Detergent phosphate bans and eutrophication*

Data were available for 40 bodies of water in 1978; today, data are available for more than 750

By G. Fred Lee and R. Anne Jones

The guest editorial by Werner Stumm ("Clean shirts and clean water," *ES&T*, November 1985, p. 1013) is critical of an earlier editorial by Russell Christman ("Phosphate here, phosphate there...," *ES&T*, June 1985, p. 467). Christman had commented that in some situations detergent phosphate bans may produce "no noticeable improvement in water quality."

This editorial exchange is typical of those that have taken place over the past 20 years [when this paper was originally published – and, for that matter, still take place today – e.g., *SCOPE Newsletter* 66: 7 (2006), www.ceep-phosphates.org]. It basically reflects the controversy that has existed over whether every bit of phosphate control helps to manage eutrophication or whether a certain amount of phosphate must be controlled before a water body will show a discernible improvement in water quality.

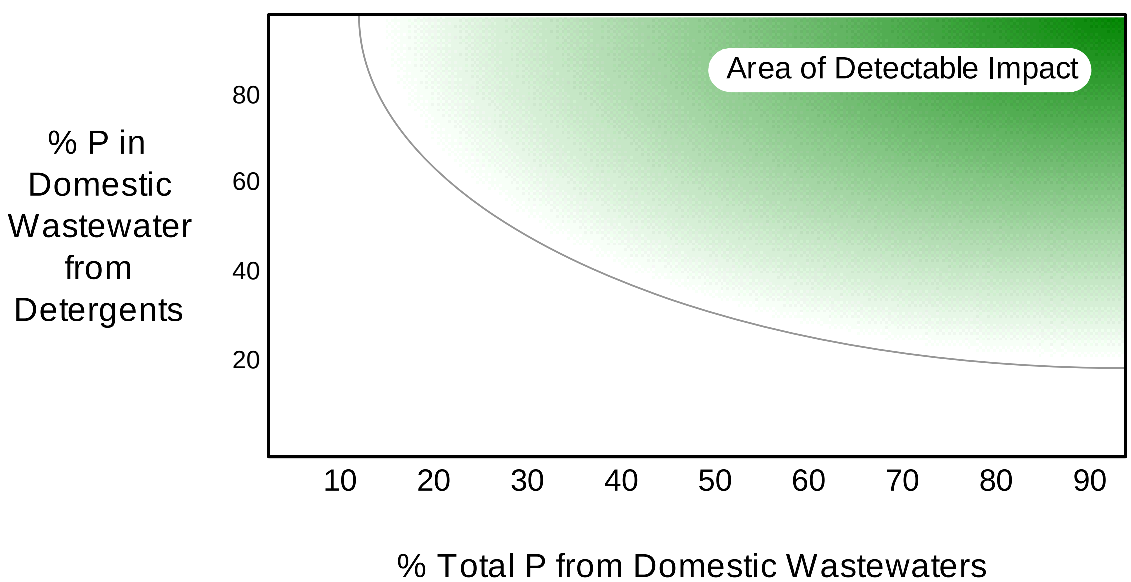
Recently; Maki and colleagues have concluded that the detergent phosphate bans enacted in various regions and states in the United States have not produced measurable improvements in water quality (1). The reason for this is that insufficient phosphate control was achieved by the bans to bring about a measurable reduction in phosphorus. Christman's position is strongly supported by this research.

In his editorial Stumm stated that "our power to predict the effect of phosphate loadings on lakes (of different morphology and hydraulic residence time) is remarkably quantitative and suited to generalization." We strongly agree. R. Vollenweider and the Organization for Economic Cooperation and Development (OECD) conducted eutrophication studies during the mid-1970s, and we did follow-on studies that showed it is possible to predict with a high degree of reliability the effects of altering the phosphorus load to a water body (2-6).

The Vollenweider-OECD eutrophication model has been expanded to approximately 750 lakes, reservoirs and several estuaries (5). It is clear that it is indeed possible to make a quantitative prediction of the effects of a detergent phosphate ban and thereby to ascertain the potential benefits of such a ban.

Recently, we developed a general relationship (Figure 1) that can be used to evaluate the potential benefits of a detergent phosphate ban (7).

Figure 1. Effect of Detergent Phosphate on Eutrophication-Related Water Quality



* Originally published as Lee, G. F. and Jones, A., "Detergent phosphate bans and eutrophication," *Environmental Science and Technology* 20:330-331 (1986). Updated in January 2007.
http://www.members.aol.com/annejlee/DetergentPBan.pdf
Published by the American Chemical Society.

It is based on the finding that a reduction of approximately 20% in the phosphorus load to a water body must be achieved to produce a discernible effect on water quality. This 20% value is independent of the trophic state. It is based on our experience and has been corroborated by many colleagues. It was developed from the phosphorus load-chlorophyll relationship that was developed in the Vollenweider-OECD eutrophication studies (2-5). It is also demonstrated in Table 1 (7).

Table 1
Perceptible changes in eutrophication-related water quality[a]

Trophic State	**Annual Average Chlorophyll** (µg/L)	Detectable change[b]
Oligotrophic	< 2	0.5
Mesotrophic	4-10	1-2
Eutrophic	10-45	3-5
Hypereutrophic	> 45	10

[a] Based on Vollenwieder-OECD phosphorus-load relationship
[b] Based on chlorophyll (µg/L)

Figure 1 is read as follows: If 40% of the phosphorus in domestic wastewater were due to detergents, and if the domestic wastewater discharge represented 30% of the total phosphorus load to the lake, the removal of detergent phosphate would result in no detectable change in water quality of the water body. On the other hand, if the domestic wastewater discharge represented 60% of the total phosphorus load to the lake, removal of detergent phosphate would result in a detectable improvement in water quality. An even greater improvement would result from the removal of detergent phosphate if the domestic wastewater represented 100% of the total phosphorus load to the lake.

In order to assess the effect of a detergent phosphate ban on water quality it is necessary to know the percentage of phosphorus in the domestic wastewater that enters the water body, either directly or indirectly, and the percentage of the total phosphorus load that is derived from domestic wastewater. These are, respectively, the ordinate and the abscissa in Figure 1. The stippled area in the figure is the region in which a discernible change in water quality would be expected as a result of changing the phosphorus load. The density of stippling indicates the magnitude of the change expected, with the greatest change occurring in the upper right corner.

Those water bodies that derive most of their phosphate from detergent phosphate in domestic wastewater should show the greatest change as a result of a detergent phosphate ban. It is important to note that for water bodies that have coordinates just entering the stippled area, the change in water quality would be just detectable.

The relationship in Figure 1 can be used to explain why Maki and colleagues concluded that detergent phosphate bans have not in general produced measurable improvements in water quality (1). Few water bodies have a high enough detergent-derived phosphorus load to show more than a 20% change in the total phosphorus load as a result of a detergent phosphate ban.

In the early 1970s detergent formulations in the United States contained a much higher percentage of phosphorus than they do today (mid-1980s). At that time (in the early 1970s), it was generally agreed that 50-60% of the phosphorus in domestic wastewater was derived from detergent formulations. Today, however (mid-1980s), in Michigan and Wisconsin, for example, where detergent phosphate bans have been enacted, studies have shown that 20-25% of the phosphorus is derived from detergent formulations. If only 20% of the phosphorus in a domestic wastewater effluent is derived from detergents, then it is unlikely that there would be any water body in which a detergent phosphate ban would result in a significant improvement in water quality, even if domestic wastewater were the only source of phosphorus for the body of water.

Almost all water bodies other than sewage ponds receive phosphorus from other sources, and detergent bans in the United States will have little or no effect on eutrophication-related water quality. In the early 1970s there was a possibility that such bans would affect water quality; however, this would have been for water bodies that had approximately half of their total phosphorus load derived from domestic wastewater.

This discussion does not consider a situation in which phosphorus is removed at wastewater treatment plants by iron or aluminum precipitation or by enhanced biological uptake. Ninety percent of the phosphorus in domestic wastewater can be readily removed by these methods at a per capita cost of less than one cent each day for populations exceeding 10,000.

It is obvious that where there are excessive fertilization problems in water receiving domestic wastewater discharges, the most effective way to control the phosphorus input is by iron or aluminum precipitation or advanced biological treatment at the treatment plant. Stumm stated, "Phosphate removal in treatment plants is necessary but insufficient because some wastes unavoidably escape treatment; not all households are connected to treatment plants and storm water overflows."

Figure 1 can be used to determine on a site-specific basis whether septic tank systems, combined sewer overflows, and wastewater bypasses are the source of sufficient phosphorus to justify a detergent phosphate ban in addition to phosphorus control at the wastewater treatment plant. If these sources contribute more than 20% of the total phosphorus load to the water body, then enactment of a ban will likely produce a marginally detectable improvement in eutrophication-related water quality. It is important to note, however, that most septic tank wastewater disposal systems do not contribute significant amounts of phosphate to surface water (8).

We agree in part with both Stumm and Christman in that although detergent phosphate bans generally will not result in an overall improvement to water quality, there may be some situations in which eutrophication-related water quality would be improved by a ban. These situations are probably rare and would be characterized by a high percentage of the phosphorus entering the water body being derived from domestic wastewaters and a substantial percentage of the phosphorus in the domestic wastewaters being derived from detergents. These situations can be readily identified from the information available today.

While this discussion focuses on the impact of detergent phosphate bans on water quality, the results are applicable to evaluating all situations where there are questions about the impact of altering the phosphorus loads to a water body on the water body's eutrophication-related water quality.

References

(1) Maki, A. W.; Porcella, D. B.; Wendt, R. H. *Water Res.* **1984**, 18, 893-903.

(2) Lee, G. F.; Rast, W.; Jones, R. A. *Environ. Sci Technol*. **1978**, 12, 900-908. http://www.members.aol.com/apple27298/Eutrophication-EST.pdf

(3) Organization for Economic Cooperation and Development. Eutrophication of Waters, Monitoring, Assessment, and Control; OECD: Paris, France, **1982.**

(4) Jones, R. A.; Lee, G. F. *Water Res.* **1982**, 16, 503-15. http://www.members.aol.com/annejlee/RecentAdvWaterRes.pdf

(5) Jones, R. A.; Lee, G. F. *World Health Organization Water Quality Bulletin* **1986**, 11(2) 67-74, 118. http://www.gfredlee.com/voll_oecd.html

(6) Rast, W.; Jones, R. A.; Lee, G. F. *J. Water Pollution Control Fed*. **1983**, 55, 990-1003.

(7) Lee, G. F.; Jones. R. A. *Lake Line Newsletter* January **1986**, pp. 8-11.

(8) Jones, R. A.; Lee, G. F. *J. Water Pollution. Control Fed.* **1979**, 51, 2164-75.

At the time of development of this paper, G. Fred Lee was a distinguished professor and R. Anne Jones was an associate professor in the Department of Civil and Environmental Engineering at the New Jersey Institute of Technology in Newark, N.J. Current affiliation for both is G. Fred Lee & Associates, El Macero, California, gfredlee@aol.com, http://www.gfredlee.com