Water Quality of Swimming Places

—*A Review*—

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NEARLY FIVE YEARS have elapsed since the Joint Committee on Bathing Places of the Conference of State Sanitary Engineers and the American Public Health Association set forth its Recommended Practice for Design, Equipment, and Operation of Swimming Pools and Other Public Bathing Places. As a result of research, investigations, and experience since that time, articles have appeared in the literature which confirm, disagree with, or suggest modification of these recommendations. A review of these will be useful at this time.

Disease Transmission

No discussion of bathing water quality would be complete without reference to the extent and prevalence of disease transmitted by such waters. Although authorities agree that there is insufficient scientific evidence to prove a direct relationship between bathing water quality and illness among bathers, evidence suggests that such a relationship does exist (*1*).

Eye, ear, and nasal infections are common complaints of swimmers, with pinkeye, conjunctivitis, otitis media, colds, and sinus infections of particular concern. Other complaints include gonococcus infection of the eyes, schistosome dermatitis, sometimes called swimmer's itch, and gastrointestinal diseases. Schistosome dermatitis is not national in scope; it seems to be endemic in the upper midwest and is acquired only in natural bodies of water, which provide breeding places for the snails involved in the life cycle of the disease-producing organism.

Bathing waters have been suspected of transmitting poliomyelitis, although there is no proof of this. However, for elimination of all suspicion that bathing water plays any part in the spread of poliomyelitis or any other diseases, certain standards of safe water quality should be maintained.

Joint Committee Recommendations

Some of the recommendations for water quality set forth by the joint committee (*2*) are summarized below:

A. Chemical and physical quality (swimming pools).

1. Residual chlorine following disinfection: Free available chlorine, 0.4 to 0.6 p.p.m; or combined available chlorine (chloramine), 0.7 to 1.0 p.p.m.

2. Acidity–alkalinity: The pH of the pool should never be less than 7.0.

B. Bacterial quality (swimming pools).

1. Bacteria count on standard nutrient agar, 24 hours, 37° C., and confirmed test: Not more than 15 percent of the samples covering any

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considerable period of time shall contain more than 200 bacteria per milliliter, nor show positive test in any of five 10-ml. portions of water at the time the pool is in use.

2. The standard methods for the examination of water and sewage should be used in making chemical and bacteriological analyses.

3. The presence of streptococci in bathing waters is very undesirable, but their elimination with present-day recommended practices is considered impracticable.

C. Bacteriological standards for outdoor bathing places.

The committee emphasizes that final classification of water in natural bathing places should depend largely upon sanitary survey information. Findings from bacteriological analyses should be used only as a guide. The committee considers it neither practicable nor desirable to recommend any absolute standard of safety for the water based merely on bacterial or chemical analysis or on sanitary surveys. However, it did conclude that waters which show a concentration of most probable numbers of coliform organisms of less than 1,000 per 100 ml. are generally considered fairly acceptable for bathing, unless the sanitary survey should disclose immediate dangers from human sewage.

Coliform Density as an Index

Some other guides to permissible coliform densities in natural bathing waters are indicated in standards which have been adopted by official bodies of the areas shown in the table.

The Tennessee Valley Authority considers the numerical groupings it uses in appraising natural bathing water quality to be helpful as collateral criteria, but it considers such groupings to be of questionable value in the absence of sanitary surveys. The TVA does not subscribe to standards for swimming areas based on bacteriological data to the exclusion of sanitary survey data.

Thus, TVA suggests interpretation of the 0–50 coliform density as indicating a preferred classification not generally attainable, but recommends that, if such waters are found in the absence of an adverse sanitary survey, they may be selected for bathing areas without question.

The second density group of 51–500 is interpreted by TVA as a state of contamination presumably normal for inland streams free of sewage pollution, but which are subject to surface wash. It recommends that bathing be permitted in such areas in the absence of convincing adverse sanitary surveys.

The density group of 501–1,000 is viewed by TVA as indicating a water of suspicious quality which should be considered dangerous for bathing purposes in proximity to fresh sewage pollution, but which might be considered satisfactory if unfavorable conditions are not disclosed by a careful sanitary survey.

The TVA recommendation with respect to waters showing coliform densities above 1,000 per 100 ml. is that such areas should not be selected for swimming until further sanitary survey information discloses the origin of the high densities and that they are not due to fresh sewage contamination.

The question continues to arise as to why there should be so wide a variance between water quality standards for artificial pools and those for natural bathing areas. This is generally explained (*3*) by recognition of the difference in significance given to the presence of coliform organisms in natural waters and those in artificial pools. The source of water used in swimming pools is relatively free of coliform organisms in most instances. Therefore, the presence of these organisms in these pools must be regarded, usually, as of recent human origin. On the other hand, coliform organisms in natural waters may be of animal origin or from soil and, thus, of relatively less significance to public health.

The absence or presence of coliforms as an indication of bathing water quality has long been under attack. It has been recognized by early authorities (*4, 5*) that coliform organisms indicate merely the absence or presence of organisms from the intestinal tract. Their significance, therefore, is related primarily to intestinal diseases, which probably play only a minor role in the public health aspects of swimming pools. Gilcreas (*6*), Klassen (*7*), and Stevenson (*8*) have recently reiterated the need for an indicator organism which would reflect more closely the water quality needs of bathers.

Bacterial limits for natural bathing waters as recommended by 4 agencies

Water classification	Coliform density per 100 ml.			
	West Virginia	Great Lakes and Upper Mississippi River Boards	Tennessee Valley Authority [1]	New York State
Satisfactory for bathing	0–1,000	100–500	0–50	0–1,000.
Satisfactory with reservations		501–1,000	51–500	1,000–2,400.
Use doubtful; not recommended		1,001–10,000	501–1,000	50 percent of samples, over 2,400.
Do not use		10,001–100,000	Over 1,000	Evidence of infection from area.

[1] See text discussion of TVA on p. 743.

Studies on bathing water quality carried out by the Robert A. Taft Sanitary Engineering Center, Public Health Service (*8*), have furnished information as to the incidence of illness among bathers, by age, sex, and other groupings. They have demonstrated that higher incidence may be expected in the swimming group than in the nonswimming group, regardless of water quality. Eye, ear, and respiratory ailments have been shown to represent more than half of the overall illness incidence, with gastrointestinal disturbances accounting for up to one-fifth of illnesses among bathers, and skin irritations and other illnesses, the remainder.

Two instances of statistically significant correlation between illness incidence and bathing water quality were noted. Data were presented indicating that where the coliform count was high, gastrointestinal disturbances tended to increase. However, the author suggests that these results be used with caution, and concludes, also, that the observed results imply that some of the most rigid requirements for natural bathing waters could be relaxed without detrimental effect on the health of the bathers.

Following a bacteriological study of swimming pool waters from 13 pools, Albright and Rich (*9*) concluded that a check for hemolytic organisms in the water would be more important than one for coliform organisms. Lackey (*10*) has suggested that, since skin diseases, together with eye and ear troubles, are common complaints among swimmers, it might be worth while to develop a technique for field surveys to determine the causative organisms of such illnesses. He suggests, further, that any future bathing water surveys might well divide coincident illnesses into two categories: the enteric and the three groups of bacteria associated therewith, namely, coliforms, enterococci, and salmonella, could be one, and the other category might be eye, ear, nose, throat, and skin ailments and the organisms, including fungi, associated with them.

Disinfection Agents and Procedures

In 1948, Klassen and Sieg (*11*) described what they considered the ideal disinfecting agent for swimming pool waters. Klassen and Sieg's standards are:

1. Effective, residual, bactericidal action is obtained in the shortest possible time.
2. Effective, residual, bactericidal action is maintained throughout the body of water in the pool and its recirculation system.
3. Application equipment is simple, adequate, foolproof, and trouble free.
4. Dosage control is simple and accurate.
5. Agent and equipment are inexpensive.
6. Agent (after addition to pool water) is nontoxic and nonirritating to swimmers' eyes, skin, and mucous membranes.
7. Agent remains stable and effective through a wide range of varying conditions, such as pH, temperature, turbidity, organic matter, and mineral content.
8. Agent is colorless, odorless, tasteless, noncorrosive and has no adverse effect on materials likely to be immersed in the water.
9. Agent is compatible with chemicals commonly used in water treatment.

10. Complete and dependable research and experience have demonstrated that the agent has the above qualities.

Chlorine is generally considered to conform most nearly to these desired qualities. It is also the only disinfectant which has been approved by all State health departments for use in treating bathing waters. Bromine, another halogen which is somewhat like chlorine, has been approved recently by some States and might be considered to meet many of the requirements set forth above. Hendrickson (*12*) notes that bromine has been approved for use in New York, Wisconsin, Florida, and Illinois. Klassen estimates that approximately 10 percent of the Illinois pools are now using bromine. *Chemical Week* (*13*) reports that 1,000 pools in southern California are using bromine as the disinfectant of choice. Since California was not identified as having approved the use of bromine in public pools, it is assumed that this wide usage is confined to private pools.

Reports on bacteriological studies have indicated bromine to be about equal to chlorine for disinfection of waters which are fairly low in organic matter. One such study by Vandervelde, Mallmann, and Moore (*14*) presented the following conclusions:

1. Nearly the same bacteriological results were obtained from a residual of 0.5 p.p.m. of either bromine or chlorine.

2. Routine operation shows that about twice as much bromine, by weight, is needed to carry a residual of 0.5 p.p.m. than is required with chlorine.

3. Coli indexes are usually zero at normal residuals of bromine or chlorine.

4. Satisfactory equipment can be developed for applying bromine to swimming pools.

5. Irritation of the eyes does not result from either bromine or chlorine when used in normal concentrations.

There has been some discussion as to the efficacy of "high-free" chlorine residuals (equal to or greater than 1 p.p.m.) over what might be termed the normal, recommended free residual chlorine (0.4 to 0.6 p.p.m.). Mood and Robinton (*15*) and Mood (*16*) reported on a preliminary study of the bactericidal efficiency of high-free residual chlorine in swimming pool water concluding that:

1. High-free residual chlorination of swimming pool water produces bacteriological results within the maximum limit recommended by the joint committee report for the number of bacteria per milliliter.

2. High-free residual chlorination is effective in maintaining a low bacteria count in both indoor and outdoor swimming pools.

3. High-free residual chlorination is superior to marginal chlorination for bactericidal treatment of swimming pool water.

4. The minimum value of 0.7 p.p.m. which has been suggested by the joint committee for a chloramine residual in swimming pools was insufficient to produce results, under conditions of the study, which met the bacteriological standards of the joint committee.

5. Several common types of bacteria are capable of surviving high-free residual chlorine, in small numbers, for at least a limited time. Streptococcal bacteria in swimming pools are more resistant to chlorine than are coliform bacteria.

6. High-free residual chlorination is capable of keeping swimming pool water free of coliform bacteria while occupied by bathers.

Other observations of these disinfectants, reported by Mood (*17*), have to do with the sometimes irritating effects of chlorine. He states that high-free residual chlorination of swimming pool water reduces the amount of irritation to the eyes of swimmers, as compared with marginal chlorination. He found that optimum conditions of the swimming pool, insofar as minimal irritation to the eyes of swimmers is concerned, are found in waters with a pH of 8.0 to 8.9 and a residual chlorine level of 1.0 to 3.99 p.p.m., with the principal portion of the fraction as free residual chlorine. He cautions, however, that high-free chlorination cannot be applied to every pool. He believes this type of treatment to be most suitable for waters that are recirculated and filtered 24 hours a day.

Burgess, Burns, and Tidy (*18*) investigated methods of improving the quality of water in less modern pools, which may have been designed without regard to presently accepted principles of swimming pool construction. Among other things, they studied the reason for the loss of chlorine residual, the relationship between bacteriological conditions and chlorine residuals, various means of increasing chlorine input and, thus, chlorine residuals and the significance of albuminoid nitrogen in relation to clarity and bacterial purity.

Sunlight was considered the factor causing the greatest loss of free chlorine in an outdoor pool. Original water quality and bather loads were also significant. Data are presented showing that the disappearance of free chlorine quickly results in an increase of the agar count, followed by the presence of viable coliform organisms. Alteration of the position of the chlorine application was found effective in increasing chlorine input with existing equipment. Changing the point of chlorine application from the filter outlet, where the pressure is in the region of 5 to 10 pounds per square inch, to the suction side of the circulating pump, where the pressure difference increases, permits a greater input. The interpretation given to the data on albuminoid nitrogen indicates that it is possible to have a practically sterile water containing a high albuminoid content. However, when such a water is so polluted, the time taken to kill any bacteria which may be introduced will be increased according to the amount and type of organic pollution present.

Except for chlorine and bromine, no disinfectants for swimming pool waters have been introduced that approach the desired qualities recommended by Klassen and Sieg. At various times, ozone, ultraviolet light, chlorine dioxide, quaternary ammonium compounds, and silver have been suggested. All of these are effective in their bactericidal action but present practical difficulties in maintaining or determining an effective residual, and it is doubtful that they can compete with chlorine on an economic basis.

Swimming Pool Filters

One other relatively new item concerned with swimming pools is germane to the subject of water quality. This concerns the use of diatomite filters. A very recent article on the principles and operation of this type of filter, as compared with other filters, appeared in *Waterworks Engineering* (*19*). Perkins (*20*) made a comparison of different types of filters for swimming pools and concluded that, for efficiency and economy of operation, the vacuum-type septum filter is as good as any filter available. Although diatomaceous earth is usually foremost in mind when referring to septum filters, recently other types of media have been tried for filter purposes (*20*).

Some of the advantages of using diatomite filters may be listed as follows:

1. If the filters are not overloaded, coagulants are not needed.
2. Filtration rates may be varied as much as 100 percent or more without reducing the clarity of the effluent.
3. Efficiency of filtration is not reduced by excessive head losses.
4. Diatomite filters are compact units, serving to advantage where space is at a premium.

The results of 7 years of experience in the District of Columbia in using several types of commercial diatomaceous-earth filter units for filtration of swimming pool waters are discussed by Levin and Cary (*21*). According to the authors, general considerations indicated that filters with which they had experience were liable to corrosion because of galvanic action. It was stressed that minimum use should be made of dissimilar metals in the manufacture of the filter. The other important observation revealed that inadequate backwashing was evident. It was reported that experimental tests conducted by the Army indicate that air-bump backwashing and use of mechanical air compressors may clean the filter units satisfactorily, if instantaneous rates of 100 to 200 times maximum filter rates are used. The authors recommend that units without special backwash facilities be disassembled and cleaned manually at least once each year.

The present status with regard to the use of diatomaceous-earth filters was summed up by Kiker (*22*) at the Sixth Florida Public Health Engineering Conference. He stated that these installations are likely to increase in number in the future as they have in the recent past. Their initial cost is less than that of pressure sand filters, and they require much less space. They can produce an effluent at least as good as that from sand filters. The cost of operating septum filters is comparable to the cost of operating pressure sand filters. But, as compared to pressure filters, they are still in a relatively early stage of development. Under the circumstances, Kiker believes that rapid sand gravity or pressure filters are still to be preferred for most permanent filtration installations where adequate space is available. Kiker indicates his comparative evaluation is subject to change with further improvements in septum filters and with increasing operational experience.

Summary

Since the report of the joint committee (*2*), much has been written on the interpretation of bathing water quality and its relation to public health. Research, investigations, and experiences have been reported that indicate a need to refine old procedures or substitute new ones, in order to provide a safe quality of bathing water.

It is evident also that no mutually acceptable opinion exists on what constitutes minimum bacteriological standards for natural bathing areas. There is general agreement, however, that the results of bacteriological and chemical analyses and sanitary surveys should be considered in judging the acceptability of any particular area for bathing purposes. Application of bacterial guides to natural bathing areas must depend upon such factors as availability of other, more suitable places. This will vary according to geographic area.

As yet, no substitute for the coliform group, as an indicator of pollution in bathing water, has received general approval. The consensus still indicates that one is needed.

It appears that chlorine and bromine remain the disinfectants of choice. Other suggested agents, though effective in their bactericidal action, do not come as close as chlorine and bromine toward meeting the requirements of the "ideal" disinfectant.

Though diatomite filters are gaining in popularity, there are those who feel that these filters still need to pass the test of time before they can be given full acceptance on a par with other proved types of swimming pool filters.

The public and public health officials are rightfully concerned about the hazards of bathing in contaminated waters; however, present epidemiological evidence does not offer a clearcut picture of the actual danger of disease transmission through bathing waters. Nevertheless, there is sufficient correlation of data between bathing water quality and swimmers' complaints to warrant continued regulation and supervision by health authorities pending further accumulation of knowledge through additional research and experience.

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