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Determinants of Bacterial Contamination in Pools, Spas, and Wading Pools: Should Chlorine Standards Be Revised?

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Using a retrospective case-control study, we compared poolside tests with bacteriological samples during three consecutive summers. A total of 844 matched samples were obtained. Increased chlorine levels were associated with lower rates of contamination. Alkalinity, pH, and TDS were not statistically associated with bacteriological failures. In swimming pools with ≥ 1 ppm of chlorine, 27/30 (90.0%) passed bacteriologic evaluation. In spas with < 1.0 ppm of chlorine, only 12/28 (42.9%) passed. Of the spas with ≥ 3.0 ppm of chlorine, 170/176 (96.6%) passed. Of the wading pools with < 1ppm of chlorine, only 12/25 (48.0%) passed. Of the wading pools with ≥ 2 ppm, 263/290 (90.7%) passed. Of available poolside tests, only chlorine levels are predictive of positive testing for fecal contamination. Higher levels of chlorine were associated with higher passing rates. Current standards for disinfection in spas and wading pools may need to be increased to help prevent contamination.

Swimming is a very popular activity worldwide. Safety of participants involves many aspects, including maintaining water quality through filtration and disinfection. The goal of both of these is to prevent the transmission of infectious diseases. Although disinfection can be achieved by a number of methods, the most commonly used disinfectants are chlorine and bromine (National Swimming Pool Foundation, 2009).

Research on chlorine use as a disinfectant for swimming pools dates back almost 100 years (Lyster, 1911). Higher free residual chlorine has been demonstrated to decrease likelihood of fecal contamination (Leoni, Legnani, Guberti, & Masotti, 1999). Swimming pools with >1.0 ppm (ppm) of chlorine (which is the same as milligrams per liter for chlorine) have very low levels of bacterial contamination (Esterman et al., 1984; Leoni et al., 1999). Although the value of proper chlorination of swimming pools has been recognized for almost100 years, the most desirable level of chlorination has not been definitively established for spas or wading pools (Lyster, 1911).

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Since the early part of the 20th century, state and local health departments have regulated public swimming pools (Luehring, 1939). These regulations focus on everything from design to filtration to disinfection. Initially, regulations focused on swimming pools; however, eventually spas were also regulated. Wading pools (also called baby pools) are variously defined; however, usually they are any shallow pools with less than 18 inches in depth. For all state regulations in the United States, swimming pools and wading pools are often grouped together for regulation of disinfection (Hooker, 2009). Spas are usually regulated separately.

Most states require pool operators to maintain chlorine levels at a minimum of 1.0 ppm in swimming pools and wading pools (Hooker, 2009). A small number of states require higher levels (Vermont, 2.0; Nebraska, 2.0; Georgia, 1.5; and Maryland, 1.5), and ten states have lower minimum levels. The National Swimming Pool Foundation (NSPF) recommends that free chlorine levels should optimally be maintained between 2.0 and 4.0 ppm for swimming pools (3.0–5.0 ppm for spas) and should never fall below 1.0 ppm (National Swimming Pool Foundation, 2009). Minimum required chlorine levels for spas are extremely variable across the United States. Required levels range from 0.4 ppm to 10 ppm (Hooker, 2009). The goal of the current research was to identify those poolside tests that are predictive of bacterial contamination. In addition we compared the results to the currently recommended state standards for pools, spas, and wading pools.

Method

Samples

All public pools and spas in the City of Cincinnati are regulated by the Cincinnati Health Department. During the months of operation, pools are randomly sampled to determine their compliance with health department standards. We conducted a retrospective case-control study using data from the Cincinnati Health Department pool-testing program from 2006 to 2008. A case was defined as a pool or spa with an abnormal fecal coliform count (FCC) or standard plate count (SPC). A control was defined as a pool or spa with acceptable levels of FCC and SPC.

Poolside Testing

Pools and spas were tested using poolside technology for chlorine, bromine, pH, total alkalinity, and total dissolved solids (TDS; Taylor Technologies, Sparks MD). Testing for chlorine was performed using ferrous ammonium sulfate—n,n-diethyl-p-phenylenediamine (FAS-DPD) method. The Ohio standards for these poolside tests are chlorine swimming and wading pools: ≥ 1.0 ppm (ppm) chlorine; chlorine spas: ≥ 2.0 ppm chlorine; bromine swimming and wading pools: ≥ 1.0 ppm bromine; bromine spas: ≥ 2.0 ppm bromine; pH should be between 7.2 and 7.8; total alkalinity should be above 60; total dissolved solids (TDS) must not exceed 3000. Any swimming pool with a violation of a poolside test had a second sample taken for bacteriological analysis. All spas and wading pools that were tested at poolside had a second sample taken for bacteriological analysis.

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Bacteriological Analysis

Samples for bacteriological analysis were collected in presterilized 125 ml nalgene bottles containing 0.1 ml of 10% sodium thiosulfate. Recommended maximum elapsed time between collection and analysis was 8 hr (6 hr transit time and 2 hr processing time). If the elapsed time exceeded 8 hr, the sample was stored at 4 degrees C for up to a maximum of 24 hr. Each sample was tested for contamination using fecal coliform count (FCC) and a standard plate count (SPC). Indicators of unacceptable water quality were FCC ≥ 1 Colony Forming Units (CFU)/ 100 ml or SPC > 100 CFU/ml.

Statistical Analysis

Multiple logistic regression analysis was performed to identify any associations between poolside testing results and laboratory evidence of fecal contamination. Data were analyzed using SPSS for Windows, version 17.0 (SPSS, Inc., Chicago, IL). All statistical tests were performed using two-tailed analysis, and the alpha was set at 0.05.

Results

During the three summers, 5,339 poolside samples were taken. During the same period, there were 941 bacteriological samples. Our study focused on these bacteriological samples. Due to the problems of either missing data ($n = 83$) or bromine samples ($n = 14$), we discarded a total of 97 samples. The remaining samples included 174 samples from pools, 398 samples from wading pools, and 272 samples from spas.

Poolside Testing

The four poolside tests were evaluated for their relationship to bacterial contamination. Using multivariate analysis, bacteriological contamination was found to be associated with chlorine levels, but there was no association with TDS, alkalinity, or pH. Swimming pools with chlorine <1.0 ppm had 7.8 (95% confidence interval [CI]: 2.3, 27.1) times the odds of bacterial contamination than did swimming pools with chlorine levels ≥ 1.0 ppm. Wading pools with chlorine < 1.0 ppm had 8.3 (95% CI: 3.4–20.2) times the odds of bacterial contamination than did pools with chlorine levels ≥ 1.0 ppm. Spas with chlorine <1.0 ppm had 20.0 (95% CI: 7.8–52.0) times the odds of bacterial contamination than did pools with chlorine levels ≥ 1.0 ppm. Spas with a chlorine < 2.0 ppm still had 12.6 (95% CI: 5.4–29.2) times the odds of bacterial contamination than did pools with chlorine levels ≥ 2.0 ppm.

Swimming Pools

In the 174 swimming pools tested, there were a total 235 poolside violations: 144 with Chlorine < 1, 59 with pH < 7.2 or > 7.8, 16 with TDS > 3000, and 16 with alkalinity > 60. Bacteriologic contamination was noted in 71 of the pools (40.8%). Of these 71, 68 (95.8%) occurred in pools with chlorine levels < 1.0 ppm. In swimming pools, with ≥ 1 ppm of chlorine, 27/30 (90.0%) had acceptable levels on bacteriologic evaluation (Table 1).

Table 1 Results of Bacteriologic Testing Based on Chlorine Levels

Free Chlorine level	Swimming Pools		Spas		Wading Pools	
	# tested	% Pass	# tested	% Pass	# tested	% Pass
PPM						
0–0.9	144	52.8	28	42.9	25	48.0
1.0–1.9	3	100	13	84.6	83	83.1
2.0–2.9	3	100	55	83.6	71	93.0
3.0–3.9	5	100	26	96.2	52	90.4
> 4.0	19	84.2	150	96.7	167	89.8

Wading Pools

In the 398 wading pools tested, there were a total 276 poolside violations: 25 with Chlorine < 1, 208 with pH < 7.2 or > 7.8, 30 with TDS > 3000, and 13 with alkalinity > 60. Bacteriologic contamination was noted in 54 of the wading pools (13.6%). If the wading pool had < 1.0 ppm of chlorine, only 12/25 (48.0%) passed. When the chlorine level was between 1.0 and 1.9 mg/L, 69/83 (83.1%) passed. Of the wading pools with ≥ 2.0 ppm, 263/290 (90.7%) passed (Table 1).

Spas

In the 272 spas tested, there were a total 176 poolside violations: 41 with Chlorine < 2, 78 with pH < 7.2 or > 7.8, 22 with TDS > 3000, and 35 with alkalinity > 60. Bacteriologic contamination was noted in 33 of the spas (12.1%). If the spas had < 1ppm of chlorine, only 12/28 (42.9%) of the spas passed bacteriological testing. When the chlorine level in the spas was between 1.0 and 1.9 ppm, 11/13 (84.6%) passed. When the chlorine level in the spas was between 2.0 and 2.9 ppm, only 46/55 (83.6%) passed. Of the spas with ≥ 3.0 ppm of chlorine, 170/176 (96.6%) passed bacteriological testing (Table 1).

Discussion

The importance of insuring proper disinfection of pools and spas cannot be over emphasized. All states have recognized the importance through development of regulations for minimum levels of chlorine in pools and spas (Hooker, 2009). While previous research has demonstrated that maintaining levels of chlorine at a minimum of 1.0 ppm will minimize bacterial contamination in swimming pools, spas, and wading pools have not been studied (Leoni et al., 1999). The current research found that requiring minimum levels of 1ppm or less in wading pools or spas may result in bacterial contamination occurring more frequently. When the chlorine level in the spas was between 1.0 and 1.9 ppm, only 11/13 (84.6%) passed. When the chlorine level in the spas was between 2.0 and 2.9 ppm, only 46/55 (83.6%) passed. However, in spas with ≥ 3.0 ppm of chlorine, 170/176 (96.6%) passed bacteriological testing. When the chlorine level in the wading pool was between 1.0 and 1.9 ppm, 69/83 (83.1%) passed; however, of the wading pools with ≥ 2 ppm, 263/290 (90.7%) passed bacteriologic testing.

Most, but not all, states have standards requiring 1ppm of chlorine as a minimum disinfection for pools and wading pools. Currently, no states have separate disinfection regulations for wading pools. Instead, these regulations are grouped together with swimming pools. Based on this current research, states may want to consider raising their minimum chlorine disinfection standards for wading pools to 2.0 ppm.

There is a great deal of variability in regulations for spas in the United States. The current research indicates that spas likely require higher levels of chlorine to prevent bacteriological contamination. Based on the results of the current study, states may want to consider raising the minimum chlorine standards for spas to 3.0 ppm.

The value of poolside testing is in maintaining the pools and spas in the most hygienic fashion and providing for comfort of the bathers. Previous research has demonstrated an association between bacterial contamination and the chlorine level in the pools. Other factors also have been implicated including time of sampling, water temperature, and load of swimmers (Rabi, Khader, Alkafajei, & Aqoulah, 2008). Two previous authors have failed to find any association between bacterial contamination and the pH of the water in swimming pools (Esterman et al., 1984; Rabi et al., 2008). The current research confirmed this lack of association. There may be value in maintaining correct pH range due to its impact on comfort of swimmers due to irritation of the eyes (Mood, Clarke, & Gelperin, 1951). The current research is also the first to demonstrate the lack of association between bacterial contamination and alkalinity or TDS.

Limitations

As with any retrospective study, the current research is only as good as the quality of the data recorded at the time of the sampling. We have no way of verifying that collection methods were done correctly. The sample of spas and wading pools was a random sample with adequate numbers to validate the conclusions; however, most of the swimming pools with laboratory samples had chlorine levels below 1.0 ppm. There were only 30 swimming pools with ≥ 1.0 ppm.

Conclusions

Of available poolside tests, only chlorine levels are predictive of positive testing for fecal contamination. Higher levels of chlorine were associated with higher passing rates for spas and wading pools. The state-regulated minimum requirements for chlorine in spas and wading pools should be increased to help minimize bacterial contamination. Increasing the minimum required chlorine concentration of chlorine for wading pools to 2.0 ppm and spas to 3.0 ppm should result in fewer wading pools and spas having significant bacterial contamination.

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