Smart Water Fund

Flemington Racecourse
Multiple Water Reuse (MWR)
Sewer Mining
Demonstration Project

Report prepared by

Waste Technologies of Australia Pty Ltd

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FOREWORD AND ACKNOWLEDGEMENT

The objective of this Project is to demonstrate water recycling as a form of “sewer mining” using the Multiple Water Reuse (“MWR”) wastewater treatment technology patented by Waste Technologies of Australia Pty Ltd (WTA).

This report is prepared to fulfil the requirement of the Smart Water Fund contract conditions and also the requirement of the EPA RD&D approval conditions.

Funding provided from Smart Water Fund of Victoria for this “sewer mining” water recycling project is gratefully acknowledged. The assistance and cooperation provided by the following organisations and their staff are greatly appreciated:

Smart Water Fund:

City West Water

Environmental Protection Authority (EPA) Victoria

Department of Human Services (DHS) Victoria

Victoria Racing Club

EnviroZel Ltd was subcontracted to Waste Technologies of Australia for the construction, commissioning, testing and initial operation of the demonstration MWR plant.

Water Treatment of Australia Pty Ltd was subcontracted to Waste Technologies of Australia for the final operation phase of the demonstration project.

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1. INTRODUCTION

"Sewer mining" involves extraction of wastewater from a sewer main to a localised wastewater treatment plant and distribution of the treated (or "reclaimed") water for use (or "water recycling" or "reuse") at the local site. Wastes or reject streams such as biosolids and backwash wastewater from the treatment plant are returned to the same sewer main.

A self-contained MWR plant was installed and operated at Flemington racecourse (Melbourne) to demonstrate the sewer mining and water purification processes, and to assess it under full-scale technical and commercial parameters. Extracted water is treated to Class A reclaimed water standard by the MWR treatment plant. The demonstration will establish operating costs, process characteristics and water quality achievable for the kind of wastewater feed available at Epson Road Main sewer.

This plant is a small demonstration system producing about 20 kL/d of Class A reclaimed water for irrigation on a remote small-grassed area.

Raw sewage is pumped from the Flemington Branch Sewer, which is 450mm in diameter and traverses the Flemington Racecourse, then connects to the main sewer in Epsom Road, Flemington. The abstraction point is Manhole RAE3, which is located within a plant and machinery maintenance compound close to the area of garden to be irrigated. The sewer to be mined services a small residential catchment and the Flemington Racecourse. The average dry weather flow in this sewer varies from zero between 11:00PM and 06:00AM and up to 5 L/s during the day. During major events at Flemington such as the Melbourne Cup, the flow peaks at about 50 L/s.

A weir was installed by City West Water in the manhole to create a pool about 300mm in depth, which is adequate for pumping sewage directly out of the manhole channel to the MWR Treatment Plant. A level sensor was installed in the manhole and connected to City West Water's SCADA system to ensure any operational issues with the sewer or pump are communicated to standby sewer maintenance teams.

The MWR Treatment Plant, which is contained in a converted 6m (20ft) shipping container, was installed in a fenced off area adjacent to Members Drive in the Flemington Racecourse. The site has been selected to avoid interference with racecourse operations for its proximity to the services required to run the plant (ie: power, water and access to the sewer manhole). The MWR plant is shown in Figure 1 below.

Figure 1 "Flemington Racecourse MWR Demonstration Plant"

2. MULTIPLE WATER REUSE (MWR) TECHNOLOGY

The Multiple Water Reuse (MWR) technology is a novel patented wastewater recycling plant that produces reclaimed water without the use of a biological treatment process. MWR utilizes dual membrane system to treat wastewater to exceptionally high quality reclaimed water suitable for all non-potable water reuse applications including toilet flushing, garden watering and car washing. The dual membrane system consists of a membrane microfiltration unit followed by a reverse osmosis unit. Because of its compact size (as it does not have a large biological reactor tank) it is ideal for "on-site" applications such as in office or apartment buildings and offers the following advantages:

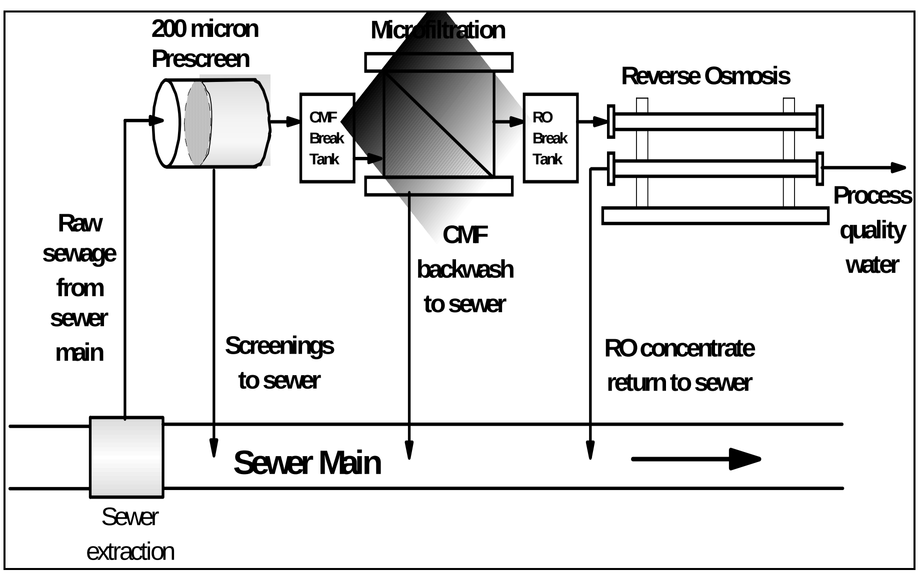
- As it relies solely on treatment by membrane filtration, it is very simple to operate and is fully automated. In contrast, a biological treatment process relies on live microorganisms such as bacteria to treat the wastewater and is thus quite a sensitive process and requires considerably more effort to operate.

- It is very safe as the dual membrane system provides two barriers for the removal of pathogens in the wastewater compared to a single barrier in most other water reuse plants. The addition of either chlorine or ultra violet ray disinfections provides a third barrier for public health protection.

- Its compact size makes it ideal for on-site applications such as for recycling water for toilet flushing and other external use in an office or apartment building. A schematic of such an application (generally referred to as a "sewer mining" application) is shown in Figure 2 below.

- The treatment process is enclosed making odour control easy.

Figure 2. Schematic of the MWR "sewer mining" process.



The patented MWR concept was developed by the CRC for Waste Management and Pollution Control and bench scale and pilot plant trial was carried out over a 2-year period. The results of the trial are summarized in the following Table 2.

Table 2. MWR Pilot Plant Treated Water Quality

Parameter	Screened Sewage	Microfiltration Filtrate	Reverse Osmosis Permeate
BOD (mg/L)	230	89	<2
TOC (mg/L)	103	46	0.6
Suspended Solids (mg/L)	144	<2	
TDS (mg/L)		403	12
TKN (mg/L N)	50	51	3.9
Total P. (mg/L P)	11.2	9	0.03
Faecal Coliforms (cfu/100mL)	$5.1x10^6$	1.3	<0.1

The faecal coliform results are based on the geometric mean of non-chlorinated samples.

The reuse water quality will meet reuse criteria for non-potable residential reuse.

Prescreen

As shown in Figure 2 above, raw sewage is pumped from an existing sewer to the prescreen consisting of a 200 micron stainless steel mesh screen. Screened sewage flows through the screen by gravity to the microfiltration feed tank. The prescreen will remove gross suspended solids (mostly fibrous materials) and some oil and grease present in sewage. Water sprays (microfiltration filtrate) are used to wash the solids (screenings) from the screen and are collected in a bin and drained back to the sewer. Hence, there is no handling of the screenings.

Microfiltration

The microfiltration unit consists of thousands of hollow fibre membranes. The membrane wall has microscopic pores generally around 0.2 micron in size. The prescreened sewage is filtered through the membrane and is collected as filtrate from the inside of the hollow fibre to a filtrate storage tank. Solids that accumulate on the membrane are periodically backwashed with a combination of air and filtrate or screened sewage. The backwash wastewater is collected in a storage tank and periodically returned to the sewer. Biofilm formed on the membrane wall through the filtration process will eventually block the membrane if not removed. Filtration performance is maintained by periodical chemical cleaning of the membrane with either an acid or alkali (or combination of both) cleaning solution. Chemical cleaning is required about every 10 days and the process is fully automated.

Biofilm film growth may also be controlled by the addition of chlorine to the prescreened sewage. The chlorine also provides a residual disinfection that prevents regrowth of bacteria in the reuse pipeworks.

The membrane with 0.2 micron pore size will remove essentially all suspended solids including bacteria which are generally about 1 micron in size. The bulk of the viruses will also be removed.

Reverse Osmosis

The reverse osmosis unit uses flat sheet membranes and will not allow any suspended solids to pass through and is also able to remove most dissolved solids and salts. Hence, no bacteria or viruses should pass through the reverse osmosis membrane. The product water (permeate) quality will meet all drinking water criteria except for ammonia... The permeate appearance is similar to typical potable water with colour of about 3 PCU (apparent colour) and turbidity of <0.1 NTU. The dissolved solids content is approximately one tenth of that of typical potable water.

Because of biofouling, the reverse osmosis membranes have to be chemically cleaned about once every week to two week to maintain performance.

Footprint

A 50 to 100 kL/d MWR plant (excluding prescreen and sewage and product water storage tanks) will fit into a 6.1 m standard shipping container (about 15 m^2).

3. PROCESS DESCRIPTION AND CRITICAL CONTROL POINTS

The MWR technology relies on proven water treatment unit processes to provide a multiple barrier approach which has been proven as a reliable and safe method of water reclamation

Multiple Barriers

The MWR plant (refer diagram next page) adopts three barriers after the 200 micron screening (itself a barrier) for the removal of harmful substances such as pathogens. These are:

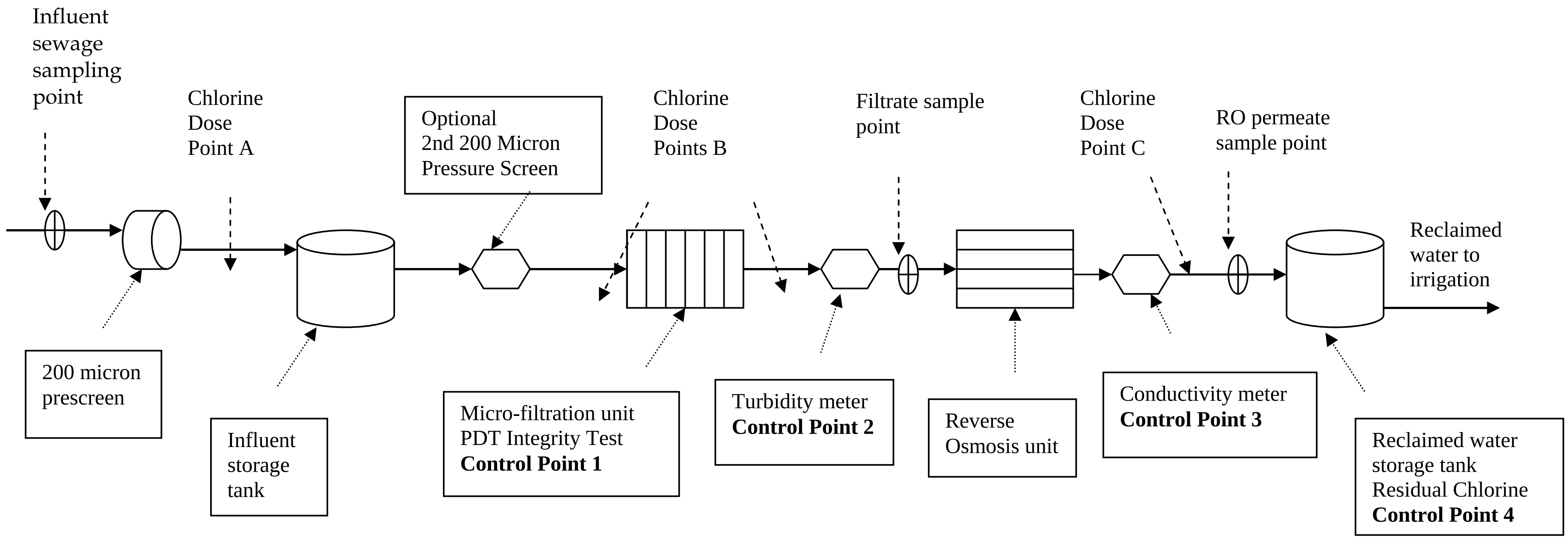
- Microfiltration (MF) - an effective and extensively used tertiary filtration and disinfection process as all particles greater than the membrane pore size of 0.2 micron will be rejected. This includes all protozoa such as cryptosporidium and giardia, bacteria, and virus that are attached to particulate matter. The microfiltration process has a well accepted method for performance verification using pressure decay tests (PDT) to ensure integrity of the membrane hollow fibres.

- Reverse Osmosis (RO) – is a well accepted water purification and disinfection process used by medical/pharmaceutical industry to ensure pathogen free water. Due to its low molecular weight cut off it removes all particles including all virus down to and including dissolved salts. It has the added benefit of reducing salinity which has further benefits in elevated salinity feedwater.

- Chlorination - a well established disinfection process. Although the main aim of chlorination is to control biological film growth in the membrane processes through the formation of chloramine, it will also disinfect the reclaimed water post RO providing a residual disinfectant.

The equipment used in the MWR plant is commercially available proven equipment that has been used worldwide in municipal water and wastewater treatment plants and lends itself to full automation and remote management. Since this plant is automated and remotely monitored it is expected any trend towards key parameters moving outside operating guidelines can be addressed before they occur. With this approach failure of the equipment is low and for all barriers to fail together at the same time is not likely. Should any key parameter move outside specification the control will initiate plant shutdown and/or by-pass allowing for operator intervention to verify the problem and act on checks accordingly.

MWR Process Flow Diagram



Process Control

The MWR treatment plant is fully automated based on PLC control and can operate without operator attendance. The systems proposed are "evidence based" those systems are functioning to the accepted specification to achieve Class "A" water or better.

The operation and performance of all three barriers are continuously monitored with in-line meters and or manually checked as noted below. These critical control points are:

- A turbidity meter will continuously monitor the filtrate from the micro-filtration unit. An alarm and shut down initiation will occur if the turbidity exceeds 1.0 NTU for more than 15min duration. On this event the controls would then initiate a pressure decay test (PDT) of the MF unit. Should the PDT not confirm an integrity loss of membrane the source of the turbidity spike would be investigated and rectified.

- Conductivity meter will continuously monitor the feed and permeate of the reverse osmosis unit. An alarm will be raised if the conductivity of the permeate is greater than 50 μS/cm for more than 15min duration and the plant will automatically shutdown. On investigation the permeate would be diverted to drain while the out of limit is investigated and rectified.

- Chlorine will be monitored as chlorine residual in the RO permeate. The monitoring will be undertaken initially as manual checks of residual chlorine in the treated water tank. It is expected that with the low chlorine consumption of RO permeate stored in a shaded, UV stable, sealed tank variation in chlorine levels will be minimal. Should more frequent monitoring be required following review of data a meter would be installed.

In all cases of confirmed excursions of critical control points as described above; the production of treated water would be bypassed to sewer or stopped and irrigation supply of treated water would be stopped. Once the excursion has been resolved treated water would continue to bypass to sewer until the water quality can be confirmed to be within the required limits. Reinstatement of irrigation supply would only occur once treatment and stored treated water was confirmed to be within specification. Details of such excursions, actions taken and water supply parameters after remedy would be recorded in plant log book for auditing and plant optimisation purposes.

All the plant operating data (pressure, temperature, flow rate and cumulative volume treated, turbidity, conductivity and chlorine residual, operating mode, alarm, etc) is either continuously monitored or manually entered into a data logger.

The MWR plant is designed so that there is no emergency discharge or delivery of out of specification reclaimed water. The plant will automatically shut down when there is a critical failure and will also alert the plant operator. All tanks have emergency overflow that is connected to the sewer.

Some of the failures are not critical and these will just activate an alarm. In addition to the critical control points detailed above the following alarms are provided:

- Failures of sewer mining pump - not critical. Consequence is that the influent tank water level will drop to BWL and this will automatically stop the feed to the Micro-filtration and RO units. When level in micro-filtration feed tank drops to bottom level the micro-filtration unit followed by the RO units will stop automatically. The effluent storage tank water level will eventually fall to the BWL and the irrigation pump will stop automatically.

- Failure of pre-screen - not critical. This will stop the sewer mining pump and the consequence will be the same as the failure of the sewer mining pump.

- Failure of level switches in influent and effluent tanks - not critical - pumps will stop when no flow detected by flow meter. Both tanks have gravity overflow to wastewater return pump station for overflow to be returned to the sewer.

- Failure of micro-filtration and/or RO units - not critical. Influent and effluent pumps will cut out automatically when TWL and BWL are reached respectively.

- Failure of effluent pump - not critical. Effluent for irrigation not available.

- Failure of wastewater return pump (to sewer) - critical. The plant will automatically shut down and automatically page the plant operator.

Membrane Integrity

Both the micro-filtration and reverse osmosis membranes are protected from physical damage by screening and filters. Inflow from the sewer mining pump is screened through a 200 micron stainless steel mesh screen before entering the influent storage tank. Water that is pumped from the influent tank to the micro-filtration unit is filtered through an in-line automatic backwash filter. Feed to the reverse osmosis is also filtered through an in-line cartridge filter.

The micro-filtration unit conducts a Pressure Decay Test (PDT) automatically every day or on start up to monitor the membrane integrity. The test is fully automated and requires no operator input.

If a loss of membrane integrity does occur the control system will automatically generate a warning alarm and the treated water will be diverted and/or shut down while the reported breach is investigated and rectified.

With regards to the Reverse Osmosis plant, if the membrane integrity were compromised there would be an increase in salt passage and hence a rise in the normalised permeate conductivity. Feed water and permeate conductivity is automatically logged by the PLC onboard the reverse osmosis unit. A limit of 50μS/cm has been set for the alarm and shutdown limit on conductivity. The control system will automatically generate a warning alarm and the system will be diverted and or shut down while the reported breach is investigated and actioned.

4. RECLAIMED WATER QUALITY RESULTS

Two set of tests were conducted.

The first set of tests were conducted to demonstrate that the MWR plant is capable of producing Class "A" reclaimed water that meets the water quality objectives set out in Table 1 of EPA Victoria Guidelines for Environmental Management "Use of Reclaimed Water".

The second set of tests was conducted to obtain Department of Human Services (DHS) Victoria verification for Class "A" reclaimed water. This is based on demonstrating that the MWR plant is capable of providing 7 log removal of viruses and 6 log removal of protozoan parasites (Giardia and Cryptosporidium) as determined in risk assessment work undertaken by DHS and EPA.

4.1 Class "A" Reclaimed Water Quality Objectives

Water quality objectives for Class "A" reclaimed water as set out in Table 1 of EPA Victoria Guidelines for Environmental Management "Use of Reclaimed Water" is summarised in Table 3 below.

Table 3 EPA Victoria Class "A" Reclaimed Water Quality Objectives

Parameters	Median Values unless specified
E.coli	< 10 org/100mL
Helminth	< 1 per L
Protozoa	< 1 per 50L
Virus	< 1 per 50 L
Turbidity	< 2 NTU
BOD/SS	< 10/5 mg/L
pH	6 – 9 (90th percentile)
Chlorine residual (or equivalent disinfection)	1 mg/L

The first series of samples were collected on the 18 March, 5 and 27 April and 10 May 2004 and the test results are summarised in Table 4 below. The samples were collected and analysed by WATER ECOscience

Table 4 Test Results for March, April and May 2004

Chemical Analysis	**Influent Raw Sewage**	**Microfiltration Effluent**	**RO Permeate**
pH	6.7 to 7.4	7.2 to 8.2	6.3 to 7.4
Turbidity, NTU		2.3 to 2.7	0.2 to 0.8
Suspended Solids, mg/L	200 to 400	1 to 2	<1
BOD5, mg/L	44 to 280	5 to 36	<1 to 13
Total Nitrogen, mg/L	31 to 150*[1]	7.5 to 31	0.6 to 11
Total Phosphorus, mg/L	6.4 to 24*[1]	1.3 to 5.6	<0.05 to 0.18
Microbiological Analysis	**Influent Raw Sewage**	**Microfiltration Effluent**	**RO Permeate**
E.coli, per 100mL	(1.4 to 9)x10^6	0 to <10	0
Giardia, cysts/L	140 to 6600		<0.02
Cryptosporidium, oocyst/L	<10 to <200		<0.02
Helminth, ova/L	6 to 14		<0.5
Adenovirus, pfu/L	675 to 925		<0.02
Enteroviruses, pfu/L	145 to 655		<0.02
Reoviruses, pfu/L	42 to 68		<0.02
Total Enteric Viruses	888 to 1520		<0.02

Note *[1]: The raw sewage characteristics for the sample collected on 5/4/2004 was affected by collapse of the sewer upstream of sewer mining location; resulting in exceptionally high TN of 150 mg/L and TP of 24 mg/L.

The test results in Table 4 above demonstrated that the MWR plant is capable of producing a final effluent (RO permeate) meeting Class “A” Reclaimed water quality objectives.

The laboratory report comments that “NO Giardia or Cryptosporidium or enteric viruses were detected in 50L of the RO permeate. No Helminth ova were detected in 2L of the RP permeate.”

The second series of tests were conducted utilising E.coli as a surrogate indicator for the removal of bacteria, protozoa and helminths, and FRNA coliphage as a surrogate indicator for the removal of enteric viruses. This is to establish the reliability of surrogate performance indicators for ongoing plant monitoring.

The results of daily samples collected and analysed by Water ECOscience from 16 to 20 August 2004 are summarised in Table 5 below.

Table 5 Test Results for samples collected from 16 to 20 August 2004

Chemical Analysis	**Influent Raw Sewage**	**Microfiltration Effluent**	**RO Permeate**
Turbidity, NTU		0.2 to 1	
Electrical conductivity, μS/cm			17 to 33
Free chlorine, mg/L	0.6 to 1.8		0.14 to 0.33
Total chlorine, mg/L	>2.2 to 13		>2.2 to 7.7
Microbiological Analysis	**Influent Raw Sewage**	**Microfiltration Effluent**	**RO Permeate**
E.coli, per 100mL	1.4×10^6 to 1.1×10^7	0	0
FRNA coliphage, pfu/100mL	3.8×10^4 to 1.7×10^5	<1 to 8	<1

The test results demonstrated the following MF performance:

- 3.7 – 5.2 log removal of FRNA phage (virus surrogate). It was noted that chlorination contributed to removal.
- 6.1 – 7.0 log removal of E. coli (conservative surrogate for *Cryptosporidium* removal)
- Turbidity range from 0.2 to 1.0 NTU

The test results demonstrated the following RO performance:

- Performance of the RO was not demonstrated as viruses and E. coli were effectively removed by chlorination/MF to non-detectable levels in the RO feed.
- Electrical conductivity range fro 17 to 33 μS/cm

4.2 Log Removal of Pathogens from Raw Sewage

Results from the first set of tests were not able to establish the log removal performance of the microfiltration (MF) and reverse osmosis (RO) units separately as the contribution of chlorination to the removal process could not be separated out. Also the performance of the RO unit could not be demonstrated as the MF unit removed almost all of the E.coli and viruses.

In order to measure the effectiveness of the microfiltration and reverse osmosis units as part of MWR water reclamation process for the rejection of virus, tests were conducted whereby both units were separately challenged with artificially elevated levels of virus to determine actual log removal without the presence of chlorine.

FRNA coliphage were selected as the indicator virus based on previous advice given by the Department of Human Services (DHS) Victoria it is a suitable virus for indication purposes of plant performance. Samples of the coliphage were prepared, supplied, seeded, tested and supervised by Water ECOscience to ensure appropriate virus management procedures were followed.

Prior to testing the plant was set up as per normal operation (with exception of no chlorine dosing) running on untreated screened raw sewerage with an estimated background feed to the MF of between 30,000 to 160,000 pfu/100ml. Additional phage was dosed into MF and RO feed to ensure that there would be adequate counts so that the expected levels of log reduction could be demonstrated. Further more, by testing at artificially higher levels of phage (5 logs more than normal); any feed variation that may occur would be insignificant.

A restriction of feed tank capacity of 240L for MF and 600L for RO meant testing of filtrate/permeate samples had to be conducted in relatively short time period so as not to rely on fresh feed thus diluting feed conditions during test.

MF Test:

Prior to testing, pressure decay test was manually initiated and confirmed that the MF unit had integrity well within guidelines of manufacturer.

The MF was tested under the following operating conditions and without chlorine dosing:

- Filtrate flow 0.30 L/s
- Temp feed and filtrate of 17.8 °C
- Feed turbidity was 104/105 NTU and filtrate turbidity was 0.81/0.78 NTU
- Feed pH was 7.30 and filtrate pH was 7.35
- Feed chlorine measured for confirmation (no free and total residual detected)

The following testing procedures were adopted:

- Background phage in feed and filtrate taken and reported.
- MF was then stopped.
- Phage spiked into MF feed tank and well mixed for 20 minutes.
- Feed samples (2) of MF taken to verify feed levels.
- MF restarted with feed transfer pump to MF disabled.
- MF filtrate sample point was disinfected by flaming.
- Filtrate samples (5) taken at approx 2,3,4,5, and 6 minutes. At completion of filtrate sampling feed phage retaken to verify constant during tests.

The RO test results are presented in Table 6 below

Table 6 - Phage MF Test Data

Sample	FRNA Coliphage pfu/100ml
Initial MF Feed	1.48×10^{6}
Initial MF Filtrate	3.60×10^{3}
Spiked Feed Sample 1	1.33×10^{10}
Spiked Feed Sample 2	1.35×10^{10}
Spiked Feed End	1.32×10^{10}
MF Filtrate 2 minutes	3.30×10^{6}
MF Filtrate 3 minutes	1.36×10^{7}
MF Filtrate 4 minutes	2.52×10^{7}
MF Filtrate 5 minutes	2.13×10^{7}
MF Filtrate 6 minutes	2.75×10^{7}

MF analysis shows an increasing permeate virus level which most likely relates to the virus concentration front coming through.

Based on average of 2, 3, 4, 5, and 6 minutes samples against average of feed samples the MF demonstrated a 2.9 log reduction of virus without contribution from chlorination.

RO Test:

The RO unit was tested first to ensure phage feed levels could be approximated without potential interference of MF tested phage.

The RO2 unit was selected for testing under the following operating conditions without chlorine dosing:

- No chlorine dose applied throughout the test
- RO feed flow 1500 L/hr
- Permeate flow 400 L/hr (no recycle)
- Permeate conductivity was 25.2 μs/cm
- Feed temp was 17.8 °C
- Feed turbidity was 0.61 NTU and permeate turbidity was 0.34 NTU
- Feed pH was 7.35 and Permeate pH was 8.25
- Feed chlorine measured for confirmation (no free and total residual detected)

The following testing procedures were adopted:

- Background phage in feed and permeate taken and reported.
- RO was then stopped and MF stopped once feed tank full.
- Phage spiked into RO feed tank and well mixed for 10 minutes.
- Feed samples (2) taken from tank to determine actual phage feed level.
- RO restarted and stabilized by monitoring conductivity of permeate.
- Permeate sample point was sterilized with alcohol and 3 permeate samples taken at 3, 6 and 9 minutes with the MF not running so as not to dilute phage.

- At completion of permeate sampling feed phage retaken to verify constant during tests.

The RO test results are presented in Table 7 below

Table 7 - Phage RO Test Data

Sample	**FRNA Coliphage pfu/100ml**
Initial RO Feed	1
Initial RO Permeate	0
Spiked Feed Sample 1	1.1×10^8
Spiked Feed Sample 2	1.5×10^8
Spiked Feed End	1.7×10^8
RO Permeate 3 minutes	5
RO Permeate 6 minutes	0
RO Permeate 9 minutes	0

RO analysis shows zero counts in permeate for the last 2 samples and 5 for first sample. Given inconsistency of this one reading in that if anything it should show up in later samples it has been decided to ignore the 3 minute sample on basis that it could have been contaminated by aerosol given sampling point was relatively close by to feed tank.

The RO unit demonstrated an 8 log removal of virus without contribution from chlorination.

5. PLANT OPERATIONS DATA

5.1 Operational Problems

Significant interruption of the plant operations occurred due to the following events and factors.

(1) Trial of new submerged microfiltration unit.

The pressure microfiltration unit was replaced with a new submerged microfiltration unit for trial as the submerged microfiltration unit requires less energy than the pressure unit. However, the submerged unit did not perform satisfactory due to the following problems:

- Irreversible fouling of membrane which has to be replaced

- Excessive detergent foaming due to continuous aeration of the membrane tank.

After three months of testing, the submerged unit was replaced with the original pressure unit

(2) Automatic shut down of plant due to false high turbidity readings

The MWR plant could not operate continuously due to the frequent automatic shut down of the plant caused by:

- False high turbidity readings in the effluent from the microfiltration unit due to the presence of air and detergent bubbles.

Because of the high turbidity readings due to air bubbles in the effluent, the plant would shut down almost every day (the longest continuous operation was 2 days). No recycled water has been supplied to the irrigation area as the VRC did not want to switch over to recycled water until the plant can run continuously.

Air stilling tube was installed to try to overcome the turbidity problem but was unsuccessful. Also, the turbidity meter was not functioning properly for some time.

A new turbidity meter and data logger was hired from ABB Kent and was installed downstream of the microfiltration effluent tank. This overcomes the problem as the air bubbles were eliminated in the effluent tank. Turbidity readings ranged from about 0.1 to 0.2 NTU.

(3) Removal of sewer mining pump for the Melbourne Cup racing carnival period

The sewer mining pump was removed at the request of the Victorian Racing Club in anticipation of the expected high flow during the Melbourne Cup festival.

The sewer mining pump was fully reinstated in February 2006.

After some problem with the diesel generator not starting, the plant was finally operating automatically from last week of March 2006.

5.2 Operational Performance

The sewer mining pump was reinstalled early March but automatic operation of the sewer pump was only achieved around 28 March due to problems with the diesel generator not starting. This problem was fixed following the installation of a battery isolation switch and the battery replaced.

As the plant has been idle for months, all the tanks were emptied and cleaned out. The pre-screen spray nozzles were unblocked and cleaned, strainer, filter and flow control valves were installed in the spray nozzle line.

The plant was fully commissioned on the 4 April, 2006.

(1) Operation Data for the Period from 3 April to 3 May, 2006

The sewer mining pump is set at a flow rate of 1.15L/s. The pump is started when the level in the influent storage tank is reduced to 340mm and the pump is stopped when the level is increased to 1140mm. Each time the sewer pump is started it transfers about 7250L of raw sewage through the 200 micron prescreen into the influent tank over a period of about 1h 45 minutes.

Screened sewage is pumped to the MF feed tank (70L capacity) at a rate of 5L/s and so only runs for about 14 seconds each time. Sodium hypochlorite is dosed into the screened sewage as it is transferred to the MF feed tank. The initial dose rate was set at 5 mg/L chlorine.

The MF unit was set to operate at a rate of 0.3L/s or about 1,080L/h. This resulted in a TMP of about 20-25KPa and a resistance of 6. The resistance climbed slowly to around 9 over a 3 week period. Following a CIP chemical clean with sodium hypochlorite, the resistance recovered back to 6.

The two parallel RO units were set with a feed flow of 800L/h each, a recirculation flow of about 450L/h and a reject flow sufficient to maintain system pressure of about 1000KPa. This gave an initial permeate flow of 400L/h which off to about 275L/h. Following the chemical clean the permeate flow recovered to 400L/h.

The MF unit shut down on 6/4 and was restarted by turning the power off and back on.

The second RO unit shut down on the 11/4 and 5/4 with no apparent visible reasons and were restarted without problem.

The plant shut down on 15/4 due to low compressed air alarm. The alarm was reset and the plant started automatically. This happened on the 26/4 and the problem fixed by installing a second compressor.

The plant shut down on the 19/4 and 20/4 due to “low feed tank level” and was due to complete blockage of the transfer screen. The problem was fixed by clearing the blockage.

Approximately 26kL of sewage was treated producing about 10kL of reclaimed water. The total recovery of 40% is lower than expected figure of 60 to 70%. This is not helped by the fact that the MF flow rate is less than the RO flow rates so that the RO units have to stop for the MF to catch up.

Results for the sample collected on 12/4/06 is shown in Table 9 below

Table 8 Results for Reclaimed Water Collected on 12/4/06

pH	6.8
Turbidity, NTU	0.7
Suspended Solids, mg/L	<1
Nitrate + Nitrite N, mg/L	<0.01
Ammonia N, mg/L	1.3
TKN, mg/L	2.0
Total Nitrogen, mg/L	2.0
BOD5, mg/L	5
E.coli, per 100mL	0
FRNA coliphage, pfu/100mL	<1

(2) Performance for the Period from 3 May to 1 June 2006

The problems experienced with many pieces of equipment in the previous period are due to the plant being idle for many months. Once these problems were fixed the plant ran smoothly for the whole month except for one day.

Only one plant shut down occurred on the 1/5 due to the controller loosing power.

RO2 unit on two occasions stopped running for no apparent reasons and was restarted by pressing the start button.

The MF feed rate was increased from 0.3 to 0.6L/s on the 5/5. However, the resistance increased quickly from 6 to 12 after one week. The MF was given a chemical clean (sodium hypochlorite) and the feed rate reduced to 0.4L/s. The resistance recovered to 6 after the chemical clean and slowly increased to 10 over 3 weeks.

Feed rate to both RO units was set at 600L/h each with a recirculation rate of 400L/h. The system operating pressure is around 1200KPa. Permeate flow were 350L/h for RO1 and 400L/h for RO2. The permeate flow dropped to about 300L/h at the end of the period. No chemical clean was performed on the RO units in this period.

During the period about 32kL of sewage was treated producing about 19 kL of reclaimed water. The total recovery has improved to the 60% level.

Results for the sample collected on 29/5/06 are shown in Table 11 below. A second sample collected on 15/5/06 was mislaid by the laboratory.

Table 11 Results for Reclaimed Water Collected on 29/5/06

pH	6.6
Turbidity, NTU	0.1
Suspended Solids, mg/L	<1
Ammonia N, mg/L	1.0
BOD5, mg/L	<2
E.coli, per 100mL	0
FRNA coliphage, pfu/100mL	<1

(3) Performance for the Period 1 June to 29 June 2006

The plant would not perform consistently from 1 June to 12 June. The problems were traced to a fault in the UPS unit and also a blown fuse in the RO unit.

The plant operated consistently from the 12 to 29 June.

The chlorine dose to the screened sewage was increased to 10mg/L to try and prolong the time required between chemical clean. However, this was not supported by the limited available data at this stage.

The MF resistance climbed fro 6 to over 8 in 2.5 weeks.

The RO permeate flow was about 400L/h each and dropping to about 350L/h after 2.5 weeks.

A total reclaimed water recovery of 60% was also obtained for this period.

Results for the sample collected on 15/6/06 are shown in Table 12 below.

Table 12 Results for Reclaimed Water Collected on 15/6/06

pH	6.6
Turbidity, NTU	0.1
Suspended Solids, mg/L	<1
Ammonia N, mg/L	1.0
BOD5, mg/L	<2
E.coli, per 100mL	0
FRNA coliphage, pfu/100mL	<1

5.3 Operational Costs

(1) Operator Costs

For the period from 3 April to 3 May, 2006, total operator attendance time at the plant was 31.5 hours. This included 5 hours for starting and commissioning the plant, 3 hours for replacement of floats in the RO units, and 3 hours for pulling apart and cleaning the prescreen. Total hours spent on routine plant monitoring, samples collection and chemical cleaning of the MF and RO units were 20.5 hours which equate to about 5 hours per week as anticipated. A chemical clean was conducted on 26 April.

For the period 3 May to 1 June, total operator attendance time was 31 hours. This included 8 hours for the installation and commissioning of a second air compressor (the first air compressor show low pressure readings although there is no apparent fault). Also, 6 hours were spent on installing a replacement turbidity meter and data logger. Total hours spent on routine plant monitoring, samples collection and chemical cleaning of the MF and RO units were 17 hours. This equate to about 4 hours per week as anticipated. A chemical clean was conducted on 12 May.

It is expected that the number of operator hours for routine plant operation would be about 4 hours per week (including chemical clean but excluding attending to faulty equipment). The same hours would apply to larger capacity plants (say 50 kL/d) as the equipment is the same except for more MF and RO membrane modules.

(2) Chemical Costs

A chemical clean is required every 2 to 3 weeks and this interval is longer than anticipated. Sodium hypochlorite (100mg/L) is used for MF CIP clean. Hot water and 3.2L of Memclean A10 (caustic based cleaner) solution are used for the RO chemical clean.

Sodium hypochlorite is also dosed into the screened sewage to control biofilm growth in the membranes. For the period from 3 April to 3 May, 2006 the chlorine dose was set at 5 mg/L for the first period and increased to 10 mg/L for the second period. Increasing the chlorine dose did not prolong the period between chemical clean.

Chemical costs based on a dose of 5 mg/L chlorine including chemical clean solutions are about 15cents per kL of reclaimed water.

(3) Power Costs

Because power was supplied from a diesel generator a kW hour meter could not be installed to measure the power usage. Power usage for a 50 kL/d plant was previously estimated to be about 2.5kWh/kL of reclaimed water produced. Power for this plant would be higher because of its lower capacity and also that there is two parallel RO units instead of a single unit.

6. CONCLUSIONS

It is concluded that the MWR plant has been successfully demonstrated in this project to be a safe and reliable water recycling plant for sewer mining applications following achievement of the following objectives:

1. The plant achieved DHS validation that the plant is capable of providing 7 and 6 log reduction in viruses and protozoan parasites respectively, and therefore producing reclaimed water of a Class A quality.

2. The plant operated successfully on a continuous and automatic mode from April to June 2006 and consistently producing Class A reclaimed water.

The plant has also achieved all the project milestones with the exception that reclaimed water was not used for irrigation on the Flemington Racecourse grounds. This was due to operational restrictions at the site, not to the quality of the reclaimed water.

The VRC considered that it is not worthwhile to switch from the current water supply to reclaimed water for the short duration and for the small quantity of reclaimed water. It was also during the period of low irrigation demand, and if reclaimed water is used, the irrigation system will have to be flushed and disinfected before reconnecting to the existing water supply.

The VRC is still very interested in using reclaimed water and is considering the installation of a much larger capacity plant of about 1 ML/day.

The demonstration plant is too small for the VRC requirement and it is planned to move the plant to another sewer mining application.

The MWR plant as demonstrated is suitable for other sewer mining applications. The addition of a SCADA system to allow remote monitoring and control of the plant would be beneficial and would reduce operating cost through reduced site attendance time. This has been shown to be feasible in the present application.

Projected cost for a 100 KL/d MWR plant based on similar site conditions is as follows:

1. Capital cost for supply, install and commissioning $350,000

2. Operation cost 60 cents/kL