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A REPORT ON THE CONCENTRATION, DISTRIBUTION AND  
IMPACT OF CERTAIN TRACE METALS FROM SEWAGE  
TREATMENT PLANTS ON THE CHESAPEAKE BAY

by

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## EXECUTIVE SUMMARY

### TO MANAGEMENT:

RESEARCH HAS BEEN DIRECTED TOWARDS ASCERTAINING THE IMPACT OF METALS FROM SEWAGE TREATMENT PLANTS ON THE CHESAPEAKE BAY ECOSYSTEM AND TO DEFINE THE PHYSICAL-CHEMICAL-BIOLOGICAL DYNAMICS OF THESE METALS ONCE IN THE ESTUARINE ENVIRONMENT. OUR RESEARCH IS NOT COMPLETE, BUT DUE TO THE SERIOUSNESS OF THE PROBLEM, WE PRESENT OUR PRELIMINARY FINDINGS.

### CONCLUSIONS:

I) FROM DETAILED ANALYSES OF SEWAGE EFFLUENTS FOR METALS AND UTILIZATION OF EXISTING PUBLISHED DATA FROM OTHER AREAS IN THE UNITED STATES, WE CONCLUDE THAT: FOR THE METALS CADMIUM, COPPER, ZINC AND LEAD, THE SUPPLY CONTRIBUTED TO THE CHESAPEAKE BAY BY SEWAGE TREATMENT PLANTS IS PROBABLY WITHIN ONE ORDER OF MAGNITUDE OF THE FLUVIAL SUPPLY. ON THE OTHER HAND, FOR MANGANESE, IRON AND NICKEL, THE SUPPLY FROM RIVERS EXCEEDS THAT FROM WASTE WATER.

II) FOR AT LEAST ONE SEWAGE TREATMENT PLANT\* MOST OF THE METALS RELEASED BY THE EFFLUENT ARE DEPOSITED WITHIN A FEW MILES OF THE OUTFALL. COMPARISON OF THE SEDIMENT METAL CONCENTRATIONS NEAR THE OUTFALL WITH DATA FROM OTHER AREAS OF THE BAY SHOWED THAT ZINC, LEAD, CHROMIUM, CADMIUM AND COPPER WERE ONE TO TWO ORDERS OF MAGNITUDE HIGHER IN THESE SEDIMENTS THAN IN UNCONTAMINATED AREAS. SUCH LARGE CONCENTRATIONS COULD HAVE AN ADVERSE EFFECT ON THE BIOTA. THIS MAY HAVE OCCURRED SINCE THE BOTTOM OF THIS RIVER IS ESSENTIALLY A BIOLOGICAL DESERT WITH A BIOMASS OF MUCH LESS THAN  $100\text{mg}/\text{m}^2$ .

III) THE OYSTER, CRASSOSTREA VIRGINICA, CAN CONCENTRATE METALS FROM SEWAGE

EFFLUENT IN A VERY SHORT TIME PERIOD. OYSTERS WERE SUBJECTED TO VARYING CONCENTRATIONS OF SEWAGE EFFLUENT IN A CONTROLLED LABORATORY ENVIRONMENT AND THEIR METAL BODY BURDENS WERE ASCERTAINED AT THE END OF THE EXPERIMENT. IT WAS FOUND THAT THE MAGNITUDE OF UPTAKE VARIED DEPENDING ON THE METAL IN QUESTION BUT THAT IN THE CASE OF ZINC, FOR INSTANCE, LEVELS INCREASED FROM AN AVERAGE OF 1000 PPM TO 1500 PPM IN ONLY 13 DAYS AT AN EFFLUENT CONCENTRATION OF 0.6%. THIS IS EXTREMELY IMPORTANT IN LIGHT OF THE FACT THAT BETWEEN 1 AND 2% OF THE FRESH WATER ENTERING THE BAY IS NOW SEWAGE EFFLUENT AND THE AMOUNTS WILL UNDOUBTEDLY INCREASE.

RECCOMENDATIONS:

I) TRACE METALS ARE NOW ENTERING THE CHESAPEAKE BAY FROM SEWAGE TREATMENT PLANTS IN QUANTITIES WHICH RIVAL NATURE. THEREFORE THESE POTENTIALLY TOXIC INPUTS SHOULD BE CONSIDERED IN THE DESIGN AND SITING OF SEWAGE TREATMENT PLANTS ON THE CHESAPEAKE BAY.

II) ECOLOGICALLY AND COMMERCIALY IMPORTANT ORGANISMS, SUCH AS OYSTERS, CAN ACCUMULATE METALS FROM SEWAGE EFFLUENTS. EVEN IF ACUTE OR CHRONIC EFFECTS OF SEWAGE METALS ARE NOT EXHIBITED IN A SPECIES, THE RESOURCE MAY NOT BE USABLE BY MAN DUE TO RESULTING METAL CONCENTRATIONS WHICH ARE ABOVE FDA TOLERANCE LEVELS. THEREFORE PROCESSES WHICH REMOVE METALS FROM SEWAGE SHOULD BE INCORPORATED INTO TREATMENT DESIGNS FOR PLANTS CONSTRUCTED NEAR PRODUCTIVE SHELLFISH GROWING AREAS.

\*TO DATE ONLY ONE PLANT HAS BEEN STUDIED.

## PREFACE

Population densities are ever increasing on the shores of the Chesapeake Bay and hence the flow of goods and services is being shifted to supply these people. This self perpetuating system demands more and more of the surrounding environment for recreation, work and waste disposal. This is the case for the Chesapeake and its sub-estuaries.

According to Brush (1974), of the total fresh water input into the Chesapeake Bay, between 1 and 2 percent is treated sewage. Toxic components on these waters may be of paramount importance in the Bay ecosystem and may have disastrous effects on the biota. It is essential then that the magnitude of the existing problem be determined and understood, and results and recommendations be made available to decision makers so that in the future we can control the inputs, properly select sewage outfall locations and preserve the Chesapeake Bay for future generations. This document is a first attempt at this.

The inputs of sewage into the tidal portions of the Chesapeake Bay are increasing yearly. As an example, in 1952, the treated sewage flow into the estuarine James River and its tributaries was 37 million gallons per day, in 1962 it had increased to 53 million gallons per day and by 1972 the flow was 87 million gallons per day (Figure 1).

More and more are the estuaries being called on for waste disposal with little attention being given to the composition of the waste other than biochemical oxygen demand (BOD), suspended solids (SS) and coliforms. Nutrients such as the nitrogen and phosphorus compounds, so abundant in domestic sewage, are now being investigated and their dynamics and responses, once in the estuary, modeled. These efforts were initiated in part as a result of the visible, noxious results of over fertilization of the waters by sewage. Just within the last two years massive fish kills have been observed in the Potomac and James Rivers which are apparently due to chlorine and its derivatives from sewage treatment plants. Hundreds of thousands of fish were killed, thus supplying the emphasis and need for a better understanding of the after effects of disinfection by chlorine.

Trace metals in treated sewage effluents pose a similar problem with respect to the well-being of the receiving stream. Data indicate that on a yearly basis, nearly as much or more of the metals cadmium, copper, chromium, lead and zinc enter the Bay from sewage treatment plant outfalls as from natural fluvial supplies (Figure 2). Obviously there is need for concern. Only recently have the newspapers reported on the deaths of scores of people due to mercury poisoning in Japan and more recently in Iraq. Scientific literature now reports that Cadmium may cause a sometimes fatal disease, Itai-Itai. In these "metal poisonings", man

has been implicated as being negligent by improper use and/or disposal of trace metals. In the case of some of our marine and estuarine species, the natural metal levels are high - mercury in sword fish and tuna for instance. Other examples are easily obtained by examining the available literature on oysters. It is not uncommon to find oyster concentrations of 2000 ppm zinc, 100 ppm copper and 1 ppm cadmium occurring naturally. In areas where there are known trace metal effluents, the levels increase dramatically - 20,000 ppm zinc, for instance, in oysters near an outfall disposing zinc. It is, therefore, apparent that the "unnatural" inputs can be manifested in the biota, and may be of public health significance. Aside from the direct effects of toxic metals on man, the elements exhibit toxicity to the marine biota. This discussion serves only to show that we must be concerned with many components of treated sewage which before, due to the relatively small percentage of effluents entering the Bay have been ignored.

The following sections summarize the preliminary finds of the metals group of the Chesapeake Research Consortium. These data resulted from a project funded by the National Science Foundation - RANN Program.

Metals in Sewage and Receiving Waters



## Introduction:

Many trace metals are known to be toxic in high concentrations to a wide variety of estuarine plants and animals (Bryan, 1971; Ackefors, 1971). Furthermore, even at subtoxic levels, the presence of harmful metals such as Hg can render commercially valuable fish and shellfish unmarketable. Although these metals enter estuaries from many natural and man-made sources, one of the most important is unquestionably ordinary municipal wastewater. For example, Young, et al (1973) estimated that municipal wastewater was the principal contributor of Ag, Cr, Cu, and Ni to the Pacific Ocean in the Southern California Bight; it was also a major source of Hg, Pb, and Zn. Similar conclusions were reached by Galloway (1972). Because wastewater is a major source, it is important to determine the fate of trace metals discharged by wastewater treatment plants. The question whether natural processes rapidly deposit them from the receiving water or if they remain mobile and thus available to organisms needs to be answered.

## Conclusions:

To obtain information on the fate of trace metals discharged to an estuarine environment, analyses have been made on water and sediment samples from Back River, Md., and on effluent from the large wastewater treatment plant that discharges there. Within 2-3 km of the outfall, the concentration (in  $\mu\text{g}/\text{l}$ ) of all metals decreases as follows: Mn, 120 to 90; Fe, 570 to 300; Cu, 53 to 7; Zn, 280 to 9; Cd, 3.5 to 0.5; and Pb, 31 to 4. Except possibly for Mn and Fe, these decreases are much greater than can be ascribed to simple dilution, so physical, chemical or biological processes must be removing metals to the sediments. Correspondingly, sediment concentrations of Cu, Zn, Cd, and Pb are approximately one order of magnitude higher than normally found in uncontaminated areas. After the initial decrease, concentrations of Mn and Cd in the water begin to rise again, suggesting remobilization from the sediments. Comparison of the estimated annual discharge of 8 trace metals to the Chesapeake Bay from wastewater treatment plants and from rivers suggests that the wastewater input may be within one order of magnitude of the fluvial input for Cr, Zn, Cd, and Pb. Of the metals studied, Cd presents the greatest potential for serious pollution because its input from wastewater probably exceeds fluvial input, it appears to be readily remobilized from sediments, and it is known to be toxic to many organisms.

Sewage Metals in Bottom Sediments

## Introduction:

The Chesapeake Bay estuarine system, a major feature of the eastern seaboard, is an important resource for the Middle Atlantic region. It supports a large seafood industry, provides varied recreational opportunities to a large segment of the east coast population, and serves as a spawning ground and habitat for a wide variety of marine organisms and waterfowl. The Bay and its tributaries have also been used by man as convenient disposal sites for his sewage wastes and as heat exchangers for cooling his power generating plants. Initially these insults had little effect on the overall bay system; however, accompanying large population increases, the pressures of man's activities have reached proportions such that deleterious effects are beginning to be felt in various parts of the bay system. Shellfish from some areas of the Bay, for instance, cannot be safely consumed because of bacterial contamination from sewage effluent or are unpallatable because of their high content of heavy metals. It is clear that man must carefully and intelligently plan future use of all segments of the Chesapeake Bay estuarine system in order to maintain the quality of this environment and prevent its further deterioration.

Intelligent planning of future development of the bay area requires information on all aspects of the system--physical, chemical and biological. Sewage plant effluent and the cooling water discharge from power plants are sources of heavy metals. Little work has been done in the Bay to delineate natural levels of trace metals, the amounts added by man's activities, the behavior of trace metals in the estuarine environment or their sources and sinks.

## Conclusions:

The concentrations of selected trace metals (Cu, Pb, Fe, Cd, Cr, Co, Ni and Zn) in bottom sediment and pre waters were investigated (1) in the Back River Estuary as a function of distance from the Back River sewage treatment plant outfall and (2) with depth in the sediment column. Initially, samples of the upper surface distribution of these metals in the estuary. Striking trends were observed in the concentrations of Pb, Cd, Cu, and Zn with distance from the outfall. Pb exhibits a maximum in concentration in the sediment at the outfall (800 ppm) and decreases to its lowest level (70 ppm) at the mouth of the estuary. Cu, Cd, and Zn all show maximum accumulations at a distance of two miles downstream from the outfall, suggesting a different chemical behavior for these elements than for Pb. With depth, the trace metals examined exhibit sharp decreases in concentration between 40 and 70 cm beneath the sediment-water interface along the length of Back River. Physically, the sediment changes abruptly from a compact green clay to a black organic-rich mud at the same level. This break may represent the start of sewage discharge into Back River. The green clay preserves abundant burrows of benthic organisms, but the black mud is devoid of both preserved remnants of burrows and of live benthic organisms. Apparently, the environment in Back River is toxic to benthic organisms, either due to the high trace metal content, or perhaps due to other toxic substances released in sewage outfall or industrial discharges. More extensive research is needed on the chemical mechanisms regulating the trace metals in this environment.

Sewage Metal Uptake by Oysters

## Introduction:

The Chesapeake Bay and its tributaries have long been regarded as being among the best shellfish producing regions in the world. However, the growing areas are rapidly decreasing as human population expands and shifts. More and more are the shorelines being populated and the accompanying wastes are being dumped into the waters. Not only are the shellfish decreasing in numbers but also many productive beds are "off limits" due to pathogenic bacteria from sewage effluents. Within the next several years there will undoubtedly be human health standards established for other substances such as trace metals. Already the tolerance level for mercury in shellfish is 0.5 ppm.

Oysters and other benthic filter feeders are efficient concentrators of trace metals and commonly contain levels which are four to five orders of magnitude above those in the surrounding waters. Therefore any proposed unnatural source of trace metals must be scrutinized in light of its effect on shellfish. These effects may be manifested in many ways. One way would be death of the animals but others are not so obvious. These may include sterility of adults, decreased growth rates or animals which have concentrated trace metals to an extent that they are unsafe for human consumption. In either case the ecosystem is harmed relative to man's use.

With these facts in mind, we have conducted experiments designed to determine the uptake of selected trace metals from sewage effluents by the eastern oyster, Crassostrea virginica. To achieve this goal we have subjected oysters (spawned in the laboratory) to various concentrations of sewage effluent. Experimental and control animals were then sacrificed, digested and analyzed for cadmium, cobalt, chromium, copper, nickel, lead and zinc. The resulting concentrations were then compared to the effluent concentrations.

## Conclusions:

From the data it was apparent that oysters can accumulate trace metals from sewage effluents. In the experiments chromium, copper, nickel and zinc were elevated in the animal's tissues above ambient. Cadmium, cobalt and lead did not increase, probably due to relatively low concentrations of these elements in the effluent tested. These values were obtained after 13 days of exposure. It is logical, therefore, to assume that animals exposed to effluents for longer periods of time would be more severely affected.

Very little is known about the maximum body burden of trace metals that shellfish can tolerate without either chronic or acute effects. Oysters have been collected which contain 19,000 ppm of zinc and were apparently healthy

. This aspect of the metal pollution problem needs more investigation.

The most obvious consequence of sewage metals being concentrated by oysters is the resulting decreased usefulness of the animals to man. When tolerance levels are established by the Food and Drug Administration for metals other than mercury, it is conceivable that many productive areas will be condemned due to sewage related metals. This is further exemplified by the fact that bacteria from sewage can be depurated from oysters by exposure to clean water in only two weeks, but metals may require years.

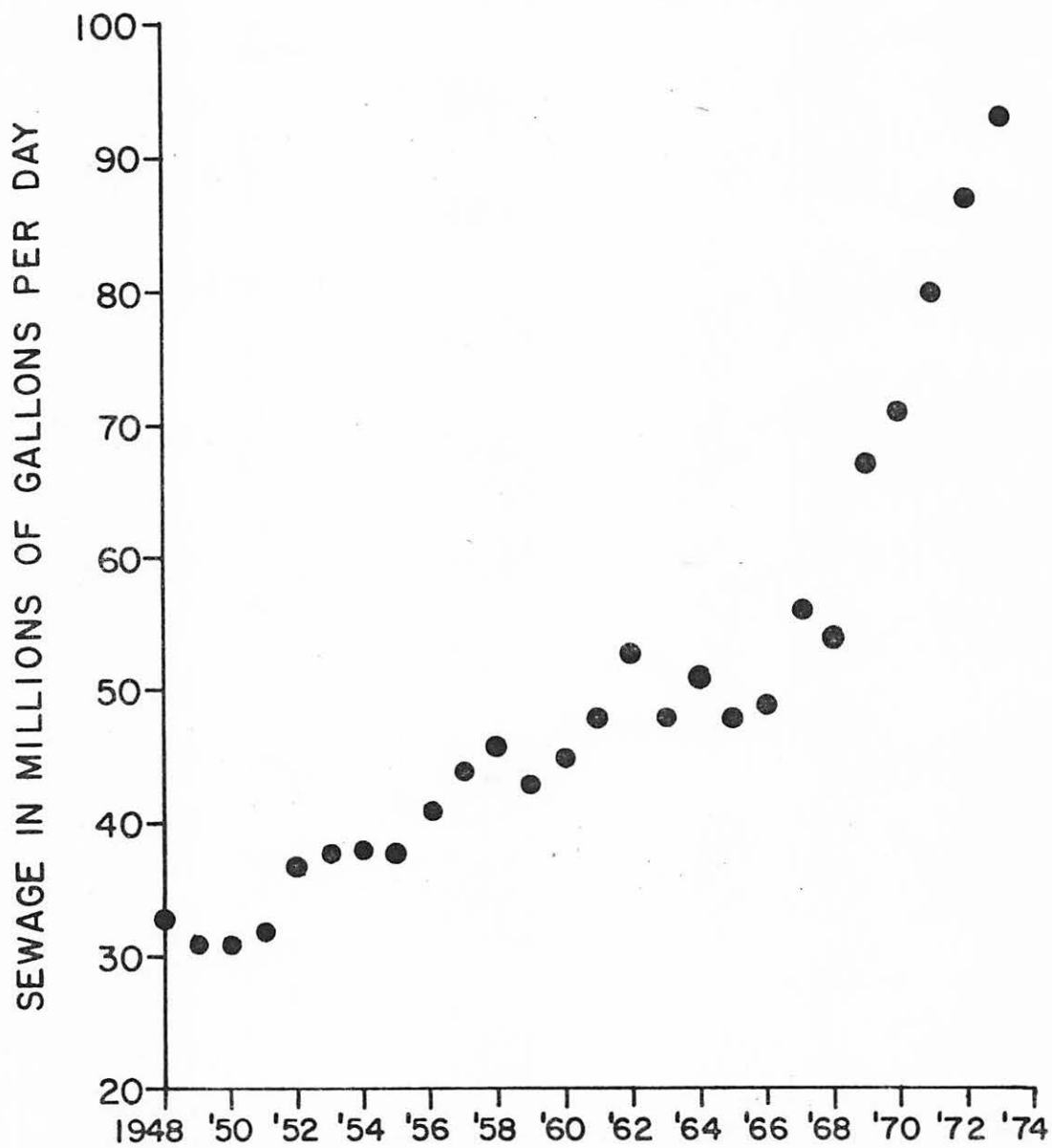


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FIGURE I

SEWAGE FLOW INTO THE LOWER JAMES RIVER  
(Estuarine)



# COMPARISON OF ANNUAL DISCHARGE TO CHESAPEAKE BAY OF SELECTED TRACE METALS FROM WASTEWATERS AND RIVERS

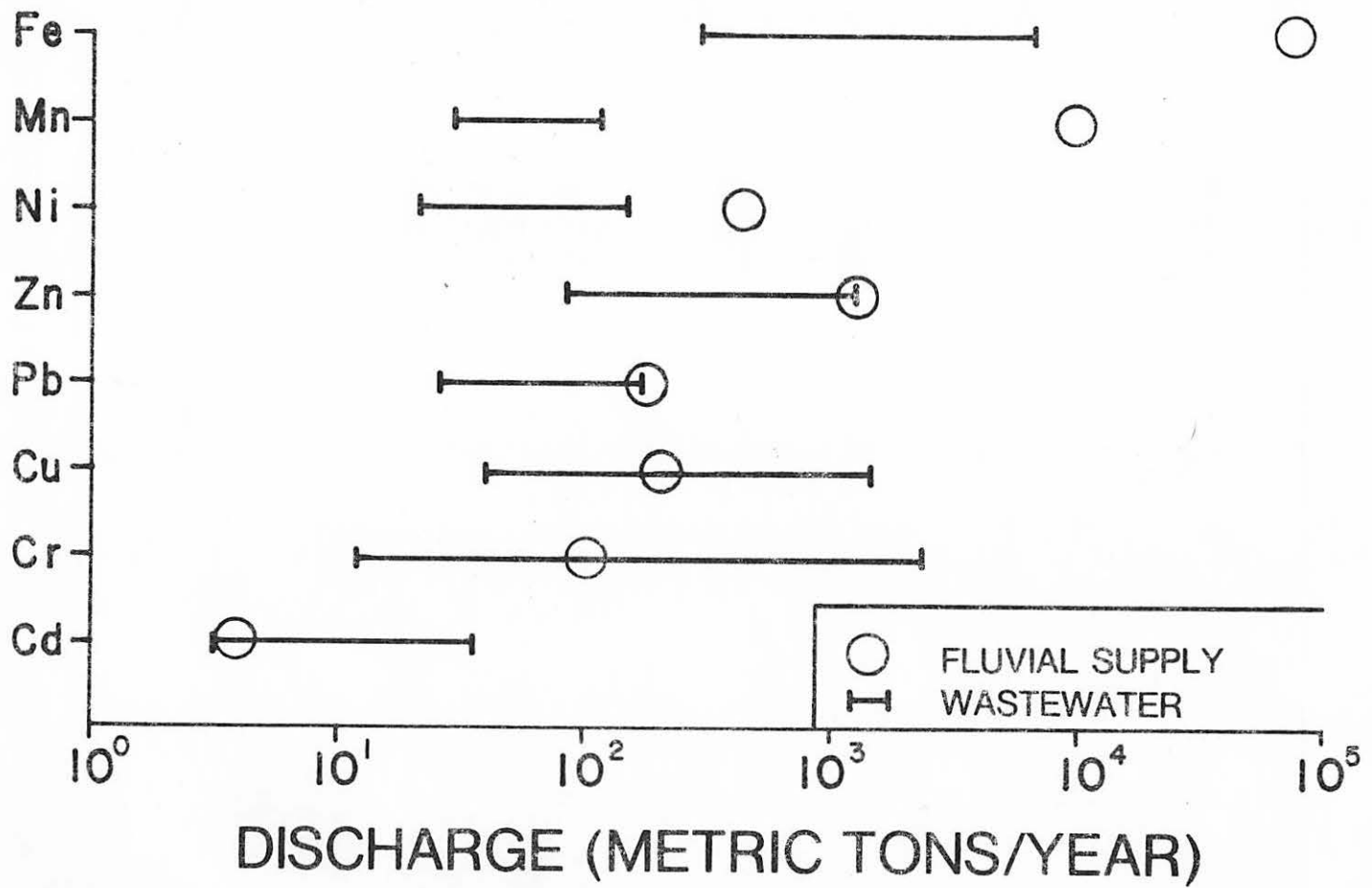


FIGURE II