

This Week's Citation Classic®

Vollenweider R A. *Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication.* Paris: Organisation for Economic Co-operation and Development, 1968. Technical Report DAS/CSI/68.27. 250 p.
[Organisation for Economic Co-operation and Development, Paris, France]

This report, originally produced for the Organisation for Economic Co-operation and Development, was a synthesis of the current scientific knowledge of the process of accelerated eutrophication of inland waters and was the first time that the trophic response of lakes to nutrient load was systematically explored. Attempts to quantify this relationship led to the concept of acceptable and excessive loading levels and the basis for practical lake management. [The *SCI*® indicates that this report has been cited in over 545 publications.]

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It is probably quite unusual that an "unpublished" report reaches a citation level that qualifies it as a *Citation Classic*. Indeed, the paper has never been "formally" printed in a "reputable" scientific journal. Nonetheless, the Organisation for Economic Co-operation and Development (OECD) had to recopy the article several times to meet the demand that exceeded some 10,000 requests worldwide. Until a few years ago, not a week passed in which my secretary did not have to supply another and still another copy.

Why wasn't the report published in an established journal? The OECD has never given me permission to print it elsewhere and, to confuse the matter still further, has recopied it twice listing two different publication years (1968 and 1971). Overall, the report's history has been bewildering: it was only because I violently disagreed with the international bureaucracy, and because the advisory committee under the chairmanship of the late O. Jaag, then director of the Swiss Federal Institute for Water, Water Pollution, and Protection in Dubendorf, backed me in my battle, that the report has taken the form in which it is now known. In addition, the OECD wanted to publish the report without listing an author. (They did publish my second major report on eutrophication¹ without author credits!) The scientific and management community hailed the report's appearance as a "milestone," and this, together with some other major publications,^{2,3} brought me the 1986 Tyler Prize along with other recognition.

Why did the report have such extraordinary success? In the 1960s eutrophication was recognized as a major water-quality problem affecting progressively many, and among them the most valuable, lakes, rivers, estuaries, and coastal areas. Few scientists understood why it happened. Some considered eutrophication a natural aging process, others thought it involved climatic changes, and some believed it was due to increasing pollution. Of course, these latter scientists were right in principle, but it still had to be proven scientifically that the crucial factors were neither vitamins, trace elements, nor other obscure unspecified factors.

The 1968 report was not the first attempt to analyze eutrophication, but it seems that my training in algology, plant nutrition, photophysiology, limnology, geography, and mathematics gave me just the right combination of background knowledge to succeed. In my previous studies of lakes in several countries, I became intrigued with the observation of how closely limnological properties reflect properties of the catchment basin. This, of course, is now standard knowledge, but at the time the prevailing view was still that of lakes as self-sufficient microcosms. I approached the question with the concept of lakes as open systems; also, my natural inclination to search for quantifiable relationships in natural phenomena led me to analyze the literature in and related to limnology from this perspective. It became progressively clear that (1) nitrogen and phosphorus are the motors of the process, (2) phosphorus is normally the more important factor, (3) nitrogen and phosphorus load to lakes provides the basis for explaining the degree of eutrophication, and (4) as a consequence, control of these factors would lead to the solution of the problem.

The last step in this chain of thoughts was to define tolerance levels of loading, which I did preliminarily and further pursued in subsequent studies. This matter was more intricate than it appears now because there were few reliable loading figures at that time. As a consequence of my findings, I stimulated the OECD to launch a major study program that would involve as many institutes as possible. This led to the OECD Cooperative Programme on Eutrophication in which some 18 countries and some 50 institutes collaborated and in which some 200 lakes were studied throughout the temperate zone. This program had a major impact on eutrophication research and eutrophication management throughout the world.^{4,5}

However, perhaps the most immediate impact of the 1968 report was on the agreement between Canada and the US to control eutrophication of the Laurentian Great Lakes. A major multimillion-dollar program was established in 1972 to reduce the phosphorus load to these lakes.

1. *Eutrophication of waters: monitoring, assessment and control.*

Paris: Organisation for Economic Co-operation and Development, 1982. 154 p.

2. Vollenweider R A. Input-output models with special reference to the phosphorus loading concept in limnology. *Schweiz. Z. Hydrol.*—*Swiss J. Hydr.* 37:53-84, 1975. (Cited 155 times.)

3. ———. Advances in defining critical loading levels for phosphorus in lake eutrophication. *Mem. Ist Ital. Idrobiol.* 33:53-83, 1976. (Cited 75 times.)

4. Reckhow K H & Chapra S C. *Engineering approaches for lake management.* Boston: Butterworth, 1983. 2 vols.

5. Uhlmann D. *Hydrobiology: a text for engineers and scientists.* London: Wiley, 1979. 313 p.