Overberg Water (OW) Rûensveld East EMAWS Tech Internal Testing Results

1. Summation:

1.1. Outcome

It has been conclusively shown that EMAWS Technology substantially improves all parameters monitored routinely in the final water and reduces both operator input requirement (by stabilisation of the process during raw water quality changes), and chemical usage (by improving flocculation, sedimentation efficiency and settling rate).

1.2. Key Findings

1.2.1. Reduced Chemical Consumption = cost savings
- 1.2.1.1. Chlorine
- 1.2.1.2. Flocculent (Alum in this instance)
- 1.2.1.3. Lime

1.2.2. Reduced operator intervention
1.2.3. Reduced management requirement
1.2.4. Improved Sedimentation
- 1.2.4.1. Faster settling time
- 1.2.4.2. Improved removal of contaminants
- 1.2.4.3. Higher plant capacity due to improved sedimentation parameters

1.2.5. Improved Post sedimentation water quality
1.2.6. Higher quality final water
1.2.7. Health standard compliance
- 1.2.7.1. Longer residual chlorine effect
- 1.2.7.2. Zero count microbiological tests in final water
- 1.2.7.3. Lower Auminium
- 1.2.7.4. Lower THM's

1.2.8. Reduced logistical costs for chlorine dosage

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1.3.1. **Brief History of Technology**

1.3.1.1. Combines four different recognised and documented water treatment technologies in one powerful process. These technologies have been individually applied for more than 30 years in the global water industry.

1.3.1.2. Uses no chemicals and produces high quality water

1.3.1.3. Designed to be self-managing and versatile to handle supply water quality variations

1.3.1.4. Technology used by Wihelmsen Maritime Services (Registered in Norway, with offices worldwide.) for application in shipping services globally for treatment of ballast water discharge as approved by the International Maritime Organisation.

1.3.1.5. Due to success achieved in the shipping industry it was decided to adapt the technology for domestic and waste water treatment. This 3 year development was completed and installed at Overberg Water to demonstrate cost effective solutions to water treatment problems in South Africa.

1.3.2. Why Overberg Water? – Overberg water is a recognised and respected role-player in the South African water industry, and is conveniently situated to Sanakwa's Cape Town base for operations for introduction to the water industry.

1.3.3. Why this site ? Sanakwa equipment was installed at the Rûensveld East, a conventional design water treatment plant which, according to OW, has historically been a problematic site with extreme water quality problems.

1.3.4. Other Technology at Rûensveld East - Prior to the SanAkwa installation alternate technology had recently been installed to expand the plant throughput capacity.

1.3.5. OW Requirements - Overberg Water requested that a testing programme be completed to demonstrate the impact of EMAWS Tech after installation and initial testing of equipment at the Rûensveld East water treatment plant.

The tests were devised to verify that the water treatment process was enhanced and that basic monitoring parameters, namely colour, turbidity, aluminium, and sanitisation are improved in final water when EMAWS Tech is used. Focus was on maintained throughout on improved health related parameters in final water.

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1.4. **Summary of Testing**

In order to limit aluminium in the treatment process the optimum dosage of Alum was determined. This proved to be approximately 50% of the previously used dosage. Reduction in the acidic Alum dosage also reduced the lime dosage required for pH correction in pre-sedimentation water.

Assessment of optimal sedimentation process pH initially demonstrated optimum sedimentation and removal in the range pH 6.2 to pH 6.4. However during final testing, while monitoring residual Aluminium concentration, better residual results for all parameters including aluminium were obtained in the pH6.5 region and an operating range of pH6.4 to pH6.5 was adopted. All parameters performed optimally at this pH, demonstrating that HCA™ promoted flocculation and sedimentation of all materials in this range. This improved sedimentation rate provided high quality water even a flow rates up to double those previously achieved at this plant during an exercise by OW staff.

Removal of aluminium to within SANS241 limits was achieved during initial tests, when the membrane plant was switched off. However with the increased lime dosage into the post-sedimentation water, required to correct the pH of the membrane plant final water, increased the final water pH to above SANS241 limits; and the aluminium introduced by lime addition also increased the aluminium level in the final water to above SANS241 limits. The aluminium in the HCA™ treated final water was reduced due to improved removal of aluminium during sedimentation, but was still above limits. During sampling and optimisation for SANS241 sampling residual aluminium could be kept in range by closely monitoring post settling lime dosing and aluminium in final water. Further work done after the heavy rains where extremely high colour and turbidity was experienced at the beginning of November however did not confirm this; and as soon a post-sedimentation lime was dosed the aluminium in the final water increased to above SANS241 limits, but was still far lower than without EMAWS Tech treatment.

An exercise was carried out with the EMAWS Tech system under pressure to assess if the pressure affected aluminium removal, and while this was effective for improving sedimentation parameters, and removal of colour and turbidity. The aluminium increased to above SANS241 limits as soon as post sedimentation lime dosage was resumed.

However, post-sedimentation lime dosage detrimentally affects residual aluminium concentration in final water and even more so at the increased levels required to correct membrane plant final water pH.

Final water samples were collected to confirm the influence of EMAWS Tech on residual chlorine maintenance during distribution through the pipelines and reservoirs, and satisfactory concentrations were found, even at the extremities of the pipelines, where residual chlorine had previously been inadequate to maintain sanitisation.

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The membrane filtration plant was stopped due to its inability to cope with the poor water quality during the high rainfall period, and this enabled post-sedimentation lime adjustments to be made in order to obtain samples for SANS241. These analysis reports have been appended.

It is clear that EMAWS Tech improves the removal of all contaminants in the water and improves flocculation at lower dosages of treatment chemicals, and that the post-treatment EMAWS Tech improves residual colour and demonstrated greatly improved sanitisation over an extended time period. The combination of these beneficial effects resulted in higher quality water being produced and improved health criteria compliance, while reducing operator and other interventions to maintain quality.

(Final Comment: The poor plant design requiring post-sedimentation lime dosage for pH correction is a contributing factor to filter backwash frequency, residual turbidity and residual aluminium concentration. Literary searches indicate that using Ferric Sulphate as flocculent will provide improved colour removal and that the entire lime dosage may be moved to the pre-sedimentation point where residual aluminium will be reduced by removal during sedimentation. It is hence recommended that OW investigate changing the flocculent to a type that will not require post-sedimentation pH adjustment.)

2. Testing Philosophy

In order to enable an understanding of the effect of EMAWS Technology on the chemical dosing parameters on water quality at the Rûensveld site, with its unique water quality parameters, a phased optimisation on chemical dosage was planned, followed by a comparison of the efficacy of the process without EMAWStreatment and with EMAWS treatment. Aluminium was specified as a critical parameter for compliance to SANS241 quality standards in the final water and optimisation of aluminium removal was a focus throughout this work.

The initial stages have been divided into three separate optimisation strategies:

a. Alum dosage reduction is critical in determining the minimum dosage required to achieve colour reduction and satisfactory levels of turbidity, while reducing dosage to an absolute minimum in order to optimise flocculent concentration to reduce residual aluminium in the final discharge water. It was anticipated that the effects of EMAWS on the suspended and dissolved solid and organic material in the raw water would enhance removal during flocculation and sedimentation, as seen in initial demonstration work.

b. Once acceptable treatment dosage parameters for Alum have been achieved the optimisation of pre-sedimentation lime dosage must be investigated to determine the pH at which the sedimentation process will remove the maximum colour, turbidity and aluminium. Literature studies indicate that the optimum will be in the pH 5.6 to pH 5.8 range, however with the unique water quality parameters at this site this had to be determined specifically to the site.

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c. Once a basic operational range for pH and Alum dosage was established a third optimisation was done to determine where, within these ranges, the aluminium removal is maximised. During step two (sedimentation pH optimisation) post-sedimentation aluminium concentrations were monitored to provide an indication for the range within which aluminium reduction proved to be most effective. (For this process SanAkwa provided reagents for analysis using the plant instrumentation – a Hach DR890 spectrophotometer) Once optimisation was indicated by the spectrophotometric method samples were processed using an accredited laboratory and Inductively Coupled Plasma Atomic Emission Spectrophotometry.

Additional Benefits –

Chlorine

d. Residual chlorine enhancement effect was demonstrated by following the pipeline and sampling at strategic points to determine the residual chlorine readings at those points.

THM Formation Potential

e. CSIR analysis confirmed that THM formation was reduced to below detection limits during normal operation. However during the flooding period when carbon, colour and turbidity were high these levels increased as would be expected with the increased formation potential due to increased carbon levels.

SANS241

f. SANS241 compliance of water leaving the treatment plant was demonstrated by sampling the final water and submitting samples to certified laboratories.

Chemical Dosing Optimisation

Historically Overberg Water has used Aluminium Sulphate (18 H2O) as flocculent in its water treatment facilities. In order to remove the high levels of (mostly organic humic) colour and turbidity in the water unusually high dosage parameters are often required to ensure basic water quality compliance, however at these levels residual aluminium has been problematic in achieving full compliance to the prescribed standards for drinking water.

In order to reduce the risk of aluminium contamination alternative flocculants should be tested at the site, but this was beyond the scope of this exercise.

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3. **Initial Alum Dosage Adjustment**

Aim: To establish the optimum dosage (minimum usable) in the pH 6.4 to pH 6.5 range, as originally used by Overberg Water

	BEFORE	DURING	AFTER
Date	01/09	03/09	20/10
Time	10h00	14h00	04h00
Pre-sedimentation Parameters:	pH 6.2 to 6.5	pH 6.2 to 6.4	pH 6.4 to 6.5
	Alum Dosage 90ppm	60ppm	80ppm
Raw Water Quality:	Turbidity 21.4 NTU	14.6NTU	22.7NTU
	Colour 194 ˚H	188 ˚H	204 ˚H
Pre-settling Quality:	pH7.04	pH6.30	pH6.98
Post-settling Quality:	Turbidity 11.9 NTU	6.67NTU	4.04NTU
	Colour 72 ˚H	56 ˚H	10 ˚H
After Filtration Quality	Turbidity 4.30 NTU	1.55NTU	0.96NTU
	Colour 28 ˚H	20 ˚H	0 ˚H
	pH 9.31	pH9.10	pH7.10
Final Water Quality	Turbidity 3.14 NTU	2.44NTU	0.91NTU
	Colour 19 ˚H	20 ˚H	0 ˚H
	pH 8.94	pH8.74	pH7.13
	Aluminium >0.800ppm	0.587	0.098ppm

NOTE: Massive change in Raw water quality during this exercise and the reduced dosage of both Alum and Lime still produced improved Final water quality

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Aluminium Reduction Plan Initial Results – pH and Alum Dosage Vs Colour and Turbidity

The effect of variations in sedimentation pH / alum dosage were conducted to establish the effect on sedimentation performance and linked to post-filtration quality in order to establish optimum conditions for basic plant performance monitoring parameters

Figure 1 – Alum Reduction Assessment (In One Day – 24hr Cycle)

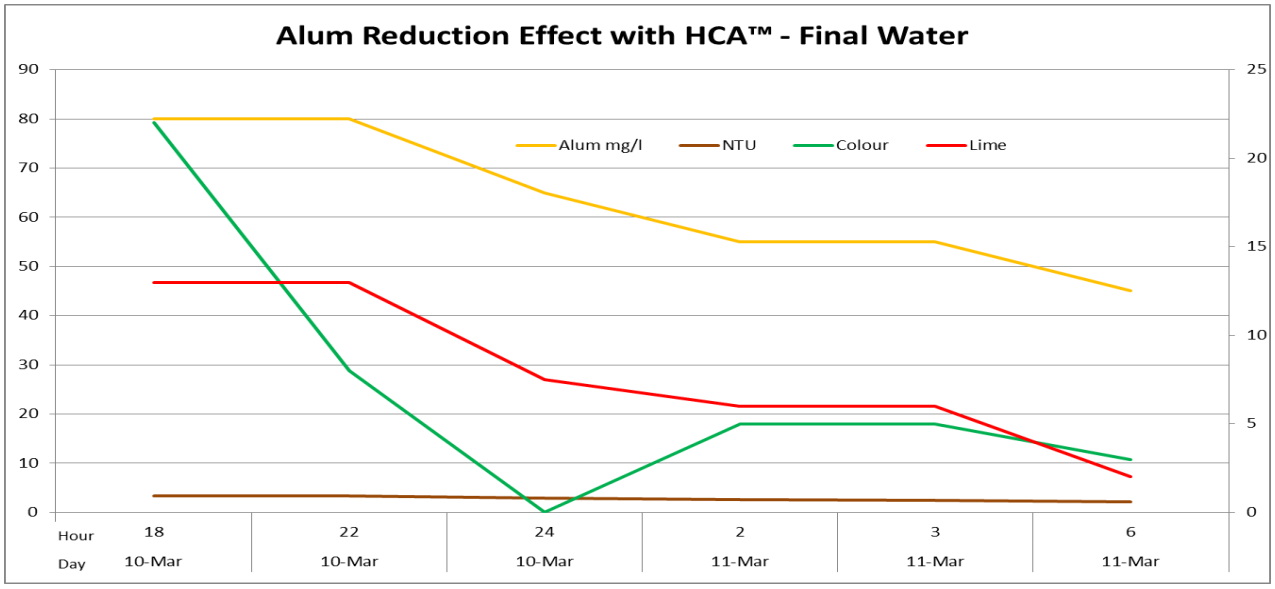
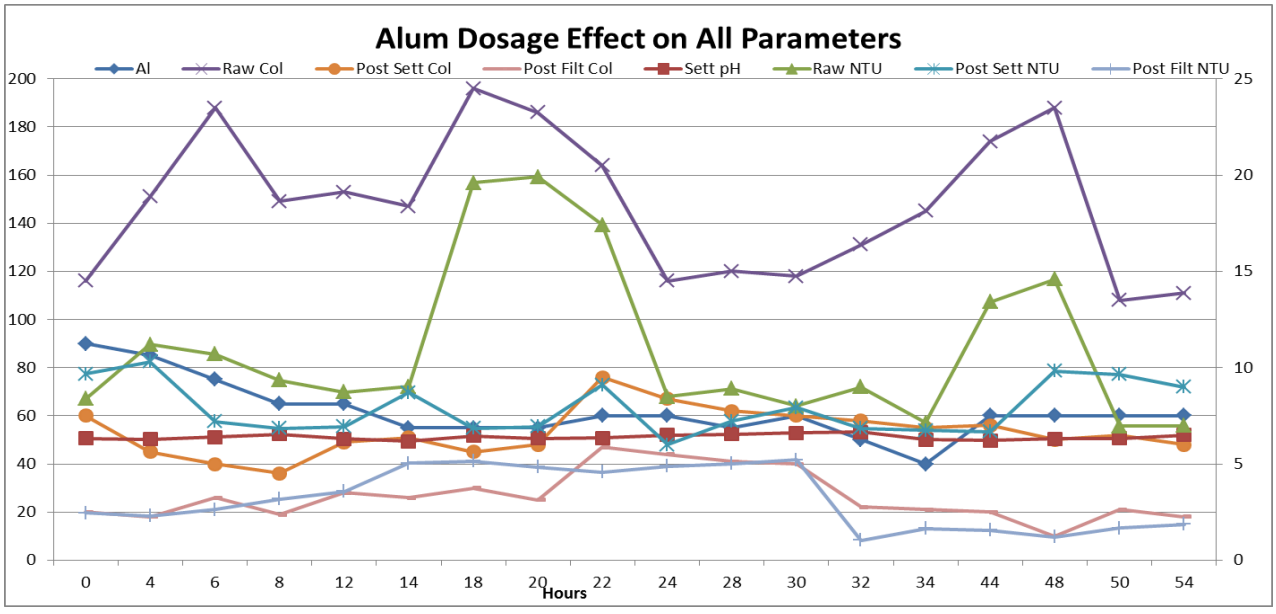


Figure 2 - Graph of Aluminium Reduction Plan Initial Results (48Hr Cycle)



Left Axis reflects: Raw Colour, Alum Dosage, and Post Settling Colour
Right Axis reflects: Raw NTU, Post Settling NTU, Settling pH, and Post filtration NTU

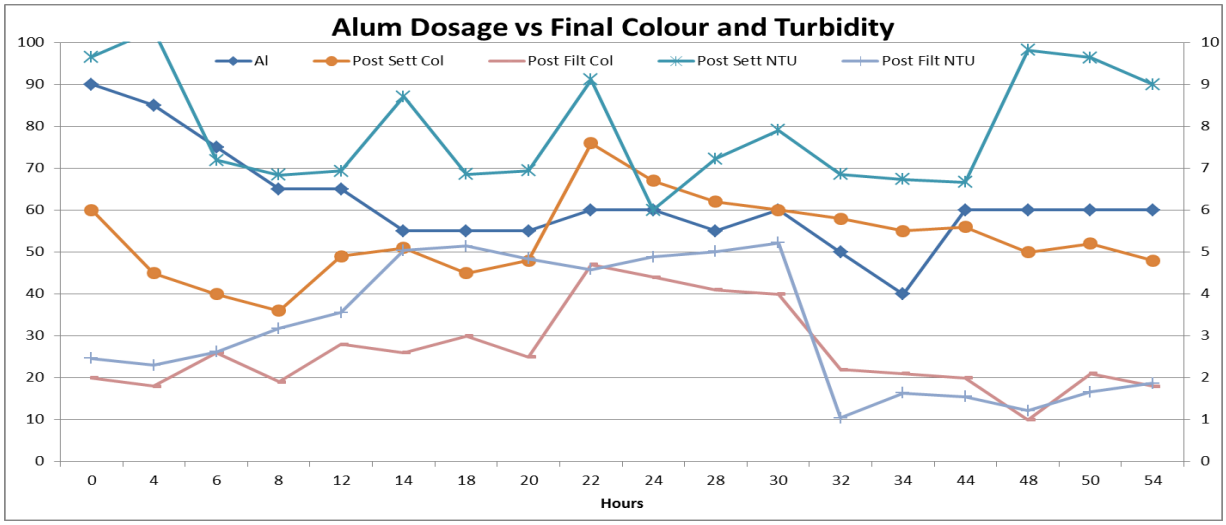
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The effects of decreasing the alum dosage up to hour 34 in this test were complicated by two large variations in the raw water quality, as seen in purple and green lines in Fig 2.

Interestingly the historic method of treating this type of variation would have been a dramatic increase in alum and lime dosage to cope with the quality changes, however with EMAWS Tech water the general trend was largely maintained with little effect on the post settling and final water quality, as illustrated in the expanded scale Fig 3 below.

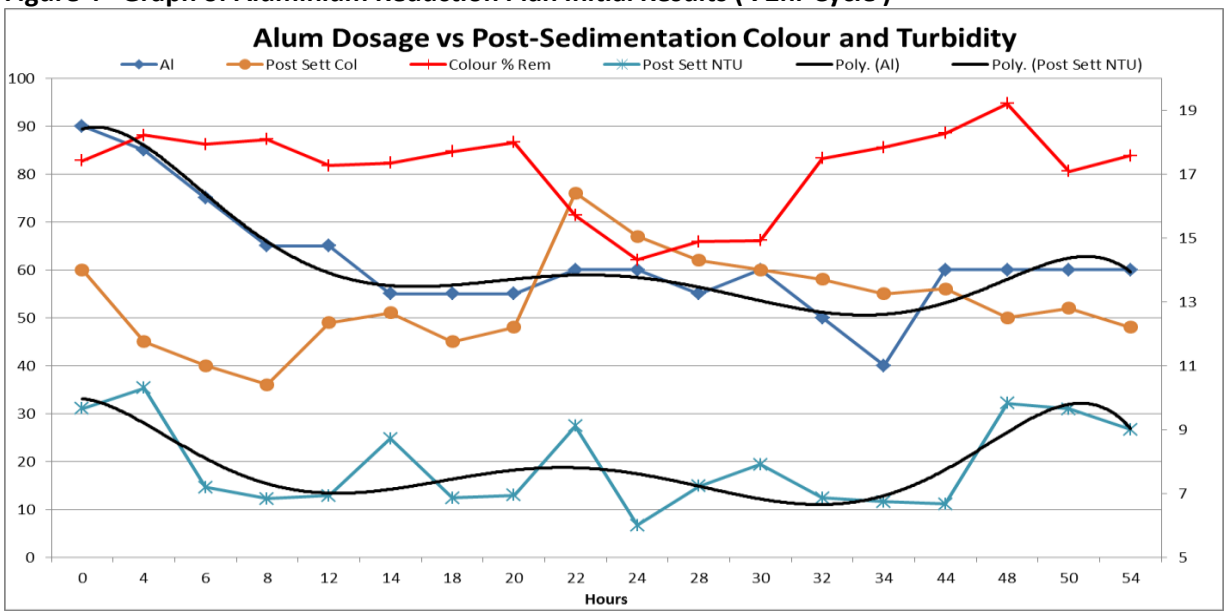
This is an important factor in reduction of operator workload and water quality maintenance.

Figure 3 - Graph of Aluminium Reduction Plan Initial Results (72hr Cycle)



Left Axis reflects: Alum Dosage, and Post Settling Colour
Right Axis reflects: Post Settling NTU, Post filtration Colour, and Post filtration NTU

Figure 4 - Graph of Aluminium Reduction Plan Initial Results (72hr Cycle)



Left Axis reflects: Colour % Removed, Aluminium Dosage, and Post Settling Colour Right Axis

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Note: 1.

Trend Lines (denoted as "Poly. ---") have been inserted to demonstrate the correlation between alum dosage and Post settling turbidity.

Note: 2.

Removal of Raw water colour is consistent despite huge variations in the Raw water colour. Percentage colour removal was used to compensate for the variation in raw water quality during this test, and shows remarkable consistency despite lack of compensation in chemical dosing.

Note: 3.

The Final Colour and Turbidity increased during the poor water quality period, but remained within acceptable limits despite no major chemical dosage adjustment– shown in Fig 3.

Conclusion:

With the water quality prevalent at the time of the investigation alum dosages of 60ppm Al2SO4-18H2O to 40ppm Al2SO4-18H2O gave the best performance and pH values below pH 6.5 appeared to be optimal.

For the balance of work done a pH range of pH6.2 to pH 6.4 and alum dosage of 60ppm was maintained (Hour 44 onward).

Although good results were obtained at 40ppm prudence indicated use of 60ppm to allow for poor water quality incidents.

4. **Colour Removal:**

Literature searches for work done on colour removal in waters with high humic organic matter, using alum as flocculent, indicated that optimal colour removal could be achieved at lower sedimentation pH values and that best results had been achieved between pH 5.6 and pH 5.8. A short test was performed using EMAWS Tech activated water and with adjusted pH values to determine if the lower pH values were beneficial, however at pH values below pH6 post-settling turbidity and colour both increased and the test was stopped in order to maintain final water quality.

Conclusion:

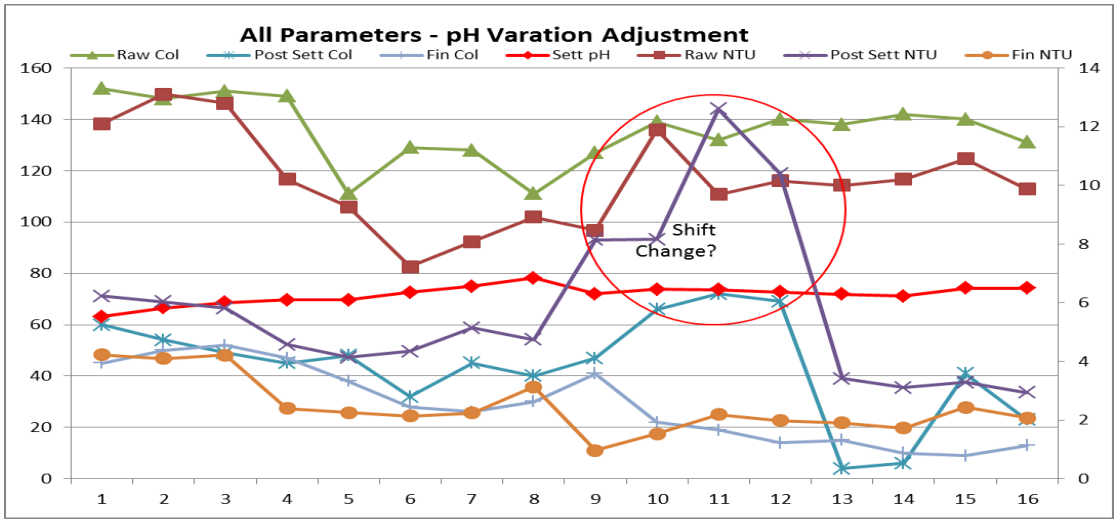
The pH range between pH 6.2 and pH 6.5, as determined below, shows superior performance to lower pH values.

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5. Initial pH Adjustment

An initial trial to determine the effect of reduction in pH, and find an optimum pH for operation, was carried out. pH adjustment began at pH 5.5 and was continued to pH 6.8, and then decreased to pH6.2; and again up to pH 6.5 to verify optimal pH operating range.

Figure 5 - Graph of pH Adjustment Results (72hr Cycle)



Left Axis reflects: Raw Colour, Final Colour, and Post Settling Colour
Right Axis reflects: Raw NTU, Post Settling NTU, Settling pH, and Final NTU

Note:

There was a major step change in post-sedimentation results at the beginning and end of one shift without direct proportional changes in other parameters that has led to this portion of the data being regarded as highly questionable.

Dotted trend lines have been added in Fig 6 to demonstrate the expected effect of exclusion of the questionable results.
Figure 6 - Graph of pH Adjustment Results (72hr Cycle)

Left Axis reflects: Post Settling Colour

Right Axis reflects: Settling pH, and Post filtration NTU

Despite the questionable post-sedimentation data, the data for final water showed clear trends related to the pH adjustment.

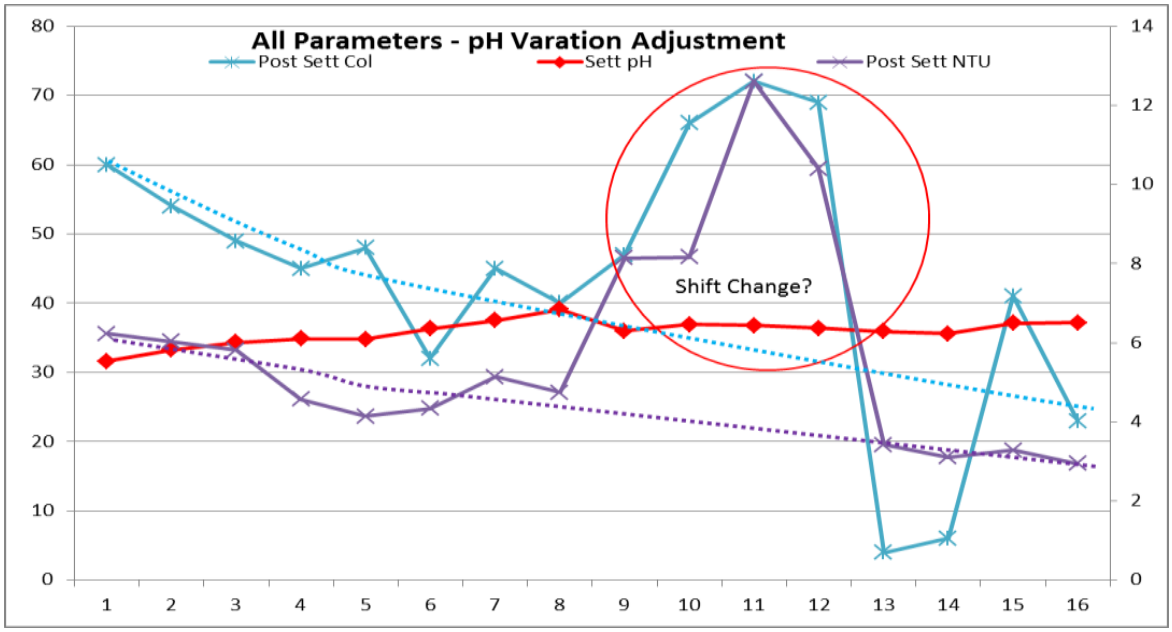
With best performance at the crossover point of the two trend lines, and representing the pH range pH 6.2 to pH 6.4.

Conclusion: Acceptable results were in the range of pH 6.2 to pH 6.5 and an optimum operating range of

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pH6.2 to pH 6.4 was chosen for further work.

Figure 6 - Graph of pH Adjustment Results (72 hr Cycle)



Left Axis reflects: Post Settling Colour
Right Axis reflects: Settling pH, and Post filtration NTU

Despite the questionable post-sedimentation data, the data for final water showed clear trends related to the pH adjustment.

With best performance at the crossover point of the two trend lines, and representing the pH range pH 6.2 to pH 6.4.

Conclusion:

Acceptable results were in the range of pH 6.2 to pH 6.5 and an optimum operating range of pH6.2 to pH 6.4 was chosen for further work.

Repeat pH Adjustment

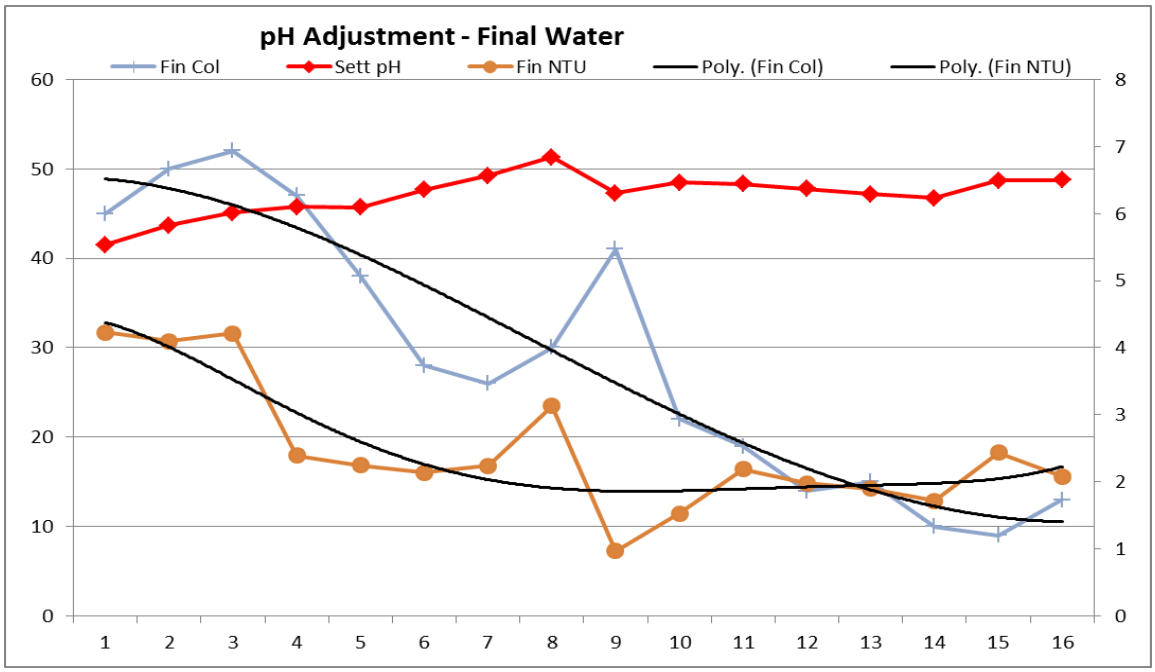
A repeat of the above was attempted, Fig 7, but this test was terminated due to inconsistent flow affecting settling tank control parameters resulting in poor flocculation and settling.

However, once again the data confirmed that the previously determined optimum pH range gave best results.

During on-going work and observation optimal pH was confirmed to be between pH 6.2 and pH 6.5 by observation with reduced post-sedimentation turbidity in general being lower in the range pH 6.2 to pH 6.4.

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Figure 7 - Graph of pH Adjustment Results

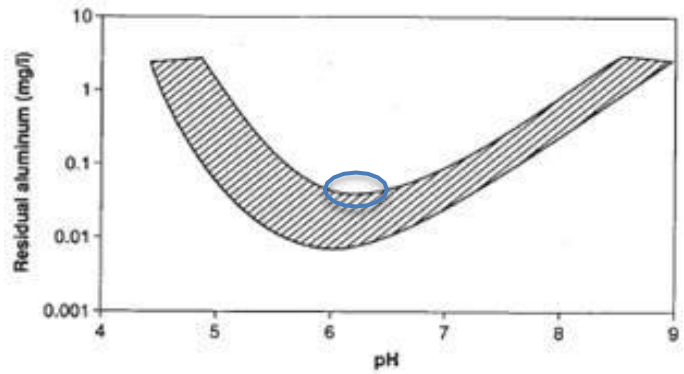


Left Axis reflects: Final Colour
Right Axis reflects: Settling pH, and Final NTU

6. Residual Aluminium Control

From literature the residual aluminium concentration on treated water post-sedimentation is accepted to be represented by the curve shown below (extracted from IWA report) and it appears from data collected that the Rûensveld water would approximate the curvature of the upper portion of the shaded area. This concurs with the data collected above and the decision to continue the investigation in the pH 6.2 to pH 6.4 range.

Figure 8 – Aluminium Solubility in Water Treatment Processes



Alum Dosing Accuracy

During the initial phase of this work it was noted that the previously installed alum dosing system was introducing substantial variations in dosing and that this often was detrimental to the maintenance of optimum conditions in the settling tanks. In order to maintain consistency for this

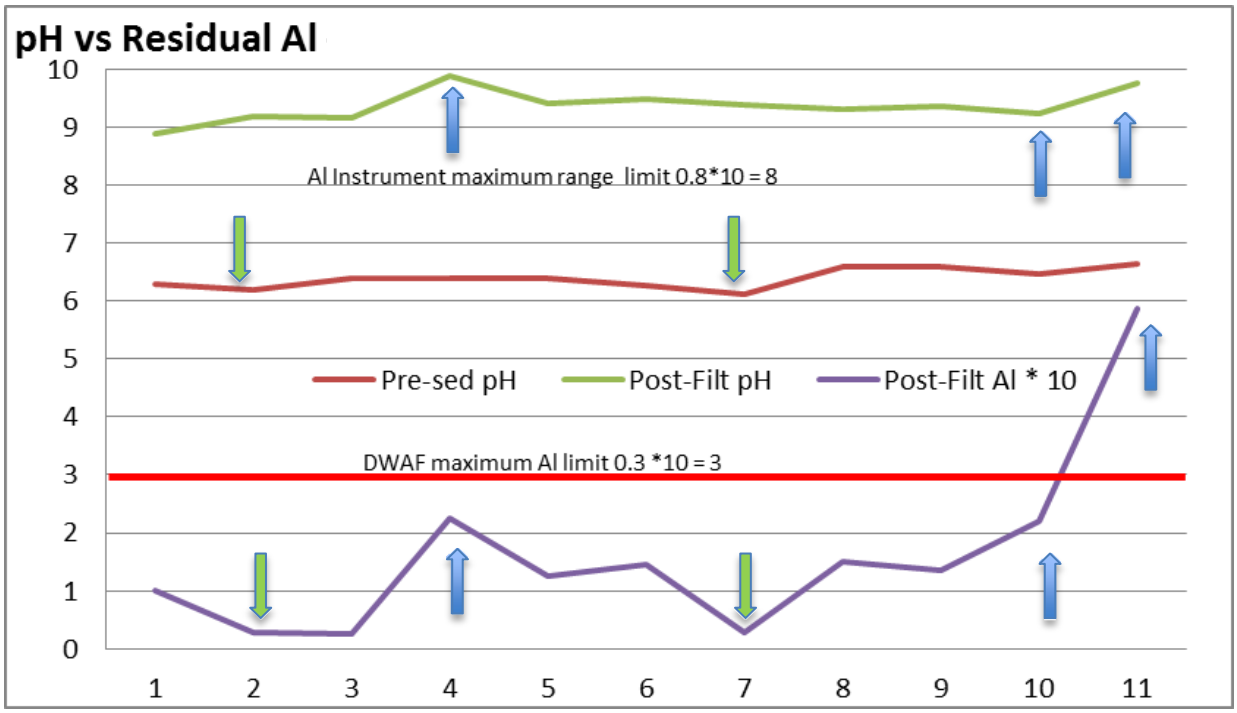
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period a new mechanical system was installed with the aim of reducing human error, need for operator intervention and errors related to the feed from the storage tanks.
The pump was calibrated and conversion factors supplied to the OW staff, who quickly adapted to operating the system. General comment from OW staff is of approval for the simplicity, accuracy and ease of operation compared to the previously used method.

Residual Aluminium Control (with membrane plant off)
In order to reduce the potential for post-settling aluminium carryover alum dosage was reduced to within the range previously determined to achieve efficient flocculation and sedimentation, while maintaining efficient colour removal and acceptable post-sedimentation turbidity. During initial investigations, after installation of the HCA™ unit this had been determined to be between 40mg/l and 50mg/l for general operation, however during periods when highly coloured water was received then an increase to 60mg/l or 70mg/l (as opposed to the 80mg/l to 120 mg/l previously used) may be required to ensure efficient colour removal. In order to confirm these initial results a short test was carried out with alum dosage at 60mg/l.
Post-filtration Al was monitored in preference to final water as it had been noted that final water is sampled after the reservoir and contains progressively diluted water from previous hours and may be contaminated with accumulated sludge residues from the reservoir.

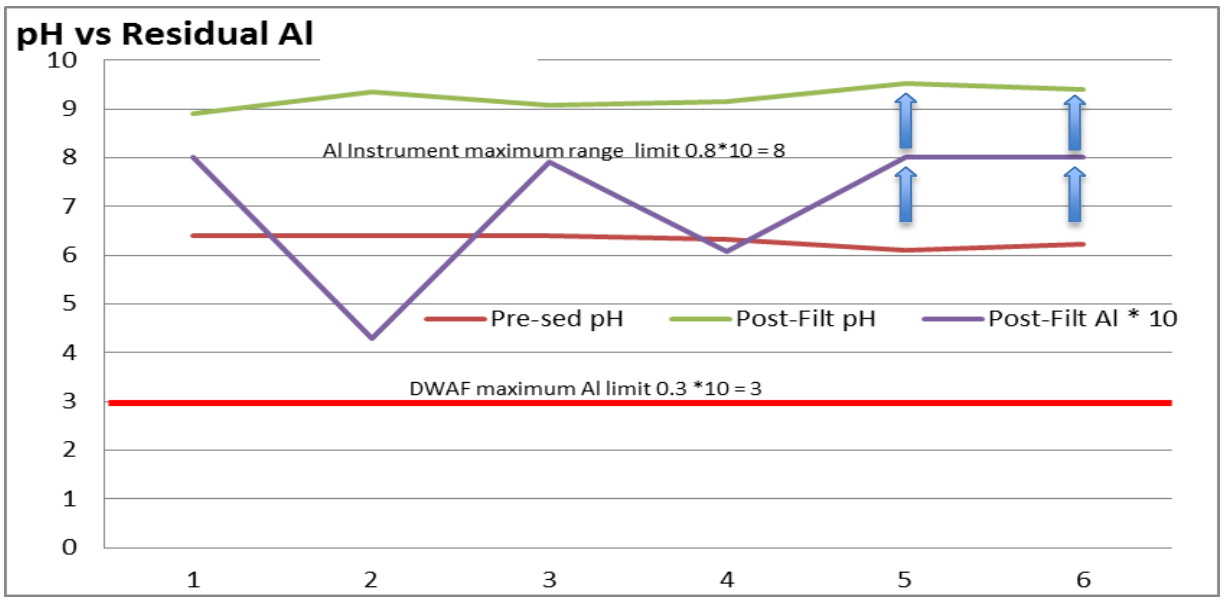
Post Filtration residual Aluminium vs pH in Post Filtration Water (Membrane plant off)
The data collected clearly demonstrates the EMAWS effective reduction of residual aluminium to within acceptable standards during this test period (Fig 9) as opposed to the levels measured with the EMAWS system switched off (Fig 10) where measurements were above the DAWF limit.
Note that large increases in post-sedimentation pH (lime dosage) show an increase in residual aluminium (Blue arrows) and reduction shows a decrease (Green Arrows).

Figure 9 – Residual Post-filtration Aluminium vs pH – with EMAWS



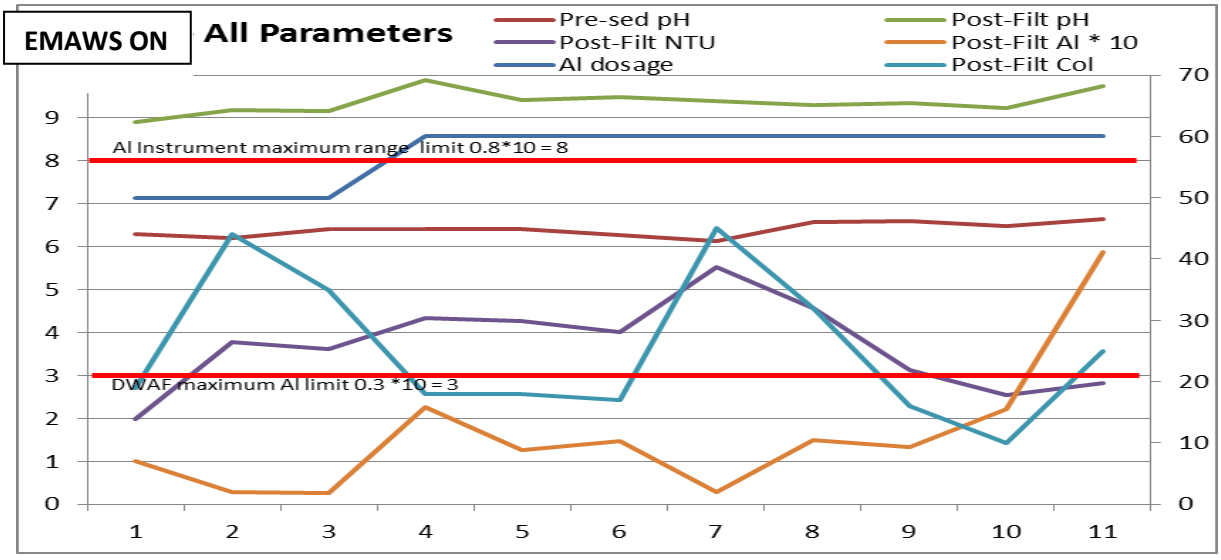
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Figure 10 – Residual Post-filtration Aluminium vs pH – without EMAWS Tech



Post Filtration All Parameters vs pH in Post Filtration Water (Membrane plant off)
During this period residual post filtration Aluminium (Light Brown line) as low as 0.028, 0.028, 0.026 and 0.048 were measured at four hour intervals while the plant was operating within prescribed parameters.(I.e. between pH6.2 and pH6.5 with alum dosage of 50mg/l and 60mg/l), and Post-sedimentation lime was reduced as the membrane plant was not operational.
The other basic parameters also were within acceptable limits when the pH was within the chosen range.as shown on Fig 11 and Fig 12 below.

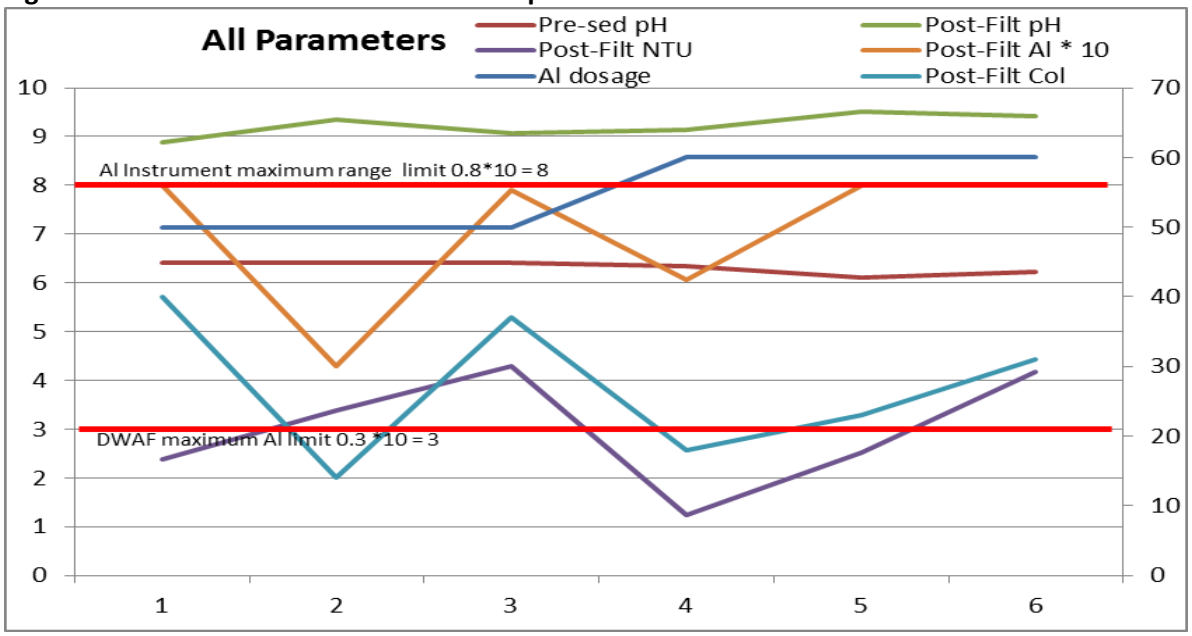
Figure 11 – Residual Post-filtration Data vs pH



Left Axis reflects: Post-filtration pH, Pre-sedimentation pH and Post-filtration NTU
Right Axis reflects: Alum Dosage, Post-filtration Colour and Post-filtration Aluminium concentration X 10

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Figure 12 – Residual Post-filtration Data vs pH – without EMAWS

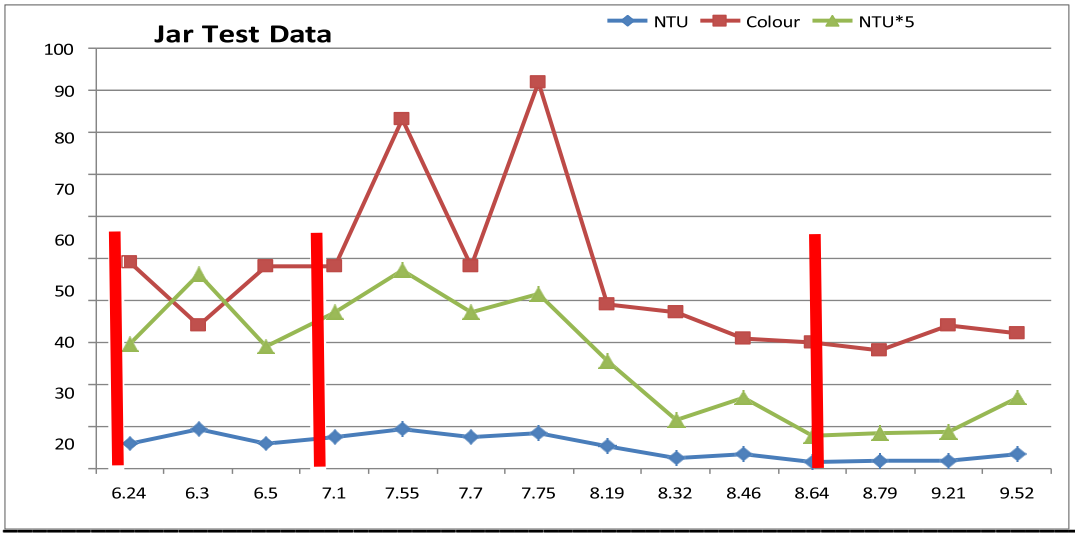


Left Axis reflects: Post-filtration pH, Pre-sedimentation pH and Post-filtration NTU
Right Axis reflects: Alum Dosage, Post-filtration Colour and Post-filtration Aluminium concentration X 10
Conclusion: EMAWS Technology improves aluminium removal to within SANS241 limits.

Pre-Sedimentation pH Adjustment Options to Reduce Post-Sedimentation Lime Requirement
Having witnessed the effect of post-sedimentation lime on residual aluminium concentration it was decided to determine if increasing the pH of the pre-sedimentation water was an option to allow for a decrease in post-sedimentation lime dosage, to remove lime based aluminium during sedimentation.

A series of jar tests were carried out to establish the effect using colour and turbidity as indicators of potential process efficiency at a variety of pH values.

Figure 13 – Jar Test Data vs pH – with EMAWS Tech



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While the turbidity and colour results indicated some promise at alternative pH values (indicated by red lines) the residual aluminium in post sedimentation samples increased to well above acceptable values when the pre-sedimentation pH was above pH 6.7.

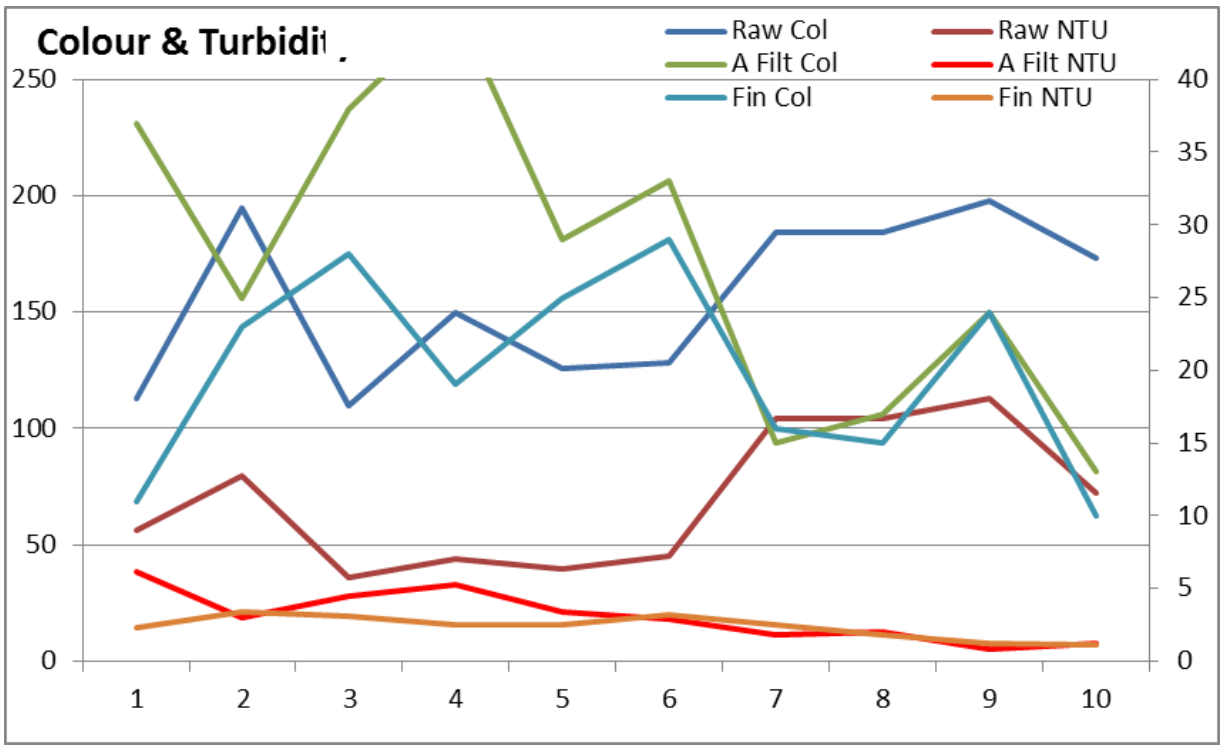
This avenue for reduction in post-sedimentation lime dosage was considered not viable and the investigation was discontinued.

7. Detailed Study of Optimised Conditions for Colour, Turbidity and Aluminium Removal (with Membrane plant operating)

Having examined the previous data it was decided to collect one set of representative data that could be used to compare all results at the chosen operational range between pH 6.2 and pH 6.4 and at a fixed alum dosage of 60mg/l.

Colour and Turbidity HCA effects

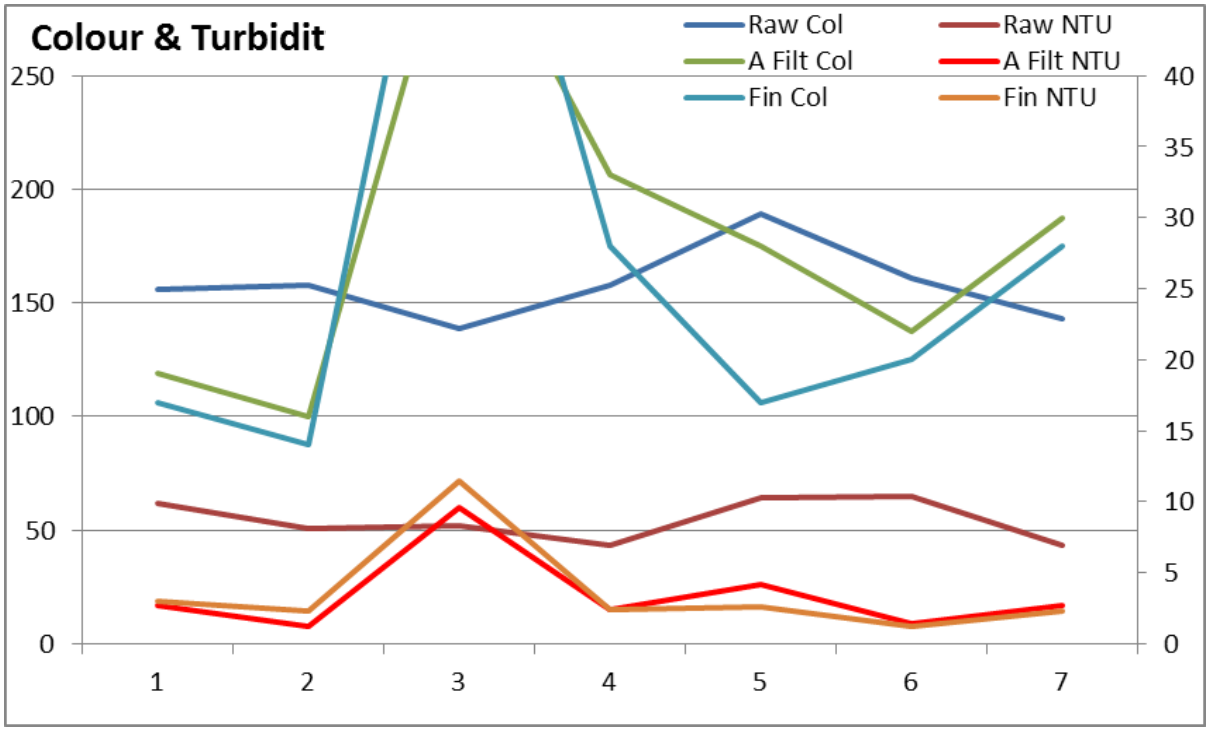
Figure 14 – Residual Post-filtration Data with EMAWS Technology on



Left Axis reflects: Raw Colour
Right Axis reflects: After Filter Colour, Final Colour, Raw NTU, After Filters NTU and Final NTU

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Figure 15 – Residual Post-filtration Data vs pH – without EMAWS Technology



Left Axis reflects: Raw Colour

Right Axis reflects: After Filter Colour, Final Colour, Raw NTU, After Filters NTU and Final NTU

Note 1: During this test colour and turbidity increased dramatically in the raw water of both periods, but colour of the "HCA™" treated water increased to almost double that during the HCA Off period.

Note 2: Raw Colour is plotted against the axis on the left in order to preserve scale on other parameters. All other parameters are plotted against the scale on the right.

The instability in raw water quality during this test is thought to be representative of normal diurnal fluctuations experienced in raw water quality at this treatment plant.

Stability of process parameters displayed in the post-settling turbidity and colour and those in the final water quality are typical of the improved flocculation and settling observed during initial work done at this site.

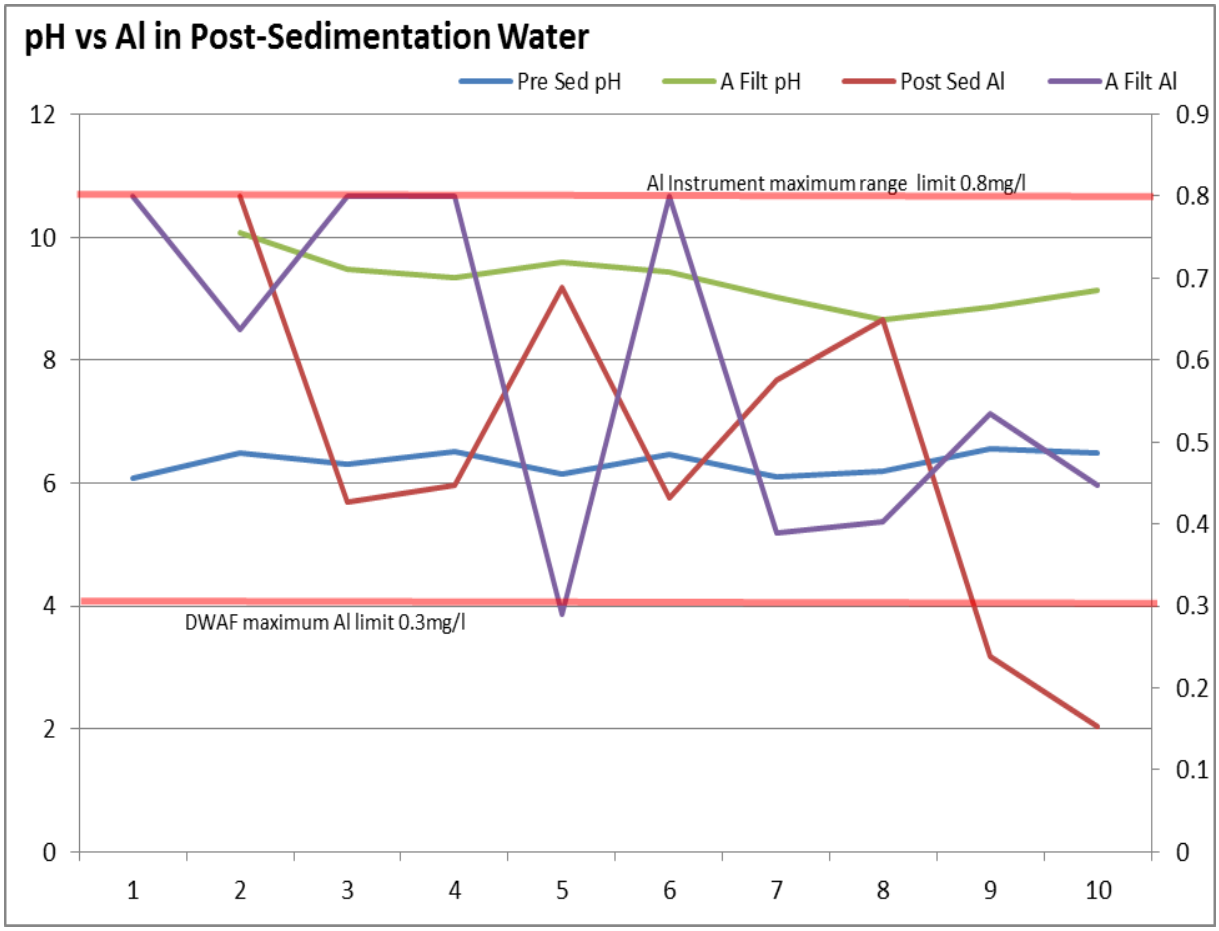
The post-filtration colour and turbidity (Green and Red lines) on both sets of data show a large increase at around point 3 and 4 due to change in raw water quality, but the data from the water receiving HCA™ treatment the increase is much lower than that using the "conventional treatment. This stability and improvement in colour and turbidity reduction with EMAWS Tech is reflected in the final water parameters (light blue and brown) where both parameters remain close to, or within, SANS241 limits; as opposed to the non-treated water which mostly exceeds the limits.

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Conclusion: EMAWS Technology treatment improves colour and turbidity in post-sedimentation and post- filtration water, even when increased post-sedimentation pH adjustment is used.

Aluminium Reduction HCA™ Effects vs pH

Figure 16 – Residual Post-filtration Data vs pH – with EMAWS Tech



It was anticipated that during this work the previous short test data (Fig 9 & Fig 10) would be confirmed, however it was noted that aluminium removal performance was erratic and that previously achieved efficiencies could not be duplicated and SANS 241 limit was only achieved on one occasion.

There was no correlation to pre-sedimentation pH, or to post sedimentation lime dosage, to pH adjustment.

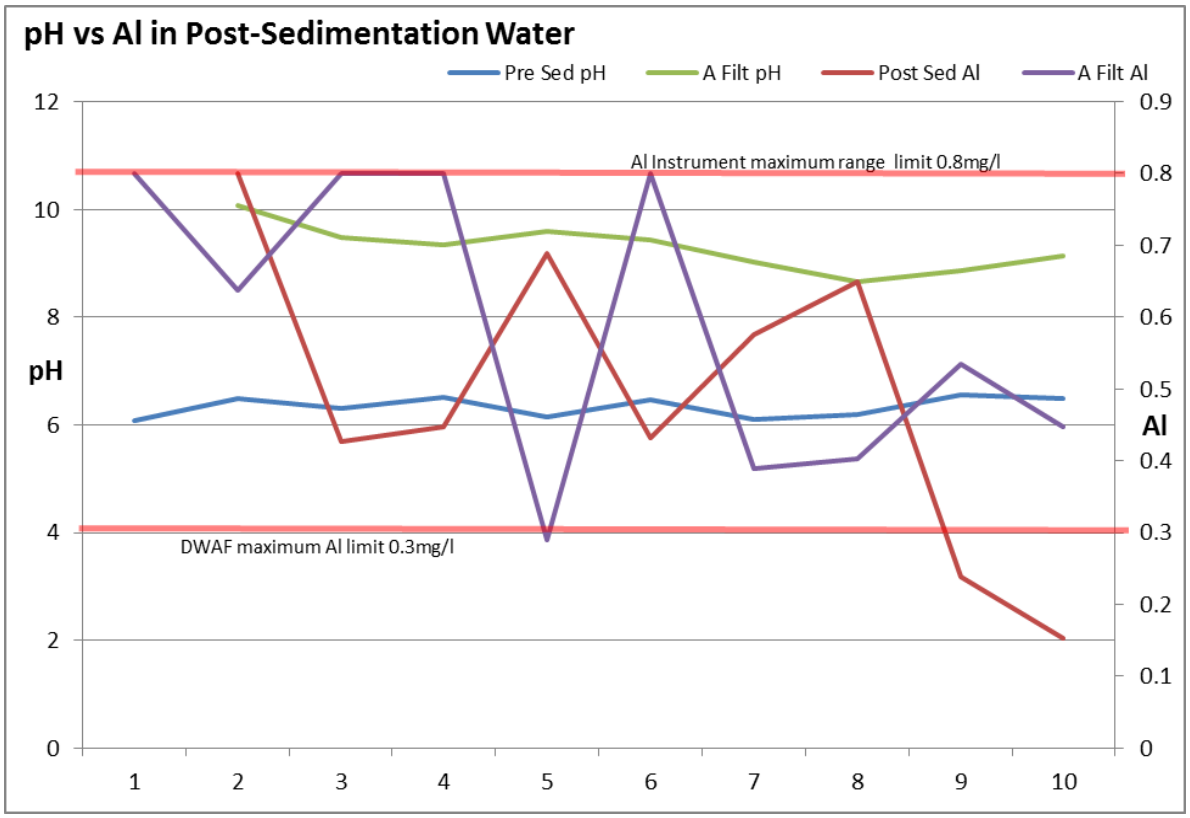
(During the point 9 and 10 period an anomaly occurred, where the plant operator erroneously increased alum dosage to 263mg/l for that period.

Despite this extremely high alum dosage the post-sedimentation and post-filtration aluminium concentration remained low.

This demonstrates the efficiency of EMAWS Tech in promoting flocculation and removal of aluminium from the process during sedimentation.)

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Figure 17 – Residual Post-filtration Data vs pH – with EMAWS Tech



Once again the water without HCA™ treatment showed higher residual aluminium in both post-sedimentation and post-filtration water, and both exceeded the instrument maximum capability limit for aluminium determination on a number of occasions.

As with the data in Fig 11 and Fig 12 there was no apparent correlation between pH and residual aluminium concentration, however the only parameter in the entire treatment process that was significantly different, from the conditions when data was collected for Fig 8 and Fig 9, was that lime dosage to correct post-sedimentation pH had been significantly increased to compensate for the low pH of the final water produced by the membrane plant.

Post-sedimentation Lime (pH adjustment) effect on Post-filtration Aluminium Concentration
In order to assess the effect of post-sedimentation pH adjustment to higher pH values a number of samples were analysed for aluminium at both sample points.

Where large increases in aluminium were found in post-filtration samples over post-sedimentation samples the difference was calculated and found to be 0.337mg/l in HCA™ treated water, and 0.452mg/l in water without HCA™ treatment, on average.

A laboratory test was performed where five samples' pH was adjusted by adding "lime water" from the plant dosing systems to adjust the pH to pH 9.5 and the increase in aluminium concentration varied between 0.4mg/l and 0.5mg/l, confirming that the lime being added to the process was contaminated with aluminium.

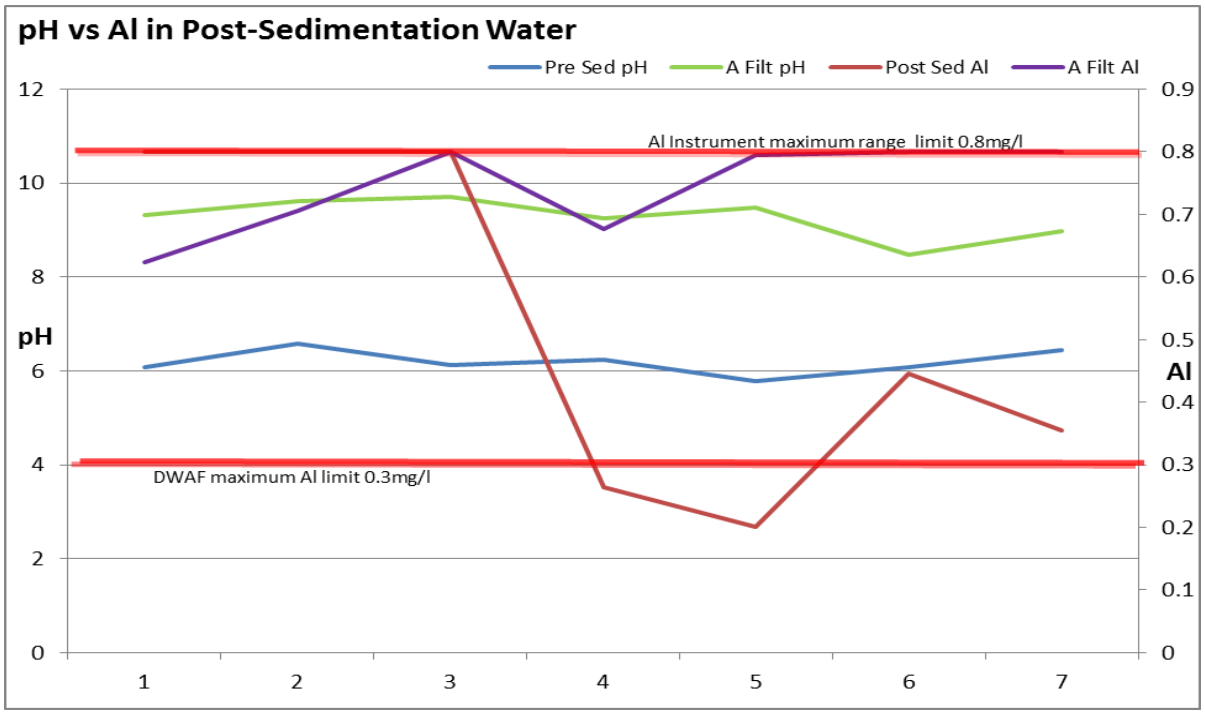
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It is thought to be unlikely that this aluminium, if added after sedimentation process to adjust pH, will be removed during filtration.

By observation it was noted that the difference in aluminium contamination in the post sedimentation water varied when plant conditions were stable. This variation is presumed to be due to variations in aluminium concentration between bags of lime that are added to the dosing station equipment one bag at a time, as and when the lime level in the dosing equipment becomes low.

In an attempt to verify the assumption that higher post-sedimentation lime dosage was responsible for aluminium contamination it was theorised that the difference in pre-sedimentation pH and post-filtration pH would bear some relationship to the differences in aluminium in the same samples.

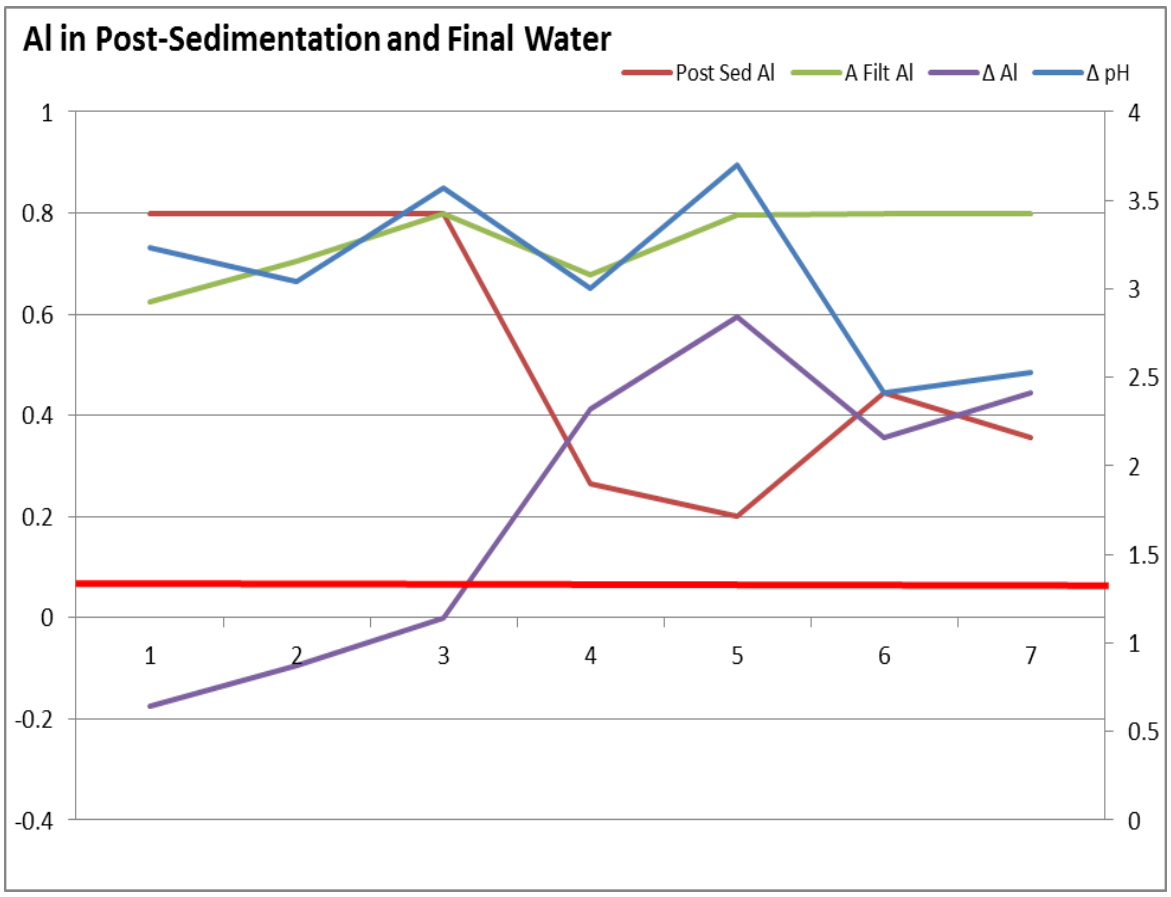
Figure 18 – Post-sedimentation and Post-filtration Al without EMAWS Tech



Only a small inverse correlation could be statistically determined on EMAWS treated samples.

Figure 19 – Post-sedimentation and Post-filtration Al without EMAWS Technology

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Samples with no EMAWS treatment showed no statistical correlation.

Conclusion:
It was thus concluded that the observed aluminium contamination level of the lime varied unpredictably, although there was a net general increase in the aluminium concentration in post-filtration water due to the pH adjustment after sedimentation.

Additional Benefits

8. Residual Chlorine Enhancement Effect

OW routinely dose Calcium Hypochlorite to their reservoirs to ensure adequate residual chlorine for water sanitation at the consumption points along their supply pipelines.

The increased effective chlorine provided by conversion of chloride and from dissociation of water molecules in the EMAWS treated water is expected to improve the stability and sanitisation of water during the residence time in the distribution network.

In order to establish if this was in fact so samples were taken at selected points along the pipelines as shown on the map below.

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Samples were taken prior to chlorine being dosed and were expected to have very low, if any, residual chlorine.

Residual Chlorine Results

Sample Point	GPS Coordinates	Free l mg/l	Total Cl mg/l
Rûensveld East	34˚ 04.586S 20˚ 14.725E	1.0	1.0
Reservoir 1	34˚ 07.754S 20˚ 18.068E	0.26	0.21
Protem	34˚ 16.113S 20˚ 04.630E	0.03	0.11
487A (Central 3)	34˚ 27.994S 20˚ 05.699E	0.20	0.34
178A (BC9.2)	34˚ 25.027S 20˚14.321E	0.08	0.21

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Some Residual Chlorine was evident at all points on the route, however the lower figures at "Protem" and at "178A" are thought to be due to these points being at extremes of the lines.

Low consumption due to the heavy rainfall experienced in this period is likely to have reduced normal consumption and consequent flow to these points, resulting in the residence time in the pipelines being increased and flushing of previously treated water to be incomplete.

The treatment of final water with EMAWS Tech shows a high chlorine dosage equivalent effect immediately after treatment, as evidenced by the picture below where a "DPD" tablet was added to a sample taken before chlorine dosing.

This effect is due to the active oxygen in the EMAWS Tech treated samples and improves sanitisation by maintaining effective treatment over an extended period, compared to the usual chlorine treatment.

It is expected that this will enable reduction in chlorine dosage and reduce THM formation in the final water.

9. SANS241 Validation

Samples were taken of the "Final Water" at the plant over a three day period to verify if SANS241 compliance could be achieved.
Due to the dramatic increase in residual Aluminium as a result of post-settling pH adjustment, the post-settling lime dosage was reduced, or stopped, during these sampling periods as can be seen by the final water pH values.
Laboratory results from independent certified laboratories have been appended.

Laboratory results obtained at Rûensveld East for the samples taken

Time	Number	Alum Dosage mg/l	Pre-sedimentation pH	Final Turbidity NTU	Final Colour °Hazen	Final Al mg/l	Final pH
20h00	Raw		6.76	29.8	245		
23h30	Fin-26	75	6.39	1.30	0	0.334	8.99
10h00	Raw		6.98	25.6	199		
10h30	Fin-28	80	6.50	0.98	0	0.147	8.25
06h00	Raw		6.98	22.7	204		
07h00	Fin-29/1	80	6.47	0.99	0	0.098	7.13
12h00	Raw		6.68	20.7	189		
13h00	Fin-29/2	80	6.55	0.81	0	0.181	8.91

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It must be noted that during this period large variations in lime quality were noted between different bags of lime.

On one occasion the pre-settling pH changed from pH6.5 to pH5.5 when a new bag of lime was added, with no adjustment having been made to dosing equipment.

Large variations in residual Al were also evident due to variations in post-settling lime dosage for pH adjustment, however this was thought to be beyond the scope of work for this exercise and a full investigation will be required to verify these observations.

As can be seen from the Raw water colour and pH results there were also large variations in water quality, which was generally exceedingly poor, due to heavy rains experienced during this period.

Conclusion:

On all but one occasion (sample "Fin-26) compliance with the SANS241 limit of 0.3mg/l was achieved.

10. THM Formation Reduction

It was expected that THM formation would be reduced as a result of the improved efficiency of removal of organic material during sedimentation and the oxidation of residual organic material in the final water.

This was demonstrated during normal operation.

CSIR Analysis – With EMAWS Technology

THM Type	Raw	Final	Post - Filtration
Bromodichloromethane µg/l	**2**	**41**	**1**
Bromoform µg/l	**<1**	**2**	**<1**
Chloroform µg/l	**2**	**43**	**2**
Dibromochloromethane µg/l	**<1**	**2**	**<1**

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CSIR Analysis – With EMAWS 3 Months Later

THM Type	Raw	Final	Raw	Final
Total Organic Carbon * mg/l C	N/A	5.4	N/A	5.0
Bromodichloromethane µg/l	<1	<1	<1	<1
Bromoform µg/l	<1	<1	<1	<1
Chloroform µg/l	<1	<1	<1	<1
Dibromochloromethane µg/l	<1	<1	<1	<1

However the extremely high colour and related organic carbon loading experienced during the high rainfall period in October demonstrated that while EMAWS Tech does reduce THM formation under normal operational circumstances, it may reduce them under extreme circumstances but will not entirely prevent formation.

It should also be noted that at this time chlorine dosage had been reduced from a dosage of 2.8mgl in July to 2.5mgl in October as a result of the residual oxygen effect of the EMAWS Tech, indicating that THM formation may have been even higher if previous dosage rates had been maintained.

CSIR Analysis – With EMAWS Tech

THM Type	Final	Final	Final
Total Organic Carbon * mg/l C	**6**	**5**	**5**
Bromodichloromethane µg/l	**52**	**29**	**28**
Bromoform µg/l	**27**	**34**	**32**
Chloroform µg/l	**25**	**10**	**10**

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11. Pressurised EMAWS Treatment Validation

During initial testing of the EMAWS Tech equipment, performed by OW staff, it was reported that at high flow rates, where direct pumping pressure was applied in the electrode cells, improved sedimentation and clarification was evident. In order to assess if this was in fact so a short test was conducted with the aim of verifying these observations.

During the test an Eskom power failure was experienced for 6 hours, on the second day, which stopped testing and then required a waiting period to ensure that the process had stabilised.

As stabilisation was achieved raw water quality changed dramatically, and suddenly, due to a suspected pollution incident and provided very poor quality water.

Six hours was allowed for stabilization of the process once parameters had been adjusted for the change in water quality, and testing was resumed.

Throughout the test Final Water quality remained good, testifying to the improved flocculation and sedimentation previously observed, despite the variations and complex nature of the water resulting from the pollution incident.

Alum dosage was increased slightly during the incident to ensure colour and turbidity removal for final water quality. pH of the final water varied as post-sedimentation lime dosage was adjusted to attempt to maintain the pH within the pH8.8 to pH9.0 for the final water, and this once again influenced residual aluminium concentration.

Colour and turbidity removal was acceptable during this period, considering the Raw Water quality, but the dosing of post-sedimentation lime once again increased the aluminium in the final water to above the 0.3mg/l specification.

Date	Time	Sample	Alum Dose mg/l	Turbidity NTU	Colour ºH	pH pre-sed final	Aluminium mg/l
07/11	18h00	Raw		164	16.6	6.30	
		Final	75	0.32	0	8.60	0.460
	22h00	Raw		21.6	188	6.5	N/A
		Final	65	0.92	0	9.10	0.530
08/11	02h00	Raw		13.5	133	7.0	N/A
		Final	70	0.54	0	8.80	0.520
	04h00	Raw		9.50	123	6.8	N/A
		Final	70	1.00	0	9.16	0.560

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Under the circumstances of this test the results achieved were exceptional, particularly during the pollution incident, and final water quality was maintained. Although the residual aluminium concentration was above the limit it was better than expected, given the circumstances at the time.

Conclusion: As previously observed the higher operating pressure appears to have had a beneficial effect on the treatment process when using EMAWS Tech to assist water clarification.



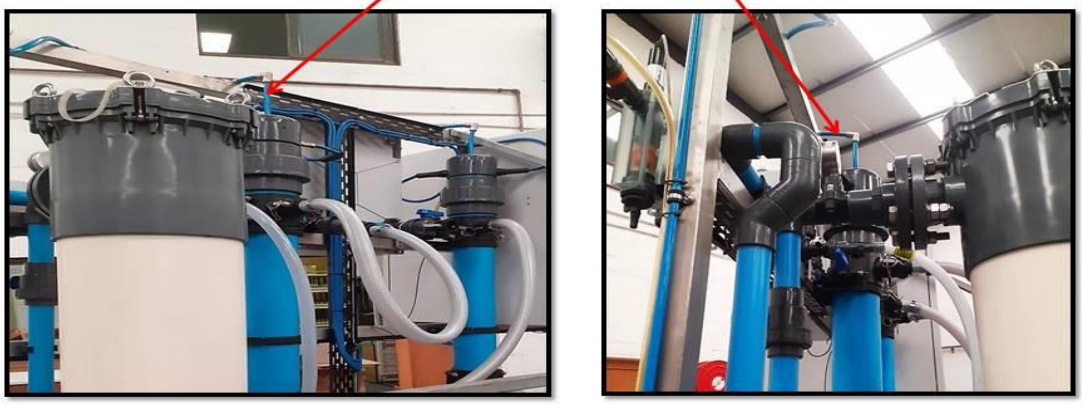
NB

The Hydrogen Chemical-free Disinfection

(Chemical-free – No Chlorine Required for Disinfection of the Treated Water)

Hydrogen is released when , with the EMAWS Technology, **the Water Molecules are split into Oxygen and Hydrogen Molecules by the Electrodes**. After this process, the Hydrogen is released out through a Pipe at the Top of the Electrode Unit Housing/Cap, **and re-routed back into the Water where it is effectively used in the Disinfection Process of the EMAWS Treated Water**

The Hydrogen Outlet Pipe — **From the Electrodes Cap**



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