RURAL SHOWDOWN: MEMBRANES VS CONVENTIONAL

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ABSTRACT

Membrane plants have been commonplace throughout the world and in New Zealand for many years and large metropolitan city councils have been implementing them with confidence. However, the majority of smaller rural councils continue to utilize traditional coagulation, filtration and sedimentation process streams for drinking water.

As the cost of membrane replacement comes down, and the drinking water quality standards increase, membrane plants are becoming a feasible and achievable option for smaller rural councils. This paper discusses the specific advantages that membranes can provide over conventional coagulation/sedimentation/filtration for smaller rural councils. Smaller rural councils have very different sources, supply requirements and operational requirements from large urban councils, and yet they must both comply with the New Zealand Drinking Water Standards.

Some of the advantages that will be looked at are; increased autonomy, lower operator attendance, not relying on chemical coagulation for solids removal, ease of construction and lower volumes of chemical usage.

A number of case studies and examples will be looked at around New Zealand, showing how a well set up membrane plant can greatly increase the security of supply to the region and the efficiency of the operators.

KEYWORDS

Membranes, Rural Councils, Implementation Issues, Small Membrane Plants

1 INTRODUCTION

Sand filtration is an extremely established process for drinking water treatment, with documented use in ancient Greek times dating back to 4,000 BC. Coagulation is also a very traditional treatment process, with rudimentary coagulation depicted by the Egyptians as far back as 1,500 BC. In comparison, membrane technology is still considered as “new” technology by some. Uptake of membrane technology has been successful by various small councils around New Zealand; however, majority of water treatment plants (WTP) throughout the country remain conventional filtration plants.

Since membrane filtration was first introduced to the market in the 1980’s, the cost of membrane installation cost per kL/day has been continually decreasing (as illustrated in Figure 1). This trend increases the feasibility and cost effectiveness of small membrane plants for small councils.

Membrane suppliers now offer small turnkey package membrane plants which can essentially be supplied and installed in a shipping container. Membrane plants can be sized to any capacity and are capable of treating a wide range of water quality, particularly when combined with pre-treatment such as clarification.

Historically there has been some aversion to replacing conventional filtration treatment plants with membrane plants. Councils are generally risk averse and membranes were often perceived as having higher operational risk arising from complexity. It is likely that at least one employee in larger councils has experience with membrane technology, which can aid in dispelling this mindset. With smaller councils there is a high possibility that the operators and district engineers have no previous experience with membrane plants. This can lead to the perception that conventional plants are “simple and robust” technology, as they are what the council has been operating with for many decades, and membranes as a complex and unnecessary installation. Discussions with council as well as completing optioneering, cost benefit analysis and developing net present value (NPV) models can dispel many of the perceived risks and challenges associated with membrane technology.

There is the possibility that membrane technology may be the most appropriate option for a WTP upgrade, depending on the raw water quality and plant's constraints. Small rural councils should be encouraged to consider membrane technology as a treatment option, along with any other appropriate treatment processes, to ensure they receive the most cost effective and robust plant to meet their requirements.

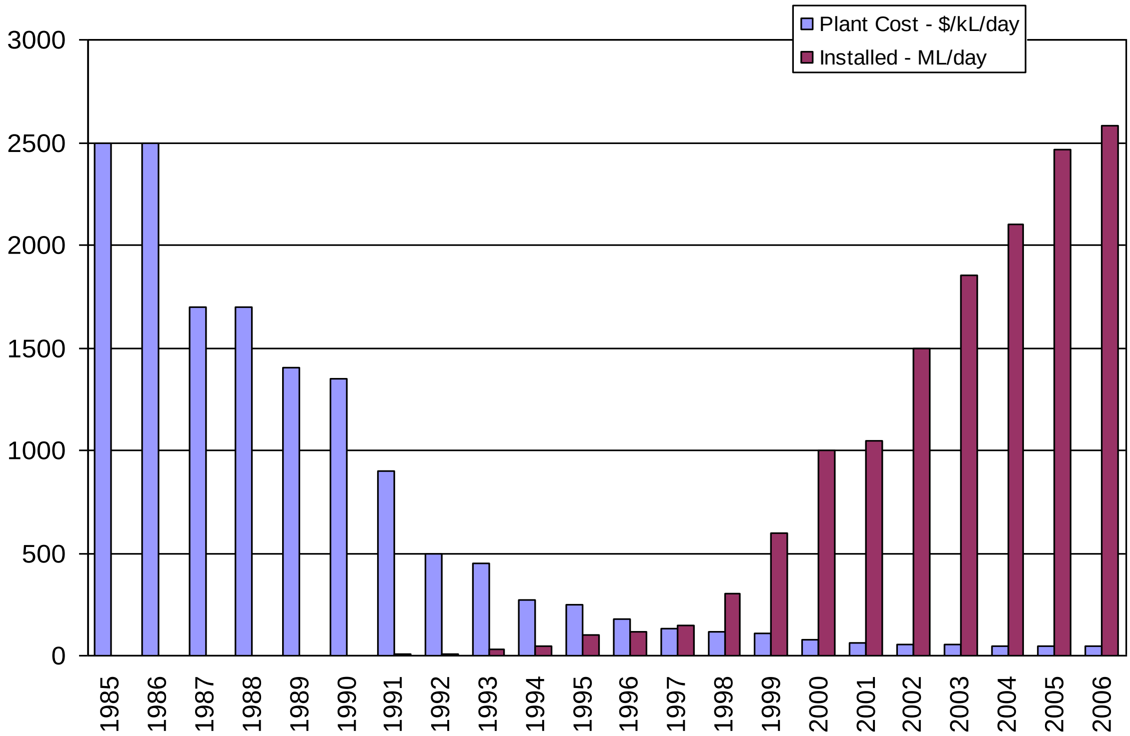

Figure 1: Plant cost and installed membrane capacity of Memcor membranes[1].

2 CHALLENGES FOR SMALL RURAL COUNCILS

Some of the challenges faced by small rural councils, and not necessarily experienced to the same extent by larger urban councils. These include the following challenges:

- High usage for small populations;
- Larger geographical areas of supply;
- Low capital budgets, and;
- Fewer operators and maintenance staff.

Rural councils tend to cover large areas and due to agricultural usage have a high water demand per rate payer. For example, Kerepehi WTP produces 12.5 million liters per day to supply only 5,000 people plus approximately 150,000 cows.

[1] Adapted from: Siemens Water Technologies; 2009; *Introduction to Memcor*.

Often rural councils spread over large geographical areas with significant distance between its regional WTPs. This increases the distance operators are required to travel between plants, hence monopolizing more of the operator attendance times.

Generally smaller rural councils tend to have fewer ratepayers and this may have a negative impact on the capital budget of their projects. Smaller budgets create a driver for very high value for money with any new installation or upgrade. There may not be sufficient budget to replace or change equipment following the installation if it does not perform as intended.

Small rural councils generally have fewer operators and they may have a narrower range of experience. Less monitoring and preventative maintenance is undertaken with less staff and this may result in the plant not operating at optimal performance.

3 NEW TECHNOLOGY

Small councils can be weary of being at the forefront of installing new technology. This often stems from the concern of being used as a trial prior to wider spread installation in larger plants. There is the perception that there is a high risk associated with equipment which has not been trialed and tested by others first. This has been endorsed by clients stating that do not want nor need “cutting-edge” technology.

Small rural council engineers have not necessarily had exposure to or experience with membranes, hence may be reluctant to commit to a full scale installation. Council engineers can attend site visits to existing plants operating with membrane systems and this can help to build confidence in the technology. Meeting with other owners and operators of similar sized plants operating with membrane installations can demonstrate the robustness and cost effectiveness of membrane technology in smaller scale WTP applications.

4 WATER QUALITY

It is commonly misconceived that membranes are a solution for metropolitan areas where the source water is of poor quality and the service expectations are high. On the contrary, membranes are capable of treating water with low solids loading as well as high. Low solids loading can often be an issue in rural applications, with the water source from a river with very low suspended solids content. The conventional sand filtration treatment process relies on solids removal through coagulation. This can be an issue if the solids loading is too low and hence there is less collision area to expedite the chemical reaction. Generally conventional plants require visual monitoring to ensure the coagulant dose is correct.

Quite often the coagulant and polyelectrolyte doses are manually raised by the operator during a high turbidity event. Occasionally these dose rates are not returned to a normal level following the event. Overdosing of polyelectrolyte causes mudballing in the filter bed and if the extent of mudballing is very high, a chemical clean is required to restore normal operation and performance.

Figure 2: An example of mudballing – mudball found in a filter at Traralgon, Australia[2].

[2] McGregor S; 2001, Know Your Filters; 64^{th} Annual Water Industry Engineers and Operators Conference

Membranes do not rely on a chemical reaction to achieve solids removal and hence are significantly more reliable when treating water with low turbidity. The output quality from a membrane plant is unaffected by the raw water solids loading, as illustrated in Figure 3. Membranes can be relied on to produce drinking water standard compliant water without operator input, despite fluctuations in the raw water quality.

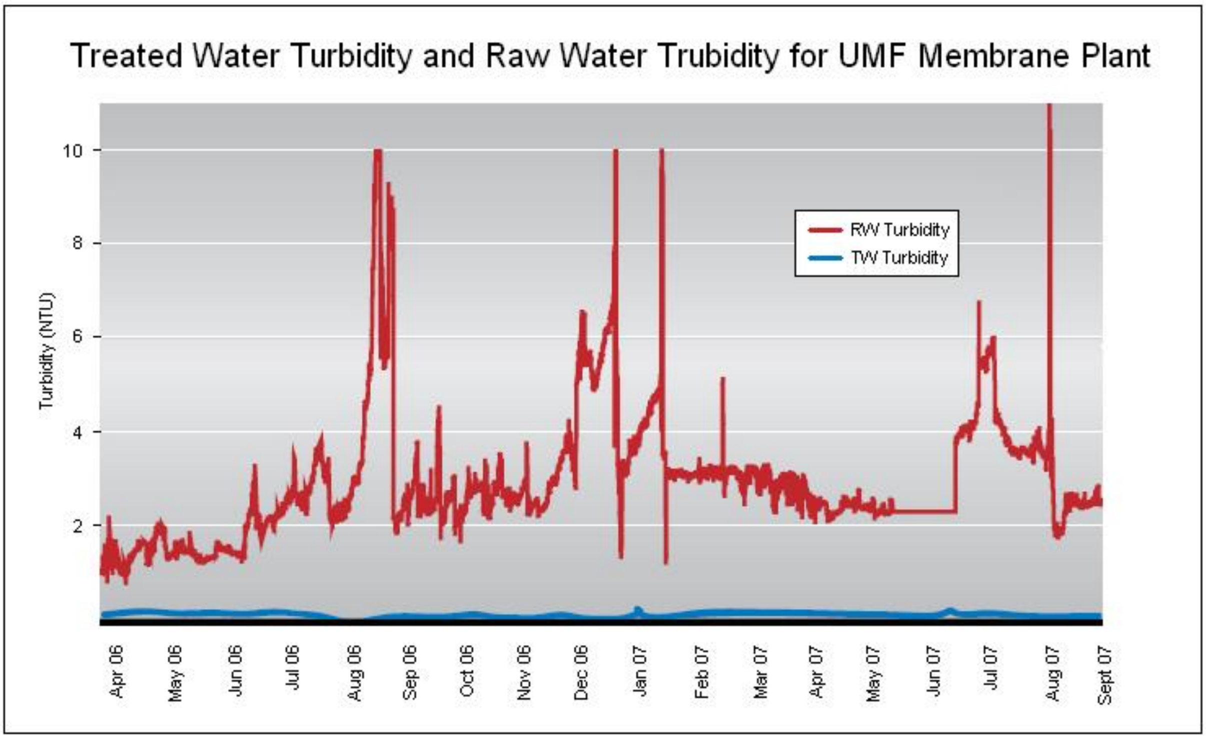

Figure 3: Raw water turbidity and treated water turbidity following membrane filtration[3].

5 CHEMICAL USAGE

As previously discussed, membrane plants are not reliant on chemical coagulation to achieve effective solids removal. Due to this, it is possible to operate membranes without upstream chemical dosing. If chemical dosing is not required, the backwash waste stream from the membrane plant can be discharged to the watercourse from which the raw water was abstracted. This is due to the sludge removed during the membrane treatment process consisting of only naturally occurring solids from the source water.

The number of chemicals required is greater for membrane plants due to the clean in place (CIP) process and following neutralisation. However, the volume of chemical usage is significantly less than the amounts of coagulants and flocculants required for conventional treatment plants. This reduction in chemical usage can contribute to reduced operating costs, making membranes a more financially viable option.

6 OPERATOR ATTENDANCE

Operator buy-in on the chosen process technology is essential to the successful operation of the upgraded or new plant. The operators will be directly managing and working with the plant on a daily basis. Operators can potentially be unwilling to adjust if they are unprepared or do not believe in the chosen technology. Plant performance can be stabilized and optimized in a more timely and consistent manner if the operator is dedicated to the process technology.

Many operators from smaller rural councils are averse to being responsible for running new membrane installations due to not having had experience with membrane plants. Engaging operators in the design process

[3] Adapted from: Siemens Water Technologies; 2009; *Introduction to Memcor*.

can improve operator buy-in and help them prepare for the new installation. Other methods to aid in this are site visits to similar plants and having all operators present for membrane operation training sessions.

In addition to this, establishing a good relationship between the operators and membrane supplier can ensure any small issues are resolved before they escalate to significant problems.

Figure 4: Membrane training for operators (left and right).

7 HYDRAULIC RESTRICTIONS

Membranes are limited by "hydraulic restrictions". If the raw water has elevated suspended solids, more frequent backwashing is required and as such, the net treated water production decreases. Conventional filtration can also be restricted hydraulically if backwashing is increased to maintain the treated water quality during high turbidity events. However, sand filters are capable of continuing to operate under such conditions without increased backwashing. The result of this is reduced treated water quality (potentially out of specification) and this contributes to conventional filtration being limited by "process restrictions". In extreme cases, it is possible for filter beds to be blinded due to high turbidity or coagulation failure.

Historically at times it may have been deemed more important to provide water to the community during high turbidity events, regardless of whether it was compliant with the drinking water standards. With more attention to drinking water standards compliance, this is not an option for future production.

Some small councils prefer to have large reservoirs to avoid night time operation, for which operators would need to be on call for. This requires constant starting and stopping of the plant. Conventional plants, particularly blanket clarifiers and rapid gravity sand filters, do cope well with hydraulic disruption and require flow to be altered very slowly. As such, start/stop operation is not recommended with conventional filtration. Membranes cope far better with rapid changes in flow and are capable of handling start/stop operation successfully.

8 VALUE OF EXISTING PLANT

Regardless of the size and age of a plant, most council's have a perceived value of their existing equipment. Often this is an elevated worth when alterations to the drinking water standards and building codes are taken into consideration. The actual value of the equipment is significantly reduced if it is unable to produce water to specification and does not meet the building code. With regard to filter upgrades, it is often found that installing new bespoke or package filters is cheaper or of similar cost to refurbishing existing filters.

The value of the existing plant should always be evaluated in the concept options assessment to find the true value of the infrastructure. Process equipment can be reused in innovative ways if it is not capable of producing drinking water standard compliant water but still meets the current building codes. An example of this is decommissioning existing sand filters and renovating them to be used as a pre-membrane filtration buffer during high turbidity events. Reuse of existing equipment, even if it is not for the initially intended purpose, maximizes the return on councils' original plant investments.

9 PROCESS COMMONALITY

Similar process treatment across a council's plants is advantageous in many regards and often favored by councils. Process commonality means operators can move between plants with solid process understanding and confidence in the operation of the plants. In addition to this, critical spares can be kept at a central location for all plants, reducing the capital spent on purchasing spares for each individual plant.

The objective of maintaining process commonality can lead to councils remaining with an installation similar to the existing plant, i.e. normally a conventional plant. Retaining commonality is a valid concern as it reduces complexity and therefore the risk for the operations team.

The cost analysis of one process versus another should provide a balance to process commonality concerns and be presented in the concept stage of design.

10 CAPEX AND OPEX

Membranes are perceived to have high capital and operating costs. Recently price competition has commenced as membranes become more commonplace and the number of suppliers in the market increases. This has caused the cost of membranes to decrease. Recent CAPEX, OPEX and NPV assessments on plant upgrades have indicated that the long term financial outcome is application dependant when comparing the costs associated with membrane technology and conventional treatment. Some recent CAPEX, OPEX and NPV outcomes are presented in the case study sections below.

11 DRINKING WATER STANDARDS COMPLIANCE

Protozoal compliance can be more difficult than anticipated when operating conventional sand filters, with 0.1 NTU required off the filters. Filter to waste times can take longer than an hour to drop the turbidity below this level. Commonly UV disinfection is required in addition to the filters to ensure protozoal compliance is achieved.

Protozoal compliance can easily be achieved through membrane filtration and bacteriological compliance by chlorine dosing for disinfection. A process guarantee can be obtained from the membrane supplier to ensure the membranes will treat the range of water quality specified in the raw water envelope.

12 CASE STUDIES

Kerepehi WTP

The Kerepehi WTP upgrade was completed in December 2012 and increased the existing plant capacity from 9 MLD to 12.5 MLD. In the initial concept phase, conventional clarification and filtration was selected for the upgrade. The council was initially reluctant to investigate the options of membranes as they believed that the capital cost would be high and that the operation and maintenance issues would be far greater than conventional plant. None of the council engineers or the operators had experience with membranes and as such had some misconceptions about membrane operation. As the raw water source suffers from extreme turbidity spikes (from 100 NTU to 2,000 NTU) membranes with pre-treatment was a very viable option to ensure compliance. After council's concerns were addressed and they visited other similar sized membrane plant to talk with the owners and operators they agreed membranes should be investigated.

A number of different options were then investigated to deal with extreme turbidity spikes in the river. Actiflo and conventional filters were assessed against tube settler clarifiers and a membrane plant. The 20 year NPV costs were very similar (within 10%), with the membrane plant having the lower CAPEX.

This shows that the CAPEX and OPEX of conventional and membrane plants are of similar order and generally will depend on the application and arrangement of the plant as to which is the cheaper option. Membrane prices have become very competitive making them a very viable option for smaller plants.

After commissioning the council was very pleased with the performance of the new membrane plant. They have found that membranes provide them with a number of specific advantages over conventional plants, considering how thinly spread their operators are around the district. The council is now considering installing membranes for other plant upgrades around the region. Some of the advantages they have come across are; lower operator attendance; greater plant autonomy and greater reliability of plant to treat poor quality water.

Figure 5: New membrane plant installation at Kerepehi WTP.

Ruakaka WTP

In 2007 Ruakaka WTP underwent an upgrade similar to that completed at Kerepehi WTP. The plant was increased in capacity from 3 MLD to 12 MLD and a MIEX plant was installed for THM removal. This project was completed only 5 years prior to the Kerepehi WTP; however at that stage the option of a membrane plant installation was $0.5 million more expensive than a conventional plant upgrade. A conventional plant was selected as the process treatment as the advantages provided by membranes was not enough to justify increasing the capital expenditure by $0.5 million. This shows how much the membrane market has changed in the past 5 years and how membranes now provide very good value for money.

13 SUMMARY

Each upgrade or new installation project is unique with its own set of conditions, objectives and constraints. Council's perceived risks and concerns with a membrane plant can be included and assessed in the concept design process, allowing them to make an informed and unbiased assessment of the options.

Membranes can provide a number of advantages for smaller rural councils, such as:

1. Increased autonomy of plant allowing less operator attendance;

2. Does not rely on chemical coagulation for effective solids removal;

3. Package supply and install of process equipment simplifying construction;

4. Lower dose rates and storage volume of chemicals held onsite (no bulk storage required);

5. Treated water compliance automatically achieved without operator input when inlet quality deteriorates.

Some of the challenges which need to be resolved when discussing a potential membrane upgrade with a smaller rural council could be:

1. Perceived high capital and operating costs;

2. Perceived high complexity and maintenance intensity;

3. Perception that membranes are only for very low quality water sources;

4. Operator resistance to new process technology from what they are familiar with;

5. Perception that membranes are higher risk because they provide "hydraulic restrictions" as opposed to "process restrictions".

As membrane suppliers develop smaller more versatile and price competitive membrane packages, the option of membrane plants for small rural councils becomes increasingly attractive. Consultation with councils can help identify what perceived risks they associate with membranes and help identify what specific advantages membranes can provide in the right application.