PRELIMINARY ASSESSMENT OF SUSPECTED CARCINOGENS IN DRINKING WATER

•

REPORT TO CONGRESS

U.S. ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

DECEMBER 1975

PRELIMINARY ASSESSMENT OF SUSPECTED CARCINOGENS IN DRINKING WATER

REPORT TO CONGRESS

Compiled by
Office of Toxic Substances
Environmental Protection Agency
Washington, DC 20460
December 1975

LIBRARY
U.S. ENVIRONMENTAL PROTECTION
N. J. 08817

PREFACE

This Report is in response to the mandate of the Public Health Service Act as amended by the Safe Drinking Water Act (PL 93-523) that the Administrator of the Environmental Protection Agency make "a comprehensive study of public water supplies and drinking water sources to determine the nature, extent, sources of and means of control of contamination by chemicals or other substances suspected of being carcinogenic" (Section 1442(a)(9)). Accordingly, the Report presents the current programs of EPA to identify the nature and extent of the contamination of the Nation's drinking water with carcinogens, to determine the possible health effects of exposure, and to develop the technically and economically feasible means of removing those contaminants of concern.

An interim Report and supporting Appendix were submitted to Congress in June 1975, with the understanding that the Report would be updated to incorporate results of subsequent research and include appropriate recommendations. This Report satisfies that understanding. The material presented in the Appendix to the June Report has not been repeated in the Appendix accompanying this Report. The June Appendix, however, contains much detailed information concerning research methodologies and other material relevant to both Reports.

Section 1442(a)(9) instructs the Administrator to provide "such recommendations for further review and corrective action as he deems appropriate." The recommendations presented in the Report should be considered preliminary, however. Only the first phases of research have been completed and many investigations are underway within EPA and other Federal agencies.

The Report is organized into a General Overview, five Sections, and Appendices. The first Section discusses the nature and occurrence of carcinogenic contaminants in drinking water. The second Section deals with the known health effects of these contaminants and efforts underway to clarify these potential health hazards. The third Section outlines the studies underway to determine the sources of these contaminants. The final two Sections deal with treatment techniques for controlling drinking water contaminants and the estimated costs of these treatment processes. The Appendices present the results of several monitoring surveys for drinking water contaminants, a selected list of references, and a list of primary contributors.

TABLE OF CONTENTS

PREFACE i

GENERAL OVERVIEW 1

Introduction 1

Activities and Results to Date 3

Recommendations 5

CHARACTER AND EXTENT OF CONTAMINATION OF DRINKING WATER 7

National Organics Reconnaissance Survey 7

Region V Organics Survey 12

Assessment of General Organic Parameters 13

Inventory of Organics Identified in Drinking Water 15

Investigations of Pesticides in Drinking Water 16

Analyses for Polychlorinated Biphenyls 17

Studies of Leaching from Polyvinyl Chloride (PVC) Water Pipes 17

Detection of Nitrosamines in Drinking Water 17

Surveillance for Inorganic Contaminants in Drinking Water 18

Occurrence of Radioactivity in Drinking Water 20

Survey of Rural Drinking Water Supplies 21

Analyses for Asbestos Fibers in Drinking Water 22

HEALTH EFFECTS OF DRINKING WATER CONTAMINANTS 25

Review of Drinking Water Contaminants by the National Academy of Sciences 25

Development of Quality Criteria for Water 26

Other Investigations of the Health Effects of Organics 26

Epidemiological Studies 30

Evaluation of Health Risks from Inorganics 31

Estimate of Risk from Radiation 32

Assessment of Effects of Oral Ingestion of Asbestos 32

SOURCE IDENTIFICATION 35

Industrial Sources 35

Discharges from Municipal Waste Treatment Facilities 36

Chlorination of Drinking Water 37

Contamination by Agricultural Chemicals 38

Other Non-Point Sources of Organics 39

Various Land Disposal Practices and Water Contamination 39

TREATMENT TECHNIQUES FOR CONTROLLING CONTAMINANTS IN DRINKING WATER 40

Overview of EPA Treatment Program 40

Techniques for Controlling Organics 40

Treatment Studies on Inorganics 45

Techniques for Controlling Radionuclides 45

Methods of Removing Asbestiform Fibers 46

COST OF TREATMENT TO REMOVE CARCINOGENS 47

General Cost of Water 47

Cost of Removing Carcinogenic Contaminants 47

APPENDICES

Appendix I - National Organics Reconnaissance Survey

Appendix II - Organic Compounds Identified in Drinking Water

Appendix III - Analyses of Radioactivity in Interstate Carrier Water Supplies

Appendix IV - Environmental Radiation Monitoring System Survey (1974)

Appendix V - Organics Survey in Region V

Appendix VI - Survey for Pesticides, PCBs, and Phthalates in Region V

Appendix VII - Selected References

Appendix VIII - List of Primary Contributors

GENERAL OVERVIEW

Introduction

Under the Safe Drinking Water Act (PL 93-523), the Environmental Protection Agency (EPA) has the task of ensuring that the nation's drinking water is safe. This task is formidable as many factors involved in determining whether drinking water is "safe" are far from resolved.

Some of the principal problems facing EPA in the control of the quality of the nation's drinking water are pressing the limits of current research capabilities in health, science, and technology. Regulatory decision making is further compounded by the dearth of definitive information, and the lack of agreement within the scientific community, on such questions as identification and characterization of carcinogens, significance of human exposure to minute quantities of potentially hazardous substances, and interpretation of results of high dose animal exposure tests in relation to human experience. EPA is trying to answer a variety of questions in the areas of hazard evaluation, epidemiology, and analytical and treatment technology development. These questions include:

1. Which compounds occur in a sufficient number of locations and in sufficient quantity to warrant possible regulation?

2. What are the effects of those compounds on human health?

3. What analytical procedures are needed to monitor finished water supplies to assure compliance with regulations?

4. What changes in treatment practices are required to minimize the formation of these compounds during transport, storage, treatment and distribution?

5. What treatment technology can be applied to reduce contaminant levels to concentrations specified in regulations?

6. What are the National and local costs of regulations?

Only within the last few years has instrumentation sophisticated enough to measure very small quantities of contaminants been applied to drinking water. Despite recent intensive efforts, investigations to date have only identified a small fraction of the contaminants present. Further, extensive additional research is necessary to determine the health effects, if any, of ingesting these substances occurring at concentrations near the microgram per liter (parts per billion) level.

Work is proceeding to provide the answers to many of those questions. The specific activities underway or planned and the progress to date are discussed in this Report.

Before the enactment of the Safe Drinking Water Act (PL 93-523) on December 16, 1974, the Federal Government's program in this area was limited primarily to preventing the spread of communicable diseases resulting from drinking water in interstate commerce. Under the authority

of the Public Health Service Act, EPA assists in the enforcement of regulations that require interstate carriers to utilize only water from sources that are in compliance with certain required drinking water standards. This authority, however, affects only 700 of an estimated 240,000 public water systems. Moreover, these drinking water standards focus on microbiological contaminants associated with waterborne diseases such as typhoid fever and cholera and do not provide legally enforceable limits for chemical contaminants associated with carcinogenic or other toxic properties. The Federal Water Pollution Control Act (PL 92-500) has had some limited effect in protecting underground drinking water supplies and is gradually improving surface waters by requiring monitoring and limiting discharges as specified in permits issued under the National Pollution Discharge Elimination System. The authorities in that Act, however, have proven inadequate to ensure the safety of all sources of drinking water.

A 1969 survey showed serious deficiencies such as the lack of trained operators and adequate surveillance and monitoring programs in over one-half of the water supply facilities investigated. Reported outbreaks of disease and poisoning attributed to drinking water allegedly resulted in thousands of illnesses and some deaths. Further, the possibility of chronic health effects resulting from the presence of organic chemicals, asbestos, and heavy metals in drinking water indicated the need for additional authority to address this problem. To a great extent, concern over these substances and their potential carcinogenic effects prompted the passage of the Safe Drinking Water Act.

The primary responsibility to operate and maintain safe drinking water systems remains with the water supplier. Under the Safe Drinking Water Act, EPA is required to prescribe national drinking water regulations for contaminants that may adversely affect health. The local utility is then required to monitor its water and to give public notice if the water fails to meet the drinking water regulations. To the maximum extent possible, State Governments are to be responsible for enforcing the regulations and for providing necessary technical assistance to the local utility.

Pursuant to Section 1412(a)(1), EPA promulgated Interim Primary Drinking Water Regulations in December 1975 to be effective in mid-1977. Maximum contaminant levels are prescribed for microbiological contaminants, certain organic pesticides, selected inorganic chemicals, and turbidity. Maximum contaminant levels for radioactivity were proposed in August 1975 and should be promulgated in early 1976. Because the Interim Primary Drinking Water Regulations do not contain maximum contaminant levels for organic chemicals other than certain pesticides, EPA concurrently published Special Monitoring Regulations that will provide a national evaluation of the presence in drinking water of approximately 20 specific organic chemicals and simultaneously attempt to correlate their presence with several general organic parameters. The results of this survey, anticipated by the end of 1976, should provide the basis for establishing maximum contaminant levels for additional specific organic contaminants that are found to be widespread or for a general organic parameter(s) that may be incorporated in the Primary Drinking Water Regulations, or both.

Activities and Results to Date

Section 1442(a)(9) directs the Administrator to report to the Congress on the contamination of drinking water by substances suspected of being carcinogenic. Although the criteria for predicting the carcinogenic potential of chemicals have been reviewed extensively during the last decade and many experts have agreed on certain guidelines, no official concensus exists as to what evidence is required to categorize a substance as "carcinogenic". This Report considers a large number of chemicals in addition to those that have been demonstrated as human carcinogens. No attempt is made to distinguish among the various degrees of evidence of carcinogenicity that apply to different "suspect carcinogens."

In the past year, EPA has undertaken an extensive program to characterize the nature of drinking water problems. One step, initiated in November 1974, was the National Organics Reconnaissance Survey designed to provide an estimate of the nationwide distribution of organics in drinking water. Other projects have involved sampling and analysis of drinking water for selected inorganics, pesticides, asbestos, and radioactivity. Several studies are underway to investigate the toxicity of these substances when ingested. Still other efforts are designed to identify the sources of these contaminants and various treatment techniques effective in removing them.

Organics

November 1975 data identify 253 different specific organic chemicals in drinking water in the United States. The occurrence of these compounds in drinking water suggests that other organics not yet identified may also be present, and that the total number of compounds could be considerably larger. The range of concentration for individual organics was from a high of 366 μg/ℓ for chloroform (based on EPA Region V's survey) to a low of 0.001 μg/ℓ for dieldrin. Another analytical procedure that approximates the total organic carbon content showed concentrations ranging from below the level of detection (0.05 mg/ℓ) to over 12 mg/ℓ.

The majority of chemicals identified in drinking water have not been examined for potential carcinogenicity, although some have been classified as carcinogens or suspected carcinogens by bioassay experiments. On the other hand, even in the case of recognized carcinogens, the actual risk posed by ingesting very low concentrations is not known at this time.

Among the identified sources of these chemical compounds are industrial and municipal discharges, urban and rural runoff, natural sources, and water and sewage chlorination practices. Water treatment techniques involving modification of current processes, use of adsorbents such as granular activated carbon, or the use of oxidants such as ozone, are being investigated for their value in reducing the concentration of organics. Research is underway to develop the most cost effective treatment technology.

Inorganics

Several inorganic chemicals might be carcinogenic in drinking water under certain circumstances: arsenic, beryllium, cadmium, chromium, nickel, selenium, and nitrogenous compounds (possible nitrosamine precursors). Research is underway to determine the occurrence of these and other inorganics that may prove to be carcinogenic. A 1969 study found that a small percentage (two percent or less) of drinking water supplies sampled contained levels of arsenic, nitrate-nitrogen, and selenium that exceeded the limits in the U.S. Public Health Service Drinking Water Standards. Treatment technologies are available for the control of all three, although selenium in its oxidized form can only be removed by reverse osmosis, a rather expensive process at the present time.

Radionuclides

The presence of radionuclides in drinking water results from natural contamination, primarily from ground waters flowing through radium bearing geological formations, and from man's activities. These activities may release naturally occurring radioactivity into the environment, through phosphate and uranium ore mining operations, for example. In addition, man-made radioactivity may enter from various sources such as nuclear tests, nuclear power generation, and the use of radionuclides in hospitals, scientific research, and industry. Several treatment techniques, including lime softening, ion exchange softening, and reverse osmosis, are effective for removing radium 226.

Recent monitoring data from interstate carrier water supply utilities indicate that the average concentrations of radium 226 were 0.28 pCi/ℓ (46 samples in 1975); strontium 90, 0.82 pCi/ℓ (46 samples in 1975); and tritium, 200 pCi/ℓ (71 samples in 1974). Of these samples, 22 to 59 percent contained radionuclides below the detection limit of the analytical method used. Following the recommendation made by the National Academy of Sciences, EPA bases its estimates of the health effects of radiation exposure through ingestion of drinking water on the assumption that no harmless dose level exists and that health effects will be proportional to the radiation dose delivered by drinking water.

Asbestos

Over one-half of the 63 drinking waters tested had asbestos fiber counts so low that they could not be quantified by the analytical method used. Nine had fiber counts in excess of 500 thousand fibers per liter and five had counts in excess of one million fibers per liter. In order to clarify the effects of ingested asbestos, several studies are underway to examine various aspects of this problem: asbestos absorption in the gastrointestinal tract, possible correlation between cancer incidence and asbestos in drinking water, and toxicology of ingested asbestos in rats.

Techniques for the removal of asbestiform fibers have been demonstrated in pilot plants in Duluth, Minnesota. Pursuant to this research,

the city of Duluth is constructing a full-scale water treatment plant for fiber removal. Because the health effects of ingesting asbestos are not fully understood, a maximum contaminant level for asbestos is not included in the Interim Primary Drinking Water Regulations.

Recommendations

Although recent efforts outlined in this Report have dramatically enhanced our understanding of the problems associated with drinking water contamination, they represent only the beginning of the research needed to assess confidently the character, extent, and health implications of drinking water contaminants and the most cost-effective approach to control them. The following general recommendations are presented to identify the major areas of future research needs.

Future Monitoring

In order to address the problem of drinking water contamination, additional research is needed to clarify the nature and extent of the contamination. Although the National Organics Reconnaissance Survey in 80 locations was important in that it indicated that chlorinated by-products were found in all the finished waters of the chlorinating water utilities investigated, its focus was limited to six volatile contaminants. The more comprehensive organic analyses in ten cities were not extensive enough to demonstrate conclusively that the environmental contamination found was likely to be present nationwide. The expansion of this survey is critical to provide data on the qualitative and quantitative occurrence of selected compounds and of total organic chemical concentrations in water supplies representing a wide distribution of geographical areas and various types of raw water sources. Such information is a prerequisite for promulgating maximum contaminant levels for specific contaminants, or for establishing a general organic parameter(s), or both. As discussed later in the Report ("Monitoring to Assess Parameters"), an expanded survey is about to be initiated. Ongoing surveillance programs directed to organics, inorganics, asbestos, and radioactivity in drinking water may show the need for further research.

Health Effects Research

Several projects are underway to examine the health effects of compounds found in drinking water. The results of these studies will provide information needed to assess the health risks associated with exposure to these contaminants. As emphasized by EPA's Science Advisory Board, additional health effects research is greatly needed. Specifically, EPA feels that long-term animal laboratory and epidemiological studies of the effects of various concentrations of specific contaminants are needed. Likewise, various epidemiological studies relating exposed populations to known common patterns of water contamination are important to clarify the health risks involved. Although some epidemiological studies are in progress, they are limited by inadequate data concerning the presence of various contaminants, estimates of populations at risk, and the accuracy of morbidity and mortality data.

New Analytical Methodology

When the drinking water regulations are in effect, monitoring will be required for each regulated contaminant or parameter. Research will be initiated to make existing surveillance and analysis methodologies practical or to develop new ones. In particular, methods to monitor the effectiveness of contaminant removal unit processes are needed.

Water Treatment Research

Research is continuing to develop treatment technology capable of reducing exposure to environmental contaminants to acceptable concentrations. Water treatment plant studies are now planned to test the effectiveness of certain treatment techniques developed in the laboratory. Methods of curtailing or eliminating potentially harmful contaminants are being investigated while the needed health effects research is taking place.

Future Regulation

An extensive study of possible drinking water contaminants by the National Academy of Science (NAS), mandated by Section 1412(e)(1), should be completed in about one year. EPA will consider these NAS findings in developing Revised Primary Drinking Water Regulations. Other revisions will be made as additional data on the presence and effects of various contaminants indicate that such revisions are warranted to protect the public health. These will include amendment of the Interim Primary Drinking Water Regulations prior to their June 1977 effective date if adequate data become available.

CHARACTER AND EXTENT OF CONTAMINATION OF DRINKING WATER

On April 18, 1975, EPA announced the preliminary results of a nationwide survey for organics in drinking water. This National Organics Reconnaissance Survey is one of several efforts underway to investigate the possible problem of suspected carcinogens in drinking water. Another investigation is focusing on whether drinking water contains significant quantities of three pesticides (aldrin, dieldrin, and DDT).

In addition to the studies of organic contaminants, inorganic chemicals, especially those that are included in the Interim Primary Drinking Water Regulations, are the subject of monitoring and analysis efforts. A special assessment of rural drinking water supplies will be underway in early 1976, and a study of asbestos in drinking water has started. This Section discusses these and other programs to determine the nature and extent of contamination of the Nation's drinking water.

Since the June report, five additional water utilities were analyzed for a wide range of organic compounds, completing the National Organics Reconnaissance Survey (NORS) of ten cities. In addition, several water utilities have worked with EPA to address specific drinking water problems identified in the survey. Among the activities conducted on the regional level, EPA's Region V has undertaken a survey of the finished water of 83 utilities in that Region to determine levels of organic chemicals and other contaminants. The results of the NORS and Region V's survey are summarized here. Other new material includes a brief assessment of various general organics parameters and discussions of polychlorinated biphenyls (PCBs), vinyl chloride, nitrosamines, and radioactivity in drinking water. Some recent results from the nationwide survey for certain pesticides and from investigations of asbestos are also reported here.

National Organics Reconnaissance Survey

One of the Agency's most significant efforts to delineate the problem of organics in drinking water was the National Organics Reconnaissance Survey (NORS). Initiated in November 1974, NORS had three major objectives. One was to determine the extent of the presence of the four trihalomethanes--chloroform (trichloromethane), bromodichloromethane, dibromochloromethane, and bromoform (tribromomethane)--in finished water, and to determine whether or not these compounds are formed by chlorination. The second objective was to determine the effects that raw water source and water treatment practices other than chlorination could have on the formation of these compounds. The third objective was to characterize, as completely as possible using existing analytical techniques, the organic content of ten drinking waters. These ten utilities represent five major categories of raw water sources in use in the United States today.

Survey of Eighty Water Utilities for Selected Contaminants

Eighty water utilities were chosen to determine the presence of six specific organics of particular concern: the four trihalomethanes,

carbon tetrachloride, and 1,2-dichloroethane. Selected in consultation with State water supply officials, these 80 utilities provide a reasonably representative sample of the Nation's community drinking water utilities that chlorinate their water, representing a wide variety of raw water sources, treatment techniques, and geographical locations. Survey findings indicate that chlorination results in the formation of the four trihalomethanes.

Results from the analysis of the raw or untreated water are presented in Table 1. In 30 of the 80 locations surveyed, none of the six compounds was detected.

Table 1

RAW WATER ANALYSIS
(Based on 80 Samples)

	Number of Locations Detected	Range of Concentrations (μg/ℓ)
Chloroform	49	<0.1 - 0.9 (16)*
Bromodichloromethane	7	<0.2 - 0.8 (11)*
Dibromochloromethane	1	- (3)*
Bromoform	0	-
Carbon Tetrachloride	4	<2 - 4
1,2-Dichloroethane	11	<0.2 - 3

*One location received raw water prechlorinated by a nearby industry. This water contained 16 μg/ℓ of chloroform, 11 μg/ℓ bromodichloromethane, and 3 μg/ℓ dibromochloromethane.

In contrast to these findings for raw water, the presence of the four trihalomethanes, although mostly in low concentrations, was widespread in finished water. Table 2 shows the distribution and range of concentrations of the trihalomethanes, carbon tetrachloride and 1,2-dichloroethane in finished water. Appendix I summarizes the results of the analyses of the raw and finished water for each of the 80 utilities.

Table 2

FINISHED WATER ANALYSIS
(Based on 80 Samples)

Compound	Number of Locations Detected	Median Concentration (μg/ℓ)	Range of Concentrations (μg/ℓ)
Chloroform	80	21	<0.1 - 311
Bromodichloromethane	78	6	0.3 - 116
Dibromochloromethane	72	1.2	<0.4 - 110
Bromoform	26	93.8%≤5	<0.8 - 92
Carbon Tetrachloride	10	-	<2 - 3
1,2-Dichloroethane	26	-	<0.2 - 6

Local Actions Pursuant to Survey

The findings of the survey reported in mid-April 1975 stimulated several water utilities to take action. The water utilities in Miami, Florida; Huntington, West Virginia; Whiting, Indiana; Mt. Clemens, Michigan; and Philadelphia, Pennsylvania, cooperatively participated with EPA in conducting additional sampling in their areas in attempts to determine the sources of various organic contaminants or to develop the treatment capability for their removal. In two cases, industrial discharges were demonstrated to be sources of organic contaminants. Steps are currently being taken to control these discharges. In addition, Huron, South Dakota, has received a research grant from EPA to study methods of reducing the chloroform concentration in their finished water.

Survey of Ten Water Utilities for Broad Range of Organics

The second principal component of the National Organics Reconnaissance Survey involved selecting ten of the eighty water utilities as sites representing five major categories of raw water sources for a more comprehensive survey of the organic content of their finished water. Two cities were selected for each basic type of water source. The cities investigated and their raw water sources are: Miami, Florida, and Tucson, Arizona, (ground water source); Seattle, Washington, and New York, New York, (uncontaminated upland water); Ottumwa, Iowa, and Grand Forks, North Dakota, (raw water contaminated with agricultural runoff); Philadelphia, Pennsylvania, and Terrebonne Parish, Louisiana, (raw water contaminated with municipal waste); and Cincinnati, Ohio, and Lawrence, Massachusetts, (raw water contaminated with industrial discharges).

Three different techniques were used to identify as broad a range of organic compounds as possible. One technique, volatile organic analysis (VOA), measured the organic contaminants that could be purged from the sample by aeration with an inert gas. A second technique captured organic contaminants that could be removed from the sample by liquid-liquid extraction. A third technique involved adsorption of organics onto activated carbon and desorption with chloroform. The concentration data obtained with the first technique have been corrected for recovery efficiencies. The other concentration data have not been corrected and should be considered minimum values. That is, the actual concentrations obtained in those cases are equal to or greater than the concentrations listed. All of the data are listed in Appendix I, Table III.

The summary of these data presented in Table 3 shows the differences found between utilities using similar types of raw water. The most striking difference between two utilities using the same type of raw water is between Miami, Florida, and Tucson, Arizona. The deep ground water of Tucson was obviously far less contaminated with organics than the shallow ground water of Miami. Subsequent studies in Miami have indicated that its ground water is contaminated by metropolitan and industrial activities in the area of the water treatment plant.

Terrebonne Parish, Louisiana, had fewer organics present in its water than its companion city, Philadelphia, Pennsylvania; and Lawrence, Massachusetts, had fewer than its "partner", Cincinnati, Ohio. These results might be partially attributed to the use of granular activated carbon filters/adsorbers in Terrebonne Parish and Lawrence. Because no raw water samples were collected, however, the reasons for these differences cannot be determined. Further research on the behavior of specific organics during activated carbon treatment is underway to clarify the role of such treatment in removing organics.

Table 3

SUMMARY OF TEN CITY SURVEY

City and Series	Type of Raw Water Source	No. of Compounds Identified	No. of Compounds Quantified
Miami, FL (I)	Ground Water	76	33
Tucson, AR (II)	Ground Water	7	4
Seattle, WA (I)	Uncontaminated Upland Water	31	13
New York, NY (II)	Uncontaminated Upland Water	28	15
Ottumwa, IA (I)	Raw Water Contaminated with Agricultural Runoff	35	17
Grand Forks, ND (II)	Raw Water Contaminated with Agricultural Runoff	24	10
Philadelphia, PA (I)	Raw Water Contaminated with Municipal Waste	59	22
Terrebonne Parish, LA (II)	Raw Water Contaminated with Municipal Waste	22	11
Cincinnati, OH (I)	Raw Water Contaminated with Industrial Discharges	63	21
Lawrence, MA (II)	Raw Water Contaminated with Industrial Discharges	30	14

Series I sampled January-February 1975
Series II sampled July-August 1975

The data from the survey of the ten water utilities (see Appendix I, Table III) were reanalyzed to determine the frequency of occurrence of the various organics compounds identified. The data in Table 4 show that almost one-half (46.5 percent) of the 129 compounds were found in only one location and only 13.9 percent were found in six or more locations.

Table 4

FREQUENCY OF OCCURRENCE OF ORGANIC COMPOUNDS IN THE TEN CITY SURVEY

Number of Locations Where Given Compound Occurred	Number of Compounds Occurring in Given Number of Locations	Percent of Total Compounds Found
10	2	1.5
9	4	3.0
8	3	2.2
7	1	0.7
6	6	4.4
5	11	8.2
4	15	11.1
3	14	10.4
2	15	11.1
1	64	47.4

The 18 compounds in Table 5 occurred most frequently in the ten city survey. According to the scientific literature as of November 1975, none of these 18 have been adequately evaluated for carcinogenicity. Some have been tested, although the test protocols have not been evaluated for adequacy. Two are now being tested by the National Cancer Institute, as indicated. EPA will review the scientific literature on these 18 compounds and prepare a report on their carcinogenicity in 1976.

Table 5

COMPOUNDS OCCURRING IN MORE THAN ONE-HALF OF THE TEN FINISHED WATERS

Compound	Occurrence	Currently Under NCI Test
1. Bromodichloromethane	9/10	-
2. Chloral (Trichloroacetaldehyde)	6/10	-
3. Chlorobenzene	9/10	-
4. Cyanogen Chloride	8/10	-
5. Dibromochloromethane	9/10	-
6. Di-n-butyl Phthalate	6/10	-
7. Dichloroiodomethane	7/10	-
8. Dichloromethane (Methylene Chloride)	9/10	-
9. Diethyl Phthalate	6/10	-
10. Ethylbenzene	6/10	-
11. Methanol	6/10	-
12. 2-Methylpropanal (Isobutyraldehyde)	7/10	-
13. Propanal (Propionaldehyde)	7/10	-
14. 2-Propanone (Acetone)	10/10	October 1974
15. Tetrachloromethane (Carbon Tetrachloride)	8/10	-*
16. Tetrachloroethene (Tetrachloroethylene)	8/10	October 1974
17. Toluene	6/10	-
18. Trichloromethane (Chloroform)	10/10	-**

*Used by the National Cancer Institute in several tests as positive carcinogen control.
**Feeding study complete, and undergoing evaluation.

Region V Organics Survey

Raw and treated water from 83 utilities in Region V were checked for organic chemical content during the first three months of 1975. In addition to the six volatile organic compounds included in the National Organics Reconnaissance Survey, water from these cities was analyzed for methylene chloride, insecticides, herbicides, fungicides, polychlorinated biphenyls, and certain phthalate esters. The results of volatile organic analyses are summarized in Table 6 and are presented in Appendix V. The pesticide survey is discussed later in this Section, and Appendix VI contains the complete pesticide, polychlorinated biphyenyl, and phthalate data for the survey.

Table 6

SUMMARY OF ANALYTICAL RESULTS FOR VOLATILE ORGANICS

Compound	% of Samples Giving Positive Results		Mean Concentration (μg/ℓ)		Maximum Concentration (μg/ℓ)	
	Fin. Water	Raw Water	Fin. Water	Raw Water	Fin. Water	Raw Water
Chloroform	95	27	20	<1	366	94
Bromo-dichloromethane	78	5	6	<1	51	11
Dibromo-chloromethane	60	2	1	<1	14	1.4
Bromoform	14	0	<1	<1	7	<1
Carbon Tetrachloride	34*	18	2*	<1	26*	20
Methylene Chloride	8	1	1	<1	7	1
1,2-Dichloroethane	13	14	1	<1	26	15

*The 11 samples from Minnesota may have been contaminated by being exposed to laboratory air containing carbon tetrachloride.

This study led to several conclusions: (1) Raw water with low turbidity resulted in finished water that was relatively free of chloroform and related halogenated compounds. Of the 25 utilities having the lowest concentration of chloroform, 12 obtain water from the Great Lakes, 8 use

deep wells, and only 5 use surface sources other than the Great Lakes; (2) Chloroform, bromodichloromethane, dibromochloromethane, and bromoform result from chlorination of precursors in the raw water. On the other hand, carbon tetrachloride, methylene chloride, and 1,2-dichloroethane do not appear to be produced by chemical reaction in the treatment process; (3) A correlation seems to exist between chloroform, dibromochloromethane, bromodichloromethane, and bromoform. Examination of data for only those ten cities having over 100 μg/ℓ of chloroform shows that the level of bromodichloromethane is about 13 percent of the level of chloroform and that dibromochloromethane levels average approximately 6 percent of the levels of bromodichloromethane. This relatively constant ratio indicates a common precursor or group of precursors of these halogenated pollutants. This same ratio, however, did not always occur in the NORS; and (4) The use of powdered activated carbon treatment as practiced by the water treatment plants studied was not effective in removing volatile organic compounds. Of the 31 locations using powdered activated carbon treatment, 14 had finished water chloroform concentrations exceeding the mean concentration of 20 μg/ℓ.

Assessment of General Organic Parameters

The National Organics Reconnaissance Survey reaffirmed previous indications that organics in drinking water are a national problem. Accordingly, EPA included in the proposed Interim Primary Drinking Water Regulations of March 14, 1975, a maximum contaminant level for an organic parameter measured by an activated carbon adsorption-solvent extraction test, using chloroform as a solvent. The shortcomings of this procedure were highlighted in comments on the proposed regulations and, consequently, a parameter based on this procedure is not included in the regulations as promulgated. This parameter and others, however, are currently under review. The following outlines some of the considerations involved in selection of a general organic parameter. This discussion was not included in the June report.

Organics - Carbon Adsorbable

Despite its recognized limitations, the principal method used for quantifying the organic content of drinking water has been the Organics-Carbon Adsorbable test (O-CA). Because chloroform is used as a solvent in this test, it is often mistakenly termed the Carbon Chloroform Extract (CCE) test.

Developed in the 1950's as an aid to taste and odor control, this method has several advantages that have promoted its use in testing drinking water. (1) The method selectively recovers non-polar organics from the wide variety of organics that might be present in a given water sample. (2) Natural organic materials are generally not recovered. Because they are usually more polar or are easily converted to polar compounds, they are less readily desorbed upon extraction with chloroform, a low polarity solvent. (3) Because inorganics are very soluble in water and not very soluble in chloroform, they are not likely to be present in the O-CA extract (CCE). (4) Known taste and odor causing compounds have been

recovered from O-CA extracts (CCE). (5) The techniques involve relatively inexpensive instrumentation and only one staff-day of effort per sample. (6) The residue obtained is useful for further research.

On the other hand, the O-CA test has the following disadvantages. (1) No known correlation exists between the concentration of the O-CA extract (CCE) and the presence or absence of organics of health significance in the water supply. (2) The concentration obtained in any given test is influenced by adsorption and desorption kinetics. For example, the presence of particulates in the water, changes in water temperature, or changes in the organic content of the water may influence the final concentration obtained. (3) The O-CA test does not measure the more volatile types of organics, such as chloroform, vinyl chloride, and others that have recently been of concern. (4) The test is not sufficiently sensitive to small changes in concentrations of selected organics. (5) The test procedure involves the use of a possible carcinogen, chloroform. (6) The test produces delayed results. (7) The test indicates only a portion of the total organic composition.

Perhaps the major shortcoming of this test is that it cannot be confidently relied upon as an index of the toxicity of drinking water. For example, although the finished waters of several of the utilities surveyed in the National Organics Reconnaissance Survey had O-CA extract concentrations considerably below the proposed maximum contaminant level of 0.7 mg/ℓ, further study indicated that these water supplies contained low levels of various organics that were potentially carcinogenic.

Alternatives include general organic parameters such as total organic carbon (TOC), total organic chlorine (TOCl), ultraviolet (UV) absorption, fluorescence, biochemical oxygen demand (BOD), chemical oxygen demand (COD), or total oxygen demand (TOD). In comparison with the O-CA test, many of these determinations are more easily performed. Some of the specific advantages and disadvantages of each are enumerated below.

Total Organic Carbon

Both total organic carbon (TOC) and non-volatile total organic carbon (NVTOC) are parameters with potential applicability as measures of drinking water quality. Both methods are general and do not distinguish between compound types. The precision of the TOC method is particularly affected by experimental difficulties in accurately quantifying the volatile portion of the organic compounds that are present. At the present time, no good method is available for measuring TOC between the concentrations of 0 to 5 mg/ℓ, the typical range for finished water. The instruments that are capable of measuring in this range require that the sample be purged of carbon dioxide. This purging process simultaneously removes some of the more volatile organic compounds of concern, such as chloroform and vinyl chloride, that are consequently not included in the measurement. NVTOC has been applied for organics determinations with a detection limit of approximately 0.1 mg/ℓ or less.

Total Organic Chlorine

This test is a general indicator for chlorine-containing organic compounds, most of which are from agricultural runoff, industrial sources, and disinfection processes, and would not be influenced by most natural organic compounds or other non-chlorine-containing organics of possible concern. One disadvantage of this test is that current techniques are incapable of measuring the total amount of organic chlorine in water. EPA is investigating the applicability of the test for possible use in the National Monitoring Program.

Ultraviolet Absorbance and Fluorescence

These determinations are rapid and inexpensive in unit cost. They probably do not indicate the distribution of organics present in a water sample, but are dominated by the aromatic fraction of the measured organics. The other organic fractions such as low molecular weight chlorinated hydrocarbons, chloroform, and others are excluded.

Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Oxygen Demand

The BOD, COD, and TOD tests are not particularly useful as drinking water organics monitoring tools. BOD and COD measurements lack precision at low concentrations. Further, all three measure significant inorganic fractions.

Monitoring to Assess Parameters

In view of EPA's desire to promulgate maximum contaminant levels for certain nonpesticidal organics, a concerted effort will be made to evaluate further the potential application of these general organic parameters to specific organic contaminants of concern.

Using the authority of Sections 1445 and 1450 of the Public Health Service Act as amended by the Safe Drinking Water Act, EPA will expand the scope of the National Organics Reconnaissance Survey beyond the 10 water utilities evaluated for a wide range of specific organic contaminants. This monitoring effort will cover about 100 utilities and a variety of raw water sources and water treatment practices. The objectives of this monitoring will be to: (1) determine the occurrence and concentration of specific organics, selected for suspected health effects, that are in the Nation's drinking water; (2) determine if any of the candidate general organic parameters can be related to the concentration of these chemicals; and (3) attempt to determine if any of the candidate general organics parameters can be related to the measurement of toxicity of drinking water.

Inventory of Organics Identified in Drinking Water

EPA maintains a list of organic compounds that have been isolated and identified from drinking water. Appendix II lists 253 compounds identified to date (November 1975) with their highest reported concentrations. In addition to cataloging these compounds, EPA is assembling and evaluating data concerning their chemical properties and toxicity.

Investigations of Pesticides in Drinking Water

Analysis for Chlorinated Hydrocarbon Insecticides and Herbicides

To determine compliance with the 1962 U.S. Public Health Service Drinking Water Standards, samples are periodically collected from approximately 700 water utilities serving airplane, train, and bus terminals, and are shipped to EPA for analysis. Over the past 1-1/2 years, EPA has tested some of these samples for chlorinated hydrocarbon insecticides and herbicides, compounds that were considered for inclusion in the Interim Primary Drinking Water Regulations. Of the 106 samples examined for chlorinated hydrocarbon insecticides, six contained DDT in the range of 1 to 2 ng/ℓ (nanogram per liter or parts per trillion) and 54 contained dieldrin in the range of 1 to 10 ng/ℓ. Of the 54 samples examined for herbicides, six contained from 60 to 440 ng/ℓ of 2,4-D, and two contained 10 to 70 ng/ℓ of 2,4,5-TP.

Region V Study

Out of 83 finished waters sampled in Region V's survey, five contained DDT, with concentrations of 6 to 68 ng/ℓ. Four of these samples contained from 4 to 7 ng/ℓ of dieldrin, one sample contained 4 ng/ℓ and another 6 ng/ℓ of aldrin, and one contained 4 ng/ℓ of lindane. Of the other pesticides quantified, one sample contained 6 ng/ℓ hexachlorobenzene and another 4 ng/ℓ of gamma chlordane. Of the herbicides, one sample contained 50 ng/ℓ of treflan. All of the data are contained in Appendix VI.

National Survey of Aldrin, Dieldrin, and DDT in Drinking Water

A survey of drinking water utilities representing a stratified geographic sample of supplies is in progress. The survey's primary objective is to ascertain ambient concentration levels of aldrin, dieldrin, and DDT in the nanogram per liter concentration range. The results should provide guidance to the Agency in the establishment of maximum contaminant levels for these pesticides in drinking water.

The survey was designed to obtain samples of both raw and finished water from two ground and nine surface water utilities in each of three population ranges (less than 5,000, 5,000 to 49,999, and 50,000 or greater) within each of the ten EPA regions. A computerized random sampling program selected 330 of the approximately 40,000 community water utilities. Two additional utilities were selected in each Region based on high pesticide contamination potential and available treatment technology. A total of 350 supplies were sampled in this study.

A screening analysis is performed on all samples by gas-liquid chromatography utilizing a halogen-specific detector. Subsequent to this analysis, positive samples (identified as either ≥ 4 ng/ℓ dieldrin, ≥ 510 ng/ℓ aldrin, or ≥ 10-20 ng/ℓ DDT) are confirmed by gas chromatography/mass spectrometry/computer analysis. The latter technique will also confirm the identity of other chlorinated compounds that may be present in quantities that appear significant from an analytical standpoint. Included among these will be chlordane, heptachlor, heptachlor

epoxide, and polychlorinated biphenyls (PCBs). The data generated by this study will be evaluated on the basis of degree of pesticide removal from raw water following water treatment, effect of agricultural practices on levels found, and an assessment of population exposure to these pesticides. The sampling began March 1, 1975. A final analysis of the significance of the findings, including populations at risk, should be prepared in early 1976.

Analyses for Polychlorinated Biphenyls

Of 106 interstate carrier finished water samples examined for chlorinated hydrocarbons over the past 1-1/2 years, two contained PCBs. The finished water of Winnebago, Illinois, contained 3.0 μg/ℓ of Arochlor 1242 and that of Sellersburg, Indiana, contained 0.1 μg/ℓ of Arochlor 1260. Of the 83 water utilities surveyed in EPA's Region V, no PCBs were detected in drinking water using an analytical technique sensitive to 0-2 μg/ℓ. Additional data are being collected that indicate the possible presence of small quantities of PCBs in other drinking water supplies. Among those identified to date (November 1975) are Escondido, California, (0.4 μg/ℓ), New Bedford, Massachusetts, (2.5 μg/ℓ), and Bridgeport, Connecticut, (1 μg/ℓ).

Studies of Leaching from Polyvinyl Chloride (PVC) Water Pipes

EPA has surveyed five water supply distribution systems utilizing both old and new PVC pipe of various lengths in both hot and cold climates. Little or no difference was found between the vinyl chloride (VC) concentrations in the source water versus water that had traversed the PVC pipe, except in one case, where the VC concentration was undetectable before and was 1.4 μg/ℓ after passing through the pipe. (Jonah Water Supply Corporation, Williamson County, Texas; 12-1/2 miles of 8 month-old pipe.) VC levels in two cases approached the detection limit of 0.03 μg/ℓ. Pioneer, California, 7 miles, 9 year-old pipe, had a VC level of 0.06 μg/ℓ, and Roseburg, Oregon, 3.4 miles, 4 to 9 year-old pipe, contained 0.03 μg/ℓ of VC. No VC was detected in the waters of the other two systems. (Coolidge, Arizona, 1.7 miles, 11 year-old pipe; Salado, Texas, 0.5 miles, 7 year-old pipe).

In addition, limited simulation studies were conducted in an EPA laboratory using two types of potable grade chlorinated PVC pipe. Preliminary conclusions are that the concentrations of VC in water in contact with PVC pipe tend to increase as the monomer content of the pipe, temperature, and contact time increase.

Detection of Nitrosamines in Drinking Water

Nitrosamines are compounds formed when secondary amines react with nitrous acid (nitrite at low pH). The relative rates of their formation and hydrolysis (reaction with water) are important in determining their significance as possible contaminants of drinking water. At the present time, no evidence exists to show that these reactions occur in drinking water sources.

In November 1974, EPA provided samples of Carbon Chloroform Extract concentrates taken from three New Orleans area water treatment plants for analysis for the presence of nitrosamines. In early December 1974, results of this analysis showed that "volatile" N-nitroso compounds did not exist in the water down to the one ng/ℓ level. More recently, however, analyses of the same samples using a combination of high pressure liquid chromatography and thermal energy analysis indicated that a number of "non-volatile" nitrosamines were present. Carbon Chloroform Extract concentrates from finished water at the three water treatment plants in the New Orleans area were very similar. Recent liquid-liquid extracts taken from Mississippi River raw water also indicated the presence of nitrosamines. Approximately 24 N-nitroso compounds were detected by this technique, although their identities were not verified by independent analyses. One of the peaks in the chromatogram was tentatively identified by its retention time as N-nitrosoatrazine, which is derivable from the pesticide atrazine (a herbicide). Estimated concentrations of individual compounds ranged from 50 to 100 ng/ℓ. The investigators concluded, however, that "...even this must be considered tentative and speculative until the identity of each peak is confirmed by other techniques."

The joint USDA/FDA Study Group on Nitrites, Nitrates, and Nitrosamines is concerned that nitrosamines might be present in drinking water in locations where the nitrate content of the water is excessive. Twelve samples from wells with a known nitrate content were collected from Runnels County, Texas, and Washington County, Illinois, during the week of September 23, 1975. A combination of chromatography and thermal energy analysis was used to analyze samples from some of these wells for both volatile and non-volatile N-nitroso compounds. Nitrate-nitrogen (NO_3-N) levels found in these wells ranged from 49 to 458 mg/ℓ; one sample had a NO_3-N concentration of < 0.1 mg/ℓ. The sampling included wells with histories of both high and low bacterial counts. The possibility of the formation of nitrites by bacterial reduction of nitrates was considered. The wells were used as drinking water sources until a few years ago; because of the known high nitrate concentrations, most are now used only for other purposes. N-nitroso compounds were found (≤ 15 ng/ℓ) in the samples from these wells with high nitrate content.

Surveillance for Inorganic Contaminants in Drinking Water

Many inorganic chemicals in drinking water are potentially toxic at certain concentrations. The Interim Primary Drinking Water Regulations present maximum contaminant levels for 10 inorganics: arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, and silver. All the water utilities sampled in the National Organics Reconnaissance Survey were analyzed for these inorganics. In addition, several other EPA projects are investigating the presence of these and other inorganic chemicals in drinking water, as discussed below. Extensive efforts have been directed to radionuclides and asbestos; because of the special nature of these contaminants, they will be discussed separately.

Analyses of Drinking Water Utilities

Until the passage of the Safe Drinking Water Act, the Federal Government's authority to regulate drinking water was limited to interstate carrier water supply utilities. At about six-year intervals, a survey of each of the approximately 700 utilities is made jointly by the states and the EPA Regional Offices. At the time of the survey, a water sample is collected and analyzed for the chemicals limited by the 1962 U.S. Public Health Service Drinking Water Standards. Tabulations of these data are published in the *Chemical Analysis of Interstate Carrier Water Supply Systems*. The results published in October 1973 indicate that chromium, lead, and mercury were found in concentrations that exceed the Drinking Water Standard limits in some instances. Mercury, which most frequently exceeded the limit, did so in only 1.5 percent of the samples analyzed. This report was updated in April 1975.

Special Studies in Selected Water Utilities

An analysis of drinking water quality at the consumer's tap was performed using samples collected in the Community Water Supply Survey of 1969. The concentrations of arsenic, barium, cadmium, chromium, lead, selenium, and fluoride that were found in public drinking water utilities instances exceeded the U.S. Public Health Service Drinking Water Standard limits. Of the 2,595 distribution samples analyzed, fluoride, that most frequently exceeded the proposed limits, did so in only 2.2 percent of the samples; the lead limit was exceeded in only 1.4 percent of the samples; and the nitrate-nitrogen limit in 2.1 percent of the samples. With respect to the suspected inorganic carcinogens, the arsenic limit was exceeded in 0.4 percent of the samples, and the selenium limit in 0.4 percent.

Water occasionally is contaminated by metals from corroded plumbing. Special studies of the lead content in drinking water have shown that approximately one-fourth of the homes surveyed in Boston and in Seattle have lead in their tap water in amounts exceeding the 1962 U.S. PHS Drinking Water Standard limit for lead. Preliminary data from the Boston study indicate that lead is present in high enough concentrations in the drinking water to affect the total body burden. In both Boston and Seattle, lead levels in drinking water were frequently reduced to below the PHS limit if the water was allowed to run before sampling. As a long-term solution, however, a means of reducing the corrosion of the pipes is critical. Various methods of accomplishing this are being tried in the Boston and Seattle areas.

In addition, EPA and the National Heart and Lung Institute are jointly studying the inorganics present in approximately 120 community water utilities in 350 areas selected to be representative of U.S. water utilities. Some 28 elements and other parameters will be investigated. An attempt will be made to determine the effects of drinking water quality on health, especially the correlation between soft drinking water and heart disease mortality. The field work has nearly been completed and analysis of the data is in progress. Because some utilities are being sampled over a 12-month period, a final report is not expected until late 1976, or early 1977.

Occurrence of Radioactivity in Drinking Water

Radium in drinking water is primarily a problem of smaller public water systems. About 40 percent of the U.S. population is served by 200 regional systems supplying large metropolitan areas. Yet, most of the nation's 50,000 community water utilities serve fewer than 1,000 persons. Large regional systems utilize surface water that generally contains very low concentrations of radium. Small utilities commonly use ground water that in some cases may contain radium as the result of geological conditions not subject to control. Radium-226 is the most important of the naturally occurring radionuclides likely to be found in public water systems. As shown in Table 7, the average radium-226 level in 36 interstate carrier water supply utilities was 0.28 pCi/ℓ (picocuries per liter).

In contrast to radium, man-made radioactivity is ubiquitous in surface water because of radioactive fallout from nuclear weapons testing. In some localities this radioactivity is increased by small releases from nuclear facilities (such as nuclear power plants), hospitals, and scientific and industrial users of radioactive materials. The residual radioactivity in surface waters from fallout caused by atmospheric nuclear weapons testing is mainly strontium-90 and tritium, the former being the more important in health considerations. Current data on the impact of strontium-90 on public water utilities are incomplete. The available data (Table 7), however, indicate strontium-90 concentrations averaged < 1 pCi per liter, corresponding to a dose equivalent of less than 1 millirem[1] (mrem) annually. Tritium concentrations in surface water rarely exceed 1000 pCi per liter, corresponding to a dose equivalent of less than 0.2 mrem per year, and averaged 200 pCi/ℓ. These levels are well below the maximum contaminant levels set forth in the Interim Primary Drinking Water Regulations for radioactivity.

As part of the Agency's Environmental Radiation Monitoring System (ERAMS), measurements of tritium radioactivity are made in drinking water samples from 77 major population centers and communities near selected nuclear facilities. Results of the 1974 ERAMS survey are included in Appendix IV. In 1974, the highest observed concentration of tritium was less than 20 percent of the maximum contaminant level for radioactivity now prescribed for drinking water. The average concentration was about one percent of this level. Additional data on radioactivity in community water systems should become available as States begin to implement monitoring requirements established under the Interim Primary Drinking Water Regulations.

---

[1] A millirem is one-thousandth of a rem, the unit of dose equivalent from ionizing radiation that produces a biological effect.

Table 7

SUMMARY OF INTERSTATE CARRIER WATER SUPPLY RADIONUCLIDE DATA
(January - March 1975)

	Number of Samples Total	Number of Samples Quantified	Average Level in Quantified Samples	Remarks
Gross Beta	61	61	2.9 pCi/ℓ	--
Gross Alpha	61	1	5.5 pCi/ℓ	60 Samples <2 pCi/ℓ
^{90}Sr	46	19	0.82 pCi/ℓ	27 Samples <0.5 pCi/ℓ
^{226}Ra	46	36	0.28 pCi/ℓ	10 Samples <0.1 pCi/ℓ
Specific Gamma Activity	61	-	None Detected	-
Jan-Mar 1974 Tritium	71	33	200 pCi/ℓ	38 Samples <200 pCi/ℓ

Survey of Rural Drinking Water Supplies

Section 3 of the Safe Drinking Water Act requires the Administrator to survey rural water systems to determine the quality, quantity, and availability of water supplies for rural Americans. EPA has designed a survey of 5300 randomly selected rural households to assess, among other things, the availability of water, water sources, and the quality of drinking water.

In addition to bacteriological analyses of water samples to detect the presence of contamination (total coliform, fecal coliform, standard plate count), chemical and radiological analyses will be performed. All samples will be analyzed for specific conductance, nitrate-nitrogen, calcium, magnesium, sodium, lead, sulfates, manganese, iron, turbidity, and color. Every tenth sample will also be analyzed for the inorganic chemicals in the Interim Primary Drinking Water Regulations (arsenic, barium, cadmium, chromium, mercury, selenium, silver, nitrate, lead, and fluoride) and for chlorinated hydrocarbon insecticides and herbicides, gross alpha, and radium 226/228. The survey is scheduled to begin in 1976 and will be completed in one year.

Analyses for Asbestos Fibers in Drinking Water

Asbestos fibers in the drinking water of Duluth, Minnesota, have been, at least partially, traced to industrial discharges into Lake Superior. Monitoring studies in other locations indicate non-industrial sources of asbestos, such as asbestos-cement pipe or naturally occurring asbestos, as well. These findings suggest that asbestos may be widely distributed in drinking water throughout the nation.

Review of Asbestos in Duluth, Minnesota

A few months after the presence of asbestos fibers in Duluth's potable water was confirmed in the fall of 1973, EPA began periodic asbestos analyses of the raw water. These analyses, for amphibole masses by x-ray diffraction and for asbestos fibers by electron microscopy, demonstrated the continuing presence of asbestos fibers. Additional data on amphibole mass values and asbestiform fiber counts were obtained during five months of pilot plant filtration research at Duluth.

In addition to these studies, an extensive lake sampling program showed that the concentration of asbestos fibers was highest near the industrial discharge and declined steadily at increasing distances from the discharge. Extended periods of easterly and northeasterly winds in western Lake Superior may raise the amphibole mass concentration at the Duluth intake by promoting circulation from the industrial discharge area and by resuspending recently settled amphibole-rich sediments by wave action in shallow parts of the lake. Sediments are particularly susceptible to resuspension when the western end of the lake is isothermal.

Selected Analyses for Asbestos

In the process of attempting to develop a procedure for the routine analysis of asbestos in water, EPA selected some samples from interstate carrier water suppy utilities. Only nine of the 63 samples (14 percent) had counts in excess of 500 thousand fibers per liter (f/ℓ). Furthermore, only five of these cities (8 percent) had counts over one million f/ℓ. The five cities were Duluth, Minnesota; North Troy, Vermont; Seattle, Washington (Tolt River supply); Skidaway Island, Georgia (atypical fiber type); and San Francisco, California. These findings prompted EPA to develop the nationwide asbestos sampling program described below.

National Asbestos Sampling Program

A nationwide asbestos sampling program is underway to determine the environmental levels of asbestos resulting from discharges from various sources. Sampling locations have been chosen that include four major categories of asbestos discharges. A "natural site" category was selected because known asbestos rock formations may contribute significant amounts of asbestos in run-off or emissions because of natural weathering processes. Other categories include "asbestos mining"; "mining of other

ores," such as talc and vermiculite, which may also be sources of asbestos; and "asbestos manufacturing." For all categories, both air and water samples are being taken. Over 60 sampling sites have been chosen, including the water utilities of several major cities, such as San Francisco, Denver, Chicago, Atlanta, and Dallas. In addition, 20 to 30 other drinking water utilities are being sampled.

Although fiber counts in discharges from asbestos plants have been found as high as 10 billion f/ℓ of effluent, dilution of the discharge in asbestos-free waters can reduce these levels downstream to minimal levels, generally well below the level of detection by electron microscopy. In one case, a discharge in excess of 10 billion f/ℓ was calculated to be diluted to approximately 2000 f/ℓ downstream. On the other hand, even in the absence of active asbestos mining, water sampled in areas with naturally occurring asbestos have shown counts in excess of 10 million f/ℓ of chrysotile plus 10 million f/ℓ of asbestiform amphibole fibers.

Because the geological degradation processes in these natural site areas have probably been reasonably constant over a considerable period of time, the asbestos levels in the surface water of these areas have probably been equally constant. Accordingly, the medical records of populations in such areas could provide useful data on the effects of prolonged ingestion of asbestos fibers.

Results of Investigations of Asbestos from Asbestos Cement (A-C) Pipe Erosion

Erosion of asbestos fibers from the walls of asbestos-cement (A-C) pipe used in water distribution systems may be a source of asbestos in drinking water. Investigations of this possibility involve a controlled experiment with water of a known chemical quality circulated through two 100-foot lengths of A-C pipe. One pipe is four inches in diameter, the other six inches. Weekly samples of the effluent are being analyzed by electron microscopy to determine whether or not asbestos fibers are released from the pipe wall.

For the period May to September 1975, the chrysotile asbestos fiber counts ranged from 14 to 1950 f/ℓ in the four-inch pipe, and from 360 to 2670 f/ℓ in the six-inch pipe. The average chrysotile count during this period was 475 f/ℓ for the four-inch and 1350 f/ℓ for the six-inch pipe. The water being used was "mildly aggressive," with pH 7.5 and total hardness of 20 mg/ℓ.

Disturbance probably causes an increase in fiber release. A sample taken following disconnection and reassembly of the six-inch pipe had 19,000 chrysotile f/ℓ. In contrast, the current (November 1975) fiber counts have declined to 86 chrysotile f/ℓ. The pipes will be drilled and tapped to determine how these operations affect fiber counts. A "very aggressive" water, with pH 5.5 and total hardness of 20 mg/ℓ, will be tested following completion of the test now in progress.

Another phase of this project is investigating tap waters in locations where water low in asbestos fibers flows some distance through A-C pipe prior to use. Bimonthly analyses are being made to determine whether asbestos fiber content increases in water which passes through A-C pipe.

Systems using A-C pipe are being selected to provide a wide range of "aggressiveness," as determined by the pH and hardness, of the water. Thus far, of the six systems selected, some waters have been sampled only once or twice while others have been sampled and analyzed five or six times. These preliminary data indicate that only the two more "aggressive" waters, Pensacola, Florida, (Montclair Subdivision) and Seattle, Washington, contain relatively high numbers of fibers. Pensacola water, classed as "most aggressive," had 0.7 to 32 million f/ℓ, and Seattle water, which was "somewhat less aggressive," had 0.4 to 1.5 million f/ℓ.

HEALTH EFFECTS OF DRINKING WATER CONTAMINANTS

With the aid of modern analytical techniques, such as gas chromatography, mass spectrometry, and atomic absorption, many types of organic chemicals and heavy metals have been detected in drinking water for the first time. Knowledge of the health effects of most of these contaminants, particularly in the low concentrations that occur in drinking water, is inadequate. Complete analyses of the health risks involved should include evaluation of human exposure to these chemicals from all sources, including contaminants in food and in the air. Although the efforts described below are extensive, they represent only the beginning of the research needed to assess fully the health effects of drinking water contaminants.

Since the June report, data obtained from the National Organics Reconnaissance Survey have been compared with cancer mortality occurring in populations served by the water utilities surveyed. Two other epidemiology studies have focused on the association between chloroform in drinking water and cancer mortality, and the correlation between fluoridation and cancer incidence. The results of these preliminary analyses are reported here. Other new material includes discussion of a proposed study on arsenic, estimation of risk from radiation, and studies concerning effects of asbestos.

Review of Drinking Water Contaminants by the National Academy of Sciences

In fulfilling its responsibilities under the Safe Drinking Water Act, EPA has arranged for a study by the National Academy of Sciences (NAS) to provide health data for setting maximum contaminant levels in drinking water. NAS will provide information and scientific judgments concerning the health effects that might be expected at various ranges of concentrations for the contaminants. This information will enable the Administrator to determine appropriate health goals for these contaminants and then, after considering technological and economic feasibility, to establish levels for National Primary Drinking Water Regulations.

For those contaminants for which a sufficient data base exists, NAS will make recommendations concerning the relationships between contaminant levels and health effects. Among the factors the Academy will consider are the margin of safety required to protect particularly susceptible segments of the population; exposure to the contaminants by other routes; synergism among contaminants; and the relative risks of different levels of exposure to the contaminants.

The Academy will also investigate and report those contaminants that may pose a threat to human health, but whose current level in drinking water cannot be determined. For those contaminants, the Academy will recommend studies and test protocols for future research. The project, initiated in April 1975, is scheduled for completion by December 16, 1976. This NAS review of drinking water contaminants should provide an overview of the drinking water problem that will be essential in determining future national strategies.

Development of Quality Criteria for Water

In addition to the studies being conducted by the National Academy of Sciences to recommend maximum contaminant levels, EPA is developing Quality Criteria for Water pursuant to the Federal Water Pollution Control Act Amendments of 1972 (Section 304(a)(1) of PL 92-500). These criteria are being developed to provide a scientific basis for establishing ambient water quality goals. These goals should be useful as benchmarks for setting water quality standards, including State Water Quality Standards, Effluent Guidelines, and the 1979 Interim Raw Source Drinking Water Standards for the Safe Drinking Water Act (Section 1401(1)(D) of the PHS Act, as amended by PL 93-523). Included in the list of about 60 constituents are organic and inorganic materials, including some suspected carcinogens.

Other Investigations of the Health Effects of Organics

EPA Science Advisory Board Review of Selected Organics

EPA has sought the advice of its Science Advisory Board regarding potential carcinogenic or other adverse health effects resulting from exposure to organic compounds in drinking water. Principal attention was directed to the compounds listed in Table 8, particularly chloroform, carbon tetrachloride, chloroethers, and benzene.

The Board prefaced its Report[2] with the caveat that the chemicals thus far identified in drinking water account for only a small fraction of the total organic content, as previously noted in this Report. Thus, the possibility exists that additional substances of equal or greater toxicological significance may be in drinking water. The Board also expressed concern that future studies should take into account possible synergistic effects of common combinations of contaminants. It recommended that a complete analysis of the problem consider data from all routes of exposure, such as dietary and occupational exposure, to these substances in addition to drinking water. Some of these additional sources of exposure may pose a much greater potential intake than the consumption of drinking water.

---

[2] *A Report: Assessment of Health Risk from Organics in Drinking Water*, Hazardous Materials Advisory Committee, Science Advisory Board, Environmental Protection Agency, May 20, 1975.

Table 8

SELECTED CONTAMINANTS IN U.S. DRINKING WATER SUPPLIES

Contaminant(s)	Concentrations in μg/ℓ	Estimated Distribution*
Carbon Tetrachloride	<2 - 3	10%
Chloroform	<0.1 - 311**	100%
Other Halogenated C_1 and C_2	<0.3 - 229	100%
Bis(2-chloroethyl)ether	0.02 - 0.12	low
β-chloroethylmethylether	unknown	low
Acetylenedichloride	<1	low
Hexachlorobutadiene	∿0.2	low
Benzene (inc. Alkylated Benzenes to C_6)	<10	high
Octadecane	∿0.1	high
C_8-C_{30} Hydrocarbons	<1	high
Phthalate Esters	∿1	50%
Phthalic Anhydride	<0.1	low
Polynuclear Aromatics	0.001 - 1	high

*These distributions for drinking water contaminants represent very rough estimates made by the Ad Hoc Study Group of the Science Advisory Board.

**The maximum chloroform concentration of 366 μg/ℓ found in Region V survey was not known at the time of the Board's review.

The Board indicated that, in general, for all the compounds reviewed, the carcinogenicity data and experimental designs were either inappropriate or below the standard of current toxicological practice and protocols for carcinogenicity testing. Additional well-designed experimental studies to determine the carcinogenicity of lifetime exposures by ingestion are sorely needed.

The Board concluded that some human health risk does exist from exposure through drinking water, although this risk is currently unquantifiable. This conclusion was based on evidence of widespread contamination of drinking water, particularly by chloroform. Laboratory animal studies indicate production of hepatomas by chloroform, but experimental carcinogenesis data for chloroform at that time (May 1975) were extremely limited. The Board recommended that EPA seek ways to reduce exposure to these compounds without increasing the risk of infectious disease. As described in a later Section, EPA has been reviewing various chlorination practices to determine whether simple modifications might minimize the formation of chloroform and other chlorinated organics.

According to the Board's report, carbon tetrachloride, a demonstrated carcinogen in laboratory studies, occurs in drinking water generally at much lower levels and is much less widespread than chloroform and related trihalomethanes. Benzene has not been clearly established to be carcinogenic in experimental animals, although epidemiological and clinical studies, largely of occupational exposures, suggest its possible carcinogenicity. Certain haloethers, chloro-olefins, and polynuclear aromatic hydrocarbons have

been demonstrated to be carcinogenic in laboratory animals and have been identified in drinking water. Further sampling and analyses are necessary to determine the levels to which the public is exposed to these contaminants. The survey described earlier to monitor additional water utilities should help provide this information.

Data from epidemiological studies on the contaminants of primary concern to the Board were very limited and the designs of studies were generally inadequate for a conclusive assessment of health risk. Recent studies alleging an association of high cancer incidence in New Orleans with consumption of contaminated drinking water were considered by the Board to be useful for forming hypotheses for future epidemiological studies, but were not indicative of any clear cancer hazard. Numerous other variables might explain the apparent associations. Experimental toxicology studies suggest that, if a carcinogenic risk did exist, increased liver cancer would be a probable finding. This was not, however, revealed by the epidemiological studies. As part of its recommendations to EPA, the Board suggested that epidemiological studies be undertaken to relate drinking water contamination with differences in cancer incidence or other effects in exposed populations. Some of these studies are described in a later Section of this Report.

Experimental Evaluation of the Toxicity of Organics

Although the occurrence of organic compounds in tap water is universally accepted, the human health effects of exposure to these compounds via drinking water are as yet unclear. Of those compounds known to occur in tap water (Appendix II), a relatively large number require intensive investigation to generate suitable data for health hazard evaluations. Data are needed to evaluate whether these compounds might produce tumors, genetic mutations, birth defects, or other equally serious chronic diseases.

EPA is actively engaged in research to elucidate chemically-induced chronic illnesses from organics present in the Nation's drinking water. EPA will determine whether certain organic contaminants in drinking water pose a risk to human health and to characterize that risk, if any. A two-pronged approach is used to investigate organics in drinking water. The first determines the toxic properties of individual compounds with specialized protocols and systems. The second emphasizes the toxic properties of mixtures of organics with the use of multiple biological screening systems.

Several compounds are being investigated with respect to their toxicity and metabolism in experimental species. These compounds include bis(2-chloroethyl) ether, bis(2-chloroisopropyl) ether, dibromochloromethane, bromodichloromethane, the homologous series of chlorinated benzenes, and the homologous series of brominated benzenes. Comparative metabolism studies are being conducted to determine the animal models that are most predictive of responses in man. Comparative toxicity studies (both acute and chronic) have been undertaken

to determine types of pathological lesions, target organs, reversibility of the lesions, and threshold doses associated with each compound. Specialized studies are being carried out to examine the possible role of the halogen-substituted benzenes in synergistically altering the toxicity of other foreign organic compounds.

The investigation of the toxicity of mixtures of organics from drinking water is being pursued with the use of several bioassay procedures. Organic extracts from the drinking water of five U.S. cities (See Table 3, cities in Series I) are being collected for analyses by these biological systems. If these extracts demonstrate activity suggestive of carcinogenicity, mutagenicity, teratogenicity, or other serious effects, they will be chemically fractionated to isolate the active portion(s). Ultimate fractionation should lead to the identification of the toxic agents. These compounds will then be subjected to more definitive toxicity tests to assess the human health hazard.

Finally, the National Cancer Institute is studying chloroform in an attempt to assess the health effects of ingesting chloroform and to provide data for evaluating any health risks associated with the presence of chloroform in drinking water. The results of this very important study, which involves both rats and mice in a two-year experiment, are expected to be reported soon.

Three other efforts to determine mutagenic effects may also be useful in predicting the carcinogenic potential of the tested compounds. One study has used histidine-dependent mutant strains of *Salmonella typimurium* to screen water at various locations in the lower Mississippi River to determine the presence of potential mutagens/carcinogens. Water samples were screened without concentration both directly and after activation by use of liver homogenates. After a number of samples were found to be positive, the study was expanded to include the screening of raw and finished waters of other utilities using the lower Mississippi River in addition to some using ground water.

A second study involves an EPA contract now underway to test the mutagenic properties of 85 chemical compounds. Approximately 20 of these compounds will probably be organics found in drinking water. *In vitro* mutagenicity testing will be done on *Salmonella, E. coli,* and yeast, using metabolic activating systems derived from mammalian livers. In a third study, EPA is developing preliminary information on the potential mutagenicity of substances that might be produced during the ozonation process. A number of chemical compounds are being subjected to conditions similar to those encountered during disinfection processes using ozone. The ozonation product mixtures are being tested to determine the potential mutagenic effects on certain microorganisms.

Health Effects of Organics Occurring in Nature (Humic Substances)

As noted before, organics thus far identified in drinking water represent only a small percentage of the total organics recoverable from drinking water. The remaining fraction is heterogeneous and includes mixtures of high molecular weight organics not susceptible to rigorous chemical definition.

When subjected to chlorine or ozone treatment, humic substances might produce either halogenated organic compounds or oxidized forms, including peroxides or epoxides, that may be hazardous to man. Studies concerning the chemistry and toxicology of humic substances that occur naturally in water are being planned.

Epidemiological Studies

Epidemiology, the study of the occurrence of disease in selected human populations, is difficult because precise data on environmental exposure are seldom available. Epidemiological studies of chronic diseases, for example, must make use of death certificate data that are not always indicative of the underlying causes of death. Nonetheless, epidemiology is based on a study of actual conditions and any indication of an adverse health effect should be seriously evaluated.

Environmental Levels of Organics and Health Effects

An investigation scheduled to begin shortly will seek to identify and measure environmental concentrations of selected halogenated organic compounds and to determine the correlations of various concentrations with health effects observed in the exposed population. This study will focus on areas suspected of having high levels of these organics in the environment and areas known to have a high incidence of cancer. Comparative analyses will be made of other areas with moderate and low environmental levels of the substances. The project should be completed in the spring of 1976.

Estimating Exposure to Organics

EPA plans to explore the correlation between the concentrations of organics that have been measured in each drinking water and the number of users of that water. Extrapolations from these data to national exposure curves will be attempted. The estimate of national exposure to organics, in conjunction with the various local exposure levels, will assist in providing a basis for estimating health risks.

Correlation of Cancer Mortality with Chloroform Content of Drinking Water

Data obtained from the National Organics Reconnaissance Survey have been compared with cancer mortality occurring in populations served by these water utilities. One preliminary study has indicated a statistically significant correlation between the cancer mortality for all anatomical sites and both sexes combined in the years 1969-71 with the chloroform concentration in the samples collected in spring 1975. Such a correlation was not noted with total mortality or with the sum of the concentrations of the four trihalomethanes in the drinking waters.

In this analysis, only data from 50 of the 80 water utilities could be utilized. Some of the cities were only partially served by one of the water utilities sampled and some of the cities were too small to have data available on mortality. A similar epidemiological analysis of 43 cities from the Region V survey of 83 cities (Appendix V) did not show a statistically significant correlation between chloroform and cancer mortality in contrast to the finding above.

Data concerning the chloroform concentrations in nine water utilities have been analyzed using the average of the two samples (NORS and Region V) collected for each utility. A statistically significant correlation was again found between chloroform concentration in the drinking water and cancer mortality for all disease sites and both sexes combined. These epidemiological studies had several data validation problems and should be considered preliminary. These preliminary results do, however, underline the need for more definitive analyses.

The National Cancer Institute also studied the correlation of cancer incidence at a number of anatomical sites with the presence of chloroform in drinking water. The study looked at only a small number of counties, however, and the results were inconclusive. Another study at NCI focused on the effects of natural and artificial fluoridation. This study failed to produce evidence linking natural or artifical fluoridation of public water supplies to cancer.

Evaluation of Health Risks from Inorganics

Some of the inorganic chemicals that investigators have suggested may be potentially carcinogenic in drinking water under certain circumstances are arsenic, beryllium, cadmium, chromium, and nickel. Some studies and brief assessments of the carcinogenicity of these inorganics are described below. All the metals are being tested for mutagenicity.

Arsenic, beryllium, nickel, and cadmium have been tested in a bioassay system using cultured mammalian cells to determine mutagenicity. Of these inorganics, beryllium and cadmium were found to produce mutations; the others yielded no mutants, probably because they were either not mutagenic or too weakly mutagenic to permit detection in this particular assay.

Although arsenic has been associated with the occurrence of cancer, its exact role as a carcinogen has not been determined. Exposure apparently must be high and occur over an extended period of time before skin cancer develops. At certain exposure levels, however, arsenic is generally recognized to be acutely and chronically toxic to man. In view of the recent reduction in permissible arsenic concentrations set by the Occupational Safety and Health Administration for the workplace, EPA is reviewing the concentrations allowed in drinking water.

In addition, EPA is currently considering a study to help clarify risks associated with exposure to arsenic. The first, part of a larger study on various toxic substances, involves the relationship between

environmental exposure to inorganic arsenic and health effects. Populations exposed to significant amounts of arsenic would be the subjects of epidemiological studies to help determine the health effects of arsenic exposure. A second study just beginning seeks to determine the body burden of arsenic in humans who consume drinking water containing arsenic at or exceeding the current maximum contaminant level of 0.05 mg per liter.

Nitrate concentrations in drinking water have been limited because of the possibility that infants who ingest water high in nitrates may develop methemoglobinemia. In addition, a possibility exists that nitrates may be one of the precursors of nitrosamine formation. This reaction, however, was demonstrated at much higher concentrations than would normally occur in water.

Existing health effects evidence does not conclusively show whether selenium is carcinogenic. After a complete review of its health effects, the Food and Drug Administration last year concluded that selenium could be safely used as an additive to animal feed. Very low levels of selenium are apparently necessary for red blood cell integrity. On the other hand, some FDA critics are concerned because several animal studies show that tumors were developed from exposure to selenium. The doses used in those experiments were very high, however.

Estimate of Risk from Radiation

Radionuclides are recognized carcinogens. Following the recommendation made by the National Academy of Sciences, EPA bases its estimates of the health effects of radiation exposure through ingestion of drinking water on the assumption that no harmless dose level exists and that any health effects produced will be linear and proportional to the radiation dose received from drinking water.

Eighty to 85 percent of ingested radium is deposited in bone. Other organs are also irradiated to a lesser extent, however, and the total health risk from radium ingestion has been estimated by summing the dose and resultant risk from all organs. Risk estimates indicate that continuous consumption of drinking water containing radium-226 and radium-228 at the proposed maximum contaminant level of 5 pCi/ℓ may cause between 0.7 and 3 fatal cancers per year per million exposed persons.

Assessment of Effects of Oral Ingestion of Asbestos

Toxicity

Although the development of cancer from exposure to airborne asbestos has been documented by epidemiological studies, the effects of ingested asbestos have not yet been determined. Several current projects are studying various aspects of this problem, including asbestos absorption

in the gastrointestinal tract, the possible correlation between cancer incidence and asbestos in drinking water, and the toxicology of ingested asbestos in rats.

Research on the problem of ingested asbestos in man has revealed that excessive gastrointestinal cancer and peritoneal (abdominal) mesotheliomas (neoplasms of the lining cells) occur in workers exposed to airborne asbestos. Scientists believe that the workers under study ingested asbestos particles that were in their mouths and respiratory tracts and that this ingestion is related to the incidence of cancer. EPA is studying the passage of asbestos fibers through the gastrointestinal tract in an effort to evaluate this aspect of ingestion exposure. One study involves labelling asbestos with tritium to elucidate the mechanism of asbestos absorption.

In a very important project, the National Institute of Environmental Health Sciences has funded a toxicological study of the ingestion of various asbestiform types. This four-year study is expected to begin shortly.

Epidemiology

Several studies have focused on the possible correlation between asbestos in drinking water and the incidence of cancer. These studies represent the beginning of work in this area. Because of the long latency period between exposure and the development of the disease, data being developed must be viewed as baseline. Two studies of the population of Duluth, Minnesota, where the concentrations of asbestos fibers in drinking water were very high, have recorded no unusually high incidence of cancer. In a National Cancer Institute study, risk ratios were calculated for Duluth in comparison to the State of Minnesota and Hennepin County (Minneapolis). Of 21 cancer sites in the body, only cancer of the rectum had an excess that was statistically significant and highest in the latest 5-year period of the comparison. The authors felt that this finding was probably not related to asbestos exposure.

A second study, conducted by the Minnesota Department of Health, in cooperation with the University of Minnesota and the Center for Disease Control, was based on cancer incidence data instead of mortality and compared Duluth with the Twin Cities. No clear pattern of difference in gastrointestinal cancer incidence existed among the three cities in 1969-1971. This study is currently being continued, however, to include cases of gastrointestinal cancer recorded in 1973 and 1974 in the three cities as well as cases recorded in smaller communities (Two Harbors, Silver Bay, and Beaver Bay, Minnesota) where asbestos fiber counts are known to be even higher.

In cooperation with the Minnesota Department of Health, the Mayor and Chief Health Officer of Duluth have organized a reporting system

wherein all physicians are requested to report cases of diagnosed mesotheliomas. All cases will be interviewed to obtain occupational and residential histories. A retrospective study of all deaths caused by mesothelioma in Minnesota during a five-and-one-half year period was undertaken by the Minnesota Department of Health to see if more cases without occupational histories occur in the Duluth area. The results of this study indicate that in almost every case mesotheliomas were associated with some asbestos exposure other than through drinking water. Finally, a study of lung cancer incidence data is planned to search for additional cases of asbestos-related cancer during the period 1969 to 1974.

SOURCE IDENTIFICATION

Investigations underway address a variety of suspected sources of contaminants, such as industrial effluents, municipal waste treatment facilities, chlorination of drinking water, agricultural runoff, and landfills. These investigations are discussed below.

Industrial Sources

EPA is identifying substances remaining in municipal and industrial wastes and sludges after various treatment processes. This effort will provide information on the presence of substances that are potentially damaging to man and the environment; provide data on the effectiveness of various treatments; and allow identification of the sources of organics in water at microgram per liter or greater concentrations.

Several studies of industrial effluents have produced an extensive inventory of organics that suggests that industrial sources may be major contributors of organics found in drinking water. Two of the substances in drinking water that have been rather clearly identified as suspected carcinogens, chloroform and bis(2-chloroethyl) ether, appear in industrial wastes and not in domestic sewage, an alternate possible source. As noted earlier in this Report, however, the major source of chloroform in drinking water is from chlorination practice, not industrial discharges.

Extensive studies are needed to provide further information on the relationship between industrial discharges and the appearance of organics in drinking water. Systematic studies of the composition of industrial effluents are on-going. EPA also is considering a program that will help identify the industrial sources of organics discharged into river basins that feed a number of public drinking water supplies. The goal of this program would be to correlate the organics appearing in particular drinking waters with specific industrial discharges.

Over 200 organics identified in various drinking waters have been examined to determine possible point source discharges during manufacture and use; possible non-point sources; persistence; methods of removal; and gross estimates of total discharge. Some preliminary data have been collected on industrial discharges. A report describing these efforts, along with preliminary recommendations, should be available in the summer of 1977.

The generation, treatment, and disposal of hazardous wastes of the following 13 industry categories are currently under investigation: Pharmaceuticals; Paint and Allied Products; Storage and Primary Battery Manufacturing; Inorganic Chemicals; Petroleum Refining; Primary Metals; Metals Mining; Electroplating and Metal Finishing; Organic Chemicals; Pesticides and Explosives; Textiles; Rubber and Plastics; Leather

Tanning and Finishing; and Machinery (except Electrical). These studies relate to the problem of carcinogens in drinking water insofar as they clarify the types and quantities of recognized and potential carcinogens that are disposed on land and subsequently might be transmitted to nearby surface and ground waters. The first study (storage and primary battery manufacturers) has been completed; the last in the series is expected to be issued by the summary of 1976.

Discharges from Municipal Waste Treatment Facilities

Efforts are underway to determine the contributions of municipal waste treatment practices and effluents to the presence of organic chemicals in drinking waters. Under contract to EPA, a procedure for separating and tentatively identifying refractory organics from municipal waste treatment facilities was developed. The procedure, which is capable of detecting organics at the microgram-per-liter level, was applied to the study of primary and secondary effluents. In primary effluents, identified compounds included simple carbohydrates, amino acids, and other compounds apparently of metabolic origin. These same substances were found in both chlorinated and unchlorinated effluents. Several chlorinated compounds identified in chlorinated primary and secondary effluents have been determined to be by-products of chlorination. Although these compounds have not necessarily been identified in drinking water, their presence in various wastewaters suggests that some might also be found in drinking water.

As part of the industrial source program described earlier, a preliminary literature search has been conducted to determine which organics have been identified in municipal waste treatment effluents and which are likely to be present either from industrial discharge or as a result of biological treatment or chlorination. The preliminary results show that 23 of the organics identified in drinking water have been positively identified in municipal waste treatment effluents; an additional 27 may be found as intermediates or final products of biological treatment; and 42 could be produced during chlorination of treatment effluents.

In addition to determining whether municipal waste treatment practices and effluents are significant sources of organics in drinking water, investigations are also directed to assess whether control can be achieved by regulating industrial discharges to sewer systems or whether further treatment of municipal waste treatment effluents is required. A report describing these efforts and recommending steps that could be taken to minimize the problem will be completed in June 1977.

Chlorination of Drinking Water

As yet, no acceptable substitute exists for chlorine as a disinfectant that produces a residual, and the health hazards of foregoing chlorination would be severe. At the same time, concern is increasing over the effect of chlorination on organic materials found in natural and waste waters. In 1974, the following compounds were identified as formed by chlorination of drinking water: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. Naturally occurring humic substances are thought to be precursors of these trihalomethanes. The maximum concentrations found were: chloroform, 54 μg/ℓ; bromodichloromethane, 20 μg/ℓ; dibromochloromethane, 13 μg/ℓ; and bromoform, 10 μg/ℓ.

A later study confirmed the presence of these trihalomethanes in a variety of finished drinking waters from Ohio, Indiana, and Alabama. These findings prompted studies to determine which factors influence the rate and extent of trihalomethane formation during chlorination, and which other halogenated compounds might be formed at the same time.

Studies were conducted to compare the rate and extent of chloroform formation when chlorine was added to raw river water, dual-media filtered water, and water treated by granular activated carbon. These experiments were carried out at constant pH and at 25°C. When sufficient chlorine was added to satisfy the chlorine demand for the duration of the experiment, chlorination of raw river water yielded approximately seven times as much chloroform as did chlorination of the coagulated, settled, and dual-media filtered water, and approximately 80 times as much as did chlorination of the fresh granular activated carbon filter effluent (207 μg/ℓ, 32 μg/ℓ, and 2.7 μg/ℓ, respectively, in 7+ days). The rate of chloroform formation in the river water was approximately 10 to 15 μg/ℓ/hour for the first six hours. Similar results have been obtained when the same experiments were conducted with realistic concentrations of humic acid, but not with simple acetyl derivatives (precursors in the classical haloform reaction). Acetone (a classical precursor known to be in raw waters) was shown to react at higher pH, however. Rates of reaction for both types of precursor also have been demonstrated to increase with pH.

Concentrations of humic materials are probably reduced during alum coagulation, settling, and dual-media filtration, thereby reducing the rate and extent of chloroform formation by chlorination. These procedures may not have this effect, however, if chlorination is carried out at high pH, because the low molecular weight acetyl derivatives that react well at that pH are not likely to be so well removed by conventional water treatment.

Experiments have demonstrated that monochloramine will not react with natural water precursors to form trihalomethanes, and that the reaction rate with free chlorine at pH 7 varies directly with temperature.

Other studies investigated the chlorination of approximately 50 μg/ℓ of nitromethane, benzene, toluene, and m-xylene. Under the conditions of the test, nine days of storage at 25°C, nitromethane was readily converted to chloropicrin, and m-xylene was readily converted to chloroxylene. Benzene did not react with the chlorine under these conditions, and toluene produced chlorotoluene rather slowly. These studies indicate that other chlorination by-products can occur during the chlorination process.

The oxidation of bromide to hypobromite by hypochlorite and the subsequent reaction of hypobromite with precursor compounds to form bromo-substituted trihalomethanes has been demonstrated. This was done experimentally by adding fluoride, bromide, and iodide in the form of salts to Missouri River water and subsequently chlorinating that water. The detected reaction products included all ten possible non-fluoro mixed and single halogen-containing trihalomethanes.

Controlled studies are continuing in an attempt to identify the individual compounds other than humic materials that react with chlorine to form trihalomethanes. After identification of these precursors, alternative pretreatment and treatment conditions will be investigated with the goal of minimizing trihalomethane production.

Finally, investigations dealing with the formation of other halogenated organics that are by-products of chlorination, such as chlorophenol and dichlorobenzene, will continue. These studies will be carried out by a combination of in-house research and an extramural grant program for university investigators.

Contamination by Agricultural Chemicals

Two projects address the contamination of drinking water by agricultural chemicals. One is an assessment of the impact of intensive application of pesticides and fertilizers in underground water recharge areas that may contribute to drinking water supplies. A preliminary investigation has been done and a more detailed study should be completed by November 1976. All reported problems with pesticides have been local. Most pesticides have limited solubility in water and tend to accumulate in the soil. Subject to the actions of microorganisms in the soil, these pesticides can be metabolized to different compounds, a few of which may be more toxic than the parent compound. More information is needed to determine the sorptive properties of pesticides and their degradation products, as well as the geographic areas vulnerable to contamination.

No significant problems resulting from potassium or phosphorus nutrients have been identified. Problems related to nitrogen seem to be localized. Nitrate has slowly continued to increase in the ground waters of areas where high concentrations of septic tanks, animal feedlots over high water tables, consistent applications of nitrogen fertilizer,

and flash flooding occur. In certain areas, high concentrations of nitrates in ground water have resulted from natural sources, such as the degradation of vegetation.

A second project, which is a part of the national survey of aldrin, dieldrin, and DDT described earlier, is an attempt to determine whether various water treatment techniques effectively remove pesticides found in raw sources of drinking water. An analysis of the pesticides present in raw and finished water should indicate whether statistically significant differences in treatment efficiency occur.

Other Non-Point Sources of Organics

EPA is attempting to estimate the contribution of non-point sources to the organic compounds found in river basins from which drinking water supplies are taken. This activity will help determine whether significant abatement can be achieved by regulation of point source discharges or whether extensive treatment of drinking water is necessary.

A total of 154 organic chemicals identified in various drinking waters have been studied preliminarily to determine possible non-point sources of discharge, persistence, and methods of removal. A report including the origins and estimates of the nationwide burden of these chemicals as well as plans for major river basin investigations and adoption of a pilot program was published by EPA in April 1975, "Identification of Organic Compounds in Effluents from Industrial Sources" (EPA-560/3-75-002). Further laboratory work is needed to clarify the speculative reactions reported to occur during chlorination.

Various Land Disposal Practices and Water Contamination

Several investigations are underway to clarify the possible correlation between disposal practices and contamination of drinking water. Monitoring of surface and ground waters at dumps and sanitary landfills is being conducted to determine whether the waters have been contaminated by materials present in the dumps or landfills. As a result of the contamination of surface and ground waters, drinking water may be contaminated. Monitoring has begun at seven of the 11 selected sites and should be completed by January 1976. Preliminary results from one dump site indicate that ground water in the vicinity has been polluted. The results from other sites will probably vary with climatological and physical parameters.

Another project is entitled "Development of a Data Base for Determining the Prevalence of Migration of Hazardous Chemical Substances into the Groundwater at Industrial Waste Land Disposal Sites." This study is expected to document the migration of hazardous substances, including some suspected carcinogens, from approximately 75 industrial land disposal sites, including dumps, landfills, lagoons, pits, and basins, into the Nation's ground waters. The primary objective of this effort is to provide data for developing future land disposal guidelines and standards. This investigation began in the fall of 1975 and should be completed in the summer of 1977.

TREATMENT TECHNIQUES FOR CONTROLLING CONTAMINANTS IN DRINKING WATER

Overview of EPA Treatment Program

During fiscal year 1976, EPA will spend almost $2.0 million to expand its research effort to develop the technology needed to control economically the concentration of carcinogenic contaminants in drinking water. Universities, research institutions, and operating water utilities will perform parts of this research under grants or contracts with EPA. This Section describes this effort and significantly expands upon the material in the June Report.

The first part describes treatment process modifications intended to reduce the concentration of trihalomethanes in finished waters. This Section also presents the preliminary results of a major in-house research effort to determine under what conditions trihalomethanes or their precursors could be removed during water treatment. Five techniques have been studied and their effectiveness compared. In addition, an ongoing study on the removal of general organics with granular activated carbon beds, and future research plans involving pilot and full-scale research on treatment techniques are described. Techniques to control inorganics are discussed, including those directed to removing radionuclides and asbestos.

Techniques for Controlling Organics

Treatment Process Modification - Field Scale

EPA is attempting to keep water utilities apprised of developments in controlling organics. For example, the common practice of prechlorinating raw surface water to ensure adequate disinfection is likely to produce twice the amount of trihalomethanes compared to chlorination after the water is coagulated and settled. For this reason, EPA has been urging water purveyors to review critically their chlorination practices to see if simple modifications (such as changing the point of chlorine application) can be made that would minimize the formation of chloroform yet still provide microbiologically safe drinking water.

In an attempt to reduce the concentration of trihalomethanes in its finished water, one major water utility has made several operational changes in its 160 mgd water treatment plant. These changes include:

1. Moving the chlorination application point to follow the presettling basin stage in order to reduce the chlorine contact time (and thus the time for trihalomethane formation) and to improve the quality of water pricr to chlorination.

2. Adding powdered activated carbon (PAC) to the raw water in an attempt to reduce the trihalomethane precursor concentration(s).

3. Adjusting the pH toward conditions less favorable for trihalomethane formation.

4. Changing the coagulant dosage to improve precursor removal.

5. Reducing the chlorine dose consistent with bacteriological quality requirements.

6. Moving the point of chlorination to the last step in the treatment process.

Data collected during these operation changes are still being analyzed, but preliminary results are favorable.

Control of Specific Organics

To date, the major treatment technique investigated for the removal of specific organics from drinking water has been granular activated carbon (GAC). About ten years ago, partially exhausted granular activated carbon was shown to remove dieldrin, lindane, 2,4,5-T, DDT, and parathion to below the detection limit of the available analytic methodology. About the same time, fresh granular activated carbon used to treat Kanawha River water was shown to remove bis (2-chloroethyl) ether, α-methylbenzyl alcohol, acetophenone, isophorone, and tetralin. This removal was effective for most of these compounds for about six weeks. More recent studies have shown that fresh granular activated carbon receiving finished water from Evansville, Indiana, removed all detectable bis (2-chloroethyl) ether and bis (2-chloroisopropyl) ether. Finally, a GAC column removed approximately 30 μg/ℓ of naphthalene spiked into Cincinnati, Ohio, tap water for 8 months. After that time, although other organics were penetrating the bed, the naphthalene was being removed within the top 3 inches (10 cm) of the column. This indicates that GAC may be very effective in removing naphthalene.

Removal of Trihalomethanes and Trihalomethane Precursors

Since the fall of 1974, a major in-house research effort has been directed toward understanding under what conditions trihalomethanes or their precursors could be removed during water treatment. Because no test for trihalomethane precursors presently exists, the removal of trihalomethane precursors is measured by the concentration of trihalomethanes, primarily chloroform, formed during chlorination after some specific treatment has been applied. This result is compared with the concentration of trihalomethanes formed from a control sample after similar chlorination.

Granular Activated Carbon

The removal of trihalomethane by granular activated carbon was studied by passing Cincinnati, Ohio, tap water over one coal-based and

one lignite-based granular activated carbon bed. For about one month, both columns removed all of the trihalomethanes, and then some chloroform began appearing in the effluent. Within ten weeks, both columns were exhausted for trihalomethane removal.

At the same time, a pilot plant, made of stainless steel and glass, was treating 0.4 liters/minute (150 gal/day) of unchlorinated Ohio River water to demonstrate how effectively trihalomethane precursors could be removed. Studies have shown that coagulation of the river water with alum, sedimentation, and passage through a 30-inch (75 cm) GAC combination filter/adsorber was nearly 100 percent effective for removing trihalomethane precursors for two weeks; 50 percent effective for 10 weeks; and exhausted after 20 weeks. After 10 weeks, the amount of chloroform formed after a 4-day chlorine contact time was 16 μg/ℓ. Finally, in a companion experiment, after 20 weeks of operation, a GAC filter/adsorber that was twice as deep as the one previously described was about 50 percent effective for trihalomethane precursor removal, indicating a direct relationship between performance and bed depth. Current experience indicates that the effective life of GAC for the removal of trihalomethane precursor is somewhat limited.

Powdered Activated Carbon

Doses of powdered activated carbon (PAC) much higher than ordinarily used in water treatment were required before any removal of trihalomethanes or trihalomethane precursors occurred. A PAC dose of 100 mg/ℓ resulted in only 50 percent removal of chloroform. Similarly, in a separate experiment, the same dose removed approximately 50 percent of the trihalomethane precursors, as measured by the concentration of trihalomethanes after chlorination.

Aeration

Attempts were made to strip trihalomethanes, which have relatively low boiling points, from water using aeration techniques. Little, if any, success was obtained using diffused-air aeration with one-to-one air-to-water ratios and contact times typical of aeration in water treatment practice. On the other hand, larger doses of gas, up to fifteen-to-one gas-to-water ratios, removed approximately 50 percent of the chloroform. Even higher gas-to-water ratios were required for essentially complete chloroform removal. Studies on aeration will continue, concentrating on spray rather than diffused-air aeration.

Ozone

Ozone was used after coagulation, settling, and mixed-media filtration at a disinfection level dose (0.6 to 0.7 mg/ℓ) and for approximately 6 minutes of contact. This application of ozone did not result in reduction of trihalomethane precursors as evidenced by trihalomethane formation upon subsequent chlorination. Increasing the ozone dose 30 times still produced no reduction in trihalomethane precursors. Only at

an economically impractical dose, 350 times the disinfection dose, did a 30 percent reduction in trihalomethane precursors occur.

To investigate the role that contact time plays in precursor reduction using ozone, batch studies have also been performed. These studies show that trihalomethane precursors are resistant to ozonation, at least under the test conditions selected. For example, two hours of continuous ozonation were required to reduce the trihalomethane precursor level in dual-media filter effluent by 50 percent. Batch studies have also shown that trihalomethane precursors are more readily removed by ozone from Ohio River water than from dual-media filtered water, probably because of their presence in much higher concentrations. Further studies will be directed towards raw water ozonation for trihalomethane precursor removal. Initial studies have shown that a dose of 24 mg/ℓ of ozone was not effective in removing trihalomethanes themselves.

Chlorine Dioxide

Because of its oxidizing properties, chlorine dioxide has been used to some extent for taste and odor control, but because of its cost, it is not widely used in water treatment practice for disinfection. In this study it is being used, however, as a disinfectant to investigate the formation of trihalomethanes. Pure chlorine dioxide can be formed by slowly adding 10 percent sulfuric acid to a 10 percent solution of sodium chlorite. Under these conditions, over a wide range of doses (0.15 - 6 mg/ℓ) and contact times (30 min. to 4 days), no trihalomethanes were formed. Disinfection was satisfactory.

When chlorine dioxide is used in water treatment, it is generated by reacting excess chlorine with sodium chlorite; therefore, chlorine dioxide is rarely encountered in practice without excess chlorine also present. Initial data indicate that when water is dosed with both chlorine dioxide and chlorine, trihalomethane formation occurs. The concentration formed is less than that with the equivalent amount of chlorine alone, however. At least under the test conditions studied, chlorine dioxide apparently has some influence on the reaction of chlorine and the trihalomethane precursor(s).

Treatment for General Organics

An attempt is being made to produce continuously water low in organic content. If the organic content of the treated water is low, the likelihood that it contains any specific carcinogen is minimized. The parameter being used to judge the success of this experiment is non-volatile total organic carbon (NVTOC). The goal of this experiment is to produce continuously water with an NVTOC concentration $\leq$ 100 μg/ℓ.

The treatment method being studied is an upflow countercurrent, "moving bed" GAC column. Water enters the bottom of the column and flows upward through the GAC bed. NVTOC samples are periodically collected from the column influent, GAC bed midpoint, and column effluent. When the effluent NVTOC concentration exceeds 100 μg/ℓ and continues to show an upward trend for several days, one-half of the GAC is removed from the bottom of the bed and an equal quantity of fresh GAC is added at the top.

Three bed depths of a coal-based GAC have been investigated for effectiveness in treating Cincinnati tap water. Using an 8-inch (27 cm) bed, the NVTOC limit was met for only 1 to 3 days of operation, while a 16-inch (41 cm) bed was able to meet the NVTOC limit for 8 to 12 days. A 30-inch (76 cm) bed has met the limit for up to 30 days, although the period is variable, possibly because of hydraulic short-circuiting. Further study of GAC treatment will use various grades and types of GAC and larger diameter columns to improve hydraulic flow. The effluent will be analyzed for the penetration of specific organics of interest as well as for NVTOC.

Extramural Research

Future plans include pilot- and full-scale research designed to examine the effectiveness of granular activated carbon, aeration, synthetic resins, potassium permanganate, UV catalyzed oxidation, and ozonation for the removal of specific raw water contaminants of concern, particularly carcinogens. Negotiations are currently in progress with the water utilities of Miami, Florida; Cincinnati, Ohio; Evansville, Indiana; New Orleans, Louisiana; and Jefferson Parish, Louisiana, that hopefully will lead to the award of research grants to these utilities for the large scale study of various water treatment organic removal unit processes. In addition, the Ohio River Valley Sanitation Commission (ORSANCO) has proposed to act as a broker for several water utilities in the Ohio Valley who wish to alter their treatment practices to reduce the concentration of trihalomethanes in their finished water.

Other planned research grants and contracts will investigate various aspects of the problem of carcinogens in drinking water, such as the influence of agricultural runoff on trihalomethane formation, reaction of chlorine with activated carbon and resulting by-products, competitive adsorption on GAC of specific organics of concern, specific precursors of trihalomethane formation, methods of reactivation of GAC, and formation of other chlorinated by-products during disinfection. At this time (November 1975), none of these research grants has been awarded and funding is uncertain.

Treatment Studies on Inorganics

Of the substances studied thus far, only arsenic, selenium, and nitrates (potential nitrosoamine precursors) have been considered as suspected carcinogens in drinking water. Treatment technology studies for these substances have been conducted. Arsenic and selenium were studied in bench- and pilot-scale investigations by spiking Ohio River water and ground water from Glendale, Ohio, with concentrations of arsenic from two to ten times the levels in the Interim Primary Drinking Water Regulations.

Bench- and pilot-scale studies on arsenic, selenium, mercury, barium, cadmium, and chromium have been conducted. These investigations showed that no one technique was effective for all contaminants studied. Lime softening achieved good removals on inorganic mercury, barium, arsenic V, cadmium, and chromium III. Ferric sulfate coagulation was effective for removing inorganic mercury, arsenic V, selenium IV, cadmium, and chromium III. Alum coagulation was effective on arsenic V, cadmium, and chromium III, although ferrous sulfate produced good removals on chromium VI. No technique was found very effective for arsenic III and selenium VI. Arsenic III can be removed by any method effective on arsenic V, providing arsenic III is first oxidized (chlorinated) to arsenic V. Preliminary results showed that reverse osmosis was effective for selenium VI removal. Anion exchange resins were effective for nitrate-nitrogen removal in soft water, but were less efficient in highly mineralized water.

The optimum removals were as follows: arsenic V, excess lime softening, 60 to >90 percent removal, selenium IV, iron coagulation at pH <7, 30 to 60 percent removal, and nitrate-nitrogen, anion exchange >90 percent removal. Data presented earlier in the Report show that trihalomethane formation is enhanced by chlorination at higher pH. Therefore, any treatment processes used for inorganic contaminant removal that results in a higher pH may cause an increase in trihalomethane concentration, other factors being the same. Future work will consist of continuing the studies on the removal of selenium VI and investigating the removal of lead. In addition, a research grant was funded to study further the removal of nitrate from drinking water by ion exchange.

Techniques for Controlling Radionuclides

Information on the treatment potential of various techniques for radium 226 removal was obtained by monitoring several water treatment plants in Iowa and Illinois that are treating water that is naturally high in radium 226. Ion exchange softening, lime softening, and reverse osmosis were found to be effective for removing radium 226. To improve treatment cost data, a research grant was funded to determine the cost of unit treatment processes to remove radium 226 and the cost of disposing of the waste sludge material.

Methods of Removing Asbestiform Fibers

Mixed media filtration and diatomaceous earth (DE) filtration were shown to be effective for reducing asbestiform fiber counts in Lake Superior water during pilot plant research conducted for five months in 1974. Among the most effective techniques were pretreatment of the water with alum and a nonionic polymer before mixed media filtration, and coating of the DE filter aid with alum or a polymer. Both amphibole and chrysotile fiber counts can be markedly reduced by either filtration technique. During the pilot plant study, engineering data were also obtained for making cost estimates for construction and operation of both granular media and DE filtration plants ranging in capacity from 0.03 to 30 million gallons per day.

The City of Duluth has accepted a demonstration grant from EPA to build and operate a 30-million gallon per day filtration plant to demonstrate full-scale water treatment for reduction of asbestiform fiber count. EPA will provide guidance and direction for the research to be conducted at the plant. EPA is also considering research grant applications for development of a rapid optical means of detecting asbestiform fibers in drinking water, and for pilot plant research to reduce the chrysotile fiber count in water from a protected mountain watershed.

COST OF TREATMENT TO REMOVE CARCINOGENS

General Cost of Water

In most major metropolitan areas, the cost of drinking water, including coagulation, flocculation, sedimentation, filtration and disinfection, is from 30 to 50 cents per 1000 gallons. Of this overall cost, only 5 to 8 cents per 1000 gallons is the cost of water treatment. EPA has nearly completed a study that shows the average cost of drinking water in eleven major utilities to be about 43 cents per 1000 gallons. Twelve percent of these costs are for treatment, with the balance for acquisition of water, pumping, salaries of employees, administration, amortization of distribution systems, and other nontreatment costs. Additional treatment costs should be viewed in relation to the overall cost. Although treatment costs are relatively small, these costs will be significantly affected as a result of the implementation of the Safe Drinking Water Act.

In an effort to determine possible cost increases, an attempt was made to estimate treatment costs for the control of a variety of contaminants. These costs, which include amortization of capital equipment as well as operation and maintenance costs, are only very general estimates because of several uncertain factors. These factors include the availability of chemicals, costs of chemical handling and disposal, cost of energy, general inflationary trends in materials and labor, and uncertainty of specific technology application, such as the reactivation schedule necessary when using granular activated carbon to prevent the breakthrough of toxic contaminants. For example, other investigators have estimated the cost of treating highly contaminated water by granular activated carbon to be about 11 cents per 1000 gallons as compared with the estimates contained in Table 10. Other uncertainties are lack of knowledge as to where, nationwide, these treatment processes will have to be applied and the impact of economics of scale. For example, the unit cost of applying these treatment processes to small systems may be much higher than in large systems. Finally, future research may develop new treatment methods unknown at this time (November 1975). Therefore, although these costs are accurate within the assumptions used, they must be viewed within the context of the above uncertainties. EPA is sponsoring several extramural projects that are designed to collect better cost information so that these estimates can be refined in the future.

Cost of Removing Carcinogenic Contaminants

By-Products of Chlorination (Chloroform and Other Trihalomethanes)

Studies have shown that removing trihalomethanes is more difficult than preventing their formation. Two techniques are available for avoiding trihalomethane formation. One is the use of an alternative to chlorine as a disinfectant; the other is to remove the precursor(s) that react with chlorine.

The most common choices for alternate disinfectants are ozone and chlorine dioxide. Ozone is a very strong disinfectant, but has the

disadvantage of not producing a disinfectant residual to carry throughout the distribution system. Furthermore, the reactions of ozone with organic compounds in the water are not well known. The possibility of the formation of undesirable by-products is under investigation. Chlorine dioxide has the advantage of producing a disinfectant residual, but generation of this material without excess chlorine is somewhat difficult. Further, sodium chlorite, one of the reactants to produce chlorine dioxide, is relatively expensive, 65 cents per pound. The by-products of chlorine dioxide oxidation are also unknown at this time, and the toxicity of chlorite, should any remain in the water, is of concern.

Because the disinfecting powers of these three disinfectants are different, the most appropriate way to compare them is on an equal disinfection basis. At the present time, this is not possible and research is necessary to better understand their disinfecting powers. On the basis of a dose of 1 mg/ℓ, the cost of disinfection in cents per one thousand gallons is 0.08 cents for chlorine, 0.5 cents for chlorine dioxide, and 0.1 cents for ozone.

Studies have shown that for 10 weeks granular activated carbon can remove sufficient concentrations of trihalomethane precursors to reduce the resultant chloroform concentration to 50 percent of that which would have been produced without treatment. To illustrate the costs that are involved in using and reactivating GAC on-site, costs have been estimated for two treatment plants with 10 and 100 million gallons per day filter capacity. Estimates were calculated for various reactivation times for GAC. Depending on the quality of the input water, reactivation requirements will differ and accordingly affect the size of the furnace required to reactivate the exhausted activated carbon. The plant and furnace capacity will have a major impact on capital cost, although the rate of activated carbon attrition, maintenance, and energy requirements will affect operating costs. The cost assumptions used for the calculations are in Table 9.

The data contained in Table 10 are based on the assumptions listed in Table 9, and illustrate the dual impact of economies of scale and water quality on unit treatment costs. For example, for any given reactivation cycle and flow rate, the cost per unit volume is less for the 100 mgd plant than the 10 mgd plant, illustrating the economies of scale. In addition, operating costs (fuel, labor, attrition losses, and maintenance) decline as the reactivation cycles become longer, although the capital costs remain almost constant. Further, the increase in the unit volume costs that occurs when the treatment plant is operating at a rate below that of the initial design illustrates the cost of excess capacity. Finally, a not so apparent effect on cost is that of input water quality as reflected by reactivation frequency. The activated carbon in a 10 mgd plant operating at 7 mgd might be expected to become exhausted at a slower rate than when the plant is operating at full capacity, thereby reducing the cost of reactivation. The exact relation between flow rate and input water quality is not known at this time.

Table 9

ESTIMATED COSTS FOR GRANULAR ACTIVATED CARBON TREATMENT*

	Plant Filtration Capacity 10 mgd	100 mgd
Furnace Cost		
1 - 3 month reactivation	$304,000	$1,100,000
6 - 8 month reactivation	275,000	560,000
Initial Activated Carbon		
-Charge (lbs.)	260,000	2,600,000
-Cost ($)	98,800	988,000
Engineering Fees, Steam Generator, Quench Tank	20,000	3% of furnace and carbon costs
Labor per Reactivation	2,500	15,000

*Assumptions Used in Estimating Costs for Granular Activated Carbon Treatment of Drinking Water

Filter capacity - One million gallons per day
Filter design flow rate per square foot (for sizing) -2 gpm/ft^2

Activated carbon depth - 30 inches
Activated carbon loading per filter - 30 pound per ft^3
Activated carbon cost - $0.38 per pound
Activated carbon attrition - 10% per reactivation

Amortization rate - 20 years @ 7%

Fuel requirements - 6000 BTU's per pound of activated carbon reactivated
Fuel costs -$1.26 per million BTU's

Maintenance - 1% of capital costs*

*Capital Costs - Activated carbon, furnace, engineering fees, steam generator, quench tank.

These costs in Table 10 are in addition to the costs of treating water for particulate removal and disinfection. The data given are for the use of GAC as a replacement for the granular media used in conventional water treatment. Studies have shown that, in terms of organic removal capacity, the filtration of carryover floc by GAC does not interfere significantly with adsorption for organic removal. Calculations have estimated that this is a less expensive method of treatment than the use of GAC following filtration for clarification.

Table 10

ESTIMATED UNIT COSTS FOR USING GRANULAR ACTIVATED CARBON IN THE TREATMENT OF DRINKING WATER

Unit Costs (cents/1000 gallons)

Plant Size (mgd)	Actual Average Production (mgd)	Reactivation Frequency: 1 Month			3 Months			6 Months			12 Months			18 Months		
		C	O	T	C	O	T	C	O	T	C	O	T	C	O	T
10	10	1.1	4.8	5.9	1.1	1.5	2.6	1.0	0.8	1.8	1.0	0.4	1.4	1.0	0.3	1.3
	7	1.6	6.8	8.4	1.6	2.1	3.7	1.4	1.2	2.6	1.4	0.6	2.0	1.4	0.5	1.9
100	100	0.5	4.6	5.1	0.5	1.4	1.9	0.4	0.8	1.2	0.4	0.4	0.8	0.4	0.3	0.7
	70	0.7	6.6	7.3	0.7	2.0	2.7	0.6	1.1	1.7	0.6	0.5	1.1	0.6	0.4	1.0

C = Capital costs (activated carbon, activated carbon furnace, engineering fee, steam generator, eductor, quench tank)
O = Operating costs (Fuel, labor, attrition losses, maintenance)
T = Total cost

These costs may be significantly higher for smaller systems or for systems that do not have filters that may be converted to GAC. For example, some surface water supplies are not generally filtered.

Organic Contaminants in Raw Water

Thus far, the best method for removing environmental contaminants such as carbon tetrachloride, dieldrin, and haloethers from raw water is the use of beds of granular activated carbon. Studies are not sufficiently advanced at this time (November 1975) to determine the exact length of time of operation before the activated carbon needs to be reactivated for a wide variety of environmental carcinogens. GAC does, however, begin to lose some of its effectiveness for general organic carbon removal as evidenced by an increase in NVTOC concentration in the effluent after 4 to 6 weeks. In actual practice, the GAC beds might not have to be reactivated as frequently as these data indicate. For example, tests have shown that naphthalene is completely removed by GAC for at least 8 months (the duration of the study). Similarly, other specific organic compounds of concern may be effectively removed even though some other organics begin to pass through the bed. A further advantage of using GAC beds is that not only are environmental contaminants removed, but so are trihalomethane precursors. Finally, the extent of the national requirement for granular activated carbon treatment will not be known until the monitoring program described earlier on page 15, "Monitoring to Assess Parameters", is completed.

Inorganics

Arsenic

Chemical coagulation and lime softening can effectively remove arsenic V and also arsenic III, providing the latter has been oxidized (by chlorination) to the higher oxidation state prior to treatment. Because the two water treatment processes are somewhat similar, the estimated costs for either process to remove arsenic are approximately the same, 12 to 15 cents per 1000 gallons, for a 1 mgd treatment plant.

Selenium

Lime softening and chemical coagulation can remove selenium IV with the latter being more effective. As noted above, the costs of the two processes are approximately the same, 12 to 15 cents per 1000 gallons.

Presently, only reverse osmosis seems effective for the removal of selenium VI. Consequently, the costs of removing this form of selenium are much higher than for the reduced form. The range of costs for reverse osmosis is estimated to be 71 to 104 cents per 1000 gallons for a 0.15 mgd treatment plant.

Nitrate-nitrogen

The only known treatment system currently (November 1975) in operation in the United States that is specifically designed to remove nitrate-nitrogen from drinking water is an ion exchange plant located on Long Island, New York. The plant has been operating for only a short time and operating costs are not available. The estimated cost for a 4 mgd plant operating at 40 percent of capacity, however, was 12 to 21

cents per 1000 gallons for the removal of 20 to 40 mg/ℓ of nitrate-nitrogen. This cost includes operating and amortized capital cost. Operating costs alone were estimated at 7 to 16 cents per 1000 gallons.

Radium 226/228

Estimates on costs for removing radium from drinking water can be based on softening costs as the processes that soften water also remove radium. Typical costs are presented in Table 11.

Table 11

COSTS FOR SOFTENING WATER

Process	Plant Size	Cost Range, Cents/1000 Gal.
Ion Exchange	1.0 mgd	12 - 15
Lime Softening	1.0 mgd	27 - 34
Reverse Osmosis	0.15 mgd	71 - 104

The costs in this table may be low because they do not reflect the costs of disposing wastes generated by the treatment process in environmentally acceptable ways. If water treatment plants are compelled by pollution control agencies to treat wastes from softening processes, these costs will increase. EPA has funded a research grant designed to develop better estimates for the cost of radium removal from drinking water, including waste disposal costs.

Asbestos Fibers

As a result of the pilot-plant research on asbestos fiber removal conducted in Duluth, Minnesota, where the raw water is relatively low in turbidity, the estimated cost of water from a new 30 mdg direct filtration plant capable of removing particulates and asbestos fibers was approximately 7 cents per 1000 gallons. This included amortization of first cost, plus operating and maintenance costs. In existing plants currently operating to remove particulates, the additional cost to upgrade the treatment to remove asbestos fibers would be small, involving changes in coagulants and polyelectrolytes.

APPENDIX I

NATIONAL ORGANICS RECONNAISSANCE SURVEY

Table I-1

NAMES AND LOCATIONS OF WATER UTILITIES SURVEYED

Region I

1.[a] Lawrence Water Works
Lawrence, Massachusetts
Merrimack River[b]

2. Waterbury Bureau of Water
Waterbury, Connecticut
Wigwam and Morris Reservoirs
Morris Treatment Station

3. Metropolitan District Commission
Boston, Massachusetts
Quabbin & Wachusett Reservoirs
Norumbego Treatment Station

4. Newport Department of Water
Newport, Rhode Island Reservoirs
South Pond Reservoir Treatment Plant #1

Region II

5. Department of Water Resources
New York, New York
Croton Reservoir

6. Puerto Rico Aqueduct & Sewer Authority
San Juan, Puerto Rico
Lake Carraizo
Sergio Curevas Water Treatment Plant

7. Passaic Valley Water Commission
Little Falls, New Jersey
Passaic River

8. Toms River Water Company
Toms River, New Jersey
Ground
Well #20

9. Buffalo Water Department
Buffalo, New York
Lake Erie

10. Village of Rhinebeck Water Dept.
Rhinebeck, New York
Hudson River

Region III

11. Philadelphia Water Department
Philadelphia, Pennsylvania
Delaware River
Torresdale Plant

12. Wilmington Suburban Water Corp.
Claymont, Delaware
Red Clay and White Clay Creek
Stanton Plant

13. Artesian Water Company
Newark, Delaware
Ground
Llangolen Well Field Plant

14. Washington Aqueduct
Washington, D.C.
Potomac River
Delacarlia Plant

15. Baltimore City - Bureau of Water Supply
Baltimore, Maryland
Loch Raven Reservoir
Montebello Plant #1

16. Western Pennsylvania Water Company
Pittsburgh, Pennsylvania
Monongahela River
Hays Mine Plant

17. Strasburg Borough Water System
Strasburg, Pennsylvania
Ground

18. Fairfax County Water Authority
Annandale, Virginia
Occoquan River Impoundment
New Lorton Plant

---

[a]Table I-2 uses the same numbers to designate the different water utilities.

[b]The name of the utility is listed first, followed by the city name, the name of the raw water source, and, if the utility has more than one treatment plant, the name of the treatment plant sampled.

19. Virginia American Water Co.
Hopewell District
Hopewell, Virginia
Appomattox River

20. Huntington Water Corp.
Huntington, West Virginia
Ohio River

21. Wheeling Water Department
Wheeling, West Virginia
Ohio River

Region IV

22. Miami-Dade Water and Sewer Authority
Miami, Florida
Ground
Preston Plant

23. Jacksonville Dept. of Public Works
Jacksonville, Florida
Ground
Highlands Pumping Station

24. Atlanta Waterworks
Atlanta, Georgia
Chattahoochee River
Chattahoochee Plant

25. Owensboro Municipal Utilities
Owensboro, Kentucky
Ground

26. Greenville Water Department
Greenville, Mississippi
Ground
Water Plant Well #2

27. Tennessee American Water Company
Chattanooga, Tennessee
Tennessee River

28. Memphis Light, Gas and Water Div.
Memphis, Tennessee
Ground
Malloy Plant

29. Metropolitan Water & Sewage Dept.
Nashville, Tennessee
Cumberland River

30. Commissioner of Public Works
Charleston, South Carolina
Edisto River
Stoney Plant

Region V

31. Cincinnati Water Works
Cincinnati, Ohio
Ohio River

32. Chicago Dept. of Water and Sewers
Chicago, Illinois
Lake Michigan
South District Water Filtration Plant

33. Clinton Public Water Supply
Clinton, Illinois
Ground

34. Indianapolis Water Company
Indianapolis, Indiana
White River and Wells
White River Plant

35. Whiting Water Department
Whiting, Indiana
Lake Michigan

36. Detroit Metro Water Department
Detroit, Michigan
Detroit River Intake at head of
Belle Isle
Waterworks Park Plant

37a. Mt. Clemens Water Purification
Mt. Clemens, Michigan
Lake St. Clair

37b. Mt. Clemens Water Purification[c]
Mt. Clemens, Michigan
Lake St. Clair

38. St. Paul Water Department
St. Paul, Minnesota
Mississippi River

39. Cleveland Division of Water
Cleveland, Ohio
Lake Erie
Division Filtration Plant

40. City of Columbus
Columbus Ohio
Scioto River
Dublin Road Plant

[c]Resampled after granular activated carbon was changed.

41. Dayton Water Works
Dayton, Ohio
Ground
Ottawa Plant

42. Indian Hill Water Supply
Cincinnati, Ohio
Ground

43. Piqua Water Supply
Piqua, Ohio
Swift Run Lake

44. Mahoning Valley Sanitary District
Youngstown, Ohio
Meander Creek Reservoir

45. Milwaukee Water Works
Milwaukee, Wisconsin
Lake Michigan
Howard Avenue Purification Plant

46. Oshkosh Water Utility
Oshkosh, Wisconsin
Lake Winnebago

Region VI

47. Terrebonne Parish Waterworks District #1
Houma, Louisiana
Bayoulafourche

48. Camden Municipal Water Works
Camden, Arkansas
Ouachita River

49. Town of Logansport Water System
Logansport, Louisiana
Sabine River

50. City of Albuquerque
Albuquerque, New Mexico
Ground

51. Oklahoma City Water Department
Oklahoma City, Oklahoma
Lake Hefner
Hefner Plant

52. Brownsville Public Utility Board
Brownsville, Texas
Rio Grande River
Plant #2

53. Dallas Water Utilities
Dallas, Texas
Elm Fork, Trinity River
Bachman Plant

54. San Antonio City Water Board
San Antonio, Texas
Ground

Region VII

55a. Ottumwa Water Works
Ottumwa, Iowa
Des Moines River

55b. Ottumwa Water Works[d]
Ottumwa, Iowa
Des Moines River

56. Clarinda Iowa Water Works
Clarinda, Iowa
Nodaway River

57. Davenport Water Company
Davenport, Iowa
Mississippi River

58. Topeka Public Water Supply
Topeka, Kansas
Kansas River
South Plant

59. Missouri Utility Company
Cape Girardeau, Missouri
Mississippi River

60. Kansas City Missouri Water Dept.
Kansas City, Missouri
Missouri River

61. St. Louis County Water Company
St. Louis, Missouri
Missouri River
Central Plant

62. Lincoln Municipal Water Supply
Lincoln, Nebraska
Ground

Region VIII

63. City Water Department
Grand Forks, North Dakota
Red Lake

[d]Resampled

64. Denver Water Board
Denver, Colorado
Marston Lake
Marston Plant

65. Pueblo Board of Waterworks
Pueblo, Colorado
Arkansas River
Gardner Plant

66. Huron Water Department
Huron, South Dakota
James River

67. Salt Lake Water Department
Salt Lake, Utah
Mountain Dell Reservoir

Region IX

68. City of Tucson Water and Sewers Dept.
Tucson, Arizona
Ground
Plant #1

69. City of Phoenix Water & Sewers Department
Phoenix, Arizona
Salt and Verde Rivers
Verde Plant

70. Department of Supply & Purification
Coalinga, California
California Aqueduct

71. Contra Costa County Water Department
Concord, California
Contra Costa Canal and San Joaquin River
Bollman Plant

72. City of Dos Palos Water Department
Dos Palos, California
Delta-Mendota Canal

73. Los Angeles Department of Water and Power
Los Angeles, California
Van Norman Reservoir

74. San Diego Water Utilities Dept.
San Diego, California
Colorado River Aqueduct
Miramar Plant

75. San Francisco Water Department
San Francisco, California
San Andreas Reservoir
San Andreas Treatment Plant

Region X

76. Seattle Water Department
Seattle, Washington
Cedar River Impoundment
Cedar River System

77. Douglas Water System
Douglas, Alaska
Douglas Reservoir

78. Idaho Falls Water Department
Idaho Falls, Idaho
Ground

79. City of Corvallis Utilities Div.
Corvallis, Oregon
Willamette River
Taylor Plant

80. Ilwaco Municipal Water Department
Ilwaco, Washington
Black Lake

Table I-2

NATIONAL ORGANICS RECONNAISSANCE SURVEY WATER QUALITY DATA

DATA FROM 80 UTILITIES FOR FOUR TRIHALOMETHANES, CARBON TETRACHLORIDE, AND 1,2-DICHLOROETHANE[1]

Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
1. Lawrence Water Works	*<0.1*	*<0.2*	*<NF+*	*NF*	*NF*	*NF*	*3.7*
	91	9	0.6	NF	NF	NF	1.6
2. Waterbury Bureau of Water (Morris Treatment Station)	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*2.2*
	93	10	0.6	<1	<0.2	<2	2.9
3. Metropolitan District Commission (Norumbego Treatment Station) Boston, Massachusetts	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*2.1*
	4	0.8	NF	NF	NF	NF	2.0
4. Newport Dept. of Water (South Pond Reservoir Treatment Plant #1)	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*4.6*
	103	42	13	1	NF	NF	4.1
5. Department of Water Resources New York, New York	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*3.0*
	22	7	0.9	NF	NF	NF	2.5
6. Puerto Rico Aqueduct and Sewer Auth. (Sergio Cuevas Water Treatment Plant)	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*2.0*
	47	29	16	2	NF	NF	2.0
7. Passaic Valley Water Commission Little Falls, New Jersey	*0.3*	*NF*	*NF*	*NF*	*<0.2*	*<2*	*3.6*
	59	16	2	NF	<0.2	<2	1.9
8. Toms River Water Company	*0.4*	*NF*	*NF*	*NF*	*NF*	*NF*	*<0.05*
	0.6	<0.8	3	NF	NF	NF	<0.05

1. First line in italics is raw water data. Second line in regular type is finished water data.
2. NF - None Found
3. * - Some raw water data may be in error because of incomplete combustion of particulates in some raw waters.

	Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
9.	Buffalo Water Department	*NF* 10	*NF* 10	*NF* 4	*NF* NF	*NF* <0.2	*NF* NF	*2.6* 1.7
10.	Village of Rhinebeck Water Department	*0.3* 49	*NF* 11	*NF* 1	*NF* NF	*3* 2	*NF* NF	*3.5* 1.6
11.	Philadelphia Water Department (Torresdale Plant)	*0.2* 86	*NF* 9	*NF* 5	*NF* NF	*3* 6	*NF* NF	*2.6* 1.7
12.	Wilmington Suburban Water Corp. (Stanton Plant) Claymont, Delaware	*0.3* 23	*<0.4* 11	*NF* 3	*NF* NF	*NF* <0.4	*NF* <2	*2.8* 1.8
13.	Artesian Water Company (Llangolen Well Field Plant)	*0.2* 0.5	*NF* 0.5	*NF* 1	*NF* <1	*NF* <0.2	*NF* NF	*0.05* 0.2
14.	Washington Aqueduct (Delacarlia Plant)	*<0.2* 41	*NF* 8	*NF* 2	*NF* NF	*NF* <0.3	*NF* NF	*1.8* 1.2
15.	Baltimore City Bureau of Water Supply (Montebello Plant #1)	*NF* 32	*NF* 11	*NF* 2	*NF* NF	*NF* NF	*NF* NF	*1.8* 1.2
16.	Western Pennsylvania Water Company (Hays Mine Plant)	*0.3* 8	*NF* 2	*NF* 0.4	*NF* NF	*NF* NF	*NF* NF	*0.9* 0.8
17.	Strasburg Borough Water System	*NF* <0.1	*NF* NF	*NF* NF	*NF* NF	*NF* NF	*NF* NF	*0.2* 0.05
18.	Fairfax County Water Authority (New Lorton Plant)	*<0.2* 67	*<0.4* 6	*NF* <0.6	*NF* NF	*NF* NF	*NF* NF	*4.7* 2.7
19.	Virginia-American Water Company Hopewell District	*0.2* 6	*NF* 1	*NF* 0.8	*NF* <2	*NF* NF	*NF* NF	*4.2* 0.2

Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
20. Huntington Water Corp.	*1* 23	*NF* 16	*NF* 5	*NF* NF	*<0.3* <0.4	*4* 3	*2.2* 1.0
21. Wheeling Water Department	*0.2* 72	*NF* 28	*NF* 17	*NF* NF	*<0.3* <0.4	*NF* NF	*3.2* 1.8
22. Miami-Dade Water and Sewer Authority (Preston Plant)	*NF* 311	*NF* 78	*NF* 35	*NF* 3	*<0.2* <0.2	*<2* NF	*9.8* 5.4
23. Jacksonville Dept. of Public Works (Highlands Pumping Station)	*NF* 9	*NF* 4	*NF* 2	*NF* NF	*NF* NF	*NF* NF	*2.40* 2.3
24. Atlanta Waterworks (Chattahoochee Plant)	*<0.2* 36	*NF* 10	*NF* 2	*NF* NF	*<0.3* NF	*NF* NF	*1.3* 0.9
25. Owensboro Municipal Utilities	*NF* 13	*NF* 20	*NF* 17	*NF* 3	*NF* NF	*NF* NF	*1.7* 2.0
26. Greenville Water Department	*0.3* 17	*NF* 6	*NF* 3	*NF* <1	*NF* <0.2	*NF* NF	*3.3* 4.0
27. Tennessee American Water Company Chattanooga, Tennessee	*0.9* 30	*NF* 9	*NF* 0.7	*NF* NF	*NF* <0.4	*NF* NF	*1.1* 0.6
28. Memphis Light, Gas and Water Div. (Malloy Plant)	*<0.2* 0.9	*NF* 2	*NF* 1	*NF* NF	*NF* NF	*NF* NF	*0.2* 0.2
29. Metropolitan Water and Sewerage Dept. (Lawrence Plant)	*<0.1* 16	*NF* 5	*NF* <0.4	*NF* NF	*NF* NF	*NF* NF	*1.2* 0.8
30. Commissioners of Public Works (Stoney Plant) Charleston, South Carolina	*<0.2* 195	*NF* 9	*NF* 0.8	*NF* 0.8	*NF* NF	*NF* NF	*11.4* 4.1

Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
31. Cincinnati Water Works	*0.5* 45	*NF* 13	*NF* 4	*NF* NF	*NF* <0.4	*<2* <2	*2.3* 1.1
32. Chicago Dept. of Water and Sewers (South District Water Filt. Plant)	*<0.2/0.4* 15	*NF/<0.5* 10	*NF/NF* 4	*NF/NF* NF	*NF/NF* <0.4	*NF/NF* NF	*1.9/1.7 (Two samples)* 1.5
33. Clinton Public Water Supply	*<0.2* 4	*NF* 0.5	*NF* NF	*NF* NF	*NF* NF	*NF* NF	*7.7* 6.7
34. Indianapolis Water Company (White River Plant)	*0.1* 31	*NF* 8	*NF* <2	*NF* NF	*<0.3* NF	*NF* 2	*5.1* 2.6
35. Whiting Water Department	*16* *0.1* 0.5	*11* *<0.8* 0.3	*3* *NF* NF	*NF* *NF* NF	*NF* *NF* NF	*NF* *NF* NF	*2.0 (After pre Cl_2)* *1.9 (Before pre Cl_2)* 1.5
36. Detroit Metro Water Department (Water Park Plant)	*<0.2* 12	*NF* 9	*NF* 3	*NF* NF	*0.5* 0.4	*NF* NF	*2.6* 1.2
37a. Mt. Clemens Water Purification	*NF* 11	*NF* 6	*NF* <2	*NF* NF	*NF* <0.4	*NF* NF	*2.0* 1.4
37b. Mt. Clemens Water Purification *(After replacement of granular act. carbon)*	*0.9* 6	*NF* 3	*NF* <2	*NF* NF	*<0.2* NF	*NF* NF	*6.7* 1.4
38. St. Paul Water Authority	*<0.2* 44	*NF* 7	*NF* 2	*NF* NF	*NF* NF	*NF* NF	*7.9* 4.4
39. Cleveland Division of Water (Division Filtration Plant)	*NF* 18	*NF* 9	*NF* 4	*NF* NF	*NF* NF	*NF* NF	*2.2* 1.8
40. City of Columbus (Dublin Road Plant)	*0.1* 134	*NF* 8	*NF* <0.4	*NF* NF	*NF* NF	*NF* NF	*6.8* 2.3

Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
41. Dayton Water Works	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*0.9*
(Ottawa Plant)	8	8	11	4	<0.2	<2	0.7
42. Indian Hill Water Supply	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*0.8*
	5	7	11	NF	NF	NF	0.9
43. Piqua Water Supply	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*6.0*
	131	13	3	NF	<0.2	NF	4.2
44. Mahoning Valley Sanitary District	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*4.7*
Youngstown, Ohio	80	5	<1	NF	NF	NF	3.1
45. Milwaukee Water Works	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*2.4*
(Howard Avenue Purification Plant)	9	7	3	NF	<0.2	NF	1.7
46. Oshkosh Water Utility	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*4.5*
	26	4	<0.4	NF	<0.2	NF	3.3
47. Terrebonne Parish Waterworks	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*5.4*
District #1, Houma, Louisiana	134	32	8	<1	0.2	NF	3.2
48. Camden Municipal Water Works	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*3.1*
	40	19	7	NF	NF	NF	1.5
49. Town of Logansport System	*0.7*	*NF*	*NF*	*NF*	*NF*	*NF*	*5.3*
	28	39	24	3	NF	NF	3.5
50. City of Albuquerque	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*<0.05*
	0.4	1	2	3	NF	NF	<0.05
51. Oklahoma City Water Department	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*3.6*
(Hefner Plant)	44	28	20	6	<0.4	<2	2.8

Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
52. Brownsville Public Utility Board (Plant #2)	*NF* 12	*NF* 37	*NF* 100	*NF* 92	*NF* NF	*NF* NF	*4.7* 3.1
53. Dallas Water Utilities (Bachman Plant)	*<0.1* 18	*NF* 4	*NF* <2	*NF* NF	*NF* NF	*NF* NF	*3.4* 2.9
54. San Antonio City Water	*NF* 0.2	*NF* 0.9	*NF* 3	*NF* 3	*NF* NF	*NF* NF	*0.5* 0.5
55a. Ottumwa Waterworks *(2/17/75 sample)*	*<0.2* 0.8	*NF* NF	*NF* NF	*NF* NF	*NF* NF	*NF* NF	*4.1* 2.3
55b. Ottumwa Waterworks *(4/7/75 sample)*	*NF* 1	*NF* NF	*NF* NF	*NF* NF	*NF* NF	*NF* NF	*4.9* 2.4
56. Clarinda Iowa Water Works	*<0.2* 48	*NF* 19	*NF* 4	*NF* NF	*NF* NF	*NF* NF	*3.5* 3.0
57. Davenport Water Company	*0.4* 88	*NF* 8	*NF* <0.6	*NF* NF	*NF* <0.4	*NF* NF	*6.5* 4.4
58. Topeka Public Water Supply (South Plant)	*0.4* 88	*<0.8* 38	*NF* 19	*NF* 5	*NF* NF	*NF* 3	*3.4* 2.2
59. Missouri Utility Company Cape Girardeau, Missouri	*0.2* 116	*NF* 21	*NF* 2	*NF* NF	*0.2* 0.3	*NF* 2	*4.5* 3.6
60. Kansas City Mo. Water Department	*NF* 24	*NF* 8	*NF* 2	*NF* NF	*NF* NF	*NF* NF	*3.4* 1.9
61. St. Louis County Water Company (Central Plant)	*NF* 55	*NF* 13	*NF* 3	*NF* <1	*0.3* 0.4	*NF* NF	*3.4* 2.6
62. Lincoln Municipal Water Supply	*NF* 4	*NF* 6	*NF* 4	*NF* <2	*NF* NF	*NF* NF	*1.4* 1.4

Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
63. City Water Department	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*9.2*
Grand Forks, North Dakota	3	1	NF	NF	NF	NF	5.2
64. Denver Water Board	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*2.0*
(Marston Plant)	14	10	3	NF	NF	NF	1.7
65. Pueblo Board of Waterworks	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*1.8*
(Gardner Plant)	2	2	<2	NF	NF	NF	1.6
66. Huron Water Department	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*19.2*
	309	116	49	8	NF	NF	12.2
67. Salt Lake Water Department	*<0.2*	*NF*	*NF*	*NF*	*<0.4*	*NF*	*1.2*
	20	14	8	NF	NF	NF	0.9
68. City of Tucson Water & Sewer Dept.	*<0.1*	*NF*	*NF*	*NF*	*NF*	*NF*	*<0.05*
(Plant #1)	<0.2	<0.8	2	13	NF	NF	<0.05
69. City of Phoenix Water & Sewer Dept.	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*1.0*
(Verde Plant)	9	15	17	<4	NF	NF	1.0
70. Department of Supply & Purification,	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*3.7*
Coalinga, California	16	17	15	2	NF	NF	2.4
71. Contra Costa County Water Dept.	*0.3*	*<0.3*	*NF*	*NF*	*NF*	*NF*	*3.4*
(Bollman Plant, Concord, Calif.)	31	18	6	<1	NF	NF	1.9
72. City of Dos Palos Water Dept.	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*4.4*
	61	53	34	7	NF	NF	2.9
73. Los Angeles Dept. of Water and Power	*<0.1*	*NF*	*NF*	*NF*	*NF*	*NF*	*1.2*
	32	6	3	NF	NF	NF	1.3
74. San Diego Water Utilities Dept.	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*2.9*
(Miramar Plant)	52	30	19	3	NF	NF	2.8

Utility Name (Plant Name When Applicable)	Chloroform µg/l	Bromo-dichloro-methane µg/l	Dibromo-chloro-methane µg/l	Bromo-form µg/l	1,2-Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non-Volatile Total Organics Carbon µg/l
75. San Francisco Water Department	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*1.3*
(San Andreas Treatment Plant)	41	15	4	<0.8	NF	NF	1.6
76. Seattle Water Department	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*0.9*
(End of Dist. System)	15	0.9	NF	NF	NF	NF	0.9
77. Douglas Water System	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*3.4*
	40	0.8	<0.4	NF	NF	NF	2.8
78. Idaho Falls Water Department	*<0.2*	*NF*	*NF*	*NF*	*NF*	*NF*	*0.5*
	2	3	3	NF	NF	NF	0.3
79. City of Corvallis Utilities Div.	*NF*	*NF*	*NF*	*NF*	*NF*	*NF*	*1.0*
(Taylor Plant)	26	3	NF	NF	NF	NF	0.4
80. Ilwaco Municipal Water Department	*0.1*	*NF*	*NF*	*NF*	*NF*	*NF*	*7.5*
	167	35	5	NF	NF	NF	3.1
RANGE	*NF - 0.9*	*NF - 0.8*	*NF*	*NF*	*NF - 3*	*NF - 4*	*<0.05 - 19.2*
	<0.1 - 311	NF - 116	NF - 100	NF - 92	NF - 6	NF - 3	<0.05 - 12.2

Table I-3

ORGANIC COMPOUNDS DETECTED IN SURVEY OF TEN CITIES

(Unless otherwise noted, all identifications and quantifications were performed by volatile organic analysis (VOA))

Concentrations, μg/l

COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
1. Acetaldehyde (Ethanal)	d	d 0.1[c]	d	d 0.1[c]	d					
2. Acetic acid, methyl ester (Methyl acetate)		d								
3. Acetophenone				1.0[c]						
4. Atrazine			0.1[c]							
5. Azulene			d							
6. Benzaldehyde							d	d	d	
7. Benzene	d 0.1		0.1	d 0.2	d 0.3					
8. Benzoic acid			15.0[b]							

Key

a Combination vinyl chloride and cyanogen chloride
b Liquid-liquid extraction
c Carbon chloroform extract
d Detected by 500-ml VOA but not quantified

Nomenclature: Chemical Abstracts; ( ) = common name

Cities:
MIA = Miami, Fla.
SEA = Seattle, Wash.
OTT = Ottumwa, Iowa
PHI = Philadelphia, Pa.
CIN = Cincinnati, Ohio
TUC = Tucson, Arizona
NYC = New York, N.Y.
LAW = Lawrence, Mass.
Gr F = Grand Forks, N.D.
Tr P = Terrebonne Parish, La.

COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
9. Bromochloromethane	d									
10. Bromodichloromethane	d 73.0 4.5[c]	d 4.0 0.1[c]	d	d 20.0 1.0[c]	d 15.0 1.0[c]		17.0 1.3[c]	1.8 0.6[c]	3.2 0.6[c]	23.0 2.0[c]
11. Bromoethyne (Bromoacetylene)	d									
12. Bromomethane	d				d					
13. Bromotrichloroethene	d				d					
14. 1-Butanol					d					
15. Butene									d	
16. 2-Butanone	d	d	d	d	d					
17. 2-Butenal	d									
18. t-Butyltoluene				0.01[c]						
19. 2-n-Butoxyethanol							d			
20. Camphor	0.5[c]	0.5[c]	0.1[c]		0.1[c]					
21. Carbon disulfide	d			d	d		d		d	
22. Chloral (Trichloroacetaldehyde)		3.5[c]		5.0[c]	2.0[c]		0.02[c]		0.01[c]	1.0[c]
23. Chlorobenzene	d 1.0[c] d	 d	 d	d 0.1 d	d 0.1 0.5[c]		 4.7	 0.12	 d	 5.6
24. Chloroethane	d	d		d	d		d			
25. Chloroethene (Vinyl chloride)	d 5.6			d 0.27[a]						

	COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
26.	Bis(2-Chloroethyl)ether				0.5[b]						
27.	Chloroethyne (Chloroacetylene)	d			d	d					
28.	1,2-Bis(2-Chloroethoxy)ethane				0.03[b]						
29.	Chloromethane	d	d	d	d	d					
30.	2-Chloropropane					d					
31.	p-Chlorotoluene	1.5[c] d									
32.	Cyanogen chloride	d		d	d	d		d	d	d	d
33.	Cyclohexanone			0.1[c]							
34.	Cymene isomer	0.1[c]									
35.	Dibromomethane	d									
36.	Dibromochloromethane	15.0[c] 32.0	3.0		0.5[c] 5.0	0.05[b] 3.0 d	0.01[c]	0.4[c]	0.01[c]	0.1[c]	1.0[c]
37.	2,6,Di-t-butyl-p-benzoquinone	0.1[c]									
38.	Di-t-butyl ketone								0.02[c]		
39.	Di-n-butyl phthalate	5.0[c]	0.01[c]	0.1[c]	0.05[c]				0.01[c]		0.02[c]
40.	1,2-Dichlorobenzene	1.0[c] d			d	d					
41.	1,3-Dichlorobenzene	0.5[c] d			d	d			d		
42.	1,4-Dichlorobenzene	0.5[c] d			d	d			d		

COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
43. 1,1-Dichloroethane	d							d		
44. 1,2-Dichloroethane	d			d	d					
45. 1,1-Dichloroethene (Vinylidene chloride)	d 0.1			d 0.1	d			d		
46. cis 1,2-Dichloroethene	d 16.0			d 0.1	d 0.1					
47. trans 1,2-Dichloroethene	d 1.0									
48. Dichloroiodomethane	d			d	d		d	d	d	d
49. Dichloroethyne (Dichloroacetylene)	d			d	d					
50. Dichlorofluoromethane	d				d					
51. Dichloromethane (Methylene chloride)	d	d	d	d	d		0.1	1.6	0.1	d
52. Dichloronitromethane					d					
53. 2,4-Dichlorophenoxy acetic acid (2,4-D)									0.04	
54. Dieldrin	0.002[b]	0.001[b]	0.002[b]		0.001[b]					
55. Diethyl ether (Ethyl ether)	d			d	d					
56. Diethyl malonate			0.1[c]		0.01[c]					
57. Diethyl phthalate	1.0[c]	0.01[c]		0.01[c]	0.1[c]		0.01[c]	0.04[c]		
58. Di-(2-ethylhexyl) phthalate	30.0[c]			0.5[c]				0.8[c]		0.04[c]
59. Dimethyl ether (Methyl ether)		d		d	d					

COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
60. Dimethyldisulfide (2,3-Thiabutane)			d							
61. 2,6-Dimethyl-4-heptanone				d						
62. Di-m-octyl adipate	20.0[b]									
63. 1,4-Dioxane								0.01[c]		
64. Di-n-propyl phthalate	0.05[c]									
65. Ethanol	d	d	d	d	d					
66. Ethylbenzene	d			d	d		d	d	d	
67. 2-Ethylbutanal							0.05[c]	0.04[c]	0.02[c]	0.01[c]
68. p-Ethyltoluene		0.05[c]								
69. Fluorotrichloromethane			d	d	d			d		
70. Formaldehyde, dimethyl acetal (Dimethoxymethane)	d			d						
71. Formic acid; methyl ester (Methyl formate)		d								
72. Heptadecane							d			
73. Hexachloro-1,3-butadiene									<0.01[c]	
74. Hexachloroethane	0.5[c] 0.07[b]									
75. Iodomethane (Methyl iodide)	d									
76. Isoamyl chloride							0.01[c]			
77. Isophorone					0.02[b]					

COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
78. Isopropylbenzene (Cumene)										0.01[c]
79. Lindane (γ-BHC)					0.01[c]				d	
80. Methanol	d	d		d	d		d	d		
81. 3-Methylbutanal (Isovaleraldehyde)	d	d	d	d	d					
82. 3-Methylbutanoic acid nitrile (Isovaleronitrile)	d	d		d	d					
83. 3-Methyl-2-butanone	d	d	d	d	d					
84. Methyl cyanide (Acetonitrile)	d									
85. 2-Methyl-5-ethylheptane										0.01[c]
86. Methyl ethyl maleimide							0.02[c]			
87. 5-Methylhexa-3-ene-2-one							0.07[c]			
88. 3-Methyl-3-pentanal			1.0[c]							
89. 4-Methyl-2-pentanone (Methyl isobutyl ketone)	d			d	d					
90. 2-Methylpropanal (Isobutyraldehyde)	d	d	d	d	d				d	d
91. 2-Methylpropanoic acid nitrile (Isobutyronitrile)	d	d		d	d					
92. 2-Methyl-2-propanol (t-Butyl alcohol)	d	d		d	d					
93. 2-Methylpropenal	d			d						

COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
94. N-methyl pyrrole									d	d
95. Nicotine	3.0[b]									
96. Nitromethane	d			d	d	d				
97. Nitrotrichloromethane (Chloropicrin)	d 0.4		0.05[c]	d 2.0	d 3.0					
98. n-Nonane							0.02[c]			
99. n-Pentanal			0.5[c]							
100. Pentane	d	d		d	d					
101. 2-Pentanone	d		d 0.1[c]	d	d					d
102. Phenylacetic acid		4.0[b]								
103. Propanal (Propimaldehyde)	d	d	d	d	d		d		d	
104. Propanoic acid nitrile (Propionitrile)	d									
105. 2-Propanone (Acetone)	d	1.0[c] d	d	d	d	d	d	d	d	d
106. Propenoic acid nitrile (Acrylonitrile)	d									
107. n-Propylbenzene	0.05[c]				0.01[c]					
108. n-Propylcyclohexane	0.2[c]									
109. 2-Santalene		0.01[c]								
110. Styrene (Vinyl benzene)							d	d	d	

	COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
111.	a-Terpineol			0.5[c]							
112.	Tetrachloroethene (Tetrachloro-	0.1[c] 0.1 d		d 0.2	d 0.4	0.1[c] 0.3 d	<0.01[c]	0.05[c] 0.46	0.07[c] d	0.2[c]	
113.	Tetrachloromethane (Carbon tetrachloride)	d		d	d	d		0.13	0.1	0.1	d
114.	1,1,3,3-Tetrachloro-2-propanone (Tetrachloroacetone)	0.2[c]			1.0[c]	0.5[c]					
115.	Tetramethylbenzene isomer	0.2[c]									
116.	Tetramethyltetrahydrofuran isomer			0.5[c]							
117.	Toluene				d 0.7	d 0.1	d		d	d	d
118.	2,4,5-Trichlorophenoxy propionic acid (Silvex)								0.02[b]		
119.	Tribromomethane (Bromoform)	1.5[c] 0.2[b] d			d	d	3.0[c] 1.5	1.5			
120.	Tri-n-butyl phosphate	0.5[c]				0.05[c]					
121.	Trichlorobenzene isomer								d		
122.	1,1,1-Trichloroethane			d	d	d					
123.	1,1,2-Trichloroethane	d									
124.	Trichloroethene (Trichloro-ethylene)	d 0.2		d 0.1	d 0.5	d 0.1			d		

COMPOUNDS	MIA FL	SEA WA	OTT IA	PHI PA	CIN OH	TUC AR	NYC NY	LAW MA	Gr F ND	Tr P LA
125. Trichloromethane (Chloroform)	d 301.0	d 21.0	d 1.0	d 65.0	d 38.0	0.08	44.0	32.0	40.0	130.0
126. Trichlorotrifluoroethane								d		d
127. 1,3,5-Trimethyl-2,4,6-trioxo-hexahydrotriazine (Trimethylisocyanurate)					0.02[b] 0.5[c]					
128. s-Trioxane							d			
129. Xylene										d

APPENDIX II

ORGANIC COMPOUNDS IDENTIFIED IN DRINKING WATER

ORGANIC COMPOUNDS IDENTIFIED IN DRINKING WATER IN THE UNITED STATES

The following list of 253 compounds was compiled from an extensive search of the chemical literature and from EPA reports generated from the Agency's analytical activities. These compounds were identified from only a few public water supplies and do not constitute a definitive list of all compounds in all supplies. Because of the restrictive nature of the analytical systems used, the list does not include all compounds present in the water samples analyzed. These identifications represent the result of single or duplicate "grab" samples and, consequently, cannot be used to conclude continuous occurrence. Likewise, fluctuations in concentrations with time cannot be determined unequivocally from these same samples.

This list was compiled from several sources. The nomenclature assigned by each source was used despite lack of uniformity. Similarly, the concentrations listed are those reported. In most cases, these concentration values are determined by extrapolation from the extracted sample to the original volume of water. These values must be considered minimum concentrations because the extrapolations did not usually take into account recovery efficiencies. In cases of quantification by more than one analyst, the highest reported concentration was used.

This list of organics identified from potable water is being continuously updated, and information concerning the chemical properties and toxicity of these compounds is being assembled and evaluated.

Table II

ORGANIC COMPOUNDS IDENTIFIED IN DRINKING WATER IN THE UNITED STATES

	Highest Concentration Reported[a] µg/ℓ
Acenaphthylene	
Acetaldehyde	0.1
Acetic acid	
Acetone	1.0
Acetophenone	
Acetylenebromide	
Acetylenechloride	
Acetylene dichloride	
Alachlor (1-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide)	1.7
Alachlor (2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide	2.9
Aldrin	
Atrazine	5.4
Barbital	
Behenic acid, methyl ester	
Benzaldehyde	
Benzene	10.0
Benzene sulfonic acid	
Benzoic acid	15.0
Benzopyrene	
Benzothiazole	
Benzothiophene	
Benzyl butyl phthalate	1.8
Bladex	
Borneol	
Bromobenzene	
Bromochlorobenzene	
Bromodichloromethane	116.0
Bromoform	42.0
Bromomethane	
Bromophenyl phenyl ether	
Butachlor	0.06
Butanal	
t-Butyl alcohol	0.01
Butyl benzene	
Butyl bromide	
Butyl octyl maleate	
Camphor	0.5
e-Caprolactam	
Carbon dioxide	<5.0

[a]Concentration equal to or greater than reported data.
See text on previous page for explanation of concentration data.

Carbon disulfide	
Carbon tetrachloride	5.0
Chlordan(e)	<0.1
Chlordene	0.1
Chlorobenzene	<5.0
Chlorodibromomethane	100.0
Chloroethane	
1,2-bis-Chloroethoxy ethane	0.03
Chloroethoxy ether	
Bis(2-Chloroethyl) ether	0.42
2-Chloroethyl methyl ether	
tris(Chloroethyl)phosphate	
Chloroform	366.0
Chlorohydroxybenzophenone	
Bis(2-Chloroisopropyl) ether	1.58
Chloromethyl ethyl ether	
m-Chloronitrobenzene	
2-Chloropropane	
1-Chloropropene	<1.0
3-Chlorophyridine	
p-Chlorotoluene	1.5
o-Cresol	
Crotonaldehyde	5.0
Cyanogen chloride	0.1
Cycloheptanone	
Cyclohexanone	
Cyclopentanone	
Cymene isomer	0.1
DDE	0.05
DDT	
n-Decane	2.4
Decane, branched isomer	
Deethyl atrazine	0.8
Dibromobenzene	
Dibromomethane	
Dibromodichloroethane isomer	0.63
2,4-Di-t-butyl-p-benzoquinone	0.23
2,6-Di-t-butyl-p-benzoquinone	0.25
Dibutyl phthalate	5.0
Dichloroacetonitrile	
o-Dichlorobenzene	1.0
m-Dichlorobenzene	<3.0
p-Dichlorobenzene	1.0
Dichlorodifluoroethane	
1,1-Dichloroethane	
1,2-Dichloroethane	8.0
1,1-Dichloroethylene	0.1
1,2-Dichloroethylene	
cis 1,2-Dichloroethylene	16.0
trans 1,2-Dichloroethylene	1.0
1,1-Dichloro-2-hexanone	<1.0
Dichloroiodomethane	0.5

2,4-Dichlorophenol	36.0
1,2-Dichloropropane	<1.0
1,3-Dichloropropene	<1.0
Dicyclopentadiene	
Dieldrin	8.0
1,4-Diethyl benzene	1.0
Di (2-ethylhexyl) adipate	0.31
Di (2-ethylhexyl) phthalate	30.0
Diethyl malonate	0.01
Diethyl phthalate	1.0
Dihexyl phthalate	0.16
Dihydrocarvone	0.14
Diisobutyl carbinol	
Diisobutyl phthalate	0.59
1,2-Dimethoxy benzene	
Dimethoxymethane	
Dimethyl benzene	
Dimethyl disulfide	
Dimethyl ether	
1,3-Dimethylnaphthalene	
2,4-Dimethyl phenol	
Dimethyl phthalate	0.82
Dimethyl sulfoxide	
4,6-Dinitro-2-aminophenol	
2,6-Dinitrotoluene	
Dioctyl adipate	20.0
1,4-Dioxane	
Diphenylhydrazine	1.0
Dipropyl phthalate	0.5
Docosane	
n-Dodecane	0.4
Eicosane	
Endrin	0.08
Ethanol	5.0
Ethyl acetate	
Ethylamine	
Ethyl benzene	
Ethyl ether	
2-Ethyl-n-hexane	
cis 2-Ethyl-4-methyl-1,3-dioxolane	
trans 2-Ethyl-4-methyl-1,3-dioxolane	
o-Ethyltoluene	0.04
m-Ethyltoluene	0.05
p-Ethyltoluene	0.05
Heptachlor	
Heptachlor epoxide	
1,2,3,4,5,7,7-Heptachloronorbornene	0.07
Heptachloronorbornene isomer	
Hexachlorobenzene	
Hexachloro-1,3-butadiene	0.07
Hexachlorocyclohexane	0.1

Hexachloroethane	4.4
Hexachlorophene	0.01
Hexadecane	
2-Hydroxyadiponitrile	
Indene	
Isoborneol	
Isocyanic acid	
Isodecane	5.0
Isophorone	9.5
1-Isopropenyl-4-isopropylbenzene	
Isopropanol	
Isopropyl benzene	
Lignorceric acid, methyl ester	
Limonene	0.03
p-Menth-1-en-8-ol	0.5
Methane	
Methanol	
2-Methoxy biphenyl	
o-Methoxyphenol	
Methyl acetate	
Methyl benzoate	<0.01
Methyl benzothiazole	
2-Methyl biphenyl	
2-Methyl butanal	
3-Methyl butanal	
2-Methyl-2-butanol	
3-Methyl-2-butanone	
2-Methyl butyl nitrile	
3-Methyl butyl nitrile	
Methyl chloride	
Methylene chloride	<5.0
Methyl ether	
Methyl ethyl benzene	
Methyl ethyl ketone	
2-Methyl-5-ethyl-pyridine	
Methyl formate	
Methylidene	
Methyl methacrylate	<1.0
Methyl naphthalene	
Methyl palmitate	
3-Methyl-3-pentanal	1.0
Methyl phenyl carbinol	
2-Methylpropanal	
2-Methyl propyl nitrile	
Methyl stearate	
Naphthalene	1.0
Nicotine	3.3

Nitrobenzene	
Nitromethane	
Nitrotrichloromethane	3.0
n-Nonane	
Octadecane	
Octane	
Octyl chloride	
Pentachlorobiphenyl	
Pentachloroethane	<0.1
Pentachlorophenol	1.4
Pentachlorophenyl methyl ether	<0.1
n-Pentadecane	0.1
n-Pentanal	0.5
Pentane	
Pentanol	1.0
2-Pentanone	0.1
Phenol	
Phenylacetic acid	4.0
Phenyl benzoate	
Phthalic anhydride	
Piperidine	
Propanal	
Propanol	1.0
Propazine	<0.1
Propylamine	
n-Propylbenzene	<5.0
n-Propylcyclohexanone	0.2
2-Santalene	0.01
Simazine	<0.1
1,1,3,3-Tetrachloroacetone	
Tetrachlorobiphenyl (isomer)	
1,1,1,2-Tetrachloroethane	
Tetrachloroethylene	<5.0
Tetrachlorophenol (isomer)	
1,1,3,3-Tetrachloro-2-propanone	0.5
n-Tetradecane	0.12
Tetramethyl benzene	<1.0
Tetramethyltetrahydrofuran	0.5
Thiomethylbenzothiazole	
Toluene	11.0
Tri-n-butyl phosphate	0.5
Trichloroacetaldehyde	5.0
Trichlorobenzene	1.0
Trichlorobiphenyl (isomer)	
1,1,1-Trichloroethane	
1,1,2-Trichloroethane	8.5
Trichlorofluoromethane	<1.0
2,4,6-Trichlorophenol	
1,1,1-Trichloropropane	<0.1

1,2,3-Trichloropropane	<0.2
n-Tridecane	0.30
Trimethylbenzene (isomer)	6.1
3,5,5-Trimethyl-bicyclo(4,1,0)heptene-2-one	
Trimethyl isocyanurate	0.02
1,3,5-Trimethyl-2,4,6-trioxo-hexahydrotriazine	
Triphenyl phosphate	0.12
n-Undecane	0.02
Undecane branched isomer	
Vinyl benzene	<1.0
Vinyl chloride	10.0
o-Xylene	<5.0
m-Xylene	<5.0
p-Xylene	<5.0

APPENDIX III

ANALYSES OF RADIOACTIVITY IN INTERSTATE CARRIER WATER SUPPLIES

Table III

ANALYSIS OF RADIOACTIVITY IN INTERSTATE CARRIER WATER SUPPLIES

Location	Sample Code & Date Collected	Mg/l	Indicated Activity in pCi/l (a) Gross Beta (b) Date Counted	Gross Alpha (c) Date Counted	^{90}Sr	^{226}Ra	Specific Gamma Activity
#16532 Springfield, MA	IW-23 1/2/75	96.0	1.2 ± 36% 1/10/75	< 2.0 1/10/75			(d)
#21620 Melbourne, FL	IW-108 12/27/74 - 1/9/75	182.2	4.9 ± 24% 1/29/75	< 2.0 1/29/75			(d)
#26523 Wood River Madison, IL	IW-150 1/9/75	253.0	2.1 ± 59% 1/29/75	< 2.0 1/29/75			(d)
#26525 Fairport Harbor, OH	IW-236 1/21/75	308.0	3.3 ± 34% 2/3/75	< 2.0 2/3/75			(d)
#26527 Ashtabula, OH	IW-237 1/22/75	278.0	2.6 ± 48% 2/3/75	< 2.0 2/3/75			(d)
#11040 Conneaut, OH	IW-271 1/24/75	256.0	2.1 ± 56% 2/3/75	< 2.0 2/3/75			(d)

(a) The error expressed is the percentage relative to 2-sigma counting error.
(b) The minimum detectable limit of gross beta is 1.0 pCi/l.
(c) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(d) Indicates specific gamma activity not detectable.
(e) Special study.
(f) Community Water Supply sample.

Location	Sample Code & Date Collected	Mg/l	Indicated Activity in pCi/l: Gross Beta Date Counted	Gross Alpha Date Counted	^{90}Sr	^{226}Ra	Specific Gamma Activity
#26529 Lorain, OH	IW-272 1/24/75	316.0	4.2 ± 31% 2/3/75	< 2.0 2/3/75			(d)
#31157 (e) (f) Miami, FL	IW-290 1/20/75	344.0	1.7 ± 63% 2/6/75	< 2.0 2/6/75	< 0.5 3/3/75	0.50 ± 5% 3/18/75	(d)
#31113 (e) (f) San Juan, PR	IW-291 1/30/75	376.6	4.3 ± 33% 2/6/75	< 2.0 2/6/75	0.7 ± 73% 3/3/75	0.10 ± 15% 3/18/75	(d)
#16535 Springfield, MA	IW-344 1/30/75	70.0	1.9 ± 46% 2/14/75	< 2.0 2/14/75			(d)
#31184 (e) (f) Chicago, IL	IW-363 2/4/75	136.0	2.2 ± 55% 2/14/75	< 2.0 2/14/75	0.9 ± 33% 3/3/75	< 0.1 3/18/75	(d)
#31161 (e) (f) Jacksonville, FL	IW-364 2/3/75	250.0	1.6 ± 61% 2/14/75	< 2.0 2/14/75	< 0.5 3/3/75	0.37 ± 6% 3/18/75	(d)
#31129 (e) (f) Philadelphia, PA	IW-386 2/3/75	245.0	2.9 ± 38% 2/18/75	< 2.0 2/18/75	< 0.5 3/3/75	0.13 ± 12% 3/18/75	(d)
#31139 (e) (f) New Castle, DE	IW-387 2/5/75	88.0	5.2 ± 22% 2/18/75	< 2.0 2/18/75	< 0.5 3/3/75	0.61 ± 5% 3/18/75	(d)
#31142 (e) (f) Stanton, DE	IW-388 2/6/75	397.0	1.5 ± 71% 2/14/75	< 2.0 2/14/75	1.3 ± 64% 3/3/75	< 0.1 3/18/75	(d)
#31179 (e) (f) Clinton, IL	IW-389 2/5/75	172.0	3.6 ± 32% 2/18/75	< 2.0 2/18/75	< 0.5 3/3/75	0.27 ± 7% 3/18/75	(d)
#31181 (e) (f) Mt. Clemens, MI	IW-390 2/3/75	226.0	4.4 ± 29% 2/18/75	< 2.0 2/14/75	0.58 ± 89% 3/3/75	0.15 ± 12% 3/18/75	(d)
#26212 (f) Baltimore, MD	IW-411 2/3/75	184.0	1.9 ± 55% 2/18/75	< 2.0 2/14/75			(d)

Location	Sample Code & Date Collected	Mg/l	Indicated Activity in pCi/l: Gross Beta Date Counted	Gross Alpha Date Counted	^{90}Sr	^{226}Ra	Specific Gamma Activity
#31163 (e) (f) Chattanooga, TN	IW-419 2/10/75	192.0	2.9 ± 37% 2/20/75	< 2.0 2/21/75	< 0.5 3/3/75	0.10 ± 14% 3/20/75	(d)
#31133 (e) (f) Baltimore, MD	IW-240 2/11/75	202.0	2.9 ± 43% 2/21/75	< 2.0 2/21/75	< 0.5 3/3/75	0.10 ± 12% 3/20/75	(d)
#26215 Baltimore, MD	IW-421 2/6/75	218.0	1.7 ± 61% 2/21/75	< 2.0 2/21/75			(d)
#31131 (e) (f) Annandale, VA	IW-426 2/10/75	228.0	3.9 ± 34% 2/20/75	< 2.0 2/21/75	0.6 ± 52% 3/3/75	0.13 ± 15% 3/20/75	(d)
#26538 Youngstown, OH	IW-427 2/12/75	578.0	3.3 ± 37% 2/21/75	< 2. 2/21/75			(d)
#31135 (e) (f) Washington, DC	IW-431 2/13/75	252.0	1.9 ± 61% 2/21/75	< 2.0 2/21/75	< 0.5 3/3/75	< 0.1 3/26/75	(d)
#31191 (e) (f) Youngstown, OH	IW-432 2/13/75	254.0	3.9 ± 30% 2/21/75	< 2.0 2/21/75	0.6 ± 33% 3/3/75	0.18 ± 11% 3/26/75	(d)
#31187 (e) (f) Cincinnati, OH	IW-433 2/11/75	54.0	2.2 ± 51% 2/21/75	< 2.0 2/21/75	< 0.5 3/3/75	0.10 ± 15% 3/26/75	(d)
#31165 (e) (f) Atlanta, GA	IW-434 2/13/75	78.0	2.3 ± 39% 2/21/75	< 2.0 2/21/75	< 0.5 3/3/75	< 0.1 3/26/75	(d)
#31115 (e) (f) Toms River, NJ	IW-444 2/18/75	93.0	8.5 ± 17% 2/24/75	5.5 ± 25% 2/24/75	< 0.5 3/3/75	1.9 ± 2% 3/26/75	(d)
#26250 (e) (f) Pittsburgh, PA	IW-445-A 2/17/75	246.0	3.2 ± 40% 2/25/75	< 2.0 2/24/75			(d)
#26250 (e) (f) Pittsburgh, PA	IW-445-B 2/17/75	224.8	2.6 ± 41% 2/25/75	< 2.0 2/24/75			(d)

Location	Sample Code & Date Collected	Mg/l	Indicated Activity in pCi/l: Gross Beta Date Counted	Gross Alpha Date Counted	^{90}Sr	^{226}Ra	Specific Gamma Activity
#31167 (e) (f) Memphis, TN	IW-451 2/20/75	136.0	1.5 ± 61% 3/5/75	< 2.0 3/5/75	< 0.5 3/5/75	0.32 ± 7% 3/27/75	(d)
#31102 (e) (f) Lawrence, MA	IW-455 2/19/75	166.0	2.1 ± 49% 3/5/75	< 2.0 3/5/75	< 0.5 4/16/75	< 0.1 5/8/75	(d)
#31195 (e) (f) St. Paul, MN	IW-458 2/21/75	144.0	2.8 ± 67% 3/5/75	< 2.0 3/4/75	< 0.5 3/31/75	0.11 ± 15% 4/1/75	(d)
#31143 (e) (f) Huntington, WV	IW-459 2/24/75	8.0	2.1 ± 41% 3/5/75	< 2.0 3/4/75	< 0.5 3/31/75	0.14 ± 10% 4/1/75	(d)
#31197 (e) (f) Indianapolis, IN	IW-481 2/25/75	300.0	4.6 ± 28% 3/5/75	< 2.0 3/5/75	< 0.5 3/31/75	9.24 ± 8% 4/1/75	(d)
#31104 (e) (f) Boston, MA	IW-482 2/26/75	70.0	1.9 ± 46% 3/5/75	< 2.0 3/4/75	< 0.5 3/31/75	0.11 ± 14% 4/1/75	(d)
#? (sheet torn up) Indian Hill, OH	IW-483 2/19/75	472.0	1.7 ± 73% 3/5/75	< 2.0 3/4/75	< 0.5 3/31/75	0.28 ± 7% 3/27/75	(d)
#31199 (e) (f) Whiting, IN	IW-484 2/27/75	192.0	2.4 ± 42% 3/4/75	< 2.0 3/4/75	0.7 ± 29% 3/31/75	9.12 ± 13% 4/1/75	(d)
#31146 (e) (f) Wheeling, WV	IW-510 2/25/75	286.0	2.4 ± 48% 3/10/75	< 2.0 3/10/75	< 0.5 3/31/75	9.10 ± 14% 4/1/75	(d)
#31169 (e) (f) Nashville, TN	IW-511 3/3/75	334.0	2.2 ± 48% 3/10/75	< 2.0 3/10/75	< 0.5 3/31/75	< 0.1 4/1/75	(d)
#31117 (e) (f) Little Falls, NJ	IW-546 3/4/75	190.0	1.8 ± 50% 3/10/75	< 2.0 3/10/75	0.8 ± 52% 5/21/75	1.3 ± 3% 6/3/75	(d)
#31201 (e) (f) Columbus, OH	IW-559 3/3/75	284.0	4.0 ± 30% 3/14/75	< 2.0 3/14/75	< 0.5 3/31/75	0.13 ± 12% 4/14/75	(d)

Location	Sample Code & Date Collected	Mg/l	Indicated Activity in pCi/l: Gross Beta Date Counted	Gross Alpha Date Counted	^{90}Sr	^{226}Ra	Specific Gamma Activity
#31200 (e) (f) Cleveland, OH	IW-560 3/5/75	176.0	2.7 ± 38% 3/14/75	< 2.0 3/14/75	0.6 ± 27% 4/16/75	0.14 ± 12% 4/14/75	(d)
#31148 (e) (f) Pittsburgh, PA	IW-581 3/4/75	266.0	2.4 ± 47% 3/14/75	< 2.0 3/14/75	< 0.5 4/16/75	0.11 ± 14% 4/14/75	(d)
#31171 (e) (f) Owensboro, KY	IW-582 3/10/75	1514.0	2.4 ± 44% 3/18/75	< 2.0 3/18/75	< 0.5 4/16/75	0.19 ± 8% 4/14/75	(d)
#31106 (e) (f) Newport, RI	IW-589 3/11/75	374.0	5.8 ± 24% 3/18/75	< 2.0 3/18/75	0.6 ± 27% 4/16/75	0.10 ± 16% 4/14/75	(d)
#31214 (e) (f) Milwaukee, WI	IW-600 3/11/75	182.0	3.6 ± 33% 3/21/75	< 2.0 3/21/75	0.9 ± 36% 4/16/75	0.10 ± 16% 4/14/75	(d)
#31212 (e) (f) Oshkosh, WI	IW-607 3/12/75	262.9	2.1 ± 50% 3/21/75	< 2.0 3/21/75	0.8 ± 53% 4/21/75	0.19 ± 10% 4/14/75	(d)
#31149 (e) (f) Strasburg, PA	IW-611 3/11/75	94.0	3.5 ± 28% 3/21/75	< 2.0 3/21/75	< 0.5 4/21/75	0.92 ± 4% 4/14/75	(d)
#31173 (e) (f) Greenville, MS	IW-615 3/17/75	220.0	1.7 ± 52% 3/21/75	< 2.0 3/21/75	< 0.5 4/21/75	< 0.1 4/14/75	(d)
#31120 (e) (f) Buffalo, NY	IW-616 3/18/75	232.0	2.8 ± 39% 3/26/75	< 2.0 3/26/75	1.4 ± 29% 4/21/75	0.13 ± 13% 4/17/75	(d)
#26542 Marietta, OH	IW-624 3/17/75	350.8	2.4 ± 46% 3/26/75	< 2.0 3/26/75			(d)
#21108 (e) (f) Waterbury, CT	IW-625 3/18/75	56.0	1.6 ± 55% 3/26/75	< 2.0 3/26/75	1.0 ± 49% 4/21/75	< 0.1 5/8/75	(d)
#31205 (e) (f) Pigua, OH	IW-626 3/18/75	82.0	1.9 ± 44% 3/26/75	< 2.0 3/26/75	< 0.5 4/21/75	0.10 ± 16% 5/8/75	(d)

Location	Sample Code & Date Collected	Mg/l	Indicated Activity in pCi/l: Gross Beta Date Counted	Gross Alpha Date Counted	^{90}Sr	^{226}Ra	Specific Gamma Activity
#31208 (e) (f) Dayton, OH	IW-627 3/19/75	550.0	2.9 ± 44% 4/11/75	< 2.0 4/10/75	0.6 ± 81% 4/21/75	0.20 ± 10% 5/8/75	(d)
#31122 (e) (f) Rhinebeck, NY	IW-638 3/25/75	356.0	8.1 ± 37% 4/22/75	< 2.0 4/22/75	< 0.5 5/19/75	0.10 ± 13% 5/8/75	(d)
#31203 Columbus, OH	IW-639 No date	340.0	1.8 ± 69% 4/22/75	< 2.0 4/22/75			(d)
#31125 (e) (f) Tarreytown, NY	IW-640 3/26/75	228.0	3.0 ± 41% 4/22/75	< 2.0 4/22/75	0.5 ± 65% 5/14/75	< 0.1 5/8/75	(d)
#31175 (e) (f) Charleston, SC	IW-641 3/27/75	90.0	1.1 ± 73% 4/21/75	< 2.0 4/22/75	1.4 ± 50% 4/21/75	0.28 ± 7% 5/8/75	(d)
#31209 (e) (f) Detroit, MI	IW-713 3/25/75	318.0	2.4 ± 51% 4/22/75	< 2.0 4/22/75	1.0 ± 31% 4/21/75	< 0.1 5/8/75	(d)
#31137 Hopewell, VA	IW-1004 4/28/75	94.0	1.8 ± 52% 5/12/75	< 2.0 5/9/75	0.6 ± 44% 5/19/75	0.10 ± 12% 6/5/75	(d)

APPENDIX IV

ENVIRONMENTAL RADIATION MONITORING SYSTEM SURVEY (1974)

ENVIRONMENTAL RADIATION MONITORING SYSTEM SURVEY (1974)

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation monitoring networks to form a single monitoring system more responsive to current and projected sources of environmental radiation.

The ERAMS Drinking Water Component is an expansion of the previous Tritium Surveillance System which was operated by the Office of Radiation Programs from 1970 through June 1973. The Drinking Water Component consists of 77 quarterly drinking water samples taken from major population centers and selected nuclear facility environs. Tritium, a long-lived (half-life of 12.3 years) isotope of hydrogen (hydrogen-3), is analyzed on a quarterly basis with grab samples. Tritium is produced in nuclear power production and nuclear weapons testing, and naturally by cosmic radiation. Because it is chemically similar to hydrogen, tritium readily enters the body in water and is incorporated into living tissue.

The following table presents the tritium concentrations in drinking water at the Drinking Water Component stations for 1974. The average tritium concentration was 0.3 nCi/liter.

Table IV

ERAMS DRINKING WATER COMPONENT, 1974

Location		Tritium concentration[a] (nCi/liter ± 2σ)[b]			
		Jan-Mar	April-June	July-Sept	Oct-Dec
Ala:	Dothan	0	0	0	0
	Montgomery	0	.2	0	0
	Muscle Shoals	0	.3	.3	.2
Alaska:	Anchorage	NS	0	.5	.4
	Fairbanks	.5	.5	.5	.3
Ark:	Little Rock	0	0	0	0
Calif:	Berkeley	.2	.2	.2	0
	Los Angeles	0	0	0	0
C.Z.:	Ancon	.5	0	0	0
Colo:	Denver	.5	.5	.4	.6
	Platteville	.9	1.0	.9	.6
Conn:	Hartford	0	0	.2	.2
Del:	Wilmington	.3	0	.3	.3
D.C.:	Washington	0	.2	0	0
Fla:	Miami	0	0	0	0
	Tampa	0	0	0	0
Ga:	Baxley	NS	0	NS	0
	Savannah	3.1 ± 0.3	6.8 ± 0.3	3.0	2.9
Hawaii:	Honolulu	0	0	0	0
Idaho:	Boise	.3	0	NS	.2
	Idaho Falls	.3	.3	.6	.3
Ill:	Chicago	1.0	.6	0	.2
	Morris	0	0	0	0
Iowa:	Cedar Rapids	NS	NS	.3	.5
Kans:	Topeka	0	0	.3	0
La:	New Orleans	.2	0	.3	.3
Maine:	Augusta	.2	0	0	.2
Md:	Baltimore	0	NS	.3	.5
	Conowingo	0	0	.3	.3
Mass:	Lawrence	0	.2	.2	0
	Rowe	.3	0	NS	.4

Location		Tritium concentration[a] (nCi/liter ± 2σ)[b]			
		Jan-Mar	April-June	July-Sept	Oct-Dec
Mich:	Detroit	.4	.4	.4	.2
	Grand Rapids	.3	0	.3	.2
Minn:	Minneapolis	.4	.3	.5	.5
	Red Wing	0	0	0	0
Miss:	Jackson	0	0	0	.2
Mo:	Jefferson City	0	.4	0	0
Mont:	Helena	.3	.5	.4	.4
Nebr:	Lincoln	.2	.2	.2	0
Nev:	Las Vegas	.8	.7	.6	.7
N.H.:	Concord	0	.2	.2	.3
N.J.:	Trenton	0	NS	.2	0
	Waretown	0	NS	0	0
N.Mex:	Santa Fe	.5	NS	.5	0
N.Y.:	Albany	0	.3	0	.3
	Buffalo	.3	.2	.2	.5
	New York	.3	NS	.3	0
	Syracuse	.6	.6	.5	.7
N.C.:	Charlotte	0	.7	.3	.2
	Wilmington	0	0	.2	.2
N.Dak:	Bismarck	.5	.5	.7	.4
Ohio:	Cincinnati	0	.3	.2	.2
	East Liverpool	.4	.3	.4	.3
	Painesville	0	.3	.3	.5
	Toledo	NS	NS	NS	NS
Okla:	Oklahoma City	0	0	.2	0
Oreg:	Portland	0	0	0	.3
Pa:	Columbia	0	0	.2	.7
	Harrisburg	0	.2	.3	.3
	Pittsburgh	.4	.2	.3	.3
P.R.:	San Juan	0	0	0	0
R.I.:	Providence	.2	0	0	0

Location		Tritium concentration[a] (nCi/liter ± 2σ)[b]			
		Jan-Mar	April-June	July-Sept	Oct-Dec
S.C.:	Anderson-------	.3	.2	.3	.4
	Columbia-------	0	0	.4	.3
	Hartsville-----	0	0	0	0
	Seneca---------	.2	.4	.3	.3
Tenn:	Chattanooga----	.5	.6	.4	0
	Knoxville------	.4	.4	0	0
Tex:	Austin---------	0	0	0	0
Va:	Doswell--------	0	0	0	.2
	Lynchburg------	0	.2	.2	.2
	Norfolk--------	.2	0	0	.2
Wash:	Richland-------	NS	.5	.4	.5
	Seattle--------	.2	0	0	.4
Wisc:	Genoa----------	0	0	NS	0
	Madison--------	0	0	0	0
Average		0.2	0.3	0.3	0.2

[a]The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.
[b]The 2σ error for all samples is 0.20 nCi/liter unless otherwise noted.
NS, no sample.

APPENDIX V

ORGANICS SURVEY IN REGION V

Table V

ANALYTICAL RESULTS FOR VOLATILE ORGANICS IN REGION V SURVEY
(micrograms per liter)

R = Raw Water F = Finished Water

City	$CHCl_3$ R	$CHCl_3$ F	$BrCHCl_2$ R	$BrCHCl_2$ F	Br_2CHCl R	Br_2CHCl F	Br_3CH R	Br_3CH F	CCl_4 R	CCl_4 F	CH_2Cl_2 R	CH_2Cl_2 F	$C_2H_4Cl_2$ R	$C_2H_4Cl_2$ F
SURFACE SOURCE														
Cairo, Ill.	2	14	<1	11	<1	4	<1	0.8	2	1	1	<0.5	<1	<1
Carlyle, Ill.	<1	48	<1	20	<1	2	<1	0.6	<1	<1	<1	<0.2	<1	<1
Chicago, Ill.[a]	<1	7	<1	3.4	<1	<1	<1	<1	<1	<1	<1	0	<1	<1
Chester, Ill.	5	182	<1	17	<1	1.1	<1	<0.3	<1	<1	<1	<0.5	<1	<1
Danville, Ill.	6	16	<1	6	<1	1	<1	0.7	<1	<1	<1	<1	<1	<2
Fairfield, Ill.	10	47	3	16	<1	1.4	<1	<0.3	<1	<1	<1	<0.5	<1	<2
Kankakee, Ill.	<1	52	<1	10	<1	1.1	<1	<0.2	<1	1	<1	<0.5	<1	<1
Mt. Carmel, Ill.	<1	52	<1	15	<1	1	<1	<0.2	<1	<0.5	<1	2.6	<1	<1
Newton, Ill.	<1	4	<1	5	<1	4	<1	1.3	<1	<1	<1	<0.5	<1	<2
Quincy, Ill.	<1	58	<1	13	<1	0.5	<1	<0.2	<1	<1	<1	<1	<1	<1
Rock Island, Ill.	94	79	11	8.3	<1	0.4	<1	<0.2	<1	<1	<1	<1	<1	<1
Royalton, Ill.	<1	68	<1	29	<1	6	<1	<0.1	<1	<1	<1	<0.5	<1	<1
Streator, Ill.	<1	35	<1	14	<1	1.7	<1	1.4	<1	1	<1	0.5	2	<1
Bedford, Ind.	5	84	<1	12	<1	0.8	<1	0.8	<1	2	<1	<0.5	<1	<1
Bloomington, Ind.	<1	19	<1	5	<1	0.5	<1	<0.3	<1	1	<1	0.5	<1	<1
Evansville, Ind.	<1	29	<1	12	<1	1.7	<1	1	<1	1	<1	0.5	<1	<2
Fort Wayne, Ind.	4	29	<1	0.7	<1	0.4	<1	1	<1	0.9	<1	1	4	21
Gary, Ind.	<1	7	<1	5	<1	1	<1	<0.5	<1	1	<1	<0.5	<1	<2
Hammond, Ind.	<1	4	<1	<0.5	<1	<0.5	<1	<0.5	<1	1	<1	<0.5	<1	<2
Indianapolis, Ind.[a]	<1	19	<1	6	<1	0.5	<1	0.6	<1	1	<1	2	3	<1
Kokomo, Ind.	9	30	<1	11	<1	1.4	<1	0.3	<1	0.5	<1	0.5	<1	<1
Lafayette, Ind.	<1	5	<1	1	<1	0.3	<1	0.6	<1	<1	<1	<0.5	2	<1

[a]Also sampled in the National Organics Reconnaissance Survey

City	$CHCl_3$ R	$CHCl_3$ F	$BrCHCl_2$ R	$BrCHCl_2$ F	Br_2CHCl R	Br_2CHCl F	Br_3CH R	Br_3CH F	CCl_4 R	CCl_4 F	CH_2Cl_2 R	CH_2Cl_2 F	$C_2H_4Cl_2$ R	$C_2H_4Cl_2$ F
SURFACE SOURCE (Continued)														
Logansport, Ind.	<1	7	<1	1.2	<1	<0.1	<1	<0.1	<1	<1	<1	<0.5	<1	<1
Michigan City, Ind.	<1	5	<1	4	<1	1	<1	<0.5	<1	<0.5	<1	<0.5	<1	<2
Mt. Vernon, Ind.	<1	18	<1	9	<1	1.2	<1	.9	<1	2	<1	1.5	<1	<1
Muncie, Ind.	<1	31	<1	17	<1	1	<1	0.5	<1	< 1	1	<0.5	2	<1
New Albany, Ind.	3	41	.4	15	<1	1.4	<1	1	1	1.6	<1	1.3	2	<2
Terre Haute, Ind.	4	5	<1	5	<1	6	<1	3	<1	<1	<1	<0.5	15	<1
Whiting, Ind.[a]	<1	<1	<1	<0.5	<1	<0.5	<1	<0.5	<1	<1	<1	<0.5	<1	<2
Bay City, Mich.	<1	17	<1	19	<1	13	<1	7	<1	<1	<1	<0.5	3	<1
Bessemer Township, Mich.	7	312	<1	4	<1	<0.2	<1	<0.5	<1	6.5	<1	<0.5	<1	<1
Cadillac, Mich.	<1	47	<1	8	<1	0.4	<1	<0.1	<1	1	<1	<0.5	2	<2
Detroit, Mich.[a]	<1	5	<1	6	<1	2	<1	0.3	<1	<1	<1	<0.5	<1	<1
Dundee, Mich.	1	170	<1	26	<1	2	<1	0.3	<1	<1	<1	<0.5	<1	<1
Grand Rapids, Mich.	<1	24	<1	10	<1	1	<1	<0.5	<1	1	<1	1	2	<2
Menominee, Mich.	<1	42	<1	5	<1	.6	<1	0.3	<1	1	<1	1	3	<2
Mt. Clemens, Mich.[a]	<1	10	<1	6	<1	1.3	<1	<0.1	<1	<1	<1	<0.5	9	<2
Sault St. Maria, Mich.	<1	27	<1	<0.5	<1	<0.5	<1	<0.5	<1	0.5	<1	0.5	<1	<1
Wyandotte, Mich.	<1	14	<1	7	<1	1	<1	0.4	<1	2.1	<1	<1	<1	<2
Breckenridge, Minn.	<1	128	<1	15	<1	<0.5	<1	<2	4	12	<1	<1	<1	<3
Crookston, Minn.	<1	7	<1	0.8	<1	<0.2	<1	<0.5	<1	5	<1	<0.5	<1	<1
Duluth, Minn.	<1	26	<1	1.5	<1	<0.5	<1	<1	<1	23	<1	1	<1	<1
East Grand Forks, Minn.	<1	22	<1	0.8	<1	<0.2	<1	<0.5	<1	8	<1	0.5	<1	<1
Fairmount, Minn.	9	200	<1	31	<1	0.7	<1	<0.5	<1	<1	<1	<0.5	<1	<5
Granite Falls, Minn.	5	5	<1	<0.5	<1	<0.5	<1	<0.2	<1	7	<1	<0.5	<1	<0.5
International Falls, Minn.	<1	26	<1	.3	<1	<0.5	<1	<1	<1	26	<1	1	<1	<1
Minneapolis, Minn.	<1	8	<1	<0.5	<1	<0.2	<1	<0.5	<1	5	<1	<0.5	<1	<1

City	$CHCl_3$ R	$CHCl_3$ F	$BrCHCl_2$ R	$BrCHCl_2$ F	Br_2CHCl R	Br_2CHCl F	Br_3CH R	Br_3CH F	CCl_4 R	CCl_4 F	CH_2Cl_2 R	CH_2Cl_2 F	$C_2H_4Cl_2$ R	$C_2H_4Cl_2$ F
Oslo, Minn.	3	79	<1	5	<1	<0.2	<1	<0.5	<1	7	<1	<0.5	<1	<5
St. Cloud, Minn.	<1	37	<1	4	<1	<0.2	<1	<0.5	<1	9	<1	0.5	<1	<1
St. Paul, Minn.[a]	4	82	<1	6	<1	<0.2	<1	<0.5	2	12	<1	<0.5	<1	<5
Berea, Ohio	<1	60	<1	26	<1	4	<1	<1	<1	3	<1	<1	<1	<1
Bowling Green, Ohio	<1	160	<1	27	<1	5	<1	<1	<1	<.5	<1	<.5	<1	<1
Cincinnati, Ohio[a]	4	127	<1	29	1.4	3	<1	< .5	1	<.5	<1	<.5	<1	<1
Cleveland, Ohio[a]	<1	10	<1	5	<1	0.7	<1	<1	<1	9	<1	<1	<1	<1
Columbus, Ohio[a]	<1	51	<1	6	<1	0.7	<1	0.5	<1	<1	<1	<0.5	<1	<1
Defiance, Ohio	2	14	<1	6	<1	0.7	<1	<0.2	<1	1	<1	<0.5	<1	<1
East Liverpool, Ohio	<1	5	<1	<0.5	<1	<0.5	<1	<0.5	7	6	<1	<0.5	<1	<1
Fremont, Ohio	1	366	<1	18	<1	1.4	<1	<.5	<1	3	<1	<.5	<1	<1
Piqua, Ohio[a]	<1	102	<1	10	<1	0.7	<1	<0.1	<1	<1	<1	<0.5	<1	<1
Portsmouth, Ohio	2	25	<1	14	<1	4	<1	0.6	2	1	<1	3	2	<1
Toledo, Ohio	<1	62	<1	20	<1	4	<1	<0.2	<1	<0.5	<1	<0.5	<1	<1
Warren, Ohio	<1	138	<1	19	<1	0.8	<1	<0.2	<1	11	<1	<0.5	<1	<1
Green Bay, Wisc.	<1	9	<1	4	<1	<1	<1	<.5	0	<1	<1	<.5	<1	<1
Kenosha, Wisc.	12	3	3	< 1	.7	1	<1	<1	1	2	<1	<.5	<1	<1
Manitowoc, Wisc.	<1	14	<1	6	<1	1	<1	<.5	<1	<1	<1	<.5	<1	<1
Marinette, Wisc.	<1	53	<1	6	<1	<.5	<1	<.5	2	3	<1	<.5	<1	<1
Milwaukee, Wisc.[a]	2	2	<1	<.5	<1	<.5	<1	<.5	1	3	<1	<.5	<1	<1
Oshkosh, Wisc.[a]	6	55	<1	5	<1	<.5	<1	<.5	7	<2	<1	<.5	<1	<1
Two Rivers, Wisc.	1	9	<1	4	<1	<1	<1	<.5	10	<2	<1	<.5	<1	<1
GROUND WATER SOURCE														
Galesburg, Ill.	<1	30	<1	13	<1	2	<1	<0.2	<1	1	<1	1	<1	<1
Peoria, Ill.	<1	2	<1	1	<1	0.5	<1	0.4	<1	1.3	<1	<0.5	3	<1
Morocco, Ind.	<1	12	<1	10	<1	3	<1	0.3	<1	<1	<1	<0.5	<1	<1

City	$CHCl_3$ R	$CHCl_3$ F	$BrCHCl_2$ R	$BrCHCl_2$ F	Br_2CHCl R	Br_2CHCl F	Br_3CH R	Br_3CH F	CCl_4 R	CCl_4 F	CH_2Cl_2 R	CH_2Cl_2 F	$C_2H_4Cl_2$ R	$C_2H_4Cl_2$ F
South Bend, Ind.	<1	11	<1	3.4	<1	3	<1	2	<1	<1	<1	<0.5	<1	<1
Jackson, Mich.	<1	< 1	<1	16	<1	14	<1	3	<1	<1	<1	<1	<1	3
Kalamazoo, Mich.	<1	4	<1	<0.5	<1	<0.5	<1	<0.5	<1	<1	<1	<1	<1	<1
Lansing, Mich.	<1	10	<1	0.8	<1	0.7	<1	<1.3	<1	2	<1	<1	4	<2
Mt. Pleasant, Mich.	<1	11	<1	23	<1	15	<1	3	<1	<1	<1	<0.5	<1	<1
Waterford Township, Mich	<1	<1	<1	<0.2	<1	<0.2	<1	<0.2	<1	<1	<1	<0.5	<1	<1
Mankato, Minn.	2	10	<1	9	<1	2	<1	<0.5	3	5	<1	<0.5	<1	<1
Richfield, Minn.	<1	<1	<1	<0.5	<1	<0.5	<1	<0.5	3	<2	<1	<1	<1	<0.5
Willmar, Minn.	<1	2	<1	<0.2	<1	<0.2	<1	<0.5	20	13	<1	<0.5	<1	<0.5
Black River Falls, Wisc.	<1	6	<1	<0.5	<1	<.5	<1	<.5	<1	<2	<1	<1	<1	<2
Eau Claire, Wisc.	<1	50	<1	1	<1	< .5	<1	<1	<1	2	<1	7	<1	3
Mean	2	45	<1	8.5	<1	1.2	<1	0.4	<1	<1	<1	<1	<1	<1
Median	<1	20	<1	6	<1	1	<1	<1	<1	<1	<1	<1	<1	<1

APPENDIX VI

SURVEYS FOR PESTICIDES, PCBs, AND PHTHALATES IN REGION V

Table VI

REGION V SURVEY FOR PESTICIDES - POLYCHLORINATED BIPHENYLS[a] - PHTHALATES

Concentration in nanograms per liter R = Raw Water F = Finished Water

City		Diethylhexyl Phthalate	DDT	Dieldrin	Treflan	Hexachloro-benzene	Aldrin	Zytron	Lindane	2,4-D(IP) 2,4-D-isopro-pyl ester	Gamma Chlor-dane	Total Value #
Bedford, Ind.	R			8								1
	F			6								1
Ft. Wayne, Ind.	R	1000										1
	F	4000		7								2
Gary, Ind.	R	17000										1
	F	5000										1
Hammond, Ind.	R		14									1
	F											
Indianapolis, Ind.	R											
	F		6									1
Kokomo, Ind.	R		32									1
	F											
Lafayette, Ind.	R						10			50		2
	F						4					1
Logansport, Ind.	R		16									1
	F											
Michigan City, Ind.	R	3000										1
	F											
Morocco, Ind.	R							40				1
	F											
Muncie, Ind.	R											
	F											
Mt. Vernon, Ind.	R			3								1
	F											
New Albany, Ind.	R			16								1
	F		14									1
South Bend, Ind.	R	4000	6	7								3
	F	2000										1
Cairo, Ill.	R	1000	6	4		10						4
	F	3000										1
Carlyle, Ill.	R		8									1
	F											
Chester, Ill.	R											
	F	3000	68	7							4	4
Galesburg, Ill.	R											
	F					4						1
Kankakee, Ill.	R				10							1
	F			4								1

[a]All concentration values not reported were below the detection limits. Using analytic techniques sensitive to levels of 200 ng/l, no polychlorinated biphenyls were detected.

City		Diethylhexyl Phthalate	DDT	Dieldrin	Treflan	Hexachloro-benzene	Aldrin	Zytron	Lindane	2,4-D(IP) 2,4-D-isopro-pyl ester	Gamma Chlor-dane	Total Value #
Mt. Carmel, Ill.	R			11	28							2
	F			6	50							2
Peoria, Ill.	R											
	F											
Streator, Ill.	R			3								1
	F								4			1
Rock Island, Ill.	R											
	F		12									1
Bay City, Mich.	R	1000										1
	F	1000										1
Bessemer Twp., Mich.	R	1000										1
	F											
Cadillac, Mich.	R											
	F											
Detroit, Mich.	R											
	F											
Dundee, Mich.	R		4	5	7							3
	F						6					1
Jackson, Mich.	R	2500										1
	F											
Mt. Pleasant, Mich.	R		4									1
	F		6									1
Sault St. Marie, Mich.	R											
	F											
Wyandotte, Mich.	R	1000										1
	F											
Crookston, Minn.	R											
	F	1000				6						1
Duluth, Minn.	R	1000										1
	F	2000										1
East Grand Forst, Mich.	R	2000				6						2
	F	1000										1
Fairmont, Minn.	R	1000										1
	F											
Minneapolis, Minn.	R	6000										1
	F											
Oslo, Minn.	R					6						1
	F											

City		Diethylhexyl Phthalate	DDT	Dieldrin	Treflan	Hexachloro-benzene	Aldrin	Zytron	Lindane	2,4-D(IP) 2,4-D-isopro-pyl ester	Gamma Chlor-dane	Total Value #
Richfield, Minn	R											
	F	2000										1
St. Cloud, Minn.	R	2000	8				6					3
	F											
Berrea, Ohio	R	4000										1
	F	2000										1
Cincinnati, Ohio	R	2000		3								2
	F	17000										1
Cleveland, Ohio	R	1000										1
	F	2000										1
Columbus, Ohio	R	1000										1
	F											
East Liverpool,	R											1
Ohio	F	1000	10									1
Portsmouth, Ohio	R											
	F											
Toledo, Ohio	R											
	F	4000										1
Green Bay, Wisc.	R											
	F	2000										1
Kenosha, Wisc.	R	2000										1
	F	1000										1
Marinette, Wisc.	R											
	F	1000										1
Milwaukee, Wisc.	R	12000										1
	F											
Oshkosh, Wisc.	R											
	F	1000										1
Two Rivers,	R											
Wisc.	F	6000										1
Total # Values		40	15	14	4	5	4	1	1	1	1	86

APPENDIX VII

SELECTED REFERENCES

SELECTED REFERENCES

ORGANIC CONTAMINANTS

Activated Carbon in Water Treatment, University of Reading Conference. The Water Research Association, Medmenham, Marlow, Buckinghamshire, SL7 2HD, United Kingdom. April 3-5, 1973.

Bellar, T. A. and Lichtenberg, J. J. 1974. "Determining Volatile Organics at the μg/l Level in Water by Gas Chromatography." Journal of American Water Works Association. 66:739-744, December 1974.

Bellar, T. A., Lichtenberg, J. J. and Kroner, R. C. 1974. "The Occurrence of Organohalides in Chlorinated Drinking Water." JAWWA. 66:703.

Buelow, R. W., Carswell, J. K. and Symons, J. M. 1973. "An Improved Method for Determining Organics by Activated Carbon Adsorption and Solvent Extraction (Parts I and II)." JAWWA. 65:57-72, 195-199.

Bunn, W. W., Haas, B. B., Deane, E. R., Klopfer, R. D., 1975. "Formation of Trihalomethanes by Chlorination of Surface Water." Accepted for publication, Environmental Letters.

Burnham, A. K., Calder, G. V., Fritz, J. S., Junk, G. A., Svec, H. J. and Willis, R. 1972. "Identification and Estimation of Neutral Organic Contaminants in Potable Water." Anal. Chem. 44(1):139-41.

Burnham, A. K., Calder, G. V., Fritz, J. S., Junk, G. A., Svec, H. J. and Vick, R. 1973. "Trace Organics in Water: Their Isolation and Identification." JAWWA. 65(11):722-25.

Deinzer, M., Melton, R., Mitchell, D., Kopfler, F. and Coleman, E. 1974. "Trace Organic Contaminants in Drinking Water; Their Concentration by Reverse Osmosis." Presented to Division of Environmental Chemistry. A.C.S., Los Angeles, Cal.

Dressman, R. C. and McFarren, E. F. 1974. "Detection and Measurement of Bis-(2-chloro) Ethers and Dieldrin by Gas Chromatography." Second Annual Water Quality Conference of American Water Works Association, Dallas, Texas. December.

Dressman, R. C. and McFarren, E. F. In preparation. Improved Methodology for the Gas Chromatographic Detection and Measurement of Vinyl Chloride in Water -- Application to Pilot Plant and Field Studies of Polyvinyl Chloride (PVC) Pipe as a Source of Vinyl Chloride Contamination.

Dostal, K. A., Pierson, R. C., Hager, D. G. and Robeck, G. G. 1965. "Carbon Bed Design Criteria Study at Nitro, West Virginia." JAWWA. 57(5):663-674.

Dowling, W. T. 1974. "Chlorine Dioxide in Potable Water Treatment." Water Treatment and Examination. 23(Part 2):190-204.

Dowty, B. Carlisle, D. and Laseter, John L. 1975. "Halogenated Hydrocarbons in New Orleans Water and Blood Plasma." Science. 187(4171):75-77.

Dunham, Lucia J., O'Gara, Roger W. and Taylor, Floyd B. 1967. "Studies on Pollutants from Processed Water: Collection from Three Stations and Biologic Testing for Toxicity and Carcinogenesis." Amer. J. Public Health. 57(12):2178-85.

Friloux, James (Acting Chief). 1971. Petrochemical Wastes as a Water Pollution Problem in the Lower Mississippi River. Lower Mississippi Basin Office, Water Quality Office, EPA, Baton Rouge, Louisiana. Submitted to Senate Subcommittee on Air and Water Pollution, New Orleans, Louisiana - April 5, 1971.

Georlitz, D. T. and Lower, W. L. Determination of Phenoxy Acid Herbicides in Water by Electron Capture and Micro Coulometric Gas Chromatography. Geological Survey Water Supply Paper 1817C, U.S. Government Printing Office.

Gleason, Marion N., Gosselin, Robert E., Hodge, Harold C. and Smith, Roger P. 1969. Clinical Toxicology of Commercial Products: Acute Poisoning. 3d ed. Baltimore, Williams and Wilkins, Co.

Gomella, Cyril. 1972. "Ozone Practices in France." JAWWA. 64:39-45.

Hueper, W. C. and Payne, W. W. 1963. "Carcinogenic Effects of Raw and Finished Water Supplies." Amer. J. Clin. Path. 39(5):475-81.

Hueper, W. C. and Ruchoft, C. C. 1954. "Carcinogenic Studies on Adsorbates of Industrially Polluted Raw and Finished Water Supplies." Arch. Ind. Hyg. Occup. Med. 9:488-95.

Kleopfer, Robert D. and Fairless, Billy J. 1972. "Characterization of Organic Components in Municipal Water Supply." Environ. Sci. and Tech. 6:1036.

Love, O. T., Jr., Carswell, J. K., Stevens, A. A., Sorg, T. J., Logsdon, G. S. and Symons, J. M. 1975. "Preliminary Results of Pilot Plants to Remove Water Contaminants." Preliminary Assessment of Suspected Carcinogens in Drinking Water - Interim Report to Congress. Appendix VI. USEPA Report. Washington, DC. June 1975.

Love, O. T., Jr., Robeck, G. G., Symons, J. M. and Buelow, R. W. 1974. "Experience with Activated Carbon in the USA. Papers and Proceedings of a Water Research Association Conference, University of Reading. The Water Research Association, Medmenham, Marlow, United Kingdom. April 3-5, 1973. pp. 279-312 and 373,74.

Medlar, Steven J. 1975. "Operating Experience with Activated Granular Carbon." Water and Sewage Works. pp. 70-73.

Murphy, S. D. 1975. A Report - Assessment of Health Risk from Organics in Drinking Water by an Ad Hoc Study Group to the Hazardous Materials Advisory Committee, US Environmental Protection Agency, Washington, DC. April 30. Mimeo, 59 pp., plus attachments.

National Academy of Sciences. 1975. Principles for Evaluating Chemicals in the Environment. Washington, DC.

New Orleans Area Water Supply Study. Draft Analytical Report Lower Mississippi River Facility, Slidell, Louisiana, November 1974.

"Organic Contaminants in Drinking Water." 1974. Willing Water. 18(12):2-4.

"Organochlorine Pesticides in Water." 1974. Annual Book of ASTM Standards, American Society for Testing Materials.

Robeck, G. G. 1972. "Purification of Drinking Water to Remove Pesticides and Other Poisonous Chemicals: American Practice." International Water Supply Association. Proceedings of 9th Congress. p. K 1-4.

Robeck, G. G., Dostal, K. A., Cohen, J. and Kreissl, J. F. 1965. "Effectiveness of Water Treatment Processes in Pesticide Removal." JAWWA. (57): 181-199.

Rook, J. J. 1974. "Formation of Haloforms During Chlorination of Natural Waters." Water Treatment and Examination. 23(Part 2):234.

Rook, J. J. 1975. "Formation and Occurrence of Chlorinated Organics in Drinking Water." 95th Annual Conference of the American Water Works Association, June 8-13, Minneapolis, Minnesota.

Saunders, R. A., Blackly, C. H., Kovacina, T. A., Lamontagne, R. A., Swinnerton, J. W. and Saalfeld, F. E. Identification of Volatile Organic Contaminants in Washington, DC Municipal Water. Naval Research Laboratory, Washington, DC, 20375.

Schafer, M. L., Peeler, J. J., Gardner, W. S. and Campbell, J. E. 1969. "Pesticides in Drinking Water: Water from the Mississippi and Missouri Rivers." Env. Sci. Tech. 3(12):1261.

Scheiman, M. A., Saunders, R. A. and Saalfeld, F. E. 1974. Organic Contaminants in the District of Columbia Water Supply. Chemistry Division, Naval Research Laboratory, Washington, DC. Submitted to J. of Biomedical Mass Spectrometry.

Schuliger, W. G. and MacCrum, J. M. 1974. "Granular Activated Carbon Reactivation System Design and Operating Conditions." Water-1974:I. Industrial Waste Treatment. AIChE Symposium Series. No. 144, Vol. 70.

Sommerville, R. C. and Rempel, G. 1972. "Ozone for Supplementary Water Treatment." JAWWA. 64(6):377.

Stevens, A. A., Slocum, C. J., Seeger, D. R. and Robeck, G. G. 1975. "Chlorination of Organics in Drinking Water." Conference on the Environmental Impact of Water Chlorination, Oct. 22-24, Oak Ridge, Tennessee.

Stevens, A. A. and Symons, J. M. 1975. "Analytical Considerations for Halogenated Organic Removal Studies." Proceedings AWWA Water Quality Technology Conference, December 2-3, Dallas, Texas, pp. XXVI-1.

Stevens, A. A. and Symons, J. M. 1974. "Measurement of Organics in Drinking Water." Proceedings AWWA Water Quality Technology Conference, Denver, Colorado. pp. XXIII-1-XXIII-25.

Symons, J. M., Bellar, T. A., Carswell, J. K., DeMarco, J., Kropp, K. L., Robeck, G. G., Seeger, D. R., Slocum, C. J., Smith, B. L. and Stevens, A. A. 1975. "National Organics Reconnaissance Survey for Halogenated Organics in Drinking Water." Water Supply Research Laboratory and Methods Development and Quality Assurance Laboratory, National Environmental Research Center, USEPA, Cincinnati, Ohio. JAWWA. 67(11):634-647.

Tardiff, R. G., Craun, G. F., McCabe, J. J. and Bertozzi, P. E. "Health Effects Caused by Exposure to Contaminants." Preliminary Assessment of Suspected Carcinogens in Drinking Water - Interim Report to Congress, Appendix VII. Washington, DC. June 1975.

Tardiff, Robert G. and Deinzer, M. 1973. "Toxicity of Organic Compounds in Drinking Water." Proceedings of 15th Water Quality Conference, Feb. 7-8, 1973, University of Illinois, pp. 23-37.

USEPA Report. 1971. Advanced Wastewater Treatment as Practiced at South Tahee. Project 17010 ELQ. NTIS PB 204 525.

USEPA Report. Industrial Pollution of the Lower Mississippi River in Louisiana. Surveillance and Analysis Division, Region VI, Dallas, Texas. April 1972.

USEPA Report. Method for Organophosphorous Pesticides in Industrial Effluents. National Pollution Discharge Elimination System, Appendix A. Methods Development and Quality Assurance Research Laboratory, Cincinnati, Ohio. November 1973.

USEPA Report. Method for Polychlorinated Biphenyls in Industrial Effluents. National Pollution Discharge Elimination System, Appendix A. Methods Development and Quality Assurance Research Laboratory. Cincinnati, Ohio, November 1973.
Dostal, K. A.,

U. S. Department of Interior. 1970. Progress Report: Identification of Hazardous Materials, Lower Mississippi River Basin, Federal Water Quality Administration, Lower Mississippi River Basin Field Station.

INORGANIC CONTAMINANTS

Buelow, R. W., Kropp, K. L., Withered, J. and Symons, J. M., 1975. "Nitrate Removal by Anion - Exchange Resins." JAWWA. 67(9):528-534.

Caldwell, J. S., Lishka, R. J. and McFarren, E. F., 1973. "Evaluation of Low-Cost Arsenic and Selenium Determination at Microgram-per-Liter Levels." JAWWA. 63:731.

Craun, G. F., and McCabe, L. J. "Overview of Problems Associated with Inorganic Contaminants in Drinking Water." Proceedings National Symposium on the State of America's Drinking Water. Chapel Hill, North Carolina. In press.

Feinglass, E. J., 1973. "Arsenic Intoxication from Well Water in the United States." New England J. Med. 288, 828; Federal Register. 40(51): 11990-11998. March 14, 1975.

Gulledge, J. H. and O'Connor, J. T. 1973. "Removal of As (V) from Water by Adsorption on Aluminum and Ferric Hydroxides." JAWWA. 65:548.

Hertsch, F. F. and Maddox, F. D., 1971. "Fluoridation Practice in Wisconsin." JAWWA. 63:778-782.

IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man. Some Inorganic and Organometallic Compounds, Volume 2, 1973. International Agency for Research on Cancer, Lyon, France.

Interim Primary Drinking Water Standards, Federal Register. 40(51, Part II): 11190-11198. March 1975.

Kopp, J. F. and Kroner, R. C. Trace Metals in Waters of the U.S., Cincinnati, Ohio.

Kopp, J. F., Longbottom, M.C. and Lobring, L. B. 1972. "Cold Vapor Method for Determining Mercury." JAWWA. 64(20).

Logsdon, G. S., Sorg, T. J. and Symons, J. M. 1974. "Removal of Heavy Metals by Conventional Treatment." Proceedings 16th Water Quality Conference Trace Metals in Water Supplies: Occurrence, Significance and Control. University of Illinois Bulletin. 71(108)111-133.

Logsdon, G. S. and Symons, J. M. 1973. "Mercury Removal by Conventional Water Treatment Techniques." JAWWA. 65(8)554-562.

Logsdon, G. S. and Symons, J. M. 1973. "Removal of Heavy Metals by Conventional Treatment." Traces of Heavy Metals in Water, Removal and Monitoring. Sabadell, J. E., USEPA Report #092/9-74-001. Region II, New York, NY. pp. 225-256.

Logsdon, G. S. and Symons, J. M. 1974. "Removal of Trace Inorganics by Drinking Water Treatment Unit Processes." Water-1973. American Institute of Chemical Engineers Symposium Series. 70:367-377.

McCabe, L. J., Symons, J. M., Lee, R. D. and Robeck, G. G. 1970. "Survey of Community Water Supply Systems." JAWWA. 62(11):670-687.

McCabe, L. J. 1974. "Problem of Trace Metals in Water Supplies - An Overview." Proceedings 16th Water Quality Conference, University of Illinois.

National Academy of Sciences. Medical and Biologic Effects of Environmental Pollutants. Chromium (ISBN 0-309-02217-7) 1974; Nickel (ISBN 0-309-02314-9) 1975.

Schmidt, A. M. "Selenium in Animal Feed." Federal Register. 39(5):1355-1358. January 1975.

Shen, Y. S. 1973. "Study of Arsenic Removal from Drinking Water." JAWWA. 65(543).

Technicon Instrument Corp. 1972. Cyanide in Water and Wastewater, Industrial Method. Tarrytown, New York, No. 119-71W.

Tseng, W. P., Chu, H. M., How, S. W., Forg, J. M., Lin, C. S. and Yels. 1968. "Prevalence of Skin Cancer in an Endemic Area of Chronic Arsenicism in Taiwan." J. Nat. Cancer Irst. 40:454-463.

USEPA Report. 1973. Chemical Analysis of Interstate Carrier Water Supply Systems.

ASBESTOS

American Water Works Association Research Foundation. 1974. "A Study of the Problem of Asbestos in Water.' JAWWA. 66(9)Part 2.

Chatfield, E. J. and Pullen, H. 1974. "Measuring Asbestos in the Environment." Canadian Research and Development. 7(6):23.

Cook, Philip M. 1974. "Semi-quantitative Determination of Asbestiform Amphibole Mineral Concentrations in Western Lake Superior Water Samples." Proceedings of 23rd Annual Conference on Applications of X-ray Analysis. Denver, Colorado.

Cook, Philip M., Glass, G. E. and Tucker, J. H. 1974. "Asbestiform Amphibole Minerals: Detection and Measurement of High Concentrations in Municipal Water Supplies." Science. 185(853-855).

Environmental Health Perspectives. Vol. 9. December 1974.

Fairless, B. "Asbestos Fiber Concentrations in the Drinking Water of Communities Using the Western Arm of Lake Superior as a Potable Water

Source." USEPA, Surveillance and Analysis Laboratory, Region V, Chicago, Illinois. 17 pp. Mimeo.

Letter dated January 31, 1974, from Train to Castleman.

Levy, B. S., Sigurdson, E., Mandel, J., Laudon, E. and Pearson, J. Incidence of Gastrointestinal Cancer Among Residents of Duluth, Minnesota, 1969-1972. In press.

Logsdon, G. S. and Symons, J. M. 1974. "Removal of Asbestiform Fibers by Water Filtration." American Water Works Association Annual Conference.

McFarren, E. F., Millette, J. R. and Lishka, R. J. "Asbestos Analysis by Electron Microscope." Proceedings AWWA Water Quality Conference, Dallas, Texas. December 1974. In press.

Masson, T. J., McKay, D. W. and Miller, R. W. 1974. "Asbestos-like Fibers in Duluth Water Supply." Journal American Medical Assn. 228(8):1019-1020.

USEPA Report. 1975. Direct Filtration of Lake Superior Water for Asbestiform Fiber Removal. EPA-670/2-75-050 a-g.

RADIONUCLIDES

Straub, C. P. 1973. Radium-226 and Water Supplies: Cost-Benefit-Risk Appraisal. Unpublished report.

Tsivoglou, E. C. and O'Connell, R. L., Waste Guide for the Uranium Milling Industry. DHEW, USPHS, DWSPC, RATSEC, Technical Report, W63-12.

ECONOMICS OF WATER TREATMENT

Clark, Robert M. "Cost and Pricing Relationships for Water Supply." Journal of the Environmental Engineering Division of ASCE. Accepted for publication.

Clark, Robert M. and Goddard, Haynes C. 1974. Pricing for Water Supply: Its Impact on Systems Management. Environmental Health Effects Research Series, National Environmental Research Center, Office of Research and Development, USEPA. EPA-670/1-74-001.

The Cost of Water Treatment by Coagulation, Sedimentation, and Rapid Sand Filtration. (Part 1 of a Report for U.S. Public Health Service.) 1966. Division of Water Supply and Pollution Control, Technical Services Branch, Louis Koenig Research. San Antonio, Texas. Contract No. PH 86-65-120. January.

Dostal, K. A., Harrington, J. J. Clark, R. and Robeck, G. 1966. "Development of Optimization Models for Carbon Bed Design." JAWWA. 58:1170-1186.

David Volkert and Associates. Monograph of the Effectiveness and Cost of Water Treatment Processes for the Removal of Specific Contaminants, Vol. 1. 1974. EPA Contract No. 68-01-1833.

APPENDIX VIII

LIST OF PRIMARY CONTRIBUTORS

LIST OF PRIMARY CONTRIBUTORS

The report was compiled by Cynthia C. Kelly of the Office of Toxic Substances, with the assistance of the staff of that office. The following list indicates those persons who were primary contributors to the Report. Unless otherwise indicated, the offices named are located in Washington, D.C.

CHARACTER AND EXTENT OF CONTAMINATION OF DRINKING WATER

National Organics Reconnaissance Survey	Dr. James M. Symons, Municipal Environmental Research Laboratory (MERL), Cincinnati, Ohio
Region V Organics Survey	Mr. Joseph F. Harrison, Region V Office, Chicago, Illinois
Assessment of General Organics Parameters	Dr. James M. Symons (MERL)
Inventory of Organics Identified in Drinking Water	Dr. Robert G. Tardiff, Health Effects Research Laboratory (HERL), Cincinnati, Ohio
Investigations of Pesticides Drinking Water	Mr. Earl F. McFarren (MERL) Mr. Joseph F. Harrison (Region V) Dr. Gunter Zweig, Office of Pesticide Programs (OPP) Dr. Edgar A. Jeffrey, Office of Water Supply (OWS)
Analyses for Polychlorinated Biphenyls (PCBs)	Mr. Earl F. McFarren (MERL)
Studies of Leaching from Polyvinyl Chloride (PVC) Water Pipes	Mr. Earl F. McFarren (MERL) Mr. Ronald C. Dressman (MERL)
Detection of Nitrosamines in Drinking Water	Mr. Gunther F. Craun (HERL)
Surveillance for Inorganic Contaminants in Drinking Water	Mr. Gunther F. Craun (HERL)
Occurrence of Radioactivity in Drinking Water	Mr. Floyd L. Galpin, Office of Radiation Programs (ORP)

Survey of Rural Drinking Water Supplies	Mr. Earl F. McFarren (MERL)
Asbestos Fibers in Drinking Water Supplies	Mr. Earl F. McFarren (MERL) Dr. Gary S. Logsdon (MERL) Dr. Robert Carton, Office of Toxic Substances (OTS)

HEALTH EFFECTS OF DRINKING WATER CONTAMINANTS

Review of Drinking Water Contaminants by the National Academy of Sciences	Dr. Edgar A. Jeffrey (OWS)
Development of Quality Criteria for Water	Dr. Leonard J. Guarraia (OWS)
Other Investigations of the Health Effects of Organics	Dr. Robert G. Tardiff (HERL)
Epidemiological Studies	Mr. Leland J. McCabe (HERL)
Evaluation of Health Risks from Inorganics	Mr. Gunter F. Craun (MERL)
Estimation of Risk from Radiation	Dr. William A. Mills (ORP)
Assessment of Effects of Oral Ingestion of Asbestos	Mr. Leland J. McCabe (HERL) Dr. Barry S. Levy, Minnesota Department of Health, Minneapolis, Minnesota

SOURCE IDENTIFICATION

Industrial Sources	Mr. John P. Lehman, Office of Solid Waste Management Programs (OSWMP) Mr. Thomas E. Kopp (OTS)
Discharges from Municipal Waste Treatment Facilities	Mr. Thomas E. Kopp (OTS)
Chlorination of Drinking Water	Mr. Alan A. Stevens (MERL)
Contamination by Agricultural Chemicals	Mr. Thomas E. Kopp (OTS) Dr. Gunter Zweig (OPP)
Other Non-Point Sources of Organics	Mr. Thomas E. Kopp (OTS)
Various Land Disposal Practices and Water Contamination	Mr. John P. Lehman (OSWMP)

TREATMENT TECHNIQUES FOR CONTROLLING CONTAMINANTS IN DRINKING WATER

Dr. James M. Symons (MERL)
Dr. Gary S. Logsdon (MERL)
Dr. O. Thomas Love, Jr. (MERL)
Mr. Thomas J. Sorg (MERL)
Mr. J. Keith Carswell (MERL)
Mr. Jack DeMarco (MERL)
Dr. William A. Mills (ORP)

COST OF TREATMENT TO REMOVE CARCINOGENS

Dr. James M. Symons (MERL)
Mr. O. Thomas Love, Jr. (MERL)
Dr. Gary S. Logsdon (MERL)
Mr. Thomas J. Sorg (MERL)
Mr. Robert M. Clark (MERL)
Mr. Robert A. Brown (OWS)
Dr. William A. Mills (ORP)

APPENDICES

Appendix I - National Organics Reconnaissance Survey	Dr. James M. Symons (MERL) Dr. Robert G. Tardiff (HERL)
Appendix II - Organic Compounds Identified in Drinking Water in the United States	Dr. Robert G. Tardiff (HERL)
Appendix III - Analyses of Radioactivity in Interstate Carrier Water Supply	Mr. Floyd L. Galpin (ORP)
Appendix IV - Environmental Radiation Monitoring System Survey (1974)	Mr. Floyd L. Galpin (ORP)
Appendix V - Organics Survey Performed by Region V	Mr. Joseph F. Harrison (Region V)
Appendix VI - Region V Survey for Pesticides, Polychlorinated Biphenyls, and Phthalates	Mr. Joseph F. Harrison (Region V)
Appendix VII - Selected Readings	Dr. James M. Symons (MERL)
Appendix VIII - List of Primary Contributors	