STATEMENT ON

PHOSPHATE - THE CRITICAL NUTRIENT

IN THE WATER POLLUTION CONTROL

OF LAKE ERIE AND THE GREAT LAKES

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PHOSPHATE

THE CRITICAL NUTRIENT IN WATER POLLUTION CONTROL

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Much study has been given in recent years to the problem of algae and their effect on water quality of rivers and lakes. Water is the normal environment for algae. Many varieties grow in waters of all kinds and qualities throughout the world. They are an important segment of the food chain from bacteria to man. As the diet of many of the higher aquatic animals, they support the "vegetarians" of the water world just as our agricultural crops are the basic foodstuff for man. Algae grow in abundance under the same general conditions as crops flourish on farmland. Sunlight, adequate temperature, water, oxygen and carbon dioxide are required as well as a number of simple and complex chemicals classed as "nutrients". Any one of these, if absent, or in short supply will retard growth of a crop. The farmer depends on nature for adequate sunlight, temperature, water and air. He adds nitrogen, phosphates, potassium and certain trace minerals to the soil in order that sufficient nutrients are present to provide the crop with all it needs for optimum growth. In effect, the farmer is fertilizing his cropland to counteract the "Law of the Minimum". This natural law simply states that variation in productivity is most often determined by limitations imposed by a lack of some nutritional element. In other words, as the least abundant nutritional element is used up, productivity decreases. The farmer thus provides enough nutrients and trace elements in his fertilizer so that his crop can grow at an optimum rate with only the factors of sunlight, temperature, water and air controlling the size of his crop.

The growth of algae in water likewise follows the law of the minimum. Since algae require the same physical conditions and nutrients for growth as other plants, the size of any given crop will depend on the supply of the most critical element necessary for algal growth. Because the excessive growth of algae in the lakes and streams is detrimental to our well being, control of its growth is one of the more important functions of our program to provide clean waters. The control of algae then becomes a matter of eliminating or controlling one of the critical nutrients essential for its propagation and growth. The one nutrient most susceptible to control is phosphate. Since algae are essential in the food chain, the problem is not one of eliminating them, but rather to devise means for limiting the crop to a level which will foster development of a desirable balanced aquatic biota with a minimum of interference to important water uses.

The application of heavier nutrient concentrations to the soil will increase plant growth, but not selectively. For example, a given field may produce more pounds of plant life, but if the faster growing weeds dominate the field, production of food plants may actually decrease. Similarly, increasing nutrients in a lake may produce more pounds of fish, but if, in the process of doing so, conditions develop that make the aquatic environment less suitable for the desirable commercial and sports fish, the latter will decrease while trash fish flourish.

Prior to World War II the amount of phosphate in sewage and municipal wastes was relatively small. Major developments in the use of phosphorus have resulted in very significant increases in phosphate in waste discharges. One is the widespread use of household detergents and the other is the increase in the use of phosphorus compounds in metal cleaning and rustproofing. Detergents alone will, in the coming year, consume 4 billion pounds of phosphate. This burgeoning use of a key nutrient ultimately becomes a part of our waste discharges. Not only has the volume of waste water discharges increased but the concentration of phosphate in the wastes has risen four to five times above that found before the war. This tremendous increase, accompanied by the greater frequency and increased extent of reported nuisance algal blooms clearly points to the necessity of controlling or removing phosphorus inputs into our waters if we are to preserve them for many beneficial uses. Unfortunately, present waste treatment technology removes very little of the phosphate contained in the incoming waste. For example, primary treatment removes no soluble phosphate, and removals in conventional secondary treatment vary from ten percent up to seventy-five percent, depending on operating and design conditions.

In summary, phosphate is an essential element of biological life. All plants and animals require phosphate for normal growth and reproduction. Because of its importance, it can become a controlling factor in the rate of growth or size of crop where conditions of limited abundance prevail, or where technical methods are available for its reduction or removal.

A knowledge of some of the physical properties of lakes of moderate depth is important to an understanding of the pollution problem found in Lake Erie. In the Spring and in the Fall such a lake becomes isothermal, that is, the temperature of the water is the same from top to bottom. At other seasons the lake water is divided into three zones known as the epilimnion, the thermocline, and the hypolimnion because of density differences resulting from different water temperatures in these zones. The epilimnion comprises the warmer upper waters of the lake, the thermocline, the zone of rapid temperature change, which separates the epilimnion and the colder waters of the hypolimnion below the thermocline. With a well-established thermocline, there is little interchange between the waters of the hypolimnion and the epilimnion even during violent storms. The effect of separation of lake waters by these temperature zones is the virtual isolation of the bottom waters from the surface of the lake, thereby preventing free exchange or absorption of oxygen from the atmosphere. In fact, conditions have been observed under which the epilimnion or surface waters were actually supersaturated in dissolved oxygen while the hypolimnion had little or no dissolved oxygen. When such conditions occur, they can lead to the disappearance of desirable aquatic life dependent upon dissolved oxygen which are replaced by an abundance of pollution-tolerant forms. This changing biological life of a lake affects all forms, restricting or eliminating fish spawning beds, eliminating the desirable intermediates in the food chain of the sport fishery, and in many other ways degrading the water quality of the lake.

The pollution caused by phosphate in Lake Erie is due to the extensive production of algae which when dead drop to the lake bottom and decay. During the processes of decay, large quantities of oxygen are used, producing zones of oxygen depletion below the thermocline. This has been shown by studies in past years, and more recently by extensive studies of the Federal Water Pollution Control Administration Lake Erie Program Office. The results of these studies are contained in the "Report on Pollution of Lake Erie and its Tributaries: July, 1965." This report revealed a zone of oxygen depletion in the hypolimnion of 2600 square miles in the central basin of the Lake. In the bottom 6 to 10 feet of water dissolved oxygen seldom exceeded two milligrams per liter, and was zero in many places. The productivity, and resultant decay that caused this tremendous oxygen loss was of massive proportions. The calculated oxygen deficit was over 270,000,000 pounds.

Some have questioned the cause of this deficit and attempt to explain it by the "oxygen consuming wastes from cities and industries discharging into the lake." Some simple calculations, presented herewith, will show the practical impossibility that this is the principal cause of the problem and will further show that it is directly related to the algae produced from the constant daily inputs of phosphate principally from waste sources.

Referring again to the report on Lake Erie, Table V-1 in Part 1 presents a summary of the municipal waste treatment facilities in the Lake Erie Basin. Adding up the population equivalents of municipal waste discharged to the basin, about 5 million PE (Population Equivalent in terms of oxygen-demanding substances) is treated by primary plants, another 5 million by secondary plants. The combined waste discharges of all these plants, should they be discharged directly to the lake, would produce an oxygen demand on the waters of the lake of about 1.8×10^8 pounds annually. This value is arrived at by estimating 40% BOD removal by primary treatment, 90% by secondary treatment, one-sixth pound BOD per PE, and 365 days in a year. This is a sizeable oxygen demand, but not nearly as great as the oxygen deficit found in the central basin of Lake Erie in 1964. To estimate the size of the deficit found, we calculate that for each milligram per liter of observed deficit there are 1740 pounds of oxygen per square mile per foot of depth in Lake Erie. Using this factor, an average depth of 10 feet for the deficit zone, 2600 sq. miles of deficit zone and a measured deficit of 6 ppm oxygen, our calculation shows $(1740 \times 2600 \times 10 \times 6) = 2.7 \times 10^8$ pounds of oxygen to be lost in this central basin.

This deficit occurred during a period of a few weeks when the Lake was stratified, closing off the bottom waters to reaeration from the surface. Since the annual oxygen demanding waste load to the lake basin is less then the deficit created within three to four weeks, it is obvious that the oxygen consuming wastes from the basin are not the direct cause of this problem. Yet this problem requires an explanation. We find this explanation in the following facts:

Table V-8 of the report presents the soluble phosphate inputs to Lake Erie, with a daily input of about 175,000 pounds as determined and estimated from all known sources. The amount of soluble phosphate leaving Lake Erie via the Niagara River is about 25,000 pounds daily, therefore about 150,000 pounds per day is accumulated in the lake. On an annual basis this is 5.5×10^7 pounds. Three pounds of phosphate can generate 100 pounds of organic carbon. If all this phosphate were taken up by aquatic plants and animals it would produce about 1.8×10^9 pounds of carbon.

Once this carbon becomes a part of the algae, it behaves as any other organic carbon compound and upon the death or decay of the algae it becomes an oxygen demanding waste substance. The ultimate oxygen demand of carbon is 2.68 times its weight, therefore 1.8×10^9 pounds of carbon will produce an oxygen demand of 4.9×10^9 pounds per year. This annual demand is at least 27 times as great as the load produced by all the population discharges into the lake basin. What is even more important is that this "natural" load occurs mostly during the warm seasons, and probably in pulses, which makes its effect on the lake much greater than if it were to occur continuously throughout the year.

It is thus apparent that a "natural" oxygen demand is created in Lake Erie from the phosphate inputs to the lake and that this is the principal cause of the oxygen deficit found there. This pollution is so large that it affects bathing beaches, fish and aquatic life, water supply, recreation, and aesthetics.

What can be done to improve this situation? The obvious solution is a direct reduction of phosphate inputs. In the Lake Erie report cited earlier it was estimated that of the 175,000 pounds of daily input, 72,000 pounds could be removed simply by treating the municipal wastes in the basin by secondary biological treatment, operated in such a way as to maximize phosphate removal. This removal alone would account for 48 percent of the phosphate that is now being metabolized in the lake and should result in a marked reduction in algae and a corresponding improvement in the oxygen resources of the central basin. Several weeks ago, Secretary Udall announced a breakthrough in the problem of phosphate removal by secondary biological treatment. He said that scientists of the Federal Water Pollution Control Administration found that up to 90 percent of phosphate in municipal sewage can be removed by secondary biological treatment, using modifications in plant operation practices. This new discovery promises even better control of the algal problem, once the treatment plants are built and operated to maximize phosphate removal in the Lake Erie Basin. This announcement is attached as an appendix to this report.

The conditions that exist in Lake Erie would also occur in Lake Ontario were it not for the greater depth of Lake Ontario. With the phosphate inputs from Lake Erie, plus those added by Buffalo, Rochester, Toronto and the streams draining the watershed, Lake Ontario has a sizeable input which produces large annual crops of algae, especially cladophora, a type of algae that grows on submerged rocks. However, Lake Ontario is deeper and has a thicker hypolimnion, which provides for a larger oxygen reservoir. This does not mean that in Lake Ontario an oxygen depletion could not occur. It means only that a longer time will pass before conditions match those in Lake Erie. Other conditions of excessive algal growth have been observed including fouling of beaches by dead cladophora and taste and odor problems in water supplies. Quantitative data on these factors are being obtained by the Lake Ontario Program Office of the Federal Water Pollution Control Administration and will be put to use in its comprehensive program of water pollution control for the Lake Ontario basin. Because of the large Canadian population draining to Lake Ontario, the control of phosphate inputs will require a joint, coordinated program.

In summary, of the many nutrients subject to control most scientists agree that the control of phosphate would provide the best means for the reduction of algae. Their judgment is based on the following considerations:

1. In most lakes or streams having little or no algal problems, the phosphate levels are very low.

2. Wherever algal blooms occur, the effect can invariably be traced to high phosphate and nitrogen levels.

3. Phosphate, when added to waters, will nearly always result in increased numbers of algae.

4. In many instances, studies have shown that increased phosphate inputs into lakes has resulted in explosive increases of algal growth. Examples are Lake Zoar in Connecticut; Lake Sebasticook in Maine, the Madison Lakes in Wisconsin; the Detroit Lakes in Minnesota; Green Lake and Lake Washington in Washington; Klamath Lake in Oregon, and Lake Erie.

5. The problems of increased algal growths in lakes and streams closely parallel the increase in use of phosphate in modern day detergent formulations, metal cleaning processes and the increased application of phosphate fertilizer on farmlands.

Since the bulk of the phosphate reaching streams and lakes is from waste sources, principally municipal and industrial wastes, its control can be affected through proper waste treatment. Conventional secondary waste treatment will remove a large portion of phosphate present in sewage or industrial waste -- as much as 90% removal has been recorded, and chemical treatment supplementary to conventional biological treatment can remove the remaining portion at a nominal cost. Additional controls, through research on substitution of other chemicals for phosphate in detergents, could provide further reductions in phosphate inputs.

The control of inputs of other nutrients, although possible, would be less fruitful for various reasons such as: (a) The methods of control of nitrogen inputs do not provide complete removal (b) Nitrogen can be "fixed" by certain algae and bacteria from the air, thereby partially offsetting its removal (c) Inputs of potassium and iron are usually a small fraction of that already available in the stream or lake environment (d) The factors for control of other nutrients such as "vitamins" and trace metals are poorly defined.

UNITED STATES
DEPARTMENT of the INTERIOR
★★★★★★★★★★★★★★★★★★★★★★news release

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MAJOR BREAKTHROUGH IN POLLUTION CONTROL

A review of operational data on three sewage treatment plants in San Antonio, Texas is expected to lead to the major and early breakthrough in water pollution control, Secretary of the Interior Stewart L. Udall announced today.

He said that scientists in the Department of the Interior's Water Pollution Control Administration have under development a fast and relatively inexpensive way to deal with one of the most baffling problems in water pollution control--the explosive, water-choking, fish-killing growth of algae.

Algal blooms, as these aquatic malignancies are called, now constitute a principal pollution problem in the Potomac River below Washington and countless other water resources. It is these tiny organisms that are slowly killing Lake Erie, threatening Lake Tahoe, and spoiling other waters all across the country.

Secretary Udall said that the newly-discovered technique for dealing with the problem was still in the pilot stage but that work would begin immediately to make it operational at the earliest possible time. Studies are already under way to apply the new knowledge to the lower Potomac, Secretary Udall said.

In brief, what the scientists at WPCA are working on is a way to cut off the food supply on which algae thrive so that they will literally starve to death and in time disappear.

This can be done, moreover, according to WPCA, with relatively simple modifications of current waste treatment techniques. Normally, the most complete waste treatment now in use removes most of the impurities from domestic wastes--except phosphates. And these phosphates provide algae with a rich food supply.

Water pollution experts have been trying for years to find an economical way to remove phosphates in large scale waste treatment operations. As is often in the case of scientific investigations, the clue the experts were looking for came about almost by accident.

Operational data on waste treatment works around the country are regularly reviewed for various purposes by scientists and engineers of the Water Pollution Control Administration in Washington. This is one of the ways they have of determining how the water pollution control methods are progressing from month to month.

In the course of these reviews it became evident late last year that either there was something wrong with the data on the three plants in San Antonio or that there was something going on there that was worth looking into.

The reports on two of the plants were like the reports on other such plants anywhere in the country. The plants were performing very effectively, with typically low phosphate removal.

But for some reason, virtually no phosphates were getting through the other plant. Yet it is basically the same kind of plant as the other two and treats the same kind of wastes.

Dr. Leon Weinberger, Assistant Administrator of WPCA for research and development, started an investigation.

For four months, scientists and engineers from the WPCA's Robert S. Kerr Research Center in Ada, Oklahoma, studied the San Antonio plants in every detail. Now they know the answer.

A secondary waste treatment plant, such as those in San Antonio and elsewhere, employ an activated sludge process involving two principal stages--settling and aeration, and the use of bacteria to break down and assimilate biological impurities that remain after the settling-out stage.

The operation of such plants is effective by their structural and hydraulic design and by the rate of input of the liquids being treated, the amount of aeration, the concentration of bacteria used, and other operational features which can be modified. The WPCA investigators found that the San Antonio plant with the high phosphate removal was being operated differently from the other two in a number of ways.

They then changed five of the operational features of one of the other plants--one that had been removing no phosphates--and phosphate removal suddenly shot up to over 90 percent.

The investigators got this result by increasing the aeration, increasing the concentration of bacteria, reducing the time for settling, decreasing the time that settled materials remained in the settling tank, and increasing the ratio of bacteria to organic materials. It is not yet known what brought about the increased phosphate removal--whether it was the result of one or several or all of these changes.

Since then, wastes at several other plants around the country have been treated experimentally in the same manner and without exception, very high phosphate removal has been achieved.

Pollution control experts at WPCA pointed out that with the mounting algae problem, interest in phosphate removal has been intensifying in recent years and that a considerable amount of research and developmental work by industry is under way in this area.

Dr. Weinberger said that WPCA scientists and engineers will begin an intensive program of coordinated investigations with non-governmental researchers in an attempt to accelerate the development of maximum removal of phosphates as a regular part of municipal waste treatment.

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