Pollution Indices of Natural Bathing Places*

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ALTHOUGH indices of pollution have been established from time to time for bathing pools, few attempts have been made to set standards for natural bathing places. California [1] has proposed a standard of 10 *Escherichia coli* per c.c. and the New York City Department of Health [1] allows 30 *Esch. coli* per c.c. Winslow and Moxon [2] in a study of New Haven bathing beaches believe that an average of 1 colon bacillus per c.c. with a maximum of not over 10 would be a more reasonable standard as based upon conditions that obtained in their studies. Scott [3] in a study of Connecticut's shore waters on Long Island Sound classified bathing waters into 5 classes according to the colon indices obtained:

	Average of *Esch. coli* per 100 c.c.
Class A+	0 to 10
Class A—	11 to 50
" B	51 to 500
" C	501 to 1,000
" D	over 1,000

In correlating the bacteriological findings with a sanitary survey, the classification in representing bathing beach qualities is as follows:

	Condition
Class A+	good
" A—	good
" B	fair to doubtful
Class C	doubtful to poor
" D	very poor

All of these studies were planned primarily to measure sewage pollution of bathing beaches and not the conditions that would occur in clean waters when large numbers of bathers were present. Scott [3] states that only a slight increase in bacterial numbers occurred on an ocean beach during periods of heavy bathing loads. He believes that the number of bacteria introduced by the bathers would not seriously affect his classification. In a survey of the coast line of lower Michigan, the Michigan Stream Control Commission [4] found results similar to those obtained by Scott in salt water beaches. Colon indices on Lake Michigan beaches that were a considerable distance from sources of sewage pollution frequently were from 0 to 100 per c.c. of water. Such areas undoubtedly represent ideal bathing places.

The conditions that occur, however, on the Great Lakes and ocean beaches are quite different from those occurring on small inland lakes. These lakes, because they frequently do not receive any raw sewage, have been assumed to be safe for bathing. This is largely true, but to date no recognition has been given to the pollution introduced by the bathers. As these lakes are frequently located near large cities, they

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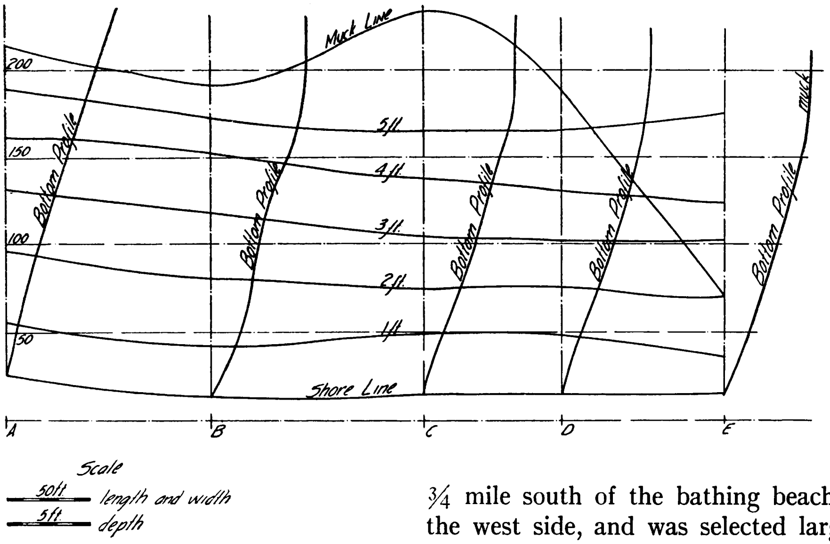
FIGURE I—Map of Lake Lansing showing location of bathing beach and sampling points

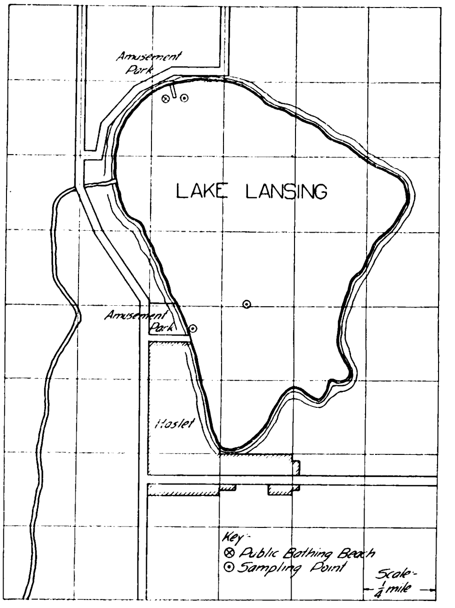


have become very popular. In lower Michigan these lakes are generally small and bathing areas, open to the public, are frequently limited in size. Beaches from 200 to 400 ft. in length are very common. Near the large cities such beaches become very congested on the warm days of August and July.

As no attempt has been made to study the bacteriology of such beaches, the work here presented was done.

A lake near East Lansing was selected due to its convenience, its freedom from sewage pollution, and the presence of a limited size bathing beach that has a heavy patronage. The beach is, in most respects, typical of most inland lakes in the lower part of Michigan. In Figure I is presented a map to show points of sampling, location of the bathing beach, and size of lake, which is approximately 1¼ miles long by 1 mile wide at the widest point. The only bathing beach is at the northern end. The control point for collecting samples as checks on the bathing beach, is at an amusement park ¾ mile south of the bathing beach on the west side, and was selected largely because of its convenience. No sewage enters the lake. It is very active biologically. Samples taken at any point show large numbers of plankton. Rotifers and water fleas are very common. In Figure II is presented a map of the beach, showing its size and

FIGURE II—Profile map of the bathing beach

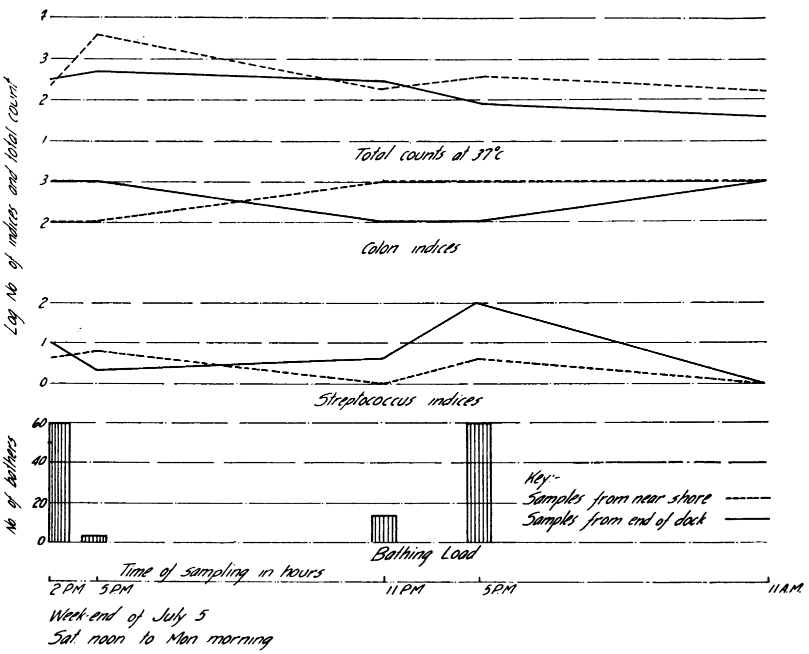


depth. It will be noted that it is sharply circumscribed by an area of soft muck, so the bathers always remain in the sandy area, about 350 ft. long, 200 ft. wide, and approximately 5 ft. deep at the deepest point. The bottom slopes very gradually. The heaviest bathing load is found at B. A bathing dock with diving platform is located here. Most of the bathers enter the water from this dock and generally stay in the close vicinity of it.

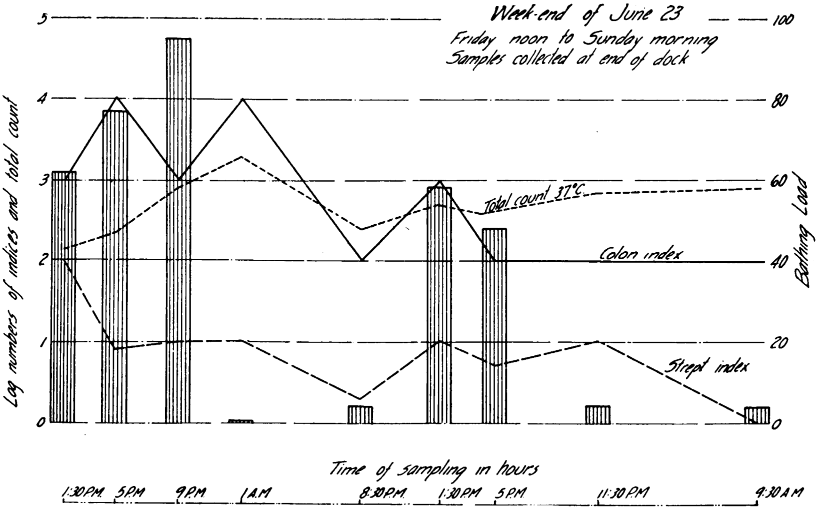
It was desired to obtain data on the bathing beach under all conditions such as light and heavy bathing loads, various temperatures, and rest periods. Samples were usually collected at frequent intervals during week-ends; in periods of use and of rest. In most cases samples were obtained early in the morning before bathers arrived, following a day of heavy loads. It was found most satisfactory and most convenient to collect two samples, one at the end of the bathing dock and the other from the dock near the shore in approximately 18 in. of water. Occasionally sand samples were taken at the latter point, particularly in the morning, to determine the influence of sedimentation on the disappearance of the bacteria over night.

The samples were collected in the usual large mouth glass stoppered water sample bottles. Immediately after collection, the following bacteriological examinations were made: Appropriate dilution plates were made using standard plain nutrient agar, and incubated at 25 and 37° C. Bacteriological counts were made after 24 hours' incubation at 37° C. and 48 hours' at room temperature, respectively. Appropriate dilutions of the water were made into standard lactose nutrient broth in Durham fermentation tubes. Generally, the series was 1 to 100,000,

GRAPH I—Comparative data on pollution indices of samples taken from the end of the bathing dock and near the shore



GRAPH II—Comparative data on pollution indices from samples collected at the bathing beach during the week-end of June 23



1 to 10,000, 1 to 1,000, 1 to 100, 1 to 10, 1 c.c., and 10 c.c. direct. Observations were made at the end of 24 and 48 hours' incubation. Tubes showing gas from the least amounts of water were smeared on eosin-methylene blue agar for confirmation of the colon bacillus. All questionable cases were further checked by refermentation in lactose nutrient broth fermentation tubes. After 72 hours' incubation, 48 hours' at 37° C., followed by 24 hours' at room temperature, all tubes were examined for streptococcus microscopically by the method recommended by Mallmann and Gelpi.[5] Indices for both the colon bacillus and streptococcus are based on 100 c.c. volumes of water and were determined by the procedure recommended by *Standard Methods of Water Analysis*.[6]

At first, samples were taken at three points on the bathing beach to assure obtaining average results, but this was soon found impractical due to inability to handle the large number collected. After careful examination of the data so obtained and a study of the beach itself, it was decided to sample at only one point—that of greatest pollution as evidenced by the density of bathers. This was a bathing dock located at one side of the beach.

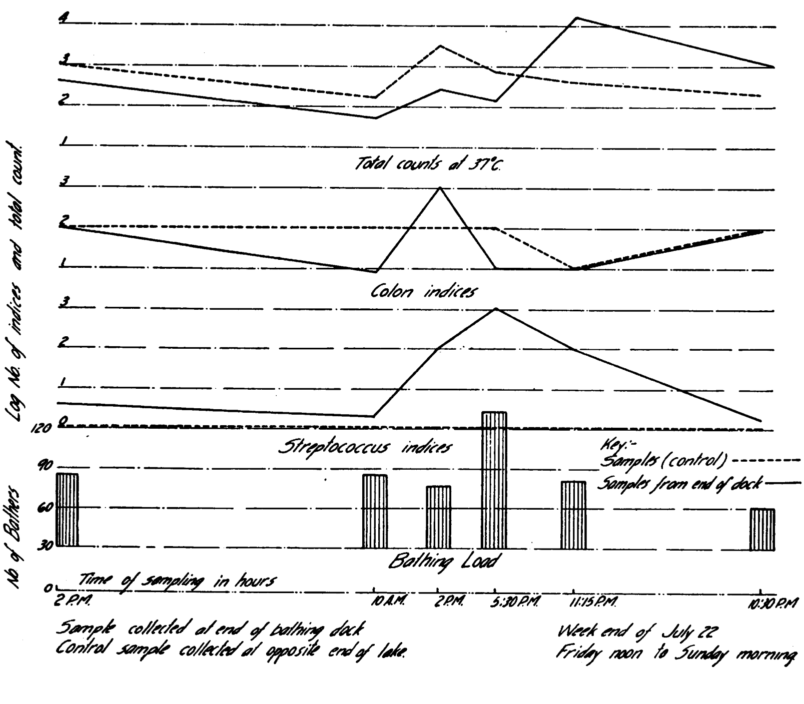
The results for this week-end are representative of all the data, and show the relationship between samples from the end of the dock and those from near shore. It will be observed that the colon indices and the total count are somewhat parallel. In general, the colon indices and total count were slightly higher near shore. On the contrary, the streptococcus indices were generally higher at the end of the dock. The latter was to be expected as the total immersion of the body is more frequent in the deeper water. Because the samples from the end of the dock gave results on total count and colon indices comparable to the samples from near shore and higher streptococcus indices, only samples from the end of the dock will be considered.

As the week-end bathing loads were always much higher than those obtained during the week, these periods were selected for more intensive study. Each week-end the sampling was started on either Friday or Saturday afternoon and continued until Monday morning, depending upon weather conditions. Samples were taken late at night after bathing had ceased and early in the morning before bathing started. In this manner the fall and rise in the pollution could be observed. In Graph II are presented the results of a typical week-end test. It will be observed that, in general, all three indices of pollution parallel roughly the bathing load, although the streptococcus index parallels it more closely; also that the number of colon bacilli and the total counts are considerably higher than the number of streptococci. This is just the opposite of the condition in a chlorinated swimming pool where the chlorine destroys the more susceptible colon bacilli and leaves only the streptococci. The total count in a chlorinated pool may also be lower due likely to the fact that the streptococci do not appear on the agar plate.

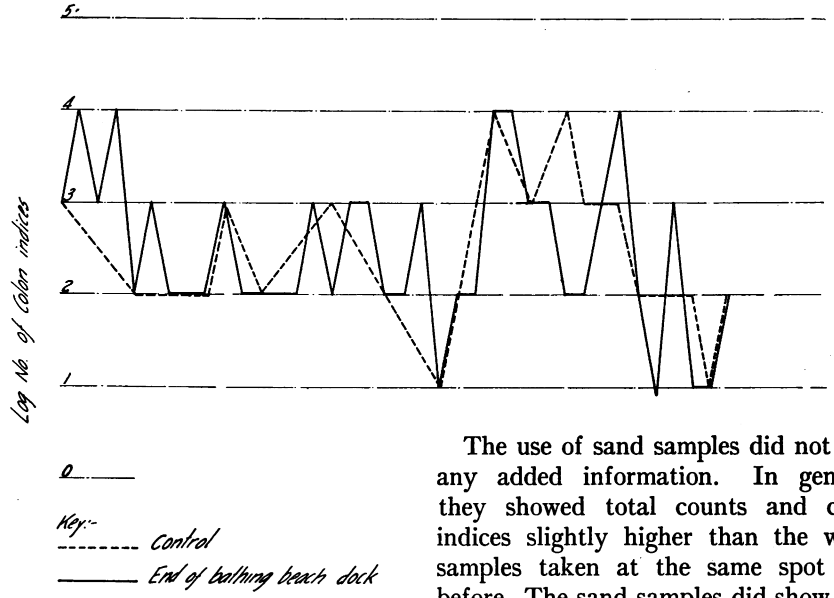
It might be argued that all three indices of pollution were equally good, though, if the control samples, taken a safe distance from the beach, are compared with the samples taken at the time of heavy bathing loads, another picture is presented, as in Graph III. It will be observed that the total counts of the bathing beach and the control area are roughly parallel, as also are the colon indices. Both of these indices show a diurnal rise, which may be due to the rise in temperature. In the case of the streptococcus index, no streptococci were observed in any dilution of the samples tested in the control samples. On days when no bathing occurred, streptococci were absent. Generally in the sample collected in the morning, even following days of heavy loads, the streptococcus incidence was low or negative.

The results presented in Graph III concerning the parallelism between the colon indices on the bathing beach and

GRAPH III—A comparison of pollution indices from samples collected on the bathing beach and a control point free from pollution during the week-end of July 22



GRAPH IV—Comparative data of colon indices from the bathing beach and control area during period of study



on the control area are more strikingly presented in Graph IV where the colon indices for the period of study are presented. The averages for these areas were practically the same.

Graph V shows the results of tests on total count for the bathing beach and the control area. The total counts for the bathing beach are, on the average, considerably higher than the control area; however, there is considerable overlapping of the counts. In Graph VI are presented the data on streptococcus indices for both the bathing beach and the control area. Here the indices for the control area are zero throughout, while a very marked fluctuation occurs in the bathing beach samples.

Graphs IV, V, VI also show the importance of repeated sampling before passing judgment upon natural bathing areas using any bacteriological index. It will be observed that catch samples taken on most any day or night might show either acceptable or unacceptable conditions when based on any of the three pollution indices presented.

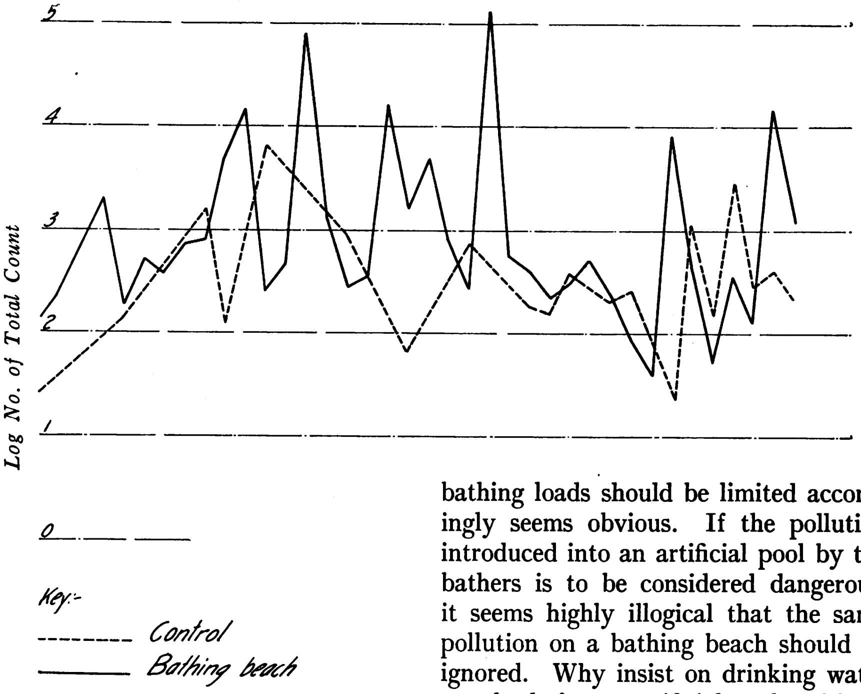
The use of sand samples did not give any added information. In general, they showed total counts and colon indices slightly higher than the water samples taken at the same spot just before. The sand samples did show that sedimentation did not account for the appearance of the streptococci overnight, as the morning sand samples were negative to tests for these organisms.

The samples taken in the center of the lake always showed lower counts than those collected near shore at the same time. The results of these tests did not give any additional information; hence the data are not presented.

On ocean and large lake beaches it is conceivable, and very probable, that currents due to wind and tides cause such changes in water that dilution removes the bacteria introduced by the bathers. Further, the large size of such beaches and the corresponding volume of water in the bathing area give such great dilution that no appreciable increase in the numbers of bacteria would be expected. However, in the light of the data here presented, the writers feel that samples collected during heavy bathing loads might show results similar to those found on the beach discussed.

Contrary to accepted opinion, the writers believe that momentarily a natural bathing beach is not different

GRAPH V—Comparative data on total counts from the bathing beach and control area during the period of study

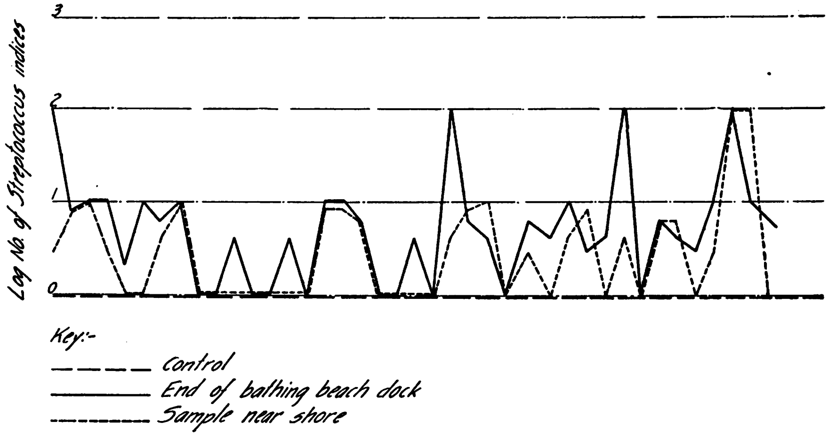


from a circumscribed indoor or outdoor bathing pool. This is particularly true of the type of beach used in this study. This beach, due to the muck areas that bound it, is very closely demarcated. Very few bathers venture beyond the 200 ft. limit due to the weeds and muck that begin there. These natural barriers delimit the beach as effectively as a wall. As Mallmann and Cary [7] found that in a sterile chlorinated pool the bacterial counts rose rapidly after the introduction of heavy loads, it is quite conceivable that changes of water on the beach are so slow that during periods of heavy loads this factor can be ignored as a means of purification. That this is true is borne out by the data which show that the streptococcus indices rise with the bathing load and disappear gradually after discontinuance of bathing. It would seem logical to treat such beaches in a manner similar to unchlorinated indoor pools. That the bathing loads should be limited accordingly seems obvious. If the pollution introduced into an artificial pool by the bathers is to be considered dangerous, it seems highly illogical that the same pollution on a bathing beach should be ignored. Why insist on drinking water standards for an artificial pool and have extremely liberal or no standards for the natural beach?

It is true that the number of *Escherichia coli* in the swimming pool and in the waters of natural beaches are not comparable; however, the data in this paper, and in earlier ones by the senior author, have demonstrated that the streptococci do measure the pollution introduced by the bather. Although no standards for streptococcus incidence are offered, it is possible to devise a standard for this organism that can be applied equally well to either artificial or natural bathing places. To arrive at a standard it will be necessary to collect a large volume of data by workers in various parts of the country under various conditions. It is hoped by the writers that the committee on swimming pools and bathing places will undertake such a project.

That the *Esch. coli* test, which serves as the best index of the sanitary

GRAPH VI—Comparative data on the streptococcus indices from the bathing beach and the control area during the period of study



purity of a water supply, is not necessarily infallible as an indicator of unsanitary conditions is again emphasized by the writers. The senior author has demonstrated that *Esch. coli* is not the best indicator of swimming pool pollution, and again in this paper it has been demonstrated that this organism does not measure the pollution introduced by the bather in sewage-free bathing beaches. It must be remembered that in a water containing large amounts of organic matter *Esch. coli* grows abundantly even in the absence of sewage or bathing pollution and thus ceases to be an indicator of pollution. The same holds true of the 37° C. total count.

SUMMARY

The most representative samples of the bathing beach water were obtained in 5 ft. of water as compared to samples taken near the shore. This was particularly true of the streptococcus indices.

The colon indices and the 37° C. total count did not always respond to changes in bathing loads. These indices obtained on the bathing beach were not markedly different from indices obtained at points free from pollution at the same time.

The streptococcus index fluctuated with the bathing load. Streptococci were not found at points free from bathing pollution.

The streptococci disappeared over night. The colon and total counts indices sometimes showed an increase over night, although they were generally lower.

Catch samples in no instance should be used as a measurement of the sanitary condition of a bathing beach.

The need of controlled bathing loads on limited inland lake beaches appears essential. Conditions on the limited bathing beach presented were similar to those obtained in indoor and outdoor swimming pools.

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