ENHANCEMENT OF THE MULTIPLE BARRIER APPROACH: STROMLO WTP UV UPGRADE

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ABSTRACT

The introduction of Murrumbidgee River water as a raw water source to Stromlo Water Treatment Plant has resulted in increased risk of pathogenic micro-organisms to Canberra's water supply. A project to enhance the existing treatment process barriers was recently undertaken, involving the installation of an ultraviolet disinfection system.

This paper discusses the design and operation of the UV system as an additional treatment barrier, and outlines the operational input into the different phases of the project. The operational impacts of the project during construction and commissioning are also considered.

KEY WORDS

Multiple barriers, critical control points, ultraviolet, UV, disinfection, cryptosporidium, LT2ESWTR.

1.0 INTRODUCTION

Investigation of future water supply sources for the ACT identified the need to pump water from the Murrumbidgee River to avoid new dam construction before ~2023. The quality of water from this source was poorer than the design specification for the Stromlo Water Treatment Plant (WTP) and a detailed risk assessment identified an increased risk of pathogenic micro-organisms such as cryptosporidium.

A major project was subsequently undertaken to upgrade Stromlo WTP by enhancing the multiple barrier approach of the treatment process. The upgrade included the installation of an ultraviolet (UV) disinfection facility, and increasing the capacity of the washwater and sludge handling system. The project was undertaken within the existing operating plant, and had a significant impact on water treatment operations.

2.0 DISCUSSION

2.1 The Multiple Barrier Approach

The 2004 Australian Drinking Water Guidelines identify that the greatest risks to consumers of drinking water are pathogenic micro-organisms. "Protection of water sources and treatment are of paramount importance and must never be compromised. The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of potential contamination facing the raw water supply."

No one step or barrier in the water treatment process is effective for all sources of contamination or works effectively and efficiently all the time. There may be operational problems with a barrier (i.e. poor coagulation, filter breakthrough, a break in chlorination) such that the barrier may not be completely effective and in these instances other barriers in the process may compensate for short term reductions in performance.

Most barriers require some form of human input in decision making or intervention and so the system must also contain fail-safes to ensure that human error does not lead to major failure of the treatment process, compromising the final water quality. Where human input is required then this must be controlled by setting critical limits for the management of the operation of that barrier.

2.2 Treatment Process Barriers

The Stromlo WTP is designed to treat 250 ML/day at 25^{o}C. The plant is manned 24 hours per day on a single operator 12 hour shift rotation. HACCP Certification for the water supply system was achieved in 2006.

Historically water has been sourced by gravity via pipeline from Bendora Dam, or pumped from Cotter Dam. Source water is generally good quality with low turbidity (1-5 NTU), low DOC (<6 mg/L) and colour (5-20 HU), but low alkalinity (10-20 mg/L). Raw water temperatures vary seasonally from 7^{o}C to 25^{o}C.

An extensive water quality monitoring and risk assessment program determined that the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) Bin Classification for the Murrumbidgee River catchment was Bin 2, requiring 4 $\log_{10}$ removal of cryptosporidium. The preventative measure applied for management of the hazards identified in source water was a set of pumping rules that limit the conditions for abstraction (i.e. cease pumping during high flow events, high turbidity, or following stormwater overflows or sewage spills).

To date, the blending of Murrumbidgee source water with Cotter and Bendora water when abstraction was available has also significantly increased raw water turbidity at the plant to > 10 NTU and colour > 100 HU. Trials are ongoing to determine the full operating envelope for the plant in poorer raw water quality conditions.

The Stromlo WTP consists of ten multimedia filters with anthracite, sand and gravel media. Historically, normal operation is direct filtration mode, however dissolved air flotation and filtration (DAF) is also available.

Pre-treatment chemical dosing includes pre-lime for alkalinity, carbon dioxide for pH control, aluminium sulphate and poly-aluminium chloride for coagulation, and polymer as filter aid. Potassium permanganate can also be dosed for dissolved manganese removal. Prior to the upgrade, post-treatment chemical dosing included chlorine gas disinfection, fluoride dosing and post-lime for final pH control.

Cryptosporidium is not inactivated by the concentration of chlorine that can be safely used in drinking water with the contact time available. Therefore the sum of credits achieved by the existing barriers at Stromlo WTP was a total of 4 $\log_{10}$ credits, summarised in Table 1.

When the filtration barrier is optimised and the plant is operating in DAFF mode, the required 4 $\log_{10}$ removal credits are achievable – Stromlo WTP has complied with targets since first abstraction of Murrumbidgee water in May 2007. However, in the event of failure of any of these barriers (i.e. loss of DAF, loss of coagulation etc) then the requirements may not be met.

Table 1: ***LT2ESWTR Log reduction credits for existing Stromlo WTP***

Process step	Log credit	Summary of requirements
Direct filtration	2.5 $\log_{10}$	Combined filter effluent ≥ 95% of measurements ≤ 0.3 NTU in each month
Dissolved Air Flotation (DAF)	0.5 $\log_{10}$	Continual operation of the DAF system is required
Combined filter performance credit	0.5 $\log_{10}$	≥ 95% of measurements ≤ 0.15 NTU in each month
Individual filter performance credit	0.5 $\log_{10}$	≥ 95% of measurements ≤ 0.15 NTU in each month and no two sequential 15 min samples > 0.3 NTU
Total process	4.0 $\log_{10}$	In DAFF mode with both filter performance credits

The UV disinfection system provides an additional barrier against cryptosporidium; high-energy protons are absorbed by DNA and RNA in the micro-organisms causing cross-linking of the double helix strands which prevents strand splitting and replication. Cells cannot replicate and are unable to infect. This allows short disruptions to the filtration barrier without compromising the final water quality.

Table 2: ***LT2ESWTR Log reduction credits for upgraded Stromlo WTP***

Process step	Log credit	Summary of requirements
Filtration	4.0 $\log_{10}$	In DAFF mode with both filter performance credits
UV Disinfection	2.5 $\log_{10}$	UV dose 27 mJ/cm^2 and not less than 50% of setpoint for a period of greater than 1 hour
Total process	6.5 $\log_{10}$	In DAFF mode with both filter performance credits and UV disinfection

ActewAGL operational policy is to operate the UV system continuously as an additional treatment process barrier. Another advantage of the UV system is the expected reduction in chlorine demand due to the UV oxidation of organics.

2.3 Project Outline

United Group Limited was awarded the project contract, having been previously involved in the construction of the New Stromlo WTP which was commissioned in 2004. The project was managed by ActewAGL Projects Branch.

The functional specification was developed by the Contractor, with PLC programming and SCADA development undertaken in-house by ActewAGL's Automation team.

The selected UV units were supplied by Calgon Carbon Corporation's UV Technologies Division in Pittsburgh USA, represented in Australia by Liquetek.

The onsite works commenced in March 2007, and the major project milestone of having the UV system operational by the end of 2007 was successfully achieved. The remaining project works will be finalised by May 2008.

A very positive aspect of the project was effective and ongoing design and construction review in consultation between the Contractor, project manager and the end user, ActewAGL's Treatment Branch. Operations and Maintenance staff contributed substantially to the design and construction process. Weekly construction meetings were set up as a forum to discuss operational impacts of the construction activities, to plan for major events such as online cut-ins to the process and to coordinate plant shutdowns.

2.4 System Design and Operation

Calgon's Sentinel® ultraviolet technology system is a medium-pressure UV system capable of achieving a greater than 3 log_{10} inactivation of cryptosporidium. The system is verified by the US EPA and third-party validated under the LT2ESWTR in the United States.

The level of inactivation is proportional to the UV dose that is applied to the water. The UV dose is calculated as follows:

$$D = I \times t$$

Where:
D = UV Dose, mJ/cm^2 (mWs/cm^2)
I = average UV intensity, mW/cm^2
t = average exposure time, s

The US EPA UV Guidance Manual provides doses required to attain inactivation credits for individual organisms.

The Stromlo WTP design dose rate specified is 27 mJ/cm^2 in order to achieve 2.5 log_{10} removal credits. This limit was specified by ACTEW's regulators, ACT Health. An event where the UV dose is less than 50% of the setpoint for a period of greater than 1 hour is reportable to the regulator.

The Stromlo WTP UV system consists of:

- Inlet tank for distribution of flow through the UV trains;
- Three parallel trains operating in duty/standby, including a flow meter, inlet and outlet isolation valves, and UV treatment reactor; and
- Outlet tank where the flow merges and post treatment chemical dosing occurs.

Each UV treatment reactor includes three banks of two high intensity medium pressure ultraviolet lamps. The lamps are powered by electromagnetic ballasts with variable power output up to full power of 20 kW. The power output is automatically regulated by the local PLC to ensure the required dose is maintained for the flow rate based on validation-derived criteria. The UV dose is validated between UV reactor flow rates of 19 to 150 ML/day. The reactor includes a sensor (one per lamp) to continuously measure the absolute UV irradiance in the water to ensure that an adequate UV dose is maintained.

Each lamp is protected from the filtered water stream by a quartz sleeve. The quartz sleeve is kept clean automatically by a wiper to minimise loss of effectiveness of the UV lamps due to fouling of the sleeve surface.

The quality of filtered water input to the units is monitored online with a target of > 90% UV transmittance for optimal performance of the UV units. Operators undertake daily

testing of a grab sample of filtered water and crosscheck UV absorbance at 254 nm using a Hach DR5000 spectrophotometer.
Routine maintenance includes monthly calibration of the UV sensors by Instrument technicians as part of Treatment Branch's quality management system.

The UV system is incorporated into the emergency shutdown sequence to ensure that the critical limits are not exceeded. Plant shutdown is automatically initiated if the UV system is enabled and the UV dose for any online unit is less than 50% for 30 minutes.

The location of the UV system installation is downstream of the existing post-treatment chemical dosing of chlorine, lime and fluoride. UV light inactivates chlorine, and lime would scale the surface of the UV lamp tubes (which can reach very high temperatures > 900°C during operation). Therefore relocation of these chemical dosing points was required as part of the project.

2.5 Management of Plant Operations

Stromlo WTP was operational for the majority of the project works. The excavation works caused several minor interruptions to the plant operation, which was to be expected for works within a "brown-fields" site. The UV system, including tanks, building, MCC and associated pipework were constructed independently of the operating plant.

A major extended plant shutdown was required to reroute the flow of filtered water through the UV system. This involved cutting into a 1.8 m diameter buried pipe and installation of a similar diameter overhead pipe length. These works rendered the plant in-operable for a period of several weeks.

During the extended shutdown, which took place in November 2007, Canberra's water supply was maintained from Googong WTP. The Contractor was required to prepare detailed cutover plan including a day-by-day plan of works and to provide daily progress reports. A provision of the contract was the return to service of the plant with 48 hours notice if required in case of an emergency.

Other interruptions to the treatment process were managed with coordination between the duty operator and the contractors. As well as considering the safety isolations required when working in an online plant, the effect of works on critical processes such as post treatment chemical dosing and sludge handling systems was important to minimise disruptions to the process.

Although the wastewater and sludge handling system is not classified as a critical control point for managing cryptosporidium, the operation of that system has the potential to impact on the performance of the filtration step and reduce the effectiveness of that barrier. The upgrade works in that area were carefully planned to avoid placing additional stress on the rest of the plant.

2.6 Commissioning and Training

Managing the risk of human error impacting on the effectiveness of the UV disinfection barrier required successful commissioning and training to ensure employee awareness and involvement with the project.

The contractor was required to provide a detailed commissioning plan separated into defined pre-commissioning, commissioning, and finally performance testing phases.
A training package component was also specified in the contract, and required the contractors to provide informal training sessions during the construction phase, followed by formal sessions during the commissioning phase.

Operators and Maintenance staff were involved in the project with ongoing information updates and informal discussions during the development of the project. Operators and maintenance staff were often consulted in review of design drawings and options, adding considerable value through practical observations and experiences and improving the outcomes for the end user.

2.7 Project, Operational and Maintenance Costs

The individual UV reactor purchase price was around $400,000 each. Installation costs are site specific.

Budget operating cost is around $200,000 per year in electricity charges, or approximately $4/ML treated water production. These costs will be reviewed when actual operational data is available.

Ongoing maintenance cost is the replacement of the UV lamps, which have an expected lifetime of 5,000 hours, dependent on the number of stops/starts per day. Replacement cost of lamps is around $1,000 per lamp.

3.0 CONCLUSIONS

The installation of the UV system and associated upgrades to the Stromlo WTP has established robust multiple barriers in the water treatment process. This enhances ActewAGL's ability to manage potential contaminants in the raw water drawn from the Murrumbidgee River.

The additional barrier provides improved confidence for ActewAGL, its client ACTEW Corporation and its regulators, and most importantly our customers. Treatment Branch WTP Operators also benefit from the additional comfort of another process for providing the best quality product possible.

4.0 ACKNOWLEDGEMENTS

ACTEW Corporation
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5.0 REFERENCES

National Water Quality Management Strategy, (2004) *Australian Drinking Water Guidelines 6*, NHMRC

USEPA, (2006) *Long-term 2 Enhanced Surface Water Treatment Rule*, United States Environmental Protection Agency, 5th January 2006.

Calgon Carbon Corporation, (2007) *Operations & Maintenance Manual for the Mt Stromlo WTP, Canberra, Australia.*