the fault of the system. Therefore, don't rush the specifications. Take the time to collect quality data and achieve a system that delivers that extra barrier to pathogens and reduced risk to public health.

References

USEPA (2006): Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule. *Office of Water (4601), EPA 815-R-06-007, November 2006.*

Lawal, O. (2009): Different Approach, Same Goal: A Comparison between European and US Drinking Water Regulations. *Oliver Lawal, Director of Technology, Berson UV-techniek,* April 2009.

www.halmapr.com/news/berson/2009/04/14/berson-uv-comparison-dvgw-usdgm-drinking-water-regulations/

The Author

Graham Smith (graham@fluidquip.com.au) is the National Sales Manager with Fluidquip Australia Pty Ltd.

FILTER MEDIA PROBLEMS AT PIMPAMA

Mark Wilson, Dion Sleep, Charlie Suggate, Lee Davies and Joel Warnes

Pimpama Recycled Water Treatment Plant on the Gold Coast receives wastewater and produces Class A+ recycled water that is reticulated to customers in the area for toilet flushing and external, non-drinking uses. An overview of the treatment process is presented in Figure 1.

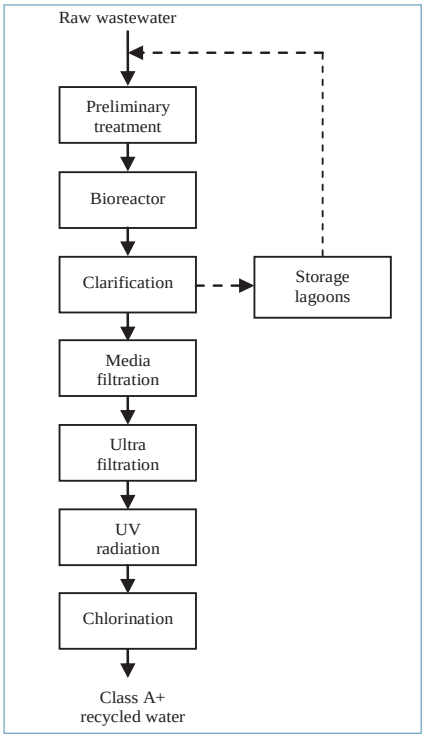


Figure 1. The treatment process at Pimpama recycled water treatment plant.

Aside from the ongoing need to optimise operation in order to maximise product quality and minimise costs, some difficulties were encountered that heightened the need for intensive investigations. The most serious challenge was a reduction in dry weather ultra-violet transmissivity (UVT) at the UV reactors that had been linked to the release of natural organic matter from the media filters. When the UVT was below the critical limit of 70%, Class A+ recycled water could not be produced because it did not comply with the conditions of the recycled water management plan.

Other issues that were potentially linked to the media filters were an increase in filtered water manganese and difficulty maintaining chlorine residuals in the Class A+ recycled water network.

The four 28m^2 filter beds contain an anthracite mono media of bed depth 1400mm and effective grain size 1.7mm. Aluminium sulphate, sodium hypochlorite and sodium hydroxide can be dosed into a flocculation chamber prior to media filtration. There is sufficient tank volume between the flocculation chamber and filter bed for a minimum 30 mins contact time.

The cleaning sequence consisted of an air scour at nominally 50m/h for 5 mins, followed by a backwash at nominally 46.8 m/h for 6 mins. This backwash velocity was specified in the design report and set during commissioning. The air scour rate was not adjustable without mechanical modifications to the blowers, but the duration could be extended up to 7 mins

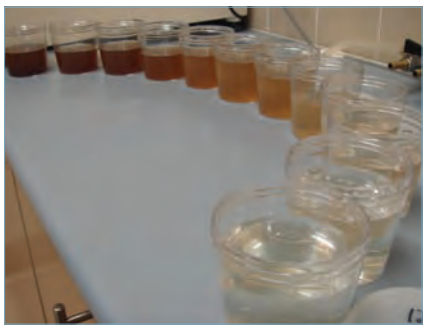


Figure 2. Backwash water samples.

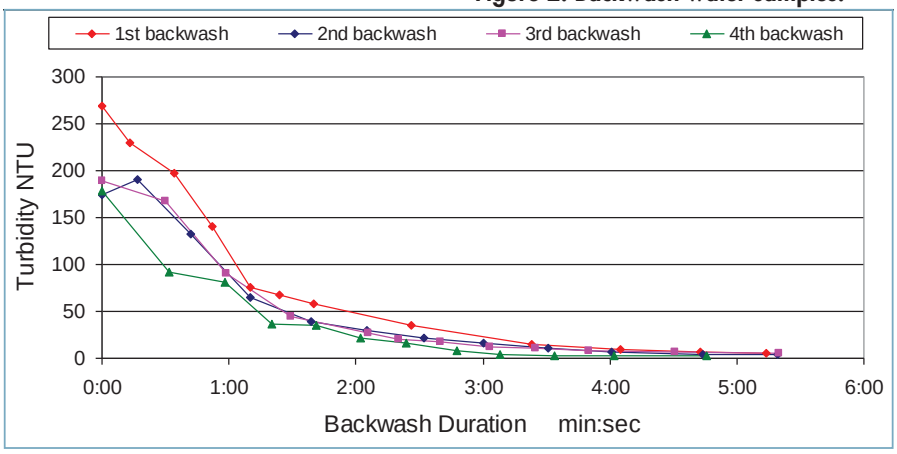


Figure 3. Backwash turbidity profiles at backwash velocity of 46.8m/h (December 2010).

Aerial view of the Pimpana Recycled Water Treatment Plant.

without control system modifications. The backwash velocity could be increased to 50m/h, at which point it was restricted by surge protection pipework, although the pumps were capable of delivering a higher velocity.

Filter Backwashing

Backwashing of the filters was observed to determine whether the air scour and backwash were being uniformly distributed across the bed. While not perfect, no serious issues were identified. The "dirtiness" or "cleanliness" of a media filter is not an easily quantifiable parameter. Three separate methods were used to assess the cleanliness of the filter beds and the effectiveness of the cleaning sequence:

- Backwash turbidity profiling;
- Sludge retention analysis;
- Media filter coring and turbidity analysis.

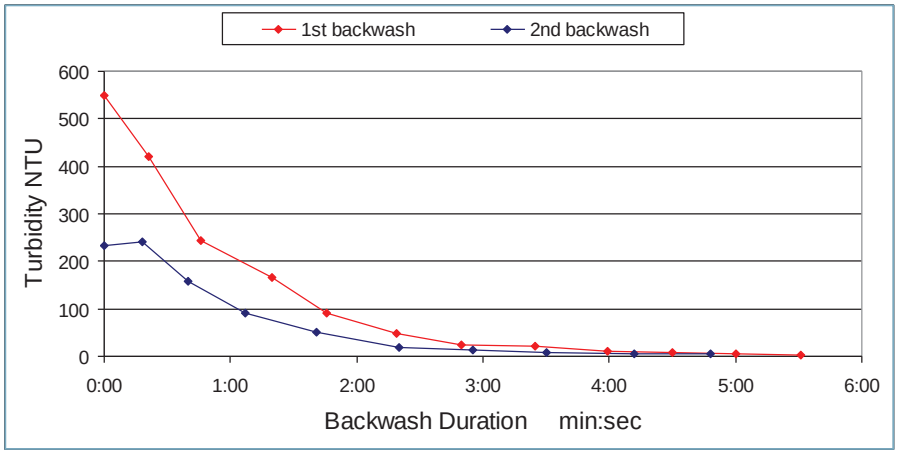


Figure 4. Backwash turbidity profiles at backwash velocity of 50m/h (December 2010).

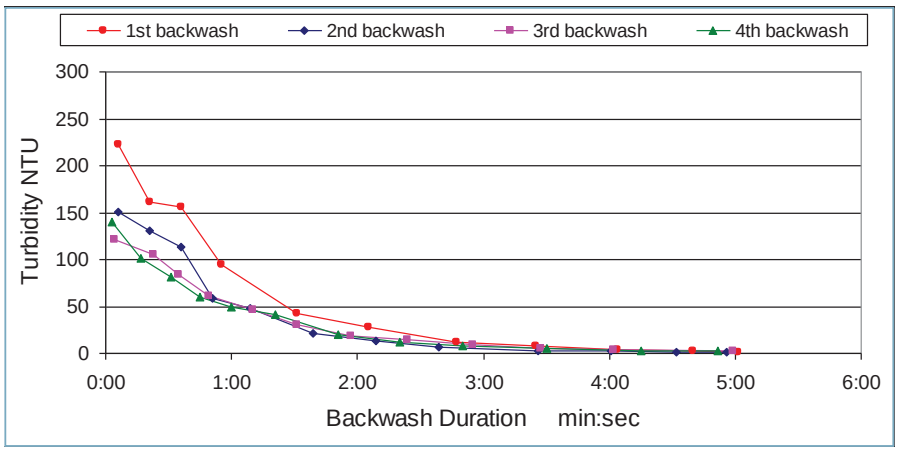


Figure 5. Backwash turbidity profiles at backwash velocity of 50m/h (June 2010).

Backwash Turbidity Profiling

Turbidity profiling of the backwash water (see Figure 2) was undertaken on consecutive cleans without the filter returning to filtration mode between cleans.

The filter was air-scoured before each backwash. The results for a backwash velocity of 46.8m/h are presented in Figure 3, and suggest that subsequent backwashes continue to remove similar quantities of solid material from the filter bed as previous backwashes.

The backwash velocity was increased to the maximum available of 50m/h. Backwash turbidity profile results at this increased velocity are presented in Figure 4. It is clear that this increased velocity removed substantially more solid material during the initial clean.

Six months later, backwash turbidity profiles were repeated, as shown in Figure 5. The quantity of material removed during backwash had reduced to the initial levels recorded at a backwash velocity of 46.8m/h. These backwash turbidity profiles are worse/lower than those presented in Kawamura (2000) as pertaining to

Table 1. Sludge retention testing results.

Filter #	Pre/Post Backwash	Sample Location	Elapsed Time min	Sludge mL	Media mL	Sludge/Media %
3	Pre Backwash	Central, surface strata	20	45	605	7.4%
		Central, middle strata	20	8	504	1.6%
		Wall, surface strata	20	39	565	6.9%
		Wall, middle strata	20	10	760	1.3%
2	Pre Backwash	Central, surface strata	20	30	600	5.0%
		Central, middle strata	20	8	640	1.3%
		Wall, surface strata	20	25	590	4.2%
		Wall, middle strata	20	15	635	2.4%
3	Post Backwash	Central, surface strata	20	0	610	0.0%
		Central, middle strata	20	0	575	0.0%
		Wall, surface strata	20	0	500	0.0%
		Wall, middle strata	20	0	570	0.0%
2	Post Backwash	Central, surface strata	20	0	620	0.0%
		Central, middle strata	20	0	590	0.0%
		Wall, surface strata	20	0	530	0.0%
		Wall, middle strata	20	0	740	0.0%

a dirty filter; however, the filter type and possibly feed water type are different from those documented, so this comparison may not be applicable.

It was postulated that increasing the backwash velocity had removed additional particulate matter from the filter and reduced the level of particulate build-up to a lower level at which the same quantity of particulate matter could no longer be removed.

Sludge Retention Testing

The sludge retention testing, as described by Mosse and Murray (2009), involved placing samples of media and water in measuring cylinders, vigorously mixing them, and recording the depth of sludge settled on top of the media as a proportion of the media depth (Figure 6).

The testing revealed that low levels of sludge were building up on the filter bed and that it was being entirely removed during cleaning (see Table 1). The guideline value for percentage sludge on clean media is 5% (Mosse & Murray, 2009).

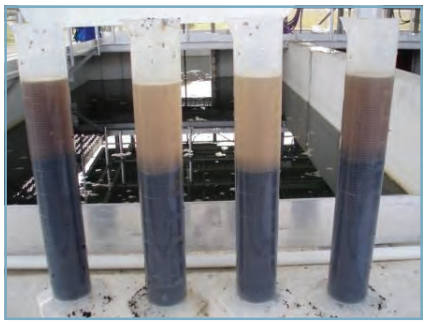


Figure 6. Sludge retention testing cylinders, pre-clean.

Media Filter Coring

The media filters were cored with a sample tube that allowed eleven samples to be collected from a range of depths through the filter bed (Figure 7).

Samples were analysed by adding media and water in a set proportion, shaking for a set time, and measuring the turbidity of the decanted solution.

Turbidity analysis of filter cores, presented in Figure 8, shows that the level of solids retained on the media is generally between 2000 and 6000 NTU/100mL, but was as low as 1000 NTU/100mL in June 2010, and is currently as high as 20,000 NTU/100mL (upper detection limit) in the lower strata of the filter following a clean.

Figure 7. Collecting samples from the filter.

According to guideline values published in Kawamura (2000), the Pimpama filters are classified as extremely dirty. They would need to be at least an order of magnitude cleaner to approach an acceptable level of cleanliness; however, these guideline values may not necessarily apply to the type of filter media and feed water at Pimpama.

To allow comparison of data taken at different times, at different backwash rates and under different operating conditions, the average of the pre-backwash turbidity readings and the average of the post-backwash turbidity readings for the 11 individual samples were calculated. The post-backwash value was then subtracted from the pre-backwash value. This means that where the backwash has been particularly ineffective the value may be negative. Figure 9 shows the results for all the conditions tested. The individual data was also plotted and allowed determination of the impact of backwashing at different depths in the media bed (see, for example, Figure 10).

There are clearly marked differences in the effect of backwashing on the cleanliness of the media. Increasing the backwash rate from 46.8m/hr to 50m/hr clearly resulted in improved backwashing. It is also interesting to note that during winter (17/06/2010) there was a marked improvement.

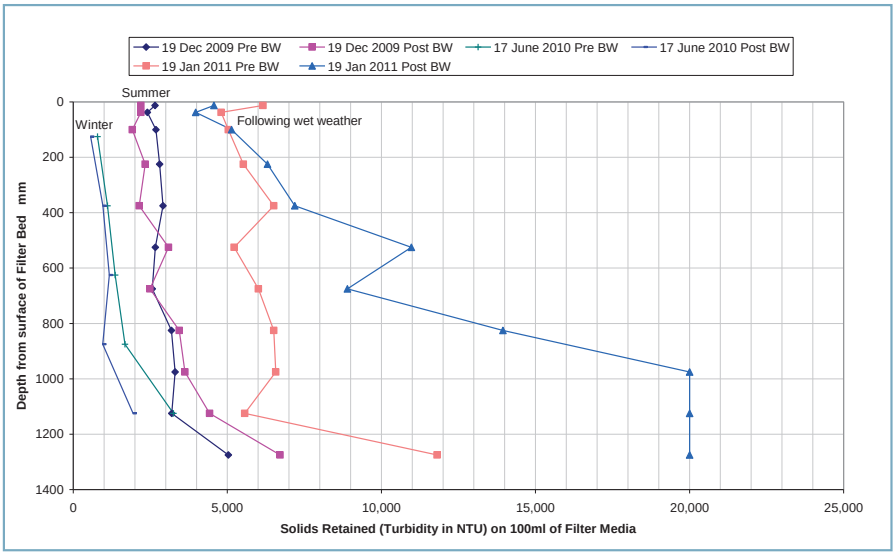


Figure 8. Filter core turbidity results. (Note: Several data series excluded for clarity.)

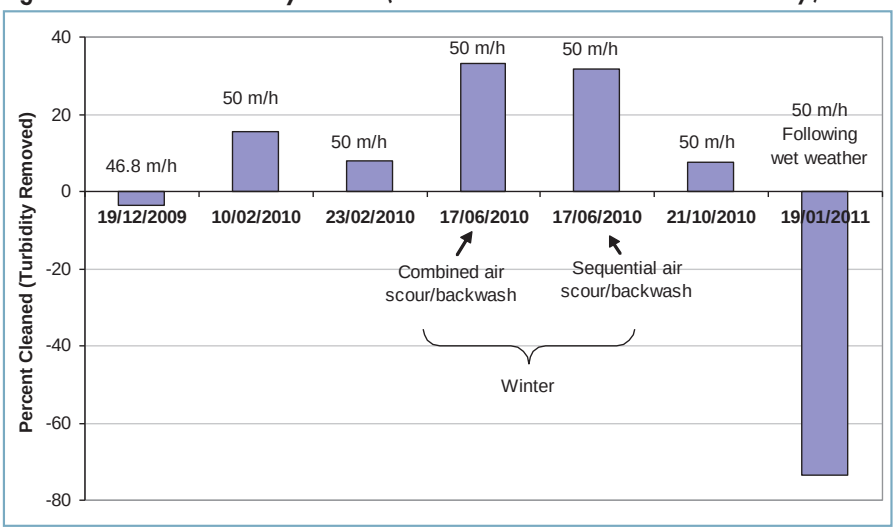


Figure 9. Percentage clean measured at different backwash velocities and seasons.

Comparison of Combined and Sequential Air Scour/Backwash

During June 2010, a trial was conducted to assess the impact of overlapping the air scour and backwash flow (combined) versus the sequential air scour then backwash.

After cleaning each trial filter exclusively with the assigned cleaning sequence for a fortnight, the filters were cored for comparison. The level of solids retained on each filter, both before and after backwash, was similar (Figure 9).

The Impact of Wet Weather Flows

There were extensive wet weather flows during December 2010 and January 2011. Following numerous cleans and the resumption of dry weather flows, a filter was cored that revealed an extreme level of dirtiness and an alarmingly negative percentage clean.

The lower strata of the filter were clearly extremely dirty, with the turbidity from the samples beyond the detection limit of 20,000 NTU/100mL following cleaning (Figure 10).

Filter Bed Expansion and Fluidisation

The guideline range for anthracite media bed expansion during backwash is 25–30% (Kawamura, 2000, and Mosse & Murray, 2009). The expansion measured in June 2010 was much less than the guideline values at 8.2% with the maximum backwash velocity (see Table 2). Filter bed expansion measurements taken in January 2011 reveal a lesser degree of expansion than that measured seven months earlier. Temperature is known to affect bed expansion due to its impact on the viscosity and density of the water (Kawamura, 2000).

At lower temperatures, the backwash water is denser and more viscous, providing greater uplift to the filter media. The bioreactor temperature, which is indicative of the media filter feed water temperature, is included in Table 2, and confirms that the predicted relationship between temperature and bed expansion holds.

An object placed on the surface of the filter bed will sink to the bottom during backwash, indicating that the entire depth of the filter bed is fluidised during backwash.

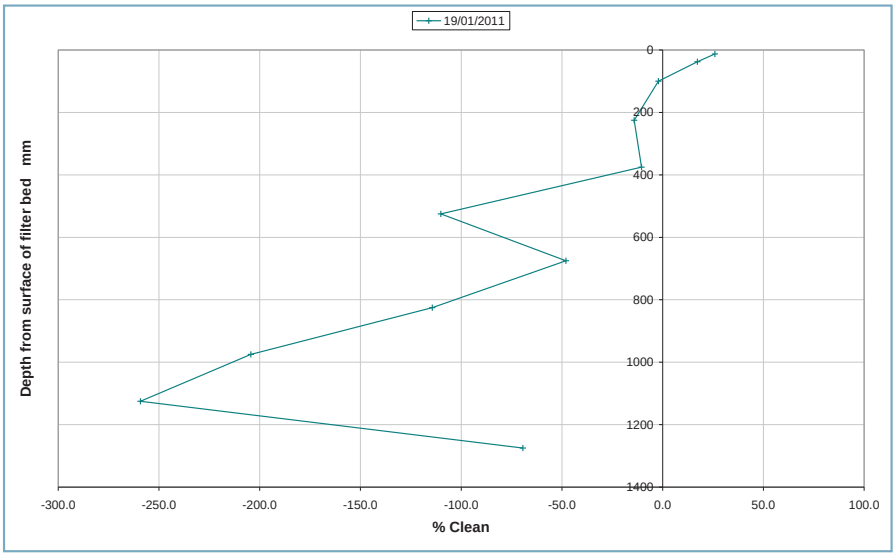


Figure 10. Percentage clean of media filter bed (19 January, 2011) subsequent to extensive wet weather flows. Backwash velocity 50m/h. (Negative values occur where the turbidity of the samples after backwash were higher than those before backwash.)

Table 2. Filter bed expansion and fluidisation.

DATE	BACKWASH VELOCITY m/h	BIOREACTOR	EXPANSION m	EXPANSION %	FLUIDISED Y/N
18/06/2010	46.8	23.0	0.060	4.3	Y
18/06/2010	50.0	23.0	0.115	8.2	Y
21/01/2011	47.7	27.5	0.070	5.0	Y
21/01/2011	50.0	27.5	0.095	6.8	Y

Data supplied by the filter media supplier indicates that the backwash velocity required to achieve 25–30% bed expansion would be 60–70m/h, significantly more than the 50m/h currently applied.

Conclusions

- The cleaning protocol in place at the plant is not sufficient to maintain the filters in an acceptably clean state.
- Cleaning effectiveness improves somewhat during winter.
- The cleaning cycle does not have the capacity to recover the filters from turbid wet weather flows.
- Trialling the overlapping/combining of the air scour and backwash did not demonstrate a significant improvement in the level of filter cleanliness.
- The backwash velocity should be increased to achieve greater bed expansion. Careful consideration will need to be given to media loss when making this modification. At the time of publication, works are in place to modify the backwash pipe work to allow an increase in the backwash rate.

References

Amirtharajah, A *et al.*, 1991: Optimum Backwash of Dual Media Filters and GAC Filter – Adsorbers with Air Scour. American Waterworks Association Research Foundation, Denver, Colorado.

Kawamura, S. 2000: Integrated Design and Operation of Water Treatment Facilities. John Wiley & Sons, New York.

Mosse, P & Murray, B. 2009: Practical Guide to the Operation and Optimisation of Media Filters. Water Industry Operators Association, Shepparton, Victoria.

The Authors

Mark Wilson, **Dion Sleep**, **Charlie Suggate**, **Lee Davies** and **Joel Warnes** all work for Allconnex Water, which operates the Pimpama Treatment Plant. Mark Wilson can be contacted at mark.wilson@allconnex.com.au or 0439 226 146. Dion Sleep can be contacted at dion.sleep@allconnex.com.au or (07) 5581 1861.

ONLINE MONITORING OF COD AT ECHUCA WWTP

Kay White

One of the features of the upgrade of the Echuca WWTP in 2003 was the requirement for the direct online measurement of Chemical Oxygen Demand (COD) in the plant influent to allow the real-time monitoring of influent COD. Such monitoring could provide early warning of an increased COD load, thereby enabling the optimisation of plant operation for that particular load. Moreover, the online COD measurements could assist in identification of sources of COD peaks for charging purposes.

The plant receives a mixture of domestic and industrial effluents. A peak industrial load occurs during the tomato harvest season (approximately mid-January to March), when Cedenco Pty Ltd discharges volumes up to 5ML/d of high-strength waste to the sewer. The waste is transferred to a wet well and pumped to the plant.

An s::can spectrolyser was installed and trialled. Satisfactory performance was defined as achieving a good correlation (R^2 = 0.75) between the instrument value and values obtained from a NATA registered laboratory. The spectrolyser is an online spectrophotometer capable of measuring absorbance in both the visible and UV light ranges. The instrument is equipped with a microprocessor that calculates the concentration of various parameters (including COD) from the absorbance measurements.

The spectrolyser was installed in the inlet works to the existing lagoon treatment plant (see Figure 1). The nature of the flow at the installation site was complex. A lagoon recycle flow was also received into the channel where the spectrolyser was located. The water coming from the lagoons had a very high algal content and was quite green in colour. During pumped flow periods the influent passed through the channel, mixed with the recirculation water and, thence, passed to the lagoons. During periods of no pumping, the recirculation flow moved backwards up the channel and apparently for some distance back down the rising main. Due to this intermittent flow, the collection of both the influent and the algal-laden lagoon recirculation water samples was unpredictable.

The spectrolyser was set up to measure COD at 15-minute intervals. The spectrolyser was able to differentiate

Figure 1. Online s::can spectrolyser (see arrow) installed in the inlet works at Echuca WWTP.

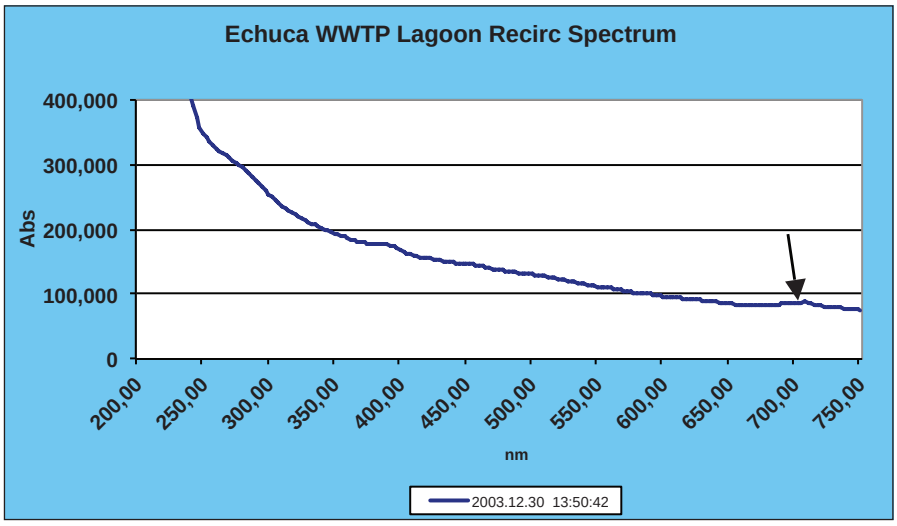


Figure 2. UV-Vis absorbance spectra of the lagoon recirculation water. The absorbance peak for chlorophyll is arrowed.

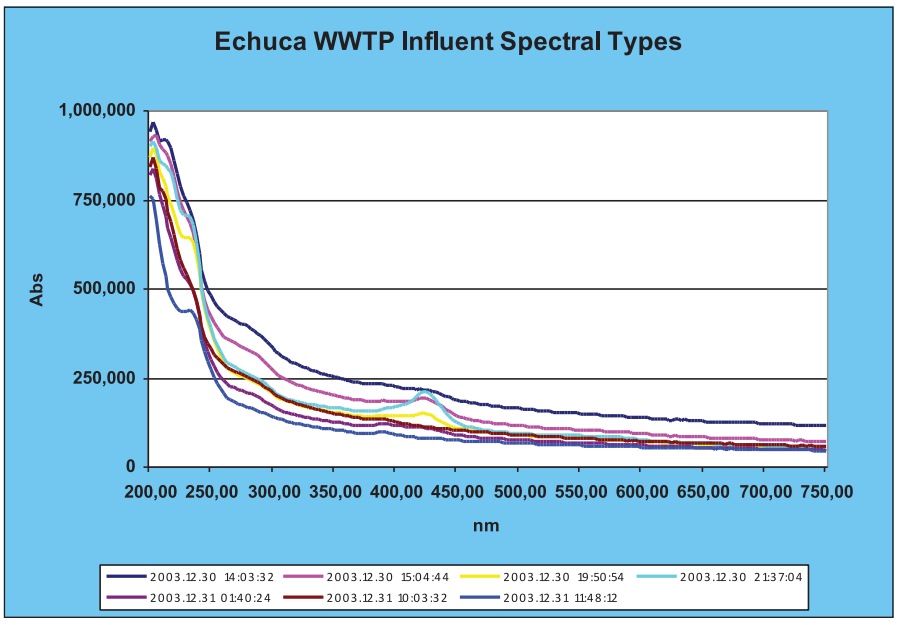


Figure 3. UV-Vis absorbance spectra of the plant's influent at different times. The commas in the numbers represent the European decimal point.

between the chlorophyll-laden samples because of their green colour, and the industrial waste stream (see Figure 2). Any later samples containing chlorophyll were rejected for further analysis.

Trials were conducted during the period prior to commencement of tomato processing at the Cedenco factory, during the ramp-up, in production and after reaching full operation at the factory. The aim was to obtain samples covering the whole spectrum of qualities resulting from the industrial flows.

Grab samples were collected by dipping a sample bucket next to the spectrolyser. At the same time, the instrument was activated to record COD result, which was saved to a calibration file within the instrument memory. Grab samples were submitted to a NATA accredited laboratory for analysis. These results were used to fine-tune (to locally calibrate) the instrument for the waste that it would be measuring.

Figure 3 shows spectral characteristics for a range of influent types observed at different times during the collection trial period. A comparison of these absorbance spectra revealed that the quality of influent being received to the treatment plant varies over time.

Monitoring Results

Monitoring data for the period prior to the start-up of Cedenco for the season are shown in Figure 4. The trend shows a slight diurnal variation in the COD concentrations in the influent, which probably indicates the mixed domestic nature of the catchment.

A comparison of the COD results obtained from the NATA-registered laboratory and the instrument during this period are shown in Figure 5. The correlation coefficient (R^2) for the two sets of data is 0.81, indicating the lab results and the spectrolyser results agree closely.

Because COD is a general rather than a specific laboratory test, there can be significant variations in results obtained by even registered labs. For this reason unidentified duplicate samples were submitted to the contract laboratory to allow a reasonable assessment of the accuracy of the spectrolyser to be made.

The results of this duplicate testing are shown in Figure 6. The correlation between the duplicate values gave $R^2 = 0.78$.

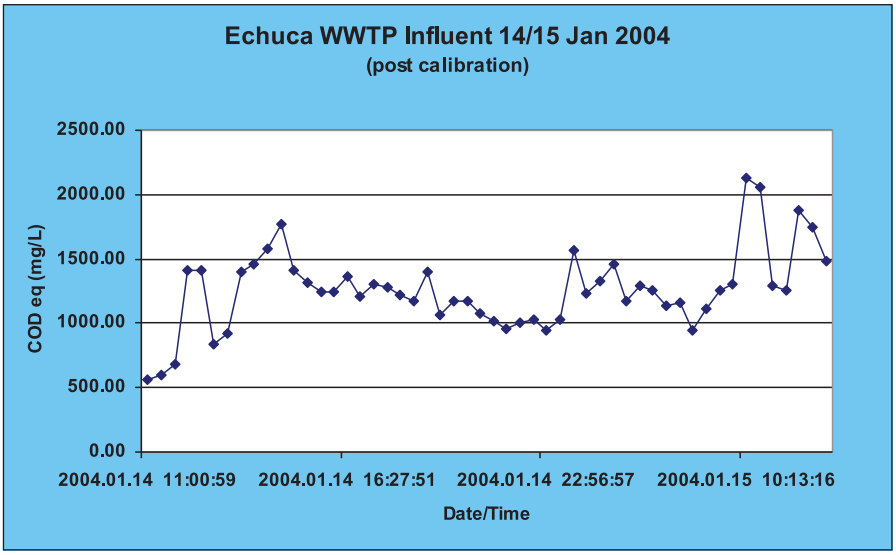


Figure 4. COD profile over a 22-hr period as determined by the spectrolyser after calibration of the instrument.

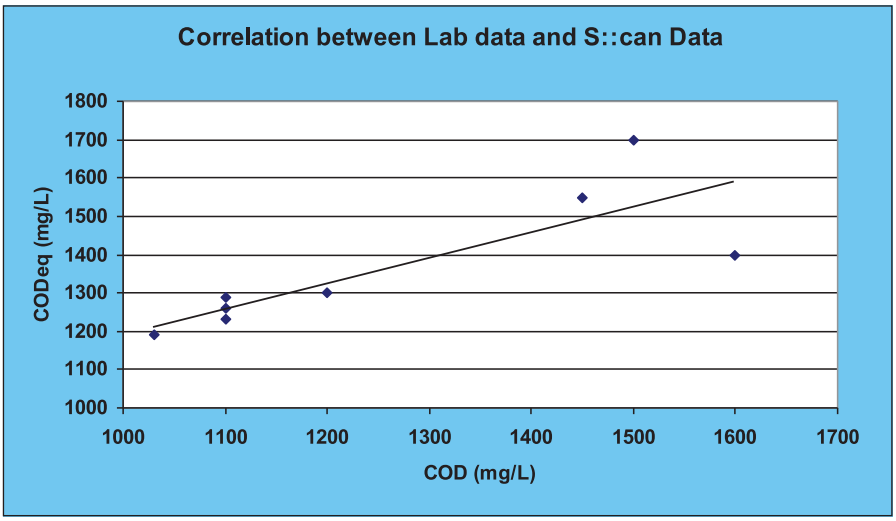


Figure 5. Correlation between NATA-registered laboratory data and spectrolyser data for samples during the low load period.

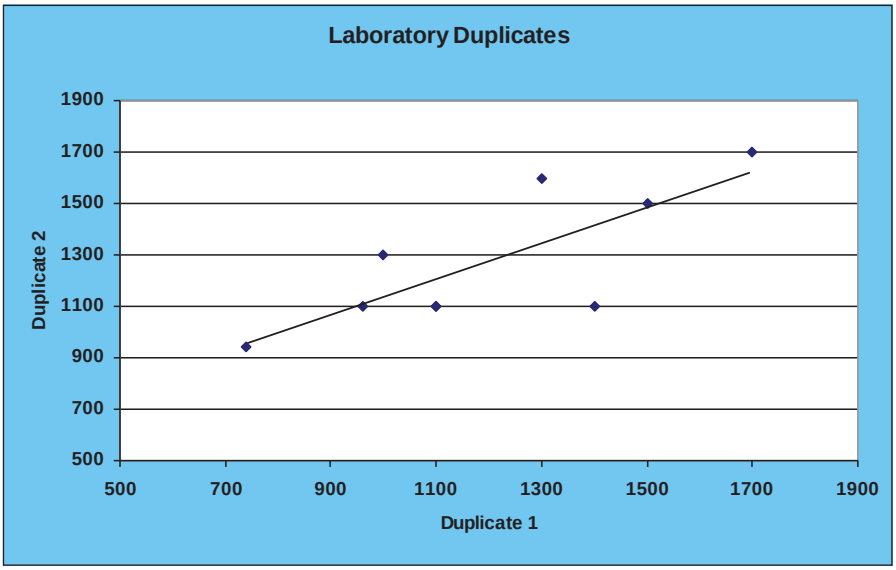


Figure 6. Correlation between NATA-registered laboratory duplicates during the trial. The duplicates have a correlation coefficient of 0.78.

Tomato Processing Time

Another sampling period was started once the tomato plant started operation to make sure the instrument worked as well during high-load periods. Again, measurements and samples were taken in parallel.

The analytical results received from the laboratory were surprising, as they suggested COD values were of between 19,000mg/L and 25,000mg/L. These were well and truly outside expected values based on years of monitoring by Coliban Water. Therefore, the laboratory was requested to check the data. Even more surprisingly, they provided a new set of results for the same samples ranging from 1600mg/L to 2100mg/L, without any explanation.

These results were used in the comparison with the instrument values. The comparison is shown in Figure 7.

As can be seen, the laboratory results were notably lower than the instrument values during the period of the trials.

Due to the lack of explanation about the discrepancies between the two sets of data from the NATA-registered laboratory (whether retesting of samples or recalculation based on some correction factor), there was a lack of confidence in the reliability of the data. Therefore, the COD results from the NATA-registered laboratory during this high-load period were considered inappropriate to use for modifying the calibration or to assess performance of the spectrolyser and were disregarded, and the existing calibration of the spectrolyser maintained.

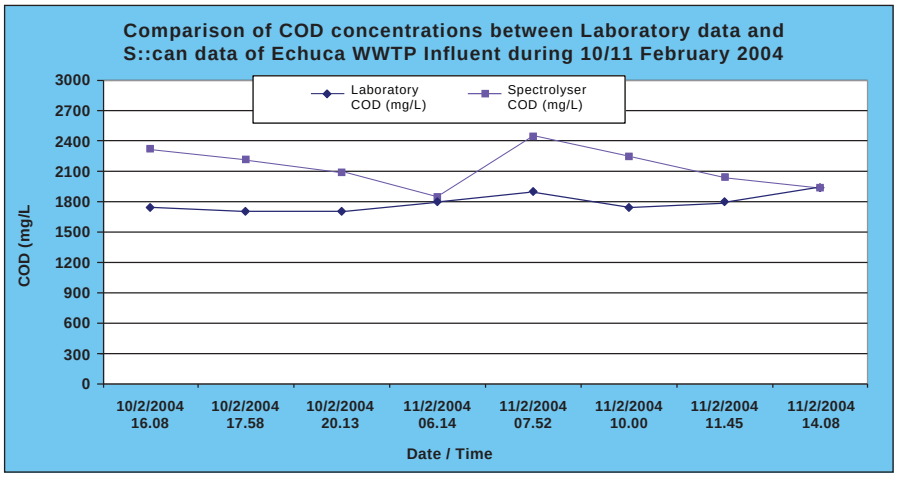


Figure 7. Comparison of COD profile over a 22-hr period as determined by the s::can spectrolyser and NATA-registered laboratory. Discharge from Cedenco was occurring at this stage.

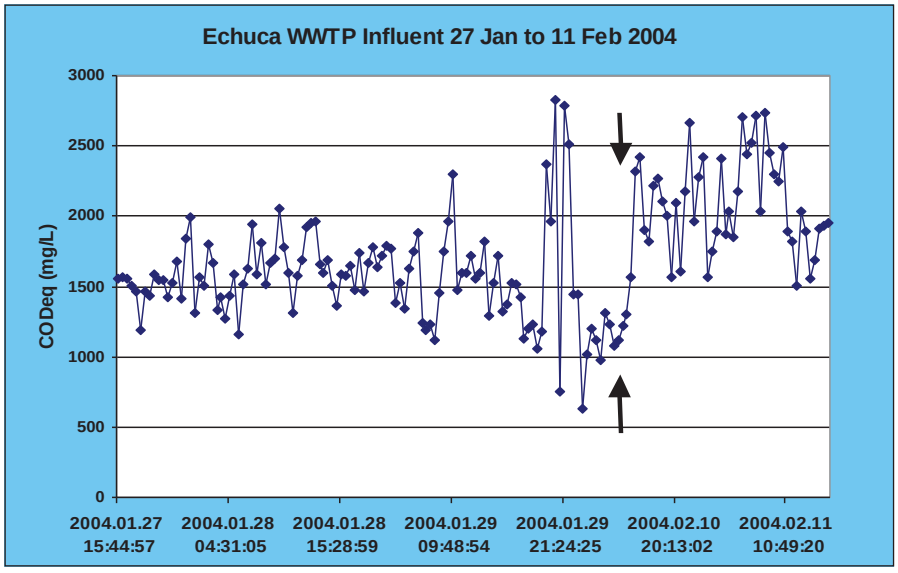


Figure 8. Composite COD trend for January and February 2004. The bold arrows indicate the commencement of peak operations at the Cedenco plant.

COD concentrations recorded by the spectrolyser during the high-load period when the Cedenco factory was processing tomatoes are shown in Figure 8. There is a clear step in COD concentrations coinciding with February 10 and 11. The figure shows lower COD levels prior to the commencement of operation of the factory, a slight increase in COD levels in late January when only a small quantity of tomatoes was being processed, and a definite jump in COD values coinciding with increased processing by the company.

Conclusions

This trial demonstrated the reliable performance of the spectrolyser. The correlation between laboratory and spectrolyser analysis prior to the commencement of discharge was high (R^2=0.81). The correlation between laboratory and spectrolyser analysis during full operation at the Cedenco factory was inconclusive due to questionable results from the consultant laboratory. The inconclusive correlation during tomato processing did not detract from the performance assessment of the instrument, but it did highlight the need for possible recalibration during final commissioning of the instrument at the new WWTP.

The instrument measures *in situ*, directly in the flow. Therefore no sampling, no sample preparation and no reagents are required. Furthermore, the advantages of low-maintenance and an environmentally friendly technique make this option a reliable alternative to the (standard) laboratory COD method. However, the s::can spectrolyser should be periodically calibrated, particularly when there are operational variations. It is recommended that laboratory COD analysis should be occasionally conducted to verify spectrolyser readings and that duplicates be issued (sometimes to alternate laboratories) as a check on the reliability of the lab results.

Acknowledgements

Thanks to Dr Peter Mosse, Graeme Bartle-Smith and Farhana Malek for their assistance in preparing this paper.

The Author

Kay White (kayleen.white@smec.com) is a Senior Process Engineer with the Water Group Process Design Team of SMEC Australia.

Want longer maintenance intervals for your analyser?

HYDROGUARD™ Water Quality Analyser

HydroGuard Water Quality Analysers have an intuitive, graphical user interface for easy set-up. HydroGuard Analysers perform a automatic zero on every analysis and are self-cleaning, providing excellent long-term stability. Minimal maintenance procedures, such as periodic reagent replacement, are easy to perform and do not require specialised skills.

The HydroGuard HG-702 offers models for Free Chlorine or Total Chlorine, as well as Free and Total Chlorine in a single instrument. Additional multi-parameter capabilities include pH, ORP, Conductivity, temperature and Turbidity – a flow sensor switch is standard.

With a selectable 2-to-10 minute measuring interval, patented colorimeter cell and proven stable DPD methodology, the HydroGuard provides low-cost, long term hassle-free Chlorine measurement.

HYDROGUARD™ HG-702

1300-735-295

www.thermofisher.com.au

InfoWaterAU@thermofisher.com

ThermoFisher SCIENTIFIC