REVIEW OF THE US EPA OFFICE OF TOXIC SUBSTANCES DRAFT REPORT, THE HAZARD OF PHOSPHATES IN THE ENVIRONMENT

by

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INTRODUCTION

In the fall of 1977, the US EPA Office of Toxic Substances released a draft report devoted to an assessment of the hazard of phosphates in the environment. This draft report was prepared in accord with the provisions of the Toxic Substances Act and represents the first of a series of reports ultimately leading to the possible establishment of national programs for the control of hazardous chemicals in the environment. This draft purports to show that excessive fertilization of natural waters results in significant water quality deterioration. It infers that since phosphate can contribute to excessive fertilization problems in some water bodies, it should be classified as a hazard to the environment and that national control programs should, therefore,

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be developed for phosphate use in commercial products. The discussion presented below, which is based on the experience of the authors in working on eutrophication problems caused by phosphorus and other compounds and on a critical review of the OTS phosphorus hazard draft report, examines the validity of the OTS draft report conclusion that phosphorus represents a hazard to the environment which requires a national control program.

The authors have great difficulty in understanding why the US EPA Office of Toxic Substances chose to list phosphate as a hazardous substance. While phosphorus can and sometimes does result in a significant degradation of water quality arising from the excessive fertilization of natural waters, there appears to be no justification for ranking phosphorus among those compounds given highest priority for control efforts.

To classify phosphorus as one of the most hazardous chemicals in the environment is certainly inappropriate when consideration is given to the relative significance of phosphorus-mediated water quality problems compared to the potential toxicity problems caused by a large number of commercial compounds which are being added to the environment. Where the manufacture and/or use of phosphorus for domestic purposes does cause a problem in the environment, the phosphorus can be readily controlled through "end of the pipe" technology. Adequate regulatory authority already exists for the initiation of this type of control under the provisions of Public Law 92-500, the 1972 amendments to the Federal Water Pollution Control Act. It is the conclusion of the authors of this review, based on work that has been done on both phosphate-related eutrophication problems and hazardous chemicals, that it is inappropriate for the Office of Toxic Substances to attempt to have phosphorus classified as one of the most hazardous chemicals known to man. The basis for this position is presented below.

OVERALL APPRAISAL OF OTS PHOSPHATE HAZARD DRAFT REPORT

From an overall point of view, it has been found that this draft report is a relatively poorly-done assessment of the nature of the excessive fertilization problems caused by phosphorus in US waters. It does even a poorer job in judging the national scope of these problems. The draft report contains numerous technical errors ranging from classifying Spirogyra as a blue-green alga to the use of nutrient concentrations in rivers as a basis for judging eutrophication problems in the nation's waters. It is not the purpose of this review, however, to prepare a detailed list of all of the technical errors made in this draft report. Instead, emphasis will be given to major conceptual problems with this draft report.

The draft report dwells on a number of insignificant water quality related-eutrophication problems. For example, about three pages of the draft report are devoted to toxic algae. Someone reading this draft report who is not familiar with this topic could get the impression that the toxins generated by blue-green algae represent a widespread major problem. The discussion presented in this draft on this topic exemplifies the major problem that occurs time after time in the draft report, that is, failing to present the eutrophication problems in their proper perspective. While there is no doubt that excessive fertilization of natural waters represents a significant cause of water quality deterioration in some water bodies, there are few, if any, individuals recognized as authorities on the impact of eutrophication on water quality who would list the toxicity of blue-green algae as a significant water quality problem. The number of documented cases is very limited. The occurrence appears to be restricted to isolated farm ponds and animal watering holes. Certainly the fact that some blue-green algae may excrete toxins which can cause the death of farm animals should not be used as a basis for justifying a phosphorus control program by the Office of Toxic Substances.

Another area to which this draft report devotes excessive emphasis is that of the impact of eutrophication on fisheries. While there is no doubt that there has been a change in the

fisheries in Lake Erie in the past 50 years, the role of eutrophication in bringing about many of the changes in these fisheries is very limited. As discussed in the literature which the draft report cites, overfishing is the primary cause of decline of many of the fisheries in Lake Erie. Eutrophication has contributed to the decline of some cold water fisheries due to the depletion of oxygen in the hypolimnion in Lake Erie. Even this draft report states, however, that "Lake trout populations [cold water fish] were decimated in Lake Erie by overfishing in the 19th century." This was prior to any evidence of eutrophication in the lake. Further, eutrophication has not likely brought about any significant decline of the warm water fisheries. In fact, it has likely stimulated the stock of many warm water fish.

It is unfortunate that so much emphasis is given to the impact on fisheries of Lake Erie. In the experience of the authors, the Lake Erie situation, where there has been a significant decrease in hypolimnetic oxygen in a relatively short period of time, is uncommon in the US. During the past three years, Rast and Lee have conducted a comprehensive review of the impact of phosphorus loads to lakes and impoundments on water quality responses of these water bodies. This work was done under contract with the US EPA Eutrophication Program headquartered in Corvallis, Oregon. As part of the US OECD Eutrophication Program, Rast and Lee have examined the relationship between the phosphorus loads to lakes and impoundments and oxygen depletion in their hypolimnions. They have developed a formulation of this relationship for lakes in which algal growth is controlled by phosphorus which enables the prediction of the extent of oxygen depletion in the hypolimnion of the lake based on the phosphorus load to the lake. A comprehensive report covering this work has been submitted to the US EPA Laboratory in Corvallis, Oregon, for publication.

Examination of the results of these studies shows that the eutrophication-related water quality of lakes and impoundments is remarkably insensitive to changes in phosphorus load. For example, in order to bring about significant changes in the rates

of oxygen depletion in the hypolimnions of most lakes, very large changes in their phosphorus loads must be made. In general, lake Erie's morphology and other characteristics make it very atypical of US water bodies. It should not be used to illustrate typical phosphorus load-eutrophication response relationships (especially oxygen depletion resulting in decline of fisheries) in US water bodies.

This draft report makes the commonly made error of tying cultural eutrophication to the rate at which lakes age. The statements on page one of the draft report indicating that cultural eutrophication increases the rate at which a lake fills in to eventually become a meadow, are incorrect. Examination of the relationship between the character of lake sediments and the degree of eutrophication of lakes has been one of the areas of intensive research by one of the authors (Lee). The results of his studies, which were similar to the results of other studies, showed that in general eutrophication does not significantly affect the rate of filling-in of a water body. The rate of filling-in of water bodies is primarily controlled by the rate of transport of erosional materials from the watershed. Eutrophic lakes do not, in general, have any greater organic content in the sediments than oligotrophic lakes. The organic content of the sediments of many lakes appears to be determined primarily by the transport of terrestrial organics from the watershed. Phytoplankton production in a lake plays little or no role in the filling of that lake. In general, if one wishes to control the rate of lake aging, i.e., filling, efforts must be directed toward controlling land erosion, not phosphorus input.

By far, the greatest deficiency of the draft report is the assumption that the phosphorus-related eutrophication problems of the Great Lakes Region occur to the same degree in other parts of the US. Based on the research that has been conducted in the Great Lakes Region by one of the authors (Lee) and many others, there is no doubt that phosphorus is a key element controlling the excessive fertilization of lakes and impoundments in this

area of the US. Further, a review of the limnological and water quality literature will show that, in general, lakes in this area of the US have received the greatest amounts of study. Water bodies, especially impoundments, in other parts of the country such as the lower midwest, southeast, and southwest have been much less intensively studied. For example, the State of Texas has more surface area of inland waters than any other state except Alaska. Yet, until the recent completion of the study of Lake Ray Hubbard, located near Dallas, Texas, by Lee and his graduate students at the University of Texas at Dallas, no comprehensive study of nutrient load-lake response relationships had been conducted on any water body within that state. Similar situations exist for other states in the southern part of the US. Based on the experience of the authors in having conducted eutrophication-related research in both the midwest and eastern US, as well as in the southern US, it is concluded that it is inappropriate to assume that the phosphorus-related eutrophication problems of the Great Lakes Region would occur to the same degree in other parts of the US.

Several years ago, the topic of the extent of eutrophication problems in the US was extensively discussed. While those who review the published literature on the limnology and water quality in the Great Lakes Region could conclude that water quality-eutrophication problems that are prevalent in this area of the country are prevalent throughout the country, a critical examination of the situation will show that this is not likely to be the case. Several years ago, Dr. D. A. Okun of the University of North Carolina estimated that approximately 15 percent of the US population would likely see an improvement in water quality in nearby waters as a result of the control of phosphorus in domestic wastewaters. He correctly assessed that those parts of the US population that discharge their wastewaters to the major unimpounded rivers, coastal and marine waters and to septic tank wastewater disposal systems, would not likely detect any significant improvement in water quality due to reduced phosphorus content in their

domestic wastewaters, in the waters of their region. This does not mean that phosphorus does not cause excessive fertilization problems in many parts of the US. It does mean, however, that outside of the Great Lakes watershed, the populus is likely to detect limited improvements in water quality resulting from US EPA OTS classifying phosphorus as a hazardous chemical and requiring control of phosphorus in commerce in accord with the provisions of the Toxic Substances Act.

The likelihood of OTS being able to control the use of phosphorus in agricultural fertilizer is, in the opinion of the authors, remote. Therefore, because of the ways phosphorus is used by society, the major thrust of any OTS control program would likely be toward control of phosphorus in municipal and industrial wastewaters. It is, therefore, appropriate to use the approach developed by Dr. Okun to assess the potential national significance of phosphorus as an environmental hazard. The authors agree with Dr. Okun's assessment that only a limited portion of the US population would likely benefit from imposition of phosphate control in domestic wastewaters.

Even within the Great Lakes basin, further technologically and economically feasible controls of phosphorus, beyond those already initiated, are, in the opinion of the authors, going to be difficult to achieve. Within a few years, all of the municipalities will, as a result of advanced wastewater treatment, be achieving phosphorus concentrations in domestic wastewater treatment plant effluent of 1 mg/l P or less. It does not appear that further restriction of sale or use by the public will have any significant impact on the phosphorus levels reaching the Great Lakes.

Examination of the OTS draft report on the hazard of phosphates in the environment shows that three principal references were used as the basis for their conclusion that phosphorus represents a significant national problem which would justify its classification by OTS as one of the most environmentally hazardous chemicals. These were the National Eutrophication Survey, National

Water Quality Inventory Report, and the National Commission on Water Quality Report. Examination of the expanded writeup of the work summarized by the NCWQ 1976 report shows that the conclusions drawn by the NCWQ are likely not technically valid with respect to the extent of the eutrophication problems in the US. It appears that the concentrations of nutrients in rivers was used by the NCWQ staff as a basis for indicating eutrophication-related water quality problems. It has been known for many years that one cannot relate the concentrations of nitrogen and phosphorus in a river to excessive fertilization problems in standing waters. It has been well documented that it is the load of available forms of the limiting nutrient that controls eutrophication-water quality problems in lakes and impoundments. Support for this approach has been provided by many investigators, including Rast and Lee in their recently completed US EPA report.

The National Commission on Water Quality Report is confusing in that it appears that they have classified nutrient-related water quality problems based on the ammonia content of the river, A substantial number of the problem areas cited by NCWQ are areas where the reasons for the water quality problems are excessive ammonia. It appears that the NCWQ staff has not clearly distinguished between what they have termed excessive concentrations of nutrients and eutrophication. From an overall point of view, it is concluded that, at this time, the work of the National Commission on Water Quality staff in assessing the extent of the eutrophication problems in the US and in particular the role of phosphorus in influencing this problem, is questionable and possibly not technically valid.

The second primary source of information used by the Office of Toxic Substances in their attempt to justify classifying phosphorus as a national environmental hazard is the US EPA National Eutrophication Survey Reports. This is a multi-year study initiated on the east coast and will have covered approximately 800 lakes when completed on the west coast. While summary reports covering the National Eutrophication Survey work on the eastern lakes and on lakes in the Great Lakes area have been published, reports covering

the work on the lakes in the western US are still in preparation. It has been found, however, that some of the procedures used by the National Eutrophication Survey have proven to be unreliable for assessing the relative significance of nitrogen and phosphorus as causes of excessive fertilization problems. The complete results of the National Eutrophication Survey must be critically examined before any assessment can be made of the significance of phosphorus in causing excessive fertilization problems in lakes and impoundments throughout the US. The importance of having data from the southern and western US stems from the fact that the nitrogen load to western water bodies, from the atmosphere in the form of precipitation, may be much less than it is in the eastern lakes, thereby creating many more nitrogen limited water bodies than are found in other parts of the US. As found by Rast and Lee, several of the US OECD Eutrophication Study water bodies located in the western US show nitrogen limitation of algal growth. It is the opinion of the authors that it is premature to use the National Eutrophication Survey results as a basis for judging the significance of the eutrophication problems in the US and the role of phosphorus in causing these problems.

The National Water Quality Inventory was cited as a source of information used by OTS to evaluate the magnitude of the eutrophication problem. Examination of the most recent edition of the National Water Quality Inventory (1976) shows that only seven states outside of the East or Upper Midwest reported information on lake eutrophication conditions. While the basis by which a state chose to report lake eutrophication conditions was not indicated in the report, it is apparent that few states' pollution control agencies chose to report eutrophication as one of the major water quality problems in the state. It is certainly unjustified to utilize the National Water Quality Inventory Reports for the significance of eutrophication as a national water quality problem and especially for assessing the role of phosphorus in causing these problems. It should be emphasized that a state's reporting the presence of eutrophic lakes within its boundaries does not

provide any information on the extent of the problem or the role of phosphorus in causing the problem. There can be little doubt that every state has some eutrophic lakes within its boundaries. In order to assess the role of man and phosphorus in causing eutrophication of a water body, a study of the water body must be conducted. Simply indicating that there is a change in the phosphorus concentration as a result of some activity, provides no information on the change in water quality associated with the activity. As noted earlier, the work of Rast and Lee, as well as that of several others, has shown that in order to effect a significant change in water quality, large changes in the phosphorus load must be made. The removal of a few percent of the total phosphorus load to a lake will usually have little or no inpact on eutrophication-related water quality problems. As discussed by Rast and Lee, in order to bring about a significant improvement in water quality in many phosphorus limited eutrophic lakes, essentially complete removal of phosphorus from domestic wastewater and possibly phosphorus control from land drainage must be achieved.

This report is also inadequate in terms of evaluating the hazards of phosphates in the environment since it does not include a discussion of the environmental chemistry of phosphorus. The valid approach to hazard evaluation involves the evaluation of the toxicity and/or other adverse effects in light of the sources, environmental behavior (fate) and environmental concentrations of the chemical of concern. For each source of a contaminant, in this case, phosphorus, information must be available on the forms and amounts of the contaminant introduced into the environment and the transport and transformations of each of the forms in the environment in order to evaluate the potential hazard the substance may have for the environment and man. There are many forms of phosphorus which are not, and will not become, available to affect algal growth or aquatic ecosystems. There are also numerous mechanisms in the environment by which available phosphorus is rendered unavailable for assimilation by algae and also by which less available forms are made available. In addition, nature has

a highly dispersive ability to reduce the concentrations of available forms of contaminants to levels below those which have been found to have adverse effects on the environment.

The predicted environmental fate and concentration data provide guidance on toxicity testing by establishing the forms of the chemical and its transformation products that should be evaluated and their expected concentrations in various parts of the environment. While this draft report presents the US EPA Office of Toxic Substances' view of the adverse effects of phosphates in the environment, it does not address the sources and the environmental chemistry of phosphate.

It is the understanding of the authors of this review that the US EPA OTS will soon issue a contract for work on the sources of phosphate to the environment. It, therefore, appears that a major building block of the hazard assessment, i.e., the environmental chemistry, has been completely left out of the OTS plans for the assessment of phosphates in the environment. Without the environmental chemistry component, it is impossible to assess, in a meaningful way, the potential hazard associated with any chemical such as phosphate that is currently in production.

The importance of the environmental chemistry-fate component of hazard assessment has been recognized for some time by those who are actively involved in evaluating the environmental impacts associated with the production and use of new and expanded-use chemicals. For example, the American Society for Testing Materials has parallel sections devoted to aquatic toxicology and environmental chemistry-fate. G. Fred Lee serves as chairman of the Environmental Chemistry-Fate Section. Both of these sections are designed to provide information necessary for the assessment of hazards of chemicals to man and the environment.

It is felt that a comprehensive report should be prepared by the Office of Toxic Substances on the aqueous environmental chemistry of phosphate. Without this information, it is impossible to proceed in a logical manner toward meaningful control

programs for those situations where phosphate does cause a significant deterioration of water quality. Information of this type will show that the proper approach to take for assessing excessive fertilization problems caused by phosphorus is a case by case approach in which the sources of available phosphorus to a water body are determined and the most cost effective method available for control is implemented.

The authors have found that the approach used by the US EPA Office of Toxic Substances in connection with classification of phosphorus as a major environmental hazard requiring a national control program above that already available through Public Law 92-500, is not technically valid.

EXPERIENCE OF AUTHORS

G. Fred Lee has extensive experience in teaching, conducting research and serving as a public and private consultant in the area of eutrophication of natural waters. He has a bachelors degree in Environmental Sciences from San Jose State College (1955), a masters degree in Public Health with a specialization in environmental science from the University of North Carolina (1957), and a Ph.D. degree in Environmental Engineering and Environmental Sciences from Harvard University (1960). He held the position as Professor in the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison where he directed the Water Chemistry Program for thirteen years. For the past four years, he has held a position on the professional staff at the University of Texas at Dallas. He is a registered professional engineer in the State of Texas and is the President of EnviroQual Consultants and Laboratories, Inc. of Plano, Texas.

Focal points of G. Fred Lee's professional career have been teaching, research, and public service in determining the causes of and developing control programs for excessive fertilization of fresh and marine waters. He has authored over 150 professional papers, approximately 50 percent of which have been devoted to

eutrophication-related areas. The majority of the rest of his papers have been concerned with the sources, environmental chemistry, and significance of hazardous chemicals in the environment. He has served as an advisor to numerous governmental agencies, including the Council on Environmental Quality, in the area of eutrophication. Further, he worked with Council staff in developing the original version of what has evolved into the Toxic Substances Act. He has been a member of various committees of the Research Advisory Board of the US-Canada International Joint Commission. He is currently a member of the IJC RAB Expert Committee on Engineering and Technology. One of the primary areas of activity of this committee is the development of a phosphate management strategy for the Great Lakes. He is serving as an advisor for the Organization for Economic Cooperation and Development (OECD) Eutrophication Technical Bureau. He and Walter Rast, former graduate student working under his supervision, completed a comprehensive review of the US OECD Eutrophication Study Program data, a report of which has recently been submitted to the US EPA for publication. He has served as an advisor to the New York District of the Corps of Engineers on the excessive fertilization problems of the New York Bight, to the Emilia Romagna Region of Italy on the eutrophication problems of the nearshore waters of the Adriatic Sea, and to the Spanish Government on the eutrophication problems of Spanish impoundments. He is currently involved in a review of the excessive fertilization problems of fresh and marine waters of Japan.

In addition to extensive research experience on eutrophication problems in the Upper Midwest, Dr. Lee has also been involved in nutrient load-impoundment response relationships in the southern US. He is in the process of completing a 15-month, approximately $300,000 study devoted to the amounts of nutrients derived from various types of land use in the Lake Ray Hubbard watershed located north of Dallas, Texas, and the impact of these nutrients on water quality in this impoundment. These results, coupled with the results of the US EPA contract study devoted to nutrient load-lake

eutrophication response relationships, have provided him the opportunity to examine eutrophication problems in various parts of the US.

In addition to working with governmental agencies, G. Fred Lee has also been active as a consultant to industry, helping to evaluate the significance of phosphorus in the environment and the potential environmental impact of compounds that might be used as a substitute for phosphate as a builder in detergent formulations.

A. Jones received her bachelors degree in Biology from Southern Methodist University (1973) and her masters degree in Environmental Sciences from the University of Texas at Dallas (1975). She is currently working toward her Ph.D. degree in Environmental Sciences at UTD. A portion of her dissertation is devoted to the significance to water quality of phosphorus release from dredged sediments during open water disposal.

She has been involved in the New York District Corps of Engineers supported study of the excessive fertilization problems in the New York Bight, and in the study of the excessive fertilization problems of the northeastern Italian coastal waters of the Adriatic Sea. Currently, she is involved in the study of eutrophication problems in Spanish impoundments and also in the study of the excessive fertilization problems of fresh and marine waters of Japan.

REFERENCE

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