CRYPTOSPORIDIUM AND THE MILWAUKEE INCIDENT

(U.S.) ENVIRONMENTAL PROTECTION AGENCY, CINCINNATI, OH

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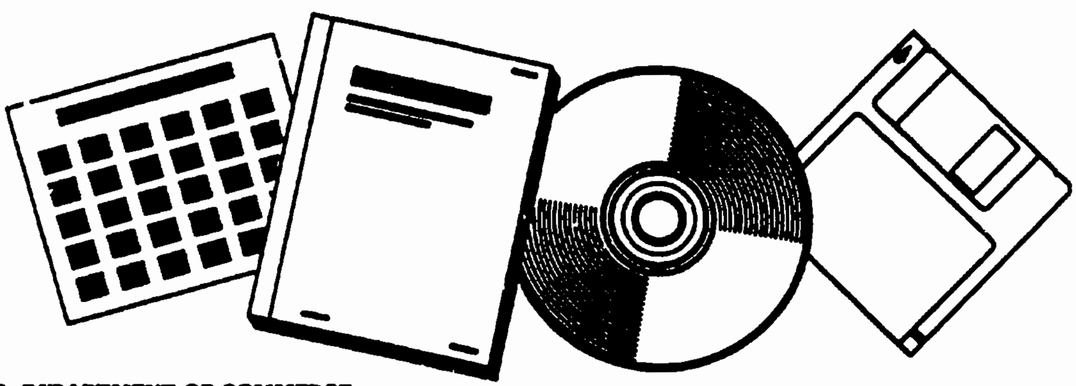

U.S. DEPARTMENT OF COMMERCE
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Cryptosporidium and the Milwaukee Incident

Kim R. Fox and Darren A. Lytle[1]

Introduction

In early 1993, Milwaukee, Wisconsin reported a sharp increase in the number of diarrhea patients and shortages of over the counter drugs for diarrhea control at local pharmacies. The increase in diarrhea was determined to be caused by the organism Cryptosporidium. Preliminary investigations conducted by State and City officials suggested that the drinking water may have been partially responsible for distributing the organism around Milwaukee.

On April 6, a doctor ordered a parasitic analysis on a patient's fecal specimen. Cryptosporidium was detected in the fecal smear. At that time, the local and state officials were notified of the Cryptosporidium detection. A concurrent survey of diarrhea cases in local nursing homes indicated that residents in nursing homes in the southern part of the city were fourteen times more likely to have had diarrhea than those in the northern part of the city. In addition to the nursing home survey, turbidity problems at the southern water treatment plant also implicated drinking water and this plant as being suspect in the cryptosporidiosis outbreak (Figure 1). At that point, the southern (Howard) plant was shut down and all water for Milwaukee was supplied by the northern (Linwood) plant under a boil water order.

The closure of the Howard Water Treatment Plant, the boil water order, the magnitude of the number of reported diarrhea cases, and the media attention, all helped to

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MILWAUKEE INCIDENT

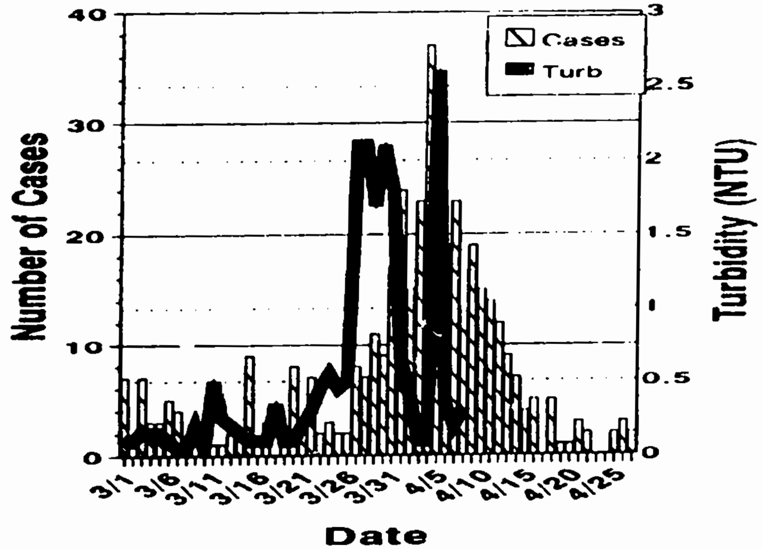

Figure 1. Diarrhea Onset & Max. Filter Turbidity

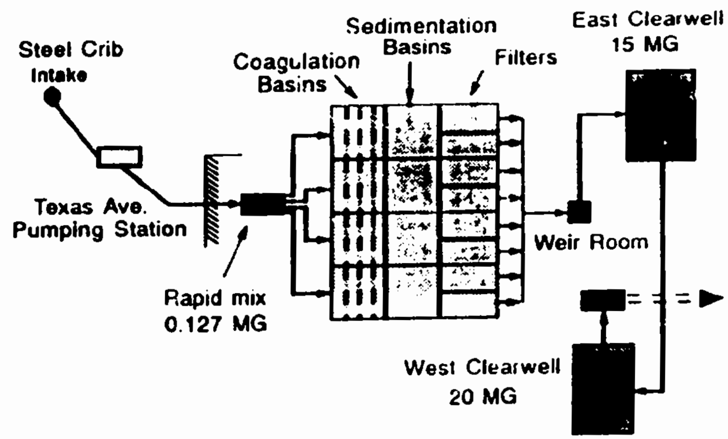

Figure 2 Howard Avenue Water Treatment Plant

focus water utility personnel, engineers, scientists, government officials, and rule-making bodies onto this waterborne outbreak. Follow up surveys have indicated that as many as 403,000 people may have been ill during the Milwaukee incident (Edwards 1993).

Cryptosporidium is a protozoan that if ingested by a healthy adult human may cause some discomfort such as that felt with stomach flu, however, it can be life threatening to others such as infants, AIDS patients and the elderly. Research has shown that most surface waters are contaminated with this parasite (LeChevallier 1991). Cryptosporidium oocysts are very resistant to chlorination and, therefore, their effective removal from surface waters is highly dependent on the operation of a filtration facility.

During the initial stages of the outbreak, the City of Milwaukee requested the assistance of the U.S. Environmental Protection Agency (EPA) to provide technical assistance. A team from the EPA's Drinking Water Research Division (DWRD) familiar with filtration processes and with the removal of Cryptosporidium oocysts by filtration went to Milwaukee. The team concentrated its efforts on evaluating the operational and monitoring data available from the southern Howard Avenue Water Treatment Plant. The goal was to assess how (from an engineering standpoint) Cryptosporidium may have passed the water treatment facility.

As part of the EPA Assistance, the team called upon research previously sponsored or conducted by the DWRD on removing Cryptosporidium from drinking water. This research included both extramural and in-house laboratory and pilot plant filtration studies. Both the in-house studies and the field studies have indicated that good turbidity and particulate removal is necessary for good removal of Cryptosporidium from drinking water.

Plant Inspection

The source water for Milwaukee, Wisconsin, is Lake Michigan (City of Milwaukee 1992). The city's water is treated at two water treatment facilities: the northern situated Linwood treatment plant and the southern Howard treatment plant. Both treatment facilities treat Lake Michigan water by conventional water treatment processes (coagulation, sedimentation, filtration, and disinfection). The Linwood facility has a water treatment capacity of 275 million gallons per day (MGD) and the Howard treatment facility has a filtration capacity of 100 MGD. During typical operation, the

Linwood plant supplies the northern 2/3 of the water district. The Howard plant supplies the remaining 1/3. Large mixing zone exists in the distribution system between the two treatment facilities, but the general flow of water is northern or southern. The initial investigation linked the cryptosporidiosis outbreak to drinking water treated at the Howard treatment facility, resulting in temporary shutdown of the facility. The EPA team focused its efforts on understanding the operation of the Howard treatment plant.

The Howard Plant is a conventional coagulation, sedimentation filtration facility (Figure 2). A complete description can be found in Fox and Lytle (1993b). Alum (aluminum sulfate) was the coagulant used until August of 1992. In August of 1992, the facility switched to polyaluminum chloride (PACL). The switch to PACL was done with the belief that a benefit of higher finished water pH for corrosion control would be met as well as reduced sludge volume and improved coagulation effectiveness in cold raw water conditions. Before switching to PACL, the city consulted with the chemical manufacturer, Wisconsin DNR, and other communities receiving Lake Michigan water and using PACL.

In the time frame immediately preceding March 1993, the Howard Plant (HWTP) was consistently producing a low effluent turbidity water (daily averages of 0.1 NTU or less). During the period of March 18 thru April 8 (plant was shut down April 8), the effluent turbidity from the HWTP was highly variable and ranged from between 0.1 and 1.7 NTU (Figure 1). The team was asked to look at what caused the higher turbidity levels to occur. At all times during this period, effluent water samples were negative for coliforms and met the Wisconsin DNR regulations for turbidity.

The HWTP receives a highly variable quality of influent water (from Lake Michigan) to be processed through the plant. During the time period of March 18 through April 8, the raw water turbidity levels ranged from 1.5 to 44 NTU. Total coliforms ranged from <1 CFU/100 mL to around 3200 CFU/100 mL in the raw waters. All effluent water samples were negative for coliforms. Average raw water turbidity levels for previous months were around 3 or 4 NTU and influent coliform levels <20 CFU/100 mL.

During the time period investigated, plant facility personnel responded to turbidity changes throughout the treatment processes by adjusting coagulant dosages. Coagulation dosage adjustments were also made to compensate for coagulation demands resulting from taste and order controlling treatment. Throughout the period, coagulant dose adjustments were continuously being made to meet the demands of raw water quality.

Although the coagulant dosages were being adjusted, filter effluent turbidities on several occasions exceeded turbidity values that were achieved in previous months. As the coagulant doses approached what might be optimum dosages for the particular raw water conditions, improvements in settled water turbidities and filter effluent turbidities were achieved. This pattern was seen twice. The first time was when polyaluminum chloride was the primary coagulant at the HWTP. The second time was when the primary coagulant was switched back to alum on April 2, 1993. The improvements in filter effluent turbidity demonstrated that the plant is fully capable of producing low turbidity water under optimal chemical coagulation conditions (i.e. dosages applied) even when challenged with high turbidity raw water.

There are several factors that may have increased the time to reach the optimum coagulant dosages for low filter effluent turbidities during this time. One of these factors may include a lack of historical use records for PACL. The previous coagulant had been used for almost thirty years. The new coagulant had only been used for a short time and the historical records were not fully developed. The optimum chemical dosages were sought through laboratory testing and consultation with DNR and chemical supplier to achieve the lowest turbidity possible. The coagulant adjustments were made based on all available data.

Another important factor is the time required to see a result in the treated water quality after chemical adjustment. With a short residence time for the water in the plant and a rapidly changing influent water quality, dosage optimization was difficult.

During the higher effluent turbidity episodes, greater numbers of particulates passed through the HWTP as evidenced by the higher turbidity values exiting the plant clearwell. Although a greater number of particulates passed through the plant, this does not necessarily mean that Cryptosporidium oocysts passed through the plant. This does, however, suggest that if a large number of oocysts were present in the source water at this time, the likelihood of passage would increase. There is no way to know for sure that this scenario resulted in Cryptosporidium oocysts passage. Monitoring for this organism is not a common practice in the drinking water supply industry, nor required in Wisconsin

by Wisconsin Administration Code.

Experimental Studies

The Drinking Water Research Division (DWRD) has conducted, and is conducting filtration studies on removing microorganisms from drinking water. Current efforts are focused on removing Cryptosporidium oocysts. In addition to the filtration studies, charge/attachment studies are also being conducted to look at the zeta potential of the organisms as they are subjected to the rigors of a water treatment plant.

The DWRD has pilot-scale water treatment facilities located at the Cincinnati laboratory. Various waters can be brought to the treatment facility to challenge the filter units with differing water qualities. Specific organisms of choice are also spiked into the water to achieve levels desired. The organisms are cultivated in-house and are grown in broths, on agar, or in animals.

Experimental Results

In early studies, Cryptosporidium parvum oocysts (stored in dichromate) were used in jar test studies. The initial jars were spiked with 10,000 oocysts/liter and the water subjected to optimum coagulation, flocculation and settling conditions. The supernatant from the settling process contained 1,000 oocysts/liter (90% reduction). Tests with fresh (unpreserved) oocysts at the same coagulant dosages only exhibited 50% reduction in oocysts. Although these tests are preliminary, there does appear to be substantial differences between fresh and stored oocysts. One of the pilot plant filter systems was challenged by 100,000 oocysts/liter. The filter effluent was monitored for oocysts and 99% removal of preserved oocysts were routinely seen. The pilot slow sand filter was also challenged with water containing 100,000 oocysts/liter. Effluent concentrations were consistently below 1,000 oocysts/liter and in most cases less than 200. The filter was monitored two weeks after the spiking stopped and no oocysts were found in a fifty gallon sample of the effluent. Particle counting showed a removal of around 96% of particles in the 2.5 to 5 µm range. In all of these tests, the percent total particulate removal measured by particle counters, was less than the percent removal of oocysts.

Slow sand filter tests conducted by Ghosh 1989 showed three log removal of Cryptosporidium through the filter during ripening and greater than four log reduction on a fully ripened filter. Ghosh conducted several experiments using various grades of diatomaceous earth (DE) on a precoat filter. Observed oocysts removals exceeded three log removal for all runs, but removals were dependent on DE grade. The larger the grade, the more oocysts found in the effluent.

Zeta potential measurements were made in DWRD labs using clean suspensions of Cryptosporidium oocysts (both muris and parvum) diluted into a river water that had been filtered through 1μm membrane filters. Tests were conducted to evaluate variables such as age of oocysts, storage solution, and pH of suspension fluid on oocysts. Muris oocysts were highly variable in regard to zeta potential as the charge increased from -21 mv to -1.8 mv as the pH was lowered from 10.0 to 4.6 (muris oocysts were not stored in dichromate). Muris oocysts stored in dichromate had a considerable greater charge magnitude than those in clean suspensions (-31.1 versus -20.1 mv, respectively). The parvum oocysts displayed a change from -17.8 mv (in clean suspensions) to -25.2 mv in suspensions stored in dichromate. In one study, the fecal material from a calf was stored in dichromate for twelve hours until the material could be processed the next day. The oocysts were harvested and stored without dichromate. Twenty-four hours after preparation, the measured charge was -6 mv. The suspension was monitored for eight days and the charge gradually changed to -14.1 mv. There were not enough oocysts to continue the study to determine if the charge would recover to -17.8 mv seen with most fresh oocysts. Zeta potential studies by Ghosh showed values 5 mv more negative than the results in the EPA tests with preserved oocysts.

Discussion

The prelimin[illegible] ests have indicated that most filtration systems [illegible] ffective in removing greater than 2.5 logs of oocysts [illegible] ideal operating conditions. These tests for the m[illegible] t have been done with oocysts preserved in dichromate [illegible] ith formalin fixed oocysts. Both the preservation solution and the fixation fluid have shown an effect on the measured zeta potential and may have an effect on the rigidity of the organism. The few studies completed with fresh oocysts have shown less effective removal but more work is planned. Several surveys in the literature (LeChevallier 1991) have indicated that oocysts are passing through some filter plants. The passage of oocysts may indicate that fresh (or untreated) oocysts may be more difficult to remove than those that are pretreated by some manner. The preservation processes may affect the physical characteristics of the oocysts and may make them more susceptible to filtration processes than those in the natural environment.

In order to achieve good reduction in turbidity at all times, stringent controls on coagulant/flocculant dosages are required. This control could be automated or done by operator attention and that determination would be at the discretion of the water utility. Subtle changes in effluent turbidity from a filtration plant may result in large changes in particulates passing through the filters that may or may not be associated with pathogens. The goal therefore, should be to remove these particulates and not have to worry about whether or not they are of concern.

In Milwaukee, the inability to maintain a low filter effluent turbidity may have allowed Cryptosporidium oocysts to pass through the water treatment plant (Fox and Lytle 1993a).

Acknowledgements

The authors wish to acknowledge all the individuals and organizations that worked very hard during the Milwaukee incident. Without the cooperation of everyone, the investigation could not have happened.

References

City of Milwaukee (1992). "1991 Annual Report", Water Engineering Division, .

Edwards, Diane D. (1993). "Troubled Waters in Milwaukee", ASM News, Vol 59, Number 7.

Fox, Kim R. and Lytle, Darren A. (1993a) "Press Conference Presentation". Milwaukee, Wisconsin, April [illegible]

Fox, Kim R. and Lytle, Darren A. (1993b) "The Milwaukee Cryptosporidiosis Outbreak: Investigation and Recommendations", Proceedings AWWA Water Technology Conference, Miami, Florida.

Ghosh, M.M., et al. (1989). "Field Study of Giardia and Cryptosporidium Removal from Pennsylvania Surface Waters by Slow Sand and Diatomaceous Earth Filtration". Environmental Resources Research Institute.

LeChevallier, M.W., et al. (1991). "Giardia and Cryptosporidium in Water Supplies". AWWA Research Foundation. ISBN 0-89867-569-3.

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16. ABSTRACT

In March and April of 1993, Milwaukee, Wisconsin reported a very large increase in the number of diarrhea patients and shortages of over the counter drugs for diarrhea control at local pharmacies. Preliminary investigations conducted by State and City officials suggested that the drinking water may have been partially responsible for distribution Cryptosporidium around Milwaukee. In addition to turbidity data, a survey of diarrhea cases in local nursing homes implicated the Howard Water Treatment Plant. A team of investigators from the EPA's Drinking Water Research Division (DWRD) assisted with the investigation. This paper describes the approach the EPA team took in evaluating the effectiveness of the water treatment facility to remove particulates, including a discussion of the key operational data and a description of what was observed at the treatment facilities. Research including both extramural and in-house laboratory and pilot plant studies for Cryptosporidium removal is also discussed. A brief summary and discussion of this data is presented in this paper.

17. KEY WORDS AND DOCUMENT ANALYSIS

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