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ALUMINIUM, YOUR TIME HAS COME!

Peter Mosse and Peter Gebbie

Over the past few years at WIOA Conferences and Workshops, we have raised the issue of the often confusing way that the concentration of aluminium-based coagulants such as alum (aluminium sulphate) or aluminium chlorohydrate (ACH) is quoted.

For example the concentration of alum can be expressed as mg/L alum, mg/L dry alum, ppm V, mg/L Al_2O_3. This makes it very difficult for operators when they are discussing doses to be sure the numbers being quoted are comparable. Unfortunately some newer operators are not really aware that such differences even exist!

There is also a tendency to compare doses of alum and ACH directly without any appreciation of the differences in the nature of the chemicals. ACH contains approximately 23% w/w aluminium (strictly Al_2O_3) while alum contains approximately 8% w/w aluminium (strictly Al_2O_3). Therefore since it is the aluminium that does the work in coagulation, there is clearly more aluminium in ACH than in alum. In other words the doses cannot be compared directly.

If we look back into the history of the production of alum we can start to understand where this confusing situation started. Alum was produced from bauxite or alumina under the direction of metallurgists, and the strength of liquid alum was expressed as "percent weight Al_2O_3" (aluminium oxide) rather than "percent weight aluminium" or "percentage weight aluminium sulphate". The reason for this was that the starting material in the production of alum was aluminium oxide. (i.e. bauxite or alumina)

Of course there are straight forward factors you can apply to convert from one method of reporting to another, e.g. multiply the concentration in percentage weight/weight Al_2O_3 by 0.53 to get weight/weight aluminium. But that just adds to the confusion!

If we consider the chemical structure of alum it gets even more interesting. Alum is a strange beast. In Australia, we understand alum to have the chemical formula $Al_2(SO_4)_3.18H_2O$, i.e. it has eighteen water molecules (water of hydration) attached to it. By the way, this results in the Aussie version of alum having the molecular weight of around 666, which for those of you who are fans of Iron Maiden will recall, is the Sign of the Beast!

However, you'll find American alum often has 14- or even 14.3-H_2O's! In the UK, it can have 16- or even 21-H_2O's! So what are we really dealing with? A mess!

We would like to propose to the Australian Water Industry and, the Australian manufacturers of aluminium-based coagulants in particular, that we adopt the convention of "percent weight/weight aluminium" as the preferred way of quoting chemical strength.

We would also like to suggest that Operators and others working in water treatment start quoting alum and other Al-based coagulant doses as "mg/L aluminium". Once the suppliers come on board it will be much easier to progress from the chemical supplier's documents to the actual dose in the plant.

The other important benefit of this approach is that it would be very easy to compare doses of alum with say ACH. All the aluminium based coagulants would be on a "level playing field" as all doses would be quoted using the same unit, mg/L Al.

This method has already been pretty-well adopted for ferric-based coagulants such as ferric chloride, PFS® and others. So why not do it for aluminium-based coagulants?

To progress this idea further, we would like some feedback from Operators, the guys and gals who actually have to work with and dose these chemicals in water and wastewater treatment facilities! Let us know what you think.

In the mean time we will try to take this up with the chemical manufacturers, possibly WSAA, and other stakeholders.

In the interim, cheers and happy jar-testing!!

OUR COVER

Clockwise from top left: **Winner of the 2010 "TopOpShot Award"** ***submitted by Greg Whorlow*** – *Plenum Entry*, GWM Water – Greg wins a Coles Myer voucher for $200; **Runner Up** ***submitted by David Barry*** – *Read the Sign!* Aqualift P/L wins a set of WIOA practical guide books; **Building Blocks** (Editor's Note – Apologies to the company that submitted these, I lost the email); **Digester on the Move** – Wannon Water.

SEWER REPAIRS OVER SHOALHAVEN RIVER

Steve Glennan and Phil Critchley,
Winner of the Actizyme Prize for Best Operator Paper at the 2010 WIOA NSW Conference

Nowra is situated 160 kilometres south of Sydney where the Princes Highway crosses the Shoalhaven River (Figure 1). The river supports an oyster industry, and is used for many and varied recreational activities. It is a breeding ground for many species of fish and therefore any incident that pollutes the river could have a major effect on public health and those activities.

Figure 1. The Shoalhaven River Bridge over the Shoalhaven River.

North Nowra is a suburb of Nowra with a population of 5,445 permanent residents. Approximately 1.2ML of wastewater is transported each day via a 300mm AC pipeline suspended under the Shoalhaven River Bridge to the Nowra STP. The pipeline is made up of 3.0 metre lengths of AC pipe connected together by 300mm gibault joints (86 in total) (Figure 2).

Figure 2. Underside of the Shoalhaven River Bridge with the 300mm AC main on the right.

The North Nowra surcharge main is controlled by a pressure sensitive automatic opening & closing valve, located at the Nowra STP. The valve is normally closed and the main fills until it reaches a pressure of 180Kpa, at which time a signal is sent via telemetry for the valve to open. Once opened, it stays open for 30 minutes to allow for the main to empty and scour any sediment that may have built up each time the valve closes. This process operates continually unless there is either a power failure or the line pressure reaches 200Kpa which forces the valve to open and stay open until the normal operating conditions return.

Shoalhaven Water received word that the pipeline appeared to have a minor leak at the northern abutment. Upon investigation, it was found that the first gibault joint past the steel expansion/contraction slip joint was leaking. All the wastewater was contained in a stainless steel 200 litre drum (Figure 3) and natural bund at the abutment which was reinforced by sand bagging. The captured effluent was pumped out by an effluent tanker. The leak was stemmed initially by tightening up the gibault joint while further investigations were carried out.

Figure 3. The initial leakage control.

The RTA was contacted in regards to the design specifications for the expansion and contraction of the bridge and Shoalhaven Water was advised that the bridge could move between 60 and 70 millimetres at each abutment depending on the bridge concrete temperature variation.

The conclusion reached was that the first two gibault joints on each of the northern and southern abutments were creeping along the pipes as a result of the gap between the pipes being the points of least resistance, instead of the design expansion and contraction joints.

The northern gibault joint had moved to a point where the rubber sealing ring had reached the gap between the two pipes and the decision was made to effect temporary repairs by removing that joint and replacing it and the first section of AC main with a new style multi fit collar and a section of PVC pipe (Figure 4) while all the materials for permanent repairs were sourced.

Figure 4. The temporary repair.

Work started at 10 pm in the evening and the temporary repairs were completed by 5.00am the following morning in time for the morning peak flows. The bridge crossing main was first drained down into tankers using a combination of scour points. Tankers also emptied the upstream pumping stations. All the wastewater was transported to the Bomaderry STP for treatment.

It was decided to check all the remaining gibault joints under the bridge before undertaking permanent repairs. This was carried out by using a hired barge onto which a mobile elevated work platform was placed (Figure 5).

Figure 5. The barge and elevated work platform.

The barge was then manoeuvred into position and held there while the elevated platform was raised. Each gibault joint was checked including the tension of the individual bolts. There were no visible signs of any of the remaining gibault joints having moved (Figures 6 and7).

Figure 6. Positioning the barge.

Figure 7. Checking the gibault joints.

The bridge crossing was drained down twice more to complete the permanent repairs.

The permanent repairs consisted of the two existing steel expansion and contraction joints being cut off and in-house fabricated steel table flanges welded onto the steel main (Figure 8) where it exited the bridge abutments. A double diaphragm bellow of a suitable pressure rating was bolted to the flanges (Figure 9). The bellows would flex before there was any movement of any of the remaining gibault joints. The first sections of AC pipe on each side were discarded and new sections of ductile iron, cement lined (DICL) pipe were fitted in their place with new multifit collars.

Figure 8. Welding the flange in place.

Figure 9. The new expansion joint.

Two tee sections and locked scour valves were also added at each repair site. A new stop valve and a scour point were also provided either side of the stop valve and inserted as close to the southern abutment as possible to facilitate any future needs to drain down the bridge crossing for repairs or maintenance. The completed repair is shown in Figure 10.

Figure 10. The completed repair.

All the remaining gibault joints have been witnessed marked and are being monitored for any signs of movement and creep and to date there been no signs of either, especially the first two gibault joints after each of the new multifit collars.

The temporary and permanent repairs were carried out by Shoalhaven City Council's Mechanical Services Section, assisted by the Northern Wastewater Headworks and Wastewater Distribution Maintenance Sections. At no time during any of the repair stages was there any loss of wastewater into the Shoalhaven River, thereby protecting the sensitive oyster industry using the River.

The Authors

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LAMELLA CLARIFIER TRIALS AT DINNER PLAIN

Tony McKean,
Awarded Actizyme prize for the Best Paper by an Operator at the 2010 WIOA Vic Conference Bendigo

Dinner Plains is a small ski resort located in the Victorian Alps. Due to its popularity as a winter tourist destination, the wastewater treatment plant is subject to large seasonal fluxes in the quality and quantity of the influent wastewater. During normal operation, the treatment facility consists of preliminary treatment via a mechanical step-screen, followed by primary sedimentation in a conventional sedimentation tank. Primary effluent is discharged to a series of oxidation/polishing lagoons (Figure 1).

All reclaimed water is beneficially reused for irrigation purposes. Primary sludge is digested in an aerobic digestion tank. One of the problems with the plant is the likelihood of algal blooms occurring during the summer months which have the potential to cause disruption to irrigation.

The challenge facing East Gippsland Water was to better manage the raw influent to provide a reduced BOD and nutrient load to the lagoons.

Lamella clarifiers have been used to provide a large effective settling area within a small footprint. The influent solid/liquid stream is stilled upon entry into the lamella clarifier unit, and solid particles settle onto a series of inclined plates and accumulate and thicken in collection hoppers at the bottom of the unit (Figure 2).

The apparent advantages of these systems over conventional primary settlement tanks led East Gippsland Water to investigate their effectiveness for primary treatment of domestic wastewater.

A 'SiltBuster® HB50' lamella clarifier unit was acquired. To avoid inter-plate clogging when treating unsettled wastewater, every second inclined plate was removed to allow 50 mm spacing between plates (Figure 3). The lamella clarifier was positioned after the existing mechanical screen. Liquid effluent was directed to the lagoon system and sludge from the hoppers to geotextile bags.

In order to evaluate the performance of the lamella clarifier unit relative to the existing primary sedimentation tank, testing was performed before and after the lamella clarifier was brought online. The

Figure 1. Dinner Plain maturation lagoons responsible for polishing the primary effluent before re-use for irrigation purposes.

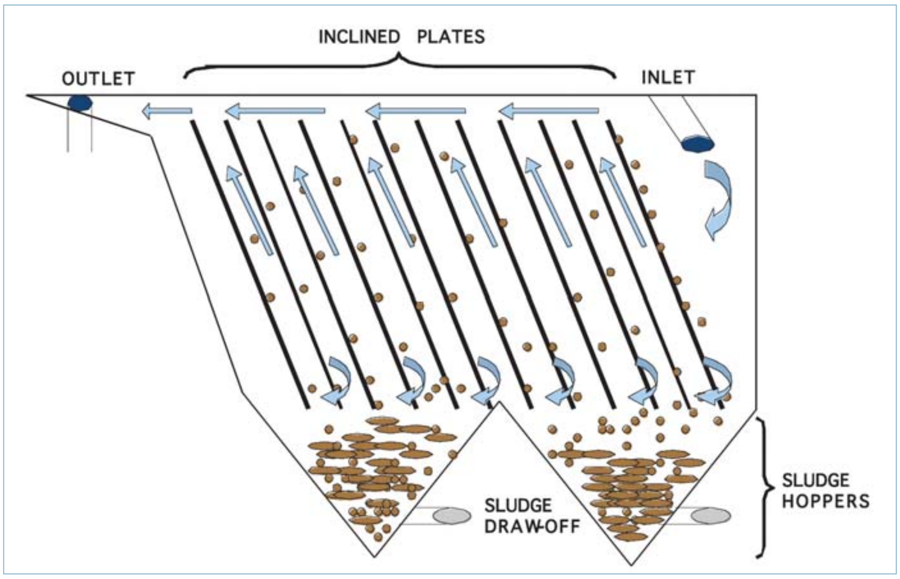

Figure 2. Schematic of the lamella clarification process.

Figure 3. The "Siltbuster" lamella clarifier.

concentrations of biochemical oxygen demand (BOD_5), suspended solids (SS), total nitrogen (TN) and total phosphorus (TP) were determined for each sample.

The trial was divided into three experimental phases:

Phase I: operation of the primary sedimentation tank

Phase II: operation of the lamella clarifier

Phase III: operation of the lamella clarifier with polyaluminium chlorohydrate (PAC 23) dosing of the preliminary effluent

These different phases are summarised in Figure 4.

Testing was performed on samples from the influent (raw) wastewater (SP1), preliminary treatment effluent (SP2) and effluent from either the primary sedimentation tank or the lamella clarifier unit (SP3; Figure 4). Samples were composites of at least 5 grab samples, blended over the course

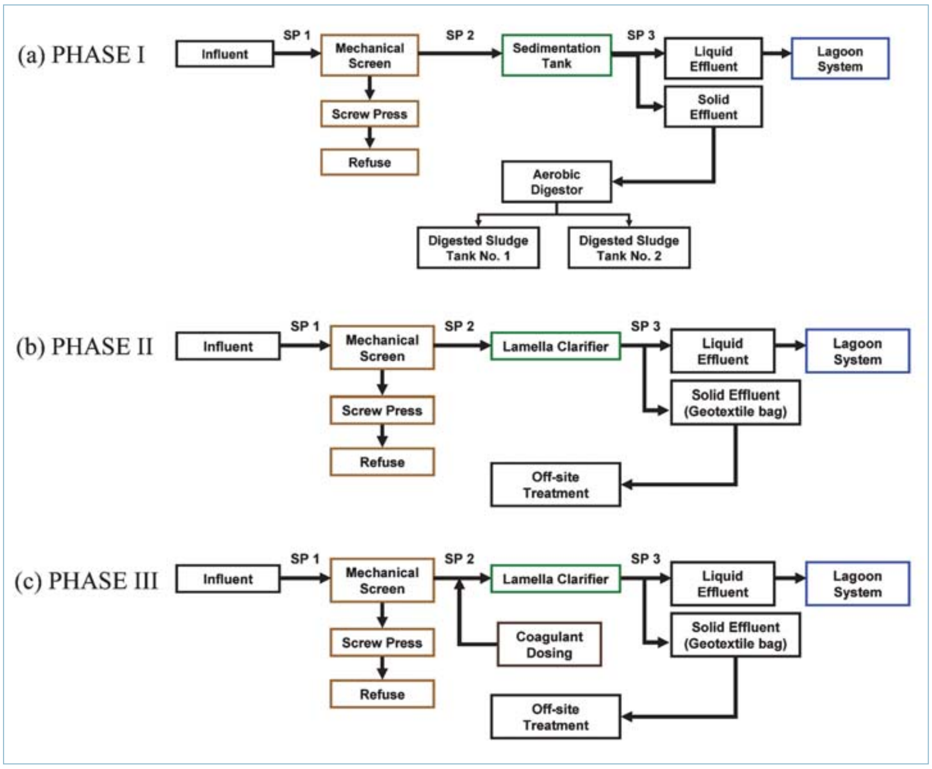

Figure 4. Diagrams showing the phases of the trial.

of the day, to represent both peak and off-peak daily flows.

Results

The results from the phases are shown in Table 1. The operation of the clarifier is shown in Figure 5.

In general, the BOD_5 and SS concentrations were found to be higher in the primary effluent than in the raw influent. This observation is likely due to solid material breaking up during the preliminary treatment process. As such, removal efficiencies for each parameter were calculated as the percentage reduction in value recorded between primary effluent and the final effluent from the lamella clarifier.

During Phase I, the primary sedimentation tank reduced the SS concentration of the preliminary effluent by 43%. The BOD_5 and TP levels were reduced by 10% and 21%, respectively, whilst no reduction in TN was observed (Table 1).

Figure 5. The lamella clarifier unit in operation. A separation plate traps floating scum, allowing the clarified wastewater to exit via discharge weir.

Once the primary sedimentation tank was taken offline, and the lamella clarifier unit was in operation (Phase II), the overall performance of the lamella clarifier compared favourably to the primary sedimentation tank, with SS removal efficiencies increasing to 57%; a corresponding increase in BOD_5 removal was observed. In contrast, nutrient levels remained relatively unchanged, with observed TN and TP removal efficiencies of 1% and 6%, respectively.

In an attempt to further improve the performance of the lamella clarifier, coagulant dosing commenced in Phase III. During this phase, higher organic loads were observed relative to Phases I and II, which may be as a result of the increased occupancy within the town due to the start of winter season and/or reduced infiltration arising from an extensive sewer repair program undertaken during this period.

Despite the higher organic loading during Phase III, BOD_5 and SS removal efficiencies were similar to those obtained during Phase II (Table 1). Higher nutrient removal was observed during Phase III, with TN and TP removal efficiencies of 15% and 47%, respectively. The higher TP removal is likely due to the formation of chemical phosphorus precipitates, arising from the addition of coagulant, with subsequent settling out on the inclined plates of the lamella clarifier unit. The reason for improved TN removal during Phase III is unclear, and needs further investigation.

Based on the results from this evaluation, the performance of the lamella clarifier, operating in conjunction with coagulant dosing, compares favourably to the primary sedimentation tank, improving the overall effectiveness of primary treatment at the Dinner Plain treatment facility. This in turn will reduce the organic loading to the lagoon system. Importantly, the improved nutrient quality should reduce the likelihood of algal blooms occurring during the summer months, thereby minimising potential disruption to irrigation.

Future consideration will be given to evaluating the efficacy of the primary sedimentation tank operated in conjunction with coagulant dosing, as this configuration may produce comparable results to those observed during Phase III.

It is likely that optimisation of the coagulant dosing regime will further improve the overall efficiency of the lamella clarifying unit; jar testing studies are currently underway to investigate the influence of reduced wastewater temperature on the rate of floc formation, and the feasibility of commissioning a flocculation tank prior to the lamella clarifier unit is being evaluated.

Importantly, these encouraging results reflect operation during the relatively quiet, off-peak spring period (flow rate, 1-4 L/sec). At the time of publication, the trial was entering the busy winter period (flow rate, 5-10 L/sec). The process performance and sludge draw-off will now need to be closely monitored and optimised for the peak winter hydraulic/organic loads.

Table 1. Removal efficiencies during the three phases of the trial.

Trial Period	BOD_5 Removal (%)	SS Removal (%)	TN Removal (%)	TP Removal (%)
Phase I (Primary Sedimentation Tank)	10	43	<1	21
Phase II (Lamella Clarifier)	30	57	1	6
Phase III (Lamella Clarifier/Coagulant)	31	59	15	47

The Author(s)

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THE SWITCH

Peter Gebbie

In September 2009 and January 2010, I travelled to Tanzania to provide water treatment process and design advice to our Project Team upgrading the largest WTP in the country at Lower Ruvu. This plant supplies about 70% of the potable water requirements of Dar es Salaam, the nation's largest city of about 3.5 million inhabitants. Also within the scope of this US-funded aid project were refurbishment works at two smaller WTPs located at Morogoro, a provisional capital located about 200 km from Dar.

The Lower Ruvu WTP currently has a capacity of 180 ML/d making it pretty large, even by international standards. The principal objective of our project was the expansion of the plant capacity to 270 ML/d.

The plant features three clarifiers, two of which use the solids-contact clarification (SCC) process and were provided when the treatment plant was first constructed back in the 1970's (Figure 1).

Figure 1. The solids-contact clarifier at Lower Ruvu WTP.

The SCC process was quite popular at that time and in Australia, quite a number were built, with many still operating well today. The Winneke WTP, which supplies treated water to Melbourne from the Yarra River at Yering Gorge, is a good example. There, two large square SCC's were installed.

Key to the SCC process is a mechanical flocculator installed to a central zone (Figure 2). The flocculator slowly rotates through a geared-motor assembly to encourage the growth of floc particles by providing gentle mixing and agitation. These particles then travel radially from the flocculation zone to a clarification zone where settlement occurs. Some of the settled sludge is recirculated back into the flocculation zone by the action of the flocculator impeller. These act as nuclei, enhancing the development of large, settleable particles.

Figure 2. The central flocculation zone of the SCC. Note the clouds of floc.

The third clarifier at Lower Ruvu is a new Degrémont up-flow sludge blanket Pulsatube unit. This unit was commissioned early last year as part of extensive refurbishment and repair works to the WTP. This type of clarifier employs in-situ flocculation, as the chemically dosed water flows up through a sludge blanket that forms in the base of the unit.

During the dry seasons (January to March inclusive, and then from June to October, inclusive), the raw water quality at the plant is such that the Dar es Salaam Water Supply Company (DAWASCO), who runs the Lower Ruvu WTP, doses a cationic polymer as the primary coagulant in-line at the discharge of raw water pumps. (During the wet season, alum is used in lieu of the polymer). The polymer is rapidly mixed and dispersed into the raw water and micro-flocs form in a delivery pipeline, which is about 100 m long, before then entering a flow-splitter and distribution to the three clarifiers.

There has been considerable concern about the performance of the two SCC's. The turbidity of the clarified water from the SCCs is typically around 5 to 8 NTU while that from the Pulsatube is between 0.5 and 1 NTU. The word was out, "the SCC's don't work, they feature old, out dated technology; their time has come, etc, etc". Even the UK-based consultants reviewing our initial work for Lower Ruvu suggested that two new Pulsatube clarifiers should be built to replace the SCC's, at an additional cost of $US1M plus!!

So, our Team Leader and I visited the plant on Australia Day (Yes, I worked: The things we do for the "company") to check on a few things, including trying to figure out the truth about these apparently recalcitrant SCC's.

On clambering onto the bridge of one of them, I noticed that the flocculator drive switch was OFF. I also noticed, "swirls" or "clouds" of almost-formed flocs within the floc zone (Figure 2). Intrigued, I asked the WTP Operator why the flocculator drive was not operating. He replied: "Because the mixer (sic) would break up the flocs formed in the pipeline", or words to that effect.

I tried to argue that this is not correct and that for the SCC's to work properly, the flocculators MUST be on!! He shook his head. So, in exasperation, I offered to do a jar-test to prove my point. We collected a plastic bucket full of the chemically dosed water taken from the centre of the clarifier in the floc zone and trundled off to their laboratory. I had visited this during an earlier visit and knew there was a jar-test apparatus inside sitting on a bench. Hopefully, it would be in working order!

I then gently mixed the water in our bucket and transferred some into two beakers. One as a "control" and the other I flocculated at 20 RPM, according to the digital read out on the jar-tester.

Now, guess what happened?? Within a minute, no make that 30 seconds, these lovely, plump, delicious flocs developed!! And after 5 minutes, the flocs were completely formed and the interstitial water between them had excellent clarity (Figure 3 and 4).

I then allowed the flocculated sample to settle for 15 minutes. The clarified water was tested and had a turbidity of 3 NTU, compared to the "control" of 45 NTU (Figure 5).

Figure 3. Commencement of the jar-test.

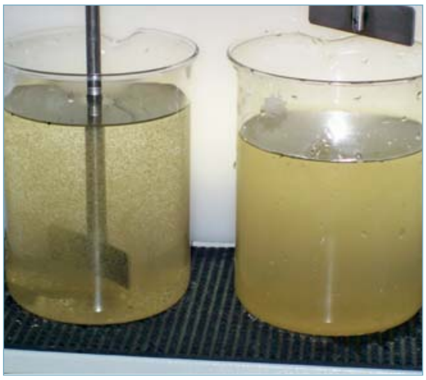
Figure 4. Flocculation after about 3 minutes. The "Control" without flocculation is on the right.


Figure 5. After 15 min settlement. The "Control" without flocculation is on the right.

I beckoned the WTP Operator from DAWASCO to come over and take a look: His eyes popped out and his jaw hit the floor!!!

I then tried to explain to him the "in's" and "out's" of SCC and sludge blanket clarifier operation and the fact that the flocculator switch must be turned ON to get the SCC to work properly and reduce the turbidity of the settled water.

The reason why the Pulsatube works so well is that it has built-in flocculation. The Operator had the mistaken belief that flocculation was occurring within the pipeline and that the flocs so formed would then settle out in each clarifier; he did not appreciate that flocculation is required within each clarifier to achieve optimum performance and, in the case of the SCC units, the mechanical flocculator drive switch for each had to be turned ON.

It was striking how this simple experiment spectacularly demonstrated what the problem was, why the performance of the SCC's was so poor and how the performance of the Lower Ruvu WTP could be vastly improved!!!

The moral of the story here is that it is essential that operators **and** management fully understand the processes and the treatment equipment which is in their charge.

And, as I write this article, The Switch is still in the OFF position on each of the SCC flocculator drives at the Lower Ruvu WTP. Why, I hear you ask?? Well, I think the DAWASCO Operator's pride could not allow him to acknowledge that he had misunderstood what was going on at his plant. When our Team Leader later queried him and suggested that at least our idea should be given a trial, he said he had referred the matter to his boss at DAWASCO's Head Office for a decision and was still waiting for a response.

Waiting: yes, there's a lot of that in Africa…

Well, happy jar-testing!

The Author

Peter Gebbie (peter.gebbie@smec.com) is Principal Process Engineer with SMEC Australia's Water Group in Melbourne and Team Leader of the Process Design Team. SMEC provides a wide range of process design and engineering services to the Australian Water Industry, as well as supporting international water and wastewater treatment projects for sister company, SMEC International..

Editor's Comment

It is a sad commentary on our WTP operations how often poor dosing and poor mixing are the root causes of poor treatment plant performance. Also too often expensive fixes are recommended when all that might be required is the energy to flick a switch or a bit of energy, static or mechanical, to provide the necessary mixing.

HOW'S YOUR PIPE?

Greg Moore

One of the challenges in managing water pipelines is knowing the condition of the pipes. Modern management practice is increasingly aiming to replace mains before they fail. This is particularly important for very critical mains where the consequences of failure are extreme. An example is the failure of a large water main or sewer passing under a major arterial road. A recent event in Boston highlights the potential problems. A steel connector joining two sections of 3 m diameter pipe failed, resulting in a boil water alert being issued to 2 million people and remaining in place for 59 hours! Water was lost at a rate of approximately 30 ML/hr before the section was isolated for repair. This took 9 hours.

Condition assessment of pressure water pipelines is a relatively new technology, although it has been well developed in the oil and gas industry for decades. There are two main types of assessment, direct and indirect. Direct condition assessment involves physical measurements of the pipe itself whilst the indirect methods measure some surrogate parameter such as soil corrosivity.

Although condition assessment can and does frequently relate to steel water mains (and to a much lesser degree the newer ductile iron) the major effort is in the assessment of cast iron pipes since these represent a large proportion of pipes in Australia and many are approaching the end of their reliable service life.

The graphitic network of a typical cast iron pipe, and the resultant corroded mass referred to as 'graphitisation' represents a significant barrier for the traditional 'intelligent pigs' used in the oil and gas industry. Intelligent pigs are highly complex devices that are inserted into the pipe and are propelled through the pipe with the fluid pressure. These devices have traditionally used ultrasonics and magnetic flux techniques to collect data such as pipe wall thickness losses or pipe cracking, but these do not easily work on corroded cast iron, and this is further complicated by the presence of a Cement Mortar Lining (CML) which prevents the direct metal contact required by most of the 'intelligent pig' technologies. Virtually the only commercially viable technology that can successfully interrogate a CML cast iron pipe is eddy current based methods, often referred to as Remote or Near Field Technology (RFT, NFT). These have been developed and successfully used in the water industry but there are several drawbacks:

- RFT still requires extensive analysis of the data once it has been collected and does not provide 'instant' or real time answers.
- The civil works required to insert the pig are expensive and require the 'critical' main to be out of commission for some time.
- There are currently severe size limitations on the size of the pipe that can be inspected in this way. The upper limit of this technology at present is approximately 375 mm.

Indirect methods rely on all those techniques that attempt to make an assessment of pipeline condition by measuring a surrogate parameter that can be extrapolated to give a measure of remaining pipe life. Actual 'break' or failure analysis remains an industry standard. The input of break data into various economic models is still currently the major replacement trigger for water mains in Australian water utilities. Realistically, this is appropriate for small diameter reticulation mains where the costs of condition assessment are not justified. For critical larger diameter water mains however, prior knowledge of future failure regimes is becoming increasingly important. Whilst a number of indirect technologies have been available for some time, the most usual parameter for buried ferrous water mains is an assessment of soil corrosivity. This is itself a parameter in which strong evidence exists for a direct

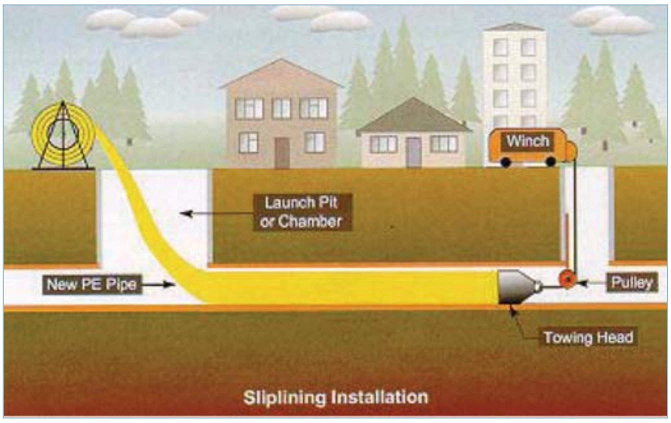

Figure 1. Schematic of Slip lining.

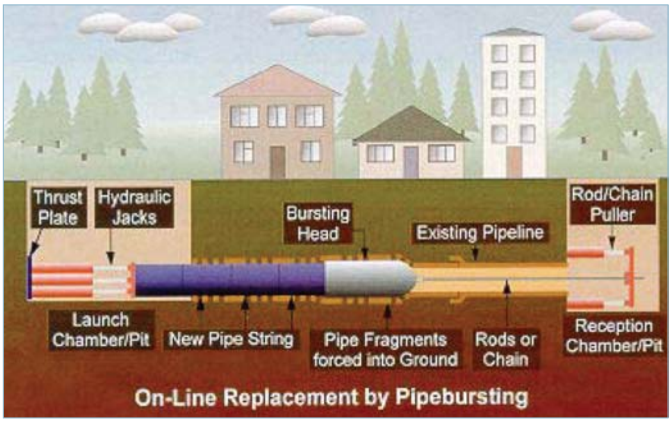

Figure 2. Schematic of pipe bursting technique.

casual relationship with cast iron and steel pipe performance.

Historically a number of corrosivity measurements have been widely used. These all had limitations and are now largely disregarded for quantitative purposes.

A recent approach is to assess soil corrosivity in quantitative terms such as provided by Linear Polarisation Resistance (LPR) measurements. Whilst LPR is not new, its use to predict future pipe performance certainly is. The soil sample has to be prepared with a moisture content at wilt point (this is the point where a plant starts to wilt due to limited moisture in the soil) before being subjected to electrochemical testing. The results are then fed into a set of algorithms which can be used to predict pipe performance. The algorithms, LPR analysis and predictions are currently intellectual property and are not yet industry wide practice. Further research and development is currently underway to refine this technique. At the moment it is the major indirect technique being used in Australia by one commercial organisation which is capable of predicting future pipe performance.

Acoustic and transient pressure methods have also been under development for some years but like most of these indirect techniques, the major issue to be addressed is the ability to detect pitting attack. Despite this limitation, they are being used to provide an economical assessment of a pipeline segment.

However, simply blindly applying LPR technology to a buried steel or cast iron pipeline will not necessarily provide an accurate prediction of the future performance of that pipeline. A careful review of the history and circumstances of each water main under assessment will be required before its future performance can be predicted with sufficient accuracy.

Condition assessment of non metallic pipe is limited to AC pipe where there are considerable quantities of this pipe in service. The acoustic and transient pressure techniques are having some success but these still require further research and validation. In many cases the water industry practice of "hot" or "under pressure" tapping results in the acquisition of a small section of the pipe which can be assessed to provide information on the rate of internal and external deterioration. The rate of internal deterioration in a non bitumen coated AC pipe system can be quite uniform. However, externally there can be considerable variability but this is nowhere near as variable as the external corrosion of a metallic pipe. These aspects can simplify the assessment of AC pipe systems in comparison with metallic pipe systems.

There is not yet a high demand or major need for detailed condition assessments of PVC or PE although some general information on performance can be assessed by some reverse engineering techniques and testing of some mechanical properties of the plastic materials. The reverse engineering technique looks at the operating conditions of the pipeline under assessment, and determines the actual operating pressures and the extent of any pressure surges. This data is then used to establish if the pipeline is operating within its design capability. This is particularly the case for pumped mains subjected to surge and fatigue which can result in premature and unexpected failures of plastic pipes.

Replacement Materials

Once a decision has been made to replace a particular pipeline, the replacement material and method of installation needs to be determined. In smaller diameter pipes up to 450mm, plastic pipes such as PVC or PE are most commonly used, largely because of their corrosion resistance and lower cost. With modern manufacturing and quality control standards, these pipes when correctly installed have a probable service life of 100+ years. For larger diameter pipes, material selection becomes more critical and the expected operational aspects both now and in the future need to be considered. In these cases the choice of materials gets down to ductile iron, steel, GRP or PE. It often comes down to economics but where specific resistance to high pressure, surge and fatigue are paramount, other factors take precedence over cost.

Techniques for Pipeline Replacement

Pipes can be replaced using conventional open trench techniques or with the newer trenchless technologies. Trenchless techniques are commonly used in built up areas to minimise inconvenience to the general public. The major trenchless techniques used to date in Australia for pressure mains are

- **Slip lining** - Possibly the simplest technique for renovating non-man-entry pipelines. Slip lining basically entails pushing or pulling a new pipeline into the old one (Figure 1). The concept of using the 'hole in the ground' by installing a new pipe within the old is long established. While in theory, any material can be used for the new pipe; in practice polyethylene (PE) is the most common choice.
- **Pipe bursting and splitting** – Pipe bursting is referred to in certain countries as 'pipe cracking'. In its earliest forms, pipe bursting involved the use of a percussive tool (usually a modified impact mole) or a hydraulic expander to break out the existing pipe. At the same time a continuous length of polyethylene pipe is pulled through the existing hole thereby replacing the existing pipe Figure 2).
- **Close Fit Thermoplastic Lining** - The use of liners that are deliberately deformed prior to insertion, and then reverted to their original shape once in position so that they fit closely inside the host pipe, is often

known as 'close fit lining' or 'modified slip lining'. Such techniques are a logical development of basic slip lining, and can be applied to both gravity and pressure pipes. There are a number of materials that can be used for this technique but for pressure applications the process is confined to swage lining or folding using PE pipe. The PE pipe is pulled (Figure 3) through a mandrel or draw down die or folded into a U shape to reduce its diameter (Figure 4) to enable it to be pulled through the pipe. Once in place, the pipe is heated or pressurised which allows it revert to its original dimensions but results in a close fit with the host pipe.

Figure 3. Hydraulics and rods used to pull PE pipe though the host pipe.

Figure 4. Draw down die to reduce PE pipe diameter.

Figure 5 shows an example of a rehabilitation project involving a 100+ year old pipe in Adelaide. The first photo shows the welded length of pipe ready for insertion and the second shows the PE pipe being pulled through.

Figure 5. Installation of a 630 mm PE pipe in the Adelaide Parklands into a 100+ year old riveted steel pipe.

- **In-situ applied coatings** – This technique has been used for many years and was first used in the 1950's to apply in-situ cement mortar linings to previously unlined cast iron or steel pipe. This proved to be a master stroke of asset management at that time for it was instrumental in extending the life of these pipelines for periods of 50+ years. Today, in-situ cement mortar lining is rarely used but alternative coatings are being used. Most recently these consist of high build polyurea coatings. This is typically being applied to the internal surfaces of cast iron pipes (which may or may not have a cement mortar lining) and asbestos cement pipes. These coatings are applied by a rotating spray head which is pulled through the pipe once it has been isolated and internally cleaned. These coatings not only provide some corrosion protection to the internal surfaces of cast iron and asbestos cement pipe, but also provide a semi structural lining to maintain and enhance the mechanical properties of the host pipe.
- **"Plough In" pipe laying** – although this is strictly not a trenchless technology, vibratory plough in techniques have been used to lay smaller diameter PE pipe up to 125 mm diameter. PE pipe coils are fed though a vibrating plough head which places and pulls the pipe into a preformed hole at a nominal depth of 600mm. High laying rates in excess of 500 meters per day including all associated site establishment, construction and site cleanup activities have been achieved which results in considerable cost savings. Figures 6 to 8 show examples of this method.

Figure 6. Caterpillar with plough head.

Figure 7. Coil of PE pipe being pulled in.

Figure 8. Vibrating plough head which creates hole in the ground.

These plough in systems are being used in the water industry in "Greenfield" installations where other existing buried infrastructure is either absent or very minimal.

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The Author

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REHABILITATION OF SEWERS FOR THE FUTURE

Nev Brown,
Winner of the Actizyme Prize for Best Operator Paper at the 2010 WIOA Qld Workshop

In the past, councils have constructed sewers, backfilled them and let them drain away without much care or attention, or at times not even a second thought. Like a corpse in a grave, buried and never to be seen again. Fitzroy River Water was no exception.

The Fitzroy River Water Experience

Rockhampton commenced to operate a sewage scheme sometime in the 1930's. The original sewers were predominately constructed in earthenware or asbestos cement with the larger diameters in concrete. The original sewers in the lower areas of the city were, and still are, subject to inundation at times of flood. These mains are on the flood plain of the Fitzroy River and the inverts are either just above or below the Highest Astronomical Tide. Indeed some of the lower mains are below the Lowest Astronomical Low Tide and are constantly charged with ground water.

The original access chambers were cast in-situ, not very well sealed at the junction with the main and some lids were below ground level. Some newer pre-cast units were also not sealed at the joints and permitted inflow of ground water into the access chamber and the sewer.

In response to excessive flows through the sewage treatment plants at a time of peak wet weather flows in 2000, a program of sewers inspections was devised to determine how severe the groundwater inflows entering the system were.

A program of CCTV inspections was put together to have a look at a representative sample of the network. What was discovered was horrific.

- Heavy silting in the mains, at times 30% of the diameter
- Disjointed pipes
- Longitudinal and spherical cracking
- Major gas attack, in particular in the first and second segments downstream from the point where a rising main drops into a gravity sewer
- Section of sewers without inverts/obverts
- Major root intrusions
- Misplaced or dropped junctions

The cracking, joint displacement and junction collapses is likely to be caused by a combination of ground movement, failing of rubber ring seals and root intrusion. The corrosion mainly occurs in concrete or asbestos cement pipes, where the methane and hydrogen sulphide gases eat away the exposed surfaces of the pipe leading to collapses and severe longitudinal cracking.

Figure 1. Section of pipe missing.

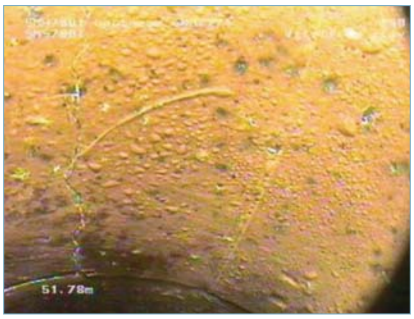

Figure 2. Longitudinal cracking in an earthernware pipe.

Figure 3. Invert missing, severe gas attack in a concrete pipe. Note the uneven bedding.

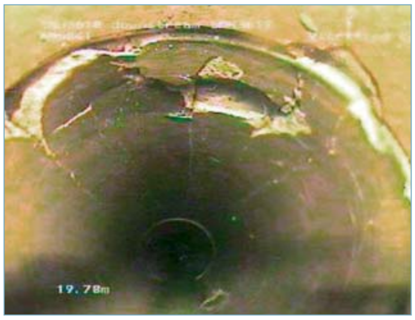

Figure 4. Longitudinal and circular cracking.

Figure 5. Root growth in a junction.

All of the above problems challenge the structural integrity of the infrastructure and result in a reduction to the hydraulic efficiency of the sewer.

What to do to fix the problem

It was clearly understood from the beginning that it was not practicable or possible to replace the sewers, therefore a trenchless technology was called for where the sewer is repaired by inserting a lining into the original sewer.

From information gained from the inspections undertaken in 2000/2001 it was apparent that there was an urgent need to undertake a rehabilitation program on the sewer network in Rockhampton.

These mains in particular needed to be rehabilitated urgently as most were the large diameter trunk mains that carried the sewage to the treatment plants and should they fail, all hell would break out upstream.

We needed to act and act fast. A tender was prepared for a cleaning and CCTV inspection and condition assessment contract for the trunk mains - this being lines > 450 mm up to 750 mm. At the same time, a tender was prepared for the in-situ lining of the trunk mains.

Both contracts were let and FRW commenced to rehabilitate its sewers.

The need to accelerate and expand the program was recognised and the budget allocation has been raised from an initial $800,000 in 2001 to $5,000,000 in 2009. The future budgets as identified in the Strategic Asset Management Plan (SAMP) will seek to have similar amounts (in excess of $5 million) allocated for the rehabilitation of the sewers.

To date approximately 37.5 km of high risk sewers 300 mm to 900 mm have been lined and their original hydraulic capacity has been restored.

FRW has recently invited tenders for the next phase of this work including approximately 100 km of 150 mm and 225 mm diameter lines to be cleaned and inspected. From these inspections a lining program will be formulated and acted on immediately.

Impact caused by the Amalgamation of Councils in Queensland

Since the amalgamation of the Local Government areas in 2008, Rockhampton Regional Council – Fitzroy River Water now have responsibility for the sewer networks of Yeppoon and the Capricorn Coast, Gracemere and Mount Morgan as well as the Rockhampton City networks.

Preliminary investigations have indicated that the condition of the sewer network at Yeppoon is as bad, if not worse, than the system in Rockhampton.

With this additional rehabilitation work, the program that was planned to be completed sometime in 2014 will need to be extended to permit the additional work to undertaken. It is envisaged that it will take another 5 years from 2014 to complete this work.

So what have we learned?

To maintain a fully functional sewer system, all information on the location and condition of all sewers must be known and must be current. Ask yourself, DO YOU know what you have got underground?

- Do you know what condition your sewers are in?
- Do you know the exact location of all of your sewers?
- Are their sewers under rail lines, bridges, highways or buildings?
- Are those sewers that are in critical positions in good condition?
- Should one of these lines that are in critical locations collapse, what would be the consequence?

  - Would it be minor inconvenience requiring a dig up and repair, or

  - A catastrophic situation that caused the closure of major infrastructure

  - Would it be the cause of a major environmental incident?

Think of it this way, can you prove to the Environmental Protection Agency if challenged, that you have a program in place that is designed to alleviate these occurrences, or will you need to rely on lady luck?

The sewer assets need be identified segment by segment, chamber by chamber. The information should include but not be limited to:

- The type of material i.e. earthenware, Asbestos Cement, Polyvinyl Chloride or concrete.
- Invert levels upstream and downstream of the chamber connection
- Depth of the main.
- As built details of house line junctions.
- Segment number and asset number of all access chambers
- Size and length of sewer main, and
- Date constructed.

To ensure that you have current information on the condition of your assets it is important that you check the condition of the asset regularly.

- All sewers should be cleaned on a 10-15 year cycle. Cleaning is best carried out with a pressure hose flushing the main with water.
- All silt, fat, roots and debris should be removed and completely clean conduit should be the result.
- Cleaning should be followed by a CCTV inspection.
- Condition assessment using a recognised computer program such as "WinCan Version 8" to give a consistent rating.
- Condition Assessments should be undertaken by qualified trained inspectors/camera operators.
- All condition reports should be in accordance with the *"Conduit Inspection Reporting Code of Australia WSA 05-2008 2nd edition, version 2.2"*.

By implementing a full sewer maintenance program the following potential benefits are likely to be the result:

- Reducing and eliminating chokes in the sewer.
- Reducing and eliminating call outs.
- Limiting surcharges (Health and Environmental issues).
- Maintaining the efficiency of the system.
- Locating illegal connections (e.g. illegal roof connections).
- Providing proof that maintenance is required, and
- Allowing for sensible planning of this.

All this will add up to reduced operating and maintenance costs and a saving in money for the community.

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