UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

EPA-SAB-DWC-91-004

February 27, 1991

OFFICE OF
THE ADMINISTRATOR

Honorable William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W
Washington, D.C. 20460

Subject: Review of the Office of Research and Development's Drinking Water Microbiology Research Plan

Dear Mr. Reilly:

The Science Advisory Board's Drinking Water Committee met in Cincinnati, Ohio June 21-22, 1990 to review the Office of Research and Development's research program in the area of drinking water microbiology. The charge to the committee was to determine if the current and future programs in the area of microbiology research by the ORD were adequate to provide the scientific basis for regulations.

The research needs in the area of drinking water microbiology result from three primary regulatory programs in the Office of Drinking Water; viz., Disinfectants and Disinfection By-products, Surface Water Treatment and Ground Water Disinfection Rules. The Surface Water Treatment Rule is in place and the other two rules are being developed. All three of these rules are interconnected, interrelated and need information in the area of microbiology that is not available or complete at this time.

The Drinking Water Committee has for several years commented on the research needs in the area of microbiology (e.g. the Drinking Water Subcommittee report on disinfectants and disinfection by-product research (SAB-EHC-88-005) and on the surface water treatment rule in 1988).

In view of the increased needs of the Office of Drinking Water and a decrease in activity in the Office of Research and Development, the Drinking Water Committee undertook a comprehensive review of the research program in drinking water microbiology.

At the meeting these various elements of the current and future research program of the Office of Research and Development were presented by representatives of the Office of Drinking Water, Risk Reduction Engineering Laboratory, Environmental Monitoring and Support Laboratory, and the Health Effects Research Laboratory. The Office of Research and Development concluded that research the program is funded "at just about the right level". The DWC concludes, however, that the drinking water microbiology research program to support the regulatory effort is inadequate, underfunded and disporportionately low compared to the research effort on chemical contaminants. The research needs in drinking water microbiology far exceed the available resources. Many chemicals are being considered for regulation because of "potential occurrence" in drinking water and potential adverse health effects, and therefore, it is essential that the many microbial agents "actually present" in drinking water and capable of causing waterborne disease also be considered for regulation. It is clear to the Committee that there are issues of microbial proliferation and contamination of drinking water as a consequence of inadequacies of proposed alternative disinfection methods, recent re-evaluations of current disinfection efficacy, and new technologies that have not been sufficiently researched to support the process of promulgating regulations. If such research is not conducted, it is possible that through new regulations the Agency could require costly changes in treatment practices that would not result in improved water quality. The research needs in drinking water microbiology far exceed the available resources.

The research needs and deficiencies are summarized below in order of highest to lowest priority, based on their importance in providing a scientific basis to assess and manage the risks of waterborne microbial disease. Items 1 and 2 are essential research needs that provide the ultimate basis for the other needs identified.

1. Epidemiology. The DWC recommends that the Agency engage in prospective epidemiological-microbiological studies patterned after a recent study in Canada in order to verify the models for assessing microbial health risks and to identify the best indicators of the microbial quality of water. Despite its high cost (ca. $500,000 per study) this research is essential in quantifying the risks of endemic waterborne microbial disease and identifying the best microbial indicators or surrogates for assessing or monitoring microbial water quality for such health risks.

2. Health Risk Modeling and Assessment. The DWC recommends that research on microbial risk modeling and risk assessment be extended, formalized and compared with the health risks from chemical contaminants. This research is needed in order to reliably estimate waterborne microbial health risks and to provide a basis for quantitative comparison with the risks from chemicals, especially disinfectants and disinfection by-products.

Relative health risk comparisons for microbial and chemical agents in water are not being done now. We also wish to point out that a comparative risk assessment of this type is consistent with the recommendations of the recent SAB report "Reducing Risk: Setting Priorities And Strategies For Environmenal Protection", which we understand to be a guiding document of the Agency.

3. Detection, Occurrence and Characterization of Microbes in Water. The DWC recommends the re-direction of several existing research efforts and the addition of new ones in order to best meet regulatory priorities. Specifically, new and/or expanded research efforts are needed on (i) direct detection and improved indicators of viral and protozoan pathogens; (ii) Legionella contamination of drinking water; (iii) methods to measure microbial growth potential in water; and (iv) the development of gene probe detection methods for the highest priority waterborne viruses, specifically Norwalk and related viruses, hepatitis A virus and rotaviruses. This last research area should replace current EPA research on detection methods for adenoviruses and rotaviruses because adenoviruses are less important waterborne viral disease agents and because rotavirus detection by antigenic methods is less promising and more problematic than detection by gene probe methods.

4. Distribution Systems. The DWC recommends the expansion of research on distribution systems to include: (i) better measures of microbial growth potential; (ii) maintenance of disinfectant residual; (iii) distribution system maintenance; (iv) nitrification, biofilms, particulates and opportunistic pathogens in distribution systems; (v) modeling of distribution systems; and (vi) establishing the relationships between system design, operation, maintenance and water quality. Current research efforts in these areas is either non-existent or too limited in scope, while the need for such knowledge is essential in appraising alternative disinfectant efficacy and safety.

5. Treatment and Water Quality. The DWC recommends that EPA support and/or undertake pilot and field studies to evaluate the ability of treatment processes and systems to control microbes under more realistic conditions than provided by laboratory model systems. This is because the data derived from laboratory model system studies of treatment processes utilizing purified, laboratory-grown, model organisms in "clean" systems are unrealistic and inadequate to predict the responses of naturally occurring microbial pathogens to these processes in water matrices under field conditions.

6. Other Needs

a. The DWC recommends greater and more effective coordination and integration of EPA's microbial and other water quality research as it relates to both microbial and non-microbial regulatory efforts in drinking water. This is because interchange and interaction among key research laboratories and

program offices are not adequate to meet the time frame imposed on the Agency.

b. The DWC recommends that more microbes be on the drinking water priority list of contaminants for regulation because these microbes are documented drinking waterborne pathogens, and cause a quantified incidence of human disease.

c. The DWC recommends that more resources be put into drinking water microbiology and health effects research to meet regulatory needs. Current resources, including Agency personnel are inadequate and they are continuing to decline.

We appreciate having been given the opportunity to conduct this particular scientific review. We request that the Agency respond formally to the scientific advice provided herein. In particular we are interested in your comments concerning items 1 and 2 and their relative importance to each other and the rest of the items.

Sincerely,

Raymond C. Loehr

Raymond C. Loehr
Chairman
Executive Committee

William H. Glaze

William H. Glaze
Chairman
Drinking Water Committee

REPORT OF THE SCIENCE ADVISORY BOARD'S DRINKING WATER COMMITTEE ON THE DRINKING WATER MICROBIOLOGY RESEARCH PROGRAM

1.0 EXECUTIVE SUMMARY

The Science Advisory Board's Drinking Water Committee (DWC) met in Cincinnati, Ohio on June 21-22, 1990 to review the Office or Research and Development's (ORD) research program in the area of drinking water microbiology. In view of the current and future regulatory needs of the Office of Drinking Water (ODW),

The DWC concludes that the drinking water microbiology research program to support the regulatory effort is inadequate, underfunded and disporportionately low compared to the research effort on chemical contaminants. The research needs in drinking water microbiology far exceed the available resources. The research needs and deficiencies are summarized below in order of highest to lowest priority, based on their importance in providing a scientific basis to assess, and manage the risks of microbial disease from drinking water. Items 1 and 2 are essential research needs that provide the ultimate basis for the other needs identified.

1. Epidemiology. The DWC recommends that the Agency engage in prospective epidemiological-microbiological studies patterned after a recent study in Canada in order to verify the models for assessing microbial health risks and to identify the best indicators of the microbial quality of water. The Committee recognizes that such epidemiological-microbiological studies are costly, perhaps in the range of $500,000 each. Nevertheless, the committee believes that this research is essential because, aside from acute epidemics from treatment deficient water supplies, the risks of endemic waterborne microbial disease are uncertain and presently, there are inadequate microbial indicators or surrogates to assess or monitor microbial water quality for such health risks.

2. Health Risk Modeling and Assessment. The DWC recommends that research on microbial risk modeling and risk assessment be extended, formalized and compared with the health risks from chemical contaminants. This research is needed in order to

reliably estimate waterborne microbial health risks and to provide a basis for quantitative comparison with the risks from chemicals, especially disinfectants and disinfection by-products. Relative health risk comparisons for microbial and chemical agents in water are not being done now, in part because of unresolved or unaddressed issues concerning the differences between microbes and chemicals in the approaches used for their risk estimation and assessment. We also wish to point out that a comparative risk assessment of this type is consistent with the recommendations of the recent SAB report "Reducing Risk: Setting Priorities And Strategies For Environmenal Protection", which we understand to be a guiding document of the Agency.

3. Detection, Occurrence and Characterization of Microbes in Water. There are important research needs in this area that are not being met, and therefore, the DWC recommends the re-direction of several existing research efforts and the addition of new ones in order to best meet regulatory priorities. Specifically, new and/or expanded research efforts are needed on (i) direct detection and improved indicators of viral and protozoan pathogens; (ii) Legionella in drinking water (iii) methods to measure microbial growth potential in water; and (iv) the development of gene probe detection methods for the highest priority waterborne viruses, specifically Norwalk and related viruses, hepatitis A virus and rotaviruses. This last research area should replace current EPA research on detection methods for adenoviruses and rotaviruses because adenoviruses are less important waterborne viral disease agents and because rotavirus detection by antigenic methods is less promising and more problematic than detection by gene probe methods.

4. Distribution Systems. The DWC recommends the expansion of research on distribution systems to include: (i) better measures of microbial growth potential; (ii) maintenance of disinfectant residual; (iii) distribution system maintenance; (iv) nitrification, biofilms, particulates and opportunistic pathogens in distribution systems; (v) modeling of distribution systems, and (vi) establishing the relationships between system design, operation, maintenance and water quality. Despite the importance of the need to understand the changes that occur in the microbial quality of drinking water in distribution systems and the factors that govern or control them, current research efforts in these areas is either non-existent or too limited in scope.

5. Treatment and Water Quality. The DWC recommends that EPA support and/or undertake pilot and field studies to evaluate the ability of treatment processes and systems to control microbes under more realistic conditions than provided by laboratory model systems. This is because the data derived from laboratory model system studies of treatment processes utilizing purified, laboratory-grown, model organisms in "clean" systems are unrealistic of and inadequate to predict the responses of naturally occurring microbial pathogens to these processes in water matrices under field conditions.

6. Other Needs.

a. The DWC recommends greater and more effective coordination and integration of EPA's microbial and other water quality research as it relates to both microbial and non-microbial regulatory efforts in drinking water. This is because interchange and interaction among key research laboratories and program offices is either inadequate or non-existent.

b. Microbes being regulated or considered for regulation are underrepresented compared to chemicals. Therefore, the DWC recommends that more microbes be on the drinking water priority list of contaminants for regulation because these microbes are documented drinking waterborne pathogens and cause a quantified incidence of human disease.

c. The DWC recommends that more resources be put into drinking water microbiology and health effects research to meet regulatory needs. Current resources are inadequate and they are continuing to decline. A noteworthy aspect of this decline in resources is the inability to recruit outstanding junior scientists and retain outstanding senior scientists in EPA laboratories for bench-level drinking water microbiology research. This has had a negative on the research effort in support of the regulatory needs.

2.0 INTRODUCTION

The Science Advisory Board's Drinking Water Committee (DWC) met in Cincinnati, Ohio June 21-22, 1990 at the Omni Netherland Hotel to review the Office of Research and Development's research program in the area of drinking water microbiology in view of the regulatory needs of the Office of Drinking Water (ODW).

The research needs in the area of microbiology result from three primary regulatory programs in the Office of Drinking Water; viz., Disinfectants and Disinfection By-products, Surface Water Treatment and Groundwater Rules. The Surface Water Treatment Rule which is intended to control turbidity, Giardia Lamblia, viruses, Legionella and heterotrophic bacteria by mandatory treatment requirements for filtration and disinfection, is in place (Federal Register 54:124:27486, June 29, 1989), and the other two rules are being developed. All three of these rules are interconnected, interrelated and need information in the area of microbiology that is either not available or complete at this time.

The DWC has for several years commented on the research needs in the area of drinking water microbiology [e.g. the DWC report on disinfectants and disinfection by-product research in 1987 (SAB-EHC-88-005) and on the surface water rule in 1988 (SAB-EEFTC-88-006)]. Just this year the Office of Health Research in the Office of Research and Development (ORD) decided to move its water related health research from the laboratory in Cincinnati, Ohio to Research Triangle Park, NC and in so doing curtail the microbiology research program.

In view of the increased needs of the ODW and the impending decrease in activity in the ORD, the Drinking Water Committee undertook a comprehensive review of the research program in drinking water microbiology. In view of the current and future regulatory needs of ODW, the charge to the Committee was to determine if the current and future programs in the area of microbiology research by the ORD were adequate to provide the scientific basis for regulations.

At the meeting in Cincinnati the ORD presented their current and future plans and concluded that the program is funded "at just about the right level".

Controlling the occurrence of waterborne disease, including microbial disease, is the primary concern of drinking water treatment. According to the Safe Drinking Water Act and its Amendments, the U.S EPA is required to regulate contaminants in drinking water which "...may have an adverse effect on the health of persons;".... New drinking water regulations, specifically the Surface Water Treatment, Coliform, Groundwater, and Disinfectant and Disinfection By-products Rules, will result in changes, both negative and positive, in the microbial quality of drinking water and the risks of waterborne microbial disease. Hence, it is essential to establish current baseline or existing levels of both epidemic and endemic microbial disease from drinking water supplies, in order to determine the resulting impacts on public health of the microbial water quality changes that will occur as a consequence of these new regulations. The risks of epidemic microbial death and illness from drinking water in the U.S. are documented by the compiled data on waterborne outbreaks (Craun, G.F., 1986, "Statistics of Waterborne Outbreaks in the U.S. (1920-1980)", pp. 73-159, Waterborne Diseases in the United States, CRC Press, Boca Raton, FL. ; Bennett, J.V., S.D. Holmberg, M.F. Rogers and S.L. Solomon, 1987, "Infectious and Parasitic Diseases," Closing the Gap; the Burden of Unnecessary Illness, R.W. Amler and H.B. Dull, eds., Oxford University Press, New York, pp. 102-114; see appendix). During the most recent period of 1971-1988, 564 waterborne outbreaks involving over 138,000 cases of illness were reported (Craun, G.F., 1991, Water Science and Technology, Part 2, in press; Levine, W.C., W.T. Stephenson and G.F. Craun, 1990, "Waterborne Disease Outbreaks, 1986-1988", Morbidity Mortgality Weekly Report, Vol. 39, No. SS-1, pp. 1-13, Center for Disease Control, Atlanta, GA). Reported waterborne outbreaks represent only a fraction, perhaps only one-tenth to one-half, of total outbreaks because of failure to recognize and report outbreaks by the existing passive, voluntary reporting system.

The continued risks of severe, epidemic waterborne microbial diseases and death are highlighted by the recent outbreak of E. coli (serotype O157:H7) bloody diarrhea in Cabool, MO., where

there were 85 severe cases and three deaths in a community of 2,090 people (Swerdlow, D. et al., 1990. Abstract #917, 30th Interscience Conf. Antimicrobial Agents and Chemotherapy, Amer. Soc. Microbiol., Washington, DC). The DWC was briefed concerning this outbreak at the June meeting in Cincinnati. The causative organism was not detected in water by routine coliform monitoring using standard MPN and P-A coliform tests. However, this organism is capable of surviving for long periods of time in drinking water, and the pattern of disease spread through the community was consistent with the movement of fecally contaminated water through the distribution system.

Also, there is documentation that considerable endemic, community-wide gastrointestinal (GI) disease is due to consumption of conventionally treated drinking water produced from fecally contaminated sources. The recent epidemiological-microbiological study by Payment and colleagues in Laval (Quebec), Canada, while not free of methodological limitations, suggested that about one-fourth of all endemic, community-wide GI illness was due to drinking water produced by complete, conventional treatment that met all current water quality standards in Canada, including those for coliforms, turbidity, pH and disinfectant residual (Paymant, P., 1990, Proceedings of the 1990 American Water Works Association Water Quality Technology Conference, AWWA, Denver, CO, to be published). The Canadian standards are essentially the same as those in the United States. The findings of this important study were presented to the DWC by Dr. Payment during the June 21-22 meeting.

3.0 DRINKING WATER MICROBIOLOGY RESEARCH DEFICIENCIES AND NEEDS

The recommendations of the DWC to alleviate specific research deficiencies in support of drinking water microbiology and related regulatory efforts are identified below. They are listed in order of highest to lowest priority, based on their importance in providing a scientific basis to assess and manage the risks of microbial waterborne disease. Items 1 and 2 are essential research needs that provide the ultimate basis for the other needs identified. These other research needs are interdependent. All of the items identified are sufficiently important to deserve the Agency's attention.

3.1 Epidemiology of Drinking Water Associated Microbial Disease

As part of the overall research effort to assess drinking water microbial health risks, the DWC recommends that studies be conducted to verify the models for assessing health risks and to identify the best indicators of the microbial quality of water. To achieve this we recommend epidemiological-microbiological studies patterned after those of Payment and colleagues (Payment, P., 1990, "Prospective epidemiological study on drinking water-related gastrointestinal disease," Proceedings of the 1990 American Water Works Association Water Quality Technology Conference, AWWA, Denver, CO, to be published) should be undertaken which include microbial analyses of the water consumed using the best available candidate indicators.

While these studies are costly, perhaps $500,000 each, the DWC believes that such epidemiological research is extremely important for both the Surface Water Treatment Rule and the forthcoming Groundwater Disinfection and Disinfectant-Disinfection By-products Rules.

Based on the studies of Payment et al., the incidence of endemic waterborne microbial disease is much greater than previously expected, with about 20-25% of community-wide gastrointestinal illness attributable to conventionally treated drinking water meeting all applicable Canadian standards which are similar to those in the U.S.

In the Surface Water Treatment Rule (SWTR) the assumption is that microbes can be "controlled" by treatment. While control by filtration has a scientifically supported basis for Giardia and perhaps Cryptosporidium, it is less certain that filtration and disinfection will adequately "control" all viruses and certain bacteria such as Legionella. Furthermore, the likely changes in disinfection practices required by the Groundwater, and Disinfectants and Disinfectant-Disinfection By-products Rules and the impact of these changes on public health cannot be evaluated because there exist no baseline data on either microbial occurrence in or endemic disease from drinking water.

3.2 Drinking Water Microbial Risk Modeling and Assessment

The DWC recommends that the research effort on microbial risk assessment and the modeling of risks from waterborne microbes (both morbidity and mortality) be extended, formalized and reconciled with the level of current risk assessment research programs for chemical contaminants.

a. The current microbial risk modeling effort appears to be conducted on an informal, ad-hoc basis and lacks the orientation that would acquire the information necessary to define health risks from methods of alternative disinfection on a time line consistent with the promulgation of regulations on Groundwater Disinfection and Disinfectant-Disinfection By-products. The Committee recommends that the research effort be improved and expanded by attempting to refine and verify the risk models, subjecting the risk modeling effort to rigorous external peer review, and establishing and utilizing a formal risk analysis strategy.

b. The existing Surface Water Treatment Rule and the forthcoming Groundwater and Disinfectant-Disinfection By-products rules will impact both the microbial and chemical quality of water because they will result in changes in water sources and/or the type of water treatment employed. Therefore, the DWC recommends that the Agency formulate and utilize a rational and realistic scientific basis for risk assessment that allows for quantitative comparisons of the risks of waterborne, microbial disease and the level of risk of waterborne chemical disease. Disinfectants and disinfection by-products deserve particular attention in this

effort. This comparative risk analysis is necessary because too much attention in controlling one class of agents may jeopardize the ability to control the other class. Furthermore, the uncertainties of the risks of chemicals and microbes are different. If anything, there is greater certainty of the risks associated with microbes and less certainty of the risks of chemical exposures leading to frank illness. There is a low but verified (real) level of risk associated with microbes in water; but for chemicals, especially carcinogens, there is only a low level risk calculated from conservative models, currently not adequately verified by epidemiological data.

Since there are more confirmed deaths from drinking waterborne microbes than estimated deaths for all of the organic chemical contaminants, the current risk analyses/assessment efforts of the Agency may be biased towards overestimating chemical risks and underestimating microbial risks. The identification of drinking water research priorities must be based on a rational and integrated approach for risk minimization, which is not being done at present.

3.3 EPA's Research on Detection, Occurrence and Characterization of Microbes in Drinking Water Must be Expanded into New Areas and several existing areas must be redirected towards addressing more pressing research needs.

3.3.1 The DWC recommends new research efforts by EPA on the following pressing research needs that are not being adequately addressed by current and planned research activities.

a. Microbial indicators of pathogens

Greater research efforts are recommended on the development and evaluation of improved indicators and indicator analysis methods, especially for viruses and protozoans in water. As noted in section 2.1, the DWC recommends the integration of this research effort with epidemiological studies as soon as improved candidate indicators and indicator methods are available. The need for this research is due to the present inability to establish and verify the effectiveness of treatment practices for microbial control that are required by the Surface Water Treatment Rule and that will be required by the forthcoming Groundwater and Disinfectants and Disinfection By-Products Rule. Presently, there is no reliable basis for actually demonstrating

that the prescribed treatment will indeed achieve the desired goal of controlling waterborne viral and protozoan pathogens by minimizing the risks of disease from them to acceptable levels under actual field conditions.

b. Legionella

The DWC recommends new EPA research on Legionella in water in the areas of improved detection methods, virulence and pathogenicity of waterborne strains, occurrence in drinking water supplies and vulnerable temperature settings (e.g., hospital and other institutional hot water systems), and effectiveness of the treatment processes required in the SWTR to prevent proliferation and outbreaks in vulnerable settings. Current detection methods are inadequate for addressing these crucial, unmet research needs concerning the occurrence, virulence, proliferation and control of Legionella in drinking water.

The SWTR states that Legionella as well as viruses, Giardia and heterotrophic bacteria are controlled through its enactment and implementation. However, there no research to support this claim. Additionally, changes in disinfection practice that may be required under the Disinfectants and Disinfection By-products Rule could have a positive or negative effect on Legionella control, yet no research is being done on this issue.

The Agency's claim that Legionella cannot be regulated at the consumer's tap because of possible proliferation of the organisms in residential plumbing is inconsistent with the strategy being considered for regulating lead, which also increases at consumers' taps due to contributions from household plumbing. For those contaminants that are likely to increase to unacceptable levels in the consumers' plumbing, it is essential to devise strategies to control such problems whether the contaminants are chemicals or microbes. This is yet another example of the conflicting approaches to dealing with chemicals and microbes.

c. Measures of microbial growth potential and other microbially-mediated water quality changes

The DWC recommends that EPA drinking water microbiology research efforts be directed towards improved measures of microbial growth potential (i.e., methods for assaying of

biodegradable organic carbon [BDOC]), and an assessment of ammonia as a nutrient causing microbial proliferation, nitrification and corrosion problems in drinking water from both ground and surface sources. This research is especially important because the Disinfectants and Disinfection By-products Rule may well introduce treatment strategies that will increase the potential for microbial regrowth in distribution systems, if they are not properly managed.

3.3.2 The DWC recommends redirection of some current EPA research because it is likely to provide little useful payoff and does not address pressing research needs.

a. Legionella

EPA's Legionella research is now limited to studies on the role of purported surface receptors for Legionella infection of free-living, waterborne amoeba hosts and the potential to prevent such receptor-mediated infection. There is little evidence to suggest that amoeba infection is strictly receptor-mediated, and furthermore, it is not clear how understanding of such a reaction will lead to improved control strategies for Legionella in water. The DWC recommends a redirection of the Legionella research effort as noted above in section 3.3.b.

b. Adenovirus 40/41 gene probes

This research is directed towards gene probe detection of two enteric viruses, adenovirus types 40 and 41, for which there is no evidence of waterborne transmission or disease. The DWC recommends a re-direction of this research to gene probe detection of hepatitis A virus, rotaviruses, Norwalk virus and Norwalk-like viruses (e.g., astrovirus; calicivirus), which are known to cause waterborne disease.

c. Evaluation of antigen test kits for rotavirus detection

The DWC recommends a re-direction of this research to gene probes. This is because antigen detection by these kits is too insensitive to detect the low levels of rotaviruses in water, and the kits are likely to detect non-infectious rotavirus antigens and incomplete particles, which are of no health risk for infection.

d. Measures of microbial growth potential

EPA's research in this area has emphasized the development of a coliform growth response bioassay and improvement of the Van der Kooij method. A briefing on this research effort was provided by Dr. Donald Reasoner, EPA, RREL, Cincinnati, Ohio, at the June meeting. Outside of EPA, many more methods of measuring BDOC are being researched, because there is an industry consensus that microbiological growth in distribution systems is a significant problem and that current procedures for growth potential measurement are inadequate. Overall, the research effort on measuring microbial growth potential is not being pursued in an integrated manner and may indeed be haphazard. The DWC recommends that EPA, as the national agency with regulatory authority, orchestrate the research effort needed to answer the many questions on this scientific issue that go beyond the needs of specific water utilities and that EPA support research to determine the overall, national impact of microbial water quality changes as a consequence of changes in treatment under the Disinfectant- Disinfection By-products Rule.

3.4 Research On Design, Operation, and Maintenance of Distribution Systems

The DWC recommends that EPA engage in and/or support research to identify the elements which most contribute to the deterioration of water quality in distribution, because presently, there is inadequate scientific knowledge and understanding in this area. This deficiency in scientific understanding of water quality in distribution systems and factors controlling it will be further exacerbated by the changes in treatment practices that undoubtedly will come about as a result of the Surface Water Treatment, Groundwater Disinfection and Disinfectant/Disinfection By-products Rules.

The DWC recommends expansion of the limited work on AOC to include a range of research on distribution water quality problems. Problems to be addressed include:

a. better measures of microbial growth potential
b. maintaining an adequate disinfectant residual
c. distribution system maintenance
d. nitrification
e. modeling of distribution systems

f. establishing the relationships between system design, operation and maintenance, and water quality.

a. Microbial growth potential and its impacts

The DWC recommends an expansion of EPA's research efforts to include not only improved measures of microbial growth potential (i.e., methods for assaying biodegradable organic carbon; see sections 3.3.c and 3.4.d above) but also studies that attempt to: (i) associate BDOC, ammonia and other nutrients with distribution system performance, (ii) model microbial behavior and impact in distribution systems, and (iii) assess chlorine and chloramine stability in distribution systems.

The Committee recommends that EPA not only expand its efforts in methods development but that it also undertake a research program to associate these measurements with the prevention of the development of water quality problems.

b. Nitrification

The DWC recommends that EPA invest in laboratory and field scale research to characterize and develop methods for control of the problem of nitrification in distribution systems. Presently, the nitrification problem is poorly understood and control strategies are inadequate. It is known, however, that nitrification can cause dissolved oxygen depletion, the development of odors and corrosion problems, formation of nitrite (which is of health concern), and it may contribute to the loss of chlorine residual. The increasing use of chloramines makes it imperative that the nitrification problem be well characterized and that effective control strategies be developed. For example, many ground waters contain ammonia at concentrations >0.2 mg/l, and therefore, free chlorine disinfection would necessitate breakpoint chlorination or other means of ammonia control, thus possibly leading to the formation of chlorinated disinfection by-products.

c. Biofilms, particulates and opportunistic pathogens.

The DWC recommends that EPA increase its research efforts on biofilms and particulates as degraders of water quality in distribution systems, because these issues are closely related to the problems of microbial growth potential and nitrification cited above. It is known that biofilms and particulates in treated drinking water can cause serious problems in distribution

systems by producing excessive levels of microbes, interfering with the maintenance of a disinfectant residual, and causing turbidity, taste, odor and other aesthetic problems. The research effort in this area is deficient.

Probably the most important factor regarding biofilms and their impact on the microbial quality of water is the nature and extent of opportunistic pathogens in these growths. This is an unresolved, poorly understood public health issue. There is a pressing need for in depth investigation of opportunistic pathogens in drinking water because of the growing proportion of immunocompromised members of the population who are highly susceptible to these pathogens has now grown to >15% and because it is already established that the SWTR will not completely eliminate many of these pathogens. Only one in-house research effort is now under way that is focused on assessing virulence by conventional cultivation and physiological methods. However, more direct methods using nucleic acid (DNA) probe technology are now available to look for toxic genes in a variety of health-related bacteria. The Committee recommends that additional resources be provided by EPA to extend such studies.

d. Modeling of distribution systems

The DWC recommends that EPA's research on microbial problems in distribution systems include the establishment of the interrelationships between system design, operation, and maintenance and system problems (e.g., importance of dead-ends, impact of reservoir design and operation strategies, the role of flushing, etc.). This research is needed to determine the best means to control problems caused by microbial activity that are associated with these aspects of distribution systems. It is recommended that models of distribution systems be constructed which characterize the impact of system design and operation on microbial proliferation and colonization, disinfectant residual maintenance and nitrification. It is further recommended that these models be used in connection with field scale studies designed to evaluate their effectiveness and to develop effective design and operation strategies to avoid future problems.

3.5 Microbial Aspects of Treatment and Water Quality: Pilot and Field Studies

The DWC recommends a greater EPA research effort on pilot and field scale evaluation of treatment processes to control microbial contaminants. The data on microbial removal and inactivation used for the development of the regulations are largely based on studies under artificial laboratory conditions that do not adequately reflect or account for environmental conditions. The Committee recommends that research be carried out to determine if the treatment data from laboratory studies that now provide the basis of treatment requirements of the SWTR and the proposed groundwater disinfection rule are valid in the real world. In particular, both pilot and field studies are needed on the microbial inactivation efficiency of the different disinfection options.

3.6 Administrative and Other Aspects of the Drinking Water Microbiology Research Program

a. Lack of coordination and integration

The DWC recommends greater EPA research efforts to coordinate and integrate the microbiological research and regulatory activities, not only as they relate to microbial rules but also as they relate to other drinking water rules, including those for chemical contaminants. At present, interchange among the Agency's research laboratories and program offices that should be involved in the research and regulatory effort for drinking water microbiology is inadequate, and some important units are not directly involved at all. For example, the ground water research laboratory in Ada, Oklahoma is not involved at all in the research activities for the Groundwater Disinfection Rule. The Committee recommends that, within the framework of a comprehensive plan, a mechanism be established for interchange and coordination among key research laboratories and programs, in order to facilitate and better utilize the research effort in support of the regulations.

b. Underrepresentation of microbial components in regulation

The DWC recommends an expansion of the Drinking Water Priority List of waterborne contaminants to include the numerous microbial agents that have been identified as having the potential to be transmitted via drinking water. The number of microbial agents is substantial, and there is no scientifically valid reason to exclude them from consideration for regulation

(see Table in Appendix). At present only a few bacteria, viruses and protozoans are scheduled or being considered for regulation. Many chemicals are being considered for regulation because of potential occurrence in drinking water and potential adverse health effects, and therefore, it is essential that the many microbial agents actually present in drinking water and capable of causing waterborne disease also be considered for regulation.

c. Inadequacy of resources and programs in drinking water microbiology and health effects

The DWC recommends that EPA develop appropriate programs and provide sufficient people to adequately address the issue of risks of microbial waterborne disease. This effort is needed because microbial waterborne disease risks have not been adequately assessed (see sections 1 and 2, above).

The health effects research program in drinking water microbiology has been further compromised by the elimination of the health effects microbiology research laboratory and a re-direction of its efforts to environmental monitoring and support. The move of the drinking water epidemiology program from Cincinnati to Research Triangle Park (N.C.) may lead to further de-emphasis and diffusion of microbiological aspects of drinking water epidemiology research and may lead to communication and coordination problems due to its physical separation from the drinking water microbiology research program in Cincinnati.

d. Lack of long range planning and research

The DWC recommends longer range planning in the drinking water research program, including microbiological research, to meet pressing informational needs for promulgation of regulations. For example, the proposed amendments to the Coliform Rule prompted numerous criticisms about the methods for analysis of E. coli, because there was inadequate planning for how E. coli methods could be researched and evaluated for equivalency to the one method proposed. In addition to such failures to anticipate immediate needs for short-term regulatory-driven research, there is too little longer term research planning to anticipate and address the next generations of drinking water microbiology regulations.

e. Acquisition and retention of outstanding scientists in drinking water microbiology research

The DWC recommends that greater efforts be made to acquire and retain outstanding bench researchérs in drinking water microbiology. The Agency has been ineffective in retaining outstanding senior scientists at the bench and in recruiting bright, young, junior researchers. There does not appear to be an adequate "new generation" of outstanding researchers in drinking water microbiology in the Agency's laboratories. This will have a negative impact on the in-house research enterprise and its productivity.

4.0 CONCLUSION

The Drinking Water Committee concludes that the microbiology research program does not adequately address either the near term objectives for defining regulations or long term objectives that deal with broader issues of protecting public health. There are issues of microbial proliferation and contamination of drinking water as a consequence of inadequacies of proposed alternative disinfection methods, recent re-evaluations of current disinfection efficacy, and new technologies that have not been sufficiently researched to support the process of promulgating regulations. If such research is not conducted, it is possible that through new regulations the Agency could require costly changes in treatment practices that would not result in improved water quality.

Finally, the DWC concludes that the drinking water microbiology research program of the U.S. Environmental Protection Agency developed to support the regulatory effort is inadequate, underfunded and disporportionately low compared to the research effort on chemical contaminants. The research needs in drinking water microbiology far exceed the available resources. The research needs and deficiencies are, in order of highest to lowest priority; epidemiology, health risk modeling and assessment, detection, occurrence and characterization of microbes in water, distribution systems, treatment and water quality and other needs including coordination and restructuring the program.

APPENDIX

ETIOLOGY OF WATERBORNE OUTBREAKS (1920 - 1980)

(From Craun, G.F., Statistics of Waterborne Outbreaks in the US (1920 - 1980), Waterborne Diseases in the United States (G.F. Craun, Editor), CRC Press Inc., Boca Raton, FL, 1986)

Time Period	Disease	Outbreaks	Cases	Deaths
1920-1925	Typhoid fever	127	7,294	435
	Gastroenteritis	11	27,756	0
1926-1930	Typhoid fever	100	3,072	234
	Gastroenteritis	17	63,902	0
1931-1935	Typhoid fever	85	2,114	140
	Gastroenteritis	25	7,664	0
	Amebiasis	1	1,412	98
	Hepatitis A	1	28	0
1936-1940	Gastroenteritis	91	77,403	2
	Typhoid fever	60	1,281	80
	Shigellosis	10	3,308	0
	Amebiasis	1	4	0
1941-1945	Gastroenteritis	126	36,118	3
	Typhoid fever	56	1,450	46
	Shigellosis	10	2,817	6
	Paratyphoid fever	2	14	0
	Chemical poisoning	1	30	0
1946-1950	Gastroenteritis	87	10,718	0
	Typhoid fever	18	264	5
	Hepatitis A	5	173	0
	Paratyphoid fever	1	5	0
	Leptospirosis	1	9	0
	Tularemia	1	4	0
1951-1955	Gastroenteritis	31	5,297	0
	Typhoid fever	7	103	0
	Hepatitis A	7	340	0
	Shigellosis	4	732	1
	Poliomyelitis	1	16	0

1956-1960	Gastroenteritis	21	2,306	0
	Typhoid fever	13	128	3
	Hepatitis A	11	417	0
	Shigellosis	7	3,081	0
	Chemical poisoning	3	14	4
	Salmonellosis	2	17	0
	Amebiasis	1	5	0
	Tularemia	1	2	0
1961-1965	Gastroenteritis	18	20,627	0
	Typhoid fever	11	63	0
	Hepatits A	10	334	0
	Shegellosis	7	520	4
	Chemical poisoning	5	30	6
	Salmonellosis	3	16,425	3
	Giardiasis	1	123	0
1966-1970	Gastroenteritis	21	5,992	0
	Hepatitis A	19	562	1
	Shigellosis	14	1,215	0
	Typhoid fever	4	45	0
	Salmonellosis	4	226	0
	Toxigenic E. coli AGI	4	188	4
	Chemical poisoning	4	15	0
	Amebiasis	3	39	2
	Giardiasis	2	53	0
1971-1975	Gastroenteritis	63	17,752	0
	Shigellosis	14	2,803	0
	Hepatitis A	14	368	0
	Giardiasis	13	5,136	0
	Chemical poisoning	13	513	0
	Typhoid fever	4	222	0
	Salmonellosis	2	37	0
	Toxigenic E. coli AGI	1	1,000	0
1976-1980	Gastroenteritis	114	22,093	0
	Giardiasis	26	14,416	0
	Chemical poisoning	25	3,081	1
	Shigellosis	10	2,392	0
	Viral gastroenteritis	10	3,147	0
	Salmonellosis	6	1,113	0
	Campylobacterosis	3	3,821	0
	Hepatitis A	2	95	0

For more recent data see G.F. Craun, Causes of Waterborne Outbreaks in the United States, to be published in Water Science and Technology, Vol. 22, Part 2, 1991.

For lists of other microbial agents see: Feachem, R.G., Bradley, D.J., Garelick, H. and Mara, D.D., Sanitation and Disease, Health Aspects of Ecreta and Wastewater Management, John Wiley and Sons, Chapter 1, 1983 and Table 2.1, Chapter 2 on Tropical Source Water in Drinking Water Microbiology, Ed. Gordon A. McFeters, Springer-Verlag, New York.

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