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Agricultural and Urban Pollution

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Paper Inside!

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REMOTE SENSING OF THE CHESAPEAKE BAY

A conference held at
WALLOPS STATION, VIRGINIA
April 5–7, 1971

ATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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In cooperation with

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Preface

The objective of this Conference on Remote Sensing of the Chesapeake Bay is to identify the primary environmental problems of the Chesapeake Bay area and determine the extent to which remote sensing can contribute to the solution of these problems.

This volume and the conference it records will focus on ten major problem areas present in the Chesapeake Bay area. These areas include:

ENVIRONMENTAL POLLUTION

Pollution—Industrial Wastes

The petrochemical, metal, navigation, utility, and other industries are discharging increasing amounts of oil spills, exotic chemicals, and trace metals such as zinc, copper, cobalt, and mercury, as well as thermal pollution, all of which upset the ecology of the Bay and its estuaries. Also, sewage discharge from an increasing population increases nitrogen and phosphorus and decreases oxygen (eutrophication) in the water. This discharge stimulates obnoxious plant life and endangers fish life.

Pollution—Air

Undesirable discharge of gas and particulates from increasing urbanization, industrialization, navigation, and auto traffic may affect health of people as well as health of biota in local waters. Air pollution changes oxygenation potential of the water.

Pollution—Agricultural Sedimentation and Wastes

Agricultural activity increases rate of sediment runoff and introduces pesticide and animal wastes into the Bay. Also, sewage discharge from an increasing population increases nitrogen and phosphorus and decreases oxygen (eutrophication) in the water. This, again, stimulates obnoxious plant life and endangers fish life.

ENVIRONMENTAL BALANCE

Estuarine Turbidity, Flushing, Salinity, and Circulation

The physical properties of the Bay, including its ecosystem balance, need to be studied to determine their impact on the problems of the Bay. For example, the circulation pattern of the Bay affects many of the organisms.

NATURAL RESOURCES

Extractable Biological Resources

Oyster production has been decimated by excessive exploitation, and other species have been reduced by tributary dams and pollution. Nevertheless, large numbers of fish and shellfish are extracted from the Bay having an estimated value of 65 million dollars per year.

Agriculture and Forestry—Identification, Vigor, and Disease

The Bay is a highly productive estuary. Well-managed grain, tobacco, and truck farms abound; hardwood and conifer trees are abundant; wildlife areas are plentiful. These are threatened by suburban encroachment.

Recreational Uses

Boating, swimming, skiing, beaching, fishing, and hunting are all increasing rapidly. The outlook is for enormous and rapid increase in water-related recreation with attendant problems such as traffic jams, air pollution, and waste disposal.

OTHER ECONOMIC ACTIVITY

Engineering Changes

Dams, bridges, piers, and other installations tend to upset hydrology and nutrients of the system. There is a conflict of navigation demands and maintenance of an estuarine environment satisfactory for commercial and sport fisheries and for recreation. Deeper channels for navigation and disposal of dredge spoils change the hydrology of the system.

Shoreline Activities

Problems of land use, urban growth, regulation of shoreline activities, coastal erosion, tidal marsh encroachment, and coastal zone stabilization all contribute to the character of the Bay. Also, conversion of wetlands at an increasing rate upsets the hydrology of the system and also can interrupt the estuarine ecology and life cycles with far-reaching effects on fish and shellfish and myriad other species.

Urban Development and Growth

Urban development and growth on the shoreline of the Bay, along its tributaries, and in the headwaters of the Bay present some special problems with respect to the Bay.

Development rates and trends and land use should be studied for the purpose of policy-making and planning at the federal, regional, state, and local levels.

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Agricultural and Urban Pollution

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I have modified the scope of this paper slightly to include urban pollution because the pollution problems produced by the agricultural industry are essentially the same as those produced by municipalities. We know that environmental degradation occurs as a result of the discharge and the byproducts from both sources.

In the case of agricultural activities, the terrain has and still is being modified to convert it to crop production. In the livestock industry, large populations of animals are being concentrated into relatively small areas to meet the economic pressures of meat production. With the human population, the numbers of people are not only increasing but are also concentrating. Probably more important, countless square miles of terrain have been denuded and modified to make way for highway and street construction or for the development of housing units. From both sources the results are the same. We have increased siltation; we have increased organic loading; and we have increased nutrient loading.

SEDIMENT LOADING

Those of us with responsibilities in the Chesapeake Bay and its tributaries could cite many areas where the intended uses of the water have been contravened as a result of either agricultural or urban activities or both. I am not going to infer that the Chesapeake Bay is dead. Far from it; it is still one of the most beautiful and healthy estuaries in the United States. It has its problems, however, like all other bodies of water that are adjacent to human activities, but these are primarily confined to its tributaries. Figuratively speaking, several of the Chesapeake Bay's appendages–the tributaries–have "gangrene" with atypical discoloration extending from the extremes of the fall line down to the main body. Loren Jensen[1] mentioned some of these situations, and estuarine ecologists, like medical doctors, are fully aware that an otherwise healthy body may be destroyed by an infection which originates in the extremities. In fact, the extremities are far more prone to difficulties than the main body because of poor circulation and frequently the inability to flush out poisons and contaminants.

Now let us breifly review the degradation produced by the introduction of agricultural and urban wastes into estuarine systems. Wellman and others have established that agricultural activities may increase the erosion rate per square mile by a factor of 10 of so. Also in the initial steps of urbanization, the erosion rate per square mile may be increased by a factor of 1000 over that of an adjacent unmodified area. Because of this, the two sources cannot be separated when discussing turbidity and sedimentation.

According to the classical definitions of pollutants, silt and clay particles are generally classified as inert, inorganic materials. We know that they are inert only in that they exert no biochemical or chemical oxygen demand on the water. Chemically, however, they are quite active because silt particles especially are characterized by surface charges or sites capable of exchange reaction. This occurs when they come in contact with quite a few of the organics. The best example would be the florinated hydrocarbons or the polyclorinated biphenyls (PCBs), inorganic materials, ions such as the heavy metals, or even the nutrients such as phosphates. The absorptive capacity of silt particles is usually characterized and correlated with the pH value of the suspension or the solution. It is, therefore, characterized by an effect or relationship to the zero-point-of-charge (ZPC) of the species. Since the pH value of estuarine and marine water

[1] Loren B. Jensen: Industrial Waste Pollution. This conference.

is usually above that of the ZPC of many of the species with which we have concern, suspended solids can effectively remove ions from solution, carry them downstream, and deposit them, making them part of the bed load or remove them from the soluable form and incorporate them with the sediment load.

These reactions almost completely nullify the effluent standards that have been imposed by many state and federal regulatory agencies. An industry may, for example, meet any effluent standards merely by increasing the volume of effluent without increasing the contaminant loading. When the effluents are discharged into turbid waters, the ions or the molecules that might be discharged almost completely become a part of the sediment load rather than a part of the true solution. In doing this, the specific concentration is insignificant, but the total loading per day or per month becomes the significant factor. The aqueous phase, the solution a short distance below an effluent pipe, may be quite free of the contaminant when water samples filter through a membrane filter; however, the concentration of the contaminants in the sediment may be extremely high. This is only a temporary removal from the biological system, however.

We know that many of the marine and estuarine filter-feeding organisms have the ability to strip ions, especially the absorbed ions, from particulate materials as the particles pass through the digestive track. Also, the action of many of the forms that bore into the bottom can mix this loading down through the sediinent mass and, in some cases, remove them from the biological cycle; in other cases, they can return them to the biological cycle. Because of the mechanisms and the relationships between ions that may have originally been in true solution to the particulate material, we can see that much more information is required by the regulatory and management agencies regarding the turbidity levels and the movement of settleable solids than is generally available. Phosphate ions are readily absorbed on the surface of particulate material when the pH factor is within the proper range. Although phosphate is a pollutant in many estuaries, especially in upper tidal systems, the reaction with the suspended solids prevents the phosphate from being flushed from the system as part of the normal flushing action into the ocean.

The standing crop and the primary productivity of estuarine systems is also adversely affected by the high turbidity level. The autotrophic planktonic forms, plants that are responsible for energy fixations in the aquatic environment, are dependent upon sunlight for this fixation. Therefore, the quantity of organic material is directly related to the depth of light penetration. In some of our more turbid systems the depth of light penetration may be less than a meter and in some cases less than a foot.

We are very much concerned about temporary turbidity or temporary suspensions of silt and clay particles that are produced when wind-induced waves touch the bottom and therefore resuspend and re-sort material that has been deposited over the shallow areas and bring it back into solution. Haven's data, for example, indicates that the suspended solid loading may be much higher on a windy day during low-flow fresh water inflow periods than on calm days during relatively high fresh water inflow periods. In fact, the variation within days in suspended solids can be as great as the variation between days. These loads are especially harmful to the aquatic environment. They not only absorb and scatter light particles but, since the suspensoids settle quite rapidly after the wind subsides, they can mechanically entrap phytoplankton and planktonic animal forms and carry them to the bottom where they may be destroyed.

Several species of our important estuarine animals are either sedentary or sessile; therefore, they are especially vulnerable to the processes of sedimentation or the results of sedimentation. The Virginia oyster, indigenous to the Chesapeake Bay region, has a life cycle that is characterized by the release of the sex products, external fertilization and development, and a planktonic stage through the larval development until the setting time, usually 14-30 days, depending upon water temperature. If the larval form, the planktonic form, is able to survive this stage, it still depends upon the condition of the bottom. It requires a relatively clean, hard surface for setting or settlement and additional development into the adult stage.

Silt-covered surfaces are just not suitable. Therefore, in the case of the oyster, the animal is dependent upon the levels not too far exceeding the natural levels from the time the sperm and the egg are released into the water until they settle and develop into the adult form. Even the adult can be covered and smother through adnormal sedimentation.

The other commercially important species of mollusk, the soft clam and the hard clam, also have planktonic larval forms which are susceptible to death or destruction by settleable material; however, the adults can live in softer bottoms; they are slightly mobile; and, therefore, they can survive a little better than the oyster.

Turbidity and siltation are forms of estuarine pollution, in that, the physical geometry of systems may be altered by the formation of bars and shoals; the water currents may be modified by bathymetric changes; the water quality can be degraded and aquatic life suppressed. Also, the intended uses can be contravened either through the reduction in the aesthetic value or just a general deterioration of the environment. The adverse effects of destruction caused by sedimentation are not as dramatic as the catastrophic kills that can be produced by municipal or industrial waste. However, the end result is the same.

ORGANIC AND NUTRIENT LOADING

I mentioned that the second product of agricultural and urban activities was excessive organic loading. I am not going into detail on this phase because, with conventional treatment and advanced waste treatment, there really is not too much of an excuse today for aquatic systems to be overloaded organically. However, in the treatment and without advanced waste treatment that incorporates nutrient removal, over-enrichment or hyper-enrichment can result.

There are several sources of nutrients: nitrogen, phosphorous, possibly carbons, and trace elements that can produce this type of degradation. These sources include the agricultural activities from the beef factory operations, the broiler factories, the egg factories, and the piggeries. Also included are certain industrial activities, especially those involved with the production of agricultural chemicals, certain synthetic fibers, and, of course, municipal activities. I am not going to use the term eutrification because, in my opinion, it simply does not apply to estuarine or tidal systems; however, whatever term used, the symptoms and the end results are the same.

Over-enrichment can result in the production of atypical phytoplankton populations, populations where the standing crop or the biomass far exceed normal level. Probably one of the more serious and least understood is, in over-enriched environments, the phytoplankton composition frequently changes from beneficial forms to obnoxious weed forms—from forms that can be utilized by animals at the higher trophic levels to forms which apparently have little if any value in the system.

Another thing that can happen is that the aesthetic value of the body of water can be reduced. No one really cares to look at, to swim in, or to wade in a body of water that is pea-soup green so that when he comes out, he will be green.

Also, subminimal oxygen levels can be produced at night due to cell respiration and cell decomposition. The upper tidal Potomac is notorious for developing these symptoms each summer. The engineers are constantly asking the biologists to give them hard numbers on how much nitrogen, phosphorus, or carbon that water can assimilate without the production of aquatic nuisance conditions. There is really no stock answer. Each system is different. Much of the literature has been developed from work on lakes. One simply cannot transfer information from lake studies to dynamic systems such as streams or tidal systems. We know that the taxpayers should and the engineers do sincerely hope that phosphorous is most frequently the cause of these agents.

However, my experiences and the recent literature indicate that in dynamic systems such as tidal systems, during the relatively low fresh-water inflow periods of summer, the period when aquatic nuisance conditions and environmental degradation quite frequently occur from over-enrichment, available nitrogen is probably more frequently the limiting factor; therefore, in order to actually reduce aquatic nuisance conditions, nitrogen removal is also necessary. Our recent work on Virginia's three major estuaries—the James, the Rappahannock, and the York—the Chesapeake Bay Institute's studies in the Potomac and the Upper Chesapeake Bay and the Jaworski and Lear Water Quality Office comprehensive studies on the tidal Potomac have yielded similar results regardless of the salinity of the enriched waters.

Several factors, however, must be considered when discussing the elements that stimulate phytoplankton activities. First, the Chesapeake Bay and its tributaries are literally loaded with the measurable nutrient elements during the late winter and early spring when fresh water discharges are high. During this period, especially in the tributaries, the turbidity levels are high, and this alone limits photosynthetic activity; but probably the most important species of plants that are primarily responsible for environmental degradation in the fresh water part, namely the microcystis and acystis group, are fresh water forms that do not develop in large enough numbers to cause difficulties. Later in the season as the fresh water inflow volumes drop off, the nitrogen levels drop down also. During the late summer, the available oxidized forms of nitrogen are down at minimal level.

In the James River, which one might expect to be highly enriched from the fall line down to the mouth, the minimum phosphorous levels are usually found between 10 and 15 parts per thousand. Toward the mouth of the James River, the so-called available or soluable phosphorous levels increase. When we first saw these data we thought it might be attributed to the population concentration in the Hampton Roads area. However, the same phenomenon occurred in the York River with complete absence of enrichment near the mouth and likewise in the Rappahannock River.

We are all very much concerned about the phytoflagellate blooms, the red tides, or mahogany water as it is commonly called in Maryland that occur in the lower tributaries and in the Chesapeake Bay almost every summer. We know from talking with several natives that they observed red tides during dog days each summer when they were children. One thing we do not know is if the frequency and duration of these red tides are increasing. We do know that red tide blooms appear to stress many species of estuarine life and we know quite conclusively that they are capable of bringing about the demise of quite a few jelly fish.

In summary then, agriculatural and urban wastes exert many similar stresses upon the estuarine environment. Several of the upper tidal tributaries are now loaded to the point where the intended uses are being contravened. We might sum up by saying that unless the ailments of the extremities are cured, the main body of the Chesapeake Bay will eventually be degraded until it is useful only for commerce and recreational activities.