Published in final edited form as:
Fla J Environ Health. 2004 January 1; 184: 29.

A Pilot Study of Microbial Contamination of Subtropical Recreational Waters

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Abstract

Microbial water quality indicators are used to determine whether a water body is safe for recreational purposes. There have been concerns raised about the appropriate use of microbial indicators to regulate recreational uses of water bodies, in particular those located in tropical and sub-tropical environments. This prospective cohort pilot study evaluated the relationship between microbial water quality indicators and public health within two public beaches without known sewage discharge, but with historically high microbial levels for one beach, in subtropical Miami-Dade County (Florida). Monitoring was conducted in three phases: daily water monitoring, beach sand sampling, and spatially intense water sampling. An epidemiological questionnaire from a Los Angeles recreational beach-goer study was used to assess the self-reported swimming-related symptoms and exposures. There was no significant association between the number nor the type of reported symptoms and the different sampling months or beach sites, although persons who returned repeatedly to the beach were more likely to report symptoms. The number of indicator organisms correlated negatively with the frequency of symptoms reported by recreational beach goers. Results of the daily monitoring indicated that different indicators provided conflicting results concerning beach water quality.

Larger epidemiologic studies with individual exposure monitoring are recommended to further evaluate these potentially important associations in subtropical recreational waters.

Introduction

Traditionally, analogous to drinking water, monitoring of water quality for coastal waters used for recreational purposes has been regulated by measuring concentrations of indicator microbes. The microbes utilized are those typically found in human feces in high concentrations. An elevated concentration of these indicator microbes within a coastal water body would thus indicate that the water body has been contaminated by human waste and is unsafe for recreational use.

The U.S. Environmental Protection Agency (EPA) guidelines (using *E. coli* and enterococci) for coastal waters were established based on only three water quality and epidemiological studies performed in the 1980s (US EPA 1986, 1999, 2000). Recently, the use of indicator microbes to regulate the recreational use of coastal waters has come into question, particularly in the tropical and sub-tropical marine environment. There have been documented cases where coastal waters monitored for both sets of commonly used microbial indicators have passed regulatory limits for enterococci and not for fecal coliform, and vice versa. Studies have shown that total coliforms proliferate naturally in soil (Toranzos 1991), particularly in sub/tropical environments. Studies conducted in sub/tropical areas (Fujioka 2001, Rivera 1988; Hazen 1988, Wright 1989, Solo-Gabriele 2000, Desmarais 2002) have shown collectively that in the absence of any known sources of human/animal waste, fecal indicators are consistently present and recovered in high concentrations in the environment (Roll 1997, Solo-Gabriele 2000, Desmarais 2002). In addition, Griffin et al. (1999) found elevated levels of enteric viruses in waters within the Florida Keys which did not correlate with the levels of indicator microbes within those waters. Therefore, a regulator is left with a perplexing situation where it is not clear which indicator microbe(s) should be utilized particularly in sub/tropical waters, and once the data are obtained, how these data should be interpreted.

Several epidemiologic studies have found that, compared with bathing in uncontaminated waters, bathing in temperate recreational waters contaminated with domestic sewage or storm drain runoff has been associated with an increased risk for transmission of infectious diseases, including gastroenteritis, febrile respiratory illness, eye and ear infections, and skin infections and rashes (Kueh 1995, Fujioka 1994, Prieto 2001, Fleisher 1993, Fleisher 1996, Fleisher 1998, Haile 1999, Pruss 1998). However, there were weaknesses in the designs of many of these studies, including the absence of data describing microorganism levels in the water that could be used to describe an individual's exposure, and a failure to account for other risk factors for the illnesses of interest.

These results, coupled with the evidence that infectious microorganisms can occur in sub/tropical waters in the absence of specific contamination events and the dirth of information describing the impact of these illnesses, indicate that the actual public health risk associated with bathing in sub/tropical waters containing microorganisms, including those from EPA's list of microbial indicators, is unknown. A prospective cohort pilot study was performed to evaluate the relationship between microbial water quality indicators and public health in subtropical recreational marine waters.

Methods

The pilot study consisted of two months of daily monitoring for recreational water quality using multiple bacteriologic indicators, with two prospective surveys of reported symptoms from exposed beach users at two beach locations performed on various days during the two study months.

The two beach locations in Miami Dade County (FL) were selected based on results of historic water quality monitoring data. These beaches are located within 1 mile of each other, yet historically have had different water qualities. Beach 1 had a history of consistently higher indicator organisms, and anecdotally higher human health complaints associated with poor water quality; while Beach 2 had consistently low indicator organisms and relatively few human health complaints. Both beaches were used heavily for all types of water sports throughout the year by Miami Dade County natives and tourists. The 2 beaches were monitored daily during a dry season month (April) and a wet season month (July) because historic data indicated that the wet season might be associated with higher levels of indicator organisms. Monitoring was conducted in three phases: daily water monitoring, beach sand sampling, and spatially intense water sampling. The bacteriologic indicators were selected for their common and recommended use as monitoring indices (i.e. enterococci, fecal and total coliform, *C. perfringens* and *E. coli*).

Population

After obtaining approval from the Human Subjects Committee (IRB) of the University of Miami and the Miami Dade County Health Dept IRB, the Investigators enrolled residents of Miami Dade County at the two beaches who immersed their face in the beach water on the date of enrollment, had not been at the beach in the prior seven days, and agreed to the telephone follow up in Spanish or English. Tourists and non residents were considered ineligible due to logistical follow up issues. Logistically, one adult was identified to interview for each family, although symptoms were collected for all members of the participating family. After an initial beach interview at the time of enrollment, participants were contacted by phone eight to 10 days from exposure to ascertain any new symptoms, particularly gastrointestinal symptoms, as well as any additional beach exposures.

The data were entered into an Excel 2000 database and analyzed using the statistical software SPSS Version 10. Dichotomous variables were analyzed using chi squared and ttest/Fishers Exact Test analysis, while continuous variables were analyzed using ttest; correlations were performed using Pearson's correlation. The alpha level of 0.05 was used for all tests of significance, using 1 tailed tests. Given the small sample size and pilot nature of the data, multiple comparisons testing was not used.

Results

After excluding ineligibles and lost to follow up, the final study population consisted of 63 families with 208 (86%) individuals (ie. 3.3 individuals/family) from the 241 people approached who were eligible to participate. There were 98 (47%) women; the mean age and standard deviation were 20.5± 16.7 with a range of 1 to 76 years (Table 1). In this population, 75 (36%) were interviewed during the dry month and 99 (46%) at Beach 1. The majority of the study population was White Hispanic (156 (75%)), and were interviewed in English (150 (72%)).

In the follow up interview between eight and 10 days from enrollment, with regards to symptoms with onset since the enrollment, only 8 (4%) reported a fever with 3 (1%) with chills. Among the gastrointestinal symptoms, 6 (3%) reported diarrhea and 4 (3%) stomach pain. However, 11 (5%) reported a skin rash, but no infected cuts. With regards to respiratory symptoms, 8 (4%) reported nasal congestion and 5 (3%) had a sore throat. In all, 35 (17%) of the subject population reported at least 1 symptom occurring since their visit to the beach, with cough (7%) and skin rash (5%) being the most frequently reported.

There were 99 (48%) of the population recruited with exposure on Beach 1 and 109 (52%) on Beach 2 (Table 1). There were no significant differences between the 2 beaches with regards to reported symptoms. Skin rashes were more likely to be reported from Beach 1 (8 (4%)) than Beach 2 (3 (1%)), although not significantly. Participants were slightly more likely to report at least 1 symptom at Beach 1 (18%) compared to Beach 2 (15%), but not significantly.

There were 27 (13%) of the study population who returned to the beach between their enrollment and the follow up phone interview; the majority of these persons (17 (63%)) returned to Beach 1. These people could be considered “over exposed” due to repeat exposure to beach water. Those who returned to the beach were significantly more likely to have a cough with phlegm (p=0.05). In general, more symptoms were reported by those who were over exposed (22%) than those who did not return to the beach (16%), although not significantly.

There were 75 (36%) of the subjects interviewed during the dry month and 133 (64%) interviewed during the wet months. The dry month participants (18 (9%); p=0.001) were more likely to return to the beach, particularly to Beach 1. There were no significant differences between the reported symptoms for the dry and wet month participants, although there was a trend for more symptoms to be reported in the wet than the dry month. Participants were slightly more likely to report at least 1 symptom during the wet (18%) compared to the dry month (15%), but not significantly.

Environmental Monitoring

Results of the daily monitoring indicated that different indicators provided conflicting results concerning beach water quality (data not shown). For example at one site on Beach 1, the percentage of days that exceeded the daily maximum guideline of 104 CFU/100 ml for enterococci was 17% for the dry month and 23% for the wet month. No days exceeded the Florida daily maximum guideline of 800 CFU/100 ml for fecal coliform during either the dry or wet month of monitoring. The results of the sand sampling at 27 points in Beach 1 showed significant differences in microbe concentrations with different sand conditions. These conditions were sand under seaweed, uncovered sand, and submerged sand. For instance, the largest numbers of *C. perfringens* were observed in submerged sand, intermediate numbers were observed in sand under seaweed and the smallest numbers in uncovered sand The difference between submerged sand and uncovered sand was significant (p = 0.004) for *C. perfringens*. These results suggested that beach sand was not the source of *C. perfringens*, and that sunlight exposure might have influenced the concentrations. The results of the spatially intense water sampling at 58 points around Beach 1 indicated that significantly higher numbers of microbes were observed near the shoreline than for samples collected offshore ($p<0.05$). Comparatively large numbers of microbes were observed at the east end of Beach 1 at high tide; poor water circulation may be the cause of elevated microbes concentrations on this side of the beach. Overall, high correlation were observed between enterococci and *C. perfringens* (r = 0.81), between enterococci and *E. coli* (r = 0.73), and between *C. perfringens* and *E. coli* (r = 0.64); low correlations were observed between fecal coliform and others (r = 0.29 ~ 0.39).

Symptom Correlation with Indicator Microbes

There were only five days of interviewing at the two beaches over the two months of daily water sample collection and analysis in two locations at each beach. Mean microbial indicators were created by day by averaging all the indicators of the two sampling locations for each beach, and correlated with the proportion of persons reporting at least one symptom on that day by beach.

With the data from the two beaches combined, there was a consistently negative and strong correlation between the reported symptoms and all of the averaged microbial indicators; total coliform, fecal coliform, enterococcus, and *Clostridium* were statistically significant negative high correlations (data not shown). There was no significant correlation or definitive pattern between the indicator organisms and report of at least one symptom on the interview days by beach. Of note, total coliform was negatively, but not significantly associated (Pearsons Correlation= -0.79 (p=0.06)) with having at least one symptom for Beach 1.

Conclusions

The pilot study consisted of two months of daily monitoring for recreational water quality using multiple bacteriologic indicators, with a prospective cohort survey of reported symptoms from exposed beach users at two beach locations performed on five days during the two study months in subtropical Miami, FL. The epidemiologic portion of this pilot study did not support a strong hypothesized difference between either the two study site beaches or the two study months (wet vs dry). There was some indication that persons with multiple exposures to beaches may be at greater risk for reporting symptoms, suggesting a possible dose response relationship. Finally, there was an inverse relationship between the number of reported symptoms and the microbial indicators, probably due to lack of individual exposure assessment.

There was a significant correlation between organism density and reported human symptoms, however the correlation was negative: persons were significantly more likely to report symptoms when the average microbial indicator counts were decreased. In part this may be due to the lack of individual exposure assessment. It may also reflect a “family effect,” to the extent that families share communicable infectious diseases, particularly those families with young children. Finally, this study did not monitor for viruses whose levels do not necessarily correlate with microbial indicators (Griffin 1999). There were not significantly higher symptoms reported for the Beach 1 participants compared to the Beach 2 participants. However, skin rashes were more likely to be reported from Beach 1 (8 (4%)) than Beach 2 (3 (1%)), although not significantly. *Staph aureus* and other microbes more often associated with skin infections were not measured, although skin symptoms have been associated with microbial indicators in other studies (Prieto 2001). Those who returned to the beach between study enrollment and follow up, considered possibly "over exposed," were significantly more likely to report a cough with phlegm (p=0.05), but not to have a simple cough (p=0.57), nor any other symptom. In general, more symptoms were reported by those who were "over exposed" (22%) than those who did not return to the beach (16%), although not significantly, suggesting a possible dose response relationship.

There were significant limitations to this study. The most important limitation was the relatively small number of participants and the few days of epidemiologic data collection. As well as affecting the correlation analysis, this made it difficult to distinguish background health effects from a true increase associated with beach water exposure. There was also no individual exposure information, but rather "ecological" exposure measures by beach location; this may have under or over estimated the microbial exposure of the individual participants. There was also no establishment of baseline symptoms prior to exposure; thus, recall bias based on reporting of retrospective symptoms was possible. The use of residents (rather than tourists) for logistic reasons may have selected for a more "resistant" study population, less likely to experience health effects. Finally there was no definitive unexposed control group, although analyses of those who did not get their faces wet did not indicate any difference in reported health effects (data not shown).

Recommendations

Future epidemiologic studies should include a larger number of participants distributed over a greater number of sampling days. There should be evaluation of the possible effects of family interactions particularly with infectious diseases. Inclusion of relatively unexposed persons such as tourists would be recommended. Broadening of the microbial indicators to include skin pathogens and increased skin exposure assessment may be warranted. Evaluation of swimmer density is also recommended. In particular, individual exposure assessment and the establishment of symptoms prior to exposure with more frequent follow up post exposure would strengthen future studies scientifically.

Acknowledgments

The authors acknowledge the important cooperation of the Administrations of the public beaches used as study sites, as well as the study participants and their families. Funding and other support were provided by the National Institute of Environmental Health Sciences (NIEHS) Marine and Freshwater Biomedical Sciences Center (Rosenstiel School of Marine and Atmospheric Sciences, University of Miami). Student support was provided by a grant from National Institute of General Medical Sciences (NIH-NIGMS). Additional environmental assessment and logistical support were provided by the Miami Dade County Health Department. The questionnaire was adapted with permission from: Haile et al., 1999.

References

Desmarais TR, Solo-Gabriele HM, Palmer CJ. Influence of Soil on Fecal Indicator Organisms in a Tidally Influenced Subtropical Environment. Applied and Environmental Microbiology 2002;68(3):1165–1172. [PubMed: 11872464]

Fleisher JM, Jones F, Stanwell-Smith R, Wyer M, Morano R. Water and non-water risk factors for gastroenteritis among bathers exposed to sewage-contaminated marine waters. International Journal of Epidemiology 1993;22:698–708. [PubMed: 8225746]

Fleisher, JM.; Kay, D.; Salmon, RL.; Jones, F.; Wyer, MD.; Godfree, AF. Marine waters contaminated with domestic sewage: nonenteric illnesses associated with bather exposure in the United Kingdom. 1996.

Fleisher JM, Kay D, Wyer MD, Godfree AF. Estimates of the severity of illnesses associated with bathing in marine recreational waters contaminated with domestic sewage. International Journal of Epidemiology 1998;27:722–726. [PubMed: 9758131]

Fujioka, RS.; Byappanahalli, MN. Draft of Final Report, Tropical Indicator Workshop. USEPA Office of Water; Washington, D.C.: 2001.

Fujioka RS, Roll K, Morens D. A Pilot Epidemiological Study of Health Risks Associated with Swimming at Kuhio Beach. Water Resources Research Center. 1994

Griffin DW, Gibson CJ III, Lipp EK, Riley K, Paul JH, Rose JB. Detection of viral pathogens by reverse transcriptase PCR and of microbial indicators by standard methods in the canals of the Florida Keys. Appl Environ Microbiol 1999;65(9):4118–4125. [PubMed: 10473424]

Haile RW, Witte JS, Gold M, Cressey R, McGee C, Millikan RC, Glasser A, Harawa N, Ervin C, Harmon P, Harper J, Dermand J, Alamillo J, Barrett K, Nides M, Wang G. The health effects of swimming in ocean water contaminated by storm drain runoff. Epidemiology 1999;10:355–363. [PubMed: 10401868]

Hazen TC, Bermudez M. Phenotypic and Genotypic Comparison of Escherichia coli from Pristine Tropical Waters (Puerto Rico). Applied And Environmental Microbiolgy 1988 Apr;:979–983.

Kueh CS, Tarn TY, Lee T, Wong JS. Epidemiological study of swimming associated illnesses relating to bathing beach water quality. Wat Sci Tech 1995;31(5):1–4.

Prieto MD, Lopez B, Juanes JA, Revilla JA, Llorca J, Delgado Rodriguez M. Recreation in coastal waters: health risks associated with bathing in sea water. J Epidemiology Community Health 2001;55:442–447.

Pruss A. Review of epidemiological studies on health effects from exposure to recreational water. International Journal of Epidemiology 1998;27(1):1–9. [PubMed: 9563686]

Rivera SC, Hazen TC, Toranzos GA. Isolation of fecal coliforms from pristine sites in a tropical rain forest. Applied and Environmental Microbiology 1988;54:513–517. [PubMed: 3281583]

Solo-Gabriele HM, Wolfert MA, Desmarais TR, Palmer CJ. Sources of Escherichia coli in a coastal subtropical environment. Applied and Environmental Microbiology 2000;66(1):230–237. [PubMed: 10618229]

Toranzos GA. Current and Possible Alternate Indicators of Fecal Contamination in Tropical Waters: A Short Review. Environmental Toxicology and Water Quality: An International Journal 1991;6:121–130.

U.S. Environmental Protection Agency. Ambient Water Quality Criteria for Bacteria. EPA 440-584-002. U.S. EPA, Office of Research and Development; Cincinnati, Ohio: 1986.

U.S. Environmental Protection Agency. Action Plan for Beaches and Recreational Waters, EPA/600/R-98/079. 1999.

U.S. Environmental Protection Agency. Improved Enumeration Methods for the Recreational Water Quality Indicators: Enterococci and Escherichia coli. U.S. Environmental Protection Agency, Office of Science and Technology; Washington D.C.: 2000.

Wright RC. The survival patterns of selected faecal bacteria in tropical fresh water. Epidemiology and Infectivity 1989;103:603–611.

Biographies

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Table 1

Description of All Participants: Beach 1 vs Beach 2

	Total Population N (%)	Beach 1 N (%)	Beach 2 N (%)	Statistical Significance[*]
INITIAL INTERVIEW:	208 (100%)	99(48%)	109 (52%)	
Number of Families	63	30	33	
Dry Month (vs Wet Month)	75 (31%)	42 (20%)	33 (16%)	0.05
Women	98 (41%)	41 (20%)	57 (27%)	0.08
Mean Age± Standard Deviation	20.5± 16.7	19.9±15.9	21.1±17.4	0.61
Race Ethnic	50 (21%)			
WNH	156 (65%)	19 (9%)	31 (15%)	0.06
WH	2 (1%)	78 (36%)	78 (36%)	
B		2 (1%)	0	
Interview language (English)	150 (62%)	73 (35%)	77 (37%)	0.37
At beach < 7 days prior	0	0	0	
Did not get face wet	0	0	0	
PHONE FOLLOW UP:				
Return to beach	27 (13%)	20 (10%)	7 (3%)	0.003
Went to Beach 1	17 (63%)	14 (52%)	3 (11%)	0.16
Fever	8 (4%)	2 (1%)	6 (3%)	0.18
Chills	3 (1%)	0	3 (1%)	0.14
Eye Redness	1 (0.5%)	0	1 (0.5%)	0.52
Earache	2 (0.5%)	1 (0.5%)	1 (0.5%)	0.73
Ear Discharge	1 (0.5%)	1 (0.5%)	0	0.48
Skin Rash	11 (5%)	8 (4%)	3 (1%)	0.08
Infected cuts	0	0	0	
Nausea	1 (0.5%)	0	1 (0.5%)	0.52
Vomiting	1 (0.5%)	0	1 (0.5%)	0.52
Diarrhea	6 (3%)	2 (1%)	4 (2%)	0.39
blood in stool	1 (0.5%)	1 (0.5%)	0	0.48
Stomach pain	4 (3%)	2 (1%)	2 (1%)	0.65
Cough	14 (7%)	4 (2%)	10 (5%)	0.12
With phlegm	3 (1%)	1 (0.5%)	2 (1%)	0.54
Nasal congestion	8 (4%)	2 (1%)	6 (3%)	0.17
Sore Throat	5 (3%)	3 (1%)	2 (1%)	0.46
≥ 1 Symptom	35 (17%)	18 (18%)	17 (15%)	0.62

[*] by Chi square or Fishers Exact Test for categorical data or ttest for continuous data