EVENT-BASED PATHOGEN ASSESSMENT IN A DEGRADED CATCHMENT

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77th Annual WIOA Victorian Water Industry Operations Conference and Exhibition
Bendigo Exhibition Centre
2 to 4 September, 2014

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ABSTRACT

Assessment of source water pathogen contamination is the first step to quantitative microbial risk assessment of drinking water. It is well known that outbreaks of disease caused from drinking water have occurred as a result of extreme events, such as heavy rainfall, which lead to high loads of pathogens washed into the source water.

North East Water conducted a project to determine the level of microbial risk in a degraded catchment. Due to extensive cattle, dairy, and sheep farming as well as the presence of septic treatment systems, the King River was selected for this assessment. In September 2013, sampling was conducted immediately after a rain event at the raw water offtakes of Whitfield, Moyhu and Oxley Water Treatment Plants (WTP). The monitoring program included the selected pathogens *Cryptosporidium, Giardia*, *Campylobacter*, Enterovirus, Norovirus, faecal indicators (*E. coli*, and, total coliforms) as well as physico-chemical characteristics.

Results indicated that the King River is highly contaminated with *Cryptosporidium, Giardia* and very high concentrations of *E. coli* were recorded. From the results there was also an evident rise in *E. coli* and coliforms in parallel with heightened river turbidity and flow. This event-based data is important information, as it assists in the determination of appropriate treatment barriers and processes at WTPs that draw directly from similar degraded catchments.

KEY WORDS

Catchment, Pathogen, Risk, Water Quality.

1.0 INTRODUCTION

Assessment of source water pathogen contamination in normal and worst case conditions is the first step to quantitative microbial risk assessment of drinking water. It is well known that outbreaks of disease from drinking water have occurred as a result of extreme rainfall events, which lead to high loads of pathogens washed into source waters.

Cryptosporidium and *Giardia* are parasitic disease causing protozoan organisms, found commonly in the environment. There are many species, however not all pose a risk to human health. A multiple barrier approach for water treatment is preferred for decreasing the number of these organisms. This can be achieved with the normal WTP processes of coagulation, flocculation, clarification and filtration, but effective removal is only assured if the processes are fully optimised. The inactivation of protozoan cysts can be achieved with various chemicals and UV treatment. Again, optimisation of these processes is critical. The Australian Drinking Water Guidelines (2011) do not set out quantitative treatment requirements for potable water supplies regarding *Cryptosporidium* or *Giardia*. However they do promote a catchment to tap multiple barrier risk management system.

This catchment assessment was conducted to provide North East Water with a better understanding of the microbial risks present in one of the potentially highest contaminated raw water sources. The King River supplies raw water for three of North East Waters WTPs; namely Whitfield, Oxley and Moyhu.

Oxley and Moyhu source raw water directly from the river and treat it via coagulation and flocculation aided by Aluminium Chlorohydrate and then passed through pressure filtration vessels, followed by disinfection by chlorine gas. Whitfield sources its raw water from a shallow bore fed directly off the King River, the water quality from this bore was also analysed and proved a lot better than the sample that was taken directly from the River at Whitfield. The Whitfield WTP consists of coagulation/flocculation, Dissolved Air Flotation (DAF), and filtration; disinfection is achieved by UV and hypochlorite. This project was conducted during a high rainfall event in the middle of spring.

The monitoring program included the selected pathogens *Cryptosporidium*, *Giardia*, *Campylobacter*, Enterovirus, Norovirus, faecal indicators (*E. coli*, and, total coliforms) and physico-chemical characteristics of the source water (turbidity, conductivity, temperature, and pH). River height data was also monitored at the time of sampling to determine the stage of the rivers hydrograph.

To determine whether the water quality deteriorates or improves throughout the rivers hydrograph during a rain event, samples were taken from the raw water at the Oxley WTP throughout the event, during the rise, peak and fall of the rivers hydrograph. These samples were analysed for faecal indicators (*E. coli* and coliforms) and several physical parameters. A positive correlation with high levels of faecal indicators and increased river turbidity was evident.

The ability of pathogens to persist in surface water is variable. In general, survival is prolonged when water temperature is low. Other factors that influence survival include sunlight/UV intensity and the presence of aquatic microorganisms that may predate on the pathogens. Pathogens ability for adsorption to particles also facilitates survival.

2.0 DISCUSSION

2.1 Methodology

To provide a representative worst case scenario of this catchment, this project was planned and conducted mid-September during a rain event after a period of dry weather. It was conducted in Spring during the calving season as higher pathogen loads are expected, as calves are a known vector for protozoan oocysts. Sampling was conducted during the first flush of the rain event as more pathogens are released during the first runoff as river levels were starting to rise and before the river turbidity got too high for *Cryptosporidium* analyses and for the Oxley WTP to run. 50 NTU was the pre-determined turbidity cut off level. Due to all the variables that dictated the success of this project it had to be carefully planned and staff available at short notice. Sampling was conducted at the source water sites directly from the river at Whitfield, Moyhu and Oxley, on 17 September between 8:30 and 9:30 AM; 45mm of rain was recorded in the catchment at this time.

Three 10 litre samples were collected from the King River at each of the three WTP offtakes, for analyses by an external laboratory. The samples were immediately chilled to below 10 degrees Celsius. The quality of this shallow bore was also analysed for faecal indicators (*E. coli* and Coliforms) and physical parameters to determine if there was any difference in quality. A treated water sample was also taken from the Oxley WTP. To get results that represent treatment plant performance the Oxley WTP needed to be running and it was ensured that paired samples were collected for the feed and final samples. To do this a rough estimate was calculated for the time it takes the water to get from the feed to final disinfection and then the samples stratified to get a true ‘paired’ sample.
The three raw water samples and the treated water paired sample for Oxley WTP were

analysed for the following indicator species as well as several physical parameters

- **Protozoa** – *Giardia, Cryptosporidium parvum*
- **Bacteria** – *Escherichia coli*, *Campylobacter*, Coliforms
- **Viruses** – Enterovirus, Norovirus
- **Physicals** – Turbidity, conductivity, pH and temperature.

The rainfall event can be recognisable by the rapid rise in river level (Figure 1). Response time to runoff is of the order of four to six hours after rainfall; more rapid for Whitfield situated further upstream of the catchment and a longer duration for Oxley further down the catchment.

To determine if the water quality changes throughout the hydrograph (rising limb > peak > falling limb) of the river, samples were taken at different stages of the hydrograph and analysed for faecal indicator species (*E. coli* and Coliforms) and physical parameters (turbidity, conductivity, pH and temperature). From these results it was assumed that protozoan and viruses would behave in a similar manner. Percent recovery and accuracy of analyses for C*ryptosporidium, Giardia* and viruses is affected by increased turbidity. Due to the nature of the King River system and its history of high turbidity following rainfall events C*ryptosporidium, Giardia* and viruses were not analysed in these samples.
Figure 1 shows the height of the King River from the Docker road monitoring station at the time of sampling.

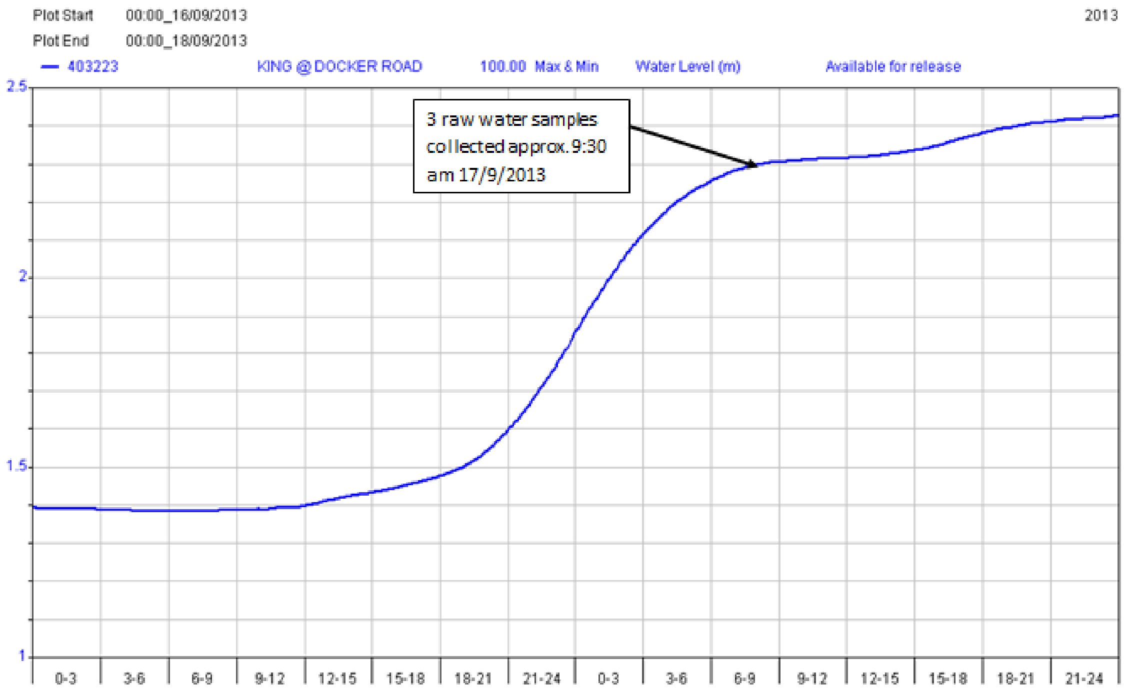

Figure 1: ***King River water level (meters) at the time of sampling. Image sourced from the Department of Environment and Primary Industries.***

2.2 Results

Results are provided in the tables below. Table 1 outlines the faecal indicator and physical parameter results from the raw water samples taken at the Oxley water treatment plant at different stages of the hydrograph from the 17 September 2013 to 19 September 2013. The '>' values resulted from insufficient sample dilution during testing. This was due to an under estimation of the rivers contamination, hence these results would have been a lot higher.

Table 1: ***Faecal indicator results taken at different stages of the King River***

hydrograph throughout the rain event.

Site	Sample Date	Sample Time	Turbidity	Coliforms (orgs/100mL)	E. Coli (orgs/100mL)
Oxley source	17/09/2013	9:45	50	>24000	12000
Oxley source	17/09/2013	15:40	38	>24000	>24000
Oxley source	18/09/2013	8:20	36	69000	9600
Oxley source	18/09/2013	15:00	34	37000	8600
Oxley source	19/09/2013	13:00	28	24000	3300

Table 2: ***Faecal indicator and physical parameter results from the three raw water samples as well as the Oxley treated water and Whitfield bore water samples.***

Site	Turbidity	Coliforms (orgs/100mL)	E. Coli (orgs/100mL)
Whitfield River	7.2	13000	2000
Moyhu River	42	>24000	>24000
Oxley River	50	>24000	>24000
Oxley Treated	0.2	0	0
Whitfield bore	1.7	20	0

Table 3 provides the *Cryptosporidium* and *Giardia* results for the three source water samples and the Oxley WTP treated water sample. This table also indicates the percent recoveries for each of the analyses and number of oocysts per a litre of sample. From other similar studies, analysed environmental flood waters tend to have poor recovery of *Cryptosporidium*. It is believed that this is due to the increased turbidity and interference with the immunomagnetic capture of the *Cryptosporidium* oocysts as well as the comparatively small size of the oocysts through shielding.

Table 3: ***Cryptosporidium and Giardia results from the three raw water samples and the treated Oxley WTP sample.***

Site	Volume analysed	# Crypto	# Giardia	% recovery Crypto	% recovery Giardia	Total Crypto	# Crypto per 1 Lt	Total Giardia	# Giardia per 1 Lt
Whitfield source	20	8	1	12	88	67	3.35	9	2.22
Moyhu source	8	6	2	19	77	32	4	3	0.38
Oxley source	8	3	1	28	83	11	0.72	1	0.13
Oxley treated	20	Not detected	Not detected	62	91	0	0	0	0

(note Crypto = Cryptosporidium, and # = number)*

2.3 Discussion

Sources of pathogen presence in the King River catchment may include sewage contamination and livestock wastes applied to land; animal faeces deposited on land by grazing animals (cattle and sheep); discharges from septic tank systems; and defecation by indigenous fauna.

Agricultural practices are most likely the highest contributing factor to the high level of contamination in this catchment. *Giardia* cysts and *Cryptosporidium* oocysts may survive in water for several months, especially at lower temperatures. High levels of *Cryptosporidium* and *Giardia* were present in all three source water samples analysed for this report. As a result of highly turbid samples only 8 litres could be analysed from the Oxley and Moyhu source water samples and percent recovery of *Cryptosporidium* was quite low. Protozoan pathogens were of particular concern due to their resistance to chlorine disinfection, making their removal solely relied on the effectiveness of the filtration barrier at both the Moyhu and Oxley water treatment plants.

In water treatment systems, the strong cell wall of the protozoan cysts protects the organisms from disinfection chemical doses (such as Chlorine) which would normally be effective for most bacteria and viruses. *Giardia* cysts can be inactivated by adequate chlorine doses and contact times. *Cryptosporidium* oocysts however are almost completely resistant to chlorine based disinfectants. From investigations based on tests for infectivity, it is evident that Ultra Violet light can affectively inactivate these oocysts.

The role of filtration is to remove suspended materials from dosed water to a degree that will optimise the subsequent disinfection step and to act as a barrier to many biological hazards in particular the chlorine resistant protozoans. To put the capability of the filtration process into perspective, you must consider that a typical bacterium is the size of about 1 micron, *Giardia* cysts are 6 to 14 micron and *Cryptosporidium* oocysts are smaller at 4 to 6 micron which is several thousand times smaller than the average filter media. Therefore without an effective coagulation, flocculation and clarification process, filtration would be significantly limited in its ability to remove these pathogens and hence could not be relied on solely for pathogen removal. No C*ryptosporidium* or *Giardia* was detected in the Oxley WTP treated water sample (Table 3) indicating that the pressure filtration plant was effectively removing the pathogens at the time of sampling.

2.4 Pathogen Longevity in the Environment

To determine what affects pathogens and their longevity in the environment several references were reviewed. A report by Nicholson and associates (2000) concluded that temperature is the single most important factor which determines pathogen survival times in the environment. Other factors found to affect pathogen survival include ammonia, high pH, desiccation and competition. Temperature results were taken with each of the samples taken and ranged from 12 to 15 degrees Celsius, which in accordance to evidence found by Quinton and Tyrell (2003) is just in the lower side of the survival spectrum. This could also have been a contributing factor to the high pathogen concentrations evident in the King River. Understanding the pathogen risks and the reasons for variations in source water quality is important, as it will influence the requirements of treatment (log reduction requirements), treatment efficiency and the potential resulting health risk associated with the treated water.

Peak events that may have an impact on microbial catchment risk and should be taken into consideration as part of any hazardous event assessment such as this include; upstream events, waste water and stormwater discharges.

Additionally, land uses such as, agriculture, forestry, and changes in land use; farming practices; different farming practices may harvest peak events must also be considered. In late winter and spring calving is at its peak in the King River catchment which adds to the protozoan risk in this particular catchment.

3.0 CONCLUSION

The pathogens analysed in this study all have high health significance. The King River catchment is highly dominated by agricultural grazing in particular dairy farming. Due to the amplification of calving in spring and the warming temperatures pathogen detection is more renown during this time of year. From other references and after analysing North East Water's past results, it is clear that there is strong seasonal variation in the occurrence of pathogens in surface waters. There are a number of factors that have been shown to influence the survival of pathogens in drinking water source waters.

Percent recovery of analytical methods can be quite low and vary between samples, as seen in this report for *Cryptosporidium* and *Giardia*. It is evident that high turbidity seems to interfere with detection, making it more difficult to determine peak river events such as the one this study was based around. Turbidity also impacted the volume of sample that could be analysed; this could also lead to an over or under estimation of pathogen risk.

An indication of a certain level of faecal indicator bacteria alone is not a reliable guide to microbial water safety. Some faecal pathogens, including many viruses and protozoan cysts and oocysts, may be more resistant to treatment (e.g., by chlorine) than common faecal indicator bacteria (WHO 2004). This study was an important reinforcer to North East Water, and provides valuable information and results on the evident pathogen risk present in their King River catchment.

This event based data is important information for North East Water to assist in determining the adequacy of treatment barriers at WTPs that draw directly of this river system and others. It also highlights the significance of the filtration barrier at these plants, as well as the importance that they are operating efficiently as filtration is the only effective barrier to remove chlorine resistant protozoan pathogens at WTPs that only have chlorine and filtration barriers. This highlights the need for high performing WTPs and an effective multi-barrier approach to control this pathogen risk. Hence results of this study could add value to future WTP design and optimisation projects at North East Water.

4.0 ACKNOWLEDGEMENTS

Thank to North East Water's Wangaratta Treatment Team for their assistance in sampling

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