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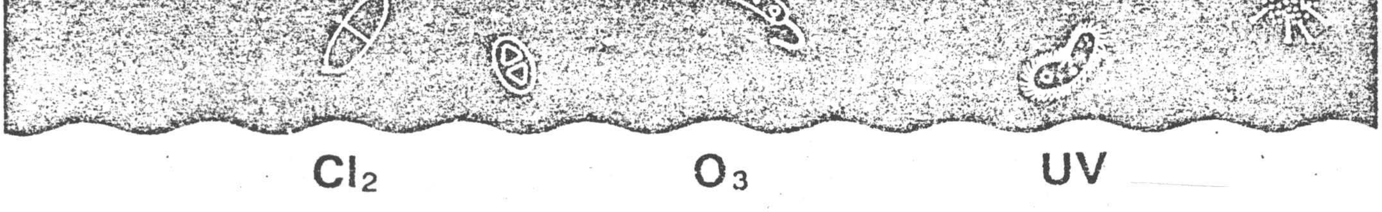

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16. ABSTRACT

The USEPA's Municipal Environmental Research Laboratory and Health Effects Research Laboratory, Cincinnati, Ohio sponsored a National Symposium on Municipal Wastewater Disinfection in Orlando, Florida, January 26-28, 1982.

The Symposium brought together scientists, engineers, and federal, state and local government officials for an exchange of information on health, technological and design/O&M considerations of wastewater disinfection. The conference was begun with philosophical pro and con papers on the need for wastewater disinfection. These thought provoking papers set the stage for the technical sessions that followed. The last paper was a summary of the conference with personal observations of a person long active in the water health field.

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	Wastewater health concerns	06M
	Disinfecting equipment	57U
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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions.

Two major functions of the EPA research and development program are (1) to develop control technologies and systems to protect people from unnecessary and harmful exposure to wastewater pollutants and (2) to determine the health effects of waste treatment and disposal practices. To these ends, the Municipal Environmental Research Laboratory and the Health Effects Research Laboratory in Cincinnati, Ohio have supported research studies in the respective areas.

This report is the result of a combined effort of the two laboratories to transfer relevant information obtained from recent research studies, most of which were funded by EPA. The holding of a research symposium and the publication of the proceedings is a viable mechanism for disseminating the latest results in a research area. This proceedings provides a comprehensive report on what is known concerning the health and technological aspects of wastewater disinfection.

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PREFACE

This symposium was the sequel to a similar one on the same topic held in Cincinnati, Ohio, in September 1978. It was designed to address many of the questions raised and deficiencies in knowledge identified at the prior meeting and to address an additional subject area, health aspects. The sessions were organized into three scientifically related but topically separate research areas: (1) health effects and epidemiology, (2) alternative disinfection technology, and (3) design and operation/maintenance considerations.

A brief comment concerning organization of the proceedings' contents is in order. The papers are printed in exactly the same order they were presented. Most of the printed material, however, appears in much greater detail than was presented orally. Those papers requiring peer review according to EPA's publication regulations were so treated. All extemporaneous discussions were tape recorded on site. Unfortunately, however, technical difficulties with the microphone and recording equipment were experienced early in the meeting, and consequently the questions and answers from the audience could not be included in the written proceedings herein. This was truly a disappointing development and the editors wish to apologize for their inability to provide a written record of this valuable informal dialog.

ACKNOWLEDGEMENTS

Appreciation is expressed to the speakers and authors of the papers for their many hours of labor and preparation, to the session chairman, and to the general registrants whose lively participation in the panel discussions contributed greatly to the success of the symposium. We also wish to thank the session moderators for the orderly progression of the sessions. Special thanks is expressed to the banquet speaker, Dr. Arthur Lane, Jet Propulsion Laboratory, whose banquet presentation entitled "The Voyager Odyssey to Jupiter and Saturn - The Legacy of a Master Storyteller" roused the fascination of all who attended.

The editors also acknowledge the perseverance and efforts of Ms. Sheri Marshall of the Dynamac Corporation and Mr. Denis Lussier of EPA's Center for Environmental Research Information for arranging for the hotel and banquet accommodations and coordinating registration and other administrative activities.

CONTENTS

1. DON'T CHLORINATE SEWAGE

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ABSTRACT

During the last decade, fisheri dependent on tributaries and fresh-water reaches of Chesapeake Bay have declined significantly. The decline took place in waters that should have benefited most by an unprecedented investment in sewage treatment plant construction. In every case, inquiries into the possible reasons for the losses implicated chlorine. Investigation showed that the use of chlorine at sewage treatment plants discharging into vital fish spawning areas had increased by several fold. More thorough study shows that chlorine and its byproducts are toxic to aquatic life, repel and thus deny spawning grounds to anadromous fish, and at barely detectable concentrations, decimate fish larvae and other first emergent forms of life. Furthermore, it is found that chlorination of ordinary sewage treatment plant effluent provides no significant public health protection and to the contrary, could result in public health hazards that might go undetected.

INTRODUCTION

Chesapeake Bay is the most productive estuary in the world. Under the dual assault of increasing population and a rising standard of living, the Bay has remained surprisingly beautiful and productive after three centuries of civilization. Where the Bay is concerned, Maryland and Virginia have practiced strong conservation measures for more than a hundred years.

However, during the nineteen seventies, aquatic life dependent on the Bay's tributaries showed signs of unusual disturbance. It is in the tributary streams that anadromous fish come to spawn, other fish reside year round, and still others come to forage. For finfish, the struggle to preserve the chemical, physical and biological integrity of Chesapeake Bay will be won or lost in its tributaries and tidal freshwater reaches.

During the Seventies, shad runs almost ceased. The commercial catch from the Susquehanna River and its flats at the head of the Bay dwindled from 184,000 pounds in 1971 to 2,300 in 1979. The Maryland Department of Natural Resources banned further harvesting of shad to protect the last remaining brood stock. Striped bass, the famed rockfish of the East Coast, went from a condition of plenty to one of relative scarcity. In 1970, the young-of-the-year averaged slightly more than thirty per seine haul during the annual survey conducted by the Maryland Department of Natural Resources. By 1981, the average was barely more than one per haul. Perch and other resident fish showed a marked decline in some tributaries.

It was puzzling that this deterioration took place during the Seventies, a decade of unprecedented expenditure for sewage treatment plants and other water pollution control measures. One possible solution to the puzzle began to emerge as the search for reasons for tributary crop failures progressed. In every case, chlorine was implicated. That led to a look at the use of chlorine. It was found in six spawning rivers that chlorine discharge increased 4.4 fold from 1974 to 1980.

An estimated 13,900 tons of residual chlorine per year are discharged by Maryland sewage treatment plants. Health Department records reveal that 115 sewage treatment plants annually discharge about 300 tons of residual chlorine into spawning rivers.

The practice of chlorinating sewage treatment plant effluent was examined to find if it is a significant factor causing damage to Chesapeake Bay's tributary dependent aquatic life. The public health aspects of the practice were examined also.

DAMAGE TO AQUATIC LIFE

Literature has proliferated in recent years as the damage to aquatic life caused by chlorinated sewage effluent has become more and more apparent. Space will not permit citation of all of the reports and publications reviewed. Instead, a small number have been selected to illustrate conclusions drawn from a far greater volume of literature.

Collins and Deaner (3) quoted literature (9) (10) to show that when wastewater is chlorinated, toxic compounds such as cyanogen chloride can be formed. Questions regarding the formation and nature of the various toxic compounds and their effect on aquatic life remain unanswered because of the complexity of sewage and chlorine reactions.

Work of Michigan's Department of Natural Resources was described which proved that chlorinated sewage is toxic to fish. Fathead minnows and rainbow trout were exposed to chlorinated and unchlorinated sewage effluents. Survival was high during the non-chlorinated phase but in every case, all trout were killed at chlorine residuals that were less than 0.1 mg/l and all minnows were killed at chlorine residuals less than 0.2 mg/l. The amperometric method was used to measure chlorine residuals. The extreme toxicity is demonstrated by the finding that amperometric chlorine of only 0.02 mg/l below two of the outfalls in Michigan killed 50 percent of the exposed rainbow trout within 96 hours.

Collins and Deaner reported also on chlorine-induced fish kills in California's Sacramento River. To test the thesis that chlorinated effluent was the culprit, king salmon fry were exposed to river water taken upstream, at the discharge point, 100 feet downstream, and 200 feet downstream. The upstream water caused no adverse effects. Water from the discharge point killed all of the fish in 12 minutes. In less than an hour, all of the fish in the water taken 100 feet downstream from the discharge point were dead and, in less than an hour and a half, all were dead in the 200 feet downstream water. In a companion test, salmon fry were suspended in the Sacramento River. All fish below the outfall were dead within 14 hours while all above survived. Downstream chlorine residuals ranged from 0.2 mg/l to 0.3 mg/l during the test period.

Osborne, et al, (17) studied the effects of chlorinated sewage effluents on fish in the Sheep River, Alberta, Canada. They found no mortality when caged fish were subjected to unchlorinated effluent but 100 percent mortality occurred when exposed to chlorinated effluent. They concluded that chlorination of effluent was the principal factor in fish death. Quantitative sampling of fish populations supported the contention that fish avoid chlorinated effluents.

Giattina, et al, (6) also investigated the avoidance of fish to chlorine at a power plant on the New River in southwestern Virginia. They reported that laboratory determined avoidance concentrations generally predicted the total residual chlorine concentrations that would elicit avoidance behavior under natural field conditions. In general, fish avoid chlorine residuals that are 50 percent or less of the median lethal concentration.

Tsai (21) studied fish life below 149 sewage treatment plants and concluded that turbidity and chlorine caused species diversity reduction below the outfalls. In the upper Patuxent River, (22) chlorinated sewage acts as a toxic material which seriously reduces fish abundance below outfalls, and chlorinated sewage will trigger fish to avoid the outfall water. Chronic physiological responses to chlorine include delayed mortality, depressed activity, decreased growth, and decreased spawning success.

Freshwater reaches of upper Chesapeake Bay are important spawning grounds for many fish species including striped bass. Annual surveys showed that by the end of the Seventies, egg-laden female rockfish still returned to their spawning areas each Spring in great numbers. Eggs were released and found fertilized in the water but few survived to become small fish. It has been shown (12) that chlorine in concentration as low as 0.01 mg/l greatly reduces the percentage of rockfish eggs that are hatched. To compound the problem it has been found (12) that the larvae once hatched continue to be decimated by chlorine. A total residual of only 0.04 mg/l is lethal in one hour to 50 percent of two day old larvae. Chlorine is equally toxic to 30 day old juvenile fish.

Chlorine in the saltwater portion of Chesapeake Bay produces toxic oxidants, chlorine-produced oxidants, from naturally occurring bromine. Eggs and larvae of oysters and clams are very sensitive to chlorine-produced oxidants. Roberts and Gleeson (18) demonstrated that 50 percent of four hour old oyster larvae are killed by only 0.026 mg/l of such oxidants. Rosenburg and co-workers (19) found that chlorine-produced oxidants were lethal to 50 percent of 96 hour old oyster larvae at concentrations of 0.06 mg/l and 16 hour old clams at 0.27 mg/l.

PUBLIC HEALTH JUSTIFICATION

Attention turned to alternatives as evidence began to demonstrate that sewage treatment plants chlorinating their effluent are a major source of toxic pollutants. Alternatives under consideration include: better control of chlorine; detoxification of the effluent; substitution of biocides that produce less toxic residuals; and use of a chemical or radiation that will produce a residual-free effluent. Unfortunately, each alternative has its own set of costly difficulties, and may damage aquatic life. Each may pose some danger to sewage treatment plant operators and perhaps to the surrounding community.

For instance, better control of chlorine application may seem to be a simple inexpensive matter, but it isn't. Much improvement can be obtained by eliminating wasteful, almost promiscuous, misuse of chlorine, but that is not enough. There are very few sewage treatment plants that have been built so that precise control of effluent residual in the part per billion range is possible. To meet an effluent standard that low, drastic changes have to be made in the capability of the sewage treatment plant and in its operation. The orthotolidine color comparitor is useless. Instead, the most precise method of analytical measurement must be used. Automatic chlorine residual monitoring and feedback control units are necessary. Only four percent of the sewage treatment plants that were surveyed (7) have feedback control. In contrast, 60 percent use a manual method to feed chlorine.

Before blindly accepting the proposition that there is a need to find a substitute for chlorine, the possibility that disinfection of sewage effluent is not necessary in most cases should be examined. The public health necessity of disinfecting sewage effluent under ordinary circumstances must be justified for the practice to continue in any form.

Some disagree (11) claiming that: "The cornerstone of public health is preventive medicine and to require the justification for wastewater disinfection is a giant step backward." The fault in that assertion is that the alleged "public health" and "preventive medicine" benefits of effluent chlorination are what need to be justified. As for requiring justification, the health of the human race was improved dramatically as soon as public health practitioners were required to justify their strongly held beliefs.

There is an assumption that the act of chlorinating sewage will decrease the danger of disease, but for all practical purposes, that assumption is not valid. Food or water contaminated with sewage will cause disease and remains dangerous whether it is chlorinated or not. After a decade of nationwide chlorination of sewage, there is no evidence to demonstrate that the incidence of any illness has decreased as a result of that practice. The United States chlorinates its sewage - England doesn't. There is no credible evidence to show that any related illness occurs more frequently in England than it does in the United States.

The U.S. Public Health Service with its Center for Disease Control in Atlanta, Georgia, is the world's outstanding authority on the causes of disease and how to prevent them. The Comptroller General reported to Congress (4) that "The Center for Disease Control has taken the official position that disinfection of sewage provides little public health benefits". In correspondence, G. F. Mallison of the Bacterial Diseases Division of the Center for Disease Control, wrote "I see, with rare exceptions, absolutely no need with respect to health in attempting to control microbial contamination after secondary sewage treatment".

Health Hazard to Workers

An examination of the health effects of chlorinating sewage might start with its effect on sewerage workers. In the debate over the public health benefit or lack thereof that comes from chlorinating effluent, the health of the sewage treatment plant operator is largely ignored. That is a mistake because chlorine creates an occupational hazard and there have been a significant number of incapacitating accidents. Chlorine in the air is almost as toxic to humans as chlorine in the water is to aquatic life. A concentration of 0.1 percent of chlorine in the air is likely to be fatal after a few breaths and almost certain to cause death within ten minutes. A safe allowable concentration of one part per million has been established by the Occupational Safety and Health Administration.

In a survey (7) conducted and reported by the Water Pollution Control Federation in 1980, it was found that over 11 percent of the sewage treatment plants surveyed reported chlorine accidents in which people required medical treatment.

Debate Over Recreation Water

Protection of the health of people using water for recreation is a frequently used justification for sewage chlorination even though epidemiological evidence of its value in that regard is nonexistent. In fact, no study has examined the proposition that recreation waters shown to cause disease can be made safe by chlorinating sewage effluent. Instead, the effort to date has been to demonstrate, if indeed it is possible to demonstrate, that swimming in polluted water causes a higher incidence of disease and, if so. to find an indicator bacterium that correlates with risk. For thirty years the aim has been to establish a number for a particular indicator organism that will give assurance against disease contracted from swimming in sewage polluted water.

That there is a safe threshold of pollution for swimming, and that such a threshold can be identified through an allowable number of easily measured indicator bacteria, is a strongly held belief, but it is not shared by all. Stevenson (2) pioneered studies in Lake Michigan and the Ohio River. Though the studies were far from conclusive, he arrived at a concentration of total coliform bacteria as the best practical standard. Geldreich (5) related Salmonella detection to fecal coliform densities and recommended a standard based on fecal coliform detection. Cabelli (2) found an increase in gastrointestinal disturbances among those swimmers who immersed their heads in water. Based on a correlation with fecal enterococci, a mathematical expression of the risk of increased incidence of disease was developed.

A higher incidence of disease caused by swimming in polluted waters is not a universal finding. The National Technical Advisory Committee found Public Health Service studies on which the coliform standards are based to be far from definitive. They expressed an urgent need to find if there is a correlation between the various indicator organisms and disease attributable to water recreation. In Sydney, Australia, many years of epidemiological study in connection with Sydney's world famous bathing beaches produced no evidence of water-borne diseases caused by unchlorinated sewage effluent.

In the United Kingdom, a committee which Moore (14) headed did research for six years in the 1950's and failed to establish any significant bacterial hazard from sea bathing. Later work by the Water Pollution Research Laboratory also failed to find a satisfactory method for establishing bacterial standards for bathing waters. It is Moore's contention that no shred of evidence has been produced in Europe during the past 20-30 years that indicates that human health has been endangered in the absence of bathing water standards.

From a realistic public health perspective, the incidence of sewage pollution related diseases contracted through recreational use of water is trivial. Competent persons have searched for such a relationship. Some claim that it does exist and others find that it does not. Even if it does exist, the effort required to ferret out the relationship is strong testimony that swimming in polluted waters accounts for a miniscule fraction of the total incidence of serious disease. Most of the minor irritations that do occur are of the eye, ear, nose, and skin variety, making it likely that transmission is person to person and not sewage to person. It is highly unlikely that an enteric disease indicator bacterium will ever be found that correlates with those ailments.

Even if a sewage treatment plant discharge to swimming water disease relationship does exist, effluent chlorination would be the wrong thing to do. In fact, health receives better protection if sewage effluent is not chlorinated. Chlorination of ordinary sewage treatment plant effluent kills more of any of the various indicator bacteria than it does of the virus in sewage effluent, and virus as well as other chlorine resistant organisms are the main cause of concern. That being the case, chlorination of sewage effluent diminishes the indicators of pollution in relation to the prevalence of the real danger, thus, creating a false sense of security. A safer course of action is to provide better sewage treatment and greater separation between outfalls and bathing beaches.

Shellfish

Like bathing beaches, chlorinating effluent gives the illusion of public health protection, but the real protection of shellfish growing waters is provided by good sewage treatment and safe separation between outfalls and shellfish beds. Consumption of raw oysters harvested from sewage polluted waters caused a high incidence of disease prior to the shellfish sanitation program initiated by the U.S. Public Health Service in the late 20's. Since the time that the program became effective, not one case of illness has been traced to oysters harvested from approved waters in Maryland.

The principal elements of this effective program are separation between pollution discharge and shellfish harvesting beds coupled with a bacteriological standard applied at the place of harvest. The bacterial standard for shellfish harvest water was derived from empirical observations at a time when the discharge of untreated sewage was commonplace and many people became ill from eating oysters taken from polluted water. Unlike recreational waters, it was clearly demonstrated that when people ate oysters taken from polluted water with an indicator bacterial density higher than the standard, they got sick. When they ate oysters from waters cleaner than that indicated by the standard, they did not get sick.

The shellfish harvesting bacterial standard works because of the general relationship that exists between the density of indicator bacteria and the density of disease agents. Chlorination of ordinary sewage treatment plant effluent alters the indicator/disease producing organism ratio in a dangerous fashion. It is disconcerting that virus can persist even after indicator bacterial organisms have been killed, because shellfish contamination by virus has replaced bacteria as the disease agent of major concern.

Olivieri, et al, produced data that strongly supports the hypothesis that free chlorine is required for significant viral reductions (16). Free chlorine for the required contact time calls for break-point chlorination, rapid mixing, and precise hydraulic control, things that are rarely achieved in conventional sewage treatment plant operation.

Recognizing that chlorine can disrupt the traditional indicator-pathogen ratio, Bisson and Cabelli (1) have looked for alternatives. They have examined the feasibility of using a spore former, Clostridium perfringens, as an indicator for the potential for infectious disease from fecal pollution because the spores of C. perfringens are much more resistant to chlorination that E.coli. For specific applications against the potential for infectious disease arising from fecal pollution of the aquatic environment, they suggest that there is no universal microbial indicator.

Destruction of the Natural Barrier

The argument is sometimes advanced that chlorination of ordinary sewage treatment plant effluent provides another barrier in a multiple barrier concept of public health protection. The strategy is to provide as many barriers between a source of disease organisms and the public as opportunity and cost will permit. The idea is sound but chlorination of sewage treatment plant effluent does not impose a dependable barrier. Instead, it destroys one of the most effective barriers in existence. That barrier is nature's relentless antagonism to the disease producing bacteria and virus found in sewage.

Mitchell (13) studied the destruction of sewage bacteria and virus that were discharged into seawater. He found that enteric bacteria are destroyed by a specific antagonistic microflora that develops. Mitchell was able to classify three groups of native seawater organisms associated with the accomplishment of this destruction: native bacteria that destroy by enzymatically lysing enteric bacteria cell walls; obligatory parasitic bacteria; and, amebae which attack and consume bacterial cells. Of these, the amebae are the most active. With respect to virus, native marine microflora are involved in a manner similar to that observed with enteric bacteria but a chemical component of seawater was also shown to be involved in the virus destruction.

The specialized culture that develops in biological sewage treatment processes exhibits similar antagonism to disease producing organisms. Unfortunately, chlorination of sewage effluent kills the predators as well as the prey. The culture of specialized organisms that started their attack on sewage-borne pathogens within the sewage treatment plant are disrupted and the disruption carries over to the organisms of natural purification in the receiving waters. Walsh and Mitchell (23) found that chlorination of effluent produced hydrocarbons which can cause damage to the natural predators responsible for self purification in the vicinty of sewage outfalls.

In most situations the barrier imposed by nature's system is far more important to the protection of shellfish beds than the superficial protection gained by the mere reduction of indicator bacteria that occurs when chlorine is added to ordinary sewage treatment plant effluent.

Disinfection

Contrary to repetitive misuse of the word in water pollution control literature, the conventional practice of chlorination at sewage treatment plants does not produce a disinfected effluent. The term "disinfection" is used to describe a process that removes all organisms capable of producing a disease. In every other field of endeavor, including milk, food, drinking water, and hospital care, "disinfection" has that meaning. It does not imply sterilization where all forms of life are destroyed, but it does mean that a disinfected material will no longer produce infectious diseases.

Water pollution control workers are quick to point out that in the general case, they don't mean that kind of disinfection when they use the word. No matter what the professional means, it is what administrators, the press, and the informed public believe that counts. The public wrongly perceives that chlorinated sewage is disinfected because water pollution control workers continually tell them that it is.

No knowledgeable person would contend that chlorination of ordinary sewage treatment plant effluent would render it disinfected, incapable of producing disease. The reverse is true; chlorinated sewage treatment plant effluents are highly infectious and should be treated with appropriate caution. The use of the word, disinfection, is in itself dangerous in this situation because it promotes a false sense of security and that could lead to relaxation of the basic principles of sanitation that are, after all, the main bulwark of public health protection.

It is well established that stringent conditions must be met before chlorine or any chemical that acts in a related fashion can disinfect. Those conditions include the removal of essentially all suspended solids, turbidity, and interfering substances including BOD. Sewage effluent requires filtering and break-point chlorination to produce on the order of 1.0 mg/l of hypochlorous acid (HOCL) for 30 minutes to achieve disinfection. Chlorine must be completely and uniformly mixed as rapidly as possible. Careful engineering of a holding and contact chamber is a necessity. Morris (15) has pointed out that any measurable degree of short circuiting is ruinous. Only 0.01 percent of raw fluid may cause the water to fall below hygienic standards.

Obviously disinfection is not accomplished when chlorine is added to the solids laden, organic rich effluent from an ordinary secondary sewage treatment plant. Only in a very few instances where sewage is being conditioned for direct reuse in specifically designed and operated purification works is true disinfection practiced.

Chlorinated Hydrocarbons

While some persons within the U.S. Environmental Protection Agency