THE FUTURE IN WATER TREATMENT – AN SA WATER PERSPECTIVE

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EXECUTIVE SUMMARY

Adelaide's water quality has been the subject of adverse media comment in regard to taste and odour for years. At times, algal taste and odours are evident due to the majority of water being sourced from the River Murray plus reservoirs in the Adelaide Hills – a primary agricultural area. Further, customers complain about chlorinous taste and odour in the distribution systems. Despite all reticulated water being treated by conventional processes, the high dissolved organic carbon (DOC) requires high coagulant doses and increases the chlorine decay rate which necessitates a higher dose (or doses) of chlorine to maintain a residual.

Any future deliberations on treatment processes to improve taste and odour would, following the Sydney water crisis, be expanded to include removal of *Cryptosporidium* and *Giardia* although the present risk is considered quite low for these protozoa. Supplies to most metropolitan areas are filtered therefore any process changes have to be retrofitted to existing operating plants.

Further, an holistic view which encompasses a 'source water – consumer' scope is essential. This includes catchment management, reservoir management, treatment processes and distribution system management.

To address the issues, a matrix was constructed which indicated the degree of effectiveness of the many process combinations and possible management strategies against the range of parameters selected.
From this, the strategies which, from SA Water's perspective have merit are:

- Reservoir management - complete the Cooperative Research Centre for Water Quality and Treatment (CRC) hybrid destratification research and development
- Treatment process - preferred process train is Magnetic Ion Exchange Process (MIEX®), microfiltration (immersed) and GAC filtration (in existing sand filters) utilising the existing infrastructure to the optimum degree
- Distribution system - extensive mains cleaning program required to gain maximum benefit from the previous strategies.

(catchment management is not included at this stage as any actions are very long term)

Of note is the innovative treatment process combination which is unique and which represents the future direction for water treatment.

- MIEX® - this process will remove the majority of DOC which is the major problem – causing parameter in Adelaide's source water
- Microfiltration - MF will efficiently remove almost all particulates, including *Cryptosporidum* and *Giardia*
- GAC filtration - with a much reduced organic load, will remove taste and odour, synthetic organic chemicals (SOC's) and generally 'polish' the water

This process train has many advantages:

- no chemicals are dosed into the water being treated (fluoride and chlorine will be added in low doses prior to distribution);
- following on, no solid residuals (sludge) or dissolved residuals (aluminium, disinfection by-products, monomers) are formed. There are reject streams from the MIEX® process, and the microfiltration units and GAC will generate backwash streams but these are relatively minor; and
- it can be retrofitted into the existing infrastructure more readily than other process combinations evaluated.

In the opinion of SA Water the process 'train' discussed which is essentially chemical free, residual free and environmentally friendly is the future direction for water treatment.

KEY WORDS

water, organics, retrofit, MIEX®, microfiltration, ozone, GAC

INTRODUCTION

Any responsible water authority will always be sensitive to its customers and to the improvements in water quality that are expected in a modern community and which, in some countries, are covered by legislation.

The main complaints about Adelaide's filtered water relate to taste and odour which are predominantly of algal origin or related to chlorine. The tastes and odours of algal origin arise from algal activity in the source waters for Adelaide – the River Murray (and its tributaries) and the catchments in the Adelaide Hills which support horticultural and agricultural activities and numerous townships. They occur during the summer months and abate during winter.

The chlorinous odours stem from relatively high levels of chlorine applied to obtain an effective residual in the distal parts of the system. The dissolved organic carbon (DOC) level of Adelaide's source waters are comparatively high and exert a high chlorine demand which increases the decay rate and forms disinfection by products.

The continuous addition of powdered activated carbon in order to produce a pleasant tasting water would be operationally very expensive and granular activated carbon (GAC) on its own would not be economic due to the DOC content reducing the life and effectiveness of the filters.

Therefore, to reduce chlorinous taste and odour, the reduction of DOC was considered critical. Other parameters such as turbidity, colour, viruses, *Giardia* and *Cryptosporidium* were added to the list of important parameters to consider in any review of future options for improvements to Adelaide's water quality. The 'Sydney Water' incident brought these considerations into more focus and raised *Giardia* and *Cryptosporidium* control to a higher level of priority on the list of important parameters.

METHODOLOGY OF REVIEW

Methods of improving Adelaide's water were considered to require a source to customer focus including catchments, reservoirs, treatment plants and distribution system. The list of parameters which should form part of the assessment process was identified and this needed to be consistent with the Australian Drinking Water Guidelines (ADWG) using multi-barrier approach to contamination. The first exercise was the determination of the existing barriers against contamination by the identified parameters.

This exercise presented the first problem as few, if any barriers were 100% effective and many were less than 10% but to ascribe a 'percentage effective' figure was extremely difficult for many parameters and very subjective. The consensus was to have 3 levels; virtually 100%, 95% or better, and less than 95%. The result for some parameters included a number of 3rd level barriers, ie less than 95% - the obvious question was, how many of these add up to a 100% barrier?

An example of this matrix of parameters, barriers and barrier effectiveness is shown in Figure 1.

The second exercise was to determine in each of the physical zones – catchment, reservoir, treatment plant and distribution system, - the options available to SA Water to increase the barriers to 'contamination' thereby achieving improvements in some aspects of water quality.

a) Catchment Controls

These are the responsibility of the many newly formed Catchment Management Boards which are implementing many measures to improve raw water quality. However, the extent of improvement is limited and they will not be discernible for a long period. This can only be ascribed a 3rd level barrier at this time.

b) Reservoir Controls

Proposals to improve the control of algae primarily in the reservoirs rely on the current CRC research project on hybrid mixer-on-pontoon destratification system. This arrangement is intended to significantly reduce or eliminate the need for copper sulphate dosing. Although the expectations are very high at this early stage, a barrier 'less than 95%' can only be ascribed.

c) Treatment Plant Controls

This area is where the greatest barriers to contamination are possible and consequently where the most effort was placed.

In metropolitan Adelaide there are six water filtration plants varying in size between 50ML/d and 850ML/d utilising conventional sedimentation/rapid gravity filter technologies or dissolved-air flotation-filtration to suit the source water quality.

Any improvement processes had to be located upstream, downstream or integrated within the process train. At only two filtration plant locations is there sufficient room to replace the existing plant if that was necessary.

Various combinations of the following processes were assessed solely in terms of barrier efficiency in this stage.

- optimised PAC dosing – achieving a 30 minute detention @ 100mg/L PAC dose prior to coagulation
- full optimised coagulation – using acid and alum to achieve optimum DOC reduction
- MIEX® DOC reduction process – DOC reduction using a magnetic resin able to be regenerated
- modified improved sedimentation – high rate sedimentation in shortened sedimentation tank
- microfiltration – use of membranes with pore size 0.1 – 0.2 microns nominally
- nanofiltration – use of membranes with pore size 0.002 microns or less
- ozone/BAC – the combination of ozone dosing and biological activated carbon filtration
- GAC – Granular Activated Carbon filtration
- chloramination – the addition of ammonia and chlorine to form monochloramine
- 'Badenoch' type of filter improvements – includes filter ripening, filter to waste, slow start and other arrangements designed to reduce turbidity breakthrough
- backwash treatment - process to remove *Giardia* and *Cryptosporidium* prior to recycling of supernatant

The processes/contamination barrier matrix for six process combinations is shown in Figure 2. This matrix covers what was considered to be the minimum, ultimate and a number of mid-range process trains in terms of outcomes, and includes (in brackets).the *Giardia* and *Cryptosporidium* log removals of the full process.

Figure 2

OPTIONS	Existing	Option 1	Option 2	Option 3	Option 4	Option 5	Option 8			
PROCESS DETAILS	Plants With No Modifications	Ex Plant + Opt PAC + Opt Coag + MF of B/W Water	Ex Plant + Opt Coag + Ozone + GAC MF of B/W Water	MIEX + Coag + Assist Sed + Ex Filt (Badenoch) + Ozone + GAC MF of B/W Water	Opt Coag + Ex Sed + MF + GAC (ex Filters)	MIEX + MF + GAC (ex Filters)	Ex Plant + MF (pre-treat) + NF	Catchment Management	CRC Reservoir Destrat	Network Management
HEALTH										
General Micro	✓	✓	✓	✓	✓	✓	✓			✓
Viruses	✓	✓	✓	✓	✓	✓	✓			✓
Giardia (log removal)	✓	✓	✓	✓	✓	✓	✓			✓
Cryptosporidium (log removal)	✓ (2)	✓✓ (3)	✓ (4+)	✓ (4+)	✓ (6+)	✓ (6+)	✓ (10)			
Hepatotoxins	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Neurotoxins	✓	✓✓	✓	✓	✓✓	✓✓	✓	✓	✓	
SOC (Pesticides)	✓	✓✓	✓	✓	✓✓	✓✓	✓	✓		
Disinfection By Products	✓	✓	✓	✓	✓	✓	✓			✓
Metals (Cu, Pb,)	✓	✓	✓	✓	✓	✓	✓✓	✓		
Asbestos	✓	✓	✓	✓	✓	✓	✓			
AESTHETICS										
Taste & Odour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Turbidity/Colour	✓	✓	✓	✓	✓	✓	✓			✓
Fe & Mn	✓	✓	✓	✓	✓	✓	✓		✓	✓
Aluminium	✓	✓	✓	✓	✓	✓	✓			✓
TDS (<500 mg/l)							✓	✓		
DOC removal	✓	✓	✓	✓	✓	✓	✓			

Legend
- ✓ (shaded) Virtually 100% Removal
- ✓✓ Removal 95% or Better
- ✓ Partial Removal Depending on Many Factors (Before assessment, the risk should also be ascertained)

Four of these process trains were chosen to be included in the next stage. This stage reviewed how the processes could be retrofitted onto several plant sites and approximate order-of-cost estimates were developed. These four process trains were:
Minimum

- Enhanced PAC dosing
- Enhanced coagulation
- 'Badenoch' type filter modification plus microfiltration of backwash water

Ultimate

- Post nanofiltration

Addition of pre and post ozonation and post GAC to the existing processes

- MIEX® in existing infrastructure
- Modified sedimentation
- MF of backwash

Complete removal of the coagulation, flocculation, sedimentation and sand filtration process components (internals)

- Installation of MIEX®, immersed microfiltration and GAC filtration in the existing concrete tank infrastructure with the appropriate modifications

The minimum and the ultimate improvement are self explanatory and the differences both in efficiency and cost are similarly obvious. These serve to form the possible range of treatment costs and options.

However, the comparisons of treatment efficiencies and costs of Option 3 and Option 5 (as defined in Figure 2) are much more difficult to differentiate. Each has some advantages over the other and additional factors such as frequency of occurrences, degree of risk and the like were then considered. Ozone has obvious advantages in being able to destroy most known algal toxins and pesticides and breakdown natural organics enabling the GAC (or BAC) to adsorb these split compounds thus removing them from the water being treated.

Microfiltration (MF) will remove much more particulate matter and give greater assurances of the removal of *Cryptosporidium* such that monitoring and analyses for these organisms can be reduced. MF (in the immersed system) can also be retrofitted to the existing plants whereas ozone and GAC are new, additional processes.

These considerations, however, were not sufficient to separate these 2 optional process trains.

It was not until these process trains were further evaluated that a preferred option emerged.

The advantages of Option 3 which includes MIEX® , ozone and GAC filtration were seen as follows:

- the remaining DOC after MIEX® treatment is significantly reduced following ozonation and GAC (BAC) filtration. This process will produce a lower level of DOC than Option 5.
- Taste & Odour and toxin removal is better assured with the ozone/GAC process
- GAC effectiveness is extended due to the effect of the ozone dosing immediately upstream

However, the disadvantages, compared to Option 5 were also identified as follows:

- alum is still dosed, therefore aluminium residuals become an operating criteria and alum sludge will be produced with attendent disposal problems
- with the existing bromide levels of up to 1.5mg/L the generation of bromate – a known carcinogen – above the 25µg/L current ADWG value is likely
- lime, alum and ozone are hazardous chemicals (potentially fatal in the case of ozone) requiring strict OHS&W policies and practices.

The following were seen as significant advantages of the MIEX®-MF-GAC process combination;

- 6 log physical removal of *Cryptosporidium* and *Giardia*
- No chemicals are dosed into the water being processed (pre-distribution chlorine & fluoride excepted)
- Consequently:
  - no solids (sludge) is produced which is contaminated by metals – alum or ferric – or by polymers
  - no residuals are generated such as aluminium, bromate, polymer/monomer, aldehydes and other ozonated organics
- Fewer chemicals means significant reductions in chemical transportation, transfer, handling and dosing making the plants much less hazardous to both the employees and the neighbourhood.
- All these aspects make this process train much more environmentally friendly.
- This process train takes a big leap into the future and moves away from the traditional chemical reliance in water treatment.

It is however acknowledged that the MIEX® process uses a brine solution for resin regeneration with quantities of organic-brine mix to be removed from site and the MF units may need an occasional chemical clean. However these substances are both comparatively small in quantity and relatively innocuous in regard to their degree of hazard.

The disadvantages of Option 5, compared to Option 3 are itemised below:

- The DOC reduction relies on MIEX® and GAC and would not be quite as efficient as Option 3
- Taste, odour and toxin reduction relies on the GAC, however, with the high hopes of the CRC destratification project, the significance of this may not be critical.

Taking all of the above advantages and disadvantages into consideration it was considered that Option 5 would be the preferred water quality improvement and plant upgrade direction for metropolitan Adelaide.

d) Distribution System Controls

There would be little point in treating the water to the high quality which would be produced by the 'preferred' process train and distributing this water through the existing pipework without close attention being paid to identifying and controlling the factors that cause water quality deterioration in water networks.

With the existing high levels of organics in the reticulated water and the fact that towards the distal parts of the supply systems there is often little or no chlorine residuals, this provides for ideal conditions for the growth of biofilms.

These biofilms can affect the water quality in a number of ways including the turbidity and colour if dislodged during high flow periods, an increase in the bacterial plate counts which usually demands some action and the possible generation of taste and odour. Any of these events results in the customer not receiving the benefit of the high quality treated water.

There are a number of options which were included in the review to minimise distribution system problems once the treatment processes have been implemented such as:

- mains cleaning in specific areas such as:
  - dead end mains
  - mains which historically generate complaints
  - mains towards the ends of the systems
  - mains at interfaces between different supplies.

- network management techniques and systems interconnections to reduce detention times in tanks, promote more even flow distribution and provide for security of supply to all areas possible should a problem occur in a plant.
- Strategically located booster chlorination stations located in the networks to provide for a lower but more consistent chlorine residual level throughout the distribution system
- monitoring reassessment would be necessary to ensure that the water quality desired from the implementation of all the actions from source to customer meter were actually delivered. This also includes the need for a taste and odour panel to regularly assess the organoleptic properties as this was one of the major areas of complaint and prompted the review in the first place.

Again, none of these measures can be assessed as being any more effective than 'less than 95%' in terms of a barrier to contamination and this is shown in Figure 2.

CONCLUSIONS

A review of the water quality requirements which SA Water might consider in a program for improving the water quality received by its customers in Adelaide has been undertaken.

Using a source-to-customer and multi-barrier approach the four physical areas of catchment, reservoir, treatment and distribution, have been considered.

At this stage the most improvements in the quickest time are to be gained from the actions nominated in treatment and distribution.

The treatment processes review was particularly significant when the 'no chemical, environmentally friendly' process train installed in the existing infrastructure emerged almost by accident. SA Water consider this approach is the direction for the future in water treatment.

The need to perform works in the distribution system to ensure that the benefits of the new treatment process are seen, and tasted, by the customers, cannot be understated.

ACKNOWLEDGMENTS

- J Caporn, Executive General Manager Water Industry & Business Development, SA Water, the sponsor of the review
- Chris Bosher, United Water, who took part in the review, particularly in relation to the ozonation alternatives
- N Priestly – US Filter (now Vivendi Water) for his assistance with the microfiltration aspects.

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