Outbreaks Caused by *Giardia* and *Cryptosporidium* Associated with Swimming Pools

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The most important factor in preventing swimming pool outbreaks is adequate disinfection. Chlorine is the agent universally selected as the swimming pool disinfectant. However, in recent years it has become evident that another means must be utilized for parasites, like Giardia and Cryptosporidium; filtration and chlorination together can provide adequate disinfection, with proper pool management. Outbreaks that were reported are described in this paper, indicating how disinfection was compromised.

INTRODUCTION

Giardia and *Cryptosporidium* are the most common intestinal parasites identified with diarrhea in the United States. They are becoming increasingly identified as the causes of diarrheal disease associated with fecally contaminated recreational and drinking waters. Both of these organisms are protozoans (one–celled) animals and are transmitted by the fecal–oral route (i.e., ingestion). They are excreted in the feces in infected humans and certain animals. Millions are usually present in a gram of feces of infected persons. *Giardia* is now the microorganism most commonly associated with drinking water disease outbreaks when an agent can be identified (Craun, 1992). Sixty percent of the cases which occurred in the United States are believed to be associated with drinking water or contact with contaminated surface water in lakes and streams (Bennett *et al*., 1987). If left untreated *Giardia* can cause recurring diarrhea lasting several months. *Cryptosporidium*, while not as often documented with waterborne disease outbreaks, has caused some very large outbreaks. In 1993, it caused the largest waterborne disease outbreak ever documented in the United States that occurred in Milwaukee, WI, in which more than 400,000 persons became ill and more than 100 died (Mackenzie, 1994). There is no medical treatment for *Cryptosporidium* infections. In normal healthy individuals it causes an infection lasting 7 to 10 days (Table 1). However, it can cause a very serious life threatening illness in immuno-compromised individuals, such as persons with acquired immuno–deficiency (AIDS) individuals, the very young, and cancer patients.

These parasites commonly infect young children and are common infections in day–care centers. However in the case of *Giardia*, water is believed to be the major source of acquisition (Bennett et al., 1987). The prevalence of *Giardia* in stool samples in the general population is one to 30 percent (Benson, 1990). *Cryptosporidium* appears to be less common with an incidence of from 2.2 to 4.5 percent in developed countries. Studies with human volunteers have shown that only a few organisms, or just one, need to be ingested to cause infection (DuPont et al., 1995). Not all persons who become infected will develop diarrhea. Many will become asymptomatic (no obvious illness), but the organism will grow in the intestine and be excreted in the feces. *Giardia* forms an environmentally resistant stage called a cyst, while *Cryptosporidium* forms oocysts (Figure 1). These forms are very stable and may survive for weeks in natural waters at cool temperatures (5^0C). However, as temperatures increase they are inactivated at a faster rate. Cysts and oocysts are also very resistant to inactivation by disinfectants commonly used in drinking water treatment and in swimming pools. At

Journal of the Swimming Pool and Spa Industry
Volume 1, Number 3, pages 9–18

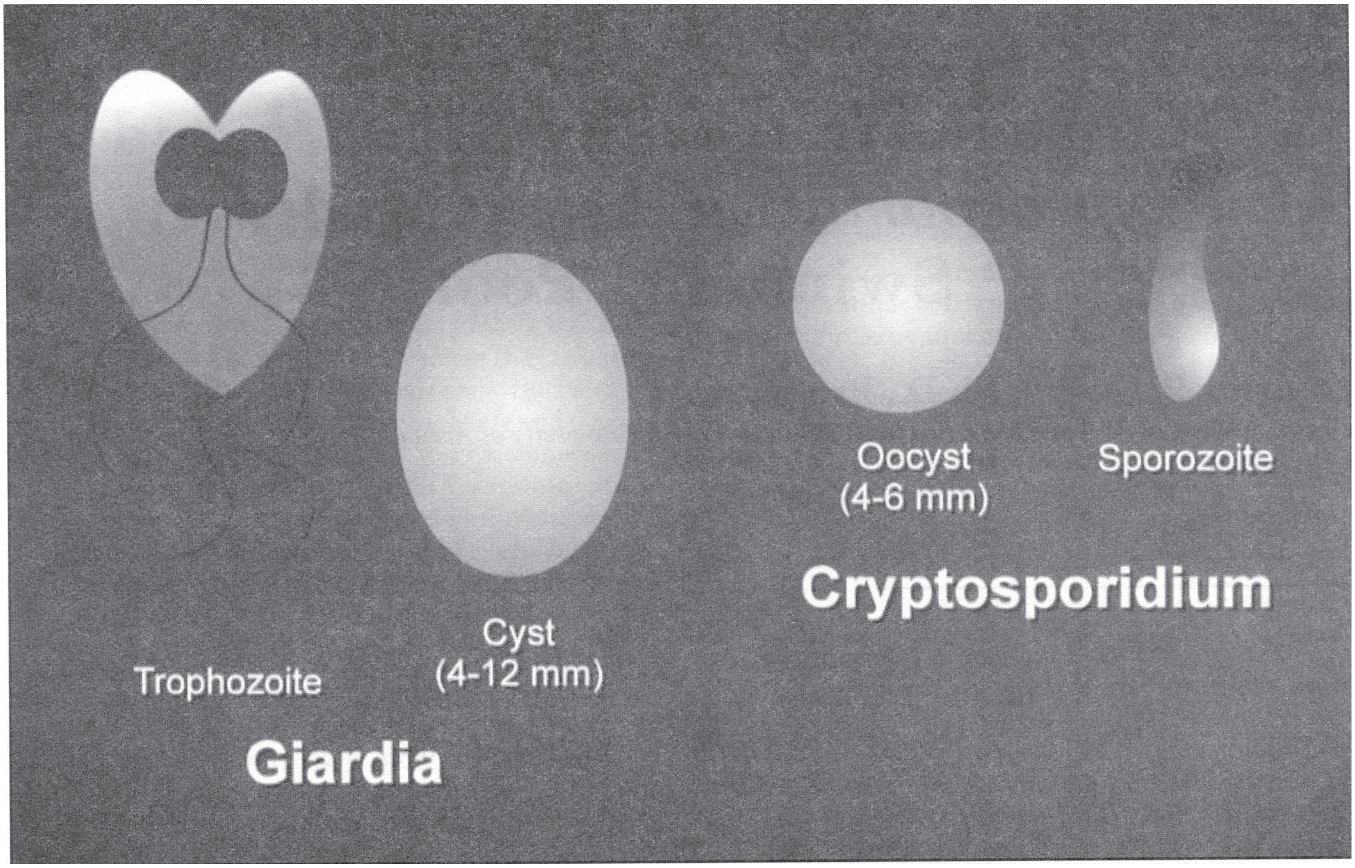

Figure 1 – *Giardia* and *Cryptosporidium*

temperatures normally maintained in pools (>25^{0}C), inactivation (99.9%) of *Giardia* cysts at free chlorine concentrations of 1.6 mg/l and pH 7.5 occurs after 50 minutes (USEPA, 1996). In contrast coliform bacteria often used to judge the sanitary quality of pool water under these conditions are killed in a few seconds. However, to kill 99.9 percent of the *Cryptosporidium* oocysts under the same conditions would require more than 100 hours (Korich et al., 1990). *Cryptosporidium* is the most chlorine resistant waterborne pathogen currently known. While *Cryptosporidium* can be killed with ozone, high concentrations of ozone are required.

Outbreaks of giardiasis and cryptosporidiosis associated with swimming pools are usually attributed to accidental release of feces by children. Table 2 is a list of documented outbreaks of cryptosporidiosis; Table 3 lists giardiasis outbreaks.

Out of five widely separated outbreaks for cryptosporidiosis, there were a total of 318 cases of infected individuals. Out of three reported outbreaks of giardiasis, 111 people became ill. All of the infected persons recovered without any fatalities. This report was intended to include spa–related outbreaks as well, but none could be found. The cysts and oocysts are killed fairly rapidly at temperatures typically found in hot tubs and spas (95 to 98^{o}F*).

Usually only outbreaks in which a local health department has made the effort to investigate are reported. There is no requirement in the United States that such outbreaks must be studied or reported. Thus, the actual number of outbreaks are undoubtedly far greater. Reported outbreaks only represent the tip of an iceberg in the true number of cases associated with pools.

Filtration is an especially important barrier in the removal of the protozoan parasites *Giardia* and *Cryptosporidium*. The cysts and oocysts of these organisms are very resistant to inactivation by disinfectants, so disinfection alone cannot be relied upon to prevent waterborne illness. However, because of their smaller size, viruses and bacteria can pass through the filtration process. Thus, disinfection remains the ultimate barrier to these microorganisms.

Outbreaks of *Cryptosporidium*

On August 28, a parent reported to the Madison Department of Public Health that her daughter was ill

*Maximum safe temperature, 104^{o}F

with laboratory–confirmed *Cryptosporidium* infection and that other members of her daughter's swim team had had severe diarrhea. On August 26, public health officials inspected the pool where the team practiced (pool A) and interviewed a number of patrons at the pool. Seventeen (55 percent) of 81 pool patrons interviewed reported having had watery diarrhea for two or more days with onset during July or August. Eight (47 percent) of the seventeen had had watery diarrhea longer than five days. Four persons who reported seeking medical care had stool specimens positive for *Cryptosporidium*.

On August 31, public health nurses at the Dane County Public Health Division identified a second cluster of nine persons with laboratory–confirmed *Cryptosporidium* infection while following up case reports voluntarily submitted by physicians. Seven of the nine ill persons reported swimming at one large outdoor pool.

To limit transmission of *Cryptosporidium* in Dane County pools, state and local public health officials implemented the following recommendations: (1) closing the pools that were epidemiologically linked to infection and hyperchlorinating those pools to achieve a disinfection (C.T) value of 9600 (C.T = Concentration of chlorine x time in minutes); (2) advising all area pool managers of the increased potential for waterborne transmission of *Cryptosporidium*; (3) posting signs at all area pools stating that persons who have diarrhea or have had diarrhea during the previous fourteen days should not enter the pool.

Joce et al. (1991) describes the investigation of the first recognized English outbreak of cryptosporidiosis associated with a swimming pool. The Doncaster Royal Infirmary diagnosed a total of 79 cases between June 1 and November 11 in 1988. Many of the early cases were children who lived in Northeast Doncaster. Most of them used the learners pool in a sports center, which also had an adult pool. The ages of the primary cases ranged from six months to 70 years (median, 6 years); 20 (63 percent) were younger than 10. Eight cases, five of whom were primary, required hospital admission, most for less than two days.

Two problems had been reported to the pool management before the pools were closed: an unusual odor in the changing rooms and difficulties in controlling the levels of free chlorine residuals. However, routine water testing showed satisfactory results.

After the learner pool was closed, liquid sewage was discovered at the deep end. Early on, it was suggested that a bather excreting oocysts might have contaminated the pool. However, after further investigation it became clear there had been a serious problem with the plumbing system, particularly backflow from the sewers into the duct around the learner pool. Intercurrent defects in the pipes from the scum channel had allowed sewage–contaminated fluid to enter the pool circulation.

The original source of the oocysts remains unknown, although it is most likely they were excreted by someone who used the toilets. Oocysts were not identified in large volumes of the water mains supplying the sportscenter, however 50 oocysts per liter were observed in the pool water.

This episode in Doncaster may be unique, but the possibility that people have swum or participated in water sports in sewage polluted water should be considered when investigating future cases of cryptosporidiosis.

In 1988, an outbreak in Los Angeles County involved 60 cases of cryptosporidiosis resulting from individuals swimming in a 100,000–gallon swimming pool in which there was a single fecal accident (Sorrillo et al., 1992). The overall attack rate was 73%. The illness was observed in several separate groups of people with no common link other than using the swimming pool. Length of exposure and immersing the head under water were risk factors in contracting the disease. In another outbreak reported in British Columbia, 66 clinical and 23 confirmed cases of cryptosporidiosis were shown to have resulted from swimming in a 70,000–gallon swimming pool. The children's pool was closed when it was found to be the probable source of infection. The pool in question had experienced an increase in the number of fecal accidents from the usual one or two per month to one or two per week, with three known diarrheal episodes.

A fourth outbreak of cryptosporidiosis occurred at a wave pool at a water park in Lane County, Oregon, in 1992 (McAnuley et al., 1994). The water park was located indoors and contained four heated pools, each on rapid–sand type filters. Up to 1300 people a day used the facility during peak periods. The largest pool in the facility was a wave pool with a device able to generate waves up to several feet high, and attached to a water slide. Case patients who had visited the water park had all swum in the wave pool between July 23 and September 24. An inspection by county sanitarians revealed no abnormalities in either in the pools' filtration of chlorination systems. Chlorine levels in the wave pool, documented at least twice daily, exceeded the recommended minimum of 0.8 mg/L on 99% of readings.

Exposure to contaminated water in a water park's wave pool likely caused an outbreak of cryptosporidiosis in Lane County. Data suggest the pool water was initially contaminated in late July. The prolonged duration of this outbreak, over several weeks, suggests either that *Cryptosporidium* from the initial contamination survived several weeks to infect the other case patients or that the wave pool was recontaminated by subsequent bathers. A single bather could have produced large numbers of oocysts, and many other bathers could have been exposed to those oocysts in the ensuing weeks. However, recontamination of the pool may be more likely since available evidence suggests that the viability of *Cryptosporidium* oocysts in warm chlorinated water is limited.

Another water slide associated outbreak has also been reported from Idaho, but remains unpublished.

Outbreaks Associated with Giardia

The first reported swimming pool associated outbreak attributed to *Giardia* occurred in Thurston County, State of Washington. This outbreak reported by Harter et al., (1984) was associated with swim classes for young children and their parents. Close interactions between instructors, parents, and children were believed to play a significant role in the spread of the organism between the various classes held in the pool. The children were infants to three years of age, and parents were always present. Classes held through the day were held twice a week, and class size varied from six to 14 children. A total of nine classes were held by the same instructor. Of the 75 children who were involved in the different classes, 61 percent were found to be positive for *Giardia*, as were 39 percent of the mothers who participated in the swim classes. *Giardia* positive children were found in all nine classes. An investigation revealed the absence of coliform bacteria and that the pH was within acceptable limits. Records indicated that chlorine levels were often low in the pool (range of 0.2 to 3.0 mg/l) and turbidity was often high.

It was concluded that there were several factors potentially contributing to the spread of the parasite between classes. Frequently, children were allowed to make up missed sessions on another day, thus exposing other classes to the parasite. The child used by the instructor to demonstrate the swim techniques to all classes was *Giardia* positive. Also, new–comers to the swim class were incorporated into existing classes, exposing these infants and parents to *Giardia* infected veteran swimmers.

Another outbreak, which occurred in New Jersey, demonstrated how a contamination event in a pool can lead to infection of swimmers throughout the course of a day if appropriate action is not taken (Porter et al., 1988). In this outbreak a fecal accident by an infant which probably occurred early in the day was believed to be responsible for infection of two children and seven adults. In this

	Cryptosporidium	Giardia
Illness	Diarrhea, vomiting, fever, abdominal cramps	Diarrhea with abdominal cramps
Incubation period (average)	7 days	7–12 days
Length of illness	10–14 days	7–10 days or longer
Sources of environmental contamination	Infected humans and domesticated animals (cattle)	Infected humans and animals (beavers, muskrats)
First documentation of waterborne disease	1986	1965
Stage found in water	oocyst	cyst
Stage found in intestine	sporozoite	trophozoite
Size of cyst or oocyst	4–6 7m	4–12 7m
Time (minutes) to kill 99.9% with 2 mg/l free chlorine, pH 7.5, 25°C	>5000	50

Table 1 – Characteristics About *Giardia* and *Cryptosporidium*.

outbreak the source of the *Giardia* was assumed to be a child in a handicapped class who defecated in the pool between 9:30 and 10:15 a.m. The accident was identified when the child, who had no symptoms of giardiasis, had removed his swimming attire after defeating in the pool. Managers were aware of the incident, but did not ask the other swimmers to vacate the pool. The handicapped person was later found to be positive for *Giardia*. The attack rate was highest, 39 percent (5/13), for a ladies swim group who next used the pool. Another handicapped class that swam at the same time as the ladies group had an attack rate of 10 percent (2/20). At 11:00 a.m. the parent/toddler group, which swam one–and–a–half hours after the ladies and handicapped groups, had an attack rate of six percent (1/16) and three subsequent groups had no cases. In the ladies group, all the swimmers put their heads under water. However, among those who dived, 100 percent (4/4) became ill, compared to one percent (1/9), of those who did not dive.

An inspection of the pool after the outbreak indicated that the pool filtration had been functioning normally. No coliform bacteria were detectable and standard plate count of bacteria were 1–2 ml. The outbreak probably occurred because of the characteristic resistance of *Giardia* cysts to chlorine. At 25^{o}C it would have required 50 minutes for 0.3 mg/l of chlorine to inactivate the *Giardia* cysts (USEPA, 1990). The investigators of this outbreak suggest that pools should be vacated by all swimmers for at least 50 minutes after any accidental fecal release to ensure enough time for any *Giardia* cysts to be deactivated.

DISCUSSION

The association between the use of swimming pools and illness has long been recognized. When maintained at proper levels, chlorine can inactivate or control most pathogens in swimming pool water. The exception are the protozoan parasites *Giardia* and *Cryptosporidium* which are extremely resistant to most disinfectants and require high levels of chlorine for long periods of time to inactivate. To reduce the possible transmission of those organisms among bathers it has been recommended that pools should be closed after any fecal accident (Kebabjian, 1995), free chlorine levels should be raised to 20.0 mg/liter and maintain for nine hours. The filtration system should be operated for a minimum of three to four turnovers. After three to four hours the filter should be thoroughly backwashed. The filter tank and filter media should be disinfected with a 20:1 solution of sodium hypochlorite. Finally after restarting the filter neutralize any excessively high chlorine residual with sodium thiosulfate.

REFERENCES

Bell, A., R. Guasparini, D. Meeds, R.G. Mathias, and J.D. Farley. 1993. A swimming pool–associated outbreak of cryptosporidiosis in British Columbia. *Canadian Journal of Public Health*. 84:334–337.

Bennett, J.V., S.D. Holmberg, M.F. Rogers, and S.L. Solomon. 1987. Infectious and parasitic disease. *American Journal of Preventive Medicine*. *3*:102–114.

Benson, A.S. (ed.). 1990. Control of Communicable Diseases. *American Public Health Association*, Washington, DC.

Bongard, J., R. Savag, R. Darn, H. Bostrum, J. Kazmierciak, S. Keifer, H. Anderson, J.P. Davis. 1994. *Cryptosporidium* infections associated with swimming pools – Dane County, Wisconsin. *Journal of the American Medical Association 272*:914.

Craun, G.F. 1992. Waterborne disease outbreaks in U.S.. *World Health Statistics Quarterly 45*:192–199.

DuPont, H.L., C.L. Chappell, C.R. Sterling, P.C. Okhuysen, J.B. Rose, and W. Jakubowski. 1995. The infectivity of *Cryptosporidium parvum* in healthy volunteers. *New England Journal of Medicine 332*:855–859.

Galbraith, N.S. 1989. Cryptosporidiosis: another source. *British Medical Journal 298*:276, 277.

Greensmith, C.T., R.S. Stanwick, B.E. Elliot, and M.V. Fast. 1988. Giardiasis associated with the use of a water slide. *Pediatric Infectious Disease Journal 7*:91–94.

Harter, L., F. Frost, G. Grunenfelder, K. Perkin–Jones, and J. Libby. 1984. Giardiasis in an infant and toddler swim class. *American Journal of Public Health 74*:155–156.

Joce, R.E., J. Bruce, D. Kiely, N.D. Noah, W.B. Dempster, R. Stalker, P. Gumsley, P.H. Chapman, P. Norman, J. Watkins, H.V. Smith, T.J. Price, and D. Watts. 1991. An outbreak of cryptosporidiosis associated with a swimming pool. *Epidemiology and Infectious Disease 107*:496–508.

Kebabjian, R.S. 1995. Disinfection of public pools and management of fecal accidents. *Journal of Environmental Health 58*:8–12.

Korich, D.G., J.R. Mead, M.S. Madore, N.A. Sinclair, and S.R. Sterling. 1990. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on *Cryptosporidium parvum* oocyst viability. *Applied Environmental Microbiology 56*:1423–1428.

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Number Affected	Symptoms	Incubation Period	Attack Rate	Age Group	Probable Cause	
60	Watery diarrhea (80% cases), and fever (50%)	5 days, median	73%	5-57 (median 17 yrs)	Fecal accident. Filter not functioning (filtration rate 30% below normal)	
79	Severe prolonged diarrhea	3 weeks	Not specified	Two-thirds children	Followed a fecal accident. Also, defective sewage disposal system	
87	Abdominal cramping, watery diarrhea, fatigue, nausea, and weight loss	12 days	8-78%	Children	Inadequate chlorination	
37	Watery diarrhea (94%), stomach cramps (93)), and vomiting (53%)	2 weeks	55%	1-40 yrs (median age, 4 yrs)	Possible fecal contamination	
55	Diarrhea (98%), cramping abdominal pain (79%), vomiting (52%), and low-grade fever (50%)	6-25 days	Not specified	Median age, 5 yr; 62% were males	Probably due to exposure to fecally contaminated wave pool water	

Table 2 – Swimming Pool Outbreaks Caused by *Cryptosporidiosis*

Disinfection Rate	Pool Description	Year/Locale	Remarks
Adequate chlorine level, 2 ppm.	School swimming pool; 100,000 gal.	1988, Los Angeles County	Two cases were hospitalized and 32 sought physician consultation. REF: Sorvillo et al., (1988; 1992)
Cryptosporidium oocyst found samples from the beginner's pool.	Local sport center with 2 swimming pools. This is the first recognized English outbreak of cryptosporidiosis with a swimming pool.	1988, in Doncaster, UK	In some cases, the onset of illness occurred after swimming in a pool for beginners. REF: Gailbraith (1989); Joce et al., (1991)
Available chlorine residual had fallen below the minimum recommended level of 0.5 mg/L.	Recreation complex includes 3 swim pools: a 150,000 gal lap pool, a 10,000 gal shallow children's pool, and a whirlpool for adult use only. Water supply and sand filtration are separate for all three pools.	1990, in Vancouver, BC	The children's pool remained closed for 10 days, for cleaning. REF: Bell et al., (1993)
Laboratory-confirmed Cryptosporidium infection identified in a cluster of 9 persons.	One large outdoor pool (Pool B). Swim Team practiced in Pool A.	1993, Dane County, WI (80 miles west of Milwaukee)	On August 27, Pool A was closed and hyper–chlorinated for 18 hr. On Sept 3, Pool B was closed for the same reason. REF: Bongard et al., (1994)
Not specified	Water park located indoors: 4 heated pools, each on rapid sand filters. Largest is the wave pool with attached water slide. Others: swim pool, hot tub, and wading pool. Bathing load up to 1300 a day during peak load periods.	1992, in Lane County, Oregon	Outbreak subsided after the pool water was drained and replaced REF: McAnulty et al., (1994)

Table 2 – (Extension)

Number Affected	Symptoms	Incubation Period	Attack Rate	Age Group	Cause	
43	Severe prolonged diarrhea	Between 5 and 25 days	43 to 54%	Infants, toddlers, and adults	Fecal accidents in both pools	
9	Diarrhea or intermittent diarrhea of 5 days duration with at least 2 of the following: flatulence (excessive intestinal gas), nausea, malaise (discomfort) and abdominal cramps defined a “case”.	Between 5 and 25 days	39%	Adults only	Fecal accident occurred	
59	Diarrhea (48), cramps (38), foul smelling stools (29), loss of appetite(23), fatigue (20), vomiting (18), greasy stools (15), fever (11), weight loss (10) and blood in stools (3).	Five or more days	55%	3–58	Source was a handicapped child who had a fecal accident in the pool. He was Giardia positive.	

Table 3 – Giardiasis Outbreaks in Swimming Pools

Disinfection Rate	Pool Description	Year/Locale	Remarks
Turbidity in both pools; free chlorine residuals low in the motel pool, but moderate for apt. pool.	Initially at a motel swimming pool; later, the swim class used an apartment complex swim pool. There were 9 swim classes of children 6–19, plus their parent helpers.	1982, Thurston County, Washington	Parents with infants arrived early for swim class or stayed after class to play in the pool, while other classes were in session. The child the instructor used for demonstration was Giardia positive. REF: Harter et al., (1984)
Chlorine level zero on days of fetal accident. Filtration 30% below normal rate.	Indoor pool with 105,000 gal capacity in a recreational center. Liquid chlorine was used for disinfection.	1985, Northwestern New Jersey	A total of 450 persons used the pool during the 3–day onset. REF: Porter et al., (1988)
Sample was negative for Giardia cysts on May 6. Slide pool disinfected through bromination by mixing water with a stick of bromine. Despite adequate pool maintenance, there's an inevitable period when infection can still occur.	New indoor water slide pool, cleaned by both bromination and sand filtration. Hotel pools include a hot tub and a wading pool. The water slide descends about 20 ft in a long spiral into the water slide pool with capacity of 13,688 gal.	1986, Manitoba, Canada	A midget hockey team had stayed overnight in the hotel, primarily to use the indoor water slide. REF: Greensmith et al., (1988)

Table 3 – (Extension)

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K.A. Blair, D.E. Peterson, J.J. Kazmierczak, D.G. Addiss, K.R. Fox, J.B. Rose, and J.P. Davis. 1994. A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply. *New England Journal of Medicine*. *331*:161–167

McAnulty, J.M., D.W. Fleming, and A.H. Gonzalez. 1994. A community–wide outbreak of cryptosporidiosis associated with a wave pool. *Journal of the American Medical Association 272*:19597–1600.

Porter, J.D., H.P. Ragazzoni, J.D. Buchanon, H.A. Waskin, D.D. Juranek, and W.E. Parkin. 1988. *Giardia* transmission in a swimming pool. *American Journal of Public Health 78*:659–662.

Sorvillo, F.J., K. Fujoka, M. Tormey, R. Kebabjian, W. Tokuship, L. Mascola, S. Schweid, M. Hillario, S.H. Waterman. 1988. Swimming–associated cryptosporidiosis – Los Angeles County. *Morbidity and Mortality Weekly Report 39*:343–345.

Sorvillo, F.J., K. Fujoka, B. Nahlen, P. Tormey, R. Kebabjian, and L. Mascola. 1992. Swimming–associated cryptosporidiosis. *American Journal of Public Health*. 82:742–744.

United States Environmental Protection Agency (USEPA). 1990. Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources. Office of Water, Washington, D.C..

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