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REPORT TO THE CONGRESS

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

Unnecessary And Harmful Levels Of Domestic Sewage Chlorination Should Be Stopped

Environmental Protection Agency

Chlorine is frequently used to disinfect domestic sewage, and it is also used in industry and is discharged in various industrial wastes. Chlorinated discharges have been shown to be harmful to the aquatic environment, but they are still largely uncontrolled. In many situations the use of chlorine is not needed. Except in areas of shellfish-harvesting or of unrestricted irrigation, disinfection of treated wastes usually is not needed to protect

--swimmable waters in cold weather months,

--waters rarely used for swimming, or

--drinking water.

When sewage disinfection is needed, present sewage chlorination practices generally result in excessive amounts of chlorine being discharged into waterways. More should be done to limit residuals and to promote the efficient use of chlorine in sewage disinfection.

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AUGUST 30, 1977

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-166506

To the President of the Senate and the
Speaker of the House of Representatives

This report discusses the use of chlorine to disinfect domestic sewage at municipal waste treatment plants constructed under grants awarded by the Environmental Protection Agency.

Chlorine is frequently used to disinfect domestic sewage. It is also used in industry and is discharged in various industrial wastes. Chlorinated discharges have been shown to be harmful to the aquatic environment, but such discharges are still largely uncontrolled. We made this review to determine whether unnecessary chlorination has been stopped and whether, when disinfection is needed, municipalities and industries have prevented harmful levels of chlorine from being discharged into waterways.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53) and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Director, Office of Management and Budget; the Chairman, Council on Environmental Quality; and the Administrator, Environmental Protection Agency.

Comptroller General
of the United States

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

UNNECESSARY AND HARMFUL LEVELS OF DOMESTIC SEWAGE CHLORINATION SHOULD BE STOPPED
Environmental Protection Agency

D I G E S T

Chlorine discharges by municipal sewage treatment plants in the United States sometimes exceed levels safe for the aquatic environment. Fish kills and water-life deterioration have resulted. Chlorine discharges, even at low-levels--roughly equivalent to a quart of laundry bleach in 2 million gallons of water--have been shown to harm fish and other water life. (See pp. 3 through 5.)

Municipal sewage treatment plant operators disinfect wastewater because it has been generally thought to protect the public health from diseases transmitted through water. GAO found that the practice is widespread. With the possible exception of chlorine needed to protect areas of shellfish harvesting or of unrestricted irrigation with sewage, the public health benefits from chlorinating sewage are minimal.

The widespread practice of sewage chlorination is questionable for a number of reasons:

--The relatively few incidents of disease transmitted through water in the United States generally are not serious and are almost always transmitted through inadequately treated drinking water.

--Sewage disinfection is not practiced extensively in other industrialized countries with public health experiences similar to those in the United States.

--Widespread sewage disinfection is a relatively recent phenomenon in the United States, with little accompanying improvement in public health. The Center for Disease Control has taken the official position that disinfection of sewage provides little public health benefit.

--Epidemiological studies attempting to relate bacterial levels in swimming waters with levels of illness have been inconclusive.

In particular, disinfection of treated wastes is usually not needed to protect waters that are ultimately used for drinking because these waters are purified in water treatment plants. Nor is disinfection usually required to protect waters rarely used for swimming; nor is it needed to protect swimmable waters in cold weather. Disinfection should not be required unless it can be reasonably demonstrated that the public will benefit. In addition, the Environmental Protection Agency's rationale for disinfecting swimmable waters has no strong scientific basis. The States feel that the Agency has not supplied sufficient guidance to them as to when disinfection is not required. According to the Agency, the decision to chlorinate should be predicated on whether or not chlorination will protect the public health. Any decision to limit chlorination of wastewaters should be made on a case-by-case basis with consideration being given to drinking water source protection, recreational water use, shellfish growing, and other public health aspects. (See pp. 7 through 13.)

Although the Agency could do more to prevent the unnecessary use of chlorine, it has taken steps to reduce the uncontrolled and excessive use of chlorine for wastewater disinfection. Since July 26, 1976, Agency regulations no longer require that all discharges from publicly owned treatment works provide a minimum level of disinfection. Because of the change, States now do not have to disinfect waste treatment plants' effluent unless it is needed to meet the States' water quality standards.

The change, which allows States to determine the conditions under which they will use chlorine for disinfection, will not fully solve the problem. Officials of 25 of the States GAO contacted (50 percent) stated that they do not plan to reduce their chlorination requirements. Many cold weather States, including Alaska, Michigan, and Minnesota, require continuous year-round sewage

chlorination, with no reductions permitted during cold weather months. In addition, the Agency's water quality bacterial criteria for swimmable waters may be interpreted by the States to mean that year-round use of chlorine is required. Since the criteria are not sufficiently flexible to allow for less disinfection because of seasonal variations or a lack of use of the waters by swimmers, the States may still disinfect regardless of how low the exposure risk to people might be. (See pp. 18 through 20.)

Many sewage treatment plants use too much chlorine and have high chlorine residuals because of inefficient chlorination systems. Even in designing new plants, State and Federal emphasis on improving chlorination efficiency has been inadequate. Chlorine production is energy intensive and a substantial reduction in its use would save a significant amount of energy. (See pp. 28 through 35.)

RECOMMENDATIONS TO THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY

The Administrator, Environmental Protection Agency, should:

--Revise the Agency's water quality criteria regarding the bacteria standard for swimmable waters to recognize seasonal variations and he should specifically delineate those circumstances in which sewage chlorination is or is not needed to protect public health.

--Include chlorine residual limitations in all National Pollutant Discharge Elimination System permits, when disinfection is judged necessary for the protection of the public health, for sewage treatment plants and for all industrial dischargers of chlorinated effluents.

--Lower the limitation on chlorine residuals in powerplant effluents.

--Require regional offices or the States, where appropriate, to tailor permits to

assure the use of chlorine testing and operating equipment which would significantly improve chlorination efficiency at individual treatment plants.

--Incorporate key factors of efficient chlorination, such as rapid, thorough initial mixing and flow-proportional dosage adjustment, into construction review criteria for all new plant construction. (See pp. 20, 35, and 36.)

RECOMMENDATION TO THE CONGRESS

To reduce unnecessary chlorination of sewage, the Congress should amend the Federal Water Pollution Control Act Amendments of 1972 to permit exceptions from the national goal of swimmable waters to recognize those situations in which waters are determined to be unswimmable because of other factors, such as heavy barge traffic, cold seasons of year, and general appearance. (See p. 20.)

AGENCY COMMENTS NOT FURNISHED

GAO requested written Agency comments in a letter dated January 11, 1977. Although several meetings were subsequently held with Agency officials to discuss GAO's findings and recommendations, the Agency has not submitted written comments. To avoid further delay, GAO is issuing the report without an official Agency expression of position.

Contents

ABBREVIATIONS

EPA	Environmental Protection Agency
GAO	General Accounting Office
NPDES	National Pollutant Discharge Elimination System
ppb	parts per billion
ml	milliliter

Glossary

Anaerobic	Refers to life or processes that occur in the absence of oxygen.
Baffle	Any deflective device used to change the direction of flow or the velocity of sewage.
Carcinogen	A cancer-producing substance.
Chlorine contact chamber	A chamber in a waste treatment plant in which effluent is disinfected by chlorine before it is discharged to receiving waters.
Coliform organisms	A group of bacteria recognized as an indication of possible fecal pollution.
Dechlorination	The partial or complete reduction of residual chlorine in water by any chemical or physical treatment.
Dissolved oxygen	The oxygen dissolved in water. Dissolved oxygen is necessary for the life of fish and other aquatic organisms and for the prevention of offensive odors.
Effluent	The wastewater discharged by an industry or municipality.
Effluent limitations	Restrictions established by a State or EPA on quantities, rates, and concentrations of chemical, physical, biological, and other constituents discharged from point sources.
Epidemiology	The study of diseases as they affect populations.
Fecal coliform	A group of organisms common to the intestinal tracts of man and animals. The presence of fecal coliform bacteria in water is an indicator of possible fecal pollution.
Nonpoint sources	Sources of pollution that are difficult to pinpoint and measure. Common examples include runoff from agriculture and forest lands, runoff from mining and construction activities, and storm runoff from urban areas.

Nutrients	Elements or compounds essential as raw materials for organism growth and development; e.g., carbon, oxygen, nitrogen, and phosphorus.
Pathogenic	Causing or capable of causing disease.
Primary waste treatment	Treatment using filtering and sedimentation techniques to remove about 30 percent of oxygen-demanding wastes. Substantially all floating or settleable solids are removed.
Secondary waste treatment	Treatment using biological processes to accelerate the decomposition of sewage and thereby reduce oxygen-demanding wastes by 80 to 90 percent.
Suspended solids	Small particles of solid pollutants which are present in sewage and which resist separation from the water by conventional means.
Water quality criteria	Specific concentrations of water pollutants which, if not exceeded, are expected to allow a body of water to be suitable for its designated use.
Water quality standards	Water quality standards contain four elements: the designated use (such as recreation, drinking water, fish and wildlife propagation) to be made for a body of water; criteria to protect those uses; implementation plans (for needed water quality improvement programs); and a plan of enforcement.

CHAPTER 1

INTRODUCTION

CHLORINATED SEWAGE AND OTHER CHLORINATED DISCHARGES

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, clearly establishes the responsibility of the Environmental Protection Agency (EPA) for reducing and controlling the pollution of navigable waters. The act establishes an interim national goal that, wherever attainable, water quality should provide for the protection of fish, shellfish, and wildlife and for recreation in and on the water by July 1, 1983. It also establishes as national policy that the discharge of toxic pollutants be limited or prohibited and requires that effluent standards be established for toxic pollutants.

In carrying out its responsibilities, EPA in 1973 included a bacterial limitation in its definition of secondary treatment of sewage. EPA had set a limit on bacterial discharge because it believed that discharges below the limitation would minimize the spread of disease. The attainment of this limitation, however, virtually required the use of chlorine in most sewage treatment facilities. In July 1976 EPA removed the limitation because of the toxic effect of chlorinated discharges on aquatic life, its concern about the public health effects of chlorinated organics, the cost of chlorine, and the energy needed to produce it.

Chlorination of sewage is aimed primarily at preventing the transmission of waterborne diseases through destruction of the disease-causing bacteria and viruses. The need for sewage chlorination is not universally agreed upon by public health officials. Unnecessary chlorination wastes energy and is also expensive. We estimate that the cost of the 200,000 tons of chlorine used for sewage disinfection in 1976 was $40 million.

Chlorine is also found in industrial discharges. It has achieved major importance as an antifoulant in electric powerplants. Powerplants are estimated to add about 100,000 tons of chlorine chemicals to cooling water each year to control slime films. Such chlorinated waters are generally discharged intermittently. A variety of food processing industries also use chlorination for equipment cleanup (slime control), product wash, and can cooling. Breweries, pulp and paper mills, and plants producing chlorine may also discharge chlorinated effluents, as do industries using chlorine for cyanide removal (for example, electroplating plants).

SCOPE OF REVIEW

Although chlorinated discharges have been found to be extremely toxic to fish and other water life, they occur widely throughout the country in disinfected sewage and other effluents. In view of the reported concern over chlorinated discharges, we reviewed the adverse effects of chlorination and EPA's efforts to reduce the discharge of chlorinated wastes.

We made our review at EPA headquarters, Washington, D.C.; EPA regional offices in Seattle, Washington; Philadelphia, Pennsylvania; and Boston, Massachusetts; and at State agencies responsible for water quality in Washington, Oregon, Maryland, Pennsylvania, and California. We also examined construction review guidelines from all EPA regions. We sent questionnaires to the State agencies responsible for water quality in all 50 States. In addition, we sent questionnaires to about 400 sewage treatment plants randomly selected from lists provided by five geographically diverse EPA regions--Philadelphia; Atlanta, Georgia; Chicago, Illinois; Denver, Colorado; and Seattle. The response rate was approximately 85 percent. We interviewed officials at the Center for Disease Control, U.S. Public Health Service, and various EPA laboratories as well as academic and professional experts on sewage chlorination. We also obtained information on the sewage disinfection practices of seven foreign countries. During the review, we were assisted by Dr. Murray Grant, GAO Medical Consultant; Dr. Frank D. Schaumburg, Head, Civil Engineering Department, Oregon State University; and Dr. Donald T. Lauria, Associate Professor of Water Resources Engineering at the University of North Carolina.

AGENCY COMMENTS NOT FURNISHED

On January 11, 1977, we forwarded a draft of this report to EPA and requested the Agency's written comments within 30 days. Although we subsequently met several times with Agency officials to discuss our findings and recommendations, the Agency has not submitted written comments. To avoid further delay, we are issuing the report without an official Agency expression of position.

CHAPTER 2

THE HARMFUL EFFECTS OF CHLORINATED DISCHARGES

Chlorinated discharges are extremely harmful to creatures which live in the water. Major fish kills and significant water-life deterioration have resulted from chlorinated discharges. Such discharges, even at extremely low levels, have been shown to harm fish and other water organisms in various stages of their life cycle. Sewage chlorination creates compounds which are potentially carcinogenic, but only a small amount of these compounds are found in drinking water.

CHLORINATED DISCHARGES ARE TOXIC TO THE AQUATIC ENVIRONMENT

Many scientific studies have demonstrated the toxic effects of chlorinated discharges. Significant fish kills have been caused by such discharges. Although fish generally try to avoid chlorinated discharges, major fish kills have been directly traced to chlorinated sewage, and chlorine residuals may have been a principal factor in other fish kills ascribed to sewage effluent. Fish kills have also been caused by chlorine discharges from powerplants. Very low levels of chlorine in sewage discharges harm fish reproduction and growth.

Chlorinated discharges have played a major role in the deterioration of aquatic life in various bodies of water in the United States as illustrated by the following examples:

--Major fish kills occurred in the lower James River in Virginia in 1973 and 1974. The Virginia Institute of Marine Science investigated the kills and attributed them to chlorine residuals from sewage treatment plants. Overall, 5 to 10 million fish probably died over a 3-week period in 1973. The species affected included bluefish, striped bass, weakfish, and menhaden. Following a reduction in the levels of residual chlorine in the sewage effluent, dead fish counts dropped from thousands to tens within 2 days. A similar experience occurred the following year. In addition, when the chlorine was cut back, the oyster season was unusually successful while other estuaries entering the Chesapeake Bay were no more productive than usual.

--A major fish kill due to chlorine residuals from sewage treatment plants was noted by the California Fish and Game Department in 1972 in the Sacramento River

of California. Estimated losses of eggs, larvae, and fingerlings were in the millions for salmon, and in the billions for striped bass and shad. Sturgeon and catfish were also killed. The California Fish and Game Department reported that the fish lost would have been a significant portion of the State's fishery resources. For king salmon alone, the Fish and Game Department estimated the loss at $1,123,200.

--In studies of San Francisco Bay published in 1972 and 1974 (made because of periodic fish kills and deterioration of the fisheries there), sanitary engineering researchers at the University of California at Berkeley suggested that chlorine in wastewaters may be the largest single source of toxicity entering San Francisco Bay. The researchers concluded that chlorinated sewage, even after secondary treatment, is harmful to aquatic life. The tests demonstrated impairment to oysters exposed near plant outfalls; and in laboratory studies, baby clams and oysters experienced 50-percent mortality at chlorine residuals less than 5 parts per billion (ppb). Chlorine discharges above 1,000 ppb are frequently found in sewage discharges.

--In some years pollution from municipal waste was the leading cause of fish kills in the United States. Five fish kills in 1974-75 were specifically ascribed to chlorine in domestic sewage. However, many reports of fish kills from municipal operations have indicated that suffocation from low dissolved oxygen caused by sewage was the immediate cause of death. Studies of research literature done by an Assistant Director of EPA's Duluth, Minnesota, Environmental Research Laboratory cited two studies published in 1975 which suggested that, because chlorine interferes with a fish's ability to respire, many fish may have died from residual chlorine or the combined effects of sewage and residual chlorine.

--A 1974 progress report prepared by fisheries researchers at Oregon State University reported that coho salmon exposed to only 20 ppb of residual chlorine had significantly impaired growth. The illustration on page 6 demonstrates the effects of various levels of residual chlorine on the growth of continuously exposed coho salmon.

--Chlorine has been found to affect the environment in very subtle ways. Several studies, including four done by Michigan Department of Natural Resources researchers in 1971, reported long river reaches downstream rendered uninhabitable to many fish due to

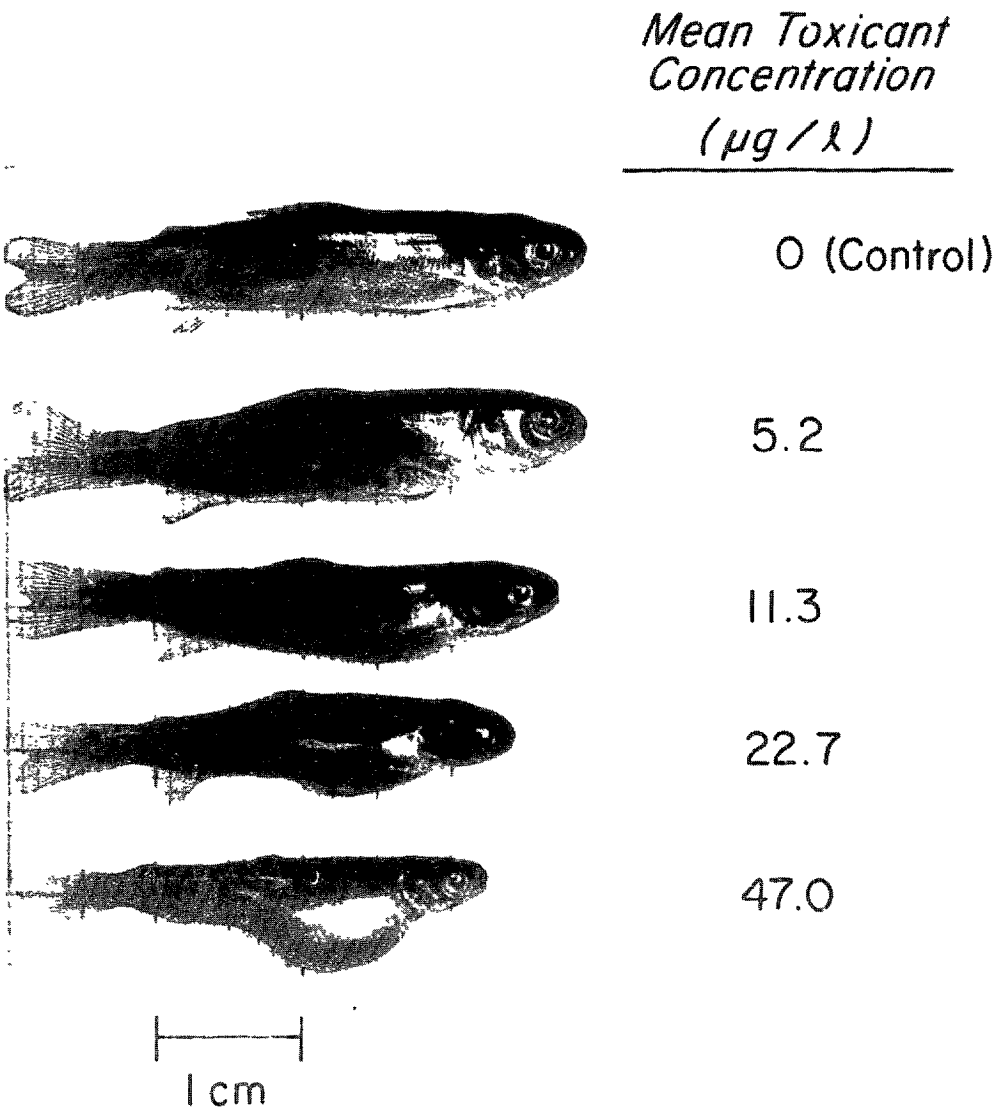
chlorine residuals in sewage effluents. Aquatic organisms in the food chain other than fish may be killed or harmed. Tests have shown that the highest total residual chlorine concentration having no measurable chronic adverse effect on an important fish food organism was 2 to 4 ppb. A level of 6 ppb is roughly equivalent to a quart of laundry bleach in 2 million gallons of water. Chlorine also interferes with the anaerobic conditions essential to the normal processes in a tidal salt marsh, or swamp, and with the reproduction of some aquatic animals. Chlorinated organics may interfere with chemical communications systems (for example, in the sensing which some fish species use for homing to breeding areas).

ONLY A SMALL AMOUNT OF SUSPECTED CARCINOGENS IN DRINKING WATER ARE A RESULT OF SEWAGE CHLORINATION

Sewage chlorination results in a large number of chlorinated organics. In a March 1976 task force report, EPA reported that some of these organics are suspected causes of cancer. One such organic--chloroform--was banned in foods and in medicinal and cosmetic products in July 1976 by the Food and Drug Administration. In a July 1975 report to the Congress, EPA reported that chloroform has been found widely dispersed in U.S. drinking waters. A study 1/ prepared for EPA reported that almost all of the chloroform found in drinking water appears to have been formed during the process of drinking water chlorination, rather than during the process of sewage chlorination.

Many organics formed in sewage chlorination have not yet been identified, and the effects of most of those which have been identified are unknown. Some scientists are concerned with the unknown effects of these organics considered either individually or collectively. Although sewage chlorination is a source of chlorinated organics in streams, fish, and shellfish, the major source is industrial discharges, especially from pulp and paper plants. Runoff of agricultural chemicals (for example, pesticides and herbicides) may also be a source of chlorinated organics.

1/"Formation of Halogenated Organics by Chlorination of Water Supplies," prepared by Harvard University and distributed by the National Technical Information Service of the U.S. Department of Commerce.



EFFECT OF RESIDUAL CHLORINE ON GROWTH OF COHO SALMON

COURTESY: OAK CREEK LABORATORY OF BIOLOGY, DEPARTMENT OF FISHERIES AND WILDLIFE, OREGON STATE UNIVERSITY

CHAPTER 3

UNNECESSARY SEWAGE CHLORINATION

The value of widespread sewage chlorination appears to be questionable because:

--The few incidents of disease transmitted through water in the United States are generally not serious and are generally transmitted through inadequately treated drinking water.

--The effectiveness of sewage chlorination varies, depending on the specific waterborne disease agent involved.

--Sewage disinfection is not extensively practiced in other industrialized countries with public health experiences similar to those in the United States.

--Widespread sewage disinfection is a recent phenomenon in this country, with little accompanying improvement in public health.

--Epidemiological studies attempting to relate bacterial levels in swimming waters with levels of illness have been inconclusive.

Specifically, sewage disinfection is usually not needed to protect

--swimmable waters in cold weather periods,

--waters rarely used for swimming, or

--drinking water.

In addition, chlorine production is energy intensive and a substantial reduction in its use would save a significant amount of energy. EPA could do more to discourage unnecessary sewage chlorination. Its virtual mandating of universal sewage disinfection in 1973 established year-round universal chlorination of sewage as a norm of water quality protection and, in many instances, resulted in chlorination of sewage which state officials believe was not necessary. Although EPA removed the year-round universal need for sewage chlorination, this action will probably not significantly reduce unnecessary chlorination since many States plan to continue year-round chlorination. In addition, EPA water quality bacterial criteria for swimming waters may effectively reinstate universal, year-round sewage chlorination

when compliance with the 1983 interim goal of swimmable waters is required.

VALUE OF WIDESPREAD SEWAGE CHLORINATION FOR DISEASE CONTROL IS QUESTIONABLE

Diseases with known causes, for which the Center for Disease Control, U.S. Public Health Service, has reported waterborne incidents, include salmonellosis, shigellosis, typhoid, cholera, hepatitis-A, amoebic dysentery, and giardiasis. The most common of these diseases, salmonellosis and shigellosis, are both characterized by abdominal pain, diarrhea, nausea, and vomiting. Two other bacterial diseases, cholera and typhoid, are more serious, but the United States averages less than 430 cases and 8 deaths per year from typhoid fever (1965-73) and has had only 1 indigenous case of cholera in the last 65 years.

Most water borne illnesses are directly traced to inadequately disinfected drinking water, not sewage water, although the contamination frequently originates from sewage.

In addition to inadequately treated drinking water, ingestion of raw or partially cooked shellfish (presumably from contaminated waters) may play a significant role in transmission of viral hepatitis. Due to the paucity of evidence, the role of swimming in sewage-polluted water in the transmission of illness has not been conclusively defined.

The effectiveness of sewage chlorination against various organisms that cause waterborne diseases varies, depending on the disease organism involved. Sewage chlorination is aimed particularly at bacteria and has been thought to be generally effective in this regard. Levels of bacteria, however, may actually establish their original numbers through regrowth. 1/

Viruses are generally more resistant than bacteria to chlorination, and they require a much heavier dosage and longer contact time. Secondary wastewater treatment followed by chlorination, as generally practiced, will not reduce virus concentrations effectively, particularly in the case of the more resistant viruses such as those which cause hepatitis. Only where plants provide tertiary treatment

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1/Report No. 76-17, "Wastewater Disinfection: The Case Against Chlorination," published in June 1976 by the Department of Research and Development of the Metropolitan Sanitary District of Greater Chicago.

(for example, high levels of filtration) to produce very clear effluent can they achieve effective virus inactivation. A relatively small number of sewage treatment plants in the United States provide such tertiary treatment.

Foreign disinfection practices

The United States appears to be unique in its extensive year-round chlorination of sewage. Representatives of other countries with public health experience similar to ours generally told us that sewage disinfection is only rarely practiced in their countries.

--Officials from Scandinavian countries 1/ said that sewage disinfection is rare in their countries and cited the harmful environmental effects of chlorine as a reason. The Secretary of the Embassy of Norway said that chlorine was not used for disinfection because of the possible poisonous effects on the receiving water body. The Science Attache of the Embassy of Sweden said that chlorine was not used for sewage disinfection and that it was regarded as a harmful substance not to be indiscriminately dumped into the nation's waters.

--The Science Attache of the Embassy of Great Britain said that sewage disinfection is rarely practiced in Great Britain and that it is considered undesirable. He said that a study found no beneficial effects on the Thames River from chlorinating sewage discharges.

--The Science Attache of the West German Embassy said that sewage disinfection is practiced very rarely in West Germany and that it is considered unnecessary. She said chlorination is only used in connection with some advanced waste treatment processes in which chlorine is used for its ability to oxidize certain substances, not necessarily for its disinfectant properties.

--The Scientific Attache of the Embassy of France stated that there is no general requirement in France for sewage disinfection. Technicians may require disinfection in particular instances. Most such instances involve the protection of (1) drinking water sources, (2) seaside resorts, and (3) shellfish. A French specialist in sanitary engineering told us that less than

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1/Denmark, Norway, and Sweden.

2 percent of the sewage in France is chlorinated and that requirements are imposed on a case-by-case basis, generally only for the 3 summer months.

--The Science Attache of the Embassy of the Netherlands told us that sewage chlorination is practiced only at plants that discharge near oyster beds and, during the summer, at several municipal sewage treatment plants that discharge near public bathing beaches.

Public health statistics shown on page 11 indicate that death rates for bacterial and viral gastrointestinal diseases are similar in these countries to rates in the United States. It should be noted that while the Swedish rate for enteritis and other diarrheal diseases is one-sixth that of the United States, the Norwegian rate is almost twice the rate for this country.

Sewage disinfection in the United States

Only recently has wastewater disinfection in the United States become widespread. Until 1945 most sewage treatment plants practicing disinfection belonged to the U.S. Armed Forces. In 1958 about 30 percent of all wastewater treatment facilities were equipped for chlorination; these chlorinating facilities served about 38 million people. In 1968, 41 percent of all municipal wastewater plants in the United States were using chlorine for disinfection. In mid-1976 our survey of nearly 400 sewage treatment plants showed that 74 percent of those responding used chlorine for disinfection. The Executive Secretary of the Water Pollution Control Federation explained that municipalities probably were slow in implementing disinfection because of the uncertain health benefits of disinfecting treated wastes and the cost of chlorine. Also, the Chief of EPA's Municipal Technology Branch stated that States have had differing views on the need for disinfection.

The Assistant Director of the Bacterial Diseases Division of the Center for Disease Control told us that there is no evidence that the substantial increase in sewage chlorination over the last 5 to 10 years has resulted in any reduction in waterborne diseases. The Center for Disease Control has taken the position that disinfection of sewage produces few public health benefits.

The GAO medical consultant contacted a variety of experts in epidemiology and sanitary engineering. He found that there is no unanimity of opinion concerning the desirability of discontinuing the chlorination of sewage effluents. On the one hand, the medical epidemiologists we contacted tended to feel that sewage chlorination is wasteful

DEATHS FROM INFECTIOUS INTESTINAL DISEASES AND INFECTIOUS HEPATITIS PER 100,000 POPULATION FOR SELECTED COUNTRIES IN 1971 OR 1972 (note a)

Disease	United States	Denmark	France	Federal Republic of Germany	Nether-lands	Norway	Sweden	United Kingdom
Cholera	None	None	None	None	None	None	None	None
Typhoid fever	0.0 b/(4)	None	0.0 b/(13)	0.0 b/(11)	None	None	None	0.0 b/(2)
Paratyphoid fever and other salmonella infections	0.0 b/(81)	0.0 b/(1)	0.0 b/(18)	0.1	0.2	0.0 b/(1)	0.1	0.1
Bacillary dysentery (shigellosis) and amoebiasis	0.0 b/(84)	None	0.0 b/(5)	0.0 b/(7)	0.0 b/(10	None	0.0 b/(1)	0.0 b/(10)
Enteritis and other diarrheal diseases	1.2	1.1	1.1	0.9	1.3	2.0	0.2	1.2
Infectious hepatitis	0.4	0.2	1.0	0.1	0.2	0.1	0.0 b/(3)	0.3
Total	1.6	1.3	2.1	1.1	1.7	2.1	0.3	1.6

a/World Health Statistics Annual-1972, vol. 1, published by the World Health Organization in 1975.

b/Number in parentheses is the total number of cases which occurred.

and does not really contribute to human health and well being. On the other hand, public health engineers favor continuing chlorination to ensure reasonably high water quality standards for recreational waters.

In our opinion, epidemiological studies attempting to relate bacterial levels in swimming waters with levels of illness have been inconclusive. (For a review of the principal studies, see app. I.) In fact, a 1952 study by the U.S. Public Health Service (see p. 38), suggested that swimming in a polluted river is no more hazardous to health than swimming in a chlorinated swimming pool.

The Assistant Director of the Bacterial Diseases Division, Center for Disease Control, told us that the risk of a swimmer incurring a bacterial gastrointestinal infection from swimming is small. According to a Center for Disease Control memorandum dated August 20, 1975, and data from volunteer typhoid fever experiments 1/, a large number of infectious organisms must generally be ingested to cause a typhoid or other salmonellosis infection in a healthy adult. The Assistant Director told us that the average number of typhoid and other salmonella bacteria occurring in the amount of sewage water normally ingested while swimming is only a fraction of the infectious dose (in the absence of raw sewage or fecal particles) and is highly unlikely to cause disease. Although the number of infectious organisms that would have to be ingested to cause one form of shigellosis is quite low, only one outbreak of swimming-related shigellosis (possibly from raw sewage) had been documented as of March 1975. 2/

CHLORINATION OF SEWAGE IS NOT NEEDED TO PROTECT SWIMMERS DURING COLD WEATHER MONTHS

We could find no justification for chlorinating municipal waste discharges during the nonswimming season (with the exception of shellfish-harvesting areas). Numerous experts told us that chlorination is usually unnecessary during cold winter months when human contact and the chance of disease transmission from undisinfected sewage is negligible.

--The Assistant Director of the Bacterial Disease Division, Center for Disease Control, said that there is

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1/A section entitled, "A Probabilistic Model of Bathing Beach Safety," in the book The Science of the Total Environment, 1975.

2/From a Center for Disease Control report dated March 18, 1975, on the transmission of shigellosis by swimming on a portion of the Mississippi River in 1974.

no public health justification for sewage disinfection during the period of the year when swimming is not likely . Although officials of two States justified chlorination during cold winter months on grounds that it is necessary to protect hunters, fishermen, and hikers, the Center for Disease Control official told us that there is little public health evidence to support chlorinating to protect fishermen and hunters who may come into casual primary contact with waters receiving unchlorinated sewage.

--A British sanitary engineer teaching at the University of California told us that chlorinating sewage in cold weather to protect fishermen from primary contact is inappropriate.

--EPA scientists and foreign experts said that, in the absence of shellfish harvesting areas, other nations with similar levels of mortality from gastrointestinal diseases practice sewage chlorination near bathing beaches, if at all, only in the summer months.

--EPA research scientists studying sewage disinfection said that the need for universal year-round sewage disinfection has not been clearly demonstrated. In addition, in March 1976, an EPA task force report on wastewater disinfection recommended that disinfection not be required in cold weather when there is no swimming. The report cited favorably the example of communities, such as New York City, which chlorinate only during the swimming season. EPA has reported in the Federal Register that requiring a minimum level of disinfection for all wastewater is of questionable benefit when the possibility of human contact with the receiving water is remote.

Even in the absence of shellfish-harvesting areas, we found that many cold weather States, including Alaska, Michigan, and Minnesota, require continuous year-round sewage chlorination, with no reductions permitted during cold-weather months.

CHLORINATION IS NOT NEEDED FOR SEWAGE DISCHARGES INTO WATERS RARELY USED FOR SWIMMING

Some lakes and streams are unswimmable for a variety of reasons and chlorinating discharges into these waters would still not make them swimmable. A public health expert from the Center for Disease Control said there is no need to chlorinate discharges into unswimmable waters since public health is not jeopardized.

Officials from several States told us that they had many lakes and streams that are never used for swimming or for irrigation and therefore they believed disinfection was probably unnecessary. One Indiana State official estimated that only 50 of Indiana's estimated 300 municipal sewage treatment plants (17 percent) discharge sewage to waters used for direct water recreation, yet 90 percent of these plants disinfect wastes. An Illinois State official estimated that 80 percent of all municipal sewage treatment plants in Illinois discharge to streams not used for swimming or other water recreation, but 60 percent disinfect wastes. A New York State official estimated that only 75 of New York's 500 municipal sewage treatment plants--15 percent--discharge to waters used for swimming, but 90 percent of the plants disinfect wastes.

According to State officials, people avoid direct water recreation in some lakes and streams for the following reasons:

--Man-made pollution makes water aesthetically unswimmable. (For example, floating debris, algae blooms, or high proportions of sewage discourage swimming in the Spokane River and Long Lake in Washington State, the Trinity River in Texas, and streams in Indiana.)

--Non-point source pollution makes water look unpleasant for swimming. (For example, soil erosion reaching levels of 20,000 tons a year makes the Palouse River in Washington State unattractive for swimmers.)

--Heavy commercial navigation prevents safe water recreation. (For example, the Chicago barge canal and the Hudson River in New York are unswimmable for this reason.)

--Stream water conditions are such that they do not lend themselves for water recreation. (For example, many streams in Illinois, Indiana, and Texas are too narrow or shallow for swimming, and in New York many are unswimmable for this and other reasons, namely, water temperature and speed of flow.)

At least one unit of local government has attempted to prevent unnecessary chlorination where water (in this case, the Chicago Sanitary and Ship Canal) is not used for primary recreation. In February 1976 the Metropolitan Sanitary District of Greater Chicago petitioned the Illinois Pollution Control Board to grant a sewage treatment plant a variance to the statewide disinfection requirement. Evidence cited by the sanitary district to support its petition included

--the board rules and regulations which designate that the Chicago Ship Canal is not intended for swimming;

--heavy commercial use (2 million tons of freight carried by ships and barges each month) and its narrow channel, which make recreational activities virtually impossible;

--a lack of historical evidence to suggest that the canal is used by the citizens for recreational purposes; and

--significant chlorination costs in excess of $1 million a year) without public health benefits.

In November 1976 the director of research and development for the sanitary district told us that the State board had denied the variance. The district now plans to request a change in the statewide disinfection requirement.

Most States, however, do not adjust requirements for disinfection of wastewater because of the use of the receiving stream (if any) or the proximity of the wastewater discharge point to the location of water use.

CHLORINATION OF TREATED WASTEWATER IS USUALLY NOT NEEDED AS A BACKUP TO DRINKING WATER DISINFECTION

Sewage chlorination has been supported on grounds that it is necessary to protect (1) raw drinking water supplies downstream from sewage outfalls, (2) water from private wells located near streams and rivers, and (3) drinking water for cattle which use streams and rivers as a source of water. We believe, however, that there is an insufficient public health basis to warrant widespread chlorination of treated sewage for any of these reasons.

In its July 1976 change in disinfection requirements, EPA encouraged continued sewage disinfection to protect public water supplies. The Center for Disease Control, however, has taken the position that disinfection of sewage as a backup to disinfection of drinking water has very little public health basis. The Assistant Director of the Bacterial Diseases Division of the Center for Disease Control made the following comments concerning protection of drinking water supplies:

--Sewage disinfection is generally not useful as a means of protecting drinking water, since water supplies can be much more appropriately and economically

disinfected during the course of drinking water treatment. Sewage disinfection as a preparation for drinking water treatment is usually not cost-beneficial because only a small percentage of diluted sewage water is generally reused in drinking water.

--Available evidence suggests that the drinking water in areas of the United States where sewage disinfection still is not widely practiced carries no more risk of disease transmission than in other areas.

--Sewage disinfection does not provide an effective backup in cases of drinking water treatment failure.

EPA research scientists also discounted the importance of chlorinating sewage as a safety factor in case of a drinking water chlorination breakdown. According to a professor of sanitary engineering at the Johns Hopkins University, the question as to whether sewage should be chlorinated should be determined on an individual basis taking into consideration proximity of the sewage outfall to the water intake, the rapidity of water movement, and the amount of sewage being deposited.

Several public health officials expressed concern that sewage chlorination was necessary to protect owners of wells close to rivers that receive sewage discharges. According to EPA officials, sanitary practice requires that wastewater be disinfected as an added level of protection from source contamination which might be transmitted to these wells. Depending on the quality of the raw well water, chlorination or other treatment to provide a potable supply may be needed. However, sewage seepage into drinking wells is unlikely because the normal hydraulic flow would be in the opposite direction (that is, toward the river). The Assistant Director of the Bacterial Diseases Divison of the Center for Disease Control said that there have been a few cases in which a well near a river had been polluted by river water because of unusual conditions. However, he said that even in those few cases, the answer is not to attempt to make the raw river water drinkable by disinfecting sewage. Instead, he said it would be much safer and cost-effective for individual well owners to chlorinate their own well water or, where feasible, jointly to build a (drinking) water treatment plant.

Several public health officials expressed a concern with transmission of diseases in human sewage to cattle who drink from streams receiving such sewage. Two professors of veterinary medicine at Washington State University told us that such concerns were invalid because cattle generally are not subject to the human diseases normally transmitted through sewage. In addition, they said that there is no scientific

evidence tracing animal disease to sewage in river water. Although cattle are subject to tuberculosis and worm infestations, normal sewage chlorination is not effective against the carriers of these diseases. 1/

EPA COULD DO MORE TO DISCOURAGE UNNECESSARY CHLORINATION

An EPA report, "Restoring the Willamette River: Costs and Impacts on Water Quality Control," published in September 1976, concluded that post chlorination of wastewaters requires large amounts of energy and should be better regulated. The report recommended, among other things, that

> "* * * Chlorine production is highly energy intensive and a substantial reduction in its use would yield significant energy savings. This fact, along with chlorine's counter-productive instream biological effects and possible carcinogenicity, clearly shows the need for further research. This work should include evaluating the need for bacterial reduction as well as evaluating, alternative means by which this reduction might occur."

For the Willamette River Basin, the study reported that the energy needed to produce the chlorine used for disinfection of municipal wastewaters was equal to between 40 and 50 percent of the electricity used to operate the treatment plants.

In August 1973, although EPA was aware of the potential for harmful environmental effects from chlorinated discharges and although we believe the public health need for it was tenuous, EPA virtually mandated year-round universal sewage chlorination. It did so by defining secondary treatment to include a bacterial limitation based on levels attainable in most facilities only by disinfection. Chlorine (in one form or another) was virtually the only sewage disinfectant available to meet these bacterial standards.

In 1973 an estimated 2,000 tons of chlorine was used for wastewater treatment in the Willamette River Basin. The total annual expenditure for chlorine in the 1973-74 period was $260,000.

1/From an article entitled, "Compatability of Wastewater Disinfection by Chlorination," in the September 1961 issue of the Journal of the Water Pollution Control Federation.

In establishing bacterial standards, EPA stated that it considered disinfection to be an important element of secondary treatment, which is necessary for protection of the public health. In our opinion, the effect of this action was to establish sewage disinfection as the norm in the protection of national water quality. The EPA action, according to State officials, resulted in much unnecessary chlorination, including that of discharges into dry stream beds.

On July 26, 1976, approximately 3 years after establishing the requirement, EPA removed the bacterial standard from its definition of secondary treatment. Now State and local water quality standards are used to determine disinfection practices. State and local water quality standards will use EPA's water quality criteria as a basis for regulating a plant's effluent. This procedure allows the States to stop some chlorination if they consider it unnecessary, for example, discharges into dry stream beds and discharges during cold weather.

The Chief of EPA's Municipal Technology Branch stated that EPA intended to have the States determine site specific requirements based on water use. EPA's change in secondary treatment standards, however, will probably have only a limited impact in reducing unnecessary chlorination. Our survey of State disinfection practices and policies showed that 25 States did not plan to reduce chlorination requirements even with EPA's change.

In addition, EPA's water quality criteria dated July 26, 1976, includes the same low bacterial levels (200 fecal coliform per 100 ml.) for swimmable waters. No consideration was given to limiting the bacteria criteria for swimming to certain times of the year. Since Public Law 92-500 establishes as a national goal that, wherever attainable, all waters be swimmable, inclusion of a bacterial limitation in water quality criteria for swimming waters will essentially reestablish universal year-round chlorination of sewage. An EPA official in the Criteria and Standards Division stated that the current water quality standards, including bacterial standards, do not allow for seasonal variation, and this might have to be changed.

EPA's criteria for bacteria in swimmable waters do not have a strong scientific basis. The level of 200 fecal coliform per 100 ml. as a safe level for swimming water was formulated from a 1952 study which reported that swimmers in a heavily polluted river experienced somewhat more nausea, cramps, and diarrhea than statistically expected when compared with swimmers in a chlorinated swimming pool. This study found no relationship, however, between bacterial

levels and disease incidence. (See p. 38.) After reviewing this and other studies, the National Academy of Sciences-National Academy of Engineering Committee on Water Quality Criteria, in 1972, refused to establish any standards for microbial organisms in swimming water because of the paucity of evidence.

CONCLUSIONS

There are many reasons for questioning the value of sewage chlorination as practiced in the United States today. There are differing views among experts concerning the need for disinfection, but it appears that widespread year-round sewage chlorination is questionable. Certainly, in the absence of shellfish harvesting or unrestricted irrigation, disinfection of treated wastes is usually not needed to protect drinking water supplies since the water is purified in water treatment plants. Nor is it usually needed to protect swimming waters in cold weather or to protect waters rarely used for swimming. Chlorine is energy intensive and a reduction in its use would save substantial amounts of energy.

EPA could do more to discourage unnecessary disinfection. Because EPA includes a bacterial limit in its water quality criteria for swimming, many States plan to continue to require universal year-round sewage disinfection.

RECOMMENDATIONS TO THE ADMINISTRATOR OF EPA

We recommend that the Administrator EPA:

--Revise the Agency's water quality criteria regarding the bacteria standard for swimming waters to recognize seasonal variations and that he specifically delineate those circumstances in which sewage chlorination is or is not needed to protect the public health.

RECOMMENDATION TO THE CONGRESS

To reduce unnecessary chlorination of sewage, the Congress should amend the Federal Water Pollution Control Act of 1972 to permit exceptions from the national goal of swimmable waters to recognize those situations in which waters are determined to be unswimmable because of other factors, such as heavy barge traffic, cold seasons of the year, and general appearance.

CHAPTER 4

NEED TO PREVENT HARMFUL LEVELS OF RESIDUAL CHLORINE IN DISINFECTED SEWAGE AND OTHER EFFLUENTS

Although sewage disinfection appears to be needed only in certain specific situations, such as reducing disease transmission through raw shellfish and sewage used for unrestricted irrigation, sewage disinfection is widely practiced. Where sewage chlorination is practiced, levels of residual chlorine are far in excess of levels found safe to the aquatic environment, and frequently, because of imprecise testing procedures, the levels being reported grossly understate the actual levels being discharged.

Public Law 92-500 calls for control of toxic pollutants, and chlorine is a toxic pollutant as defined by the act; however, EPA has not listed residual chlorine as a toxic pollutant requiring standards for its discharge. Other groups, including both the U.S. National Academy of Sciences and the European Commission on Inland Fisheries, have strongly recommended control of chlorine residuals. EPA has taken some action, though inadequate to protect the aquatic environment, to limit chlorine residuals in powerplant discharges. In addition, several States have taken actions to limit chlorine discharges. Methods of removing most of the toxicity of chlorine residuals (dechlorinating) are available, though costly.

Chlorine toxicity in receiving waters can be avoided by using other methods of disinfection. However, the principal alternatives, while appropriate under limited circumstances, all have disadvantages which make it unlikely that any of them will generally replace chlorination in the near future as the principal means of disinfecting wastewater. These alternatives include land treatment, lagoons, and disinfection with ozone, ultraviolet radiation, and bromine chloride. For further details on these alternatives, see appendix II.

Improving the efficiency of the disinfection process reduces both dosages and residuals and thus minimizes the toxic effects of chlorine on receiving waters and the discharge of potentially carcinogenic compounds. Improved efficiency can be achieved by improving the design of chlorination facilities, selecting more effective equipment for the chlorination process, and improving the quality of the effluent.

Progress has been slow, however, by the States and EPA in improving the disinfection process in existing plants or in ensuring that new construction provides for efficient and effective chlorination.

SEWAGE CHLORINATION MAY BE NEEDED TO PROTECT SHELLFISH-HARVESTING AREAS AND WHEN SEWAGE IS USED FOR UNRESTRICTED IRRIGATION

The chlorination of sewage may be of significant value in reducing disease transmission through consumption of raw shellfish grown in fecally contaminated water. In the process of feeding, shellfish, such as oysters and clams, filter and retain harmful bacteria and viruses; in doing so, they concentrate these bacterial and viral pathogens in their flesh. Shellfish grow in coastal waters, and nearly all shellfish waters are subject to some degree of pollution. In the past, when typhoid fever was more prevalent, consumption of raw shellfish was associated with the transmission of that disease. The last such case in the United States occurred in 1939. In the United States, no outbreaks of salmonellosis or shigellosis have been traced to the consumption of raw shellfish in the last 10 years. Chlorination of sewage discharges into shellfish-harvesting areas may therefore have helped control transmission of bacterial diseases in shellfish.

Infectious hepatitis continues to be associated with ingestion of raw or partially cooked shellfish. The effectiveness of sewage chlorination in killing the hepatitis virus is not known with certainty. The virus that is presumed to cause hepatitis has never been isolated. Viruses are generally more resistant than bacteria to chlorination, and the hepatitis virus appears to be among the more resistant viruses.

Fruits and vegetables growing in infected soil can become contaminated with pathogenic bacteria, and these bacteria may survive for periods from a few days to several weeks or more in the soil. However, pathogens are seldom detected on farm produce unless the plant samples are grossly contaminated with sewage or have fecal particles clinging to them.

The National Academy of Sciences-National Academy of Engineering Committee on Water Quality Criteria, after reviewing the dangers of parasitic worms and other organisms not effectively destroyed by sewage treatment or chlorination, stated in its 1972 Water Quality Criteria that it is good practice to restrict irrigation with sewage water to crops that are adequately processed before sale and to crops that are not used for human consumption. For unrestricted irrigation, for example, on fresh fruits and vegetables, the 1972 Water

Quality Criteria indicated that wastewater should receive primary and secondary treatment and adequate chlorination.

CHLORINE RESIDUALS IN MANY LOCATIONS ARE TOO HIGH FOR SAFE DISCHARGE

Very low concentrations of chlorine residuals are toxic to aquatic life. Based on scientific research, experts--both foreign and American--have developed the following residual chlorine standards to safeguard aquatic life:

--The European Inland Fisheries Advisory Commission has recommended, as criteria to protect European freshwater fish species, residual chlorine ranging from 4 to 121 ppb, depending on temperature and acidity/alkalinity of the water.

--Various U.S. scientists have developed residual chlorine criteria for freshwater aquatic life. These criteria run from 2 to 20 ppb for continuous discharge and from 40 to 200 ppb for intermittent discharge.

--The National Academy of Sciences-National Academy of Engineering Committee on Water Quality in its freshwater aquatic life criteria recommended a maximum residual chlorine concentration of 3 ppb for continuous discharge and 50 ppb for intermittent chlorination of up to 30 minutes in any 24-hour period.

--Fifteen States have established maximum residual chlorine effluent standards for at least some wastewater discharges. Some States and local areas have established maximum residual standards for all chlorinated discharges. For example, in the area of San Francisco Bay, all sewage dischargers are required to reduce chlorine residuals virtually to zero because of the toxic effects of chlorine, according to an official of the regional water quality control board.

During our review, however, we noted that wastewater effluent often contains residual concentrations many times higher than the levels mentioned above that are considered safe. For example:

--Research scientists have observed total residual chlorine values of 5,170 ppb in treatment plant

effluent in central Illinois 1/, over 10,000 ppb in southern Wisconsin 1/, and up to 7,000 ppb in California. 2/

--Ten waste treatment plants in the Tualatin River Basin in Oregon reported annual average chlorine residuals in treatment effluents ranging from 1,300 to 3,400 ppb, with most of the values around 2,000 ppb. Peak chlorine residuals during the year were much higher.

--In our national survey of sewage plant disinfection practices, we found that over 30 percent reported an average chlorine residual for 1975 at or above 1,000 ppb in their effluents. About 27 percent reported a peak measurement for the year between 2,000 and 5,000 ppb, with about 8 percent reporting even higher peak measurements.

In addition to being excessive, the reported residuals frequently understated the actual level of chlorine residual in the discharge. There are two principal causes of such understatement: (1) widespread use of an inadequate measuring method and (2) not sampling when chlorine residuals are likely to be high.

Inadequate measuring method

The most common means of measuring residual chlorine in wastewater is the orthotolidine method. Using this method, orthotolidine is added to a sample and the resulting color is compared to a color standard chart. This method is subject to interferences, and it tends to understate the presence of chlorine. Orthotolidine measurements generally report about one-half of the actual amount of chlorine 3/,

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1/From a paper by W. A. Brungs entitled, "Effects of Wastewater Chlorination on Freshwater Aquatic Life" presented at the annual meeting of the Water Pollution Control Federation in October 1975.

2/Mentioned in a November 1, 1974, transcript of proceedings of the California Regional Water Quality Control Board.

3/From an article by C. M. Robson, B. S. Hyatt, Jr., and S. K. Banerji entitled, "We Must Improve Chlorination Design," in the September 1975 issue of Water and Wastes Engineering.

and they have reported as low as one-sixth 1/ of the residual chlorine measured by more sophisticated methods. In our survey of sewage treatment plants, however, we found that 76 percent were still using the orthotolidine method.

Inadequate testing of chlorine residuals

Although chlorine residuals are monitored regularly by most treatment plants using chlorine, many plants in our survey reported that they did not test during the early morning hours (prior to 7 a.m.) when, we were told, conditions of low flow and demand and, thus, high residuals tend to predominate. The differences of chlorine residuals in tests taken at times of low flow and tests taken during periods of high flow can be substantial. An authority on wastewater disinfection said that in early morning hours (e.g., 5 a.m.) chlorine residuals from small plants may run as high as 22,000 ppb.

THOUGH A TOXIC POLLUTANT, CHLORINE RESIDUALS ARE LARGELY UNCONTROLLED

Public Law 92-500 established a national policy against discharge of toxic pollutants in poisonous amounts. Section 502 of the act defines "toxic pollutant" as a pollutant which will cause death, disease, or physiological malfunctions after assimilation into any organism (human, fish, etc.). As demonstrated in chapter 2, residual chlorine fits this definition and it is being discharged in excessive amounts.

Section 307 of the act requires the Administrator of EPA to publish a list of toxic pollutants and to set effluent standards for them. In June 1976 EPA published a list of 65 toxic substances proposed for control, but final effluent standards have not been established for any of these substances. The Chief of EPA's Criteria Branch explained that elemental chlorine was not included in the list of 65 substances because it does not persist in the aquatic environment. Scientists are concerned, however, that when chlorine is mixed with sewage or cooling waters it may form toxic compounds such as chloroform.

1/From a paper by Thomas E. Harr, entitled, "Residual Chlorine in Wastewater Effluents Resulting from Disinfection," Technical Paper No. 38, prepared by the Environmental Quality Research Unit of the New York State Department of Environmental Conservation.

Research results presented at the Conference on the Environmental Impact of Water Chlorination in October 1975, indicated that five of the EPA listed toxic substances can be created by mixing chlorine with sewage or powerplant cooling waters. Two of these substances were included on an EPA priority list of toxic substances for which "no effective threshold dose can yet be established."

The National Academy of Sciences classified substances as "highly toxic" to aquatic life when a concentration of 10,000 ppb will kill half a test population within 96 hours. The extreme toxicity of chlorine is best illustrated, therefore, by research which found that a level of 10 ppb killed 67 percent of a population of brook trout in 96 hours. 1/ The harmful effects of chlorine discharges on salmon, menhaden, and shrimp have already been illustrated earlier in this report. EPA has stated that effects on economically important species, such as trout, salmon, menhaden, and shrimp, are properly considered in the development of a protective criterion level for toxic pollutants.

Others also contend that chlorine discharges are a serious problem and that chlorine residuals should be controlled:

--The Assistant Director for Water Quality Criteria at EPA's Environmental Research Laboratory, Duluth, Minnesota, said that one might hypothesize that chlorine as a pesticide should be registered just like other pesticides.

--Water Quality Criteria-1972, a report prepared by the National Academy of Sciences-National Academy of Engineering Committee on Water Quality Criteria, under EPA contract and approved by EPA for publication, listed chlorine among toxic substances.

The Chief of EPA's Standards and Criteria Development Branch, Water Supply Division, said the feeling at EPA was that to classify chlorine as a pollutant would be "illogical" so long as it is still needed as a disinfectant. The Assistant Director of EPA's Effluent Guidelines Division said that he does not believe chlorine is toxic enough to be so classified under Public Law 92-500. He told us that

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1/From an article by William A. Brungs entitled, "Effects of Residual Chlorine on Aquatic Life" in the October 1973 issue of the Journal of the Water Pollution Control Federation.

EPA does not plan to control chlorine discharges from sewage plants or other industries.

While EPA sets no limits on residual chlorine in effluents from sewage treatment plants and other industrial effluents, in October 1974 it limited chlorine discharges in powerplant effluents. The maximum limit was set at 500 ppb of free residual chlorine, and the average limit was 200 ppb of free residual chlorine. In setting its standard, EPA noted the large quantities of chlorine added annually to waters from powerplant discharges. In contrast to the national standard, an EPA region III official told us that region III has set a maximum 200 ppb total of residual chlorine (free and combined chlorine) for powerplants in its region.

In contrast, EPA has not set a maximum standard for the levels of chlorine in discharges from sewage treatment plants, which collectively use an estimated 200,000 tons 1/, about twice as much chlorine as powerplants. 2/ When EPA proposed the powerplant standards, comments were received from powerplant officials that sewage treatment plants were not similarly controlled in their chlorine discharges.

MOST TOXIC CHLORINE RESIDUALS CAN BE REMOVED

Means are available to remove most chlorine residuals and the hazards associated with them. The addition of sulfur dioxide to wastewater is the most common dechlorination method. It increases the cost of chlorination by an estimated 20 to 30 percent. Addition of sulfur dioxide may reduce the level of dissolved oxygen, but an EPA Research Microbiologist said that reaeration would not be needed except in the case of gross overdosing with sulfur dioxide. Other chemicals may also be used as dechlorinating agents. In addition, dechlorination with activated carbon, a physical filtering process, not only alleviates the problem of toxicity associated with chlorine but it also may remove some of the potentially toxic chlorinated organics. However,

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1/From an article entitled, "Toxicity of Wastewater Disinfectants," in the July 5, 1974, issue of the EPA News of Environmental Research in Cincinnati.

2/From a paper entitled, "Effects of Wastewater and Cooling Water Chlorination on Aquatic Life," presented at the Washington State Department of Ecology Disinfection Seminar on May 26, 1976.

the costs of dechlorination using activated carbon are 13 to 20 times the cost of dechlorination with sulfur dioxide. Where sufficient land is available, holding chlorinated sewage in a pond or lagoon prior to discharge substantially reduces residual chlorine and its effects.

IMPROVING PLANT EFFECTIVENESS AND EFFICIENCY PERMITS LOWER CHLORINE RESIDUALS

Improving the quality of sewage effluent reduces the levels of chlorine needed for good disinfection and thus reduces the toxicity of the sewage effluent. The quality of sewage effluent can be improved by (1) providing a higher level of treatment and (2) improving the operation and maintenance of the treatment facility.

Many sewage treatment plants use too much chlorine and have high chlorine residuals because of inefficient chlorination systems. Even in designs for new plants, elements of efficient chlorination are often overlooked. We believe State and EPA emphasis on improving chlorination efficiency has been inadequate.

Need to improve treatment effectiveness and efficiency

In primary treatment, solids are screened out and removed by settling. Secondary treatment removes more solid material and uses bacteria to break down the organic matter. By reducing the chlorine-demanding material and the bacteria levels in sewage, it is easier to obtain good disinfection with lower chlorine residuals. Also, the amount of chlorinated organics is reduced. EPA has estimated that 40 to 50 percent of municipal dischargers will achieve secondary treatment by 1977. In addition, the EPA Administrator has pointed out that projects to be completed by 1978 will handle the wastes from approximately 80 percent of the population. As additional treatment plants are brought up to secondary treatment, effective disinfection with less chlorine will be possible.

Good plant operation also reduces the chlorine needed for effective disinfection. Operation and maintenance problems which adversely affect water quality are widespread in wastewater treatment plants. An EPA report published in September 1976 reported that overapplication of chlorine was noted at plants in the Willamette Basin, and a large savings of resources could be realized by proper surveillance of chlorine use.

Our recent report on the "Continuing Need for Improved Operation and Maintenance of Municipal Waste Treatment Plants," B-166506, April 11, 1977, stated that many municipalities are not efficiently operating their wastewater treatment facilities at designed pollution-removal levels. The basic causes of operation and maintenance problems include excessive flows of water from nonsewer sources, inadequate laboratory controls, lack of sufficient numbers of qualified staff, design deficiencies, inadequate budgets, and industrial wastes which upset treatment processes. Another recent report, "Improvement Needed in Operating and Maintaining Waste Water Treatment Plants," June 18, 1976, B-166506, stated that, of the Department of Defense waste treatment plants examined, 50 percent were understaffed and that there was a need for additional operator training. The two reports included a number of recommendations for improving the operation and maintenance of treatment plants.

Need to improve chlorination efficiency

Because most plants do not vary the amounts of chlorine in proportion to the flow of wastewater, they use excessive amounts of chlorine. In addition, most plants use extra chlorine to compensate for contact times which are too short and/or for poor initial mixing.

Flow-proportional dosage adjustment

A procedural manual for evaluating the performance of wastewater treatment plants, prepared under EPA contract and published in 1972, states that all chlorination equipment used to disinfect wastewater effluent should at least provide for chlorine dosages which are proportionate to the effluent flow. If dosage adjustment must be done manually, a dosage set to achieve adequate disinfection at higher flows, unless manually reset, overchlorinates at lower flows. Amounts and concentrations of sewage vary substantially throughout the day, and a California Department of Health official told us a chlorinator set to dispense a dosage producing a 1,000 ppb residual at peak flow may produce a residual many times higher at low flow.

In our survey of about 400 sewage treatment plants from five EPA regions, more than 82 percent of the plants using chlorine reported they still adjusted chlorine doses manually, and less than 23 percent of the plants that adjusted manually were staffed continuously. About 33 percent of the plants that adjusted manually did not adjust daily. In some cases chlorination rates appear to be set in periods of high flow (winter) and are not adjusted downward as dry weather approaches.

Contact times

Increasing contact time between sewage and chlorine permits disinfection with less chlorine residuals. The May 1974 California Interim Manual for Wastewater Chlorination and Dechlorination Practices, written by nationally known disinfection experts, and an EPA technical bulletin published in July 1974, both recommended a contact time between the sewage and the chlorine of at least 30 minutes at peak flow. If the contact time is shorter than this, even for a portion of the sewage, an unnecessarily high amount of chlorine is needed for good disinfection, and in some cases good disinfection cannot be achieved in spite of high residuals.

In our survey of sewage plants, 43 percent of those practicing chlorination were not designed to provide even 30 minutes contact time. The actual contact time for the portion of the sewage that passes through the system fastest is generally far less than the theoretical contact time.

Researchers have recommended a minimum 40:1 length-to-width ratio for the contact chamber to allow for adequate contact times. Baffling may permit a poorly designed rectangular chamber to attain this ratio. Many basins, however, have length-to-width ratios of 2:1 or less and extremely inadequate baffling. (See pictures on pp. 32 and 33.) An official of the California Water Resources Control Board told us that in many plants baffles could be added quickly and cheaply to improve contact times.

Actual chlorine contact times can be measured by dye-tests, with minimum times being measured by the time it takes for the first dye to pass through the contact chamber. In our survey of sewage treatment plants using chlorine, 54 percent had never conducted such a test, and another 30 percent did not know if such tests had ever been conducted.

Initial mixing

Rapid and thorough initial mixing of wastewater with chlorine is needed for efficient chlorination. To achieve good initial mixing, it is necessary to apply chlorine in conditions of turbulent flow or by mechanical mixing. However, specialists in sewage treatment told us it is common practice for the chlorine solution to be applied directly to chlorine contact basins or to open channels. More than two-thirds of the plants we studied had no special device--hydraulic or mechanical--to provide rapid mixing of chlorine and wastewater. An official of the Maryland State Water Resources Administration told us that existing chlorination facilities can be modified by adding mechanical mixers to improve initial mixing.

Lack of State and EPA emphasis on chlorination efficiency

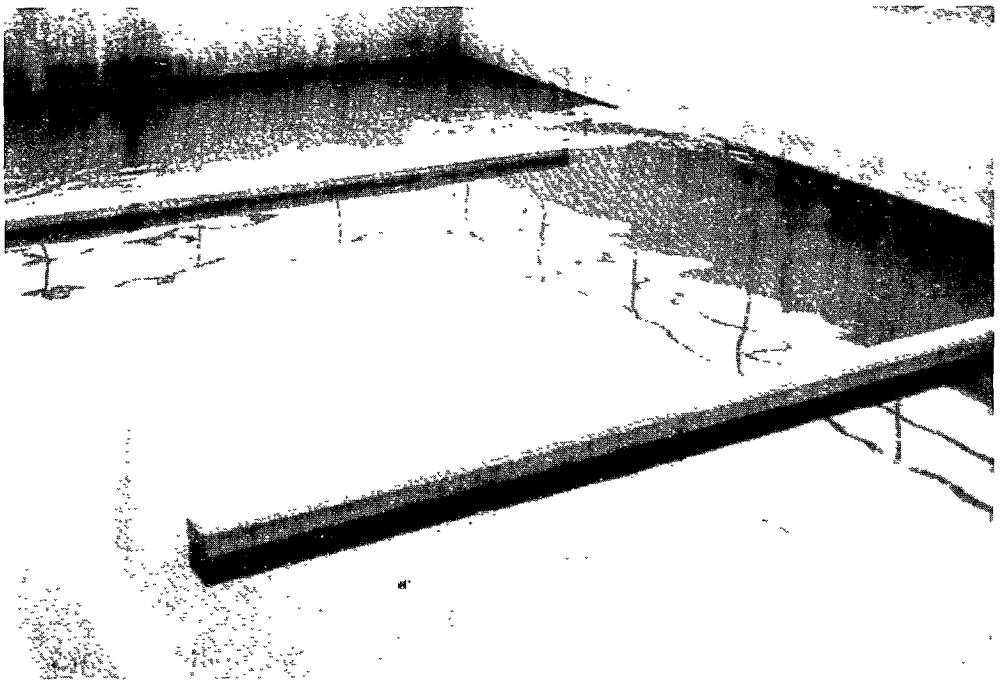
Neither EPA nor the States have effectively used the National Pollution Discharge Elimination System (NPDES) program to improve the efficiency of existing chlorination facilities. In addition, neither EPA nor the States have adequately reviewed plans and specifications for new construction of chlorination facilities to ensure chlorination efficiency.

An official of EPA's Municipal Permits Section said that EPA could include requirements for specific equipment in NPDES permits but it avoids doing so because of the problem of liability if the equipment does not achieve the desired objective. In a recent report entitled, "Continuing Need for Improved Operation and Maintenance of Municipal Waste Treatments Plants," B-166506, April 11, 1977, we recommended using the NPDES pollutant discharge permits to require specific actions at existing plants that would help improve plant operation and maintenance (for example, installing selected instrumentation). A similar approach could be used to improve the existing plants chlorination practices.

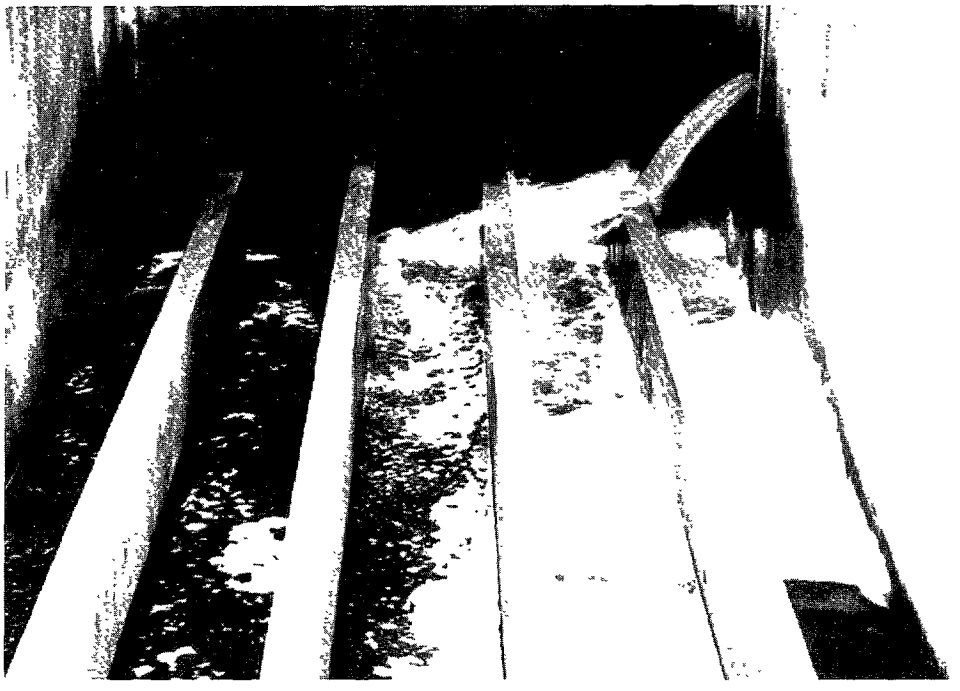
In our survey of State policies and practices, less than 12 percent of the States said they required rapid mixing devices--hydraulic or mechanical--as a permit condition. Less than 16 percent said they required automatic dosage control for sewage treatment plants. Only about 40 percent required adequate contact times, and, of these, only 2 out of 18 required as much as 30 minutes at peak flow. No States reported that they required dye testing of minimum contact times, and less than 10 percent required a minimum length-to width ratio for the contact chamber.

EPA's review of plans and specifications for new chlorination facilities is inadequate. Our review of 20 sewage treatment plant designs approved in EPA region III (Philadelphia), from July 1, 1974, through December 31, 1975, indicated the lack of review for elements of efficient chlorination. Of the 20 plants, designs for 3 were approved without automatic dosage adjustment of chlorine. Only 4 of the 20 plant designs provided for even a contact time of 30 minutes at peak flow. Ten had a contact time of 15 minutes, and six had a contact time of less than 15 minutes. None met the 40:1 length-to-width ratio; rather, they ranged from 1:1 to 33:1. Seven of the 20 plant designs provided for the addition of chlorine inside the chlorine contact chamber without mechanical mixing. According to EPA engineers, initial mixing was accomplished by turbulence of the wastewater as it entered the chlorine contact tank. At the insistence

EXAMPLES OF POOR BAFFLING IN CHLORINE CONTACT CHAMBERS

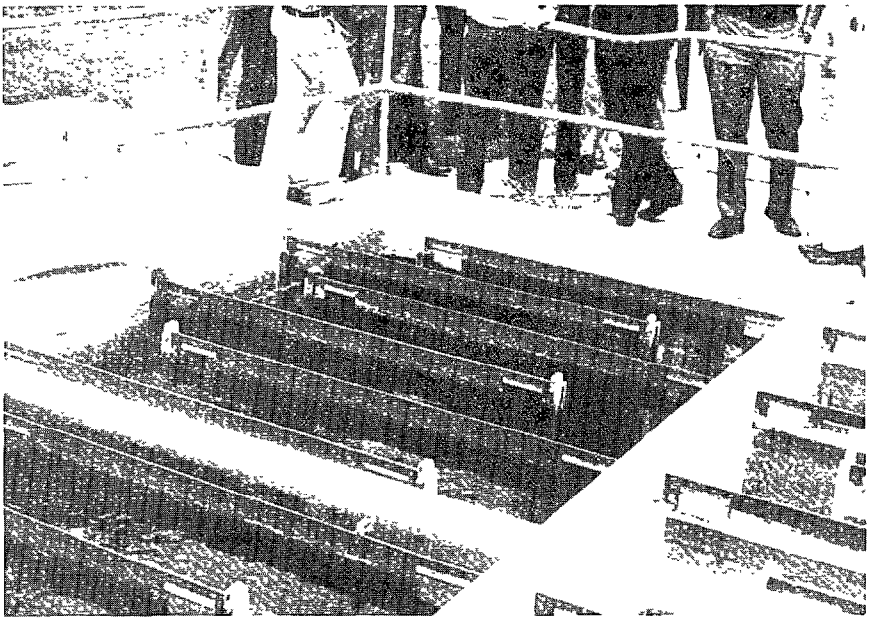


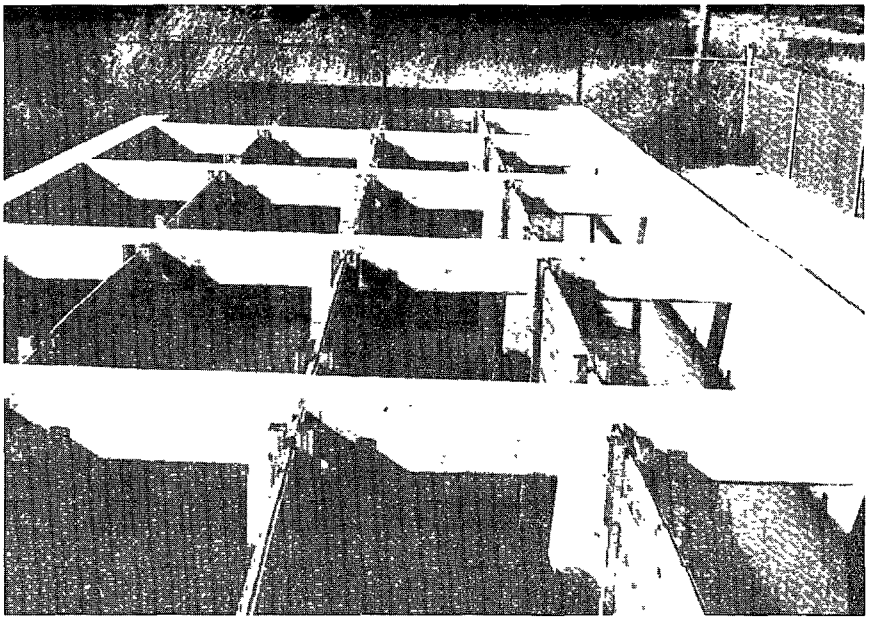
THE CHLORINE CONTACT CHAMBER AT THIS PLANT HAD ONLY TWO BAFFLES RESULTING IN LESS THAN ADEQUATE CONTACT TIME.



THE SEWAGE FLOWING INTO THIS CHLORINE CONTACT CHAMBER IS BYPASSING THE INITIAL BAFFLES.

EXAMPLES OF GOOD BAFFLING IN CHLORINE CONTACT CHAMBERS





BOTH OF THESE CHLORINE CONTACT CHAMBERS HAVE GOOD BAFFLING ALLOWING ADEQUATE CONTACT TIME.

of a State director concerned with the adequacy of mixing, plans for an eighth facility, originally designed to include an in-tank diffuser, were amended to include mechanical mixing.

An EPA technical bulletin recommended that the chlorine be rapidly and thoroughly mixed with the wastewater prior to its entering the chlorine contact chamber 1/, and experts have stated that mixing inside the contact chamber should be avoided. 2/ For these reasons, we concluded that the designs for the seven facilities would not ensure a sufficiently rapid and thorough initial mixing of chlorine and wastewater.

In EPA region I (Boston), we reviewed plans and specifications for 15 wastewater treatment plants approved between July 1, 1974, and December 31, 1974. In eight cases, mixing was effected by the natural turbulence of the wastewater as it flowed across a chlorine diffuser. Two of the plants lacked automatic dosage control, and 11 of them provided less than 30 minutes contact time at peak design flow. Length-to-width ratios for the 14 plants having chlorine contact tanks generally fell far short of the desired 40:1 ratio. Seven provided less than 20:1, and three of these provided less than 10:1.

We examined construction review guidelines from all EPA regions included in our review and found little evidence of EPA concern with minimizing chlorine residuals by efficient chlorination except in Seattle (region X) and Kansas City (region VII). Region X has published design guidelines which, in part, require that

--chlorine contact tanks be sized to provide each molecule of water with an actual contact time of not less than 30 minutes at peak flow;

--the actual contact time be verified by dye testing or an equivalent method during start-up of the disinfection facilities;

--hydraulic or mechanical rapid-mix facilities be designed ahead of the contact tanks or basins; and

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1/A technical bulletin entitled, "Protection of Shellfish Waters," published in July 1974 by the EPA Office of Water Program Operations.

2/Reported in the support for a full-scale study of wastewater disinfection by a California Department of Health Senior Sanitary Engineer.

--automatic dosage adjustment be used for larger plants.

For new construction, only about 43 percent of the States require a special mixing device--hydraulic or mechanical--to ensure good initial mixing. Only slightly more than 40 percent require automatic dosage control in new construction. While nearly all States require a minimum contact time at peak flow, only eight States require at least a contact time of 30 minutes at peak flows. Only 3 States require dye testing to assure actual minimum contact times prior to acceptance of new construction, and only 21--about 43 percent--require any specific length-to-width ratio.

In February 1976 EPA published a handbook of procedures for the construction grants program. The handbook contains a recommended checklist for the review of treatment facility plans and specifications. The checklist contains a section on chlorination facilities but it does not specify acceptable design or equipment requirements, such as rapid, thorough initial mixing and flow-proportional dosage adjustment; nor does the checklist refer to EPA technical bulletins that contain guidelines for regional and State personnel in reviewing construction grant projects. A manual of design and practice for wastewater chlorination systems is also being developed by the State of California for the EPA Office of Research and Development.

CONCLUSIONS

Sewage chlorination may be needed in certain specific circumstances. When it is practiced, however, residual chlorine is generally discharged far in excess of levels safe to aquatic life. Unnecessary use of chlorine contributes to energy sources being unnecessarily reduced since extensive amounts of energy are needed to produce chlorine. Although chlorine residuals are clearly toxic, improved sewage treatment and more efficient chlorination would allow disinfection with lower chlorine residuals. However, EPA and the States have generally failed to use NPDES permits to require sewage treatment plants to use specific pieces of equipment which would significantly improve chlorination efficiency. In reviewing plans and specifications for new construction, EPA and the States have also generally failed to require efficient chlorination facilities.

RECOMMENDATIONS

We recommend that the Administrator, EPA:

--When disinfection is deemed necessary for the protection of the public health, include chlorine residual

limitations in all NPDES permits for sewage treatment plants and for all industrial dischargers of chlorinated effluents.

--Lower the limitation on chlorine residuals in power-plant effluents.

--Require regional offices or the States, where appropriate, to tailor NPDES permits to assure the use of chlorine testing and operating equipment which would significantly improve chlorination efficiency at individual treatment plants.

--Incorporate efficient chlorination factors, such as rapid, thorough, initial mixing and flow-proportional dosage adjustment, into construction review criteria for all new plant construction.

REVIEW OF EPIDEMIOLOGICAL STUDIES OF DISEASE TRANSMISSION BY SWIMMING IN POLLUTED WATERS

Epidemiological studies attempting to demonstrate the differences in bacterial levels in bathing waters to levels of illness in swimmers have been inconclusive. A cause-and-effect relationship, at the bacterial levels typically found in the United States today, is questionable considering the amount of swimming done by the American public, the number of polluted beaches and old swimming holes, and the insignificant number of illnesses related to water contact. Marginal beaches and areas used by bathers despite high bacterial levels have had an extremely favorable epidemiological record. The few studies conducted on bathing water quality and health have been, at best, inconclusive.

In a 1961 study 1/ of salt water beaches on Long Island Sound, New York, no relationship between illness and water quality was observed. A 5-year British study 1/ came to a similar conclusion, namely, that unless there were large visible amounts of human waste in the water, there was little risk to the health of bathers in salt water.

A 1951 study at two Chicago beaches 2/ found a generally lower ratio of swimmer illness to nonswimmer illness prevalent at the poorer quality beach. In addition, the percentage of illnesses reported as gastrointestinal was smaller at the poorer quality beach. Illness data were analyzed in various ways in an attempt to correlate illness with exposure to bathing waters of varying bacterial densities. Only one method of analysis offered any suggestion of a positive result--evidence of a higher illness incidence following 3 days of swimming in high bacterial density waters compared to 3 days of swimming in low bacterial density waters. Additional analysis, however, tended to refute the suggestion of a relationship between bacterial (coliform) levels and disease.

1/Reported in Water Quality Criteria 1972, a report of the Committee on Water Quality Criteria, National Academy of Sciences-National Academy of Engineering.

2/"A Study of Bathing Water Quality on the Chicago Lake Front and Its Relation to Health of Bathers," Public Health Service Environmental Health Center, Cincinnati, Ohio.

A 1952 study 1/ compared the incidence of disease among persons swimming in a heavily polluted river and persons swimming in a well-chlorinated swimming pool and found that:

(a) The group that did most of its swimming in the chlorinated swimming pool apparently had the greatest number of illnesses.

(b) There was no correlation between the bacterial quality of the river water and the general illness incidence experienced by the bathers.

(c) Pool swimmers showed a tendency to have more illness of nongastrointestinal types (i.e., eye, ear, nose, throat, and skin) than did river swimmers.

(d) River swimmers showed a statistically significant tendency to have more gastrointestinal illness than pool swimmers, although the number of gastrointestinal illnesses reported by river swimmers was only 53 in over 3,700 swimmer-days, 13 more than statistically expected.

A 1974 study 2/ of illnesses related to two bathing beaches--a relatively unpolluted beach and a barely acceptable beach--found that the rate of subsequent vomiting, diarrhea, and stomach ache was significantly higher among swimmers (4.2 percent) relative to nonswimmers (2.6 percent) at the barely acceptable beach but not at the relatively unpolluted beach (3.9 vs. 3.5 percent). This overall finding was highly dependent on illnesses experienced by children under age 10--unusually high both for swimmers on the barely acceptable beach and for nonswimmers on the relatively unpolluted beach. Other data suggested that, within the range studied, ocean water quality is not related to rates of swimmer illness:

(a) The rate of swimmer gastronintestinal illness at the barely acceptable beach (4.2 percent) was not

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1/"A Study of Bathing Water Quality on the Ohio River at Dayton, Kentucky, and Its Relation to Health of Bathers," Public Health Service Environmental Health Center, Cincinnati, Ohio.

2/A draft paper on the Relationship of Microbial Indicators to Health Effects at Marine Bathing Beaches, EPA Health Effects Research Laboratory, Cincinnati, Ohio.

substantially different from that at the relatively unpolluted beach (3.9 percent) for persons over age 9; the rate at the relatively unpolluted beach (4.2 percent) was actually higher than that at the barely acceptable beach (3.7 percent) in spite of the fact that the barely acceptable beach was immediately adjacent to a beach posted as unsafe for swimming, and the data suggested an immediate source of raw fecal wastes.

(b) For persons over age 9, the gastrointestinal illness rate associated with swimming (i.e., swimmer rate minus nonswimmer rate) on the relatively unpolluted beach (1.0 percent) was actually higher than that on the barely acceptable beach (0.8 percent); for persons over age 19, the gastrointestinal illness rate associated with swimming on the relatively unpolluted beach (1.3 percent) was nearly twice as great as that on the barely acceptable beach (0.7 percent).

(c) Ethnic differences may account for the unusually high rate of illness associated with swimming, for children under 10, at the barely acceptable beach. The Latin Americans in the study experienced much higher swimming-associated illness rates, were more likely to swim than non-Latins, and constituted a much higher percentage of the beach population at the barely acceptable beach (54 percent) than at the relatively unpolluted beach (20 percent).

ALTERNATIVES TO CHLORINE FOR SEWAGE DISINFECTION

LAND APPLICATION

Land application frequently provides an effective way to remove harmful bacteria and viruses (and other pollutants) from wastewater. In addition, nutrients in wastewater enrich the land. Treated sewage is used for irrigation of crops, pasture lands, orchards, and vineyards; and for watering parks, golf courses, freeway landscapes, and forests. There are, however, disadvantages which limit the applicability of land treatment:

--Local conditions have a major effect on applicability and economic feasibilty.

--Each land application site generally requires a design produced specifically for it to preclude serious adverse environmental impacts; such designs frequently require input from a number of specialized professions.

--Harmful bacteria may survive for periods of a few days to several weeks or more in the soil and crops, and it may be transmitted when spray irrigation is used. According to several experts, when chlorine disinfection is practiced prior to land treatment, the effects of the chlorine residual on the soil are not known.

--Irrigation of pasture lands and of crops which are consumed raw may subject animals and humans to worm infestations. The eggs or intermediate forms of the organisms are resistant to both sewage treatment processes and chlorination.

WASTEWATER TREATMENT PONDS (LAGOONS)

There are over 5,000 wastewater treatment ponds in the United States representing about 25 percent of all wastewater treatment facilities and 90 percent of the facilities in communities under 5,000 people. Well designed wastewater lagoons can reach disinfection standards without chlorination prior to discharge but they cannot normally meet suspended solids standards consistently. Most facilities could be economically upgraded to meet suspended solids standards. They require large tracts of land, however, and the cost of land for evaporation ponds is not an eligible cost for Federal construction grants. Most lagoons are, therefore, constructed in areas where land is readily available.

OZONATION

Ozone has received the most attention as a disinfectant alternative to chlorine. Ozone has been used for 60 years to treat drinking water supplies in Europe and Canada. Its use in wastewater applications has been generally limited to pilot plant studies. Ozonated effluents appear to be less toxic than chlorinated effluents to aquatic life. Ozonation is also effective against viruses. In order to be an effective disinfectant, however, ozone requires a highly treated effluent (beyond secondary treatment) at all times and/or very high doses of ozone. Even without the cost of the additional treatment or high dosage, ozonation costs considerably more than chlorination/dechlorination and its production consumes considerably more energy than chlorine production. As with chlorine, toxic compounds may be formed from reaction of ozone with organics.

ULTRAVIOLET RADIATION

Ultraviolet radiation has seen limited use in wastewater disinfection. It is not toxic to the aquatic environment, but it is more expensive than chlorine, and, for adequate disinfection, a high quality effluent (beyond secondary treatment) must be provided.

BROMINE CHLORIDE

Bromine chloride, at an equal dosage with chlorine, will provide comparable bacterial disinfection and better viral disinfection. Brominated effluent may be as toxic as chlorinated effluent, but its residual toxicity is much shorter-lived. Existing chlorination facilities would require only minor modifications to convert from chlorine to bromine chloride. The cost may be considerably higher than that of chlorine, however, and the toxicity of brominated organic compounds is generally greater than that of the corresponding chlorine compounds.

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PRINCIPAL EPA OFFICIALS RESPONSIBLE FOR ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
ADMINISTRATOR:		
Douglas M. Costle	Mar. 1977	Present
John R. Quarles, Jr. (acting)	Jan. 1977	Mar. 1977
Russell E. Train	Sept. 1973	Jan. 1977
John R. Quarles, Jr. (acting)	Aug. 1973	Sept. 1973
Robert W. Fri (acting)	Apr. 1973	Aug. 1973
William D. Ruckelshaus	Dec. 1970	Apr. 1973
ASSISTANT ADMINISTRATOR FOR WATER AND HAZARDOUS MATERIALS:		
Thomas C. Jorling	June 1977	Present
Dr. Andrew Breidenback	Sept. 1975	June 1977
James L. Agee	Apr. 1974	Sept. 1975
Roger Strelow (acting) (note a)	Feb. 1974	Apr. 1974
Robert L. Sansom (note a)	Apr. 1972	Feb. 1974
DEPUTY ASSISTANT ADMINISTRATOR FOR WATER PROGRAM OPERATIONS:		
John T. Rhett	Mar. 1973	Present
Louis De Camp (acting)	Sept. 1972	Mar. 1973
Eugene T. Jensen	June 1971	Sept. 1972

a/Before April 22, 1974, the title of this position was Assistant Administrator for Air and Water Programs.

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