Coliform Bacteria and Streptococci in Swimming Pool Water*

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CALVERT,[1] in a brief review of the streptococcus test for water pollution, concludes: "There remains much work to do in respect to method of procedure as well as evaluation of results."

Recently the writers have had the opportunity to compare the streptococcus test with the coliform test in a college swimming pool. It is the object of this paper to report the results of that study.

The streptococcus test as first applied to water pollution was designed to show the presence of fecal streptococci. This is particularly true of the test as used in England. The test has not been recommended in this country as a standard procedure. The coliform test is accepted as a more accurate measure of intestinal pollution. When the streptococcus test was first applied to bathing places many investigators assumed that the organisms found were of intestinal origin. Some technicians and sanitarians still assume that. However, the studies made by Mallmann [2-7] certainly would seem to indicate that this is not true. In one of his studies, Mallmann [6] found that the streptococcus index in bathing places fluctuated with the bathing load, while this was not always true in the case of the coliform index. Mallmann felt then that the streptococcus index was a better measure of the pollution introduced by the bathers than the coliform index.

Calvert,[1] commenting on Mallmann's results showing that the coliform index in a chlorinated pool may be acceptable and yet streptococci be present, adds parenthetically: "This is at variance with a small amount of unpublished experimental work done on a chlorinated public supply where no streptococci were isolated from 50 ml. portions of water after passing the final point of chlorination."

The results given below will show that in the pool under test it was the exception rather than the rule to find coliform bacteria present, whereas streptococci were always present when bathers were in the pool.

METHODS

The pool used in this survey is of the recirculating type with a capacity of 110,000 gallons. Liquid chlorine is used as the germicidal agent, and the residual chlorine is kept at between 0.3 and 0.6 p.p.m. when the pool is in use. The manager of the pool holds a college degree in engineering so that the pool receives better than average care. Each bather is required to take a thorough bath, using plenty of soap, before entering the pool. At no time during this study was the pool overloaded with bathers.

The methods of procedure for demonstrating the presence of coliform

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bacteria and streptococci were those recommended in *Standard Methods of Water Analysis* (8th ed., 1936).

Samples were collected on at least 3 days of each week during the period of survey. The samples were collected according to the following daily schedule:

Sampling Period No.	*Time*	*Condition of Pool*
1	9:45 A.M.	Pool closed since 6:00 P.M. of previous evening.
2	10:20 A.M.	Pool open since 10:00 A.M.
3	11:30 A.M.	Pool in use since 10:00 A.M.
4	1:45 P.M.	Pool closed since 11:45 A.M.
5	2:20 P.M.	Pool open since 2:00 P.M.
6	3:30 P.M.	Pool open since 2:00 P.M.

Throughout the remainder of this report sampling periods will be referred to by the numbers given in the above schedule. Duplicate, and sometimes triplicate, samples were collected at each sampling period. One was taken from the deep end, one from the shallow end, and when a third sample was collected it was taken from the side and opposite the approximate center of the pool. Determinations for residual chlorine were made daily at each sampling period. At least once each day pH determinations were made. All sampling bottles contained sodium thiosulphate, and the elapsed time between the collection of the sample and its inoculation into the presumptive medium never exceeded 20 minutes. Five tubes of presumptive medium were inoculated with each sample of water.

RESULTS

Table 1 summarizes the results obtained in this study. In the case of the duplicate and triplicate samples, taken at each daily sampling period, the results were averaged and these figures considered as representing one sample. There are several interesting observations to be made from this table. The coliform bacteria were conspicuous by their absence, since positive presumptive tests were obtained from only three samples. Out of a total of 100 10 cc. inoculations (225 if the duplicate samples were considered separately), only 12 tubes were confirmed for the presence of coliform bacteria. On each occasion this occurred when the bathing load was heaviest, that is, the No. 6 sampling period.

Table 2 gives the results of a specific day when coliform organisms appeared. The bathing load was heavier than the average. In this table the duplicate samples have been considered separately, so that 10 tubes were inoculated from each portion of water. On this day, 3 of the 10 cc. portions showed the presence of coliform bacteria. In this case, as in the other 2 cases where coliform organisms appeared, they were present in only 1 of the 2 samples collected from the pool at that particular sampling period. At no time during this survey did these bacteria appear in

TABLE 1

Summary of Results

Sampling Period Number	*Total Number of Samples*	*Average Chlorine Residual p.p.m.*	*Average Number of Bathers*	*Total Number of Positive Lactose Broth Tubes*							
				Coliform Group				*Streptococci*			
				10 cc.	*1 cc.*	*0.1 cc.*	*0.01 cc.*	*10 cc.*	*1 cc.*	*0.1 cc.*	*0.01 cc.*
1	20	0.2	0	0	0	0	0	0	0	0	0
2	20	0.35	6	0	0	0	0	80	10	0	0
3	20	0.46	12	0	0	0	0	100	70	15	0
4	20	0.48	0	0	0	0	0	12	0	0	0
5	20	0.50	15	0	0	0	0	100	85	30	7
6	20	0.43	23	12	0	0	0	100	97	75	33

TABLE 2

Results Obtained on a Day When the Bathing Load Was Heavy

Sampling Period Number	Number of Bathers	Residual Chlorine p.p.m.	Number of Tubes Positive							
			Coliform Group				Streptococci			
			10 cc.	1 cc.	0.1 cc.	0.01 cc.	10 cc.	1 cc.	0.1 cc.	0.01 cc.
1	0	0.2	0	0	0	0	0	0	0	0
2	8	0.3	0	0	0	0	9	5	0	0
3	15	0.5	0	0	0	0	10	6	1	0
4	0	0.5	0	0	0	0	3	0	0	0
5	17	0.5	0	0	0	0	10	7	1	0
6	35	0.4	3	0	0	0	10	10	6	3

less than 10 cc. portions of the water. According to the standards of Mallmann [7] the coliform index of this pool would have been acceptable and the pool classified as satisfactory.

Returning to Table 1 it will be observed that streptococci were always present in the water when bathers were using the pool. At the periods of the heaviest loads the organisms were found present in as little as 0.01 cc. of water. A small number of tests made, but not included in the tables, showed that when more than 50 bathers were using the pool streptococci could be found in 0.001 cc. of the water. These results confirm Mallmann's opinion [6] that the streptococcus index closely follows the bathing load.

According to Mallmann's standards [7] for streptococci, this pool would have been classified as unsatisfactory. Thus, we have the pool being classified as satisfactory by its coliform index and unsatisfactory by its streptococcus index. Which of these indices are we to accept?

To the writers the most interesting observations to be made from these results are the relatively high streptococcus index in proportion to the small numbers of bathers, and the rapidity with which these organisms appear after bathers have entered the pool. Table 3 shows the results obtained on a day when the bathing load was much lighter than the average. It will be noted that samples collected at the No. 2 sampling period showed the presence of streptococci in 7 of the 10 cc. portions and 1 of the 1 cc. portions. Yet there were only 5 bathers using the pool at the time, and the residual chlorine was 0.3 p.p.m. Also, these bathers were the first to enter the pool after it had stood overnight, and no streptococci had been found in 5 50 cc. portions of the water taken just before the opening of the pool. This seems a rather high streptococcus index in proportion to the number of bathers. It further indicates that these organisms must have come from a heavily contaminated source. Inasmuch as the streptococci were not present in large quantities of the water after the pool had stood overnight, we must eliminate the possibility of poor filtration or of chlorine-resistant strains. Since the appearance of the organisms follows so closely the entrance of the bathers into the pool it seems fair to assume that the bathers were introducing the bacteria. The samples of the No. 2 sampling period were taken within 10 to 15 minutes after the bathers had entered the pool. On some days as few as 3 bathers were in the pool when these samples were collected. Yet it was possible to find streptococci in 1 or more of the 10 cc. quantities examined. As to the streptococci being from intestinal sources, that can be eliminated because it would not be possible to have so many fecal streptococci present without finding some coliform bacteria. The writers are making a pure culture study of these organisms, and the results obtained at this writing indicate that they are not fecal streptococci.

TABLE 3

Results Obtained on a Day When the Bathing Load Was Light

Sampling Period Number	Number of Bathers	Residual Chlorine p.p.m.	Number of Tubes Positive: Coliform Group 10 cc.	Coliform Group 1 cc.	Coliform Group 0.1 cc.	Coliform Group 0.01 cc.	Streptococci 10 cc.	Streptococci 1 cc.	Streptococci 0.1 cc.	Streptococci 0.01 cc.
1	0	0.2	0	0	0	0	0	0	0	0
2	5	0.3	0	0	0	0	7	1	0	0
3	8	0.5	0	0	0	0	9	4	0	0
4	0	0.6	0	0	0	0	2	0	0	0
5	10	0.55	0	0	0	0	10	6	1	0
6	18	0.5	0	0	0	0	10	9	3	0

Mallmann [8] in a personal communication states: "These organisms are not *Streptococcus fecalis* as they emanate from the mouth rather than from the intestine. We have carried on a series of experiments which have not been published as yet, definitely proving the source of these organisms." It is common knowledge that there occurs considerable flushing out of the nasal cavities and the mouth in swimming and diving. Also, many bathers add to this by gargling and expectorating.

In experiments now being conducted by the writers there is evidence to indicate that these organisms are also found on the body surface of the bathers before they enter the pool. This evidence will be published at a later date.

If these organisms are of oral origin then they must be given some sanitary consideration. If they are body surface saprophytes then it does not seem that they are of much sanitary significance.

From the results of this study it was found that these organisms are quite resistant to chlorine. Mallmann [4] has found that the streptococci in swimming pools are more resistant to chlorine than are the coliform bacteria. An attempt was made during the course of this survey to reduce the numbers of streptococci to a minimum, if not to eliminate them. When the residual chlorine content was raised to 0.6 p.p.m. their numbers were not materially decreased. When the residual chlorine was raised to 0.7 p.p.m. there was a noticeable reduction in their numbers, but there was also a noticeable reduction in the number of bathers. Numerous complaints were received of mucous membrane irritation, so that it was impossible to carry the experiment further at that time.

The writers expect in the course of experiments now under way to confirm the results of Mallmann that the source of these streptococci is the mouths of the bathers. It is possible that the organisms come from both the oral cavity and the body surface. Certain results obtained to date in a pure culture study of these streptococci indicate that they may not be true streptococci but micrococci which assume chain formation under certain biochemical conditions.

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