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

March 13, 1990

EPA-SAB-DWC-90-007

OFFICE OF
ADMINISTRATION

Mr. William Reilly
Administrator
USEPA
Washington, D.C. 20460

Dear Mr. Reilly:

Attached you will find the report of the SAB's Drinking Water Committee (DWC) RECOMMENDATIONS FOR RESEARCH IN THE AREA OF DISINFECTANTS AND DISINFECTION BY-PRODUCTS. This report is the result of a public meeting of the DWC on October 11-13, 1989, subsequently discussions of drafts within the Committee, initial examination of the report by the Executive Committee (EC) at their public meeting January 8-9, 1990, and final EC review by mail.

The Agency is investigating the risks associated with different approaches to disinfecting drinking water in the U. S. Although treatment with chlorine has been used extensively for this purpose for many years, concerns have been raised about possible health risks associated with some of the by-products of this disinfection process. Consequently, alternative forms (e.g., ozonation and chloramination) are being explored and in some cases employed for disinfection purposes. At the same time, any change in the treatment applied to drinking water must also maintain a sufficient level of microbial disinfection to protect public health.

The issue is a complex one. Clearly, there is need for good scientific and engineering information before final decisions are made. Hence, the SAB was asked to provide a critical review of early activities of the Office of Drinking Water (ODW) in this area.

Specifically, the charge to the DWC was to

a. Review the Office of Drinking Water's (OW) "strawman regulation", a tentative course of action to address the issues.
b. Identify significant data gaps that should be filled in order reach informed decisions on the various approaches under consideration.
c. Recommend research activities which should be undertaken to fill those data gaps.
d. Present the recommendations in some priority order.

In conducting its review the DWC has examined the research needs in the four general areas of health effects, microbiology, chemical characterization, and treatment technologies. After reading Agency documents on the subjects and receiving briefings from knowledgeable Agency staff, the Committee identified specific research needs in each of the area, highlighting those topics of highest priority.

In the area of health effects, the DWC gives highest priority to careful consideration of the possible adverse health effects associated with chlorination. For microbiology, the Committee assigns high priority to conducting a survey of pathogens in the drinking water systems and to conducting a workshop on the state of the current scientific information on microbes in the drinking water supply. In the area of chemical characterization, the Committee strongly encourages the Agency to re-examine its monitoring strategies and to develop expertise in new analytical methods. Finally, in the area of treatment technologies, the Committee gives highest priority to both the investigation of chemical methods to reduce the presence of particular disinfectants/byproducts in treated waters and to methods for removing materials with can serve as precursors for microbial infection and for hazardous byproducts of disinfection treatment.

The attached report contains the rationale for these recommendations, together with several other suggestions for moderate priority research.

The Committee appreciated the opportunity to work with your well-informed, conscientious EPA staff and to provide technical advice in this important area. We look forward to your formal response to this report.

Sincerely,

Raymond C. Loehr

Dr. Raymond C. Loehr
Chair, Executive Committee

Dr. William Glaze
Chair, Drinking Water Committee

EPA-SAB-DWC-90-007

REPORT OF THE DRINKING WATER COMMITTEE SCIENCE ADVISORY BOARD

RECOMMENDATIONS FOR RESEARCH IN THE AREA OF DISINFECTANTS AND DISINFECTION BYPRODUCTS

MARCH, 1990

U S. Environmental Protection Agency
Science Advisory Board
Drinking Water Committee - October 11-12. 1989

Dr. William H. Glaze. [CHAIR]. Department of Environmental Science and Engineering, CB# 7400, Rosenau Hall, University of North Carolina, Chapel Hill, NC 27599-7400

Dr. Verne Ray. [VICE-CHAIR]. Medical Research Laboratory. Pfitzer Inc., Groton, CT 06340

MEMBERS AND CONSULTANTS

Dr. Julian B. Andelman. Graduate School of Public Health. 130 Desoto Street. Parran Hall - Room A-711, University of Pittsburgh. Pittsburgh, PA 15261

Dr. Gary Carlson. Department of Pharmacology & Toxicology. School of Pharmacy & Pharmacal Sciences, Purdue University, West Lafayette. IN 47907

Mr. Keith Carns, Director of Water Quality. East Bay Municipal Utility District, 2131 Adeline Street. P.O. Box 24055, Oakland, CA 94623

Dr. Rose Dagirmanjian. Department of Pharmacology and Toxicology, University of Louisville, Louisville, Kentucky 40292

Dr. Charles Gerba, Department of Microbiology, Building #90, University of Arizona, Tucson, AZ 85721

Dr. J. Donald Johnson, The School of Public Health, Department of Environmental Sciences, The University of North Carolina, Chapel Hill, NC 27599-7400

Dr. E. Marshall Johnson, Chairman, Department of Anatomy, Jefferson Medical College, 1020 Locust Street, Philadelphia, PA 19107

Dr. David Kaufman, Department of Pathology, University of North Carolina, Brinkhous-Bullitt, Room 515, Chapel Hill, NC 27514

Dr. Nancy Kim, Director, Division of Environmental Health Assessment New York State Department of Helath, Room 350, 2 University Place, Albany, NY 12203-6438

Mr. Ramon G. Lee, System Director, Water Quality Research, American Water Work Service Co. Inc., 1025 Laurel Oak Road, Voorhees, NJ 08043

Dr. Betty Olson, Program in Social Ecology, University of California, Irvine, CA 92717

Dr. Edo D. Pellizzari, Vic President, Research Triangle Institute P.O. Box 12194, Research Triangle Park, NC 27709

Dr. Harold Schechter, Chemistry Department, Ohio State University, 140 West 18th Avenue, Columbus, OH 43201

Dr. Vern Snoeyink, Department of Civil Engineering Lab, 3230 Newmark Civil Engineering Lab, University of Illinois, 205 Mathews Avenue, Urbana, IL 61801

Dr. Mark Sobsey, Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina, Chapel Hill, NC 27599

Dr. James Symons, Department of Civil Engineering, University of Houston, Houston, TX 77004

Dr. Thomas Tephly, Department of Pharmacology, The Bowen Science Building, University of Iowa, Iowa City, IA 52242

Dr. R. Rhodes Trussell, Vice President, James M. Montgomery, Consulting Engineers, Inc., 250 North Madison Avenue, Pasadena, CA 91109-7009

EXECUTIVE SECRETARY

Dr. C. Richard Cothern, Executive Secretary, U.S. Environmental Protection Agency, Science Advisory Board [A101F], Washington, D.C. 20460

STAFF SECRETARY

Ms. Joanna Foellmer, U.S. Environmental Protection Agency [A101], Washington, D.C. 20460

STAFF DIRECTOR

Dr. Donald G. Barnes, U.S. Environmental Protection Agency [A101], Washington, D.C. 20460

ABSTRACT

The Drinking Water Committee (DWC) of the Science Advisory Board has examined a range of possible changes in existing regulations that currently control drinking water disinfection practices in the United States. The DWC report addresses areas of scientific and engineering research that will provide important insights on the alternatives under consideration. Research recommendations are made in four areas: health effects, chemical characterization and monitoring, microbiology, and treatment technologies. The Committee highlights those recommendations that are of the highest priority.

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RECOMMENDATIONS FOR RESEARCH IN THE AREA OF DISINFECTANTS AND DISINFECTION BY-PRODUCTS

A Report of the Drinking Water Committee
of the USEPA Science Advisory Board

1.0 Executive Summary

The Science Advisory Board's Drinking Water Committee (DWC) met on October 11-12, 1989 to develop recommendations for research in the areas of disinfectants and disinfection by-products. The Office of Drinking Water (ODW) had at that time developed an outline of a possible "strawman regulation" for controlling the risks posed by these substances. The outline included various approaches the Agency might take in addressing certain issues; e.g., ranges of maximum concentration limits (MCLs) that could be adopted for different substances in drinking water. ODW formally asked the Committee for recommendations on priority research activities which the Agency should conduct in order to undergird the technical support for such a regulatory approach.

The Committee developed recommendations in four research areas and assigned them to one of two categories; i.e., those that they felt that the Agency must do and those that they thought the Agency should do. Those in the former category are:

AREA	HIGHEST PRIORITY RESEARCH NEEDS
Health Effects	Determine more definitively if the health consequences of chlorination, particularly those associated with formation of chloroform, are of significant concern by carefully analyzing the existing data

Microbiology	Survey drinking water systems for pathogens of concern, particularly cryptosporidium, enteric viruses, Aeronomas and Legionella. Conduct a workshop to review the recent experience in the area of microbiological contaminants drawing from experience and expertise both within and outside the US
Chemical Characterization and Monitoring	Re-examine monitoring strategies for characterizing water supplies. Develop expertise in new analytical methods such as high performance liquid chromatography/mass spectroscopy and critical fluid chromatography
Treatment Technologies	Investigate chemical and physical approaches to reducing chlorine dioxide and chlorite ion levels in treated water through the use of SO_2. Investigate the effectiveness of precursor removal in reducing drinking water contamination by conducting a survey of plants that use coagulation as a method of color removal. Evaluate precursor removal by membranes or granular activated carbon and evaluate removal by membranes of precursor materials that lead to the formation of by-products.

Several other recommendations for needed research were given moderate priority.

2.0 Introduction

2.1 Background

During the past 100 years great progress has been made in improving the public health in this country through the systematic treatment of its drinking water supplies. The treatment method of choice during much of this period has been chlorination. Within the past ten years, however, concerns have been raised about the possible health risks posed by byproducts formed during the chlorine disinfection process; e.g., trihalomethanes (THMs), such as chloroform.

Consequently, the Agency has been investigating approaches to reducing the health risks in drinking water. For example, one approach under consideration would be use alternative forms of disinfection to reduce or eliminate the use of chlorine; e.g., use of ozone, chloride dioxide, or chloramine. Another approach would focus on minimizing formation of hazardous disinfection by-products (DBP) by increasing the efficiency of removal of precursors, whose presence can result in increased microbial levels and also provide substrates for formation of hazardous DBP. Any change in current practice must be done in such a manner that effective disinfection of the drinking water is not compromised.

The Agency is still exploring the various options. The ODW personnel have drafted a "strawman regulation" which focuses some of their early thinking on the matter. For example, it is likely that the final regulation will involve a lower maximum contaminant level (MCL) for trihalomethanes (THMs); e.g., in the 25-50 ug/L range (the current standard is 100 ug/L). This will be coupled with the appropriate monitoring and technology to

insure that these MCLs can and will be met. Consequently, drinking water suppliers could face the prospect of a reduced usage of chlorine. To adequately disinfect drinking water there would be an increased reliance on alternative oxidants. Probable scenarios used for disinfection will then be:

a. ozone/conventional treatment/chlorine
b. ozone/conventional treatment/chloramines
c. chlorine dioxide/conventional treatment/sulphur dioxide/chlorine or chloramine
d. chlorine dioxide/conventional treatment/granular activated carbon (GAC)/chlorine or chloramine
e. chlorine dioxide/conventional treatment/chlorine or chloramine;

possibly,

f. ozone/GAC/chlorine or chloramine;

and in a few cases,

g. chlorine dioxide/GAC/chlorine or chloramine.

The values chosen for the MCLs that will be set for both chlorine and the alternative disinfectants in relationship to what is needed for effective disinfection and/or treatment will dictate which of the above scenarios are viable. Therefore, at this time there is uncertainty concerning which technology is likely and what all the ramifications are.

2.2 DWC Charge and Review Process

The charge to the DWC was to

a. Review the "strawman regulation"
b. Identify significant data gaps that should be filled in order reach informed decisions on the various approaches under consideration
c. Recommend research activities which should be undertaken to fill those data gaps.
d. Present the recommendations in some priority order.

To carry out this charge, the DWC met October 11-12, 1989 in Washington, D.C. where they were briefed by ODW on the strawman regulation. The Committee considered four general areas of research as they relate to disinfectants and disinfection by-

products: health effects, chemical characterization and monitoring, microbiology, and treatment including precursor removal.

This final report contains the DWC's recommendations in each of the four research areas, presenting them in two priority categories: highest priority and moderate priority. The order of projects within each of these two categories are not in any particular priority order.

A DWC-approved draft of this report was briefly considered by the Executive Committee (EC) of the SAB at its meeting on January 8-9, 1990. The EC formally endorsed the final report through a subsequent mail review.

3.0 Research Recommendations Related to Health Effects

The list of known and possible disinfectants and disinfection by-products is so long that complete and documented research concerning all the possible health effects for all contaminants is not feasible. Thus the question is how to allocate scarce research dollars because no way exists to develop adequately and completely all the health effects information.

3.1 Highest Priority Recommendation:

Describe health effects of chlorination disinfection by-products more definitively

Much of the regulation being considered is related to studies on chloroform. The basic application of the animal tumor data (including conflicting data on corn oil versus water as a vehicle) and the relevance of mouse liver tumors suggests that what is needed is a greater understanding of the relationship of these data to human health. The Committee recommends that research needs to continue to investigate the basic mechanisms involved in causing the health effects to the liver.

In past reviews concerning disinfectants and disinfection by-products, the Drinking Water Committee has recommended research in several areas for disinfectants other than chlorine. The Committee recommends that the health consequences of ingested chloroform be realistically evaluated, substantiating the need for decreasing the MCL for THMs. It is recommended that this be resolved up soon so that there is a clear basis for seeking alternative disinfectants to chlorine.

If there is information lacking on the health effects associated with the disinfection by-products of chlorination, the Committee recommends that funding go first to establishing a

scientific basis for the health effects of chlorination byproducts (e.g., chloroform) and then turn attention and funding to the determination of the health effects of alternative disinfectants methods and their resulting disinfection by-products. The rationale here is that if something is to be changed, it should first be shown that the existing methods lead to unacceptable health effects.

3.2 Moderate Priority Recommendations

3.2.1 Relationship to other programs and laboratory research

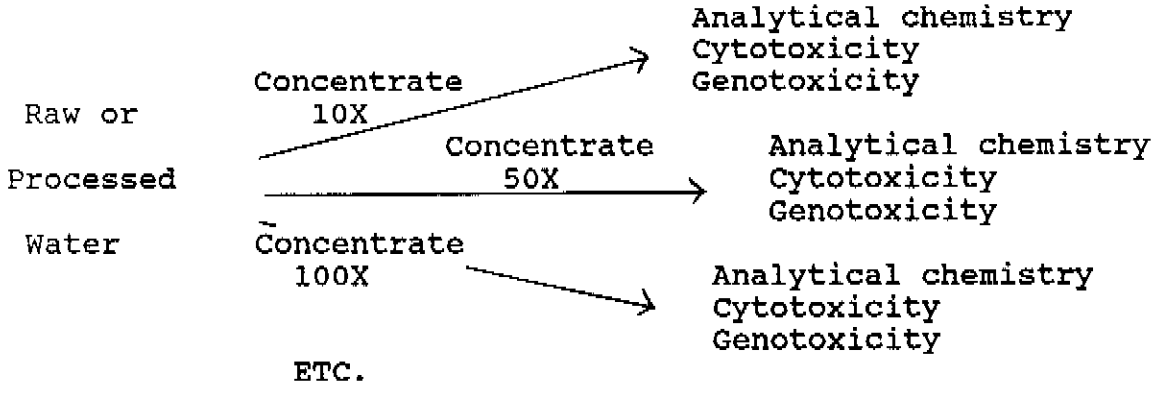
Collection and analysis of toxicological testing and health data on DBP is a slow process. It appears that EPA is dependent upon other agencies, such as the National Toxicology Program (NTP) for completion of some toxicological testing and has begun to make better and more effective use of the capabilities of that group. The Committee recommends that efforts be continued to enhance the value of this relationship by impressing upon NTP the priorities in testing disinfectants and DBP. This information should be pursued with all vigor. Furthermore, the integration of work being performed at HERL/EPA in Research Triangle Park, NC, especially in the area of neurotoxicology, is very important and should be continued.

3.2.2 Use of mixtures

Because of the resource constraints involved in developing this regulation, it is recommended that the research priorities in the disinfection area be based on toxicity determinations of chemical mixtures resulting from the alternate disinfection processes. Considering the constraints of time, money and personnel, short-term methodologies appear to be the primary means for gaining some insight into the appropriateness of any

rule-making procedure relating to alternative disinfection approaches.

One possible approach to analyzing mixtures is to perform a stepwise concentration and analysis of water samples that have been treated by the alternate disinfectants. A flow diagram of one such treatment (for ozonation) follows. At each step three analyses should be conducted; analytical chemistry, cytotoxicity in mammalian cells, and genotoxicity in the Ames Salmonella model. This approach would produce toxicological information for the effects of the disinfection method at lower cost than determining separately the effects of each of the individual by-products.



In the procedure described above one could first concentrate the sample, following this with disinfection treatment. Alternatively, one could disinfect first and then concentrate the sample. The latter approach would maximize the possible chemical interactions. By testing multiple levels of concentrates, artificial results produced by interactions of concentrated compounds could be detected. The Ames Salmonella assay should be performed using 4-5 strains of Salmonella throughout and not just one strain because of possible false negatives. Cytotoxicity could be used as an indicator for additional conventional toxicity and genotoxicity analysis. Also, the experimental treatment process steps should reflect actual process sequences;

e.g. ozonation, followed by chloramine or chlorine, etc. Since the method of concentration could significantly affect the resulting tests, two methods should be used, e.g. reverse osmosis and resin treatment, and the resulting total organic carbon tracked.

3.2.3 Possible susceptible groups

In evaluating the toxicology profile for the disinfectants and their by-products, either for individual compounds or their mixtures, special attention needs to be paid to developmental stages of the target population, including the conceptus and fetus, that could be easily susceptible to the different health effect endpoints. The Committee recommends that the EPA carefully evaluate its data base on the developmental and reproductive toxicity associated with disinfectants and disinfection by-products and seek to fill the gaps. It could be that the reproductive and developmental toxicological effects are more important than other effects currently being studied.

3.2.4 Brominated and iodated compounds

Brominated compounds are important where bromine is found in the source water; e.g., situations associated with intrusion from sea water. This is especially true if ozonation or chlorination is employed. The Committee recommends that EPA carefully evaluate the information available on the toxicity of the brominated disinfection by-products with the understanding that these may have greater toxicity than the chlorinated analogs. Health data on inorganic iodated compounds are also needed. The Committee recommends that care be taken in examining the effects of iodated compounds as they relate to the thyroid function where extrapolation from high to low dose may not be valid.

3.2.5 Compounds that may not be of significant health concern

The Committee recommends that EPA carefully evaluate how much effort may go into the examination of the compounds that may not be of health concern due to low concentrations and/or short halflives; e.g., hydrogen peroxide, formaldehyde, and chloral hydrate which are highly reactive material appearing in low concentrations. Such compounds should not be ignored, but careful allocation of time, money and personnel requires putting contaminants, like these, that are unlikely to have serious health effects at the levels found in drinking water, in lower priority categories.

3.2.6 Epidemiology studies

The Committee recommends that EPA continue to pursue the collection of epidemiology information on both exposure and health consequences associated with ozonation and chloramination.

4.0 Research Recommendations Related to Chemical Characterization and Monitoring

The recommendations described here are based on the premise that chemical information concerning a specific disinfection treatment process is needed for assessing the toxicological potential in finished drinking water. This information is also needed for assessing the performance of the treatment processes against the desired operating specifications during its day-to-day usage.

The Committee recommends that the highest priority be given to the minimization of halogen-containing products in disinfection of drinking water. Chloramination is an example of a disinfection method for which potential health effects of disinfection by-products have not been studied extensively. Possible products of chloramination include a large array of chemical classes such as nitrogen mustards, N-chloro compounds, chlorouracils, nitrite ions and various nitrogen containing heterocycles which are highly potent carcinogens. Isolation, determination of structures, and development of satisfactory analytical methods for the nitrogen-containing products of chloramination will be difficult.

4.1 Highest Priority Recommendations

4.1.1 Monitoring strategy

It is recommended that the EPA reexamine the proposals for its monitoring strategy. Specifically, the Agency should determine if the proposed sampling frequencies and sites appropriately reflect the toxicological significance of disinfection by-products, as well as the disinfection potential for the active chemical species used in disinfection. With such

information, better options can be described for potential regulations.

4.1.2 In-depth chemical characterization

It is recommended that a comprehensive chemical characterization be made of the reactants and products formed from the U.S. EPA's pilot plant in Cincinnati, Ohio which employs the disinfection technology or technologies most likely to be used. In order to perform measurements on the highly polar products predicted from disinfection processes such as ozone treatment, chloramine or chlorine dioxide, state-of-the-art analytical technologies (e.g., high performance liquid chromatography/mass spectroscopy and supercritical fluid chromatography) should be employed. Techniques based on gas chromatography are not adequate for comprehensive analysis of polar chemicals.

4.2 Moderate Priority Recommendations

4.2.1 Total oxidizing substances

The Committee recommends (within the constraints of time and funds) development of an analytical technique for the determination of levels of total oxidizing substances (TOS). An analytical technique for TOS in ozonation processes may have potential as a surrogate for DBP monitoring. However, further effort should be spent to determine whether TOS is an appropriate surrogate for the toxicologically active ozonation DBP.

4.2.2 Methods development

The Committee recommends that analytical methods for measuring disinfection by-products be developed, perfected, optimized, and validated. A priority scheme should be developed

for which chemicals (e.g. monochloramine, dichloramine, trichloramine, aldehydes, N-organochloramines, halogenated acetic acids, MX (a potent mutagenic agent found in chlorine-treated water), chlorate, chlorite, and H_2O_2) should be monitored, based upon the most probable specific disinfection process system(s) to be employed at the municipalities. The use of ion chromatography to analyze chlorite, chlorate, and similar ions appears to be sound, and the Committee would be interested in seeing the specific protocols for these methods.

The Committee recommends the evaluation of the following reported methods for routine monitoring, in addition to those found in the recent report on disinfection residual analytical methods from the American Water Works Research Foundation (Gordon, Gilbert, Disinfectant Residual Measurement Methods, AWWA Research Foundation, Denver, CO, Nov., 1987):

Monochloramine, dichloramine, free chlorine

a. Aoki, T., Environ. Sci. & Tech., 23, 46-50 (1989)
b. Jensen, J.N. and D.J. Johnson, Anal. Chem., 61 991 (1989)
c. Lukasewycz, M.T. et al., Environ. Sci. & Tech., 23, 196 (1989).
d. Palin, A.T., J. Am. Water Works Assoc., 72 121 (1980)
e. Scully, F.E. et al., Proc. AWWA Water Quality Conf., 11th, 197, (1984); AWWA Research Found., Denver,CO
f. Scully, F.E. et al, Environ. Sci. & Tech., 18, 787 (1984)

H_2O_2

a. Jalkian, R.D., AD-A194307, Femtogram level determination of cobalt and chromium by luminol chemiluminescence detected by a charge detector, 5pp., NTIS (1988)
b. Van Zoonen, P. et al, Anal. Chim. Acta, 174 151 (1985)

4.2.3 Organic and inorganic bromides

The Committee recommends that methods be developed for organic (other than THMs) and inorganic compounds containing bromine because they may become more important toxicologically

than the chlorides (see section 2.2.4).

4.2.4 Use of isotopically labelled chemicals

It is recommended that bioassay studies (see section 3.2.2 above) be performed utilizing isotopically labelled chemicals for mass balance accountability (e.g. ^{13}C, ^{37}Cl, ^{15}N). It is important to trace all of the compounds which might have potential health effects and for which treatment technologies could be needed. Further, additional chemicals should be selected for study, including the catalytic impact of metals.

5.0 Research Recommendations Related to Microbial Agents

The Committee is concerned that EPA strike an appropriate balance between health risk from chemical disinfectants and their by-products, on one hand, and microbial illness that would result if the disinfection efficacy was reduced, on the other. This concern must be extend beyond the treatment plant to include integrity within the distribution system. In the view of the Committee there is inadequate research into the microbiology of the treatment and distribution drinking water.

5.1 Highest Priority Recommendations

5.1.1 Survey of selected microbiological contaminants

The Committee recommends that a survey be conducted for selected pathogens in drinking water distribution systems since the current information is inadequate to judge their relevance. The main pathogens of concern are cryptosporidium, enteric viruses, Aeromonas, and Legionella. This survey is essential, because if this type of information is not gathered, the Agency will not be able to 1) optimize disinfection to protect water quality while minimizing disinfection by-products and 2) balance the risks between microbial diseases and chemical contaminants. This recommendation is clearly a long term one, but it is important.

5.1.2 Workshop on potable water microbiology

The Committee recommends that EPA conduct a workshop similar to that held in 1981 to insure that an adequate consensus is developed concerning the state of scientific knowledge in the microbiology of potable waters. Participants should be included

from Europe and Canada where research experience in the potable water microbiology area is greater than in the U.S.

5.2 Moderate Priority Recommendations

5.2.1 Microbial risk assessment

The state-of-the art for waterborne microbial risk assessments is currently inadequate to make the needed comparison between microbial risks and chemical risks from drinking water exposures. The Committee recommends that standard methodologies be developed for estimating microbial risks of illness and mortality from exposure to pathogens in drinking water. This information should be used to develop acceptable levels of illness from microorganisms in drinking water so that this risk can be balanced against the risks of adverse health effects from chemical contaminants associated with disinfectants and DBPs. Microbial risk assessment methodologies are needed because approaches to estimating microbial risks from drinking water have received little attention, and such efforts are still in their infancy.

5.2.2 Epidemiology study

The Committee recommends that a community-wide epidemiology study be conducted to identify and quantify any health risk of consumer gastrointestinal illness associated with treated and distributed tap water due to chlorination and to quantify this risk. This study could well be done in Europe where some data are available and the necessary treatment trains are in place. This study is needed since the surface water treatment rule is based on treatment and not directly on quantified health risks of gastrointestinal illness caused by specific microbes in drinking water. Another reason this study is needed is because pilot

plant studies being done in support of the surface water treatment rule are limited to only a few studies, in which microbiological examination of the water is minimal (only one model virus indicator is being followed). Therefore, there will be a very limited scientific basis for stating that treatment plant alterations to remove precursors will not also decrease microbial disinfection efficiency, even if the current concentration times time (CT) values are retained. Further, because the proposed strawman rule is based on treatment and not monitoring, it is not necessary to isolate and demonstrate the microbe causing the disease at the tap. Source water should be monitored for a variety of important pathogens for which treatment practices are is designated.

5.2.3 Distribution system studies

Drinking water distribution systems must be recognized as specialized and unique microbial ecosystems. Therefore, it is necessary to assess the impact of alternative disinfectants and combinations of disinfectants, such as ozone, that may stimulate the growth of microorganisms because they have a significant impact on assimilable organic carbon (AOC) or more generally biodegradable organic matter (BOM). The Committee recommends that the impact of disinfection practices on the microbial flora of distribution systems and their ecology be carefully studied and understood. At least four regional studies should be initiated to examine the total microbial ecology of the distribution systems to assess the effects of treatment plant alteration on distribution system integrity. Research is needed to develop a methodology, suitable for use by water utilities and individual systems, that can describe microbial growth in the distribution system as a function of either AOC or BOM. This information should be incorporated into a guidance document for water suppliers. In addition, changes in microbial flora should

be ascertained. Specifically, the virulence of these organisms should be tested using the assay systems developed by EPA. Also, molecular techniques such as polymerase chain reaction (PCR) should be used to assess the change in frequency of certain important opportunistic pathogens such as Legionella, Aeromonas, and Pseudomonas aeruginosa in the distribution systems.

5.2.4 Parasites and viruses

The Committee recommends that research be conducted which will lead to optimized disinfection for both parasites and viruses. This should include extended data collection on CTs for a wider group of organisms and pilot plants. Pilot plant work should not be limited to one type of pathogen, but should examine groups or subgroups (i.e. male specific coliphage, ms2 phage) as potential viral indicators.

6.0 Research Recommendations Related to Treatment

The important question here is what constitutes "continued" use of free chlorine. Surveys in the late 1970s showed more than 95% of U.S. utilities using free chlorine. During the past decade free chlorine use has dropped to 75% of existing water suppliers. Far fewer would use free chlorine if DBP MCL's equivalent to a THM level of 25 ug/L are implemented. Given a THM MCL of 25 ug/L most utilities would design and operate their systems to achieve a lower average operating THM level in order to be consistently below the MCL. If the THM MCL were to be set at 12.5 ug/L, the American Water Works Association Research Foundation (AWWARF) survey suggests that about 25% of the U.S. utilities would be able to operate using their current practice. Perhaps another 5 to 10% would be able to meet the standard if efficiencies of coagulation-based precursor removal were improved from 25% to 50%. Even these numbers are probably optimistic for two reasons: a) the AWWARF survey covered only about 1/3 of the surface water supplies; and b) the data in the AWWARF survey were collected under conditions that do not meet the CT values in the Surface Water Treatment Rule. The implication is that if a DBP level equivalent to 25 ug THM/L were set, some 65 to 75% of U.S. utilities would abandon free chlorine and go to combinations such as ozone/chloramines or chlorine dioxide/sulfur dioxide/chloramines. If chloramines were not allowed, these utilities would likely install precursor removal processes such as GAC or membranes so that free chlorine could be employed and still meet the MCL for the THMs. The Committee recommends that EPA prepare estimates of the impact of the 25 ug/L and 50 ug/L scenarios and release them for public comment.

EPA does not present a sufficient basis for the expectation that an additional 50% removal of precursors can be accomplished

with alum doses of 40 to 90 mg/L and a pH of 6 or less. EPA should also gather data on other coagulants. The Committee does not believe coagulation will be shown to be equivalent to GAC treatment where precursor removal is concerned.

The AWWARF survey indicates that 75% of the utilities meet the THM level of 50 ug/L today. There are several problems with this statement besides the weaknesses of the AWWARF database. First, a large portion of those utilities not meeting the standard are large systems, and hence more than 25% of the surveyed population is exposed to levels above 50 ug/L. Second, EPA should recognize that it is not only those utilities with THMs above 50 ug/L who must modify treatment. Most utilities with THM levels within a factor of two from the standard will undertake changes in order to have a reasonable factor of safety where the standard is concerned. In addition, many utilities treating surface water will require more disinfection to meet the new Surface Water Treatment Rule, aggravating the problem further. Thus a much larger fraction of the industry and an even larger fraction of the nation's treatment capacity will be affected. It is recommended that EPA conduct a more complete survey of U.S. drinking water industry.

Coagulation enhancement will only allow THM levels of 25-50 ug/L to be achieved in 10 to 15% of the cases. It is not clear that the adverse health impacts of mineralization (aluminum from alum and calcium or sodium from lime and/or caustic) are any more desirable than DBP precursors.

Treatment involved in the control of disinfection by-products involves many different possible approaches. Among the most promising precursor removal techniques are conventional coagulation treatment for water for general contaminants, granular activated carbon filters, and membrane filters.

Research is needed in these areas, as well as in the areas of alternative oxidants. The needs in these different areas are discussed below.

The highest priority research efforts in the treatment area are:

a. Removal of ClO_2 DBP by SO_2 or GAC as described in 6.2
b. The above mentioned industrial survey
c. Evaluation of precursor removal by membranes (6.1.3) or GAC (6.1.2) if the THM MCL is 25 ug/L or support conventional treatment if the THM MCL is higher (6.1.1).

All other proposals are of moderate priority.

6.1 Precursor Removal

Although it is unclear at this time what, if any, part of the regulation will involve precursor removal, this is an important area and the possible treatment techniques need to be better developed.

The stated goal of removal of 50% of precursor material will only be of marginal assistance in meeting a new, and possibly tougher, regulation. Removals of 90 to 95% are required if many utilities are to meet DBP levels equivalent to a trihalomethane (THM) level of 25 to 50 ug/L when free chlorine is used. Research should be aimed at producing these higher removal rates.

6.1.1 Conventional treatment modifications

Enhanced coagulation is the principal modification to conventional treatment that can be expected to increase precursor removal. As most water treatment plants on surface water supplies already achieve 20 to 30% removal of precursors, an enhancement to 50% will result in some improvement. A better information base is required to make sound judgments concerning

the extent of precursor removal that is achievable through coagulation techniques. It is important that a sound judgment be made because, as coagulation facilities are often already in place, removal of precursors by coagulation will appear to be convenient and economical. The Committee recommends the following actions to provide a sound basis for possible regulation:

a. Survey several existing water treatment plants which are currently using coagulation as a technique for color removal for disinfection by-product concentration levels. Since DBP precursors and color are thought to derive from aquatic humus, it seems reasonable to assume that these plants are nearly optimized for removal of precursors as well as color. A survey of such plants will give EPA a first hand grasp of removal rates that are achievable with high-humus waters, with important design features and with operational experiences that are encountered in a full scale plant of this type. There are many highly colored waters, but water treatment plants removing color by coagulation are not common, suggesting that design and operating details may deserve some scrutiny.

b. Conduct studies of precursor removal from a variety of water qualities using a standardized, bench scale jar test. These studies will allow EPA to systematically characterize the variation in performance of coagulation in removing precursors from different water qualities. From these studies it could be determined if 50% is a reasonable expectation for most locales.

c. Use available data on THM levels in and treatment practice at drinking water utilities in order to estimate the

impact of broad-scale adoption of enhanced coagulation on DBP levels.

d. Conduct pilot scale studies of enhanced coagulation at the Cincinnati pilot plant to determine if it is possible to achieve DBP levels equivalent to THM levels of 25 to 50 ug/L. EPA should then transport their portable pilot plant to sites with higher precursor levels and do similar work at those sites. These pilot activities will give EPA's research staff a first hand feel for the details of the process and its transferability from one site to the next.

e. Work with several U.S. utilities to conduct full-scale tests of the performance of coagulation in removing THM precursors on a variety of water qualities with a variety of coagulants.

f. Examine the impact of acidification, high levels of coagulation addition, and final upward pH adjustment on the mineral quality of the product water.

g. Examine the effectiveness of alternative coagulants such as ferric salts, poly aluminum chloride, and polymers to reduce disinfection by-product levels.

6.1.2 Granular activated carbon

The Committee recommends that EPA consider a broad range of alternatives be studied for the use of granular activated carbon (GAC) in precursor removal. Possible approaches include replacement of existing filter media with GAC, use of engineered filter-absorbers with longer contact times, or use of filter-adsorbers and post-filter adsorbers with regeneration. Depending

on their design criteria and how they are operated, these alternatives represent a wide range of costs and performance. The Committee recommends the following actions to obtain additional information to allow better prediction of likely national experience for GAC:

a. Survey the experience of precursor removal at existing U.S. GAC filters operating without a chlorine residual in the GAC influent. Such a survey could provide direct input on the performance of GAC processes of modest design. Because chlorination is so common in the U.S., it may be necessary to ask some utilities to change their operations temporarily to get the necessary data.

b. Survey precursors in water from European plants using GAC with and without regular regeneration and with and without preozonation. Such a survey cannot just be a gathering of European operating data, but must be a sampling survey where samples are analyzed by a standard formation potential test, such as Method 5710 in the 17th Edition of Standard Methods.

c. Survey GAC performance in several U.S. water supplies using a minicolumn test to be used along with modelling to predict the spectrum of responses that can be expected for precursor removal around the country. These tests should include some of the very high total organic carbon (TOC) level waters found in the Southeastern U.S. Such test data would represent a conservative view of performance because minicolumn tests, being short-term, operate only via the adsorption mechanism and the test results will not show the benefit of any additional removal that occurs in full-scale facilities due to biological removal.

d. Conduct research to determine the potential for precursor removal by biological oxidation in GAC or other porous support media, so that GAC does not have to be regenerated. Special attention should be given to processes that reduce the TOC component of the chlorine demand of the water.

6.1.3 Membranes

The Committee recommends that EPA examine closely whether membrane processes should be considered as best available technology (BAT). Although plants using the new low pressure membranes, which are most cost effective for precursor removal, do not exist at large scale facilities, there are more than 100 reverse osmosis plants in the U.S. Not only are these plants almost identical in design to their low pressure counterparts (they have larger pumps and a different membrane material, but have the same physical configurations), they also exhibit substantial precursor removal rates. The Committee recommends the following actions;

a. Visit several U.S. reverse osmosis plants and develop a summary of U.S. experience in the reduction of DBP, including measurements of performance levels where total organic carbon removal is involved.

b. Consider carefully whether existing pilot scale data, combined with the results of the upcoming one year test at Daytona Beach will be sufficient, when combined with experience involving full-scale conventional reverse osmosis, to meet the Safe Drinking Water Act's "full scale experience" clause.

c. Meet with membrane manufacturers and invite them to share information and data. Membrane technology is a rapidly developing field led by a small number of U.S. companies. EPA should meet with the leadership of these companies, give them useful information on the precursors to be removed (e.g. molecular weight, structure, surface active groups, etc.), tell them about EPA's regulatory needs, and invite them to produce membranes "tailored" to precursor removal.

6.2 Alternative Oxidants

Three areas of research effort are important in regard to alternative oxidants to chlorine. These areas include the use of chlorine, chloramines and chlorine dioxide. The magnitude of the proposed MCL for trihalomethanes and others will strongly influence the direction different public water supplies are likely to take.

The idea that chlorine dioxide and chlorite ions could be chemically reduced is attractive. It makes the $ClO_2/SO_2/NH_2Cl$ option a lower capital cost alternative to O_3/NH_2Cl. This reduction of ClO_2 and ClO_2^- via SO_2 has been demonstrated in the laboratory and via GAC in the laboratory and in the field.

The capacity of GAC for removing chlorine dioxide and chlorite under a variety of operating conditions is poorly understood, and using GAC for their removal is likely to be expensive if it controls GAC replacement frequency. At the same time a great deal of work must be done with SO_2 reduction before the influences of pH, temperature, contact time, etc. are well understood. The Committee recommends looking to the European experience for more information on GAC and SO_2 treatment. The Committee recommends the following actions to address these

issues:

a. Study ClO_2 and ClO_2^- removal via GAC on the plant-scale in a variety of water qualities. There is a need to know how effective this process is, the conditions under which it is effective, and how long a given bed of GAC can be expected to perform.

b. Conduct laboratory studies to characterize the effect of pH, temperature, contact time, and other parameters on the $SO_2/ClO_2/ClO_2^-$ redox reactions. Once this is done, full scale studies should be conducted to examine the process in a variety of water qualities.

c. Investigate the possibility of producing chlorate-free chlorine dioxide under typical plant operating conditions. In principle, methods for generating chlorate-free chlorine dioxide are available.

d. Distribute ion chromatography-based analytical methods for ClO_2^- to interested parties so that broader experience can be gained.

NOTICE

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