Microbiology Standards for Waters

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ABSTRACT

This is a discussion of the kinds of microbial standards that apply to various kinds of water and the circumstances under which the standards might be used. Standards are universal language. Appropriate standards depend upon proper personnel, materials and procedures to be effective. Comments are made on some possible situations where the concept of standards may restrain good scientific and technical development. Historically, there is circumstantial evidence enforcement of microbial standards has aided our great advances in water hygiene.

In first looking at the title of the paper to be presented for this Seminar, my reaction was that an enumeration and justification of the various numerical standards that are used in water quality bacterial monitoring was the appropriate and obvious approach. A short period of meditation made it very apparent that it would be dull and fruitless to attempt to document the many numerical standards that are prescribed or adhered to for the many types of waters, the several bacterial tests possible and, above all, the multiplicity of standards established by the nations around the world and the States and political subdivisions within the United States.

Among the waters that need monitoring controls are: sewage and industrial wastewaters; raw, recycled and finished water for potable use; recreational water in streams, lakes, ocean beaches, swimming pools, baths, etc.; water for medical uses as infusion solutions and dialysis systems; agricultural water, especially irrigation supplies and return flows; water for food processing, preparation and manufacturing; fish and shellfish rearing waters; and special industrial uses where there are needs to control organisms that produce slimes or change the forms of such elements as iron and sulfur to detrimental end products.

STANDARDS FOR SPECIALIZED USE OF WATER

For each of these specialized uses, standards for viable bacteria and bacterial products exist or should exist, well beyond the obvious coliform standard that many people feel is the only tool of the water control microbiologist. While coliform standards have been and will continue to be used as a measure of quality of several kinds of waters, we must also look to many other bacterial measures of quality. A few selected examples of number standards that have or could have important applications are the following: (a) fecal coliforms in wastewater discharges, bathing waters and farm animal runoff; (b) the fecal streptococci, often recommended as an adjunct to coliform or fecal coliform testing; (c) total or standard plate counts, a misnamed, underused, misused and abused bacteriological tool that provides a great deal of information when used properly in controlling water plant operations, wastewater and swimming pool disinfection efficiency, food processing waters, and industrial water applications; (d) modified plate count tests, done at selected temperatures for psychrotrophs, thermophiles and other organisms with optima outside of the 32-35 C range; or at various pH values above and below the usual 7.0; or at oxygen tensions lower than ambient; or in selected substrates to indicate specific enzyme activities such as gelatin degradation, lipid utilization, DNA-ase production, etc.; or modifying the incubation time to enlarge the array of organisms that will grow; (e) determination of bacterial spore counts for food industries such as sugar manufacture, canning and bottling; (f) the Clostridium perfringens counts, not commonly used in this country, but fairly well accepted as a drinking water test in Europe; and (g) enumeration of levels of Pseudomonas, Aeromonas and Flavobacterium which are of interest in controlling fish-rearing water, in medical applications of water, especially the pyrogens of Pseudomonas, and in swimming waters.

Some additional standards are often discussed as needed and are in various stages of development. These include tests for detection of animal viruses of public health significance and bacteriophages in the fermentation and food industries; direct detection of pathogenic bacteria in waters; enumeration of staphylococci and micrococci which may be significant in swimming water and in manufacture of such foods as beer; detection of bacterial endotoxin in drinking water and standards for
parasites such as *Giardia*, which is of current concern in drinking water.

While enumeration of the several kinds of standard tests in the many uses of water has hopefully introduced the breadth of the problem that this symposium might cover, further comments on standards will be limited to the areas of greatest current concern, drinking water and water pollution control from a public health standpoint.

**STANDARDS FOR WATER — PUBLIC HEALTH VIEW**

Bacterial standards for water, initially drinking water and later wastewater discharges, evolved in the late 19th century at the community level. Cities assumed primary responsibility for imposing bacterial testing, in its early crude forms, and developing allowable limits of viable organisms. Soon the States assumed an important role in establishing standards for bacteria and in developing the appropriate laboratory methods. The professional societies, the universities and the Public Health Service of the U.S. Government each made important contributions.

For the past few years we have been moving to a new governmental philosophy. From the era of somewhat uneven provision of health protection services for the people of the country, we are now attempting to provide near-zero risk to all people in the hazards from wastewater and drinking water. The Federal Government is establishing standards for bacteria, as well as several other parameters, in these waters as minimal standards to be enforced by each of the States. Establishing higher standards in any particular situation is the prerogative of the States. Some, because of their geography, industry, or local needs are establishing or adopting stricter bacterial standards than mandated nationally. Examples of this are the enforcement of fecal coliform standards for municipal wastewater effluents, stricter fecal coliform or standard plate count standards than required by EPA for land disposal of wastewater, or self-imposition of more stringent standards than required at a metropolitan drinking water utility.

There may be special needs, at the state or local level, to protect an estuary or beaches, to maintain a sports fishery or a body contact recreational lake or reservoir. Standard quality must be viewed then as the minimal requirement that is deemed essential to reduce the risk of detrimental effects to a prescribed level. It should allow for and encourage imposition of more demanding standards in terms of allowable numbers of organisms, organisms to be tested for or number or frequency of tests run.

**ADEQUACY OF TESTING**

In discussing standards for bacterial testing we normally think of the kind and frequency of tests to be done or the allowable limits of the results. It is easy to overlook the fact that the test results are no better than the quality of the sample, the sampler, the laboratory and its materials and equipment and, obviously, of the person running the tests. Very important aspects of microbiological standards for waters are the training of personnel, quality control of laboratory methods and materials, standardization of equipment and collection and transport of samples. In all too many water or sewage system operations, personnel doing the sampling or operating the laboratory are in the lowest pay categories with additional duties in the community. Adequate funding for the large hardware in the system is made available, but chipped pipettes, faulty pH meters, water baths and incubators that do not hold temperature, autoclaves that are undersized or do not sterilize and many, many other items not meeting standards are in use. Laboratories are often inaccessible to small communities and samples are agitated in the mail or other delivery systems for days or incubated without cooling in the trunk of a car. It is important that standards be applied to all water laboratories, be they publicly or privately operated, large or small. Recently a committee of the American Water Works Association under the chairmanship of W. Ginsburg (4) attempted to gain some insight into laboratory operations by a questionnaire. The results indicated a rather deplorable situation. Geldreich, who visits many of the laboratories in his assignment to initiate a required program in laboratory certification, an objective almost synonymous with standardization, has often related some of the non-standard items he has observed. In 1975 Geldreich (3) authored a second edition of an EPA *Handbook for Evaluating Water Bacteriological Laboratories* that attempted to establish a standard basis for laboratory evaluation. In looking at the glossary I found that the definition for standard to read:

"A measurement limit set by authority. Having qualities or attributes required by law and defined by minimum or maximum limits of acceptability in terms of established criteria or measurable indices."

This definition is probably a good legal one; however, my dictionary provides a number of other definitions which, I believe, justify my broader use of the term to cover the many facets that go into making the microbiological standards meaningful.

It should be added that there also are some excellent laboratories in many parts of the country that have imposed appropriate standards on their work. Several years ago some major strides were taken in improving the quality of laboratory chemicals and dye materials. If the proper grade is purchased and handled properly they do provide consistency among laboratories. More recently, with some reluctance, the manufacturers of media have made strides in standardizing their products. Competition and a broadened market have been conducive to availability of better quality laboratory equipment for water microbiology. Maintenance and repair is still a major problem. Progress has been made in another area, improvement in filter membranes.
STANDARDS AND QUALITY

One important aspect of microbial standards for water is that they provide a common base or language for relating numbers of organisms to the level of quality that is desired. This standardized numerical language is important to the legal people who are responsible for enforcement of water quality compliance regulations. They often treat (or mistreat) these numbers as though they were cast in bronze, probably one of the occupational hazards of their profession. Since we as microbiologists, in cooperation with scientists of the related technical disciplines in water quality, must supply the criteria upon which standards are set, it is important that we provide the best of advice. Providing information for standard setting by best guess, by consensus or with overly conservative safety margins is not good science nor will these standards hold up in the courts. The costs currently involved in water monitoring are high and there is always someone willing to challenge the requirements in the courts.

Abel Wolman, a great contributor to water hygiene, has written some cogent and provocative papers on the subject of standards. A few comments are worth repeating because they remind us that establishing microbial standards must not be our ultimate goal, nor by themselves will they lead to clean water.

The first quote is from a 1960 paper entitled "Concepts of Policy in the Formulation of So-Called Standards of Health and Safety" (9a). Although it was written on the subject of radiation standards, it could just as well have been microbial standards.

"From its beginning, society by one means or another, has surrounded itself with restraints. These have had, for the most part, empirical origins — moral, ethical, economic, or spiritual. All the restraints have had the common basis of an assumed benefit to the particular society establishing them. As societies became more complex and more sophisticated, efforts towards both standardization and restraint became more frequent, more necessary, and presumably less empirical, although examples of the last are not as numerous as one might expect.

There are all kinds of standards. Rigid definitions should preclude the loose application of the term 'standards' in discussions of standards for radiation control. The procedures often used to establish standards may roughly be classified as:
1. Regularization of techniques of measurement
2. Establishment of limits of concentration or density of biologic life and physical and chemical constituents
3. Regularization of administrative practice
4. Regularization of legislative fiat
5. Specification of materials."

Some interesting statements from a paper entitled, "Bacterial Standards for Natural Waters" (9) follow:

"....Standardization for all features of natural waters has become one of the major sanitary engineering indoor sports.

Historically, ample support may be summoned for the thesis that standards of judgement are dangerous, fallacious, and inappropriate to scientific workers. These warnings range all the way from the sharp but cogent comment of the late Professor Sedgwick, in describing standards of sanitation as 'devices to save lazy minds the trouble of thinking', to equally significant but more refined warnings by Phelps...."

"Reasons for growth of stream standards"

In the intervening decade, however, the search for and the introduction into law and regulation of stream criteria has proceeded at a fast pace. Part of the process has been engendered by the literal intimidation of many workers in the field by the imaginative demands of certain militant organizations. In other instances, the appeal of the convenient handbook has been overwhelming. In still others, the subtle attractiveness of 'zoning' has given the necessary fillip to this standardization technique. In this pursuit toward the quantitative millennium for qualitative matters of judgement of a number of underlying philosophies have found their full play. At the one end of the spectrum are the criteria established to preserve original quality and concomitantly, therefore, to avoid original sin. In this particular philosophy the studied and judicial comment of the late Professor Whipple that a regulatory edict, both in law and in philosophy, should establish the minimum for safety rather than the maximum of hope, is ignored. The reemphasis on this dictum was equally cogently and intelligently set forth by Frost and others, in sharpening the distinction between standard methods and so-called standards of judgement."

"Standards vs. judgement"

What can one say about criteria of stream quality, solely from the standpoint of bacterial content, when one state alone offers five ways of avoiding original sin, depending on the economic status of the bather? And what can one say, furthermore, of the state of affairs in which, as was pointed out 10 years ago, one state insists that it is unsafe to swim in a body of fresh water which exceeds 5 coli per 100 ml and an adjacent state insists with equal fervor that equal safety is afforded to the swimmer by a bacterial density of 500 times that amount? What can be said about the regulatory agency's desire when it established a standard of bacterial density that virtually rules out 99.9% of the available surface streams within its territorial limits, provided, of course, it rains on occasions and the agricultural terrain is in part washed into the surface streams?"

These statements and problems sound quite current, but they were presented orally in 1949 and printed a year later.

Our work in helping to set standards must be based on the best possible information available, and where it is not available we must strive to design our data collection and experiments and our search for better methods to answer the questions properly. An example of one of these needs was mentioned earlier, that microbiological standards should bear a direct relationship to risk to human health, to fish life, to aesthetics or similar criteria. We seem to be having difficulty arriving at the answers. We use two methods for coliform testing, the multiple tube MPN test and the newer membrane filter procedures. The tests measure different organisms and yield different kinds of results, one statistical and the other closer to a direct enumeration, and it is very difficult to justify the different standards that may be established on these tests to the lawyer or judge or to the financial officer who must pay for laboratory results.
HISTORICAL ASPECTS

As a student of the history of science, microbiology in particular, I am often concerned that we in our modern, sophisticated, complex scientific community forget some of the sage observations of the recent past. Before publication of the first edition of Standard Methods of Water Analysis (2), a committee of the American Public Health Association was charged with studying means of extending the standard procedures of an earlier 1897 committee, to all methods involved in the analysis of water. This committee’s work culminated in the 1905 edition of Standard Methods (1) and a transmittal letter stating the following:

“The methods of analysis presented in this report as ‘Standard Methods’ are believed to represent the best current practice of American water analysis, and to be generally applicable in connection with the ordinary problems of water purification, sewage disposal and sanitary investigations. Analysts working on widely different problems manifestly cannot use methods which are identical and special problems obviously require the methods best adapted to them; but, while recognizing these facts, it yet remains true that sound progress in analytical work will advance in proportion to the general adoption of methods which are reliable, uniform and adequate.

It is said by some that standard methods within the field of applied science tend to stifle investigations and that they retard true progress. If such standards are used in the proper spirit, this ought not to be so. The Committee strongly desires that every effort shall be continued to improve the techniques of water analysis and especially to compare current methods with those herein recommended, where different, so that the results obtained may be still more accurate and reliable than they are at present.”

This historic move to establish standard laboratory procedures had a direct bearing on the development of microbial standards for waters, a process still evolving.

In the area of drinking water two paragraphs from Prescott et al. (5) are quite appropriate.

“Standards for Potable Water. The information furnished by quantitative bacteriology regarding the antecedents of a water is in the nature of circumstantial evidence and required judicial interpretation. No absolute standards of purity can be established which rigidly separate the good from the bad. In this respect the terms ‘test’ and ‘analysis’ so universally used are in a sense inappropriate. Some scientific problems are so simple that they can be definitely settled by a test. The tensile strength of a given steel bar, for example, is a property which can be determined. In sanitary water examination, however, the factors involved are so complex, and the evidence necessarily so indirect, that the process of reasoning much more resembles a doctor’s diagnosis than an engineering test.

The older experimenters attempted to establish arbitrary standards, by which the sanitary quality of a water could be fixed automatically by the number of germs alone. Thus Miquel (1891) published a table according to which water with less than 10 bacteria per milliliter was ‘excessively pure’, with 10 to 100 bacteria ‘very pure’, with 100 to 1,000 bacteria ‘mediocre’, with 10,000 to 100,000 bacteria ‘impure’, and with over 100,000 bacteria ‘very impure’. Few sanitarians would care to dispute the appropriateness of the designations applied to waters of the last two classes, but many bacteriologists have placed the standard of purity much higher.”

Sternberg (7), in 1892, proposed numerical criteria as follows: (a) up to 100 bacteria/ml is good water, (b) up to 500/ml would be marginal but acceptable and (c) over 1000/ml indicative of sewage contamination. Twenty-two years later the idea of bacteria/ml was adopted as the first United States microbiological standard for drinking water by the Treasury Department (6). It was applicable to interstate common carriers, but was one of the precedents by which the United States Government, through EPA, can now impose a minimal microbiological standard to all of the country.

Microbial standards, by themselves, do not reduce the disease risk from drinking or body contact waters, but they do provide the monitoring goals and objectives that are needed by the engineers and the health officials to perform their proper roles in the maintenance and improvement of water systems of all types. The graphic presentation of the incidence of typhoid in Philadelphia from the 1880’s to 1945 (6) is a typical portrayal of the point that the value of establishing standards may often be overlooked. Without detracting from the tremendous value to public health of the technological development and application of water filtration in 1906 and of chlorination in 1913 in the Philadelphia system, the role of microbiological testing and the application of standards underlines the success (Fig. 1). It must be more than just chance that the 1905 Standards Methods date

![Reduction of typhoid fever in Philadelphia following treatment of the water supply. (from Smillie and Kilbourne, 1962)](attachment:figure1.png)

and the 1914 Treasury Standards date, previously mentioned, coincide so well with this decline in typhoid ascribed to filtration and disinfection. Microbiological standards must have played some role.
ACKNOWLEDGMENTS


REFERENCES

8. United States Treasury Department. 1914. Progress report of the commission appointed by the Treasury Department to recommend standards of purity for drinking water supplied to the public by common carriers engaged in interstate traffic. Public Health Reports, 29:2959-2966; reprint 232.