Nutrients and Eutrophication

The American Society of Limnology and Oceanography conducted a symposium on nutrients and eutrophication, "The Limiting Nutrient Controversy," at the W. K. Kellogg Biological Station of Michigan State University from 10 to 12 February 1971. Other sponsors included the Water Quality Office (WQO) of the Environmental Protection Agency, the Institute of Water Research of Michigan State University, and the Office of Water Resources Research. In attendance were university, industry, state, and government scientists and administrators. This symposium represented an effort by the American Society of Limnology and Oceanography to provide a clear statement on the relative importance of various regulating or limiting nutrients in the eutrophication of aquatic ecosystems. In the extremely complex interrelations of diverse ecosystems, various factors may regulate an ecosystem's metabolism at different times and under different conditions. One of these—nutrient availability—was selected as the subject for this symposium. Because of the recent so-called carbon-phosphorus controversy, this subject carries many political and economic overtones. The controversy is centered on a recent proposal that carbon rather than phosphorus or nitrogen limits algal productivity in many aquatic ecosystems. Since phosphorus in detergents is linked to eutrophication of lakes and streams, the controversy became emotionally charged following legislative proposals to remove phosphorus from detergent formulations as a step toward controlling eutrophication.

The published proceedings from this forum, where ideas and data were openly and authoritatively questioned and debated, are intended to provide the public and the politicians with some useful guidelines with regard to this controversy (*1*). The papers and discussions focused on phosphorus and carbon but also considered other nutrients and environmental factors that affect eutrophication. Field studies were reported from lakes in Oregon, Vermont, New York, California, Minnesota, Michigan, Washington, and Georgia, as well as Canada, Africa, New Zealand, and Antarctica.

After much debate of details, techniques, and extrapolation of short-term laboratory studies to natural situations, one generalization seemed to emerge: the efforts to remove phosphorus from influents to lake ecosystems is not a waste of time and money. A. F. Bartsch (WQO) provided a working definition for eutrophication: "Eutrophication is the nutrient enrichment of waters, which frequently results in an array of symptomatic changes, among which increased production of algae and other aquatic plants, deterioration of fisheries, deterioration of water quality, and other responses, are found objectionable and impair water use." This process of enrichment of lake ecosystems may be vastly accelerated by man's activities and is then termed cultural eutrophication. It was generally agreed by the participants that the only realistic option for controlling or reversing cultural eutrophication in a majority of lakes is to remove phosphorus from the influent waters. The industrial view, however, favors a major effort to remove phosphorus at waste treatment plants, whereas limnologists in general would urge, in addition, a modification of detergent formulas. J. R. Vallentyne (Canada Freshwater Institute) put it this way, "I have more faith in the ability of the detergent industry to reduce the inputs of phosphorus to natural waters than I do in the combined citizenry of the United States and Canada."

It was also made clear that the ecosystem is a dynamic system with a range of interacting factors that regulate the physiological availability of nutrients and thus may limit algal productivity (R. G. Wetzel, Michigan State University). During conditions of intense algal productivity, the availability of carbon dioxide can become limiting (D. L. King, University of Missouri). Also, it was pointed out that carbon could become limiting to algal productivity in certain soft-water lakes (P. C. Kerr, WQO, and H. L. Allen, Dartmouth College).

A wide spectrum of major and minor nutrients are needed for algal growth, as noted in papers by C. R. Goldman (University of California, Davis) and E. S. Deevey (Dalhousie University). However, phosphorus is the most controllable of the major nutrients required by algae and thus can be made critical in their nutrition. This is very difficult to do for nitrogen, since it has a large atmospheric reservoir, and apparently it is impossible to do for carbon (S. D. Morton, Wisconsin Alumni Research Foundation Institute). Costs for various waste water treatment alternatives were provided by G. A. Rohlich (University of Wisconsin).

A classic example of the effect of increased phosphate on lake metabolism was given by W. T. Edmondson (University of Washington). Lake Washington (at Seattle) became very eutrophic during the 1950's, but this condition was reversed during the middle 1960's with the diversion of sewage from the lake. Edmondson pointed out that the intensity of algal blooms could be accurately predicted from phosphate concentrations alone. The eutrophication trend in the lake has now been reversed, and Edmondson stated that if phosphorus had been removed earlier there would have been the same response from the lake. Similar stimulations of algal production by phosphorus were reported in a detailed analysis of the role of phosphorus in a New York lake (G. W. Fuhs, New York State Department of Health), as well as for experimental additions of phosphorus to lakes and lake waters (T. Maloney, WQO; C. F. Powers, WQO; and C. L. Schelske, University of Michigan).

Estuarine eutrophication has come under increased scrutiny recently, but there is still much research to be done. Estuaries represent problems very different from lake systems; they resemble more closely a river system, with a mixture of saltwater and freshwater. L. R. Pomeroy (University of Georgia) presented field data and a computer simulation model for various interacting factors in estuaries of the southeastern United States. In general, the availability of phosphorus was not limiting to biological production in these estuaries. A nutrient management scheme for the Potomac River and estuary was presented by N. A. Jaworsky (WQO). He pointed to the urgent need for answers and scientific guidelines for impending political decisions involving large sums of money devoted to the management of these large ecosystems.

An industrial representative (J. R.

Duthie, Procter and Gamble Company) reviewed the intensity and scale of industry's efforts to find alternative detergent formulations. These detailed and costly studies have met with little success to date. Clearly, it is exceedingly difficult to develop efficient alternative cleaning agents that will not harm man or the environment. Seven years of lead time are required to test and market a new product. Extensive study and testing of NTA (nitrilotriacetic acid) as a possible replacement for phosphorus in detergents have been done (R. D. Hamilton, Canada Freshwater Institute), but the question of its continued and widespread use is yet to be decided.

The symposium concluded with a panel discussion of "prospects and options for the future." The broader aspects of eutrophication management and control were discussed by panelists A. F. Bartsch, T. Winter (President's Council for Environmental Quality), T. F. Derr (FMC Corporation), and J. R. Vallentyne.

Unquestionably, the aquatic ecosystem is variable and exceedingly complex (G. E. Likens, Cornell University). But a general consensus of the group seemed to be that in the majority of lakes of low or medium biological productivity the nutrient concentration ratio both inside and outside the algal cell points unambiguously to phosphorus as the most limiting element. At higher levels of production (eutrophic conditions), stimulated by an excess supply of phosphorus, other nutrients may become limiting. It appears to be technologically feasible to reduce the excess supply of phosphorus and thus restore that element to its limiting role in lakes.

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Reference

1. *Nutrients and Eutrophication, Symposium Volume 1*, G. E. Likens, Ed. (American Society of Limnology and Oceanography, Allen Press, Lawrence, Kans., in press).

Forthcoming Events

June

20–24. American **Medical** Assoc., Atlantic City, N.J. (E. B. Howard, AMA, 535 N. Dearborn St., Chicago, Ill. 60610)

21–23. **Fluid and Plasma Dynamics**, 4th annual conf., Palo Alto, Calif. (A. Goldburg, Flight Sciences Lab., Boeing Scientific Research Lab., P.O. Box 3981, Seattle, Wash. 98124)

21–23. American College of **Preventive Medicine**, Atlantic City, N.J. (W. Bentley, ACPM, 801 Old Lancaster Rd., Bryn Mawr, Pa. 19010)

21–23. **Social and Economic Aspects of Water Resource Development**, Ithaca, N.Y. (L. B. Dworsky, Water Research and Marine Sciences Center, 468 Hollister Hall, Cornell Univ., Ithaca, N.Y. 14850)

21–24. American Soc. for **Engineering Education**, Annapolis, Md. (L. Hitch, ASEE, Suite 400, 1 Dupont Circle, Washington, D.C. 20038)

21–24. Canadian Assoc. of **Physicists**, Ottawa, Ont. (Secretary, CAP, Suite 903, 151 Slater, Ottawa, Ont.)

21–25. American Assoc. for the **Advancement of Science**, Pacific Div., San Diego, Calif. (R. C. Miller, California Acad. of Sciences, Golden Gate Park, San Francisco 94118)

21–25. **Health Physics** Soc., 16th annual, New York, N.Y. (R. F. Cowing, HPS, 194 Pilgrim Rd., Boston, Mass. 02215)

21–25. Modern Methods for **Industrial and Product Noise Control**, Schenectady, N.Y. (W. L. Weifenbach, Carnegie Hall, Union College, Schenectady 12308)

21–25. **Oil and Colour Chemists** Assoc. 23rd annual, London, England. (Secretary, Wax Chandlers Hall, Gresham St., London, E.C.2)

21–25. **Temperature—Its Measurement and Control in Industry and Science**, 5th annual symp., Washington, D.C. (R. P. Hudson, Natl. Bureau of Standards, Washington, D.C. 20234)

22–23. American **Diabetes** Assoc., San Francisco, Calif. (J. R. Connelly, ADA, 18 E. 48 St., New York 10017)

22–25. American Assoc. of **Bioanalysts**, Chicago, Ill. (D. Birenbaum, Suite 805, 411 N. 7 St., St. Louis, Mo. 63101)

22–25. **Data Management** Assoc., Houston, Tex. (Secretary, Conference Dept., DMA, 505 Busse Hway, Park Ridge, Ill. 60068)

23–25. Applied Mechanics Conf., American Soc. of **Mechanical Engineers**, Philadelphia, Pa. (A. B. Conlin, 345 E. 47 St., New York 10017)

23–26. American **Optometric** Assoc., 74th annual congr., Houston, Tex. (G. Allen, AOA, 7000 Chippewa St., St. Louis, Mo. 63119)

24–26. **Endocrine** Soc., San Francisco, Calif. (Mrs. N. L. Mattox, 1211 N. Shartel, Oklahoma City, Okla. 73103)

25–27. American Assoc. of **Neuropathologists**, San Juan, P.R. (E. P. Richardson, Massachusetts General Hospital, Boston 02114)

27–30. American Soc. of **Agricultural Engineers**, Pullman, Wash. (J. L. Butt, ASAE, P.O. Box 229, St. Joseph, Mich. 49085)

27–1. **Air Pollution Control** Assoc., Atlantic City, N.J. (W. O. Farley, Director of Public Information, Consolidated Edison Co. of New York, 4 Irving Pl., New York 10003)

27–1. **Design Automation** Workshop, Atlantic City, N.J. (R. B. Hitchcock, IBM, Box 218, Yorktown Heights, N.Y. 10598)

27–2. Canadian **Anaesthetists** Soc., Quebec City. (Secretary, CAS, 178 St. George St., Toronto 5, Ont.)

27–2. Conference on **Carbon**, 10th annual, Bethlehem, Pa. (H. Leidheiser, Center for Surface and Coatings Research, Lehigh Univ., Bethlehem 18015)

27–2. National **Education** Assoc., Detroit, Mich. (S. M. Lambert, NEA, 1201 16th St., NW, Washington, D.C. 20006)

27–2. **Forest Products Research** Soc., Pittsburgh, Pa. (K. E. Huddleston, FPRS, 2801 Marshall Ct., Madison, Wis. 53705)

27–2. Society of **Nuclear Medicine**, Los Angeles, Calif. (Miss M. B. Glos, SNM, 211 E. 43 St., New York 10017)

27–2. American Soc. for **Testing and Materials**, Atlantic City, N.J. (T. A. Marshall, Jr., ASTM, 1916 Race St., Philadelphia, Pa. 19103)

27–3. International Congr. for **Virology**, 2nd annual, Budapest, Hungary. (J. L. Melnick, Dept. of Virology and Epidemiology, Baylor College of Medicine, Houston, Tex. 77025)

28–30. American **Astronautical** Soc., 17th annual, Seattle, Wash. (J. Vagners, Dept. of Aeronautics and Astronautics, Univ. of Washington, Seattle 98105)

28–30. Society for **Industrial and Applied Mathematics**, Seattle, Wash. (R. K. Windsor, SIAM, 33 S. 17 St., Philadelphia, Pa. 19103)

28–30. American Soc. of **Safety Engineers**, Tampa, Fla. (A. C. Blackman, 850 Busse Highway, Park Ridge, Ill. 60068)

28–1. Canadian **Ophthalmological** Soc., Montreal. (J. L. Burns, Suite 8, 825 Coxwell Ave., Toronto, Ont., Canada)

28–2. **Biomedical Physics and Biomaterials Science** Conf., Cambridge, Mass. (H. E. Stanley, Room 13-2122. Physics Dept., Massachusetts Inst. of Technology, Cambridge 02139)

28–2. World **Energy** Conf., 8th annual, Bucharest, Roumania. (D. E. Hart, Engineers Joint Council, 345 E. 47 St., New York 10017)

28–3. British Council for **Rehabilitation of Disabled**, Edinburgh, Scotland. (I. R. Henderson, Tavistock House, Tavistock Sq., London, W.C.1, England)

29–1. **Electron Microscopy and Analysis Group**, 25th annual, Cambridge, England. (Meetings Officer, Inst. of Physics and Physical Soc., 47 Belgrave Sq., London, S.W.1, England)

29–1. Institute of **Navigation**, 27th annual, Pasadena, Calif. (R. E. Freeman, IN, Suite 832, 815 15th St., NW, Washington, D.C. 20005)

29–1. Institute of **Nuclear Materials Management**, 12th annual, West Palm Beach, Fla. (L. K. Hurst, INMM, P.O. Box 273, Argonne, Ill. 60439)

29–1. **Trace Substances in Environmental Health**, 5th annual conf., Columbia, Mo. (D. D. Hemphill, Univ. of Missouri, 426 Clark Hall, Columbia 65201)

30–4. Idaho **Medical** Assoc., Sun Valley. (A. L. Bird, 407 W. Bannock St., Boise, Idaho 83702)