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Research and Development

Status Assessment of Toxic Chemicals

Phosphates

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STATUS ASSESSMENT OF TOXIC CHEMICALS: PHOSPHATES

by

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Contract No. 68-03-2550

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report contains a status assessment of the air emissions, water pollution, health effects, and environmental significance of cadmium. This study was conducted to provide a better understanding of the distribution and characteristics of this pollutant. Further information on this subject may be obtained from the Organic Chemicals and Products Branch, Industrial Pollution Control Division.

Status assessment reports are used by IERL-Ci to communicate the readily available information on selected substances to government, industry, and persons having specific needs and interests. These reports are based primarily on data from open literature sources, including government reports. They are indicative rather than exhaustive.

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ABSTRACT

Large sources of phosphate, which result from the widespread use of detergents from human wastes, and from surface water runoff from phosphate fertilized acreage, can cause accelerated eutrophication of freshwater aquatic systems. Detergents have been found to account for 50% to 70% of phosphate in domestic wastewater, while human wastes account for the other 30% to 50%. An estimated 1% to 5% of the phosphate applied as fertilizer reaches surface water through runoff and percolation. This amounts to about 46,000 metric tons to 230,000 metric tons (P_2O_5 content) of phosphate fertilizer per year. Municipal point sources dominate phosphate loading in the Northeast, while agricultural runoff dominates in the Southeast, Midwest, and West. Phosphate control technology encompasses biological, chemical, chemical-physical and physical techniques. Although a Federal phosphate criterion has not been established, the EPA is currently considering the problem. To control accelerated eutrophication, total phosphate phosphorus should not exceed 0.05 g/m^3 in any stream entering a lake or reservoir, or 0.025 g/m^3 within the lake or reservoir; the goal in other flowing streams is 0.1 g/m^3. At this time, 16 states have adopted effluent standards, with concentration limits ranging from 0.1 g/m^3 to 2.0 g/m^3 for total phosphorus.

Areas in which additional study is recommended are: 1) a better definition of where accelerated eutrophication is a problem and what the sources of the problem are; 2) in areas of accelerated eutrophication, the effectiveness of short-range control methods such as phosphate detergent bans, plant cutting and harvesting, or chemical application should be determined; 3) effect of methods to control agricultural runoff in areas where accelerated eutrophication is a problem; 4) a better understanding of nutrient runoff into flowing streams and their environmental fate; and 5) a cost/benefit analysis of phosphate detergent bans versus clean-up of municipal wastewater.

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CONVERSION FACTORS AND METRIC PREFIXES[a]

CONVERSION FACTORS

To convert from	To	Multiply by
Centigrade (°C)	Fahrenheit (°F)	2.205
Meter (m)	Foot	3.281
Meter^2 (m^2)	Foot^2	1.076×10^1
Meter^3 (m^3)	Foot^3	3.531×10^1
Metric ton	Pound-mass	2.205×10^3
Metric ton	Kilogram	1.000×10^3
Metric ton	Ton (short, 2,000 pound-mass)	1.585×10^{-4}
Pascal (Pa)	Pound-force/inch^2 (psi)	1.450×10^{-4}
Total phosphate	Total phosphorus as elemental phosphate	0.33

METRIC PREFIXES

Prefix	Symbol	Multiplication factor	Example
Kilo	k	10^3	1 kPa = 1×10^3 pascals
Mega	M	10^6	1 MJ = 1×10^6 joules
Micro	μ	10^{-6}	1 g = 1×10^{-6} gram
Milli	m	10^{-3}	1 mg = 1×10^{-3} gram

[a]Standard for Metric Practice. ANSI/ASTM Designation: E 380-76$^\varepsilon$, IEEE Std 268-1976, American Society for Testing and Materials, Philadelphia, Pennsylvania, February 1976. 37 pp.

ACKNOWLEDGEMENT

This report was assembled for EPA by Monsanto Research Corporation, Dayton, OH. Mr. D. L. Becker served as EPA Project Officer, and Dr. C. E. Frank, EPA Consultant, was principal advisor and reviewer.

SECTION 1

INTRODUCTION

Phosphates, resulting from human wastes, the widespread use of detergents, surface water runoff, and phosphate fertilized acreage, can cause accelerated eutrophication of freshwater aquatic systems. This generates unsightly aquatic plant growth that interferes with the usage of the water.

To organize a management system for controlling phosphates, information must be obtained on emission sources, environmental effects, control technology, and present status of phosphates control.

The purpose of this report is to briefly present the information required for a phosphates management system.

SECTION 2

SUMMARY

Phosphorus is widely distributed in natural water and wastewater in three forms: organically bound phosphate, inorganic condensed phosphate, and orthophosphate. Orthophosphate is the simplest and most reactive form for chemical and biological removal.

Phosphate is necessary for the growth of many organisms in natural waters, but excessive amounts result in overfertilization. Standing crops of aquatic plants sufficiently increase to interfere with water uses and become nuisances to man. This phenomena accelerates the process of eutrophication, which is the natural process of aging in a lake caused by biological and chemical enrichment.

Phosphates originate from point and nonpoint sources. Point sources include discharges from municipal and industrial activities, while nonpoint sources mainly involve land runoff.

Domestic wastewater dominates the point source category in total phosphorus. Detergents have been found to account for 50% to 70% of this effluent.

Phosphorus contained in land runoff results largely from the addition of fertilizer to agricultural land. An estimated 1% to 5% of the phosphorus applied as fertilizer reaches surface water through runoff and percolation. This amounts to 46,000 metric tons to 230,000 metric tons (P_2O_5 content) of phosphate fertilizer per year.

A conclusion of the National Commission on Water Quality is that municipal discharges, urban storm runoff, and combined storm and sewer overflows account for many of the nutrient loadings in the Northeast; and that land runoff is a large contributor in the agricultural areas of the Southeast, Midwest, and West.

A desired goal for preventing plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments is 0.1 g/m^3 total phosphate expressed as elemental phosphorus (TPP). Most relatively uncontaminated lake districts have surface waters that contain from 0.01 g/m^3 to 0.03 g/m^3 TPP.

Phosphorus control technology encompasses several technologies. Biological, chemical, chemical-physical, and physical techniques have successfully removed phosphorus from wastewater or have been directly applied to reducing aquatic plant growth.

In states which have wastewater effluent phosphorus standards, most concentration limits range from 0.1 g/m^3 to 2.0 g/m^3 TPP, with many established at 1.0 g/m^3. Table 1 presents a brief summary of the information contained in this report.

Recommended areas for further study are:

- Better definition of where accelerated eutrophication is a problem and what the sources of the problem are.
- In areas where accelerated eutrophication has been defined as a problem, what is the effectiveness of short-range control methods such as phosphate detergent bans, plant cutting and harvesting, or chemical application.
- Effect of methods to control agricultural runoff in areas where accelerated eutrophication is a problem.
- Better understanding of nutrient runoff into flowing streams and their fate in the environment.
- Cost/benefit analysis of phosphate detergent bans versus clean-up of municipal wastewater.

TABLE 1. PHOSPHATES

Source	Extent of problem	Control technology	Regulatory action
Point:			Each state has at least one organization responsible for water pollution prevention. In the states which have effluent phosphorus standards, most concentration limits range from 0.1 g/m^3 to 2.0 g/m^3 TPP (total phosphate expressed as elemental phosphorus).
Industrial	Minor contributor.	Biological and chemical-physical methods.	
Municipal:			
Treatment facility	Major contributor in the Northeast.		
Urban runoff	Detergents generally account for most phosphate in domestic wastewaters (50% to 70%), human wastes account for the remainder (30% to 50%).		
Nonpoint:			
Land runoff Precipitation Groundwater Wildlife wastes Sediments	Agricultural land runoff is the major contributor. It is also the dominate contributor to phosphate loading in the Midwest, Southwest, and West.	Direct application of chemical, physical, and biological means of the reduction of aquatic plants.	

SECTION 3

SOURCE DESCRIPTION

BACKGROUND

Three forms of phosphate phosphorus[a] are widely distributed in natural water and wastewater: organically bound phosphate, inorganic condensed phosphate, and orthophosphate. Organically bound phosphate, the least abundant of the three forms, is found in ester and anhydride configurations. These configurations are parts of proteins, phospholipids, nucleic acids, and bacterial cell mass. Organic phosphate is broken down by enzyme action and does not precipitate with metallic salts. Inorganic condensed phosphates contain two or more phosphorus atoms in a ring or chain structure. Detergents contribute most of this form as poly- and pyrophosphates. The remainder comes from the metabolic breakdown of proteins in human waste. All the inorganic forms slowly hydrolyze in an aqueous environment to the ortho form. Orthophosphate is the simplest and most reactive form for chemical and biological removal. Orthophosphate equilibria include H_3PO_4, $H_2PO_4^-$, HPO_4^{-2}, and PO_4^{-3}, in a pH-determined system.

Some phosphate is necessary for the growth of many organisms in natural waters, but excessive amounts result in overfertilization. During the past 30 yr, standing crops of aquatic plants have increased enough to interfere with water uses to become nuisances to man. Such phenomena are associated with accelerated eutrophication, or aging of lake waters. Phosphates are not the sole cause of eutrophication, but substantial evidence indicates that it is the limiting factor for plant growth. An increase in phosphate permits use of existing nutrients.

SOURCES OF PHOSPHATES

Control of accelerated eutrophication often involves reduction or elimination of nutrient loadings. Before a phosphate loading can be controlled, sources of this nutrient must be identified. These may be point sources, such as the effluent of a municipal or industrial wastewater treatment facility, or nonpoint sources,

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[a]Note--Phosphorus and phosphate are used interchangeably in this report and should not be confused with phosphorus in the elemental form.

such as precipitation, groundwater, wildlife wastes, land runoff, and resuspension of sediments in water.

Industrial Wastewater

An unknown amount of industrially produced phosphorus wastes exists in waste treatment plant influent. However, the very low proportion of industrial phosphorus discharge (4% of the total amount of phosphorus wastes generated) measured during a government study on Lake Erie, suggests that industry is a very minor contributor (1).

Municipal Wastewater

Domestic wastewater normally contains a substantial concentration of phosphorus resulting from human activities. Human wastes such as feces, urine, and waste food disposal account for about 30% to 50% of the phosphorus in domestic wastewater (2). Detergents which contain phosphate builders and which are principally used for laundering clothes account for the remaining phosphorus, about 50% to 70%.

A study conducted during a phosphorus detergent ban in New York, found a 55.7% reduction in phosphorus loading at a domestic wastewater treatment facility (3). Other sources, such as adding sodium hexametaphosphate or other phosphorus compounds to water supplies for corrosion and scale control can account for 2% to 20% of the total phosphorus present in wastewater (2).

Nonpoint Sources

Even if all phosphates were removed from sewage effluents, less controllable nonpoint sources would still be a major problem. Unless particulate matter is picked up from the atmosphere, natural precipitation contains almost no phosphorus, and groundwater has been reported at less than 0.2 g/m^3 total phosphate reported as elemental phosphorus (3). Direct input of wild animal wastes is usually a minor source of phosphorus unless a lake supports an unusually large population of wildlife.

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(1) Willis, I. G. The Balance Between Waste Treatment and Waste Discharge in the U.S., 1957-2000. Journal of the Water Pollution Control Federation, 46(3):438-457, 1974.

(2) Process Design Manual for Phosphorus Removal. EPA-625/1-76-001-a, U.S. Environmental Protection Agency, Washington, D.C., April 1976. 260 pp.

(3) Morse, J. W., K. J. Little, and U. A. Garrison. Eutrophication in Vermont. Water Quality Surveillance Series, Report No. 3 (PB 267 844), Department of Water Resources, Agency of Environmental Conservation, Montpelier, Vermont, 1967, 69 pp.

Drainage from agricultural land produces large amounts of phosphate. Phosphorus contained in agricultural land runoff results largely from adding fertilizers to the soil to boost crop production (1). In Wisconsin it was found that runoff contributed 38 kg of phosphorus per square kilometer per year (4). Phosphates entering soil are quickly bound to soil particles; therefore, most of the phosphorus carried into lakes or streams by land runoff is actually attached to soil particles rather than dissolved in runoff water. The phosphorus content of runoff water is dependent upon the amount of erosion occurring in a watershed. The steeper the slope the greater is the contribution. The following values were calculated from figures for the annual contribution from arable land in Wisconsin (4):

Slope	Phosphorus, kg/km^2
20°	160
8°	45

It has been suggested that nearly all the phosphate reaching streams in agricultural areas does so through bank erosion (4).

Indications are that nutrients soon enter plants and are then recycled fairly fast in the stream. However, phosphate concentrations have also been found to increase in the downstream direction (4). The amounts of nutrients available and the possibility that they may actually control the growth of primary producers in streams merits further study.

Cropland or pastureland runoff contains more phosphorus than does forest runoff because of applications of fertilizer in the form of manure or commercial preparations. In addition, because the forest floor may be completely covered with vegetation or litter, little erosion occurs. A recent study found a mean total phosphorus content 10 times greater in water from agricultural land than from the forest (5). As more fertilizer is applied, more phosphorus is bound to the soil particles later carried away in runoff. Normally, an estimated 1% to 5% of phosphorus applied as fertilizer reaches surface waters through runoff and percolation (3).

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(4) Hynes, H. B. N. The Ecology of Running Waters. Liverpool Press, Liverpool, England, 1970. 450 pp.

(5) Omernik, J. M. The Influences of Land Use on Stream Nutrient Levels. EPA-600/3-76-014, U.S. Environmental Protection Agency, Washington, D.C., January 1976. 117 pp.

Using the 1974 consumption of phosphate fertilizers, 4.6×10^6 metric tons (P_2O_5 content) (6), results in 46,000 metric tons to 230,000 metric tons of phosphate fertilizer reaching surface waters per year.

The role of sediments in releasing phosphates into lakewater is controversial and not well defined; however, it is believed to be a source of phosphate eutrophication.

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(6) Commercial Fertilizers. Crop Reporting Board, U.S. Department of Agriculture, Washington, D.C., 1 November 1974. 11 pp.

SECTION 4

ENVIRONMENTAL SIGNIFICANCE

Several investigators assert that eliminating phosphates in waste streams (point sources) is essential to controlling accelerated eutrophication (7-13). One study determined that 72% of the soluble phosphorus entering one eutrophic lake came from wastewater discharges (14). Other studies have shown that wastewater accounts for 57% to 94% of the input phosphorus to eutrophic lakes (15, 16).

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(7) Stumm, W. Man's Acceleration of Hygrogeochemical Cycling of Inland and Coastal Water. Water Pollution Control, 74(2):124-133, 1975.

(8) Bradshaw, J. S., R. B. Sun, D. A. Shite, J. R. Barton, D. K. Fuhriman, E. L. Loveridge, and D. R. Pratt. Chemical Response of Utah Lake to Nutrient Flow. Journal of the Water Pollution Control Federation, 45(5):880-888, 1973

(9) Lin, S. S. and D. A. Carlson. Phosphorus Removal by the Addition of Aluminum (III) to the Activated Sludge Process. Journal of the Water Pollution Control Federation, 47(7):1978, 1976.

(10) Balmer, P., and O. F. Frederiksen. A Pilot Plant Scale Evaluation of Potential Precipitants in the Secondary Precipitation Process. Water Research, 9:721-727, 1975.

(11) Huang, V. H., J. Mase, and E. G. Fruh. Nutrient Studies in Texas Impoundments. Journal of the Water Pollution Control Federation, 45(1):105-118, 1973.

(12) Federal Register, 38(206):29646, 1973.

(13) Toerien, D. F. South African Eutrophication Problems. A Perspective. Water Pollution Control, 74(2):134-142, 1975.

(14) Hething, L. J., and R. M. Sykes. Sources of Nutrients in Cohandarago Lake. Journal of the Water Pollution Control Federation, 45(1):145-156, 1973.

(15) MacKenthium, K. M., L. E. Leup, and R. K. Stewart. Nutrients and Algae in Lake Sebasticook, Maine. Journal of the Water Pollution Control Federation, 49(2):R72-R81, 1968.

(16) Report to the International Joint Commission on the Pollution of Lake Erie, Lake Ontario, and the International

(continued)

A conclusion of the National Commission on Water Quality is that municipal discharges, urban storm runoff, and combined storm and sewer overflows account for much of the nutrient loadings in the Northeast; and that land runoff (nonpoint sources) is a large contributor in the agricultural areas of the Southeast, Midwest, and West.

A study which was performed for the National Commission on Water Quality indicated the relative importance of major effluent-generating activities (17). These activities included point sources, municipal and industrial activities, and agricultural nonpoint sources and urban nonirrigated agricultural runoff. Phosphate was studied for municipal and agricultural activities; the results--presented in Table 2 and in Figure 1--show that agriculture dominates in five geographical regions using 1973 estimates (17). These regions in Figure 1 (C, D, E, F, and G) include areas of the Southeast, Midwest, and West.

TABLE 2. ESTIMATES OF 1973 PHOSPHATE GENERATION, DISCHARGE, AND DISCHARGE AFTER CONTROL FOR SELECT SOURCES (17)

	10^3 metric tons total phosphorus as P					
Geographic regions[a]	1973 Generation	1973 Discharge	Secondary treatment	Best practicable wastewater treatment technology	Agriculture, Runoff	Agriculture, Control
A	15	13	10	9	4	2
B	58	47	39	29	63	31
C	42	31	27	16	134	72
D	70	41	40	18	189	92
E	12	10	8	7	235	119
F	17	13	12	10	428	217
G	25	18	17	5	240	125
H	1	0.9	0.9	0.5	1	0.9
I	7	6	5	5	36	20
J	0.9	0.9	0.5	0.5	16	7
K	5	4	4	2	0.9	0.5
L	12	10	9	7	2	0.9
M	20	17	14	5	4	2
National total	285	212	186	114	1,353	689

[a]See Figure 1.

[b]1 metric ton equals 10^6 grams; conversion factors and metric system prefixes are presented in the prefatory material.

(continued)

Section of the St. Lawrence River, Volume 1. Queen's Printer, Ottawa, Ontario, Canada, 1969.

(17) Pechan, E. J. Summary Report on The National Residuals Discharge Inventory. National Commission on Water Quality, National Research Council, Washington, D.C., March 1976. 50 pp.

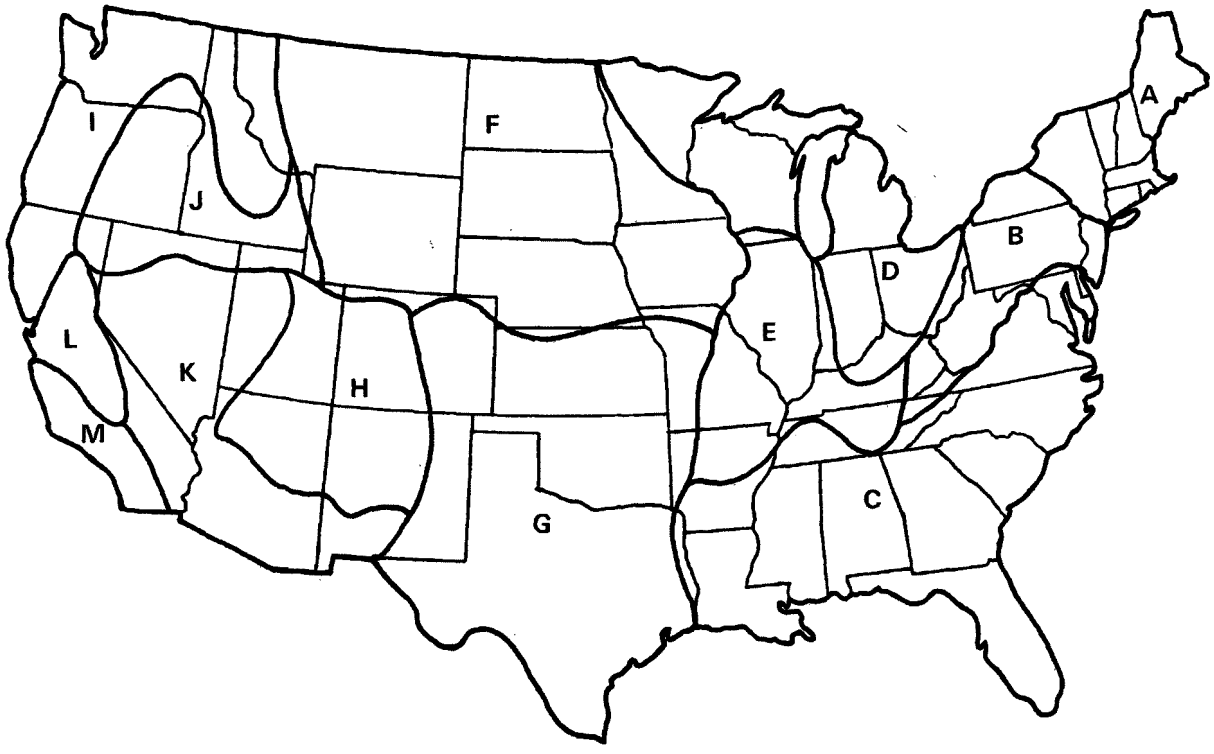

Figure 1. Geographic regions which were selected for estimates of phosphate discharge (15).

SECTION 5

CONTROL TECHNOLOGY

Phosphorus removal encompasses several technologies; biological, chemical, chemical-physical, and physical techniques have successfully removed phosphorus from wastewater or have been directly applied to reducing aquatic plant growth.

BIOLOGICAL REMOVAL

Microorganisms remove dissolved orthophosphate from wastewater in the process of cell synthesis and respiration. The overall amount of phosphorus removed by a biological unit is determined by both the cell wasting rate and the maximum amount of phosphorus that may be incorporated into the cell mass. Chemical precipitation may also occur but usually is not the primary removal mechanism in a biological system.

In conventional flow schemes a trickling filter system utilizing microorganisms can be expected to remove 20% to 30% phosphorus, an activated sludge system can remove 30% to 50% phosphorus (18). The low removal is due to the low carbon to phosphorus ratio (less than 100:1) usually encountered in sewage. Since carbon to phosphorus ratios required for cell growth must usually be 100:1, a nutritionally unbalanced situation exists with phosphorus in excess and carbon the limiting nutrient (18).

Biological methods have also been suggested for direct control of aquatic plants. These involve introducing fish, mammal, fowl, or snail populations which would feed on the plants to an area. However, these have limited applicability and are not widely used.

CHEMICAL APPLICATION

Chemical methods of controlling algae and aquatic plants are utilized throughout the United States. Chemicals used for aquatic plant control include copper sulfate, diquat, endothall, dalapon, dichlobenil, diuron, 2,4-dichlorophenoxyacetic acid,

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(18) Ryczak, R. S., and R. D. Miller. A Review of Phosphorus Removal Technology, Technical Report 7706 (ADA 040 802), U.S. Army Medical Research & Development Command, Washington, D.C., May 1977. 66 pp.

2,4,5-trichlorophenoxy acetic acid, and 2,4,5-trichlorophenoxy propionic acid. The use of chemicals is advantageous because they are easy to apply, they require minimal equipment, and they usually kill or reduce nuisance growths within a week. The disadvantages of chemical application are numerous. Application will not stop eutrophication, it will only retard it. Repeat applications are required for continuous control. In addition, long-term residual effects of introducing a toxic chemical into the aquatic environment may be worse than the effect of the phosphate, especially with nonbiodegradable products which can accumulate in aquatic organisms or sediments.

CHEMICAL-PHYSICAL REMOVAL

Phosphorus removal can be successfully accomplished by chemical-physical processes. Physical-chemical processes include precipitation, coagulation, flocculation, sedimentation, filtration, and flotation. Several of these processes are combined in series to effect phosphorus removal to desired levels. The phosphorus must first be insolubilized, then the solid must be separated from the liquid and disposed so that it will not readily reenter the environment. Physical-chemical process combinations are able to remove orthophosphate and condensed phosphate forms from widely varying waste streams.

PHYSICAL METHODS

Physical methods of controlling algae and aquatic plants are often proposed where chemical or biological control would be ineffective or harmful.

Physical control methods include aeration, dilution with nutrient-poor water, nutrient diversion, drawdowns (reducing water level), dredging, aquatic plant cutting, and aquatic plant harvesting. Although physical methods usually require more time and labor, no toxic substances or alien species are introduced to the aquatic environment. Some disadvantages are that control is only temporary or impractical (i.e., dilution which requires large quantities of nutrient-poor water).

Erosion control is also a method of managing phosphate loadings. Poor farming practices can increase agricultural loss of phosphates. If manure is spread on frozen land which slopes down to a body of water or on land which floods in the spring, most of the phosphorus applied is flushed into streams during spring thaws. Overgrazing commonly causes soil erosion while corn or other row crops leave the soil more susceptible to erosion than untilled land. When livestock is confined to a small area, surface runoff from the resultant manure is high in phosphorus. Farm ponds should be fenced to limit livestock access and consequent bank erosion (3).

The results of a nationwide survey which asked each state to describe its problems and recommended measures for controlling aquatic plant growth are presented in Table 3 (3).

Of the 39 responding states, 9 reported no serious plant and algae problems or no statewide control programs. Only 5 of the 31 states reporting aquatic algae problems have well-developed lake restoration programs. Of the seven states reporting biological control methods, most are only in the investigative stages. Finally, 12 states reported using physical control measures such as pulling up nuisance growth or water level manipulation.

TABLE 3. RESULTS OF NATIONWIDE SURVEY ON WEED AND ALGAE PROBLEMS AND SOLUTIONS (3).

	Chemicals allowed								Biological control	Physical controls used							
State	Copper sulfate	2,4-D	Silvex	Endothall	Diquat	Dalapon	Diuron	Dichlobenil	Herbivorous fish	Plant cutting	Drawdowns	Plant harvesting	Aeration	Dredging	No response	No problems	No programs
Alabama		x							x	x	x						
Alaska															x		
Arizona					x		x			x							
Arkansas	x	x	x	x		x		x									
California	x				x				x			x	x				
Colorado	x			x	x				x								
Connecticut															x		
Delaware	x	x		x													
Florida	x	x	x	x	x	x			x	x		x					
Georgia	x	x	x		x	x	x										
Hawaii															x		
Idaho																	x
Illinois	x	x	x	x	x	x		x		x		x					
Indiana	x			x													
Iowa	x			x	x												
Kansas																	x
Kentucky															x		
Louisiana															x		
Maine																	x
Maryland															x		
Massachusetts	x	x	x	x	x					x		x					
Michigan	x	x	x	x	x	x				x		x		x			
Minnesota	x	x	x	x	x	x						x					
Mississippi															x		
Missouri	x																
Montana	x	x	x	x	x	x											
Nebraska				x													
Nevada															x		
New Hampshire	x									x							
New Jersey		x	x	x	x						x						
New Mexico																x	
New York	x	x			x												
North Carolina		x															
North Dakota	x																
Ohio				x													
Oklahoma	x	x			x				x		x		x				
Oregon															x		
Pennsylvania	x		x	x	x					x							
Rhode Island	x																
South Carolina		x	x		x		x	x	x								
South Dakota															x		
Tennessee	x	x		x			x										
Texas	x	x	x	x	x	x											
Utah					x				x								
Vermont	x	x	x														x
Virginia																	x
Washington	x	x	x	x	x	x		x									
West Virginia																x	
Wisconsin	x	x	x	x	x												
Wyoming															x		

SECTION 6

REGULATORY ACTION

STATE REGULATORY AGENCIES

Each state has at least one organization reponsible for water pollution prevention, control, and abatement activities. In about one-half of the 50 states, this responsibility is divided between two state agencies. Usually one of these is the state health department and the other is an organization charged specifically by statute with the conduct of the state's water pollution control program. Although there has been an intensification of Federal activities in water pollution control over the past 20 yr, much of the responsibility for program operations rests with the states. Invariably the appropriate state agencies should be consulted in connection with the planning and conduct of water pollution control programs at cities and other communities. The U.S. Environmental Protection Agency regional office personnel work closely with state agencies and can give advice regarding proper state agency contacts.

STATE STANDARDS

As of June 1971, 16 states had adopted wastewater effluent phosphorus standards. In general, these standards have taken the form of an effluent concentration limit or a requirement for a specified percentage reduction in the phosphorus concentration in the raw wastewater. In most cases, effluent concentration limits range from 0.1 g/m^3 to 2.0 g/m^3 total phosphorus, with many established at 1.0 g/m^3. Percentage reduction requirements range from 80% to 95% (2).

It should be noted that neither an effluent nor a percentage-reduction standard actually limits the phosphorus load in terms of pounds of phosphorus discharged per day. Load (kilograms per day) is a direct function of both effluent phosphate concentration and daily effluent volume. Assuming that the effluent concentration standard is being met, an increase in the daily flow of effluent will produce a proportionate increase in the mass of phosphorus discharged daily to the receiving waters. If the phosphorus load then becomes intolerable, adjustment downward of the effluent concentration standard will be necessary. Similarly, adjustment upward of a percentage-reduction standard will be required if the phosphorus load becomes objectionable

as a result of increased wastewater flow or increased phosphate concentration in the raw wastewater or both (2).

FUTURE REGULATORY CONSIDERATIONS

Although a total phosphorus as phosphate criterion to control nuisance aquatic growths has not been presented, the following rationale to support such a criterion is being considered by EPA (19).

Total phosphate phosphorus concentrations in excess of 0.10 g/m^3 total phosphate expressed as elemental phosphorus (TPP) may interfere with coagulation in water treatment plants. When such concentrations exceed 0.025 g/m^3 at the time of the spring turnover on a volume-weighted basis in lakes or reservoirs, they may occasionally stimulate excessive or nuisance growths of algae and other aquatic plants. Algal growths impart undesirable tastes and odors to water, interfere with water treatment, become aesthetically unpleasant, and alter the chemistry of the water supply. They contribute to the phenomenon of cultural eutrophication.

To prevent the development of biological nuisances and to control accelerated or cultural eutrophication, TPP should not exceed 0.05 g/m^3 in any stream at the point where it enters any lake or reservoir or 0.025 g/m^3 within the lake or reservoir. A desired goal for the prevention of plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments is 0.1 g/m^3 TPP (18). Most relatively uncontaminated lake districts are known to have surface waters that contain from 0.01 g/m^3 to 0.3 g/m^3 TPP (18).

Another method of controlling the inflow of nutrients, particularly phosphorus, into a lake is that of prescribing an annual loading to the receiving water. Data in Table 4 suggests TPP loadings in grams per square meter of surface area per year that will represent critical levels for eutrophic conditions within the receiving waterway for a particular water volume where the mean depth of the lake in meters is divided by the hydraulic detention time in years (19). The data present a range of loading values that should result in oligotrophic lake water quality.

Regulations for feedlots and for phosphate manufacture are contained in reference 20.

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(19) Quality Criteria for Water. EPA-440/9-76-023, U.S. Environmental Protection Agency, Washington, D.C., July 1976. 501 pp.

(20) Final Effluent Guidelines and Standards. EPA-330/1-77-007, U.S. Environmental Protection Agency, National Environmental Information Center, Denver, Colorado, June 1977. 128 pp.

TABLE 4. PERMISSIBLE AND CRITICAL PHOSPHATE LOADING (19).

Mean depth hydraulic detention time, (m/yr)	Oligotrophic or permissible loading, (g/m^2-yr)	Eutrophic or critical loading, (g/m^2-yr)
0.5	0.07	0.14
1.0	0.10	0.20
2.5	0.16	0.32
5.0	0.22	0.45
7.5	0.27	0.55
10.0	0.32	0.63
25.0	0.50	1.00
50.0	0.71	1.41
75.0	0.87	1.73
100.0	1.00	2.00

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GLOSSARY

aeration: Release of air under the water surface to ensure oxygenation and mixing of a water body.

algae (alga): Simple plants, many microscopic, containing chlorophyll. Most algae are aquatic and may produce a nuisance when conditions are suitable for prolific growth.

aquatic plants: Plants growing in or on water.

cultural eutrophication: Accelerated eutrophication due to man's impact on a water body; e.g., due to point sources of nutrients or agricultural runoff.

dilution: replacement of eutrophic lakewater by water lower in nutrients; e.g., by flushing.

drawdown: Release of water from a dam structure causing the water level to go down.

dredging: Removal of sediments from a lake or river bottom by machine, such as suction or hydraulic dredges.

eutrophic: Process of aging in a lake caused by chemical or biological enrichment.

loading: Quantity of a substance entering a water body over a given time period.

limiting nutrient: Nutrient whose demand exceeds its supply such that growth is restricted until more is available.

nonpoint sources: Nutrient sources which enter a water body at numerous locations rather than at a single discharge.

nutrient: Chemical required for growth or maintenance by an organism.

nutrient diversion: Diversion of high nutrient effluents into another basin to bypass the threatened lake.

oligotrophic: Waters with a small supply of nutrients, unproductive. Little oxygen stratification.

percolation: Penetration of water through soil.

phosphate: The ion PO_4^{-3}, an important nutrient.

phospholipids: A class of complex phosphoric esterlipides that are found in all living cells.

point source: A nutrient source which is discharged to a body of water at a single location.

polyphosphate: A salt or ester of a polyphosphoric acid.

pyrophosphate: A salt or ester of pyrophosphoric acid--called also diphosphate.

retention time: Average time that water is held in a basin; e.g., the time needed to refill an emptied reservoir.

runoff: Portion of precipitation on the land that ultimately reaches streams, especially water from rain or melted snow that flows over the surface.

secondary treatment: Biological treatment of wastewater such as trickling filters or activated sludge following mechanical treatment. Bacteria consume the organic parts of the wastes.

sediment: Matter that settles to the bottom of a body of water; e.g., sand or silt from soil erosion, dead plant and animal material.

watershed: Land area which drains to a particular body of water or watercourse.

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16. ABSTRACT

Uses, sources, and quantities of phosphates are discussed in this report, with particular emphasis on the problem of fresh water eutrophication. Recommended standards and current control technologies are reviewed. Areas requiring further study are identified.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Phosphatases, Enzymes, Esterases, Hydrolases, Acid phosphatase, Alkaline Phosphatases, Phosphate deposits, Mineral deposits, clastic rocks, evaporitic rocks, igneous rocks, metamorphic rocks, sedimentary rocks, phosphorus	Phosphates, detergents, fertilizers, wastewater domestic wastewater	68D

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