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Ambient Water Quality Criteria for Bacteria - 1986

Bacteriological Ambient Water Quality Criteria for Marine and Fresh Recreational Waters

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FOREWORD

Section 304(a)(1) of the Clean Water Act of 1977 (P.L. 95-217) requires the Administrator of the Environmental Protection Agency to publish criteria for water quality accurately reflecting the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare which may be expected from the presence of pollutants in any body of water, including ground water. This document is a revision of proposed criteria based upon a consideration of comments received from other Federal agencies, State agencies, special interest groups, and indiviudal scientists. The criteria contained in this document supplements previously published EPA bacteriological criteria in Quality Criteria for Water (1976).

The term "water quality criteria" is used in two sections of the Clean Water Act, section 304(a)(1) and Section 303(c)(2). The term has a different program impact in each section. In section 304, the term represents a non-regulatory, scientific assessment of ecological and public health effects. The criteria presented in this publication are such scientific assessments. Water quality criteria associated with specific ambient water uses when adopted as State water quality standards under section 303 become enforceable maximum acceptable levels of a pollutant in ambient waters. The water quality criteria adopted in the State water quality standards could have the same numerical limits as the criteria developed under section 304. However, in many situations States may want to adjust water quality criteria developed under section 304 to reflect local environmental conditions and human exposure patterns before incorporation into water quality standards. It is not until their adoption as part of the State water quality standards that the criteria become regulatory.

The bacteriological water quality criteria recommended in this document are based on an estimate of bacterial indicator counts and gastrointestinal illness rates that are currently being accepted, albeit unknowingly in many instances, by the States. Wherever bacteriological indicator counts can consistently be calculated to give illness rates lower than the general estimate, or when the State desires a lower illness rate, indicator bacteria levels comensurate with the lower rate should be maintained in State water quality standards.

Guidelines to assist the States in modification of criteria presented in this document, in the development of water quality standards, and in other water-related programs of this Agency, have been developed by EPA.

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BACTERIOLOGICAL AMBIENT WATER QUALITY CRITERIA FOR MARINE AND FRESH RECREATIONAL WATERS

Introduction

Federal water quality criteria recommendations were first proposed in 1968 by the National Technical Advisory Committee (NTAC) of the Department of the Interior (1). The microbiological criterion suggested by the NTAC for bathing waters was based on a series of studies conducted during the late 1940's and early 1950's, by the United States Public Health Service, the results of which were summarized by Stevenson in 1953 (2). The studies were conducted at bathing beaches located on Lake Michigan at Chicago, Illinois; on the Ohio River at Dayton, Kentucky; and on Long Island Sound at Mamaroneck and New Rochelle, New York. All of the studies followed a similar design. Two beaches with different water quality were selected at each location except at the Dayton location where a beach with high quality water could not be found. A large public swimming pool was used as a substitute. Each location was chosen because, in addition to beaches having suitable water quality, there was a large residential population nearby that used the beaches. Cooperating families used a calendar system which allowed them to record their swimming activity and illnesses on a daily basis for the entire summer. Gastrointestinal, respiratory, and other symptoms such as skin irritations were recorded. The water quality was measured on a routine basis using total coliform bacteria as the indicator organism.

The results of the Lake Michigan beach study indicated that there was no excess illnesses of any type in swimmers at beaches that had median coliform densities of 91 and 180 per 100 ml over a swimming season when compared to the number of illnesses in the total study population. The water quality similarity at the two Chicago beaches was unexpected since previous experience had indicated that there was a difference in water quality at the beaches. A second method of analysis compared the illness observed in the week following three days of high coliform density with that observed following swimming on three days of low coliform density. The analyses showed that there was a significantly greater illness rate in individuals who swam on the three days when the geometric mean coliform density was 2300/100 ml when compared to the illness in swimmers who swam on the three days when the geometric mean coliform density was 43 per 100 ml. A difference was not observed when the geometric mean coliform density per 100 ml on high and low days was 732 and 32 respectively. Data from the Ohio River study indicated that swimmers who swam in water with a median coliform density of 2300 coliforms per 100 ml had an excess of gastrointestinal illness when compared to an expected rate calculated from the total study population. No other associations between swimming and illness were observed. The results of two marine bathing beach studies showed no association between illness and swimming in water containing 398 and 815 coliforms per 100 ml.

The coliform water quality index used during the USPHS epidemiological studies was translated into a fecal coliform index in the mid-'60s by using the ratio of fecal coliforms to coliforms at the location on the Ohio River where the original study had been conducted in 1949. The NTAC committee suggested that the change was necessary because fecal coliforms were more fecal specific and less subject to variation than total coliforms which were greatly influenced by storm water runoff. About 18% of the coliforms were found to be fecal coliforms and this proportion was used to determine that the equivalent of 2300 coliforms per 100 ml, the density at which a statistically significant swimming-associated gastrointestinal illness was observed, was about 400 fecal coliforms per 100 ml. The NTAC suggested that a detectable risk was undesirable and, therefore, one-half of the density at which a health risk occurred, 200 fecal coliforms per 100 ml, was proposed. The NTAC also suggested that the use of the water should not cause a detectable health effect more than 10% of the time. Thus, the recommended criterion for recreational waters was as follows:

> "Fecal coliforms should be used as the indicator organism for evaluating the microbiological suitability of recreation 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 recreation waters shall not exceed a log mean of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml."

This criterion was recommended again in 1976 by the USEPA (3), even though it had been criticized on a number of issues. Henderson (4) published one of the earliest critiques of the recommended criterion. He noted the paucity of epidemiological data in support of any numerical ceilings based on fecal indicators and criticized the one proposed as to the poor quality of the data base, the derivation of the specific limits and the indicator system used.

Moore (5) objected to the selection of only part of the data from the Lake Michigan study to develop the 200 fecal coliforms per 100 ml recreational water criterion. He observed that opposite findings in the Lake Michigan studies were ignored. He pointed out that the inclusion of all illnesses reported during the week after a bathing episode made the association of these ailments with the bathing episode tenuous, and that there was no way of knowing whether the incidence of skin irritations in bathers who swam on clean days was compared to the frequency of diarrhea in those who swam on other days, because all the illnesses reported were lumped together.

Cabelli <u>et al</u>. (6) suggested other weaknesses in the USPHS study design which <u>would</u> have precluded the identification of swimming-associated, pollution-related illnesses if, in fact, they occurred. They pointed out that "swimming" was poorly defined and that it was unknown whether or not study participants who said they had been swimming actually immersed their bodies, much less their heads, in the water. This shortcoming and the use of the calendar method for recording "swimming" episodes and illnesses also was criticized as precluding the inclusion of beachgoing but nonswimming control groups in the studies. Moreover, the use of the calendar approach with nearby residents and the day-to-day variability in the pollution levels at the beaches increased the probability of a given individual's exposure to different levels of pollution during the incubation period of the illness.

The deficiencies in the study design and in the data used to establish the 200 fecal coliforms per 100 ml criterion were noted by the National Academy of Science - National Academy of Engineers Committee in their 1972 report which stated that they could not recommend a recreational water quality criterion because of the paucity of epidemiological information available (7).

The fecal coliform indicator used to measure water quality under the current system has also been faulted because of the non-fecal sources of at least one member of the fecal coliform group. For example, thermotolerant Klebsiella species have many sources. They have been observed in pulp and paper mill effluents (8,9), textile processing plant effluents (10), cotton mill wastewaters (11), and sugar beet wastes (12), in the absence of fecal contamination.

The Environmental Protection Agency, in 1972, initiated a series of studies at marine and fresh water bathing beaches which were designed to correct the perceived deficiencies of the Public Health Service studies. One goal of the EPA studies was to determine if swimming in sewage-contaminated water carries a health risk for bathers; and, if so, to what type of illness. If a quantitative relationship between water quality and health risk was obtained, two additional goals were to determine which bacterial indicator is best correlated to swimming-associated health effects and if the relationship is strong enough to provide a criterion.

Study Design

The marine studies were conducted at bathing beaches in New York City, New York, Boston, Massachusetts, and at Lake Pontchartrain, near New Orleans, Louisiana. Two beaches were selected at each site, one that received very little or no contamination and the other whose water quality was barely acceptable with respect to local recreational water quality standards. In the New York City and Boston Harbor studies, the "barely acceptable" beaches were contaminated with pollution from multiple point-sources, usually treated effluents that had been disinfected.

The freshwater studies were conducted on Lake Erie at Erie, Pennsylvania and on Keystone Lake outside of Tulsa, Oklahoma. The "barely acceptable" beaches at both sites were contaminated by effluents discharged from single point-sources.

The epidemiological surveys were carried out on weekend days and individuals who swam in the midweeks before and after a survey were eliminated from the study. This maximized the study populations; allowed the water quality measurements for a single day to be specifically associated with the corresponding illness rates, and permitted the grouping of days with similar water quality levels and their corresponding study populations. The design of the epidemiological survey portion of the study has been described elsewhere (13,14). Specific steps taken to correct the deficiencies of earlier studies were noted earlier.

In the initial phases of the overall study, multiple indicators of water quality were used to monitor the water. This was done because it was not known which indicator of water quality might show a quantitative relationship with swimming-associated health effects. This unique approach resulted in the selection of the best indicator based on the strength of the statistical relationship between the water quality indicator and a swimming-associated health effect.

Each participant was querried at length about any illness symptoms, their date of onset and the duration of the symptoms. The symptoms were grouped into four general categories, gastrointestinal, respiratory, eye, ear and nose, and "other". Gastrointestinal symptoms included vomiting, diarrhea, stomachache and nausea. Sore throat, bad cough and chest colds comprised the respiratory symptoms, and runny or stuffy nose, earache or runny ears and red, itchy or watery eyes were considered symptomatic of eye, ear or nose problems. Other symptoms included fever greater than 100° F, headache for more than a few hours or backache.

All of the symptoms were self-diagnosed and therefore subject to variable interpretation. The potential for misinterpretation was minimized by creating a new symptom category called highly credible gastrointestinal symptoms. This symptom category was defined as including any one of the following unmistakable or combinations of symptoms: (1) vomiting, (2) diarrhea with fever or a disabling condition (remained home, remained in bed or sought medical advice because of the symptoms) and (3) stomachache or nausea accompanied by a fever. Individuals in this symptom category were considered to have acute gastroenteritis.

Data Base for Marine and Fresh Water Criteria

The results of the marine Bathing Beach Studies have been reported by Cabelli (15) and those of the freshwater studies have been described by Dufour (16). In general, those symptom categories unrelated to gastroenteritis usually did not show a significant excess of illnesses at either of the paired beaches at each study location. Moreover, the significant swimming-associated rates for gastroenteritis were always observed at the more polluted of the paired beaches at each study location. Table 1 shows the number of occasions when significant swimming-associated gastroenteritis was observed at barely acceptable and relatively unpolluted marine and fresh water beaches. Statistically significant swimming-associated gastroenteritis rates were not observed at any of the relatively unpolluted beaches. The occurrence of a statistically significant excess of swimming-associated gastroenteritis in swimmers who bathed at beaches that were, by selection, more polluted is indicative that there is an increased risk of illness from swimming in water contaminated with treated sewage, i.e., both swimming-associated and pollution-related. This finding, which was observed at both marine and fresh water locations was important because it placed in proper perspective the relationship between water contaminated with treated sewage and health risks for swimmers. This association was not very well defined in the earlier USPHS studies. The only evidence that sewage-contaminated water carried a risk for gastroenteritis in those studies was observed at the Ohio River beach where swimmers had an excess of gastrointestinal illness when the median coliform density in the water was 2300 per 100 ml. This was counter to the results found at freshwater beaches in Chicago and at marine beaches on Long Island Sound where swimmers had no more gastrointestinal illness than nonswimmers even when days of "high" and "low" coliform densities were selected. Therefore, other than the occasional association of an outbreak of disease with swimming (17), the data from Cabelli (15) and Dufour (16) are the only available evidence linking sewage contaminated water with a health risk for bathers.

Although the association of illness in swimmers using bathing water contaminated by treated sewage is an important aspect of the process for developing recreational water quality criteria, it is the establishment of a quantitative relationship between the two variables that provides a useful relationship for regulating water quality. A part of this process is the development of suitable methods for measuring the quality of the water.

A comprehensive discussion of microbial water quality indicators is beyond the scope of this document, even as the basis for the selection of those examined in the epidemiological studies. The reader is referred for this to the reports of the studies (15,16) and to reviews on the subject (18,19). The examination of a number of potential indicators, including the ones most commonly used in the United States (total coliforms and fecal coliforms), was included in the studies. Furthermore, the selection of the best indicator was based on the strength of the relationship between the rate of gastroenteritis and the indicator density, as measured with the Pearson Correlation Coefficient. This coefficient varies between minus one and plus one. A value of one indicates a perfect relationship, that is, all of the paired points lie directly on the line which defines the relationship. A value of zero means that there is no linear relationship. A positive value indicates that the relationship is direct, one variable increases as the other increases. A negative value indicates the relationship is inverse, one variable decreases as the other increases. The correlation coefficients for gastroenteritis rates as related to the various indicators of water quality from both marine and fresh bathing water are shown in Table 2.

The data from the three years of the New York City study were analyzed in two ways. The first was by grouping trial days with similar indicator densities from a given swimming season and the second was by looking at each entire summer. The results from both analyses are shown in Table 2. For either type of analysis, enterococci showed the strongest relationship to gastroenteritis. E. coli was a very poor second and all of the other indicators, including total coliforms and fecal coliforms, showed very weak correlations to gastroenteritis. Enterococci and E. coli were used in subsequent studies including the freshwater trials. Fecal coliforms also were included in subsequent studies because of their status as an accepted basis for a criterion.

The freshwater studies were analyzed only by summer. The correlation coefficient for E. coli was slightly greater than that for enterococci, however, statistical analysis indicated that the two values were not significantly different. Fecal coliforms, on the other hand, had a correlation coefficient that was very similar to that observed for fecal coliforms from the marine data analyzed by summer. The freshwater studies confirmed the findings of the marine studies with respect to enterococci and fecal coliforms in that the densities of the former in bathing water showed strong correlation with swimming-associated gastroenteritis rates and densities of the latter showed no correlation at all. The similarities in the relationships of E. coli and enterococci to swimming-associated gastroenteritis in freshwater indicate that these two indicators are equally efficient for monitoring water quality in freshwater, whereas in marine water environments only enterococci provided a good correlation. The etiological agent for the acute gastroenteritis is probably viral (20). The ultimate source of the agent is human fecal wastes. E. coli is the most fecal specific of the coliform indicators (21); and enterococci, another fecal indicator, better emulates the virus than do the coliforms with respect to survival in marine waters (22).

Basis of Criteria for Marine and Fresh Recreational Waters

Cabelli (15) defined a recreational water quality criterion as a "quantifiable relationship between the density of an indicator in the water and the potential human health risks involved in the water's recreational use." From such a definition, a criterion now can be adopted by a regulatory agency, which establishes upper limits for densities of indicator bacteria in waters that are associated with acceptable health risks for swimmers.

The quantitative relationships between the rates of swimming-associated health effects and bacterial indicator densities were determined using regression analysis. Linear relationships were estimated from data grouped on the basis of summers or trials with similar indicator densities. The data for each summer were analyzed by pairing the geometric mean indicator density for a summer bathing season at each beach with the corresponding swimming-associated gastrointestinal illness rate for the same summer. The swimming-associated illness rate was determined by subtracting the gastrointestinal illness rate in nonswimmers from that for swimmers. These two variables from multiple beach sites were used to calculate a regression coefficient, y-intercept and 95% confidence intervals for the paired data. In the marine studies the total number of points for use in regression analysis was increased by collecting trial days with similar indicator densities from each study location and placing them into groups. The swimming-associated illness rate was determined as before, by subtracting the nonswimmer illness rate of all the individuals included in the grouped trial days from the swimmer illness rate during these same grouped trial days. The grouping by trial days with similar indicator densities approach was not possible with the freshwater data because the variation of bacterial indicator densities in freshwater samples was not large enough to allow such an adjustment to be made.

For the saltwater studies the results of the regression analyses of illness rates against indicator density data was very similar using the "by summer" or "by grouped trial days" approaches. The data grouped by trial days will be used here because of the broader range of indicator densities available for analysis. Table 3 shows the results of the marine and fresh water bathing beach studies conducted from 1973 through 1982. These data were used to define the relationships between swimming-associated gastroenteritis and bacterial indicator densities presented below.

The methods used to enumerate the bacterial indicator densities which showed the best relationship to swimming-associated gastroenteritis rates were specifically developed for the recreational water quality studies. The membrane filter procedure for enumerating enterococci was developed by Levin *et al.* (23). Evaluation of the method using fresh and marine water samples indicated that it detects mainly *Streptococcus faecalis* and *Streptococcus faecium*. Although these two species were thought to be more human specific than other *Streptococci*, they have been found in the intestinal tract of other warm-blooded animals such as cats, dogs, cows, horses and sheep.

E. coli were enumerated using the membrane filter procedure developed by Dufour *et al.* (24). Evaluation of this method with marine and fresh water samples has shown that 92 to 95% of the colonies isolated were confirmed as *E. coli*.

These membrane filter methods have successfully undergone precision and bias testing by the EPA Environmental Monitoring and Support Laboratory. The test methods are available in the EPA Research and Development report, EPA-600/4-85/076 *Test Methods for Escherichia coli and Enterococci in Water by the Membrane Filter Procedure*.*

Recommendations on Bacterial Criteria Monitoring

Several monitoring situations to assess bacterial quality are encountered by regulatory agencies. The situation needing the most rigorous monitoring is the designated swimming beach. Such areas are frequently lifeguard protected, provide parking and other public access and are heavily used by the public. Public beaches of this type were used by EPA in developing the relationship described in this document.

Other recreational activities may involve bodies of water which are regulated by individual State water quality standards. These recreational resources may be natural wading ponds used by children or waters where incidental full body contact occurs because of water skiing or other similar activities.

It is EPA's judgement that the monitoring requirements for these various recreational activities are different. For the public beaches, more frequent sampling is required to verify the continued safety of the waters for swimming, and to identify water quality changes which might impair the health of the public. Increasing the number of samples improves the accuracy of bacterial water quality estimates, and also improves the likelihood of correct decisions on whether to close or leave open a beach.

Waters with more casual and intermittant swimming use need fewer samples because of the reduced population at risk. Such sampling may also be used in establishing trends in the bacterial water quality so that the necessary improvements in the sanitary quality can be identified before disease risks become acute.

The following compliance protocol is one recommended by EPA for monitoring recreational bathing waters. It is based on the assumption that the currently accepted risk level based on the QCW recommendation has been determined to be appropriate and that the monitoring methods, i.e., bacterial enumeration techniques are imprecise, and environmental conditions, such as rainfall, wind and temperature will vary temporally and spatially. The variable nature of the environment, which affects the die-off and transport of bacterial indicators, and the inherent imprecision of bacterial enumeration methods, suggests an approach that takes these elements into account. Noncompliance with the criterion is signaled when the maximum acceptable geometric mean is exceeded or when any individual sample exceeds a confidence limit, chosen accordingly or to a level of swimming use. The mean log standard deviation for E. coli densities at the nine freshwater beach sites that were studied was about 0.4. The mean log standard deviation for enterococci in freshwater samples was also about 0.4 and in seawater samples it was about 0.7. These two values, 0.4 and 0.7 will be used in calculations associated with the proposed monitoring protocol and upper percentile values.

It is recommended that sampling frequency be related to the intensity of use of the water body. In areas where weekend use is substantial, weekly samples collected during the peak use periods are reasonable. In less heavily used areas perhaps bi-weekly or monthly samples may be adequate to decide bacterial water quality. In general, samples should be collected during dry weather periods to establish so-called "steady state" conditions. Special studies may be necessary to evaluate the effects of wet weather conditions on waters of interest especially if sanitary surveys indicate the area may be subject to storm water effects.

The water samples are collected in sterile sampling containers as described in Standard Methods for the Examination of Water and Wastewater (25).

Development of Recommended Criteria Based on E. coli/Enterococci

Currently EPA is not recommending a change in the stringency of its bacterial criteria for recreational waters. Such a change does not appear warranted until more information based on greater experience with the new indicators can be accrued. EPA and the State Agencies can then evaluate the impacts of change in terms of beach closures and other restricted uses. EPA recognizes that it will take a period of at least one triennial review and revision period for States to incorporate the new indicators into State Water Quality Standards and start to accrue experience with the new indicators at individual water use areas.

EPA's evaluation of the bacteriological data indicated that using the fecal coliform indicator group at the maximum geometric mean of 200 per 100 ml, recommended in Quality Criteria for Water would cause an estimated 8 illness per 1,000 swimmers at fresh water beaches and 19 illness per 1,000 swimmers at marine beaches. These relationships are only approximate and are based on applying ratios of the geometric means of the various indicators from the EPA studies to the 200 per 100 ml fecal coliform criterion. However, these are EPA's best estimates of the accepted illness rates for areas which apply the EPA fecal coliform criterion.

The *E. coli* and enterococci criteria presented in Table 4 were developed using these currently accepted illness rates. The equations developed by Dufour(16) and Cabelli(15) were used to calculate the geometric mean indicator densities corresponding to the accepted gastrointestinal illness rates. These densities are for steady state dry weather conditions. The beach is in noncompliance with the criteria if the geometric mean of several bacterial density samples exceeds the value listed in Table 4.

Noncompliance is also signalled by an unacceptably high value for any single bacterial sample. The maximum acceptable bacterial density for a single sample is set higher than that for the geometric mean, in order to avoid unnecessary beach closings based on single samples. In deciding whether a beach should be left open, it is the long term geometric mean bacterial density that is of interest. Because of day-to-day fluctuations around this mean, a decision based on a single sample (or even several samples) may be erroneous, i.e., the sample may exceed the recommended mean criteria even though the long-term geometric mean is protective, or may fall below the maximum even if this mean is in the nonprotective range.

To set the single sample maximum, it is necessary to specify the desired chance that the beach will be left open when the protection is adequate. This chance, or confidence level, was based on Agency judgment. For the simple decision rule considered here, a smaller confidence level corresponds to a more stringent (i.e. lower) single sample maximum. Conversely, a greater confidence level corresponds to less stringent (i.e. higher) maximum values. This technique reduces the chances of single samples inappropriately indicating violations of the recommended criteria.

By using a control chart analogy (26) and the actual log standard deviations from the EPA studies, single sample maximum densities for various confidence levels were calculated. EPA then assigned qualitative use intensities to those confidence levels. A low confidence level (75%) was assigned to designated beach areas because a high degree of caution should be used to evaluate water quality for heavily used areas. Less intensively used areas would allow less restrictive single sample limits. Thus, 95% confidence might be appropriate for swimmable water in remote areas. Table 4 summarizes the results of these calculations. These single sample maximum levels should be recalculated for individual areas if significant differences in log standard deviations occur.

The levels displayed in Table 4 depend not only on the assumed standard deviation of log densities, but also on the chosen level of acceptable risk. While this level was based on the historically accepted risk, it is still arbitrary insofar as the historical risk was itself arbitrary. A detailed protocol is available* which shows how to determine the confidence level associated with any illness risk of interest, once a maximum has been established for single samples. The protocol also indicates how the confidence level approach can be applied to multiple sample geometric means. In Table 4, the limit for the measured geometric mean is determined directly from the regression equation relating illnesses to bacteriological density, without any "confidence level" allowance for random variations in the geometric mean of several samples.

Limitations and Extrapolations of Criteria

The limitations of Water Quality Criteria based on swimming-associated health effects and bacterial indicator densities have been addressed by Cabelli(18). Briefly, the major limitations of the criteria are that the observed relationship may not be valid if the size of the population contributing the fecal wastes becomes too small or if epidemic conditions are present in a community. In both cases the pathogen to indicator ratio, which is approximately constant in a large population becomes unpredictable and therefore, the criteria may not be reliable under these circumstances. These two considerations point out the importance of sanitary surveys and epidemiological surveillance as part of the monitoring program.

The presence of these indicators, in rural areas, shows the presence of warm blooded animal fecal pollution. Therefore, EPA recommends the application of these criteria unless sanitary and epidemiological studies show the sources of the indicator bacteria to be non-human and that the indicator densities are not indicative of a health risk to those swimming in such waters. EPA is sponsoring research to study the health risk of nonpoint source pollution from rural areas on the safety of water for swimming. Definitive evidence from this study was not available at the time of preparation of this criterion, but will be incorporated into subsequent revisions.

Relationship with the Criterion contained in Quality Criteria for Water (QCW)

The 1976 QCW criterion contained recommendations for both swimming and shellfish harvesting waters. This criteria recommendation is intended as a modification to the earlier criterion. Nothing in this criterion is intended to supersede the QCW recommendations concerning the bacterial quality of shellfish waters. EPA is currently co-sponsoring, with the National Oceanic and Atmospheric Administration, research into the

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application of the enterococci and E. coli indicators for assessing the quality of shellfish harvesting waters. The Food and Drug Administration is also reviewing the results of these studies. A change to the new indicators may be forthcoming if the studies show a correlation between gastrointestinal disease and the consumption of raw shellfish from waters with defined densities of the new indicators. However, these studies have not sufficiently progressed to justify any change at this time. Thus, the recommendations in QCW for shellfish waters must remain unchanged.

The QCW recommendations for swimming waters were based on fecal coliforms. Data submitted to EPA during the public comment period showed that within some beaches, a correlation could be shown between E. coli densities and fecal coliform densities. Such a site-specific correlation is not surprising because E. coli is part of the fecal coliform group. However, the EPA tests show that no general correlation exists across different beaches. Therefore, EPA believes that the newly recommended indicators are superior to the fecal coliform group. Therefore, EPA strongly recommends that states begin the transition process to the new indicators. While either E. coli or enterococci may be used for fresh waters, only enterococci is recommended for marine waters.

Table 1. Relationship Between Significant Swimming-Associated Gastroenteritis and the Degree of Pollution at Marine and Fresh Water Bathing Beaches

	Beach Water Quality	
	Barely Acceptable	Relatively Unpolluted
No. Trials	17	8
No. Trials with Excess Illness in Swimmers[1]	7	0
% Trials with Excess Swimmer Illness	41	0

[1]Difference between swimmer and nonswimmer illness rates during a trial period statistically significant at $p < 0.05$ level

TABLE 2. Correlation Coefficients for Swimming-Associated Gastroenteritis Rates Against Mean Indicator Densities at Marine and Fresh Water Bathing Beaches

Type of Water	Indicator	Correlation Coefficients: Data by Summers	Correlation Coefficients: Data by Grouped Trials[1]
Marine[2]	enterococci	.75	.96
	F. coli	.52	.56
	Klebsiella	.32	.61
	Enterobacter/Citrobacter	.26	.64
	Total Coliforms	.19	.65
	C. perfringens	.19	.01
	P. aeruginosa	.19	.59
	Fecal Coliforms	-.01	.51
	A. hydrophila	-.09	.60
	V. parahemolyticus	-.20	.42
	Staphylococci	-.23	.60
Fresh[3]	enterococci	.74	
	E. coli	.80	
	Fecal Coliforms	-.08	

[1]Groups of trials (days) with similar mean indicator densities during a given summer

[2]Data from trials conducted at New York City beaches 1973-1975 (Reference 18)

[3]Data from Reference 19

TABLE 3. Summary of Mean Indicator Density--Swimming-Association Gastroenteritis Rates From Trials of All U.S. Studies

Type of Water	Location	Beach[1]	Year	*E. coli* Density	Enterococcus Density	Number Swimmers	Number Illnesses	Number Nonswimmers	Number Illnesses	Gastroenteritis Rate per 1000
Marine	N.Y.C.	RW	1973		21.8	484	30.4	197	15.2	15.2
		CI			91.2	474	46.4	167	18	28.4
			1974		3.6	1391	7.6	711	4.2	3.4
					7.0	951	10.5	1009	6.9	3.6
					13.5	625	16.0	419	2.4	13.6
					31.5	831	18.1	440	-	18.1*
			1975		5.7	2232	8.8	935	19.3	-0.5
					20.3	1896	14.8	678	7.4	7.4
					154	579	34.5	191	-	34.5*
	Lake Pontchartrain	L	1977		44	874	32	451	11.1	20.9*
					224	720	31.9	456	8.8	23.1*
					495	895	35.8	464	8.6	27.2*
		L	1978		11.1	1230	36.6	415	14.5	22.1*
		F			14.4	248	44.3	303	23.1	21.2
		L			142	801	42.4	322	15.5	26.9*
	Boston Harbor	RE	1978		43	697	23	529	11	12
		N			7.3	1130	33	1099	28	5
		RE			12.0	222	41	376	13	28*
Fresh	Lake Erie	A	1979	23	5.2	3020	17.2	2349	14.9	2.3
		B		47	13	2056	19.5	2349	14.9	4.6
	Keystone Lake	E		138	38.8	3059	20.6	970	15.5	5.1
		W		19	6.8	2440	20	970	15.5	0.5
	Lake Erie	A	1980	137	25	2907	16.5	2944	11.7	4.8
		B		236	71	2427	26.4	2944	11.7	14.7*
	Keystone Lake	E		52	23	5121	13.5	1211	8.3	5.2
		W		71	20	3562	11.2	1211	8.3	3.0
	Lake Erie	B	1982	146	20	4374	24.9	1650	13.9	11.0*

[1]RW = Rockaways, CI = Coney Island, L = Levee Beach, F = Fontainbleu Beach, R = Revere Beach, N - Nahant Beach, A = Beach 7, B = Beach 11, E = Washington Irving Cove Beach, W = Salt Creek Cove--Keystone Ramp Beaches

*Indicates swimmer-nonswimmer illness rate difference significant at $p = 0.05$ level

TABLE 4

CRITERIA FOR INDICATOR FOR BACTERIOLOGICAL DENSITIES

Acceptable Swimming Associated Gastro-enteritis Rate per 1000 swimmers		Steady State Geometric Mean Indicator Density	Single Sample Maximum Allowable Density (4), (5)			
			Designated Beach Area (upper 75% C.L.)	Moderate Full Body Contact Recreation (upper 82% C.L.)	Lightly Used Full Body Contact Recreation (upper 90% C.L.)	Infrequently Used Full Body Contact Recreation (upper 95% C.L.)
Freshwater						
enterococci	8	33(1)	61	89	108	151
E. coli	8	126(2)	235	298	406	576
Marine Water						
enterococci	19	35(3)	104	158	276	500

Notes:

(1) Calculated to nearest whole number using equation:
$$\text{(mean enterococci density)} = \text{antilog}_{10} \frac{\text{illness rate/1000 people} + 6.28}{9.40}$$

(2) Calculated to nearest whole number using equation:
$$\text{(mean \underline{E. coli} density)} = \text{antilog}_{10} \frac{\text{illness rate/1000 people} + 11.74}{9.40}$$

(3) Calculated to nearest whole number using equation:
$$\text{(mean enterococci density)} = \text{antilog}_{10} \frac{\text{illness rate/1000 people} - 0.20}{12.17}$$

(4) Single sample limit = antilog$_{10}$ [($\log_{10}$ indicator geometric mean density/100 ml) + Factor determined from areas under the Normal probability curve for the assumed level of probability x ($\log_{10}$ standard deviation)]

The appropriate factors for the indicated one sided confidence levels are:

75% C.L. - .675
82% C.L. - .935
90% C.L. - 1.28
95% C.L. - 1.65

(5) Based on the observed log standard deviations during the EPA studies: 0.4 for freshwater E. coli and enterococci; and 0.7 for marine water enterococci. Each jurisdiction should establish its own

EPA Criteria for Bathing (Full Body Contact) Recreational Waters

Freshwater

Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the indicated bacterial densities should not exceed one or the other of the following:(1)

E. coli	126 per 100 ml; or
enterococci	33 per 100 ml;

no sample should exceed a one sided confidence limit (C.L.) calculated using the following as guidance:

designated bathing beach	75% C.L.
moderate use for bathing	82% C.L.
light use for bathing	90% C.L.
infrequent use for bathing	95% C.L.

based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.4 as the log standard deviation for both indicators.

Marine Water

Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the enterococci densities should not exceed 35 per 100 ml;

no sample should exceed a one sided confidence limit using the following as guidance:

designated bathing beach	75% C.L.
moderate use for bathing	82% C.L.
light use for bathing	90% C.L.
infrequent use for bathing	95% C.L.

based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.7 as the log standard deviation.

Note (1) - Only one indicator should be used. The Regulatory agency should select the appropriate indicator for its conditions.

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