THE EFFECTIVENESS OF SAND FILTRATION AND UV IRRADIATION FOR DISINFECTION AND OTHER WASTEWATER TREATMENT BENEFITS

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Abstract

Albury Water operates a new, state of the art wastewater treatment facility (Waterview) which was opened and commissioned in April 1999.

A feature of the plant is that effluent from the BNR process is "polished" through sand filters prior to disinfection by ultra violet irradiation.

The sand filters were included in the design with the aim of removing not only residual solids, but any particulate phosphorus carried over from the clarifiers.

A secondary benefit of the filter/U.V combination is enhanced disinfection, particularly for the removal of cysts (giardia and cryptosporidum).

This paper presents the results of a 3 year study of the effectiveness of this process.

Key Words: Sand Filters, Wastewater Treatment; Ultra Violet Light Irradiation; Particulate Phosphorus, Suspended Solids, Turbidity, Giardia, Cryptosporidium.

Introduction

Albury is situated on the Murray River, approximately 600 kilometres south-west of Sydney and 300 kilometres north-east of Melbourne.

In 1999, the Waterview Wastewater Treatment Facility was commissioned. The plant utilises activated sludge treatment technology, enhanced for biological removal of nutrients.

A feature of the treatment process is that effluent from the plant is "polished" through sand filters, prior to disinfection by ultra violet light irradiation.

This paper presents the results of 3 years of operation of the filtration process and discusses the effectiveness of the process in removing residual solids, particulate phosphorus and other parameters. The effectiveness of the process in achieving enhanced disinfection and removing oocysts (giardia and cryptosporidium) is also discussed.

Treatment Plant Elements

A schematic layout of the Waterview Wastewater Treatment Facility is presented in Appendix A.

Key elements of the Plant are summarised below:-

- Design Hydraulic Capacity

Average Dry Weather Flow (ADWF)
8ml/d (93l/s)
Peak Dry Weather Flow (PDWF)
16ml/d (185l/s)
Peak Wet Weather Flow (PWWF)
40 ml/d (465l/s)

- Inlet Works
- Step Screens
- Ultrasonic Flow Measurement
- Vortex Grit Trap
- Gas collection with discharge to aerobic zone of BNR Reactor

- Equalisation Tank
- 25 metre diameter
- pumped discharge (at up to 3 x AWDF) to Reactor
- Flows in excess of 3 x ADWF bypassed to Storm Bypass Pond (32 Ml capacity) for subsequent returns for treatment

- BNR Reactor Tank
- capacity 9400m^3
- operating sludge age: 21 days; MLSS 4000mg/l
- designed to operate in Modified UCT or Modified Johannesburg mode
- compartmentalised tanks (4 anaerobic tanks, 2 primary anoxic tanks, 4 secondary anoxic tanks and 4 aeration tanks)

- Secondary Clarifiers
- 2 No, each 25 meter diameter

- Tertiary Filtration

- U.V Disinfection

- Sludge Treatment
- gravity drainage deck
- belt filter press
- capacity 130 m^3/hr

- Chemical Dosing
- alum dosing as back-up to biological phosphorus removal, as required

- Site Stormwater Treatment
- all stormwater runoff from the treatment facilities is contained on site and discharged with the reclaimed water

EPA Licence Requirements

Under the Load Based Licensing Protocols set by the NSW Environmental Protection Authority, the Waterview Plant is required to meet the licence requirements as shown in Table 1 (Appendix B).

There is no discharge of effluent to receiving waters. All water from the treatment processes is reclaimed and used to irrigate a hardwood plantation, a softwood plantation, a lucerne crop and pasture for cattle grazing. When irrigation is not required, the water is used to sustain a wetlands area; the Wonga Wetlands.

Sand Filter Details

There are 4 filter banks, each 6.25m x 4m x 1 meter deep.

Peak flow rate to filters - 278l/s
No. of filters - Four
Area of each filter - 25.2m^2
Dimensions - 3m W x 8.4m L

Filter Media	Grade	Depth (mm)
Filter Sand	E.S. 1.6 - 1.8	100
Fine gravel	3 - 6mm	100
Medium gravel	6 - 12 mm	100
Coarse gravel	12 - 20 mm	100

Maximum filtration rate 4 filters operating - 9.93m/hr
Maximum filtration rate 3 filters operating - 13.2m/hr
Backwash process - Sequential air scour then backwash
Airscour rate - 54m/hr
Backwash rate - Up to 45m/hr
Washwater supply storage - 190^3 (two 5 minute backwashes)

Water Treatment (Australia) Pty Ltd were the sub-contractors for the design and installation of the filtration system for the Principal Contractor; Concrete Constructions P/L.

Details of the UV Irradiation System

The disinfection system at the Waterview Plant is a Wedeco UV disinfection system specifically designed to disinfect biologically treated and filtered wastewater.

The system contains UV lamps arranged in modules built into concrete channels. The UV lamps are installed horizontally and parallel to the water surface in fixed module frames. For easy service and maintenance the modules are equipped with detachable plugs.

A pneumatically operated wiping system cleans the quartz sleeves at variable intervals to prevent the forming of an absorbing coating. Two brushes keep the UV sensor head clean automatically.

The UV intensity of the lamps is monitored by a UV monitoring system indicated online by a UV intensity meter.

A water level control system is part of the UV system.

The system has been designed to minimise maintenance and provide fault free operation.

Technical Details of the system are appended as Appendix C.

Purpose of Tertiary Filtration

Typically, tertiary filtration is used at wastewater treatment plants to augment the clarifiers in removing suspended solids.

At Albury, the sand filters, in conjunction with UV Irradiation, were installed to enhance solids removal and also:-

- to remove carry-over particulate phosphorus
- to assist in the removal of pathogenic organisms, including bacteria, viruses and protozoan cysts
- to assist in the removal of nutrients and heavy metals
- to enhance subsequent disinfection by removing suspended solids and colloidal materials (which may "shield" pathogenic organisms during disinfection)

Monitoring Results

A range of parameters were monitored over the period March 1999 to March 2000, as part of the plant commissioning process. The same parameters were again monitored in June 2002 to verify, validate and check the early results and trends.

Cryptosporidium and Giardia has been monitored consistently over the period May 1999 to the present and the results of this monitoring program are also discussed.

Details of the monitoring program are summarised in Table 2 (Appendix B) and results are presented in Appendix D.

Discussion

In terms of the parameters monitored, the following comments can be made:-

1. Coliforms

   Based on the results of the 1999/2000 testing and those from the recent monitor, it can be stated that the UV disinfection appears extremely effective. Typical faecal coliform "kill" rates are 100% (with

some unexplained outriders) and similar rates are attributed to total coliform kills.

2. Protozoan Cysts (Cryptosporidium and Giardia)

   The results indicate that the combination of sand filters and UV disinfection is very effective in removing cryptosporidium and giardia.

   Giardia removal rates approached 100% (Average 93%) whilst cryptosporidum removal was slightly less and more variable, averaging 80% removal.

   The average "load" on the filter-UV-system was 4.9 cryptosporidium and 92.4 giardia (measured as No./l).

3. BOD_5

   The plant itself is extremely efficient at removing BOD. All results during the recent monitor were <3mg/l pre-filters, with no additional removal detected through the filters.

4. Suspended Solids

   Again, the plant is very efficient at removing suspended solids. The average concentration pre-filters was 5.1 mg/l during the recent monitor. Post filter results were consistently less than 0.8 mg/l (limit of detection) indicating a removal rate of suspended solids approaching 100%.

5. Turbidity

   As with suspended solids, the removal rate for turbidity was very high, approaching 71% from a very low base (average pre filter turbidity: 2.8 NTU).

   The average turbidity after filtration was 0.8 NTU, never exceeding 1 NTU.

6. Nitrogen Removal

   Nitrogen (measured as NO_x and TKN) removal was, as would be expected, non existent.

7. Phosphorus Removal

   a. Soluble Orthophosphorus

   Most soluble phosphorus in sewage is ortho-phosphate. The early monitoring results indicate that the sand filters had little or no impact on soluble phosphorus concentration.

   b. Total Phosphorus

   Since the major components of total phosphorus are soluble P and Particulate P, it could be anticipated that the sand filters would have little or no impact. This was the case in the 1999/2000 monitor. The recent monitoring indicated an uptake rate of 66% from a pre-filter average of 0.30 mg/l to a post-filter average of 0.10.

   In the recent monitoring, the pre-filter P concentrations were very low (indicating extremely good performance by the BNR Plant). At these levels, the ortho-phosphorus fraction would be expected to be low and, therefore, most of the pre-filter phosphorus was probably particulate.

   c. Particulate Phosphorus

   In the 1999/2000 monitor, there was a clear trend of particulate P removal, but it could not be validated. In the more recent set of results, although Particulate P was not specifically measured, it can reasonably be inferred that the filters are quite successful in removing Particulate P.

Conclusions

The monitoring results, over a 3 year period, indicate the following:-

1. The Waterview Wastewater Treatment Plant is performing very well and is now producing results for all parameters within the stringent effluent requirements set by the EPA.

2. The sand filtration/UV disinfection system has proven very efficient in "polishing" and disinfecting the plant effluent.

3. The UV disinfection system is extremely effective with typical "kill" rates for faecal and total coliforms in the order of 100%.

4. Kill rates for giardia and cryptosporidium cysts were also impressive with an average rate of 93% for giardia and 80% for cryptosporidium.

5. Suspended solids removal by the sand filters is typically close to 100%.

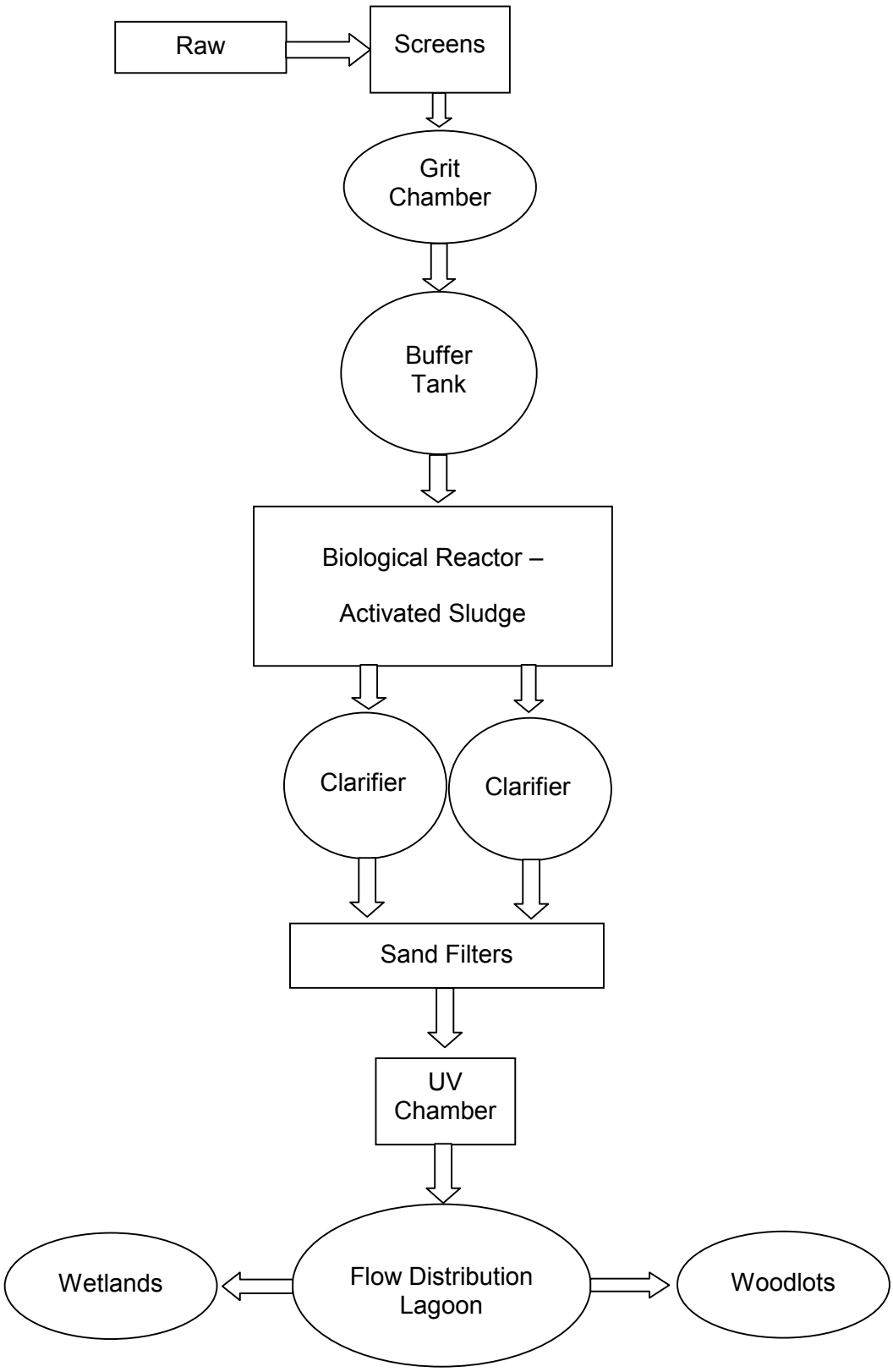
6. Turbidity is improved approximately 70% by the filters.

7. There was no perceptible nitrogen removal. However, nitrogen concentration as a base load to the filters was very low.

8. Levels of phosphorus were enhanced by filtration, particularly in the removal of residual particulate phosphorus.

Appendix A

Schematic of the Waterview Wastewater Treatment Facility



Appendix B

Table 1: EPA Licence Requirements

Pollutant	Units of Measure	50 percentile concentration limit	90 percentile concentration limit	3 DGM concentration limit	100 percentile concentration limit
Oil and Grease	mg/l				2
PH	pH				6.5-8.5
Total Nitrogen	Mg/l	10	15		30
Total Phosphorus	Mg/l	.6	1		2
Faecal	Cfu/100	200	300		1000
Coliforms	mL				
BOD	Mg/l	8	12		20
Total Suspended Solids	Mg/l	10	15		25
Nitrogen as Ammonia	Mg/l	3	5		10

Table 2: Monitoring Program

Parameter	Monitoring Period	Sampling Point Post Clarifier	Post Sand Filtration and UV Disinfection
pH	24/3/99 - 17/7/00	No	Yes
Total Alkalinity	24/3/99 - 17/7/00	No	Yes
BOD_5	24/3/99 - 17/7/00	No	Yes
	11/6/02 - 28/6/02	Yes	Yes
SS	24/3/99 - 17/7/00	No	Yes
	11/6/02 - 28/6/02	Yes	Yes
NO_x	24/3/99 - 17/7/00	No	Yes
	11/6/02 - 28/6/02	Yes	Yes
NH_4	24/3/99 - 17/7/00	No	Yes
TRK	24/3/99 - 13/6/00	No	Yes
COD	17/8/99 - 17/7/00	No	Yes
Total Phosphorus	24/3/99 - 17/7/00	No	Yes
	11/6/02 - 28/6/02	Yes	Yes
Ortho-Phosphate	24/3/99 - 17/7/00	Yes	Yes
Total Coliforms	11/6/02 - 28/6/02	Yes	Yes
Faecal Coliforms	24/4/99 - 28/2/00	No	Yes
	11/6/02 - 28/6/02	Yes	Yes
Turbidity	11/6/02 - 28/6/02	Yes	Yes
Cryptosporidium	4/5/99 - 4/6/02	Yes	Yes
Giardia	4/5/99 - 4/6/02	Yes	Yes

Analysis results and graphical presentations of data are appended as Appendix D.

Appendix C

UV SYSTEM - TECHNICAL DATA

UV channels

UV channels:	1
UV banks:	2
UV modules:	8
UV lamps (in total):	80
Total channel length:	Min. 7900 mm
Total channel width:	800 mm
Total channel height:	830 mm

UV Module

UV lamps:	10
Weight:	~ 40 kg (incl. Flexible conduits)
Quartz sleeve diameter:	33 mm
UV lamp type:	WEDECO Spectrotherm SLR 25143
Material:	Stainless steel 1.4571 (316Ti) PTFE PP PETP Quartz glass

Water Level Control

Max. total flow rate:	1000 m^3/h
Weir type:	Motor weir
Nominal water level:	500 mm
Material:	Stainless steel, 1.4571 (316Ti)

Appendix D

RESULTS

Date	Pre-Filters	UV Channel	Efficiency	Pre-Filters	UV Channel	Efficiency
	Faecal Coliforms (per 100 mL)			Total Coliforms (per 100 mL)		
11/6/02	56000	1	100%	380000	-	
12/6/02	3000	67	98%	48000	200	100%
13/6/02	65000	45	100%	210000	580	100%
14/6/02	-	-	-	-	-	-
17/6/02	-	-	-	-	-	-
18/6/02	190000	1	100%	240000	2	100%
19/6/02	50000	1	100%	2000000	9	100%
20/6/02	110000	1	100%	2000000	3	100%
21/6/02	-	-	-	-	-	-
24/6/02	-	-	-	-	-	-
25/6/02	20000	1	100%	290000	2	100%
26/6/02	33000	1	100%	380000	1	100%
27/6/02	48000	1	100%	560000	18	100%
28/6/02	-	-	-	-	-	-
		Average:	100%		Average:	100%

Date	Pre-Filters	UV Channel	Efficiency	Pre-Filters	UV Channel	Efficiency
	Suspended Solids (mg/L)			Turbidity (NTU)		
11/6/02	7.2	0	100%	5	0.85	83%
12/6/02	5.1	0	100%	2.6	0.79	70%
13/6/02	4	0	100%	2.2	1	55%
14/6/02	-	-	-	2.8	1	64%
17/6/02	6	0	100%	1.5	0.84	44%
18/6/02	5.5	0	100%	3	0.72	76%
19/6/02	5.4	0	100%	3.4	1	71%
20/6/02	5.6	0	100%	3	0.77	74%
21/6/02	5	0	100%	2.6	0.49	81%
24/6/02	-	-	-	1.5	0.83	45%
25/6/02	4	0	100%	2.5	0.71	72%
26/6/02	2.4	NR	-	2.5	0.65	74%
27/6/02	5.8	0	100%	3.6	0.75	79%
28/6/02	-	-	-	2.8	0.99	65%
		Average:	100%		Average:	68%

Date	Pre-Filters	UV Channel	Efficiency	Pre-Filters	UV Channel	Efficiency
	TKN (mgN/L)			Nitrite & Nitrate (mgN/L)		
11/6/02	4.2	3.7	12%	2.4	2.6	-8%
12/6/02	3	3.2	-7%	3.1	2.9	6%
13/6/02	4.4	2.4	45%	1.7	2.3	-35%
14/6/02	3.5	1.9	46%	2	2.4	-20%
17/6/02	3.2	3	6%	2.8	2.6	7%
18/6/02	1.7	0.92	46%	2.5	3.1	-24%
19/6/02	3.2	0.96	70%	1.3	2.3	-77%
20/6/02	3.6	1.6	56%	0.93	1.4	-51%
21/6/02	4	1.8	55%	1.5	2.2	-47%
24/6/02	3.5	2.2	37%	1.9	2.4	-26%
25/6/02	2.5	1.1	56%	2.4	3.1	-29%
26/6/02	3.5	1.2	66%	1.9	2.6	-37%
27/6/02	4.4	1.8	59%	1.7	2.3	-35%
28/6/02	2.3	2.6	0%	0.87	2.1	-141%
		Average:	39%		Average:	-37%

Date	Pre-Filters	UV Channel	Efficiency
	Total Phosphorus		
11/6/02	0.35	0.18	49%
12/6/02	0.21	0.15	29%
13/6/02	0.22	0.47	-114%
14/6/02	0.21	0.14	33%
17/6/02	0.19	0.13	32%
18/6/02	0.19	0.09	53%
19/6/02	0.32	0.13	59%
20/6/02	0.2	0.14	30%
21/6/02	0.2	0.11	45%
24/6/02	0.17	0.19	-12%
25/6/02	0.16	0.12	25%
26/6/02	0.27	0.23	15%
27/6/02	0.54	0.6	-11%
28/6/02	1.0	1.0	0%
		Average:	17%
		Adj. Avg.:	34%

Author Biography

Daryl McGregor graduated from Melbourne University in 1973 with a Degree in Civil Engineering (with honours). He obtained his Master of Engineering Science degree in 1988 from the University of New South Wales, specialising in waste management, and completed his Masters Degree in Business Administration (MBA) in 1992. He is also a qualified Engineer of Water Supply in Victoria, a qualified Municipal Engineer in both Victoria and New South Wales, a Fellow of the Institute of Engineers Australia, a Fellow of the Institute of Public Works Engineering, Australia and a Member of a further eight Professional Associations.

His areas of expertise and interest embrace local government management, water supply, water resources, natural resource management, wastewater treatment and management, civil engineering, traffic management, infrastructure development and environmental management.

Mr McGregor is a Registered Professional Engineer and a Chartered Engineer of the International Council of Engineering Institutions.

He is also an executive of the following professional Committees and Working Groups:-

- Chairperson, Murray Catchment Management Board
- Chairperson, NSW Water Directorate
- Murray Unregulated River Management Committee (Deputy Chair)
- Murray Darling Basin Commission, Community Advisory Committee to the Ministerial Council
- Murray Darling Basin Commission, Community Reference Panel on Environmental Flows
- Murray Darling Basin Commission, Rivers Knowledge Committee

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Paul is a Design Engineer with Albury Water. He is also a Graduate Member of the Institute of Engineers Australia and a Member of the Institute of Public Works Engineering, Australia.

His responsibilities include the investigation and design of water and sewerage infrastructure and facilities for the City of Albury and a range of external clients. He is also the Project Officer for the Albury Urban Salinity Management Program.

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