Control of *Cryptosporidium* with wastewater treatment to prevent its proliferation in the water cycle

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Water Science and Technology **Vol 47 No 9 pp 45–49**

Abstract The outbreak of Cryptosporidiosis in 1996 in Japan is thought to have been enlarged by the proliferation of *Cryptosporidium* in the water cycle from wastewater to drinking water through the river system. From this experience, the wastewater system must have functions to remove *Cryptosporidium* oocysts effectively. Efficiencies of wastewater treatment processes to remove oocysts were investigated using pilot plants receiving municipal wastewater. An activated sludge process and a following sand filter showed removal efficiencies of 2 log and 0.5 log, respectively. Poly-aluminium chloride dosage improved the efficiencies by 3 log for the activated sludge process and by 2 log for the sand filter. Chemical precipitation of raw wastewater with poly-aluminium chloride could achieve 1 to 3 log removal according on the coagulant concentration.
Keywords activated sludge process; coagulation; *Cryptosporidium*; sand filter; wastewater treatment

Introduction

Japan experienced an outbreak of Cryptosporidiosis in 1996 in Ogose town, Saitama Prefecture, in which about 9,000 people were infected. The direct cause of the outbreak was that *Cryptosporidium* oocysts in source water were not removed completely in the water treatment process and the contaminated water was distributed through the tap water system. However, the small wastewater treatment plants located upstream of the water source are considered to have worsened the outbreak. The cycle of water from wastewater to drinking water through a river system was formed, which led to the proliferation of *Cryptosporidium* in the cycle.

From this experience, the wastewater system must have functions to remove *Cryptosporidium* oocysts effectively during an outbreak. It is estimated that as many as 1 billion *Cryptosporidium* are discharged in one day from an infected person and so the oocyst concentration in the wastewater can increase significantly during an outbreak. Therefore, technology to greatly reduce the high concentration of oocysts is necessary.

Villacorta-Martinez de Maturana et al. (1992) reported that batch activated sludge treatment with 3-hour aeration and 40-minute sedimentation removed 80% of oocysts and reduced the infection intensity by 82–99%. Stadterman *et al*. (1995) evaluated the oocyst removal efficiency of a continuous activated sludge treatment process with 3-hour aeration time using experimental facilities, and showed 98.6% total removal. Suwa and Suzuki (2001) carried out activated sludge batch experiments of 8-hour aeration and additional coagulant dosage, and showed 2 log oocyst removal and 1 log removal improvement, respectively.

Previous researches have focused on activated sludge treatment of batch processes with a rather short aeration time, therefore, in this research the authors evaluated the continuous process of 8-hour aeration. In addition, experiments on sand filtration and coagulant dosage were conducted to improve the oocyst removal efficiency.

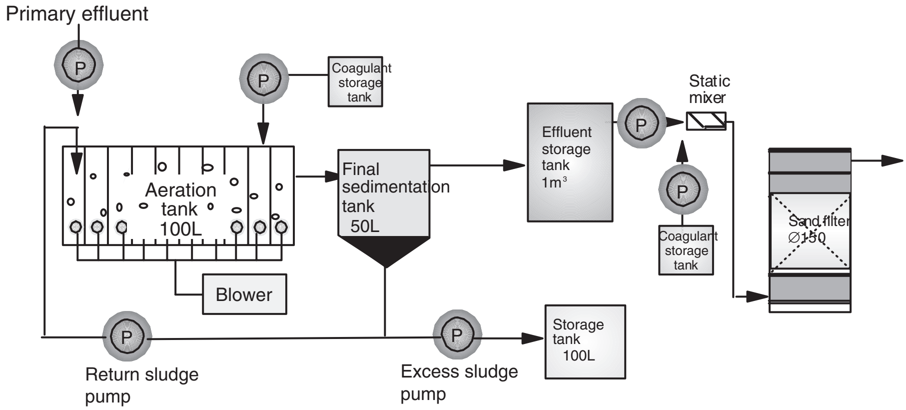

Figure 1 Pilot plants

Methods

Experiment Apparatus

Experiments were carried out using pilot plants (Figure 1) receiving primary effluent of municipal wastewater treatment plants. The apparatus for the activated sludge process consisted of an aeration tank (100 L) and a final sedimentation tank (50 L), followed by two storage tanks for the supply of secondary effluent to a sand filter. The diameter of the sand filter was 15 cm and the main sand particle size was 1 mm. Coagulant dosage devices were equipped at the end of the aeration tank and at the inlet of the sand filter.

Experimental conditions

Inactivated oocysts with formaldehyde were used for the experiments. Firstly, the oocyst removal efficiency of the activated sludge process was evaluated. Inactivated oocysts were added to the primary effluent so that the oocyst concentration in the influent became 4×10^4 oocyst/L. SRT, HRT and MLSS concentration of the process were controlled at around 7 days, 8 hours and 2,000 mg/L, respectively. Just after the start of oocyst addition, measurement of water quality was begun and the experiment was continued for 8 days.

Secondly, to improve the removal efficiency of the activated sludge process, polyaluminium chloride was dosed at the end of the aeration tank. The dosage concentration was 10 mgAl/L against the influent and the operation was continued for 8 days.

The evaluation of the sand filtration was conducted using the secondary effluent from the activated sludge process during the term without coagulant dosage. Then, the effect of coagulant dosage prior to the filtration was evaluated by dosing poly-aluminium chloride at the inlet of the filter at the concentration of 3 mgAl/L. In both cases, filtration direction was upflow and the filtration rates were set at 100 and 200 m/d. Samples were taken after 2 to 3 hours of operation.

In addition, chemical precipitation of raw wastewater was investigated, assuming the method of dosing coagulant to the raw wastewater, mixing in the grit chamber and sedimentation in the primary clarifier. In the experiment, poly-aluminium chloride was dosed to the raw wastewater up to 20 mgAl/L and the mixture was subjected to rapid mixing for 1 minute and settling for 90 minutes. Oocysts were added so that the concentration became 10^4 to 10^6 oocyst/L.

Oocyst measurement

Samples containing oocysts were filtered, and the filter was then dissolved by acetone. The liquid was purified by centrifuging and ethanol several times, and the oocysts were stained with an indirect immunofluorescent method, then counted using an epifluorescent microscope. The oocyst recovery ratio of the measurement was 50.7% for the effluent of the activated sludge process and 80 to 100% for the chemically precipitated raw wastewater.

Results

Activated sludge process

The activated sludge process, whose HRT and MLSS concentration were 8 hours and 2000 mg/L, respectively, reduced the oocyst concentration of 4.0×10^4 oocyst/L in the influent to 4.0×10^4 oocyst/L in the effluent, showing a removal efficiency of about 2 log (Figure 2 until 200 hours). This efficiency was almost the same as that calculated from the data of batch experiments (Suwa and Suzuki, 2001).

The poly-aluminium chloride dosage to the activated sludge process at 10 mgAl/L improved the oocyst removal efficiency by 3 log, reaching a total of 5 log removal (Figure 2 after 200 hours). It took about 4 days for the maximum removal efficiency to be obtained.

Compared to the former research of batch experiments, in which 10 mgAl/L of poly-aluminium chloride dosage improved the removal efficiency by 1 log (Suwa and Suzuki, 2001), the continuous dosage of coagulant showed superior improvement of 2 log at the steady state. This might have been due to the contribution of accumulated coagulant in the sludge to the removal of oocysts.

Sand filtration

Sand filtration, whose filtration rates were 100 and 200 m/d, was adapted to the treatment of the effluent from the activated sludge process, and showed 0.5 log removal of oocysts (Table 1). Because of the unsatisfactory removal ratio, 3 mgAl/L of poly-aluminium chloride was dosed and mixed prior to the filtration, then filtration was carried out. The removal efficiency was improved to 2.6 log for both filtration rates.

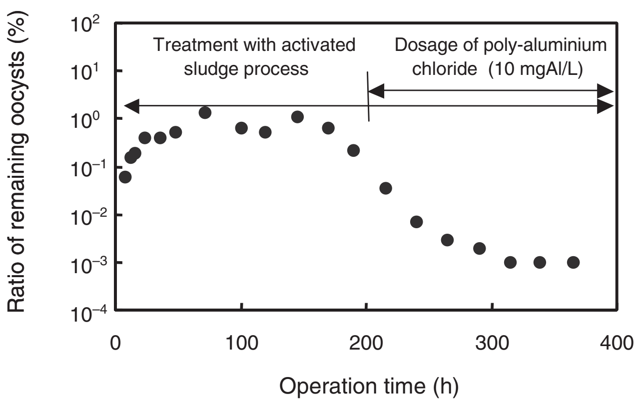

Figure 2 Removal of oocysts with activated sludge process and coagulant dosage

Table 1 Oocyst removal efficiency of sand filtration and supplemental coagulant dosage

	Sand filtration		With coagulant dosage	
	Oocyst Concentration (oocyst/L)	Removal Efficiency (–)	Oocyst Concentration (oocyst/L)	Removal Efficiency (–)
Secondary treated water	124		199	
Filtrate (100 m/d)	34	0.6 log	0.5	2.6 log
Filtrate (200 m/d)	36	0.5 log	0.5	2.6 log

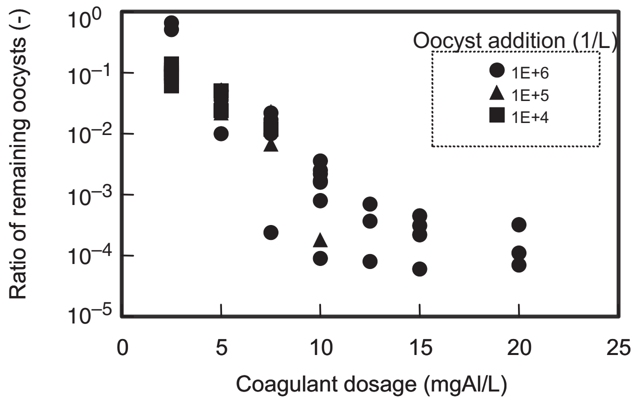

Figure 3 Effect of coagulant dosage on removal of oocysts in raw wastewater

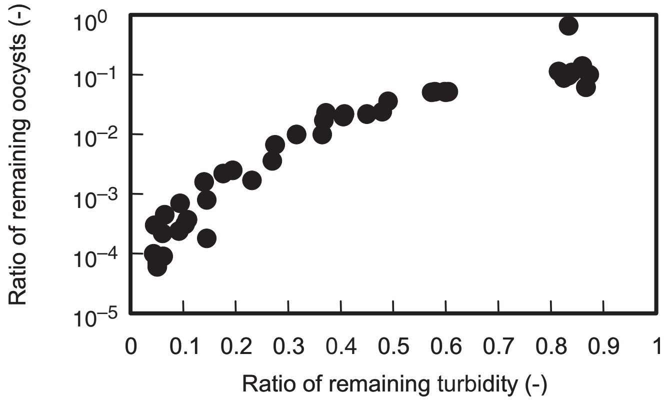

Figure 4 Relationship between removals of turbidity and oocysts with coagulant dosage to raw wastewater

Chemical precipitation of raw wastewater

Prior to the chemical precipitation of raw wastewater, settlability of oocysts was evaluated by adding oocysts to the raw wastewater and measuring the oocyst concentration in the supernatant at the beginning and after 120 minutes of sedimentation. The two concentrations were almost the same, which indicated that the settlability of oocysts was quite low.

In the chemical precipitation of raw wastewater, a high removal ratio of oocysts was observed at high coagulant concentration, 1 log at 5 mgAl/L, 2 log at 10 mgAl/L and 3 log at 15 mgAl/L (Figure 3). A higher oocyst removal ratio at lower SS concentration was observed, but the removal ratio remained almost constant when the SS concentration exceeded 200 mg/L. The oocyst removal ratio in the supernatant was correlated to the removal ratio of the turbidity (Figure 4). Therefore, turbidity could be used as an indicator for the removal of oocysts by dosing coagulant to raw wastewater.

With the treatment methods investigated here or a combination thereof, the *Cryptosporidium* oocyst concentration in treated wastewater can be reduced substantially even during an outbreak, and thus it may be possible to prevent the spread of infection.

Conclusion

From pilot plant experiments receiving municipal wastewater, *Cryptosporidium* oocyst removal efficiencies of an activated sludge process and sand filtration were evaluated together with the effect of coagulant dosage. The following results were obtained.

The activated sludge process of continuous flow with 8-hour aeration time removed oocysts by 2 log. Dosage of poly-aluminium chloride to the aeration tank improved the removal efficiency by 3 log after 4 days, achieving 5 log removal in total.

Sand filtration of secondary effluent removed oocysts by 0.5 log, and coagulant dosage improved the efficiency by 2 log.

Chemical precipitation of raw wastewater had the effect of removing oocysts by 1 log to 3 log according to the coagulant dosage concentration. Turbidity and the oocyst concentration in the supernatant showed a good correlation.

With the treatment methods above or a combination of thereof, the *Cryptosporidium* oocyst concentration in treated wastewater can be reduced substantially even during an outbreak.

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