A marine recreational water quality criterion consistent with indicator concepts and risk analysis

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The development of water quality guidelines and standards for recreational waters has followed a well-defined pattern. The first step was the development of guidelines and standards dictated largely by adoption of the best available control technology. These were usually based on limited epidemiological evidence and little, if any, data relating the risk of illness or disease to the level of the pollutant in the environment. The second stage was the modification of these guidelines and standards on the basis of detectable risk using a limited amount of data relating illness to the environmental level of the pollutant. The last step in the process, the development of guidelines based on acceptable risks, requires enough epidemiological data to define the relationship of some measure of water quality to an observable effect. In the U. S., the first and second stages have been completed for recreational waters. This paper describes and substantiates the derivation of guidelines and standards based on acceptable risk.

The two microbial guidelines or standards most commonly used in the U. S. are the total coliform limit of 1000/100 mL of water and the fecal coliform limit of 200/100 mL.[1] The total coliform limit apparently developed from two sources: the predicted risk of salmonellosis as obtained from calculations made by Streeter[2] on the incidence of *Salmonella* species in bathing waters, and attainability as determined by Scott[3] from microbiological surveys conducted at Connecticut bathing beaches. The Joint Committee of the American Public Health Association and Conference of State Sanitary Engineers[4] adopted the Connecticut standard, as did many other state agencies. The fecal coliform guideline was developed in 1968 by the National Technical Advisory Committee (NTAC) to the Federal Water Pollution Control Administration.[5] The guideline was an extrapolation from the results of two prospective epidemiological studies conducted by Stevenson and his colleagues[6] in the 1950s. By 1979, most states had adopted the fecal coliform standard.

The fecal coliform limit will be considered in more detail because, as can be seen from Table 1, it is the one most used by the states, and is currently recommended by the U. S. Environmental Protection Agency (EPA).[7] This guideline will be considered in terms of the data base that supports it, how it was derived, and the indicator system used.

The microbial guideline for primary-contact recreational waters recommended by EPA and adopted by most of the states is essentially that recommended by NTAC, which states: "Fecal coliforms should be used as the indicator organism for evaluating the microbiological suitability of recreational waters. As determined by multiple-tube fermentation or membrane filter procedures and based on a minimum of not less than five samples taken over not more than a 30-day period, the fecal coliform content of primary contact recreational waters shall not exceed a log mean of 200/100 mL, nor shall more than 10% of total samples during any 30-day period exceed 400/100 mL."

Health effects can be quantified sufficiently to prepare marine water quality criteria on which sound standards can be based.

This recommendation presented a radical change from the traditional use of coliforms as an indicator of water quality. Coliforms were rejected as the indicator of choice for evaluating sanitary conditions of recreational water because of their variable correlation with fecal contamination. It was the NTAC opinion that fecal coliforms were more fecal-specific and therefore represented a more realistic measure of a health hazard. The rationale for the specific limits was as follows: "The studies at the Great Lakes (Michigan) and the Inland River (Ohio) showed an epidemiologically detectable health effect at levels of 2 300 to 2 400 coliforms per 100 mL. Later work on the stretch of the Ohio River where the

Table 1—Bacterial indicators used by 50 states, 5 U.S. territories, and the District of Columbia to regulate the quality of primary contact fresh and marine recreational waters.[a]

	Type of primary contact recreational water			
Bacterial indicator used	Fresh-water only	Marine water only	Fresh and marine waters	Total[b]
Total coliform	1 (1.8%)[c]	5 (8.9%)	7 (12.5%)	13 (23.2%)
Fecal coliform	27 (48.2%)	1 (2.8%)	26 (46.4%)	54 (96.4%)

[a] For the year 1978.

[b] Total is greater than 100% because some regulatory areas use both indicators.

[c] Proportion of 56 regulatory areas examined.

study had been done indicated that the fecal coliforms represented 18 percent of the total coliforms. This would indicate that *detectable* health effects may occur at a fecal coliform level of about 400 per 100 mL; a factor of safety would indicate that the water quality should be better than that which would cause a health effect." (emphasis added) A further rationale was the relationship of enterovirus to fecal coliform densities in wastewater, as determined in the Santee project.

Shortly after its publication, the NTAC guideline was criticized by Henderson[8] as being too restrictive. He set forth several arguments against the promulgation of microbiological standards on a nationwide basis. The major thrust of his criticism was the paucity of definitive epidemiologic data in support of the NTAC standard. He used the British experience,[9] the observations from Santa Monica Bay, Calif.,[10] and the lack of morbidity or mortality data associated with swimming in support of a much less restrictive microbiological standard or no standard at all for bathing beaches.

In 1972, a panel of the National Academy of Sciences-National Academy of Engineering[11] came to the following conclusion: "No specific recommendation is made concerning the presence or concentrations of microorganisms in bathing water because of the paucity of valid epidemiological data."

The cases for and against the need for health effects-related recreational water quality guidelines based on microbial indicator densities and, specifically, the NTAC guidelines were presented in 1974 at the "International Symposium on the Discharge of Sewage From Sea Outfalls."[12]

The arguments used against the NTAC guidelines and, hence, those currently recommended by EPA can be placed in four categories:

- The microbial indicator (fecal coliforms) used,
- The data base in support of the guidelines,
- The derivation of the specific fecal coliform limits, and
- The conceptual framework within which they are applied.

Ideally, recreational water quality indicators are microorganisms or chemicals whose densities or concentrations in the water can be quantitatively related to swimming-associated health hazards. Historically, the concern has been with infectious, enteric diseases, such as cholera and typhoid fever, whose etiological agents are excreted in feces and are spread by water and food contaminated with fecal wastes. Thus, it is not surprising that:

- The indicator concept was developed shortly after fecal transmission of enteric pathogens was established;
- The first three indicators suggested—*Escherichia coli, Streptococcus fecaelis,* and *Clostridium perfringens*—were fecal organisms;[13] and
- These genera, or groups to which they belong, are the three most commonly used indicators today.

It is interesting to note that, with each indicator, methodological rather than conceptual considerations led to a greater heterogeneity of the group measured (that is, coliforms and fecal coliforms instead of *E. coli;* fecal streptococci instead of *S. fecaelis;* and spore-forming, sulfite-reducing anaerobes instead of *Cl. perfringens*). This extension of the indicator concept from a single organism to a broad heterogeneous group usually was justified on the grounds that this approach was conservative and therefore provided a greater degree of public health protection.

The coliform systems require further discussion because they are the ones most commonly used, and the existing criteria are stated in terms of coliform or fecal coliform densities.

The total coliform population as commonly enumerated includes four genera in the family *Enterobacteriaceae, Escherichia, Klebsiella, Citrobacter,* and *Enterobacter.* It may also include other organisms, notably lactose positive members of the genus *Aeromonas.* Only *E. coli* is consistently and exclusively found in the feces of warm-blooded animals,[14] although bacteria in all five genera can be routinely recovered from domestic wastewater in rather large numbers.[15]

The total coliform system gradually is being discarded for many applications because it is recognized that some genera within the group—namely, *Klebsiella, Citrobacter,* and *Enterobacter*—are not fecal specific. It is being replaced with the so-called "fecal coliforms," a heterogeneous group that includes thermotolerant *Klebsiella* as well as *E. coli* biotypes. The specificity of this group relative to its source seems to suffer some of the same shortcomings of the total coliform group, in that it contains organisms whose source is not exclusively fecal. In fact, evidence supporting the use of the adjective "fecal" to distinguish between coliforms and thermotolerant coliforms is far from convincing. It has been known for some time that there are substantial extra-enteral sources of *Klebsiella*,[16,17] including the thermotolerant biotype. Additionally, *Klebsiella* is infrequently present in human feces, and then generally only as a minor portion of the coliform population.[14] A number of reasons have been given to justify the use of the fecal coliform system instead of *E. coli*. It has been argued that much of the historical data is presented in terms of fecal coliforms, that the existing standards for recreational and shellfish waters are stated as fecal coliform densities, and that *Klebsiella* should be enumerated as a fecal indicator because it is an opportunistic pathogen. First of all, much of the historical data is presented in terms of total coliforms rather than fecal coliforms; second, the small amount of epidemiological data in support of existing recreational or shellfish standards were developed in terms of total coliforms and then extrapolated to fecal coliforms;[5] third, *Klebsiella* is an opportunistic pathogen of the respiratory and genito-urinary systems and not the gastrointestinal tract; finally, there are no data showing that *Klebsiella* infections have been obtained via the waterborne route, much less, that they occur at environmental fecal coliform densities of about 200/100 or 14/100 mL, the present EPA guidelines for recreational and shellfish-growing waters, respectively.[7]

The deficiencies in the design of the Stevenson studies, in the analysis of the data, and in the interpretation of the results have been noted by several workers,[8,18,19] and even recognized by Stevenson and the formulators of the NTAC guidelines. Apart from those in the experimental design, there are a number of problems with the analyses of the data and the conclusions drawn from them. First of all, the comparison of illness rates for 3 high-coliform-density days versus 3 low-coliform-density days at one of the two beaches used in the Lake Michigan study has been criticized because the differences are shown for only one set of high versus low days, and no data are given for all of the other possible combinations. Secondly, in the first study, the illness rate differences were reported for all symptoms—such as gastrointestinal, respiratory, and other types—but in the second study, they were for gastrointestinal symptomatology only; yet, the total coliform densities associated with both kinds of differences were used identically in the derivation of the NTAC guidelines. Finally, in a third study conducted at two saltwater beaches in Long Island Sound (New York), differences in symptom rates were not obtained, even when the high- versus low-days approach was used. Because swimming-associated illness was not observed in the marine water study and was found using data that was barely significant in the conventional statistical sense in the two freshwater studies, one could easily conclude that the positive results were spurious and that there was no effect of swimming in wastewater-polluted waters. Alternatively, the limitations in design and analysis notwithstanding, it might be argued that the findings described a reality obtained with a relatively insensitive epidemiological study design.

Another problem in the use of these findings in the derivation of the microbial water quality guidelines set forth in the NTAC document was the extrapolation of the total coliform data from the study to fecal densities in the guidelines. The authors of the NTAC document made the conversion in order to state the criteria in terms of "a more fecal specific indicator system." However, the very need to extrapolate the densities to a more fecal specific indicator casts doubt on the validity of the coliform-illness relationship. Moreover, the projected association of the extrapolated fecal coliform densities to the reported health effects was compromised by the protracted interval between the initial observations and the establishment of the fecal-coliform/total-coliform ratio.

The findings from the Stevenson studies were largely abandoned as a rationale for EPA guidelines in 1976,[7] despite the fact that the limits given were essentially those in the NTAC document. They were replaced in part with a rationale based on the relationship of fecal coliform densities to the frequency of *Salmonella* isolations in surface waters.[7,20] As pointed out elsewhere,[21] this relationship has not been confirmed, especially when *Salmonella* densities rather than isolation frequencies are examined. Furthermore, it is conceptually unsound to expect a uniform relationship between a fecal indicator and a pathogen that is not *extremely* prevalent in the population at large; and a relationship to the isolation frequency of a pathogen with a high infectious dose, such as *Salmonella*, hardly seems appropriate as a justification for a guideline. Finally, as Moore[9] noted a number of years ago, there are only a very few cases of salmonellosis clearly shown to be associated with swimming in wastewater-polluted waters.

Another problem with the existing microbial guidelines for direct-contact recreational waters is that they are not amenable to, or developed in the context of, risk analysis; they were derived from a barely detectable health effect rather than from exposure-response data. Therefore, they do not allow for deliberate decisions by local, state, or federal officials about incremental decreases in the health risks involved. Rather, decision-making is limited to acceptance or rejection of the specific limits. Finally, individuals or groups who recommend guidelines based on detectable risks are faced with a philosophical dilemma. When more sensitive epidemiological study designs are developed for measuring the risks involved or extrapolating them from existing information, they are forced to make the limits more restrictive in order to be conceptually consistent. This is precisely the dilemma that will arise because of the results to be presented. The logical solution is to proceed to the next stage in the evolution of the guidelines; that is, to establish guidelines on the basis of risk acceptability.

Because the conceptual basis of the microbial water quality criterion to be recommended in this paper (and, hence, the guidelines and standards that can be derived from them) is so fundamentally different from the guidelines currently recommended by EPA, it is important to define certain terms as they will be used here. A health effects recreational water quality "criterion" developed for use with indicator systems is defined as a quantifiable relationship between the density of the indicator in the water and the human health risks involved in its recreational use. It is a set of facts or a relationship on which a judgment can be made. A recreational water quality "guideline" derived from the criterion is a suggested upper limit for the density of the indicator in the water that is associated with health risks considered unacceptable. Acceptability, in this context, implies that social, economic, cultural, and political factors would be considered in deriving guidelines. A recreational water quality "standard" obtained from the criterion is a guideline fixed by law. The relationship of guidelines to the criterion from which they are derived is shown graphically in Figure 1.

In response to these very obvious conceptual and empirical defects in the existing health effects guidelines and standards for recreational waters, EPA initiated a program to re-examine the entire question of health effects consequent to swimming in wastewater-polluted waters. Basic to this program was the development of a quantifiable dose-response-type relationship between health effects among swimmers and the quality of the water as measured by some microbial or chemical water quality indicator (in effect, a criterion as defined earlier). Furthermore, the "important" illnesses and "best" indicator were to be treated as unknowns, the former to be determined by their relationship to the degree of pollution from known sources, and the latter from the strength of the association to the former.

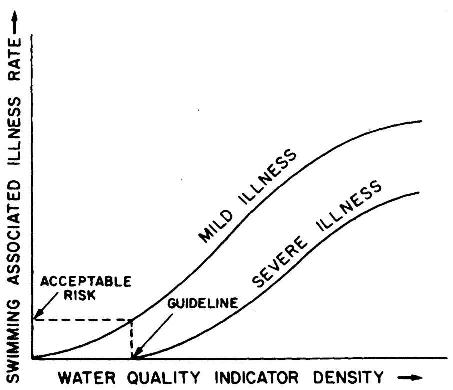

Figure 1—Graphic representation of the relationship of guidelines to a recreational water quality criterion.

The program to develop the criteria for marine recreational waters was developed in 1969–70, launched in 1972, and completed in 1979. Central to the program was the conduct over several years of prospective epidemiological-microbiological studies at multiple locations. This was supported with an extensive program to develop the necessary epidemiological and microbiological methodology. The output from the individual studies has been or will be presented elsewhere,[22–25] as has the status of the program relative to its overall objective.[26] This report will concern itself only with the final criterion and its limitations.

STUDY DESIGN

The study design has been described in an earlier publication.[27] A prospective epidemiological approach was used because of its consistency with the premise that the "best" indicator and "important" illnesses would be treated as unknowns and, with the desired output, a quantifiable and predictable illness-indicator relationship (criterion). Thus:

- Swimming was defined as the exposure of the upper-body orifices to the water. The rigorous definition of "swimming" ("ingestion of water" would have been even more restrictive) permitted comparison of the swimming population with a beach-going, nonswimming referent group exposed to the same nonswimming-associated risks of illness.
- Potential participants were recruited as family groups at the beach on weekends. By eliminating individuals who swam in the midweeks before and after the weekend trial from the study, exposure was limited to a single day, or at most 2 successive days on a weekend. The use of weekends facilitated the analysis of the data "by days," thereby minimizing the effect of day-to-day variability in pollution levels.
- Follow-up information on symptomatology and demography was obtained by telephone 8 to 10 days following a weekend trial. Information was obtained on the following gastrointestinal symptoms: vomiting, diarrhea, stomachache, and nausea. The occurrence of any one of these total gastrointestinal (GI) symptoms was considered to be evidence of illness. The respondents also were asked whether they remained home, remained in bed, or sought medical advice because of the symptoms. This information was used in establishing the credibility of the information obtained from the respondents concerning GI symptomatology. "Highly credible gastrointestinal symptoms" were defined as having at least one of the following symptom groups: (a) vomiting; (b) diarrhea accompanied by a fever or with symptoms disabling enough for the individual to remain home, remain in bed, or seek medical advice;

or (c) stomachache or nausea accompanied by a fever. To determine if the trends were the same, the rates for highly credible GI (HCGI) symptoms were calculated and compared to those for total GI symptoms. Highly credible gastrointestinal symptoms have been equated with gastroenteritis.

Water samples, collected during the time of maximum swimming activity at the beaches, were assayed for a number of potential water quality indicators. The samples were collected in sterile bottles from just below the surface of the water, at "chest high depth." They were collected at two to three locations along the beach; and, in general, three to four samples were collected between the hours of 11:00 a.m. to 5:00 p.m., the period of maximum swimming. The samples were "iced" and returned to the laboratory for assay within 6 hours of collection.

Total and fecal coliform densities were obtained using the most probable number procedure, as described in "Standard Methods for the Examination of Water and Wastewater."[28] The densities of total coliforms and their component genera (*Escherichia, Klebsiella, Citrobacter-Enterobacter*) also were measured using the procedure of Dufour and Cabelli.[29] *Escherichia coli,*[30] enterococci,[31] *Pseudomonas aeruginosa,*[32] *Clostridium perfringens,*[33] *Aeromonas hydrophila,*[34] and *Vibrio parahaemolyticus*[35] densities were determined using membrane filter procedures developed for this project. Enterovirus densities were not examined because of problems in methodology and logistics. *Shigella* enumeration also was not attempted because of methodological problems. *Salmonella* densities were not determined after the first year of the New York City study because of the very low densities observed.[27] Measurements for all but enterococci and *E. coli* were largely abandoned subsequent to the New York City study, for the reasons to be presented.

Because the "important" symptoms were found to be gastrointestinal, the swimming-associated (swimmer minus nonswimmer) illness rates for total and highly credible GI symptoms and the mean indicator densities in the water were analyzed using regression analysis. The analysis was performed on data grouped according to trials with similar indicator densities.[36] In this approach each point represents the relationship between the geometric mean of the similar indicator densities and their corresponding swimming-associated illness rates. The correlation coefficient was used to measure the strength of the relationship between swimming-associated gastrointestinal illness and the density of each indicator in the water. Regression analysis also was used to define the final criteria.

The studies conducted in the U. S. under the EPA program to develop recreational water quality criteria and the number of individuals from whom usable information was obtained are presented in Table 2.

Table 2—Number of usable responses by beach and year used in the development of the recreational water quality criterion.

		Number of usable responses during year[a]		
Location	Beaches	1	2	3
New York, N. Y.	Coney Island	641	3146	6491
	Rockaways	681	4923	
Lake Pontchartrain, La.	Levee	3432	2768	
	Fountainebleau		551	
Boston Harbor, Mass.	Revere	1824		
	Nahant	2229		

[a] Coney Island, Rockaways, 1973–1975; Levee, 1977–1978; Fountainebleau, 1978; Revere, Nahant, 1978.

RESULTS

A 3-year study at the New York City beaches was designed to determine which are the "best" indicators. The criterion used was the strength of the association with the rates of the "important" symptoms (those that correlated best with swimming in wastewater-polluted waters). It was clearly shown that these symptoms were gastrointestinal (vomiting, diarrhea, nausea, or stomachache).[22] It can be seen from Table 3 that the best correlation to total GI symptoms or the "highly credible" portion was obtained with enterococci. *E. coli* was a poor second. The superiority of enterococci versus fecal coliforms can be seen from the regression lines shown

Table 3—Correlation coefficients for total gastrointestinal symptoms and the "highly credible" portion against the mean indicator densities for 1973–1975 trials conducted at New York City beaches.

	Correlation coefficients (r)		
Indicator	Highly credible (GI)[a]	Gastro-intestinal (GI)[b]	Number of points (N)
Enterococci	.96	.81	9
E. coli	.56	.51	9
Klebsiella	.61	.47	11
Enterobacter/ citrobacter	.64	.54	13
Total coliforms	.65	.46	11
C. perfringens[c]	.01	−.36	8
P. aeruginosa	.59	.35	11
Fecal coliforms	.51	.36	12
A. hydrophila	.60	.27	11

[a] Highly credible GI symptoms (see text for definitions).
[b] Total gastrointestinal (GI) symptoms.
[c] No data for 1973.

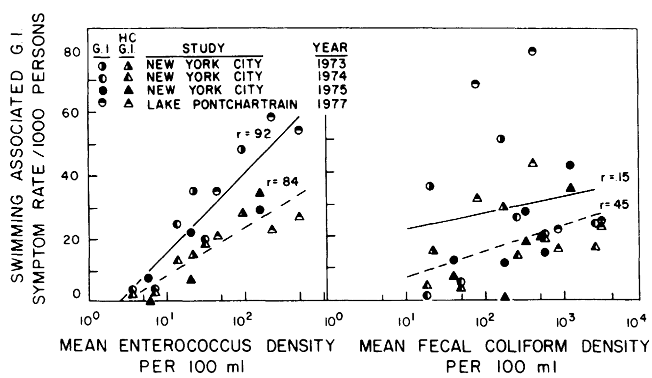

Figure 2—Linear relationships between swimming-associated rates for GI symptoms and mean enterococcus and fecal coliform densities in the water.

in Figure 2. The figure also includes fecal coliform data obtained during the first year of the Lake Pontchartrain study. The superiority of enterococci over *E. coli* as a recreational water quality indicator was even more pronounced when the data from all the U. S. studies were included in the analysis. This can be seen in Table 4, where equations used to express quantitatively the relationship between enterococci or *E. coli* densities and GI symptom rates, and their corresponding correlation coefficients, are given. A more detailed description of the relationship of these two bacterial indicator densities to GI symptom rates is presented elsewhere.[36]

The required output from the program, a criterion amenable to risk analysis, predicts the indicator density from an "acceptable" illness rate (X on Y). The regression line, along with its formula, 95% confidence limits, and correlation coefficient (r) are shown in Figure 3. Although regression lines for both total and "highly credible" GI symptoms were obtained, only the latter is presented in Figure 3 as the recommended criterion. Not only is this criterion more reliable because of the greater credibility of the information obtained, but also the consequences of the illness are more amenable to economic analysis.

DISCUSSION

To reach the objective of the overall program—the development of health effects, quality criteria for marine recreational waters—four questions needed to be answered:

Does swimming in seawater carry with it an increased risk of illness, and if so, to what type? Stevenson[6] reported a higher incidence of illness in swimmers than in nonswimmers, a result that was attributable only to swimming and not to the quality of the water, in all three of his bathing studies. The majority of these illnesses were eye, ear, nose, and throat ailments. EPA marine recreational water studies have confirmed Stevenson's observations.

Is there an association of the illness rate to pollution from domestic wastewater, and if so, to what type of illness? Stevenson's findings[6] suggested such an association for swimming in fresh water but not seawater. His results were equivocal as to the type of symptom. Moore[9] could not find an association for poliomyelitis or salmonellosis. The conclusion from the EPA program is unequivocal; there is an increased risk of acute gastroenteritis associated with swimming in waters polluted with wastewater. Furthermore, the increased risk occurs even at beaches that are far below the existing EPA-recommended guidelines and those of most of the states.

Which, if any, of the potential indicators of water quality best defines the association of GI symptomatology to water quality? The New York City study was designed to answer this question for beaches polluted with the wastewater effluents from large urban areas. The Coney Island beaches were contaminated primarily by wastewater emerging from the mouth of the Hudson River; and, although these were combined effluents subject to the effect of rainfall, treated to various degrees, and chlorinated only in part, they nevertheless represented a relatively well-defined source. It was evident, by the criterion used to select the "best" indicator, that enterococci was the best; *E. coli* was a poor second. Fecal coliforms were a relatively poor indicator system.

Can the relationship of swimming-associated health effects to the quality of the water, as determined by a microbial or chemical indicator, be quantified sufficiently to produce a health effects, quality criterion for marine recreational waters? The answer is an unequivocal "yes." Moreover, the relationship of the mean enterococcus density in the bathing water to the rate of gastroenteritis

Table 4—Regression analysis statistics for swimming-associated GI symptoms versus Enterococci and *E. coli* for all studies.

	Total gastrointestinal symptoms		Highly credible gastrointestinal symptoms	
Statistic	Enterococci	Escherichia coli	Enterococci	Escherichia coli
N	18	20	18	20
Regression equation	Y = 5.09 + 24.19 log X	Y = 15.73 + 7.37 log X	Y = 0.20 + 12.17 log X	Y = 5.88 + 6.30 log X
r	0.82	0.25	0.75	0.54

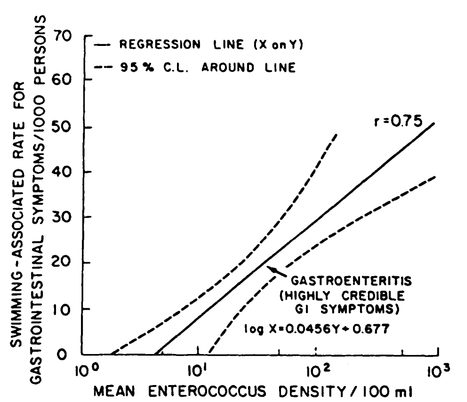

Figure 3—Recommended health effects criterion for marine recreational waters.

is compatible with risk analysis. That is, once a decision is made as to the acceptable rate of swimming-associated gastroenteritis, the criterion (relationship) can be used to derive a guideline (upper limit for the mean enterococcus density) in the bathing water. The guidelines then can be enacted into a standard.

The criterion presented in this report (the enterococcus density in the bathing water against the swimming-associated gastroenteritis rate) is a generalization that has been found to apply in a number of situations. Nevertheless, a number of considerations, including the limitations in the fecal indicator concept itself, affect the use of the criterion, as well as the guidelines and standards derived therefrom. More important, these considerations require that the findings from monitoring programs be interpreted in the light of good public health, sanitary engineering, and environmental practices. They have been described elsewhere[19] but bear repetition at this time.

The rationale for the use of guidelines and standards based on fecal indicator densities is that, under average conditions of illness in the discharging population, there is a reasonably constant indicator to pathogen ratio in the wastewater and its receiving waters. Thereby, an acceptable probability of illness caused by the pathogen can be extrapolated to a given indicator density, which is then recommended as a guideline and promulgated as a standard. Such relationships seem to hold for waters receiving the discharges from relatively large municipal wastewater treatment facilities. However, as the number of individuals who contribute to the source of the fecal wastes becomes smaller and smaller, the indicator-pathogen ratio will vary more and more from the average upon which the guideline or standard is based. In the extreme case where the fecal wastes of a single ill individual or carrier are discharged into the water, the number of pathogens may equal or exceed the number of indicator microorganisms. Therefore, routine examination of such waters for fecal indicators is of little, if any, value, as is the routine examination for the pathogens for reasons given elsewhere.[19,36] This re-emphasizes the importance of a sanitary survey.

Most epidemiologists and health officers recognize that, under epidemic conditions, the actual indicator-pathogen ratio may change sufficiently from that upon which a guideline was based so that the acceptable risk of illness will be exceeded unless the guideline is temporarily made more restrictive. The recent swimming-associated outbreak of shigellosis on the Mississippi River below Dubuque, Iowa,[38] seems to represent an instance where, although the 200/100 mL fecal coliform guideline was probably exceeded, the outbreak did not occur until there was a large enough number of ill individuals and carriers in the discharging population. Conversely, if there is a significant and constant decrease in the illness rate in the discharging population over a prolonged period, the rate for that specific illness associated with an existing indicator guideline or standard may be considerably less than predicted. The absence of recreational water-associated salmonellosis probably represents a case in point. This points out the importance of public health surveillance and argues against the blind application of "magic numbers."

By no means, should the foregoing be construed as suggesting that a recreational water quality criterion and the derived guidelines are unnecessary. To the contrary, criteria amenable to risk analysis are absolutely essential. It is evident from the nature of the illness-indicator relationships and the heavy usage of estuarine and coastal beaches in the U. S. that large numbers of individuals are becoming ill as a consequence of swimming in wastewater-polluted waters, even at some beaches that meet existing standards. Furthermore, as seen from the Dubuque shigellosis outbreak,[38] the potential for more serious illness exists. Because the observed gastroenteritis is relatively self-limiting and benign, there is undoubtedly a rate that is acceptable; however, even the acceptance of the risks to this illness should be made as deliberate and considered decisions with regard to all the factors involved and with local input.

A temporary consequence of the application of the criterion may be the withdrawal of certain recreational resources from public use, although the long-range impact should be pollution abatement. This requires better technology for obtaining the data base needed for the translation of target area criteria that have been developed into effluent guidelines on a case-by-case basis.

The findings from these studies have raised a number of questions. One is the nature of the etiological agent of the gastrointestinal symptomatology. A second is the possible need for a more human-specific and even more environmentally resistant fecal indicator. This is related to the difficult question of stormwater run-off and non-point sources of pollution. The third is the need for a separate criterion for fresh waters.

ACKNOWLEDGMENTS

Credits. The authors gratefully acknowledge the work and contributions of Paul Haberman, Center for Policy Research, New York, N. Y.; Virginia Ktsanes, Ann Anderson, and John Diem, Tulane Univ., New Orleans, La.; and David Drummond, Tufts Univ., Boston, Mass.

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