

SUSPECT CARCINOGENS IN WATER SUPPLIES

**Office of Research & Development
Interim Report
April 1975**



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I N T E R I M R E P O R T

SUSPECT CARCINOGENS

IN

WATER SUPPLIES

April 1975

Environmental Protection Agency
Office of Research and Development

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The cooperation and dedication in accomplishing the many activities that resulted in this report by the personnel within EPA are to be commended as an example of an outstanding performance within the difficult constraints involved.

Preface

Section 1442 (a)(9) of the Safe Drinking Water Act requires the Administrator of the Environmental Protection Agency to:

"conduct 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. Not later than six months after the date of enactment of this title, he shall transmit to the Congress the initial results of such study, together with such recommendations for further review and corrective action as he deems appropriate."

This document has been prepared by the Office of Research and Development at the request of the Office of Water and Hazardous Materials of the Environmental Protection Agency for inclusion in an Agency interim report on suspect carcinogens in water supplies. The Agency report is to be submitted to Congress by June 17, 1975.

This document is mainly an attempt to provide a description of the Office of Research and Development's on-going activities related to suspect carcinogens in water supplies. These activities include sources identification, surveys of water supplies for the occurrence of organic and inorganic compounds that may or may not be carcinogenic, determination of the health effects of substances

present in water supplies and, finally, development of the technology needed for the removal or control of these suspect carcinogens.

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I. SOURCES OF ORGANIC COMPOUNDS IN WATER SUPPLIES

A multitude of organic compounds has been found in the drinking water of the United States. As of late 1974, some 187 organic compounds have been identified in various water supplies (See Table 1). This list will undoubtedly grow as work continues in the analysis of drinking waters and as analytical techniques are improved for the concentration, separation, identification and measurement of organic compounds in drinking water. A major question relating to these organic compounds which may be later identified as carcinogenic is that of their source or sources. Research bearing on this question is presently ongoing and is centered at the Southeast Environmental Research Laboratory in Athens, Georgia.

The research mentioned above has as its objective the identification of substances remaining in domestic sewage and industrial wastes and sludges after various treatment processes. The purposes of this research are to provide information on the presence of substances which are potentially damaging to the environment (including man), to provide data on the effectiveness of various treatments and to allow the identification of the sources of pollutants in water. It is estimated that these projects will be completed in mid-1979 at which time most of the organic substances at the part per billion or greater level will have been identified.

Organic Chemicals in the Effluents of Municipal Wastewater Treatment Plants

Research has been and is being conducted to identify the organic compounds present in the effluents from sewage treatment processes and systems.

Under contract to EPA, the Oak Ridge National Laboratory developed a procedure for the separation and tentative identification of refractory organics from sewage treatment facilities. The procedure which is capable of detecting these organic substances at the microgram-per-liter (parts per billion) level was applied to the study of primary and secondary effluents at the Oak Ridge facility. In primary effluents, 56 compounds were identified with an additional 30 or more detected but not identified. The identified substances include simple carbohydrates, amino acids and other components apparently of metabolic origin. These same substances were found in both chlorinated and unchlorinated effluents. Table 2 provides a listing of the identified compounds.

In unchlorinated secondary effluents 33 compounds were detected. Thirteen were identified, of which 10 were also identified in primary effluents. The 13 substances are listed in Table 3.

In addition to the work performed at the Oak Ridge National Laboratory, the Southeast Environmental Research Laboratory has been systematically studying various fractions of domestic wastes. In the

acid fraction of domestic wastes, they have identified 27 organic acids, listed in Table 4.

At Oak Ridge National Laboratory, samples of both primary and secondary effluents were chlorinated under conditions simulating plant conditions and analyzed for chlorinated compounds. Out of 62 chlorinated compounds which were detected, 16 have been identified and are listed in Table 5. In addition to the Oak Ridge study, work being done at North Texas State University in Denton, Texas, has identified 13 (Table 6) polychlorinated compounds in super chlorinated domestic wastes and detected 15 other chlorinated compounds which have not yet been identified.

Of the compounds found in drinking water and recognized or suspected as being carcinogenic, only chloroform has been identified in municipal waste treatment plant effluents. It should be pointed out, however, that the effluent containing chloroform was from a treatment plant receiving both domestic and industrial wastes. Thus, chloroform may not be characteristic of municipal waste treatment systems. In fact, of all the compounds which have already been identified in water supplies, none appear to be characteristic of domestic waste treatment plants.

Organic Chemicals in Industrial Effluents

The compositions of industrial effluents are being systematically studied at the Southeast Environmental Research Laboratory. In

addition, short-term studies for special purposes have been conducted at the request of Regional and other offices. Table 7 is a composite list of substances and their sources as of mid-1973. Compounds in textile mill effluents identified since 1973 are listed in Table 8.

In general the lists of compounds already found in drinking water appear to have more in common with the lists of compounds occurring in industrial wastes than the list of compounds occurring in domestic sewage. Of those substances identified as suspect carcinogens, two, chloroform and bis (2-chloroethyl) ether appear in industrial wastes and have not been shown to occur in domestic sewage. It should be mentioned, however, that there is the possibility that these compounds are formed during the chlorination of drinking water.

With the presently available information, it would appear that the organic substances occurring in drinking water are for the large part of industrial origin. Where special studies have been undertaken to identify specific compounds causing problems, such as taste and odor, in water supplies, the results have led to the conclusion that the causative agents were of industrial origin. It should be kept in mind, however, that the analyses of drinking water, municipal wastewaters and industrial effluents is continuing and the final results may present a somewhat different picture.

Chlorination of Water Supplies

In his pioneer study, Rook found the following compounds to be formed by chlorination of water supplies: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. He further postulated that naturally occurring humic substances are precursors to the formation of these haloforms. The maximum concentrations found were: chloroform, 54.0 $\mu\text{g/l}$; bromodichloromethane, 20.0 $\mu\text{g/l}$; dibromochloromethane, 13.3 $\mu\text{g/l}$; and bromoform, 10.0 $\mu\text{g/l}$.

A later study confirmed the presence of these haloforms in a variety of finished drinking waters from Ohio, Indiana and Alabama.

A multitude of halogen-containing organic compounds has been found in water and wastewaters. Example of such compounds found in drinking water is given in Table 1. However, these compounds are not specifically mentioned here since there is yet no evidence indicating the in-situ formation of these halogenated compounds through the interaction of chlorine with organic compounds in water supplies.

Controlled studies are now being conducted in an attempt to determine what factors influence the rate and quantity of trihalogenated methanes formed during chlorination, and what other halogenated compounds might be formed at the same time.

The first study compared the rate and extent of chloroform formation when chlorine was added to raw river water, mixed-media filtered treated water, and granular activated carbon treated water. 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 7 times as much chloroform as did chlorination of the 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 10-15 µg/l/hr for the first 6 hours. What is removed from the raw river water during alum coagulation, settling, and dual-media filtration that reduces the rate and extent of chloroform formation upon chlorination is not known at this time.

Other studies investigated the chlorination of approximately 50 µg/l of nitromethane, benzene, toluene, and m-xylene. Under the conditions of the test, 9 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 and should not be overlooked in future studies.

Controlled studies of this type will continue in an attempt to define specific precursors of the trihalogenated methanes, and the

conditions under which the formation of these substances is enhanced or retarded. Investigations dealing with the formation of other halogenated organics by chlorination of water supplies will also continue.

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II. Nature and Extent of Contamination of Water Supplies by Suspect Carcinogens

National Organics Reconnaissance Survey

The National Organics Reconnaissance Survey initiated in November 1974 has three major objectives. One is to determine the extent of the presence of the four trihalogenated methanes; chloroform, bromodichloromethane, dibromochloromethane, and bromoform in finished water, and to determine whether or not these compounds are formed by chlorination. The second objective is to determine what effect raw water source and other water treatment practices could have on the formation of these compounds. The third objective is to characterize, as completely as possible using existing analytic techniques, the organic content of finished drinking water produced from raw water sources representing the major categories in use in the United States today.

For the study of the formation of chlorination by-products, 80 water supplies were chosen to participate in the National Organics Reconnaissance Survey (NORS) in consultation with State Water Supply officials. These 80 supplies were geographically distributed to include each of EPA's 10 Regions. The supplies were chosen to represent as wide a variety of raw water sources and treatment techniques as possible. Five of the above 80 cities were chosen as sites for a more comprehensive survey of the organic content of the finished water. These locations were chosen to represent five major categories of raw water sources. These were: 1) ground water; 2) uncontaminated upland water; 3) raw water contaminated with

agricultural runoff; 4) raw water contaminated with municipal waste; and, 5) raw water contaminated with industrial discharges.

- a. Eighty systems: analysis for chloroform, bromodichloromethane, dibromochloromethane, bromoform, carbon tetrachloride, and 1,2-dichloroethane.

Results from the analysis of the raw water samples showed that none of the 4 trihalomethanes were found in 38% of the samples, and none of the samples contained any dibromochloromethane or bromoform. Another 58.4% of the samples contained from 0.1 to 0.9 $\mu\text{g/l}$ of chloroform. The other 3.6% of the samples did not contain chloroform, but did contain low concentrations of bromodichloromethane, 1,2-dichloroethane, and/or carbon tetrachloride in various combinations. Because of the low concentrations of trihalomethanes in the raw water, almost all trihalomethane appearing in the finished water was concluded to be due to chlorination.

The finished water in all 80 locations contained some chloroform in concentrations between 0.1 $\mu\text{g/l}$ to 311 $\mu\text{g/l}$, with 50% of the finished waters containing 25 $\mu\text{g/l}$ of chloroform or less. With respect to bromodichloromethane, none was found in 2.5% of the finished waters. The range of concentrations found in the remaining locations was 0.3 $\mu\text{g/l}$ to 116 $\mu\text{g/l}$, with 62% containing 10 $\mu\text{g/l}$ or less. In slightly over 10% of the locations, no dibromochloromethane was found, and in the remainder of the locations, the concentrations range was less than 0.4 $\mu\text{g/l}$ to 100 $\mu\text{g/l}$. In 75% of the locations,

the concentration of dibromochloromethane was 5 µg/l or less.

Finally, no bromoform was found in 68.4% of the finished waters with the concentration range in the remainder being from 0.8 µg/l to 92 µg/l. Ninety-five percent of the finished waters contained 5 µg/l of bromoform or less.

No 1,2 dichloroethane was found in 67.1% of the finished waters, and 6 µg/l was the highest concentration found. No carbon tetrachloride was found in 87.4% of the systems, and the highest carbon tetrachloride found in finished water was 3 µg/l.

b. Five systems: in-depth studies.

Analysis of the samples collected in the comprehensive survey from the 5 selected locations is still proceeding. Thus far, the most complete qualitative analysis is available on the class of organics that can be defined operationally as those that can be purged from water with an inert gas. In general, these are the lower boiling point organics. Thus far, 35 organic compounds have been identified in the finished water from the ground water supply. The ground water chosen for this study was shallow ground water, and therefore, may not be reflective of all ground waters.

Thirteen organic compounds have been isolated from the samples representative of uncontaminated upland water. In the finished water produced from raw water contaminated with agricultural runoff, 19 organic compounds have been identified. From the location representative of raw water contaminated with municipal waste, 36

organic compounds have been identified. Finally, in the finished water selected to represent a location whose raw water is contaminated with industrial discharges, 36 organic compounds have been identified.

Inorganic Analysis of Water Supplies (Excluding Asbestos)

There are several EPA projects that obtain data on the inorganic chemical quality of drinking water. These range from the routine surveillance of quality for certifying water supply systems serving interstate carriers, assisting a utility with a particular problem, to comprehensive national survey.

For the interstate carriers supplies, the state agency makes an annual report on the chemical quality of each such supply once a year. At about a three-year interval, a joint survey is made by the state and EPA Regional Office of each of these 700 supplies. At the time of the joint survey, a water sample is collected and analyzed by the Water Supply Research Laboratory for the chemicals that are limited by the drinking water standards. Tabulations are made of this data - Chemical Analysis of Interstate Carrier Water Supply Systems: October 1973. Results show that only chromium, lead, and mercury were found in interstate water carrier drinking water supplies in concentrations that exceed the DWS limit. Mercury was the constituent that most frequently exceeded the limit and this occurred in only 1.5% of the samples analyzed.

water samples collected from the interstate carrier water supplies are collected at the water treatment plant or well head and do not reflect effects on the water quality from passing through the distribution system and household plumbing. Little change is noted in some supplies, but in others where the water is corrosive, there is a pick-up of several metals. The first comprehensive set of data on water quality at the consumer's tap was collected in the Community Water Supply Survey. The results of this activity showed that arsenic, barium, cadmium, chromium, lead, selenium, and fluoride were the constituents that were found in public drinking water supplies in concentrations that exceeded the proposed mandatory drinking water limits put forth as guidelines at that time. Of the 2,595 distribution samples analyzed, fluoride was the constituent that most frequently exceeded the proposed limits, 2.2% of the samples, whereas the lead limit was exceeded in only 1.4% of the samples. EPA has sponsored a specific study of the increase in the lead content of drinking water in the Boston area. Data of this type were also obtained for the Seattle supply. Preliminary results of both studies show that the pick-up of metals was significant enough to cause 65% of the homes in the Boston Study to have water delivered to the consumer that exceeded the drinking water standard for lead, and, in Seattle, 24% of the homes exceeded the lead standard.

A cooperative study now under way will obtain data on the inorganic chemical content of the drinking water of a representative

sample of the U.S. population. Water samples are collected at the homes of persons in the current series of the National Health Examination Survey. Because of the interest of the National Heart and Lung Institute and EPA in the suggested association of heart disease mortality and soft drinking water, attempts will be made to correlate the results of the health examination and drinking water quality. The data will be most useful for this health effect study but will also provide a unique set of data on the quality of approximately 170 community water supplies. Analyses will be made for sodium, potassium, calcium, magnesium, arsenic, selenium, silicon, fluoride, nitrate, hardness, alkalinity, conductivity, pH, total dissolved solids, lithium, vanadium, manganese, iron, copper, zinc, molybdenum, silver, iodine, chromium, cobalt, nickel, cadmium, and lead on samples from 4,000 homes. To provide data on the occurrence of chemicals not limited by the drinking water standards an additional 66 elemental determinations will be performed on these samples.

Chemical analyses for inorganic constituents limited in the standards have been performed on water plant samples collected as part of the National Organics Reconnaissance Survey.

Asbestos in Water Supplies

A few months after the confirmation of the presence of asbestos fibers in Duluth, Minnesota finished water in the fall of 1973, the Environmental Protection Agency conducted periodic asbestos analyses of the raw water to demonstrate the continued presence of asbestos fibers in Lake Superior waters. Analysis of the raw water for amphibole mass by x-ray diffraction and asbestos fibers by electron microscopy demonstrated the continued presence of asbestos fibers in Lake Superior water. In addition to these studies, Region V Surveillance and Analysis Laboratory conducted an extensive lake sampling program that further defined the extent of the problem. This study showed the concentration of asbestos fibers was highest near the industrial discharge and declined steadily as samples were collected at varying distances from the industrial discharge. To determine an effective method for treating this water, the U.S. EPA in cooperation with the U.S. Army Corps of Engineers, entered into a contract with Black and Veatch to determine whether or not granular- or diatomaceous-earth filtration could remove these fibers from Lake Superior water. Results of this investigation are reported elsewhere in this report.

Investigation of the nature and extent of the occurrence of asbestos was extended beyond source waters to investigations of the possibility that asbestos fibers could erode from the walls of

asbestos-cement (A/C) pipe that is used in water distribution systems. The investigations are being conducted in two ways. One, a controlled experiment is being conducted in which water of a known chemical quality is circulated through two 100 ft. lengths of asbestos-cement pipe. Weekly samples are being collected from the effluent and are being subjected to electron microscope analysis to determine whether or not asbestos fibers are released from the pipe wall. The other phase of this project is being conducted in the field. Locations have been selected in which water low in asbestos fibers is flowing some distance through asbestos cement pipe prior to use. Monthly analysis of the source water and tap water collected after passage through the A/C pipe should show whether or not any increase in the asbestos fiber count occurs. Thus far, three such locations have been selected, and the first two of an anticipated 12 monthly samples have been collected. Other systems will be tested in the future as time permits. No firm conclusions can be drawn from either of these two projects at this time.

III. Health Effects

Inorganics (Excluding Asbestos)

There are suggestions that evaluations should be made of arsenic, beryllium, cadmium, chromium, nickel, nitrate, and selenium as inorganic chemicals that might be carcinogenic in drinking water. Evidence that would cause concern is derived from occupational exposures to these chemicals, except for nitrate and selenium.

Apparently, the inhalation exposures to fumes or dust in the industrial setting produces a very different biological effect than an ingestion exposure from food or water. An increased risk of developing cancer is not expected from consuming water contaminated with beryllium, cadmium, chromium, and nickel. There are other health effects that require limiting the concentrations of these elements in drinking water.

Nitrate concentrations in drinking water have been limited because of the possibility of developing methemoglobinemia in infants who were fed water high in nitrates. It has been hypothesized that the nitrogen might combine with amines in the gut to form nitrosamines, a recognized carcinogen. This conversion may also occur in the environment. The development of nitrosamines has been demonstrated

experimentally using much higher concentrations of nitrate or nitrite than would occur in water. The health risk of this conversion associated with drinking water cannot be evaluated from available data but the risk would be at least an order of magnitude less than the risk associated with cured meats. Nitrate and nitrite are added to meat as a preservative and the problem is being pursued by other Agencies.

Evidence has been developed that selenium both causes and prevents cancer. Several animal studies showed that tumors were developed from exposure to selenium. Selenium was given a complete review last year when it was proposed that selenium be used as an additive to animal feed. The Commissioner of the Food and Drug Administration concluded that selenium could be safely used as an additive because of its nutritive properties and lack of health hazard. The inadequacy of the studies that had indicated tumorigenic effects were reviewed.

Of the inorganic chemical of possible concern, only for arsenic is there evidence that cancer results from drinking water with excessive levels. Experience in Taiwan and South America has demonstrated the progressive effects to the skin of excessive arsenic intake, with eventual development of skin cancer. An adequate animal model does not exist to demonstrate in toxicological studies what has been observed in man; this has stimulated endless debate between epidemiologist and toxicologist. In limiting concentrations of

chemicals in drinking water, comparisons have been frequently made with allowable occupational exposure. The recent reduction in allowed arsenic concentrations in the work place by OSHA would indicate a review of the concentrations allowed in drinking water.

Funding a grant is under consideration to determine body burdens of arsenic in humans who use drinking water at or exceeding the current limit of 0.05 mg per liter.

All of the above-mentioned metals are being tested for mutagenicity in a cultured mammalian cells test system. More direct carcinogenic screening will be conducted on the metals showing mutagenic effects.

Organics

The occurrence of organic compounds in tap water is universally accepted. However, the health significance from human exposure to these compounds via drinking water is as yet unsettled. Only a small percentage of compounds present in potable water have been identified. Of those compounds known to occur in tap water (Table 1), a relatively large number require intensive investigation to generate suitable data for health hazard evaluations. Data are required on the quantities of these agents required to produce tumors, genetic mutations, and birth defects. However, data are also needed

concerning the other equally serious chronic diseases whose etiology is chemically related.

The Water Supply Research Laboratory of the EPA is actively engaged in research aimed at the elucidation of chemically-induced chronic illnesses from the organics present in the Nation's water supplies. The purpose of these studies is to identify hazards and risks to man's health via his drinking water and to determine, if no hazard exists, the magnitude of the margin of safety from environmental exposures.

A dual approach is used in the investigation of the 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 will be most predictive of the responses in man. Comparative toxicity studies (both acute and

chronic) have been undertaken to determine the types of pathological lesions, the target organs, the reversibility of the lesions, the threshold doses, etc. Specialized studies are being carried out to examine the possible role of the halogen-substituted benzenes in the alteration of toxicity of other foreign organic compounds (e.g., synergism).

The investigation of the toxicity of mixtures of organics from drinking water is being pursued with the use of several bio-assay procedures. Organic extracts from the drinking water of 5 U.S. cities are being collected for analyses by these biological systems. With indications that these extracts demonstrate activity that is suggestive of carcinogenicity, mutagenicity, teratogenicity, or other serious toxicity, the extracts will be chemically fractionated to isolate the active principle(s). Ultimate fractionation should lead to the identification of the toxic agents. These compounds then will be subjected to more definitive toxicity tests, the data from which can be readily applied to a health/hazard evaluation to determine the impact on man.


Asbestos

Asbestos may occur in drinking water because the fibers may be in the source water or the fibers may erode from asbestos-cement pipe

that is used for water distribution. There is no direct evidence that exposures to asbestos fibers from these sources in drinking water present a health risk to man, but because asbestos has been documented to be a most dangerous occupational hazard, more research must be done to make sure that the water exposure really does not present a hazard. Because of the possibility of a hazard, it is prudent to reduce exposure to waterborne asbestos as much as practicable.

Most occupational exposures have been to airborne asbestos, and the development of cancer from past exposure to the several types of asbestos has been documented by epidemiological studies. There has also been several animal toxicological studies concerned with airborne dust exposure, but the effect of ingested asbestos has not been studied. Even with an airborne occupational exposure, there is considerable ingestion of the dust because of the clearance mechanism of the respiratory tract and swallowing dust that gets into the mouth. Excess gastrointestinal cancer has been noted in exposed workers and attributed to the ingestion of the dust.

Two studies have noted that there was not an excess of cancer in the population of Duluth, Minnesota, where the highest known concentrations of asbestos fibers have been noted in the drinking water. Because of a long latency period that occurs between exposure and development of the disease, the exposure may have not occurred



long enough to have caused an increase in mortality. The immediacy and extent of the risk are being considered by the Federal Courts.

EPA is attempting to study the passage of asbestos fibers through the gastrointestinal tract to evaluate this aspect of the ingestion exposure. EPA is also participating in a jointly funded Federal agency toxicological study of ingestion of four types of asbestos. This large study is expected to begin in June or July and will take four years. Field investigations are going on to find locations where populations have had long exposure to asbestos in the drinking water both from the source and from pipes. If areas can be found where adequate data exist on cancer morbidity and mortality, epidemiological studies will be conducted.

IV. CONTROL TECHNOLOGY

Inorganics (Excluding Asbestos)

Techniques for the control of concentration of various inorganics have been studied by EPA. Of the substances studied thus far, only arsenic, asbestiform fibers, and radium-226 have been considered as suspect carcinogens via the drinking water route. Treatment technology studies for these substances have been conducted. Arsenic was studied in bench- and pilot-scale investigations by spiking Ohio River water and ground water from Glendale, Ohio, with concentrations of arsenic from 2-10 times the proposed Interim Drinking Water Regulations limits. Information on the treatment potential of various unit processes for radium-226 removal was obtained by monitoring several water treatment plants in the State of Iowa that are treating water naturally high in radium-226.

The treatment studies on mercury, cadmium, selenium, and chromium were similar to those described above for arsenic. Barium removal was studied in bench-scale using a natural ground water high in barium. Future studies on the removal of barium using a pilot plant are planned.

The following table lists the optimum treatment techniques determined for each of these contaminants.

MOST EFFECTIVE METHOD FOR INORGANIC CONTAMINANT REMOVAL

<u>Contaminant</u>	<u>Most Effective Method(s)</u>
1a. ArsenicIII	Excess lime softening Oxidation prior to softening recommended
1b. ArsenicV	Excess lime softening Ferric sulfate coagulation pH 8
2. Asbestiform fibers	Mixed media filtration Diatomite filtration
3. Radium-226	Ion exchange
4. Barium	Excess lime softening pH 10.6 Ion exchange
5. Cadmium	Lime softening Excess lime softening Ferric sulfate coagulation pH 8
6a. Mercury, inorganic	Excess lime softening
6b. Mercury, organic	Granular activated carbon
7a. SeleniumIV	Ferric sulfate coagulation pH 7
7b. SeleniumVI	Reverse osmosis
8. Chromium	Studies just starting

Organics

To date, the major treatment technique investigated for the removal of general and specific organics has been granular activated carbon. About 10 years ago, partially exhausted granular activated carbon was shown to remove dieldrin, lindane, 2,4,5-T, DDT and parathion dosed into river water. About the same time, fresh granular activated carbon used to treat Kanawha River water was shown to remove bis-(2-chloroethyl) ether, 2-ethyl hexanol, bis-(2-chloroisopropyl) ether, α -methylbenzyl alcohol, acetophenone, isophorone, and tetralin. 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.

For about 7 months, a coal-base granular activated carbon column, 28 inches deep has been receiving Cincinnati tap water spiked with approximately 30 $\mu\text{g/l}$ of naphthalene. After this time period, the 50% removal point for naphthalene was only approximately 2 inches down the column. Two 28-inch deep columns of granular activated carbon, one coal-based and the other lignite-base, have been receiving Cincinnati tap water. The purpose of this test was to determine the effectiveness of the two types of granular activated carbon for the removal of trihalogenated methanes. Both columns removed all of the

trihalogenated methanes for about 1 month of operation, and then some chloroform began appearing in the effluent.

At the present time, the 400 ml/min stainless and glass pilot plant treating unchlorinated Ohio River water is being used in an attempt to demonstrate how to effectively remove trihalogenated methanes precursors from water so that chlorine can be used as a disinfectant without the formation of trihalogenated methanes. Ozone is also being evaluated as a possible alternative to chlorine for post-disinfection.

Future plans include pilot- and full-scale research designed to indicate the effectiveness of granular activated carbon and other organic removal unit processes for the removal of specific raw water contaminants of concern.

Asbestos

Pilot plant research conducted in 1974 at Duluth, Minnesota, demonstrated that asbestiform fiber counts in Lake Superior water could be effectively reduced by municipal filtration plants. During the study, engineering data were also obtained for making cost estimates for construction and operation of both granular and

diatomaceous earth (DE) media filtration plants ranging in size from 0.03 to 30 mgd.

Both dual and mixed-media granular filters using alum and nonionic polymer, employing flash mix and flocculation without settling, and DE filters with alum coated DE as precoat and/or body feed or with Cat-Floc B added to raw water, produced effluents with amphibole fiber counts below electron microscope detection limits. Turbidity was not a direct measure of fiber count, but amphibole counts were generally lowest at effluent turbidities's equal or less than 0.1 TU. Chrysotile removal was more difficult, but mixed media granular filtration with alum and nonionic polymer, and DE filtration with anionic polymer conditioned DE frequently reduced chrysotile fiber counts markedly.

Systems for economic reasons recommended for consideration during design studies are:

1. Mixed media direct filtration, 5 gpm/ft², multi-stage flash mix.
2. Dual media filtration, 4 gpm/ft², single stage flash mix.
3. Pressure DE filtration 1 gpm/ft², alum conditioning of precoats and body feed or alum conditioning of precoat only, with cationic polymer fed to raw water.

TABLE 1

ORGANIC COMPOUNDS IDENTIFIED IN DRINKING WATER
IN THE UNITED STATES
(MARCH 15, 1975)

Water Supply Research Laboratory
National Environmental Research Center, EPA
Cincinnati, Ohio 45268

1. acenaphthene
2. acenaphthylene
3. acetaldehyde
4. acetic acid
5. acetone
6. acetophenone
7. acetylene dichloride
8. aldrin
9. atrazine
10. (deethyl) atrazine
11. barbitol
12. behenic acid, methyl ester
13. benzaldehyde
14. benzene
15. benzene sulfonic acid
16. benzoic acid
17. benzopyrene
18. benzothiazole
19. benzothiophene
20. benzyl butyl phthalate
21. bladex
22. borneol
23. bromobenzene
24. bromochlorobenzene
25. bromodichloromethane
26. bromoform
27. bromoform butanal
28. bromophenyl phenyl ether
29. butyl benzene
30. butyl bromide
31. camphor
32. e-caprolactam
33. carbon dioxide
34. carbon disulfide
35. carbon tetrachloride
36. chlordan(e)
37. chlordene
38. chlorobenzene

39. 1,2-bis-chloroethoxy ethane
40. chloroethoxy ether
41. bis-2-chloroethyl ether
42. 2-chloroethyl methyl ether
43. chloroform
44. chlorohydroxybenzophenone
45. bis-chloroisopropyl ether
46. chloromethyl ether
47. chloromethyl ethyl ether
48. m-chloronitrobenzene
49. 1-chloropropene
50. 3-chloropyridine
51. o-cresol
52. crotonaldehyde
53. cyanogen chloride
54. cyclopentanone

55. DDE
56. DDT
57. decane
58. dibromobenzene
59. dibromochloromethane
60. dibromodichloroethane
61. di-t-butyl-p-benzoquinone
62. dibutyl phthalate
63. 1,3-dichlorobenzene
64. 1,4-dichlorobenzene
65. dichlorodifluoroethane
66. 1,2-dichloroethane
67. 1,1-dichloro-2-hexanone
68. 2,4-dichlorophenol
69. dichloropropane
70. 1,3-dichloropropene
71. dieldrin
72. di-(2-ethylhexyl) adipate
73. diethyl benzene
74. diethyl phthalate
75. di(2-ethyl hexyl) phthalate
76. dihexyl phthalate
77. dihydrocarvone
78. di-isobutyl carbinol
79. di-isobutyl phthalate
80. 1,2-dimethoxy benzene
81. 1,3-dimethylnaphthalene
82. 2,4-dimethyl phenol
83. dimethyl phthalate
84. dimethyl sulfoxide
85. 4,6-dinitro-2-aminophenol

86. 2,6-dinitrotoluene
87. dioctyl adipate
88. diphenylhydrazine
89. diethyl phthalate
90. eicosane
91. n-dodecane

92. eicosane
93. endrin
94. ethanol
95. ethylamine
96. ethyl benzene
97. 2-ethyl-n-hexane
98. cis-2-ethyl-4-methyl-1,3-dioxolane
99. trans-2-ethyl-4-methyl-1,3-dioxolane
100. o-ethyltoluene
101. m-ethyltoluene
102. p-ethyltoluene

103. geosmin

104. heptachlor
105. heptachlor epoxide
106. 1,2,3,4,5,7,7-heptachloronorbornene
107. hexachlorobenzene
108. hexachloro-1,3-butadiene
109. hexachlorocyclohexane
110. hexachloroethane
111. hexachlorophene
112. hexadecane
113. 2-hydroxyadiponitrile

114. indene
115. isoborneol
116. isodecane
117. isophorone
118. 1-isopropenyl-4-isopropylbenzene
119. isopropyl benzene

120. limonene

121. p-menth-1-en-8-ol
122. methane
123. methanol
124. 2-methoxy biphenyl
125. o-methoxyphenol
126. methyl benzoate
127. methyl benzothiazole

128. methyl biphenyl
129. 3-methyl butanal
130. methyl chloride
131. methylene chloride
132. methyl ethyl benzene
133. methyl ethyl ketone
134. 2-methyl-5-ethyl-pyridine
135. methylindene
136. methyl methacrylate
137. methyl naphthalene
138. methyl palmitate
139. methyl phenyl carbinol
140. 2-methylpropanal
141. methyl stearate
142. methyl tetracosanoate
143. naphthalene
144. nitroanisole
145. nitrobenzene
146. nonane
147. octadecane
148. octane
149. octyl chloride
150. pentachlorobiphenyl
151. pentachlorophenol
152. pentachlorophenyl methyl ether
153. pentadecane
154. pentane
155. pentanol
156. phenyl benzoate
157. phthalic anhydride
158. piperidene
159. propanol
160. propazine
161. propylamine
162. propylbenzene
163. simazine
164. 1,1,3,3-tetrachloroacetone
165. tetrachlorobiphenyl
166. 1,1,1,2-tetrachloroethane
167. tetrachloroethylene
168. tetradecane
169. tetramethyl benzene
170. thiomethylbenzothiazole

- 171. toluene
- 172. trichlorobenzene
- 173. trichlorobiphenyl
- 174. 1,1,2-trichloroethane
- 175. 1,1,2-trichloroethylene
- 176. trichlorofluoromethane
- 177. 2,4,6-trichlorophenol
- 178. n-tridecane
- 179. trimethyl benzene
- 180. 3,5,5-trimethyl-bicyclo (4,1,0) heptene-2-one
- 181. trimethyl-trioxo-hexahydro-triazine isomer
- 182. triphenyl phosphate

- 183. n-undecane

- 184. vinyl benzene

- 185. o-xylene
- 186. m-xylene
- 187. p-xylene

TABLE 2

ORGANIC CHEMICALS IDENTIFIED IN PRIMARY
WASTE TREATMENT EFFLUENTS

Ethylene Glycol	Quinic acid
Maltose	1-Methylxanthine
Galactose	2-Deoxytetronic acid
Glucose	Glyceric acid
Glycerine	4-Deoxytetronic acid
Galacitol	3-Deoxyerythropentonic acid
Erythritol	2,5-dideoxypentonic acid
Urea	3,4-Dideoxypentonic acid
N ¹ -Methyl-4-pyridone-3-carboxamide	Ribonic acid
Phenylalanine	Oxalic acid
Uracil	2-Hydroxyisobutyric acid
5-Acetylamino-6-amino-3-methyl uracil	Uric acid
N ¹ -Methyl-2-pyridone-5-carboxamide	Orotic acid
Tyrosine	Succinic acid
Thymine	Phenol
Theobromine	3-Hydroxyphenylhydracrylic acid
7-Methylxanthine	Phenylacetic acid
Inosine	4-Hydroxyphenylacetic acid
Hypoxanthine	Benzoic acid
Xanthine	2-Hydroxybenzoic acid
Copper (II) acetate (binuclear)	4-Hydroxybenzoic acid
Adenosine	3-Hydroxybenzoic acid
1,7-Dimethylxanthine	3-Hydroxyphenylpropionic acid
3-Methylxanthine	Indican
Caffeine	3-Hydroxyindole
Guanosine	<u>o</u> -Phthalic acid
2-Deoxyglyceric acid	<u>p</u> -Cresol
3-Hydroxybutyric acid	
3-Deoxyarabinohexonic acid	

TABLE 3

ORGANIC COMPOUNDS IDENTIFIED IN SECONDARY
WASTE TREATMENT EFFLUENTS

Glycerine

Uracil

5-Acetylamino-6-amino-3-methyl uracil

1-Methylinosine

Inosine

7-Methylxanthine

1-Methylxanthine

1,7-Dimethylxanthine

Succinic acid

Catechol

Indole-3-acetic acid

3-Hydroxyindole

p-Cresol

TABLE 4

ORGANIC SUBSTANCES FOUND IN THE ACID FRACTION
OF DOMESTIC SEWAGE TREATMENT EFFLUENTS

Butyric acid
Isobutyric acid
Isovaleric acid
Enanthic acid (C₇)
Caprylic acid (C₈)
Capric acid (C₉)
Lauric acid (C₁₂)
Myristic acid (C₁₄)
Pentadecanoic acid (C₁₅)
Palmitic acid (C₁₆)
Margaric acid (C₁₇)
Stearic acid (C₁₈)
Nonadecanoic acid (C₁₉)
Arachidic acid (C₂₀)
Behenic acid (C₂₂)
Palmitoleic acid
Oleic acid
Anteisopentadecanoic acid
Anteisomargaric acid
Hydroxymyristic acid
Hydroxypalmitic acid
hydroxystearic acid
Phenylacetic acid
Salicylic acid
Phenylpropionic acid
2-(4-chlorophenoxy)-2-methyl propionic acid
Pentachlorophenol

TABLE 5

COMPOUNDS IDENTIFIED IN CHLORINATED
PRIMARY AND SECONDARY EFFLUENTS

5-Chlorouracil
5-Chlorouridine
8-Chlorocaffeine
6-Chloro-2-aminopurine
8-Chloroxanthine
2-Chlorobenzoic acid
5-Chlorosalicylic acid
4-Chloromandelic acid
2-Chlorophenol
4-Chlorophenylacetic acid
4-Chlorobenzoic acid
4-Chlorophenol
3-Chlorobenzoic acid and/or
3-Chlorophenol
4-Chlororesorcinol
3-Chloro-4-hydroxy-benzoic acid
4-Chloro-3-methylphenol

TABLE 6

COMPOUNDS IDENTIFIED IN SUPER CHLORINATED
MUNICIPAL WASTEWATERS

Trichlorotoluene

Hexachloroethane

1,1,1,3,3-Pentachloro-2-propanone

2,4-Dichloroethylbenzene

o-and p-chloroethyl benzene

2,4,5-Trichloropitenetole (3 isomers)

1,2-Dichloropropane

o- and p-dichlorobenzene

Chloromethyl butene (2 isomers)

TABLE 7

ORGANIC CHEMICALS FOUND IN INDUSTRIAL WASTES

Compound	Sample source
6,8,11,13-Abietatetraen-18-oic acid	Paper mill's raw waste and trickling filter effluent
13-Abieten-18-oic acid	Paper mill's raw waste and trickling filter effluent
Abietic acid	Paper mill's raw waste and lagoon
Acenaphthalene	Petrochemical plant's five-day lagoon effluent
Acenaphthene	Petrochemical plant's five-day lagoon effluent
"	Wood preserving plant's lagoon effluent
"	Wood preserving plant's settling pond
"	Pesticide plant's raw effluent
Acetophenone	Chlorinated paraffin plant's lagoon
"	Petrochemical plant's five-day lagoon effluent

Table 7 continued

Acetosyringone	Gulf coast paper mill's settling pond
Acetovanillone	Gulf coast paper mill's settling pond
"	Paper mill's raw waste and lagoon
2-Acetylthiophene	Paper mill's raw waste
Acrylonitrile	Acrylic fiber plant's settling pond
Adipic acid	Nylon plant's raw waste
Adiponitrile	Nylon plant's raw waste
Aldrin	Pesticide plant's raw effluent
m-Anethole	Paper mill's raw waste
o-Anethole	Paper mill's raw waste
p-Anethole	Paper mill's raw waste
Anthraquinone	Wood preserving plant's settling pond
Anteisomargaric acid	Paper mill's raw waste and five day lagoon

Table 7 continued

Anteiso-pentadecanoic acid	Paper mill's five-day lagoon
Arachidic acid	Paper mill's raw waste
Arachidonic acid	Paper mill's five-day lagoon
Behenic acid	Paper mill's raw effluent and five-day lagoon
Benzaldehyde	Paper mill's raw waste
Benzyl alcohol	Petrochemical plant's five-day lagoon effluent
2-Benzothiazole	Latex accelerators and thickeners plant's holding pond
"	Synthetic rubber plant's aerated lagoon
Biphenyl	River below textile finishing plant
Borneol	Paper mill's raw waste and trickling filter effluent
1-Butanol	Petrochemical (alcohols) plant's raw effluent
2-Butoxyethanol	Petrochemical plant's five-day lagoon effluent
n-Butylisothiocyanate	Latex accelerators and thickeners plant's holding pond

Table 7 continued

Camphor	Paper mill's raw waste and trickling filter effluent
"	Gulf coast paper mill's settling pond
Caproic acid	Nylon plant's raw waste
Carbazole	Wood preserving plant's settling pond
Chlordane	Pesticide plant's raw effluent
Chlordene	Pesticide plant's raw waste
o-Chlorobenzoic acid	Chlorinated paraffin plant's lagoon
bis-(2-Chloroethoxy) methane	Synthetic rubber plant's treated waste
bis-2-Chloroethyl ether	Synthetic rubber plant's treated waste
bis-2-Chloroisopropyl ether	Glycol plant's thickening and sedimentation pond
trans-Communic acid	Paper mill's raw waste and trickling filter effluent
o-Cresol	Wood preserving plant's settling pond

Table 7 continued

Dehydroabiatic acid	Gulf coast paper mill's settling pond
"	Tall oil refinery's settling pond
Diacetone alcohol	Petrochemical plant's five-day lagoon effluent
4,4'-Diamino-dicyclohexyl methane	Nylon and polyester plant's effluent after neutralization and sedimentation
Dibenzofuran	Wood preserving plant's settling pond
"	Wood preserving plant's lagoon effluent
"	Nylon plant's settling pond
2,3-Dibromo-1-propanol	Acrylic fibers plant's settling pond
Dibromopropene isomer	Acrylic fibers plant's settling pond
Dibutylamine	Latex accelerators and thickeners plant's raw effluent
Dieldrin	Anaerobic lagoon of yarn finishing mill

Table 7 continued

o-Cresol	Petrorefinery's eight-hour lagoon effluent
m-Cresol	Wood preserving plant's settling pond
p-Cresol	Paper mill's raw waste and lagoon
Cumene (isopropylbenzene)	Petrochemical plant's five-day lagoon effluent
Cyclohexanol	Nylon plant's raw waste
1,5-Cyclooctadiene	Petrochemical plant's five-day lagoon effluent
p-Cymene	Paper mill's raw waste and trickling filter effluent
"	Pesticide plant's raw waste
Decane	Polyolefin plant's lagoon
1-Decanol	Petrochemical (alcohols) plant's raw effluent
Dehydroabietic acid	Wood preserving plant's settling pond
"	Paper mill's raw waste and trickling filter effluent

Table 7 continued

Dieldrin	Pesticide plant's raw effluent
N,N-Diethylformamide	Latex accelerators and thickeners plant's raw effluent
Diethyl phthalate	Synthetic rubber plant's settling pond
3,4-Dihydroxyacetophenone (pungenin)	Paper mill's trickling filter effluent
3,5-Dimethoxy-4-hydroxy- acetophenone	Paper mill's raw effluent and five-day lagoon
2,4-Dimethyldiphenylsulfone	Nylon plant's settling pond
"	Acrylic fibers plant's settling pond
Dimethyl furan isomer	Petrochemical plant's five-day lagoon effluent
2,6-Dimethyl naphthalene	Petrochemical plant's five-day lagoon effluent
Dimethyl naphthalene isomer	Pesticide plant's raw effluent
Dimethyl phthalate	Plastic (PVA) plant's settling pond
"	Synthetic rubber plant's settling pond

Table 7 continued

Dimethyl pyridine isomer	Wood preserving plant's settling pond
Dimethyl quinoline isomers	Wood preserving plant's settling pond
Dimethyl sulfone	Paper mill's raw waste and trickling filter effluent
Dimethyl sulfoxide	Paper mill's raw waste and trickling filter effluent
10,12-Dimethyl tridecanoic acid	Paper mill's five-day lagoon
4,6-Dinitro-o-cresol (2-methyl-4,6-dinitro-phenol)	Specialty chemical plant's effluent
2,4-Dinitrotoluene	Explosives (DNT) plant's raw waste and settling pond effluent
2,6-Dinitrotoluene	Explosives (DNT) plant's raw waste and settling pond effluent
"	TNT plant's raw effluent
3,4-Dinitrotoluene	Explosives (DNT) plant's raw waste and settling pond effluent
Diphenylene sulfide	Wood preserving plant's settling pond

Table 7 continued

Diphenyl ether	Pesticide plant's raw effluent
3,3-Diphenylpropanol	Petrochemical plant's five-day lagoon effluent
2,6-Di-t-butyl-p-benzoquinone	Surface drainage from closed waste treatment system of particle board plant
p-Dithiane	Synthetic rubber plant's treated waste
Dodecane	Petrorefinery's lagoon effluent after activated sludge treatment
"	Petrorefinery's eight-hour lagoon effluent
"	Paper mill's raw effluent
Eicosane (C ₂₀)	Petrorefinery's lagoon effluent after activated sludge treatment
Endrin	Pesticide plant's raw effluent
Ethyl carbamate	Paper mill's trickling filter and aerated lagoon
2-Ethyl-1-hexanol	Gulf coast paper mill's settling pond

Table 7 continued

2-Ethyl-1-hexanol	Laboratory sewage
"	Plastic (PVA) plant's settling pond
"	River below textile finishing plant
Ethylidenecyclopentane	Paper mill's raw waste
Ethyl isothiocyanate	Latex accelerators & thickeners plant's raw effluent
Ethyl naphthalene isomer	Petrochemical plant's five-day lagoon effluent
Ethyl naphthalene isomer	Pesticide plant's raw effluent
m-Ethyl phenol	Paper mill's raw waste and lagoon
Ethyl phenylacetate	Resin plant's lime treated holding pond effluent
o-Ethyl toluene	Petrochemical plant's five-day lagoon effluent
Eugenol	Paper mill's raw waste and lagoon
Fenchyl alcohol	Paper mill's raw waste and trickling filter effluent
Fenchone	Paper mill's raw waste and trickling filter effluent
Fluoranthene	Wood preserving plant's settling pond

Table 7 continued

Tetradecane	Petrorefinery's lagoon effluent after activated sludge treatment	(
"	Petrorefinery's eight-hour lagoon effluent	
Tetramethylbenzene isomer	Pesticide plant's raw waste	
2,2'-Thiodiethanol (Thiodiglycol)	Synthetic rubber plant's treated waste	
Toluic acid	Chlorinated paraffin plant's lagoon	
Trichlorobenzene isomer	River below textile finishing plant	
Trichlorobenzene isomer	Textile chemical plant's raw effluent	
Trichlorocyclopentene isomers	Pesticide plant's raw effluent	
1,1,2-Trichloroethane	Chlorinated solvents plant's raw effluent	
Trichloroguaiacol	Paper mill's raw waste	
n-Tridecane	Petrorefinery's eight-hour lagoon effluent	
"	Petrorefinery's lagoon effluent after activated sludge treatment.	

Table 7 continued

n-Tridecane	Paper mill's raw waste
Triethylurea	Latex accelerators & thickeners plant's raw effluent
3,4,5-Trimethoxyaceto- phenone	Paper mill's raw waste and trick- ling filter effluent
2,4,6-Trimethylpyridine	Wood preserving plant's settling pond
2,4,6-Trinitrotoluene	TNT plant's raw effluent
n-Undecane	Paper mill's raw waste
"	Petrorefinery's eight-hour lagoon effluent
"	Polyolefin plant's lagoon
"	Petrorefinery's lagoon effluent after activated sludge treat- ment
Valeric acid	Nylon plant's raw waste
Vanillin	Paper mill's raw waste and trick- ling filter effluent
"	Gulf coast paper mill's settling pond
Veratraldehyde	Paper mill's raw waste & lagoon

Table 7 continued

4-n-Propylphenol	River below textile finishing plant
Pimaric acid	Paper mill's raw waste and trickling filter effluent
"	Gulf coast paper mill's settling pond
beta-Pinene	Paper mill's raw waste
Pinene isomer	Gulf coast paper mill's settling pond
Polychlorinated biphenyls (Arochlor 1254)	Nylon plant's raw waste
2-Propionylthiophene	Paper mill's raw waste
4-n-Propylphenol	Paper mill's raw waste and lagoon
Pyrene	Wood preserving plant's settling pond
Quinoline	Wood preserving plant's settling pond
Sandaracopimeric acid	Paper mill's raw waste and lagoon
Stearic acid	Textile chemical plant's raw effluent

Table 7 continued

Stearic acid	Gulf coast paper mill's settling pond
Styrene	Petrochemical plant's five-day lagoon effluent
"	Synthetic rubber plant's settling pond
Syringaldehyde	Gulf coast paper mill's settling pond
"	Paper mill's lagoon
Terpinene-4-ol	Paper mill's raw waste
alpha-Terpineol	Nylon plant's settling pond
"	Paper mill's raw waste and trickling filter effluent
"	Petrochemical plant's five-day lagoon effluent
Terpineol isomer	Gulf coast paper mill's settling pond
Terpinolene	Paper mill's raw waste
1,1,2,2-Tetrachloroethane	Chlorinated solvents plant's raw effluent
Tetrachlorophenol isomer	Wood preserving plant's raw effluent

Table 7 continued

Palmitoleic acid	Paper mill's five-day lagoon
Pentachlorocyclopentadiene isomers	Pesticide plant's raw effluent
Pentachloronorbornadiene isomer	Pesticide plant's raw effluent
Pentachloronorbornene isomer	Pesticide plant's raw effluent
Pentachloronorbornene isomer	Pesticide plant's raw waste
Pentachloronorbornadiene epoxide isomer	Pesticide plant's raw waste
Pentachlorophenol	Latex accelerators and thickeners plant's holding pond
"	Wood preserving plant's raw effluent
"	Resin plant's lime treated holding pond effluent
"	Synthetic rubber plant's aerated lagoon
"	Wood preserving plant's lagoon effluent
Pentadecane	Petrorefinery's eight-hour lagoon effluent

Table 7 continued

Pentadecane	Petrorefinery's lagoon effluent after activated sludge treat- ment
"	Paper mill's raw waste
"	Petrochemical plant's five-day lagoon effluent
Pentadecanoic acid	Paper mill's lagoon
Phenanthrene	Wood preserving plant's lagoon effluent
"	Wood preserving plant's settling pond
Phenol	Laboratory sewage
"	Petrorefinery's eight-hour lagoon effluent
"	Wood preserving plant's settling pond
"	Petrochemical plant's five-day lagoon effluent
"	Paper mill's raw waste
Phenyl ether	Nylon plant's settling pond

Table 7 continued

2-Nitro-p-cresol	Chemical company's lagoon after steam stripping
o-Nitrophenol	Chemical company's lagoon after steam stripping
o-Nitrotoluene	Paper mill's five-day lagoon
"	TNT plant's raw effluent
"	DNT plant's raw effluent
m-Nitrotoluene	DNT plant's raw effluent
p-Nitrotoluene	Chemical company's lagoon after steam stripping
"	DNT plant's raw effluent
Nonachlor	Pesticide plant's raw effluent
Nonadecane	Petrorefinery's lagoon effluent after activated sludge treatment
"	Petrorefinery's eight-hour lagoon effluent
Nonylphenol	Anaerobic lagoon of yarn finishing mill

Table 7 continued

Nonylphenol	River below textile finishing plant
Norcamphor	Paper mill's raw waste
beta-Ocimene	Paper mill's raw waste
1-Octanol	Petrochemical (alcohols) plant's raw effluent
Octachlorocyclopentene	Pesticide plant's raw effluent
Octadecane	Petrorrefinery's eight-hour lagoon effluent
"	Nylon plant's settling pond
Oleic acid	Tall oil refinery's settling pond
"	Paper mill's raw waste and trickling filter effluent
Octylphenol	River below textile finishing plant
Palmitic acid	Textile chemical plant's raw effluent
"	Tall oil refinery's settling pond
"	Paper mill's raw waste and trickling filter effluent
"	Gulf coast paper mill's settling pond

Table 7 continued

1-Methyl indene	Petrochemical plant's five-day lagoon effluent
3-Methyl indene	Petrochemical plant's five-day lagoon effluent
1-Methyl naphthalene	River below textile finishing plant
"	Petrorefinery's eight-hour lagoon effluent
"	Petrochemical plant's five-day lagoon effluent
"	Synthetic rubber plant's settling pond
2-Methyl naphthalene	Petrorefinery's eight-hour lagoon effluent
"	Petrochemical plant's five-day lagoon effluent
Methyl naphthalene isomer	Wood preserving plant's lagoon effluent
Methyl naphthalene isomers	Pesticide plant's raw effluent
13-Methyl pentadecanoic acid	Paper mill's five-day lagoon
Methyl phenanthrene	Wood preserving plant's lagoon effluent

Table 7 continued

Methyl quinoline isomers	Wood preserving plant's settl pond
o-Methylstyrene	Petrochemical plant's five-da effluent
beta-Methylstyrene	Petrochemical plant's five-da lagoon effluent
Methyl trisulfide	Paper mill's raw waste
Myristic acid	Paper mill's raw waste
Naphthalene	Nylon plant's settling pond
"	Surface drainage from closed treatment of system of particle board plant
"	Petrochemical plant's five-da lagoon effluent
"	Pesticide plant's raw waste
2-Naphthoic acid	Wood preserving plant's settl pond
Neoabietic acid	Paper mill's raw waste
Nitrobenzene	Chemical company's lagoon aft steam stripping

Table 7 continued

Homovanillic acid	Paper mill's raw waste and five-day lagoon
p-Hydroxyacetophenone	Paper mill's raw waste and lagoon
p-Hydroxybenzaldehyde	Paper mill's raw waste and lagoon
o-Hydroxybenzoic acid	Paper mill's raw waste
Hydroxybiphenyl isomer	Pesticide plant's raw effluent
4-Hydroxy-3 methoxypropio-phenone	Paper mill's raw effluent
p-Hydroxythiophenol	Paper mill's raw waste
Indan	Petrochemical plant's five-day lagoon effluent
Indene	Petrochemical plant's five-day lagoon effluent
Isodrin	Pesticide plant's raw effluent
Isoeugenol	Paper mill's raw waste and lagoon
Isopalmitic acid	Paper mill's five-day lagoon
Isopentyl alcohol	Laboratory sewage
Isooctyl phthalate	Nylon plant's raw waste
Isopimaric acid	Paper mill's raw waste and trickling filter effluent

Table 7 continued

Jasmone	Pesticide plant's raw effluent
Lignoceric acid	Paper mill's raw waste
Limonene	Paper mill's raw waste and trickling filter effluent
Linoleic acid	Paper mill's raw waste and lagoon
Mandelic acid	Paper mill's raw waste
Margaric acid	Paper mill's raw waste
2-Mercaptobenzothiazole	Synthetic rubber plant's aerated lagoon
"	Paper mill's raw waste and lagoon
alpha-Methylbenzyl alcohol	Petrochemical plant's five-day lagoon effluent
Methyl biphenyl isomer	Petrochemical plant's five-day lagoon effluent
Methyl 3,4-Dimethoxybenzyl ether	Paper mill's raw waste
2-Methyl-4-ethyl dioxolane	Fiberglass plant's effluent
Methyl ethyl naphthalene isomer	Petrochemical plant's five-day lagoon effluent

Table 7continued

Fluorene	Wood preserving plant's settling pond
"	Petrochemical plant's five-day lagoon effluent
2-Formylthiophene	Paper mill's raw waste
Furfural	Paper mill's raw waste
"	Synthetic rubber plant's settling pond
Guaiacol	Gulf coast paper mill's settling pond
"	Paper mill's raw waste and trickling filter effluent
Heneicosane (C ₂₁)	Petrorefinery's lagoon effluent after activated sludge treatment
Heptachlor	Pesticide plant's raw waste
Heptachloronorbornene isomers	Pesticide plant's raw effluent
Heptadecane	Nylon plant's settling pond
"	Petrorefinery's eight-hour lagoon effluent

Table 7 continued

Heptadecane	Petrorefinery's lagoon effluent after activated sludge treat- ment
Hexachlor epoxide	Pesticide plant's raw waste
Hexachlorobenzene	Chlorinated solvents plant's raw effluent
Hexachlorobutadiene	Pesticide plant's raw effluent
Hexachlorocyclopentadiene	Pesticide plant's raw waste
Hexachloronorbornadiene isomers	Pesticide plant's raw effluent
Hexadecane	Nylon plant's settling pond
"	Petrorefinery's eight-hour lagoon effluent
"	Petrorefinery's lagoon effluent after activated sludge treat- ment
"	Paper mill's raw waste
"	Petrochemical plant's five-day lagoon effluent
Hexadieneal	Pesticide plant's raw effluent
1-Hexanol	Petrochemical (alcohols) plant's raw effluent

Table 7, continued

o-Xylene	Synthetic resin plant's settling pond
"	Petrochemical plant's five-day lagoon effluent
m-Xylene	Petrochemical plant's five-day lagoon effluent
p-Xylene	Petrochemical plant's five-day lagoon effluent
2,5-Xylenol	Wood preserving plant's settling pond
3,4-Xylenol	Wood preserving plant's settling pond
3,5-Xylenol	Wood preserving plant's settling pond

TABLE 8

Organic Compounds in Textile Effluents

Compound

1,2,4-trichlorobenzene
benzoic acid (methyl ester)
p-nonylphenol
p-tert.-butylphenol
di-n-butyl phthalate
methyl isobutyl ketone
acetophenone
chlorobenzene
p-dichlorobenzene
toluene
ethylbenzene
naphthalene
1-methylnaphthalene
dodecane
2-methylpyrrolidone
1,3,5-trimethylbenzene
cymene
tridecane
tetradecane
chloroform
tetrachloroethylene
styrene
o-phenylphenol
biphenyl
diphenyl oxide
ethylene dichloride
benzophenone
n-butanol