THE NATIONAL EUTROPHICATION SURVEY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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A Working Paper of the Office
of Research and Monitoring

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by

Special Projects Staff

Introduction:

On September 15, 1971, the Surgeon General of the United States Public Health Service and the Administrator of the Environmental Protection Agency, together with the Commissioner of the Food and Drug Administration and the Chairman of the Council on Environmental Quality, held a joint press conference to announce information regarding efforts to limit the use of phosphorus in detergents. They announced that nitrilotriacetic acid (NTA) should not be used as a phosphate substitute at this time because of unresolved questions concerning long-term effects on human health and the environment. Secondly, they stated that some new non-phosphate detergent products pose potential health hazards due to their caustic nature. Currently, the emphasis of control of phosphorus from municipal sources is at the sewage treatment plant. About half the phosphorus contained in municipal waste comes from detergent phosphates and the other half, from human metabolic waste, food waste, and other organic matter.

For these reasons, on December 15th of last year, the Environmental Protection Agency also announced the establishment of an intensive survey to identify the water bodies in the United States which have potential

or actual eutrophication problems due to phosphorus from municipal sources. The approximately $ 4.2 million National Eutrophication Survey is slated for completion by December 31, 1974. Results of the survey are an integral part of an Environmental Protection Agency control program to assist state and local governments, through construction grants, in reducing phosphates, to the extent necessary to protect water quality, by means of municipal waste treatment. Under this control program, up to 80%-98% phosphate removal may be provided at municipal treatment plants, where required.

In order to execute this total program, several offices within the Environmental Protection Agency have been charged with various tasks. While the total Agency program involves the Office of Air and Water Programs, the Office of Planning and Management, Regional offices, and the Office of Research and Monitoring, this booklet outlines only the activities of the Office of Research and Monitoring.

It should be noted that this survey centers upon phosphorus as a nutrient which is most often implicated as a cause of eutrophication in freshwater and, occasionally, in salt or brackish water. However, the process and rate of eutrophication within any particular water body can result from the introduction of other major nutrients, such as

nitrogen or, in some cases, essential trace elements, such as iron, manganese and molybdenum. Some of these nutrients can be removed from treatment plant effluents with modest success, but the state of the art of nutrient removal and the costs, design and other technology related to sewage treatment are most clearly defined for phosphorus.

Survey Objectives and Organization:

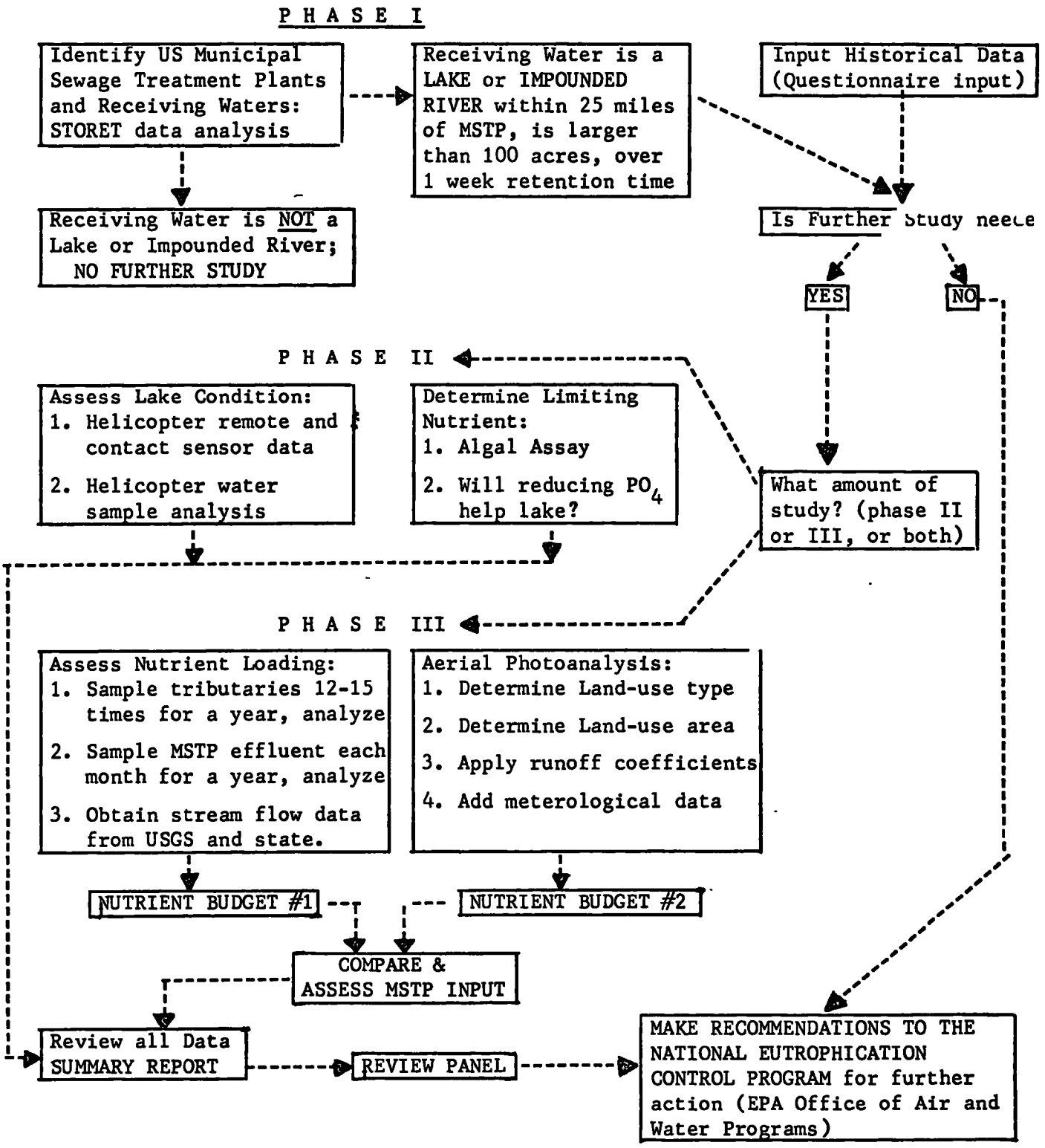
The primary mission of the survey is to determine which U.S. lakes and impounded bodies of water, such as reservoirs, which serve as receiving waters for treated municipal sewage are already eutrophic, are rapidly becoming eutrophic, or are oligotrophic and should be maintained in that condition. A eutrophic water body has high nutrient content which causes an increase in the production of algae and other aquatic plants, a reduced dissolved oxygen level, and deterioration of animal life and water quality. Ultimately, accelerated eutrophication due to cultural impact can lead to the premature extinction of a lake. An oligotrophic water body has low nutrient content, low plant productivity and ample oxygen. (Bodies of water in the midpoint of these changes are termed mesotrophic.)

The basic output of the survey will be in the form of an answer to the question: "Will increased phosphate removal at the municipal sewage treatment plant improve the water quality of the receiving water (the lake or impoundment)?"

Figure I shows the overall plan for conducting the National Eutrophication Survey and Table I (after text) is a tentative time schedule for the completion of survey activities. The project has been divided into three phases. Phase I is concerned with determining which water bodies (lakes and impoundments) in the contiguous 48 states, Alaska, Hawaii, and U.S. territories and possessions should lie within the scope of the survey and with appraising the nature, extent, adequacy and accuracy of existing data and information about these water bodies and the municipal sewage treatment plants which effect them. Phase II deals with collecting and interpreting new data on the status of the lakes and impoundments and to isolate which nutrient limits the extent of plant growth in that water body. Phase III consists of analyzing the tributaries and outfalls of sewage treatment plants affecting the candidate lakes and impoundments for phosphorus input, and making any recommendations for implementation of a phosphorus control ~~stradegy~~. Strategy

FIGURE I

NATIONAL EUTROPHICATION SURVEY



PHASE I.

The first step in Phase I (see Figure I) which was completed in January 1972, involved the identification of all U.S receiving waters, municipal sewage treatment plants (MSTP's) and their outfalls. This tabulation was made through the use of STORET (a computer-based data file). More than 12,500 treatment plants with 25,000 outfalls were identified. The survey's Preliminary Data Sheet was sent to EPA Regional personnel and established the following criteria for including a body of receiving water within the scope of the survey:

1. Is the receiving water a lake?
2. Is the receiving water an impoundment? or
3. Is the receiving water a river which enters a lake or impoundment within 25 miles downstream of the sewage treatment plant outfall?

If the answer to any of the above questions was yes, then two additional questions were asked:

4. Is the retention time of water at least one week?
5. Is the surface acreage in excess of 100 acres?

If the answer to both of these questions was yes, the receiving water was considered a candidate for further consideration. If the receiving water failed to pass any of the criteria, it fell outside the framework of the survey.

There were several reasons for this preliminary screening. First, it was necessary to limit the number of water bodies to a meaningful and manageable number. All 12,500 sewage treatment plants do not pour their effluents into lakes and impounded rivers. Further, in the professional opinion of many investigators, phosphorus is generally not the limiting nutrient in bays, estuaries and coastal waters.

Thus, from the Preliminary Data Sheet, about 3,800 sewage treatment plants and 1,100 candidate lakes or impoundments were identified. These 1,100 water bodies are those to be surveyed during the course of this project following a final screening by the EPA Regional offices and state personnel. Approximately 250 water bodies are being surveyed in 1972.

The Preliminary Data Sheet posed two additional questions to EPA Regional personnel. These questions asked for an estimate of what fraction of the phosphorus loading of a named receiving water could be attributed to the output of a sewage treatment plant, and an appraisal of the accuracy of that estimate.

Following the preliminary screening, in-house EPA staff and extra-governmental limnologists undertook a first review of the candidate receiving waters based on the Preliminary Data Sheet and additional data from files maintained by the Office of Research and Monitoring (EPA). At that point, enough data was available to make an immediate recommendation

concerning increased phosphorus removal at the sewage treatment plant on Lake Winnisquam in New Hampshire and this lake was used as a test case. Recommendations for the plant were passed onto the Office of Water Programs for implementation.

A detailed questionnaire has been sent for the first year of the survey to appropriate federal agencies, state agencies (departments of environment, conservation, water resources, etc.), municipalities (public works, sewer districts), university limnologists, local conservation organizations, and others.

This questionnaire, totaling 52 questions, is a detailed request for limnological, hydrologic, bathymetric, aerial photographic, nutrient loading, and biological data. In addition, it asks for information concerning sewage treatment type, actual and design capacity, and sludge handling. The questionnaire has been sent out to several potential sources of information for each candidate receiving water body in the States of Maine, New Hampshire, Vermont, Connecticut, Rhode Island, Massachusetts, New York, Michigan, Wisconsin, and Minnesota (the ten states to be surveyed in 1972), since it is likely that no single source will have such an array of data immediately available. Responses to the questionnaire are being collated, summarized, stored, and analyzed. A revised

questionnaire, designed to solicit information using a less technical yet equally valid format, is being prepared for use in subsequent states.

PHASE II

The second phase of the National Eutrophication Survey will assess the present condition of lakes or impoundments selected in Phase I where insufficient data exists to make immediate recommendations. The assessment will be accomplished over a one year study of physical, chemical and biological parameters collected on the selected water bodies. (The study parameters are summarized in Table II.)

Initial study by personnel from the National Environmental Research Center in Las Vegas began in May 1972 following a checkout of all instrumentation, sampling devices and techniques. During this checkout period, procedures for sample collection, shipping, analysis and data analysis and storage were verified and modified as required.

Field sampling is being performed with two Huey helicopters equipped with pontoons for water landing which were acquired on bailmant from the Department of Defense for a three year period. The aircraft platforms are equipped with sophisticated equipment to take water samples, to gather *in situ* chemical data and to remotely sense certain physical parameters. Sampling will be done four times during the year. During overflight, the crew remotely

senses chlorophyll-a and surface temperature using a differential radiometer and thermal radiometer. Following descent onto the lakes surface, at an average of four locations, a contact sensor package is lowered and depth, temperature, pH (acidity), dissolved oxygen, conductivity and turbidity data are gathered.

Discrete water samples are taken at depths selected by on-board limnologists (based on contact sensor information) and are divided into aliquots (parts) that are coded and sent via air to an EPA laboratory in Las Vegas for wet chemical analyses. Analyses are run on an automated colorimetric analyzer for dissolved phosphorus, total phosphorus, nitrate and nitrite nitrogen, ammonia nitrogen and alkalinity. Chlorophyll-a analyses will also be run. One-half meter Phleger sediment cores will be taken at each station once a year.

In addition to the water samples taken for chemical analysis, two samples will be taken during the year for algal analysis. One sample will be examined for algal identification and the second, a five-gallon sample taken during the late summer, will be for a laboratory algal assay---a procedure whereby a relationship is determined between phosphorus content of a sample and its ability to support algal growth. (see Attachment).

TABLE II

LAKE SURVEY PHYSICAL, CHEMICAL AND BIOLOGICAL ANALYSIS

TIME*	DEPTH	SECCHI DISK	TEMP. COND.	DISS. O_2	pH	TOTAL P DISSOL. P	NO_2-NO_3 NITROGEN	CHLORO-PHYLL-a	AMMONIA NITROGEN	ALKALIN ($CaCO_3$)	SED. CORE	ALGAL I.D.	ALGAL ASSAY	AMOEBA STUDY
Winter or Early Spring	X_p	X_s	X_p	X_p	X_p	X_p	X_p	X_s	X_p	X_s	(X)		(X_p)	
Mid-Spring	X_p	X_s	X_p	X_p	X_p	X_p	X_p	X_s	X_p	X_s	(X)	X_p		(X_s)
Mid-Summer	X_p	X_s	X_p	X_p	X_p	X_p	X_p	X_s	X_p	X_s	X_b	X_p		X_s
Late Summer or Early Fall	X_p	X_s	X_p	X_p	X_p	X_p	X_p	X_s	X_p	X_s	(X)		X_p	(X_s)
Analyzed By:	F	F	F	F	F	L	L	F	L	L	F	LC	LC	LO

KEY:

P = Profile
S = Surface
b = Bottom
( )= Alt. Time

Field Lab = F
Las Vegas = L
Corvallis = LC
Cincinatti= LO

* The exact time will vary according to local climatic conditions

A limited number of samples will be taken in lakes with high recreational use for study of the pathogenic amoeba Naegleria by EPA's National Environmental Research Center at Cincinnati.

The field sampling program involves a team of thirteen people---three complete aircraft crews (one pilot, one limnologist and one technician each) and mobile laboratory and support personnel. The aircraft crews rotate among the two aircraft and the mobile laboratory and conduct field sampling operations seven days a week from early spring to late summer. The mobile laboratory has the capability to perform chlorophyll-a, dissolved oxygen, pH and conductivity measurements and to prepare samples for shipment to the Las Vegas and Corvallis laboratories for analyses. Backup sampling and chemical analysis equipment and quality control checks are also handled by field personnel.

In calendar year 1972, approximately 250 lakes will be sampled in ten states (New York, Massachusetts, Connecticut, Rhode Island, Vermont, New Hampshire, Maine, Michigan, Wisconsin and Minnesota). In 1973, 450 lakes in 21 states will be sampled and the 400 lakes in the remaining states will be surveyed in calendar year 1974.

PHASE III

The purpose of Phase III is to determine in each water

body surveyed the percentage loading of phosphate that originates from municipal sewage treatment plants and what effect a specific phosphate control strategy will have on the water quality of that lake or impoundment. Phase III and Phase II will be operated concurrently, except when sufficient historical data allows one phase to be bypassed.

A major part of Phase III is the determination of the nutrient budget of phosphorus for each water body. In broad terms, this entails taking monthly samples from the mouths of the main tributaries, from both above and below municipal sewage treatment plants (MSTP's) and from the treatment plant outfalls. When combined with stream flow data, a nutrient budget can be calculated.

In detail, the collection of this data is a logistic problem of high magnitude. With an average of about four tributaries feeding each of the 250 lakes being surveyed in 1972, nearly 20,000 total samples will have to be taken. On July 15, 1972 a pilot sampling project was carried out in Vermont with the cooperation of the Vermont National Guard. EPA personnel trained guardsmen in sampling procedures and techniques with samples sent to the National Environmental Research Center at Corvallis for analysis. With the Department of Defense's approval, Guardsmen are expected to conduct tributary sampling in the other nine

1972 states.

Sampling of MSTP's will be done by the plant operators and is being coordinated through EPA Regional Offices and appropriate state officials. The analyses of these effluent samples will include total phosphorus, dissolved phosphorus, NO_3-NO_2 nitrogen, ammonia nitrogen, alkalinity, total inorganic carbon, pH and conductivity. Historical data from existing MSTP sampling will be included. The flow data on tributaries will be provided by the U. S. Geological Survey from existing stream gage station data and from new basin analysis techniques and from state sources.

Water samples will be sent to the National Environmental Research Center at Corvallis for analysis on colorimetric autoanalysis equipment. Parameters to be studied include total and dissolved phosphorus, nitrate-nitrite nitrogen, ammonia nitrogen and alkalinity.

Recent research in aerial photographic interpretation and land runoff has resulted in new photoanalysis techniques for determining a nutrient budget on a given drainage basin when land use and rainfall data are combined. The results of the tributary-MSTP and aerial photoanalysis nutrient budgets will be compared to allow refinement of the much less costly photoanalysis techniques.

FINAL REPORT

At the end of study of the trophic conditions of a year's complement of lakes and impoundments and an analysis of their phosphorus loading, a summary report will be prepared for each water body. These reports will contain several sections.

A. The present condition of the lake--presented as a compilation of survey data in graphical form and augmented by available historical data.

B. Algal assay results--graphical presentation of projected growth curves for additions of nutrients at several concentrations.

C. Loading of lake--a graphical presentation of the loading (in lbs. per unit time) of phosphorus of the water body and the percentage contribution by associated MSTP(s).

D. Photoanalysis results--graphical and tabular presentation of nutrient loading based on photoanalysis results.

The final report will be reviewed by members of the survey sampling and analysis teams, by EPA Regional personnel and by appropriate state officials before recommendations are passed on to the National Eutrophication Control Program for any necessary control strategy.

ATTACHMENTS

ALGAL ASSAY -- PROCEDURAL OUTLINE

A. Five-Gallon Lake Water Sample taken in Fall or early Spring.

B. Sample is split into two halves (1 & 2).

C. Split #1 is autoclaved to kill all organisms and to release bound nutrients. It is then membrane filtered to remove all detritus.

D. An aliquot of sample from split #2 is analyzed for total water chemistry (35 parameters). The remainder of the split has the Phosphorus removed by Alum precipitation and is filtered. The sample is then re-analyzed to check for other lost nutrients.

E. Both splits are broken into several aliquots. Additions (spikes) of various amounts of Phosphorus (up to 50 ug/l) or Nitrogen (up to 1 mg/l) or both are made. Any lost nutrients are re-added.

F. Aliquots are then innoculated with known amounts of Algae (any of three specific test species).

G. Samples are placed on shaker tables and exposed to light for several days.

H. At various time intervals, small aliquots are Coulter counted and specific growth rates are calculated as are biomass yields.

I. At the end of a batch run, several curves of Growth response are plotted. (see included figure)

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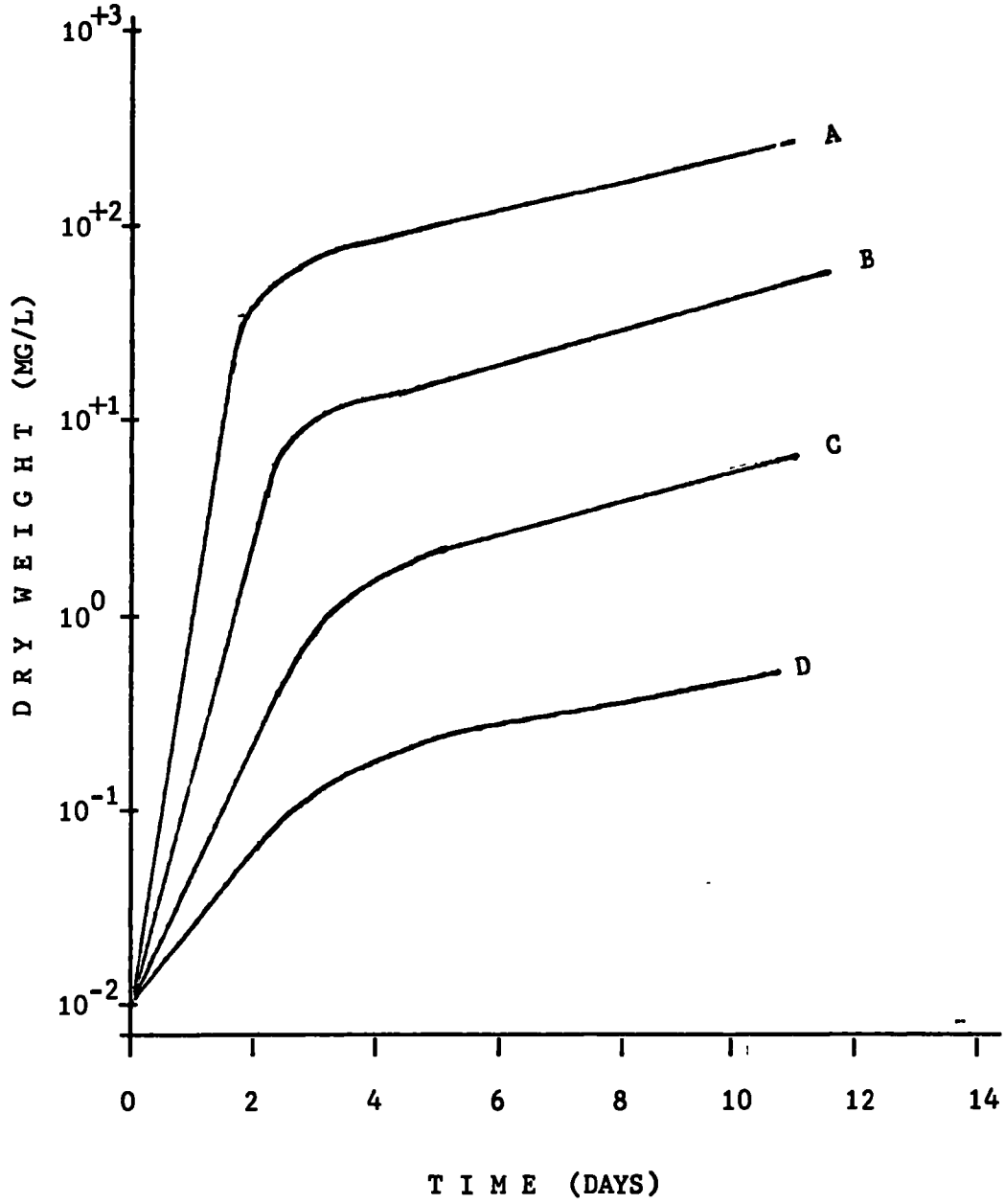
FIGURE II EXPLANATION

Line A - Nitrogen + Phosphorus added

Line B - Phosphorus only added (if close to line C, phosphate does not limit growth, if well above line C, phosphate does limit growth).

Line C - Untreated (control) lake water sample.

Line D - Sample from split #2 with low phosphate level (Suggests amount of growth expected if phosphate is removed from lake).

ALGAL ASSAY

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