

New Jersey
Department of Environmental Protection
DIVISION OF WATER RESOURCES

*Prevention and Removal of
Chlorination By-Products from
Drinking Water*

November 1988

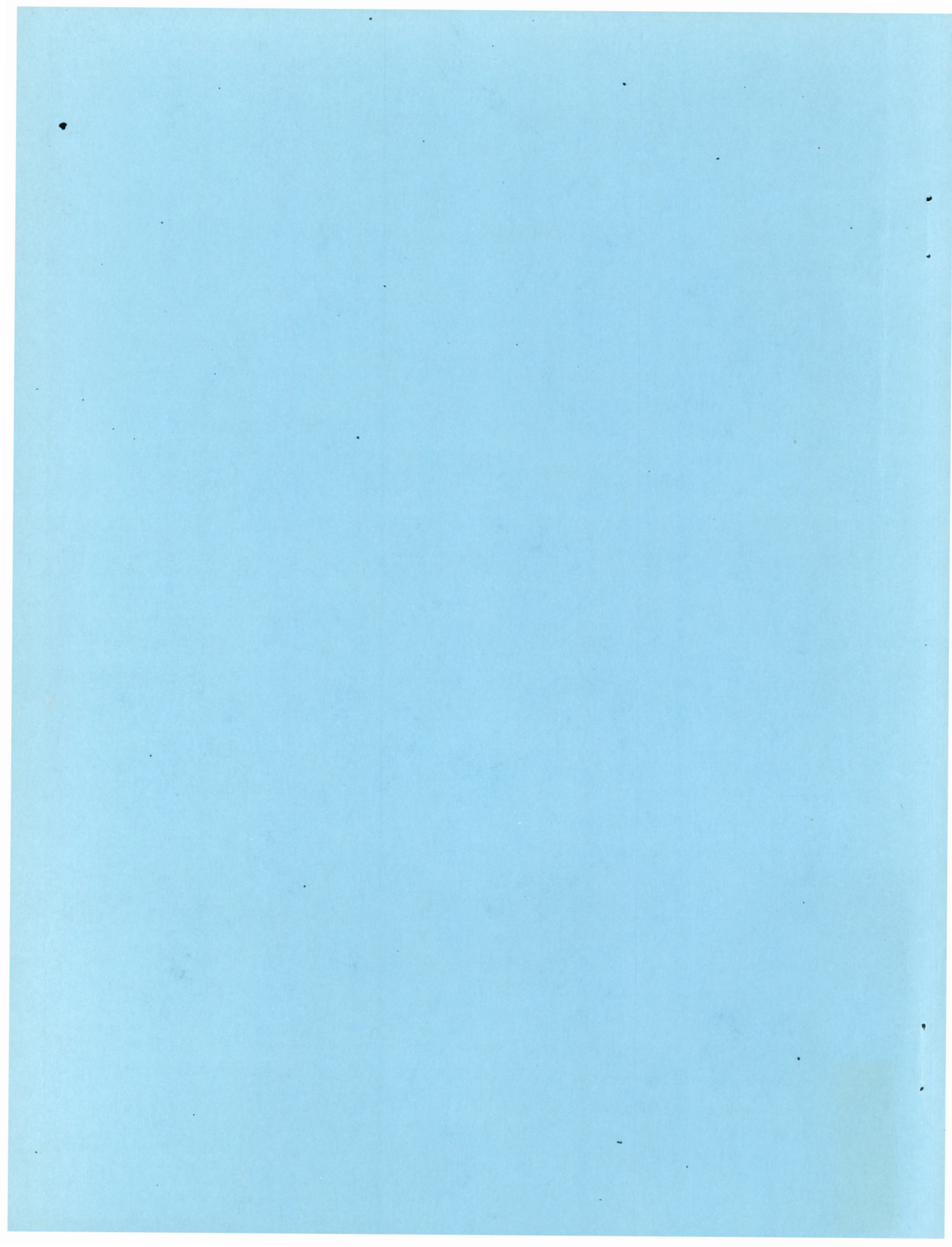


SUMMARY AND CONCLUSIONS

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Camp Dresser & McKee Inc.
EDISON, NEW JERSEY



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7.0 SUMMARY AND CONCLUSIONS

Free chlorine is widely used in water treatment because it is versatile effective, and inexpensive. Chlorine has a long history of use as a disinfectant, and sometimes is used to reduce taste, odor, and color in untreated water. In the United States, chlorine is the most widely used disinfectant.

Health effects research has indicated that use of chlorine in water treatment can lead to the formation of compounds that may be carcinogenic in humans. These compounds are generally referred to as chlorination by-products. Of major concern are a class of chlorination by-products called trihalomethanes (THM). Their presence in waters treated with free chlorine is pervasive.

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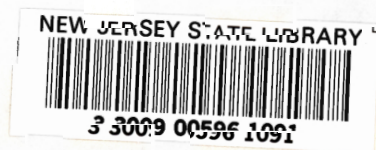
7.1 LOWER STANDARDS CONTEMPLATED FOR DISINFECTION BY-PRODUCTS

The federal government now limits the level of THMs in drinking water to 0.10 milligrams per liter (mg/l). The U.S. Environmental Protection Agency (EPA) will eventually promulgate an even lower standard for THMs as a consequence of the 1986 Amendments to the Safe Drinking Water Act.

The New Jersey Department of Environmental Protection (NJDEP) is also expected to issue revised statewide standards. NJDEP is considering a maximum contaminant level (MCL) that would limit total THMs in drinking water to as low as 20 micrograms per liter (mcg/l) and any single THM to 5 mcg/l. This level of regulation would be more stringent than the present federal limit.

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This study addresses the feasibility of implementing the more stringent levels contemplated by NJDEP. It also provides information to NJDEP on the extent of THM presence in drinking water supplies in the state, on available technologies and associated costs for THM reduction, and on any anticipated obstacles to control of THMs. NJDEP will use this information to guide policy decisions regarding the control of THMs.



7.2 FEASIBILITY OF MEETING STRICTER STANDARDS

Available information on the prevalence of chlorination by-products in New Jersey drinking water supplies was supplemented with a questionnaire survey of New Jersey water purveyors. This information was used to help evaluate the feasibility of meeting the stricter standards for THMs. (Pertinent findings are presented in section 2.0.)

Ground Water Purveyors

Trihalomethane levels in treated ground water have generally been very low, typically below 10 mcg/l in New Jersey. Ground water purveyors should be able to meet the suggested standards with little or no modifications to current treatment processes.

Surface Water Purveyors

Chlorination by-products are pervasive in New Jersey drinking water supplies taken from surface sources. Most purveyors of treated surface waters will have to make substantial changes in their water treatment practices in order to meet the stricter standards. They will need information on the feasibility of compliance, methods to achieve compliance, and the costs of compliance in order to achieve this goal.

The ability of treatment plants to control formation of chloroform is a useful yardstick for measuring the feasibility of compliance. Chloroform is the largest component of the THMs formed by use of chlorine to disinfect surface water supplies in New Jersey. Experience with treatment of surface waters from river basins throughout the Northeast confirms this finding. Formation of chloroform predominates, under different treatment schemes, and in different drainage basins. It also has been observed that, regardless of the concentration of total THMs, chloroform tends to predominate.

Thus, a purveyor's ability to meet the 5 mcg/l standard for chloroform is a valid measure of the ability to comply with the most stringent contemplated standards. The 5 mcg/l standard for any individual THM represents a more

restrictive condition than the 20 mcg/l standard for total THMs. Under the regulatory framework being suggested by NJDEP's Drinking Water Quality Institute, the total THMs will very likely remain under the 20 mcg/l standard if the standard of 5 mcg/l of chloroform is adhered to. It can be expected that total THM values between 6 mcg/l and 15 mcg/l will be found throughout the state if the regulation is implemented and complied with.

7.3 IMPLICATIONS FOR PURVEYORS

The current level of knowledge of THM formation in New Jersey surface water treatment plants is not yet complete enough to address all of the implications of stricter regulations on water purveyors. At this time, it is possible to provide only general recommendations to guide surface water purveyors in meeting lower standards. Evaluation of individual treatment plants, possibly including pilot plant studies, and site-specific solutions will be required.

Generally, THMs can be controlled by reducing THM precursors before the THMs are formed, or by using treatment to remove the THMs after they are formed. THM formation can be reduced by using alternatives to chlorine, by making changes in existing water treatment practices (such as moving the point of disinfection), and by using different treatment processes.

Use of Alternatives to Chlorine

A number of possible alternatives to chlorine -- ozone, chlorine dioxide, chloramines, and potassium permanganate -- are available to water purveyors. (The disinfection properties, historical use, and practical concerns purveyors will have to consider before using these alternative disinfectants are presented in section 3.)

Use of potassium permanganate as the primary disinfectant is not recognized as an acceptable practice by NJDEP and most other state authorities. In addition, the National Research Council characterizes potassium permanganate as a poor bactericide. There is no reliable data on its effects on

viruses or protozoan cysts. For these reasons, potassium permanganate is not a viable alternative to chlorine for disinfection.

Future minimum standards for disinfection will have to be considered by purveyors in determining which of the three remaining alternative disinfectants discussed here are applicable to a specific treatment situation. Under new regulations to be proposed by EPA, a purveyor attempting to address proposed THM standards will not be able to arbitrarily reduce the level of disinfectant dosage or the contact time without considering the new disinfection standards.

These new disinfection standards will further constrain the purveyors' use of alternative disinfectants to meet proposed THM standards. Based on review of the proposed regulations, the following assessment was made regarding the applicability of the alternative disinfectants:

Chloramines: The use of chloramines for the principal deactivation step will probably be impractical considering proposed EPA regulations. However, increased use of chloramines as a post-disinfectant is likely.

Chlorine dioxide: Because of the toxicological effects of inorganic by-products of chlorine dioxide -- chlorates and chlorites -- the federal government recommends that the maximum dosage be limited to 1.0 mg/l. Coupled with this limit on dosage, the regulations under consideration by EPA make chlorine dioxide difficult to use as a primary disinfectant, except where contact times of relatively long duration are possible.

Ozone: Although it does not leave a lasting residual, under many circumstances ozone will be ideal for the principal deactivation step. Ozone can also have a beneficial effect on filtration due to its tendency to provide microfloculation. However, the costs are higher than other approaches for smaller plants.

Treatment for Removal of THMs

Several treatment processes -- coagulation, modification of chlorination practices, pH adjustment, activated carbon adsorption, reverse osmosis, and air stripping -- were evaluated for their ability to remove THMs, or to

remove THM precursors before THMs are formed. While many of these processes can reduce THM formation, none would be capable of practically achieving sufficient THM reduction if use of free chlorine as the primary disinfectant continued.

Process changes can certainly help in meeting the contemplated standards. With use of free chlorine, however, it is generally very difficult to reduce trihalomethane formation potential to a level that insures consistent compliance with the standards contemplated, particularly for any single THM.

If traditional approaches to treatment are maintained in New Jersey, facilities treating water from a surface supply probably will not be able to meet a standard of 5 mcg/l of chloroform with the use of free chlorine as the principal disinfectant. Although it may be possible, under some circumstances, to use free chlorine for postdisinfection, in most cases the use of free chlorine would be totally precluded.

Need for Alternative Strategies

No single panacea exists for control of THMs. The problem is too complex for simple solutions. It would not be sufficient, for example, to simply replace chlorination with another method of disinfection. Rather, strategies combining use of alternative disinfectants, changing the point of disinfection, or modifying the treatment process are called for.

Purveyors must meet all drinking water standards -- for organics, inorganics, and microbiology. Methods for meeting standards in one area may impact on the ability to meet standards in another. For example, a common remedy to improve the bacteriological quality of water is to increase the dosage of chlorine. But this will almost certainly result in increased levels of THMs. The answer lies in devising a strategy that addresses all drinking water standards. (These strategies are addressed in detail in sections 3 and 5.)

General Guidance for Meeting the Contemplated Standards

Operating treatment plants in New Jersey could, with treatment and process changes, meet the suggested THM standards. As general guidance for achieving compliance, two treatment strategies are recommended:

1. Use of ozone as the principal disinfectant
2. Use of chloramines or, possibly, chlorine dioxide, as a postdisinfectant to provide a disinfectant residual in the distribution system

Because 10 percent free chlorine typically remains after onsite generation of chlorine dioxide, it would be necessary to insure that the low-level free chlorine would not result in generation of chloroform in excess of 5 mcg/l or total THMs in excess of 20 mcg/l.

7.4 HEALTH RISKS OF DISINFECTION BY-PRODUCTS

Of major concern are the health effects of by-products of all disinfectants. It is apparent from review of the existing literature that no disinfectant can, at this time, be considered entirely free of health risk. To put the risk in perspective, however, it should be noted that disinfection of public supplies has successfully curbed many major diseases of mankind. (The current state of knowledge concerning these health effects is summarized in section 4.0.)

Nevertheless, it is necessary to ascertain and to minimize the risks of the various disinfectants. The risks from chlorination by-products have been identified and steps are now being taken to minimize those risks. Similar steps have been taken to minimize risks from the by-products of chlorine dioxide. But the by-products and health effects of ozone are still relatively unknown. While preliminary indications are that the health effects of ozone are minimal, further research is needed.

The next step is to identify, through epidemiological and chemical research, the full risks of disinfection by-products and to place appropriate controls on these risks.

7.5 RECOMMENDATIONS FOR FUTURE WORK

Based on the results of this study on the prevention and removal of chlorination byproducts from drinking water, a series of future investigatory areas emerged as potentially significant. Future work should be accomplished in three separate areas. Watershed analysis, distribution system effects and treatment alternatives. Specific topics are as follows:

- o Evaluate specific seasonal effect on THM formation by correlating watershed runoff quality to formation potential. Some water purveyors maintain watershed records that provide water quality data at specific locations.
- o Evaluate the concept of developing a mobile DEP pilot trailer that can be moved to various locations to conduct bench scale studies on ozonation and other alternative disinfectants.
- o Evaluate and fractionate (laboratory) TOC into separate molecular weight groupings to better understand how THMFP may be related to TOC fraction.
- o Evaluate the effect of polymer addition in a water plant and the subsequent effect on THM formation with chlorination.
- o Determine the changes in THM formation that occur in distribution systems as related to pipe age, biological condition; material flow time, etc. If very low THM levels, distribution system condition may have a significant effect.
- o The effect on THM formation of rechlorination and storage (in a distribution system) should be explored. Some water purveyors purchase chlorinated water which has one level of THM's and then rechlorinated. The effect of multiple chlorination steps should be studied.
- o Bench, pilot and full scale studies should be conducted in the field to evaluate alternative disinfectants. Actual performance can then be determined.

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