SIMPLE SOLUTIONS TO MANGANESE PROBLEMS

Paper Presented by :

Jeff Roscoe

Author:

Jeff Roscoe, *Plant Operator,*

North East Region Water Authority

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ABSTRACT

Soluble manganese (Mn) in potable water supplies disinfected with strong oxidants such as free chlorine causes dirty black water, which in turn causes staining and damage to consumer-clothing, linen, goods etc. Tests performed at different sites using PACl and Alum, produced results that indicated PACl provided better Mn removal than Alum where 95% removal was achieved compared to 0%. In water with low levels of Mn, the management of Mn can be an option by using weaker oxidising disinfectants such as chloramines, which can be used in place of more radical oxidants such as free chlorine.

KEY WORDS

Mn (Manganese), NEW (North East Water), PACl (polyaluminium chlorohydrate)

1.0 INTRODUCTION

Benalla, Tungamah and St. James are towns supplied water from water treatment plant's (WTP) operated by North East Water (NEW). These towns have from time to time been affected by black water events, which along with health issues causes staining. Reticulation flushing is required which increases plant operational costs, whilst NEW incurs dry cleaning and sometimes replacement costs for damaged or stained goods. Also consumer confidence in the safety of the water and the Authority is diminished. Tests on raw water taken at Tungamah, St. James and Benalla indicated levels of total soluble manganese above the guideline level of 0.1mg/L. Mn is removed at different places using varied processes and treatments such as aeration, chemical oxidation, coagulation / flocculation and filtration and management of low Mn levels is sometimes an option. This paper looks at a range of simple solutions NEW trialed to solve the manganese problems encountered at the NEW sites mentioned above.

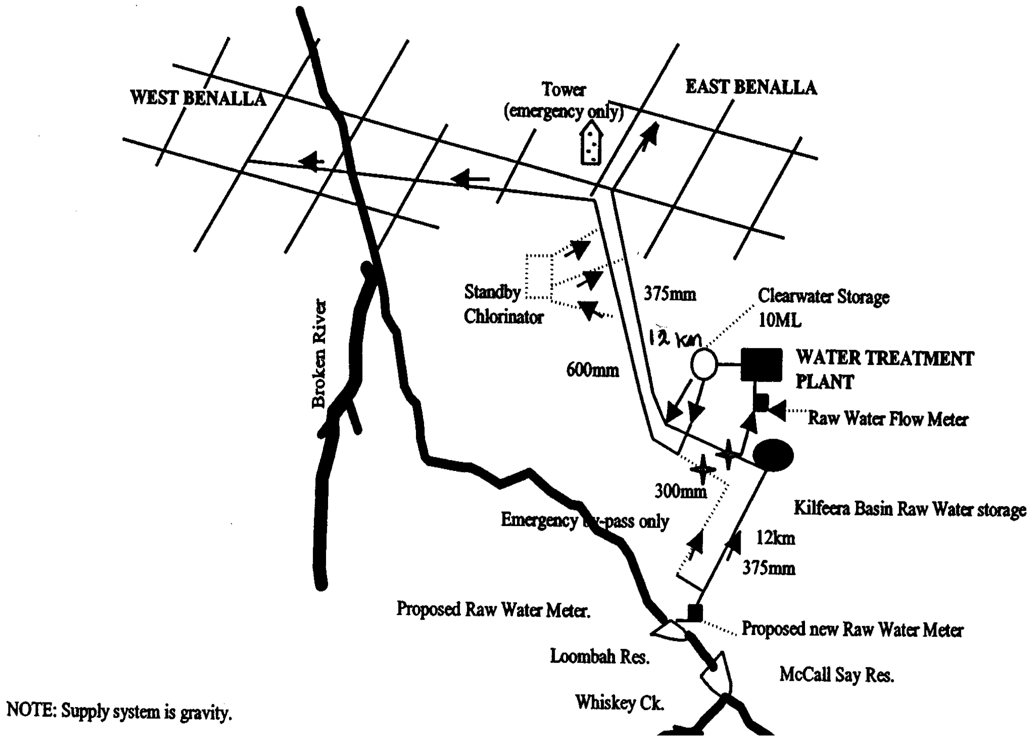
2.0 BACKGROUND

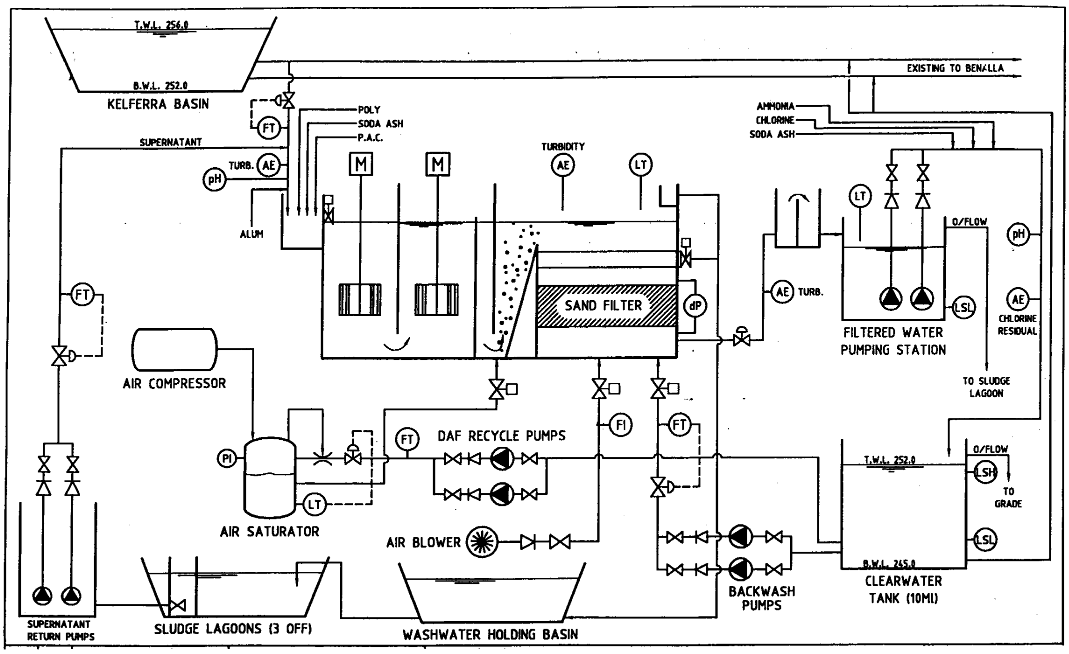
2.1 Benalla water supply

The township of Benalla was until Christmas 1998 supplied with unprocessed water with an average turbidity of 5 NTU from a closed catchment and a settling dam system. The only chemical treatment was disinfection using chlorine gas with a minimum contact time of 35 minutes during peak demands. December 1998 saw the commissioning of a 19 ML per day capacity Dissolved Air Floatation – Filtration(DAFF) water treatment plant, located approximately 12 kilometres south of the town. The plant uses liquid alum as the coagulant, LT20 polymer as the flocculation aid, and soda ash for pre and post pH correction. The filtered water is disinfected using chlorine gas dosed to provide a residual of 0.2-0.5 mg/L. Also on site are provision for powder activated carbon, potassium permanganate and aqueous ammonia treatment.

Figure 1: ***Benalla water supply and treatment process***

BENALLA

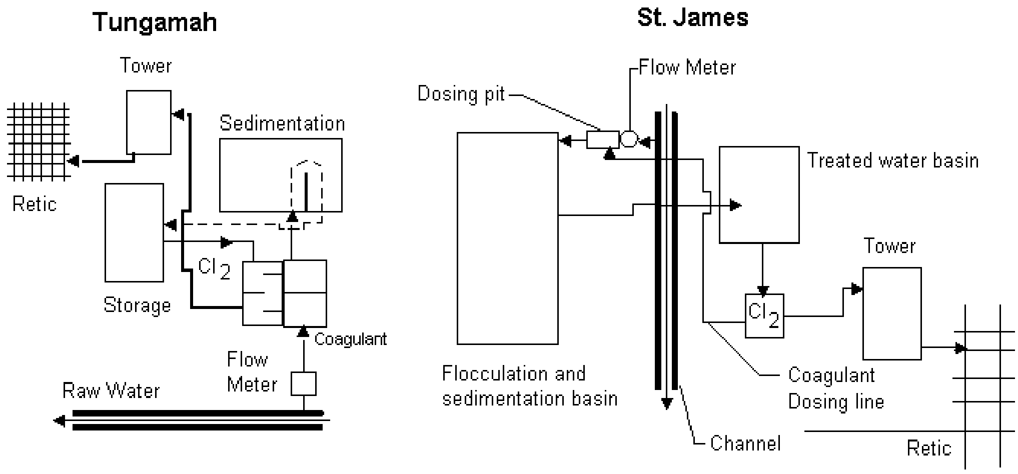




Tungamah and St. James are small isolated towns that are supplied water from a stock and domestic channel during the irrigation periods. On site storage dams suffice during the closed irrigation period.

The raw water, which has an average turbidity of 70 NTU but can reach levels of 400 NTU, is chemically treated with liquid alum batched to 50 % w/w from dry powdered alum. It is then settled in a 3 ML storage basin before being transferred to a similar sized basin for storage and further chemical treatment, such as pH correction and disinfection on it's way to the reticulation via a tower.

Figure 2: ***Tungamah and St. James water supplies***



3.0 DISCOVERY OF MANGANESE ISSUES

During October 1999 after just ten months of operation since the commissioning of the new DAFF plant, daily consumption increased in Benalla from 2.5 ML per day to 8 ML per day within a two-week period with the onset of warmer weather. This tripling of demand in such a short time frame discoloured the reticulation water which in turn made the phones light up with complaints multiplied by the publics belief that because the new treatment plant was believed by the consumers to prevent these black water events and rightly so. The sharp increase in demand scoured oxidised deposits of manganese off the walls of the 12 kilometre pipelines that feed the Benalla reticulation.

It was soon determined that even though the maximum total soluble manganese levels reached during the summer period were only 0.1 mg/L and 0.05 mg/L during the winter period. Long detention times, up to 3 days and disinfecting using chlorine to achieve free chlorine residuals was causing the build up of the manganese deposits during the lower demand periods.

Tungamah and St. James were experiencing increasing incidents of manganese related, back water events in their reticulations. Once again, because of the build up of oxidised manganese deposits in the pipelines as a result of the effect of disinfecting with chlorine gas to achieve free chlorine residuals, the ensuing customer complaints triggered an ongoing regime of weekly flushing in an attempt to clean the system and supply acceptable water

Table 1: ***Average raw water characteristics***

Location	Turbidity NTU	pH	True Color Pt/Co	Alkalinity mg/L	Total Soluble Manganese Mg/L	Total Iron mg/L

Benalla	5	6.9	35	15	0.08	1.0
Tungamah	70	7.4	40	50	0.10	1.5
St. James	70	7.4	40	50	0.10	1.5

Table 2: *Average treated water characteristics - pre improvements*

Location	Turbidity NTU	pH	True Color Pt/Co	Alkalinity mg/L	Total Soluble Manganese mg/L	Total Iron mg/L
Benalla	0.1	7	0	25	0.08	0
Tungamah	0.3	7	15	45	0.10	0
St. James	0.3	7	15	45	0.10	0

Table 3: *Jar test results using alum (unfiltered) and pH corrected with soda ash*

Analysis	Units	Benalla 19 mg/L	Tungamah 25 mg/L	St. James 25mg/L
Turbidity	NTU	0.3	0.4	0.4
Color	mg/L Co/Plt	0	0	0
Alkalinity	mg/L $CaCO_3$	20	50	50
Iron	mg/L Fe	0	0	0
Manganese	mg/L Mn	0.08	0.10	0.10
pH		7	7	7
Aluminium	mg/L Al	0	0	0

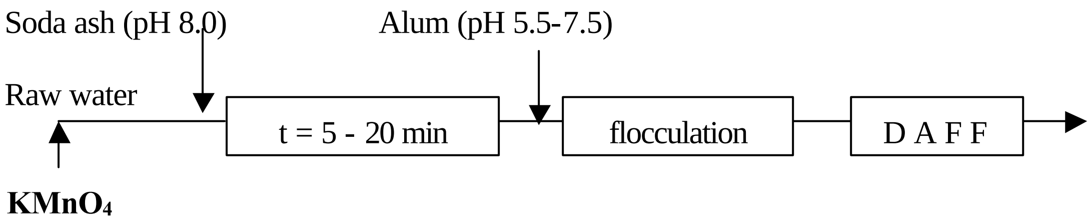
4.0 SOLUTIONS TO MANGANESE PROBLEMS INVESTIGATED

Initial brainstorming by a group consisting of the immediate operators, the treatment coordinator, the treatment manager and some external liaisons such as the Water Industry Training Centre covered a range of potential solutions reported in literature and included, optimising the current coagulant and aids, pre-treatment with potassium permanganate, the trial of alternative coagulants and finally detention times and current and alternative disinfection treatments and processes.

4.1 Potassium permanganate trial at Benalla

After jar testing revealed that optimising the existing coagulant, oxidant and pH variations would not reduce the manganese concentration in the treated water at Benalla WTP potassium permanganate was introduced as a pre-treatment to oxidise the soluble manganese. Figure 3 below shows the theoretical way to oxidise the manganese using potassium permanganate. Also given is a range of pH levels and approximate times needed for the oxidation and the flocculation stages.

Figure 3: ***Theoretical permanganate dosing for manganese removal***



Potassium permanganate oxidises soluble manganese (**Mn^{2+}**) to manganese dioxide (**MnO_2**) as shown in the reaction.

$$2\,KMnO_4 + 3\,Mn^{2+} + 2H_2O \rightarrow 5\,MnO_2 + 2K^+ + 2H^+$$

The detention times changed with the characteristics of the water but in general the higher the pH the quicker the reaction.

Permanganate dosing was applied at the Benalla WTP with poor results. The configuration of the WTP meant that the permanganate was being dosed at the same time as the Alum, giving no time for the permanganate to oxidise manganese before coagulation. It was found necessary to increase the pH to almost 8.5 to achieve manganese oxidation but this pH level was too high for the liquid alum to flocculate optimally. It was concluded that potassium permanganate would not be a solution unless major capital works in the form of an oxidisation contact tank were installed. Other solutions to Benalla's problems were sought.

4.2 Disinfection changes at Benalla

During the manganese incidents in Benalla, low free chlorine residuals were being encountered at the extremities of the reticulation especially during low demand periods. A decision was made after the necessary community and business consultation, to change our disinfection process to chloramination in an attempt to achieve more persistent residuals. The resultant change of disinfection methods not only produced stabilised and longer lasting residuals but the use of the less radical chloramine disinfectant did not oxidise the manganese and cause the dreaded manganese deposits, even in long detention times. The manganese stayed in soluble form and didn't appear to build up in pipe biofilms. It also has to be said that during extended low demand periods, the treated water storage levels are lowered in the 10 ML storage tank to reduce detention times and maintain total chlorine residuals but it also helps maintain low heterotrophic plate counts, which need to be managed when dealing with chloraminated water held longer than 72 hours.

4.3 Polyaluminium Chlorohydrate Coagulant Trials

Jar testing using a range of different coagulants on Tungamah and St James raw water in a separate project designed to assess alternative coagulants revealed a most unexpected result. It was found that PACl provided better Mn removal than Alum where up to 95% removal was achieved opposed to little or no removal using alum. Once this discovery was made, PACl was also jar tested successfully for removing manganese from Benalla's raw water, and manganese test results were reviewed at the Moyhu WTP where PACl had been in use for 12 months.

Table 4: ***Jar test results using PACl***

Analysis	Units	Benalla 4 mg/L	Tungamah 25 mg/L	St. James 25mg/L	Moyhu 3 mg/L
Turbidity	NTU	0.1	0.3	0.3	0.25
Color	mg/L Co/Plt	5	5	5	10
Alkalinity	mg/L $CaCO_3$	15	40	40	15
Iron	mg/L Fe	0	0	0	0
Manganese	mg/L Mn	0.05	0.01	0.01	0.03
pH		6.8	7	7	6.9
Aluminium	mg/L Al	0	0	0	0

Table 4 above shows at optimum doses of PACl, good removal of iron and manganese is achieved with minimal affect on alkalinity, which in turn helps, maintain a good pH level.

Based on these results, Tungamah was converted to a PACl coagulant plant. Collected ongoing data from this site since changing to PACl as a coagulant shows consistent lowering to acceptable levels of manganese and in turn occurrences of black water events in the reticulation have been eliminated. Since changing coagulant to PACl the frequency of flushing the reticulation has now been lowered to 3 monthly for turbidity reasons (no filtration) rather than for managing the old manganese issues. St. James is in the process of changing over to PACl as a coagulant.

Table 5: *Average treated water characteristics - post improvements*

Location	Turbidity NTU	pH	True Color Pt/Co	Alkalinity mg/L	Total Soluble Manganese mg/L	Total Iron mg/L
Benalla	0.1	7	0	25	0.08	0
Tungamah	1	7	10	45	0.02	0
St. James	1	7	10	45	0.02	0

It is unclear how PACl manages to remove manganese from these raw waters. The chemical make up of PACl - $Al_2(OH)_nCl_{6-n}$ would provide some chlorine to oxidise the Mn (not huge amounts but maybe enough to kick the reactions along a bit). More in-depth research needs to be done to confirm exactly how PACl removes manganese.

Another benefit that arose from the change of coagulant was that the pH correction process required when using liquid alum was no longer necessary which in turn reduced associated chemical and labor costs and storage and handling issues etc.

5.0 CONCLUSIONS

It was found in jar tests and real scale trials that PACl was an efficient means of manganese removal in the raw waters of St James and Tungamah. Mn removal rates were found to be up to 95% better using PACl in comparison to Alum. The raw water quality of Benalla did not show the same Mn removal rates as when PACl was applied to the raw water at St James and Tungamah, which leads us to believe that the increased turbidity also plays some role in causing the Mn to be bound in the floc.

This caused two different approaches to be used when assessing the issues, where Benalla was viewed in a more control and management sense rather than one of forced removal of Mn as was the case in Tungamah and St James. Since the changes to the plants have been made all towns are now consistently well below the guideline value for Manganese of 0.1 mg/L and black water complaints are now a thing of the past.

6.0 ACKNOWLEDGEMENTS

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7.0 REFERENCES

Water Industry Training Centre – Manganese report (2000)
Mike Leak – Treatment Manager NEW
Mark Samblebe – Treatment specialist NEW