Boston College Environmental Affairs Law Review

Volume 2 | Issue 1 Article 3

5-1-1972

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PHOSPHATES IN DETERGENTS—BANE OR BOON?

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> Nothing is more evident than the fact that our civilization has seriously miscalculated the effect of its impact on the structure of the environment. However, rash action without due regard for its consequences is fundamentally inconsistent with the belief that environmental abuses themselves stemmed from man's inconsiderate conduct. The very persons who charge lack of care in the conduct creating the abuse often are not disposed, in any way, to tender the same degree of care to solutions which they advocate.

The point of the above passage, which was taken from the editor's note prefacing the first issue of *Environmental Affairs,* is well illustrated by the easy condemnation of detergent phosphates, which supposedly were a principal cause for the "funeral services" for Lake Erie.[1] The purpose of this article is to examine the water quality problems attributed to phosphates, to assess the several approaches to the problem, and to place that proposal which has received the widest publicity and public espousal, namely, the removal of phosphates from detergents, into perspective. Hopefully, this may help meet the objective stated in the editor's note, that ". . . action must be well considered if it is to be in harmony with the philosophy of the environmental movement. The main point is that rational consideration of the consequences of each act is essential."

Eutrophication

Phosphates in natural waters are not a contaminant or pollutant in the same sense as are heavy metals, complex organics, or radioactive materials. Phosphates may be handled without danger and may be consumed safely in virtually whatever amounts are likely to be found in water and foodstuffs. Phosphates only become a problem when they contribute to excessive *eutrophication*.

Eutrophication comes from the Greek: *eu,* well, and *trophin,* to nourish. Eutrophication is a process by which a body of water becomes well nourished from an increase in essential plant nutrients. Just as an individual may be well nourished and healthy or be overnourished and obese, so, too, a body of water may be eutrophic without suffering any impairment of its usefulness or be overnourished, with heavy growths of green plants, especially algae, damaging its recreational value. Algae, moreover, may affect the taste of drinking waters and, when dying, may utilize limited resources of oxygen in the water so as to cause anaerobiosis (septic conditions), with its attendant unpleasant odors. The significance of the degree of eutrophication is subjective. If a body of water that has been sparkling clean becomes eutrophic, its value to those who use it will be seriously impaired. On the other hand, many attractive and useful bodies of water are naturally euthophic, and only excessive growths of algae and green plants would be of concern.

In order for eutrophication to occur, and particularly if it is to create a problem, all of several conditions must be met, among the most important of which are the following:

1. The body of water must be slow-moving so that it can retain the algae and the nutrients. For example, where phosphates are limiting (i.e., where other essential nutrients are abundant, but where phosphates are insufficient to support growth), very small concentrations (from 0.01 to 0.1 milligrams per liter (mg/1)) have been found sufficient to increase the rate of plant growth or cell multiplication. Once introduced into a slow moving body of water, such as a lake, the phosphates are recycled in the green plants and algae. When the algae die, the phosphates are released to be reused, except for a quantity that may be trapped in the lake sediments. If the influent to the lake also contains excessive amounts of phosphates serious problems of eutrophication may result. However, if the algae are swept away, the phosphates will not be able to accumulate. Therefore, eutrophication problems are generally limited to lakes and estuaries, and are seldom identified with flowing rivers.

2. The body of water must receive nutrients that can support algae. Phosphorus, nitrogen, and carbon are most important, with phosphorus, in the form of phosphates, being generally but not always the limiting nutrient in inland waters. Scientists at the EPA Water Quality Laboratory in Athens, Georgia claim that, in the southeastern part of the United States, carbon is the limiting nu-

trient. Other scientists studying marine systems indicate that, in estuaries, nitrogen is often limiting, so that even if the phosphates were reduced ". . . no reduction of algal growth or euthophication could be expected."[2] In addition to these three basic nutrients, numerous other elements are necessary in trace quantities.

3. The body of water must receive sufficient solar energy for photosynthesis. For this reason, shallow and clear bodies of water are more likely to become eutrophic than deep or turbid waters. Many lakes that meet the first two conditions above (namely, that they provide an opportunity for the accumulation of algae and that they receive ample nutrients) do not become troublesomely eutrophic because they are turbid. Also, rivers frequently are highly turbid following rainstorms, and this effectively prevents the accumulation of algae.

The nutrients necessary to initiate a cycle of eutrophication originate from many diverse sources, the most important being urban wastewaters and urban and agricultural runoff. Phosphorus originates in human wastes as well as in the synthetic detergents that have enjoyed such great popularity and increased use.[3] The phosphate concentration in urban sanitary wastewaters amounts to about 10 mg/l, some 40 to 60% of which is contributed by the phosphates in detergents. Surface runoff from urban areas that reach the same receiving waters may contain as much phosphate as the wastewaters. In 1967, the domestic use of phosphates in fertilizers was eight-fold greater than their use in detergents.

The Limited Scope of the Eutrophication Problem

The nationwide concern expressed over phosphates in detergents, as well as the plethora of Congressional hearings and the proposals before the Federal Trade Commission to require identification of phosphates as a water pollutant, would lead the casual observer, if such there still remain, to believe that phosphates in detergents are a national problem and require nationwide legislation. Eutrophication, however, is *not* a nationwide problem.

The wastewaters from approximately 85% of the population of the United States cannot be claimed by any responsible investigator to make any contribution to eutrophication problems in natural waters (and of the 15% of the population whose wastewaters might contribute to eutrophication, phosphates are not the critical nutrient in all instances). When this figure of 85% was first cited by the author at a hearing before the Federal Trade Commission on April 26, 1971, it came under critical review; thus an explanation of how this figure was obtained is in order.

First, for wastewaters to contribute to the eutrophication problem, they must reach the body of water to be affected. None of the rural population or the population in unsewered communities, which together amount to almost 30% of the total population of the United States, discharge their wastewaters to streams or lakes. Wastes for these populations are handled in privies, cesspools, septic tanks and tile fields, and other devices whereby the wastewaters are discharged into the ground. The waters themselves may eventually find their way to streams and lakes, but the phosphates are held in the ground. Thus, not only are they of little consequence to the eutrophication problem, but they actually contribute to fertilization of the soil.

About 55% of the population of the United States reside in cities and towns whose municipal wastewaters are discharged into the ocean directly or into major river systems that flow to the ocean. In the first category are coastal cities such as New York, Miami, Los Angeles, and New Orleans. Although the wastewater discharges of these large cities do pose serious pollution problems, these problems are not related to the phosphate content of their wastewaters.

Professor J. Carrell Morris of Harvard University has stated:

> . . . the continuous addition of phosphates to our coastal oceanic waters is an imperative need. Each year about three billion tons of sea food of various types are taken by our fisherman from coastal waters. Of this about 3%, or almost one hundred million pounds, is phosphate. If we are to continue to utilize the sea as a food resource and indeed to realize even greater yields from the sea for future generations, this phosphate must be constantly *replenished.* Already there have been reports that the building of the Aswan Dam which has prevented the phosphate-rich sediments of the Nile from reaching the sea has reduced the sardine catch of the eastern Mediterranean by 95%.[4]

According to Bostwick Ketchem of The Woods Hole Oceanographic Institution: "The sea is a valuable source of animal protein, but the total productivity is limited by the lack of nutrient elements."[5] It is ironic that Dade County has banned all phosphate detergents despite the fact that the wastewaters of Miami and Miami Beach, the principal cities in the County, are discharged into the ocean.

In the second category of urban population, that which discharges to major river systems, are included Pittsburgh, St. Louis, Kansas City, Cincinnati, and Chicago. Even where navigation pools and other run-of-river impoundments are created on large rivers, the long-term accumulation of algae and nutrients that is necessary for the creation of eutrophication problems is not likely to occur. For example, the recently developed 1970 "Requirements pertaining to sewage and industrial wastes discharges to the Ohio River," promulgated by the prestigious eight-state Ohio River Valley Water Sanitation Commission, do not mention "phosphorus" or "phosphates." The Commission obviously concluded that in this important, heavily populated inland river basin, phosphates were not a problem that required the Commission's attention in establishing water quality parameters.

As regards the impact of phosphates on river systems, the most controversial has been the case of the Illinois River, which receives all of the wastewaters of the metropolitan area of Chicago.[6] The wastewaters after treatment are discharged to the Chicago Ship Canal and thence to the Illinois and Mississippi Rivers. In a statement presented to the Illinois Pollution Control Board, the head of the Water Quality Section of the Illinois State Water Survey indicated that Peoria Lake on the Illinois River is void of any significant aquatic plants, including rooted vegetation and algae blooms. The Peoria Lake reach has the highest phosphorus concentrations of any major stream in the United States, ranging from 0.5 to 3.0 mg/1.[7] Evans later went on to state: "The effect of the nutrients on flowing midwestern streams has been negligible and there is no substantive evidence supporting the view that phosphorus in these streams is a major water quality degradant."[8]

The Acting Director of the Reserach and Development Department of the Metropolitan Sanitary District of Greater Chicago has stated: "Currently there is little algae in the main waterway system of the Metropolitan Sanitary District of Greater Chicago (North Shore Channel, Sanitary and Ship Canal, Cal-Sag Canal). Yet the phosphorus concentrations present ranged in the summer of 1970 from 0.3 to 2.1 mg/1."[9] He concludes: "There is no substantial evidence to indicate that the limiting nutrient is phosphorus, and phosphorus removal at wastewater treatment plants which do not discharge to Lake Michigan does not appear at this time to be justified." If it is not justified to remove phosphates from the wastewaters from Chicago, removing phosphates from the detergents that contribute to these wastewaters is certainly not justified. Yet, Chicago has been in the forefront of the cities establishing local anti-phosphate legislation.

If eutrophication is not a problem on the heavily polluted Ohio and Illinois Rivers, it can hardly be a problem on the less polluted major river systems of the United States, such as the Missouri and Mississippi.

If people in unsewered communities and in river and ocean front cities do not contribute to eutrophication, who does? The populations in the following watersheds and localities may (although it has not been demonstrated that phosphates are the critical nutrient in all instances): all of the Great Lakes, the Potomac River and estuary, San Francisco Bay and tributaries, Lake Tahoe, Lake Champlain, Puget Sound, Tampa Bay, Lake Okeechobee, plus several other minor lakes as well as cities that have been identified as having eutrophication problems, (e.g., Denver). This total comes to some 14% of the population of the United States to which may be added another 1% (more than 2,000,000 people) in order to allow for localized eutrophication problems from small communities that have not been identified in the public or technical press.

Recognizing that eutrophication is not a problem afflicting all waters, the Environmental Protection Agency initiated a study to identify those waters that are subject to eutrophication problems. While the study is not complete, Mr. William Ruckelshaus, Administrator of the Environmental Protection Agency, has stated:

> We have made one survey that I would like to mention—started in July, 1970, in conjunction with the University of Wisconsin in which we surveyed 58,000 lakes in 22 states in the country to determine the degree of eutrophication of those lakes and we found out of that survey 180 lakes in which we had a serious problem of eutrophication—we did not at each one of those instances locate phosphorus as the limiting nutrient in that lake—it could be nitrogen—it could be some other nutrient, and so we do have a start on this problem, but we by no means have completed the survey and what we need to do is get on with it.[10]

From this recognizably incomplete study, which nevertheless represents a fairly large sample of the lakes in the United States, those later affected by eutrophication amount to a fraction of one per cent.

Many lakes (particularly impoundments on rivers) which would appear to have a significant potential for eutrophication problems by virtue of heavy nutrient inflow and long-term retention have not presented, and are not likely to present, water quality problems. One important reason for this is that the natural and man-induced turbidity in these lakes retards photosynthesis. Some lakes that have been receiving nutrients in substantial concentrations from urban wastes for generations are not troubled by eutrophication.

I leave it to others to explain why this problem—which is so localized in scope and which is significant only to a small percentage of the population—has so captured the nation's attention as to create nationwide pressure for national and local legislation, the latter legislation even in areas that do not contribute to the problem. Nevertheless, where eutrophication is a problem, it may be very serious indeed, and its control and elimination deserve a high priority in our water pollution control programs.

The Control of Eutrophication

When eutrophication was identified as a major water quality problem, the attention turned to removal of phosphates from detergents. Apparently, it had not been recognized that the nutrients in urban wastewaters and in agricultural runoff had been sufficient to create eutrophication problems long before the invention of synthetic detergents. For example, one scientific paper published in 1947 described thirty-eight eutrophied lakes in the United States and abroad.[11] Thus, even a return to the habits of that pre-detergent era could not eliminate eutrophication.

What then will solve eutrophication problems? Regardless of the responsible nutrient—phosphorus, carbon, or nitrogen—one or more of the following approaches would be appropriate, economical, and efficacious:

1. *Diverting the Wastewaters around the Lake or Estuary.* Inasmuch as eutrophication is a problem in still waters and not in running waters, if it is economically feasible to divert wastewaters around a lake to a stream or to an ocean, then that lake would be protected from at least urban wastewater discharges. A good example of a seriously eutrophic lake that is now being restored to high quality by diversion is Lake Washington in Seattle. Studies of this lake are particularly encouraging, since they show that a seriously eutropic lake can indeed be reclaimed.

2. *Applying the Wastewater to the Land.* Where wastewaters can be profitably used for irrigation, particularly in the western

areas of the United States, the nutrients in the wastewaters not only are *not* a problem, but also actually constitute a significant resource, worth more than five cents per thousand gallons.[12] Thus where the wastewaters are to be applied to the land, the removal of phosphates from detergents is contraindicated.

The reuse of wastewaters for irrigation is becoming increasingly attractive both on agricultural lands and in urban areas.[13] For example, a substantial portion of the wastewaters from the city of Colorado Springs, Colorado is treated and sold to large-scale customers within the city for use for golf courses, cemeteries, and industry. This reclaimed wastewater is sold at two-thirds the price of water from the public supply. The simultaneous prevention of eutrophication makes the reuse of wastewaters for irrigation even more attractive.

3. *Treating Urban Wastewaters.* In almost all instances where eutrophication is a problem, water pollution is also a problem and a high degree of wastewater treatment is required. For example, the communities and industries around Lake Erie, the fouling of which touched off the controversy over phosphates, are far behind the cleanup schedule set in 1967 for relieving pollution of the lake.[14] Clearly, removing phosphates while permitting urban and industrial pollution to continue will not markedly improve the quality of the waters in Lake Erie.

In a comprehensive review of the strategies for control of eutrophication, Grundy points out that reduction of detergent phosphates would have little impact in the critical Great Lakes areas.[15] He states: "Restoration of Lake Erie may very well require control of all sources of nutrients, including municipal and industrial wastes, agricultural runoff, and erosion, as well as of nutrients already in the lake."

Where eutrophication is a problem, specific treatment should be prescribed to remove which ever nutrient (phosphate, carbon, or nitrogen) is identified as being limited in the particular situation. Where phosphates are the problem, and this is most likely to be the case for most inland situations, reducing the phosphate content of the urban wastewaters by eliminating or reducing the phosphates in detergents would not remove the necessity for removing the remaining phosphates from the urban wastewaters. Sufficient phosphates are present in urban wastewaters to initiate eutrophication in a susceptible body of water even if all the phosphates are removed from detergents. Further, depending upon the phosphate removal process selected, treatment costs might or might not be reduced if the phosphates in detergents were removed. Phosphate removal in wastewater treatment is estimated to cost $1 to $2 per capita annually.[16] Where lime precipitation is used, the cost is not a function of the phosphate concentration. Where alum or another coagulant is used, the saving that would result from reducing phosphate concentration 50% by eliminating phosphates from detergents would amount from 25 to 50 cents per person annually. An example of eutrophication control by phosphate removal in wastewater treatment is Lake Zurich in Switzerland.

To those who believe that the increased waste treatment costs would pose an intolerable burden on society if detergents are allowed to retain phosphates, Grundy points out (a) that removing phosphates from detergents would undoubtedly increase detergent costs and (b) that it is likely that the cost to society through this approach would be greater in dollars as well as in potential health hazard.[17]

The technology, the institutions, and the experience for initiating any one of the above three approaches for the control of eutrophication are at hand. They are slow to be implemented only because pollution control, despite the rhetoric, has not enjoyed a high priority for local, state, or national investment. It seems more politically expedient, particularly at the local level, to point a finger at the detergent industry than it is to call for the financing required for pollution control. All three approaches enumerated above have been shown to improve water quality, while the highly-touted removal of phosphates from detergents has not been demonstrated to cause any improvement.

Mitchell found that the eutrophication potentials of a phosphate-containing detergent and two phosphate-free detergents, as determined in oligotrophic algal microcosms after activated sludge treatment, were not significantly different.[18] He concludes that domestic wastewater will produce eutrophic conditions in receiving waters and that the simple elimination of phosphates from detergents will not significantly decrease the rate of eutrophication caused by these wastewaters. He states:

> Substitution of untested (high alkalinity, high carbonate) detergent formulations . . . may appear to be an easy way out politically, but there is no indication that this technique will reduce euthophication. Eutrophication may actually increase as the result of additional alkalinity, which would be still another factor added to our overall

pollution problem. A much more effective idea would be the construction of facilities for the removal of all nutrients from wastewaters in those areas where algal control is a problem.[19]

Alternatives to Phosphates in Detergents

If phosphates cause problems, why not just remove them from detergents? After all, cleanliness existed prior to the birth of the synthetic detergent industry. As with most other environmental problems, the solution does not lie in a return to "the good old days." With the development of the synthetic detergent, many other developments have proceeded simultaneously: automatic laundry washing and dishwashing machines, larger institutional and industrial washing operations made possible by the synthetic detergents, and the creation of fabrics suited to these developments.

The synthetic detergent consists of two major ingredients, the surface active agent and the phosphate, with other ingredients in smaller amounts for brightening, perfuming, bleaching, disinfecting, and the like. The surface active agent serves to reduce the surface tension of the water thereby permitting its easy penetration into the materials to be washed.[20] The phosphate in the detergent has several important functions that make the detergent serviceable: 1. it softens water by reacting with objectionable minerals, particularly those that are responsible for water hardness; 2. it sequesters, or maintains in suspension, the particles that are removed from the surfaces which are cleaned, preventing their redeposition on the clothes, a major problem in dealing with ordinary soaps; 3. it increases the efficiency of the surface active agent; 4. it furnishes the necessary buffering and alkalinity for cleansing; 5. it emulsifies oily and greasy materials.

To eliminate the phosphates without replacing them would render the detergent ineffective. Reducing the phosphate content might be helpful, but to achieve the same degree of cleansing would often require that more detergent be used.

A return to soap might be feasible in certain locations where water supplies are exceedingly soft or where a home water softener is installed. Unfortunately, soft water areas do not coincide with the areas where eutrophication is a problem. For example, Great Lakes waters, where the problems of eutrophication are the most serious, are too hard for the use of soap in washing machines. The cost of softening the entire public water supply, or of installing and operating home softeners, would be far greater than the cost of phosphate removal in wastewater treatment plants.

The main problem with soap, even in waters that are reasonably soft, is the absence of sequestering power. Contrast, for example, the appearance of a bathtub after bathing with soap to that after bathing with a synthetic detergent. The latter eliminates the ring around the tub, which corresponds to the accumulation of similar material on clothes. Such a continued accumulation on clothes reduces the effectivenes of washing. Even for those who do not care for clothes to be "whiter than white," the life of their clothes would be reduced.

Therefore, if phosphates are to be removed, a replacement that will serve the same functions must be found. That which seemed to offer the best possibility and which is already being used in Sweden and in Canada is nitrilotriacetate, NTA. Under pressure from the federal administration for phosphate removal from detergents in May 1970, large-scale manufacturing facilities for NTA were built in the United States with the expectation that NTA would be introduced as a partial replacement for phosphates as rapidly as possible.[21] However, approval for its use in the United States was suddenly held up in December 1970 because of studies at the National Institute for Environmental Health Sciences that indicated that NTA might combine with heavy metals in water supplies to cause birth defects.

Great caution must be exercised with regard to introducing *any* new substitute for phosphates. Dr. Jesse L. Steinfeld, Surgeon General of the United States Public Health Service stated: "In responding to one environmental problem great care must be exercised to assure that the alternative does not create equal or greater hazards to the environment or human health. This is certainly the case with detergents in view of the massive quantities produced and the ubiquitous nature of their distribution."[22]

More than 70,000,000 people in the United States take their drinking water from public water supply systems that utilize sources that contain some fraction of municipal and/or industrial wastewaters. Few elements or compounds are as well-understood, as innocuous to humans, and as essential to life as are phosphates. To replace phosphates by alternative chemicals in the huge quantities that are required for detergents (several billion pounds per year), and particularly where the toxic effects of these alternative chemicals are not well-established, is to endanger the environment and expose unnecessarily a considerable portion of the population. Considerable long-term testing is needed to provide reasonable assurance that substitutes for phosphates are entirely free of carcinogenic, mutagenic, or teratogenic properties when ingested through drinking water over long periods of time. Even if such a replacement introduced widely into the environment might itself prove harmless, that chemical might have potentiating or synergistic effects when combined with other chemicals that might be present in the environment. If the phosphate replacement is organic, it is likely to have myriad dissociation compounds, which in turn would have to be studied both individually and in combination with other chemicals.

NTA is one such chemical that requires great caution before its introduction. It (or similar chemicals) might be hazardous, and it could very easily introduce other polluting matter into the environment. For example, NTA would add nitrogen, and where nitrogen is found to be limiting (such as in estuaries), the eutrophication potential might be greater with NTA than with phosphates.[23]

The British have been reluctant to entertain the use of replacements such as NTA. They state ". . . it seems unlikely that phosphate has any directly adverse effects on the river or on the human consumer of water. On the other hand, there is far less experience of the polluting effects of NTA."[24] They conclude: "It is clear that where reduction of phosphate levels in sewage effluents must be achieved to protect receiving waters from eutrophication, phosphate-removal processes (in treatment plants) must be adopted."[25]

The search for phosphate replacements continues, although in my opinion it is inappropriate. Eutrophication is such a localized problem, and the technology for its control is so readily available, that to introduce an unknown compound on the scale that would be required for a phosphate replacement would be far more risky than to recognize that in phosphates we have a safe, useful product that can be controlled if we agree that pollution control in general is a national objective.

The only substitutes for phosphate detergents that are currently in use in the United States are caustic compounds. These generally do not create any problem in the environment, because they are quickly diluted in wastewaters. However, without discussing any specific detergent formulation, it can be stated without qualification that while phosphates in detergents constitute no health hazard, the caustic substitutes in a detergent formulation pose serious potential hazards to the user. These caustic substitutes in the dry form in which they are used in the household may cause severe damage to the throat, larynx, esophagus, skin, and particularly the eyes.

Dr. Geoge E. Block, Professor of Surgery at the University of Chicago Hospitals and Clinics, stated that his experimental study on the corrosive injury of the stomach and esophagus indicated that highly alkaline nonphosphate detergents are dangerous toxins, and if accidentally ingested, could cause severe injury and death. He concluded that ingestion of three representative highly alkaline non-phosphate detergents in cats was associated with a 36% experimental mortality and an 82% incidence of significant esophageal or gastric injury. He also stated that corrosive esophageal injuries after non-phosphate ingestion may precede stricture formation in survivors. He concluded that if alkaline materials are allowed to inundate the U. S. market, some 10,000 to 30,000 cripplings or deaths would result each year.[26]

Dr. Robert E. Gosselin, Professor and Chairman of Pharmacology of Dartmouth Medical School, has stated that the alkalinity of most low or non-phosphate detergent products is so high that they represent a distinct hazard in the home. While these products may carry a warning label prescribed under the Federal Hazards Substances Act, he does not expect, from his experience, that such labeling would prevent a considerable number of serious personal injuries if these products were to gain general consumer acceptance.[27]

Dr. Steinfeld, commenting on the caustic detergent replacements before the Federal Trade Commission in April 1971, stated: "In respect to efforts to displace phosphates from detergents, it should be realized that tests conducted thus far indicate that some of the currently used substitutes for phosphates are clearly toxic or caustic and pose serious accident hazards, especially to children."[28] It was no surprise, therefore, that in his highly publicized announcement of 1971, Dr. Steinfeld advised housewives concerned about the environment and the safety of their children to use phosphate detergents.[29]

Conclusion

Problems associated with maintaining and improving the quality of our environment are seldom amenable to simplistic solutions.

Banning detergents entirely (as was done in Suffolk County, New York), banning DDT, banning swordfish, and banning nuclear power, all reflect frustration with our apparent powerlessness to prevent the ravage of our environment. Actions that would remove phosphates from detergents, or that by implication would encourage detergent users to believe that non-phosphate detergents are somehow beneficial, also exemplify such simplistic and ill-founded solutions.

If phosphates were removed from detergents, we would be replacing an effective well-understood chemical that is completely innocuous to man with substitutes that would likely be less effective, certainly less understood, and very possibly dangerous. We would be exposing all society to a clear risk, while obtaining a very questionable benefit for few people and no benefit whatsoever for most people.

Ordinarily, a uniform regulatory program—one designed to apply to all areas equally, without fear or favor—would seem the most desirable. In the field of water quality, however, every situation is unique. Nationwide uniform standards, while simple to administer, would in the end exact a far greater cost from society than would a system that recognizes local variations and permits regulations to be framed accordingly.

FOOTNOTES

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[1] Incidentally, Lake Erie is hardly dead. It *is* badly polluted and its shores are ravaged. But in 1970, Lake Erie yielded the largest, if least diverse, fish catch in its history.

[2] J. H. Ryther and W. M. Dunstan, "Nitrogen, Phosphorous and Eutrophication in the Marine Environment," SCIENCE 171, 1008–13 (1971).

[3] In 1947, 3,512 million pounds of soap and 405 million pounds of synthetic detergent were used in the U.S. By 1967, these figures had changed to 1,100 million pounds of soap and 5,200 million pounds of synthetic detergent.

[4] J. C. Morris, in testimony prepared for submission to the Federal Trade Commsision (Apr. 16, 1971).

[5] B. Ketchum, "Eutrophication of Estuaries," in Euthophication:

Causes, Consequences, Correctives; Proc. of Synposium, National Academy of Sciences, Washington, D.C. (1969).

[6] In one of the great and farsighted projects of modern times, Chicago reversed the direction of the Chicago River so that its wastewaters would not foul its water supplies taken from Lake Michigan.

[7] R. L. Evans, "Effluent-Water Quality Relationships on the Illinois Waterway," presented to the Illinois Pollution Control Board (Jan. 28, 1971).

[8] R. L. Evans, in a statement made on Oct. 29, 1971 as quoted in Water in the News, a publication of The Soap and Detergent Association (Dec. 1971).

[9] C. Lue-Hing, TECHNICAL PHOSPHORUS POSITION PAPER, The Metropolitan Sanitary District of Greater Chicago (Sep. 1971).

[10] W. D. Ruckelshaus, at a press conference (Sep. 16, 1971).

[11] A. D. Hasler, "Eutrophication of Lakes by Domestic Drainage," ECOLOGY 28:4, 383–95 (1947).

[12] L. Hirsch, "Irrigation with Reclaimed Wastewater," WATER AND WASTES ENGINEERING 6:4, 58 (1969).

[13] D. A. Okun, "New Directions for Wastewater Collection and Disposal," JOURN. WATER POLLUTION CONTROL FED. 43, 2171–80 (1971).

[14] E. J. Kormondy, "Lake Erie is Aging but Effort Can Save it From Death," Smithsonian 1:9, 26–33 (Dec. 1970).

[15] R. D. Grundy, "Strategies for Control of Man-made Eutrophication," ENVIRONMENTAL SCIENCE AND TECHNOLOGY, 5:12, 1184–90 (1971).

[16] The cost of conventional wastewater treatment, without phosphate removal, is on the order of $10–15 per capita annually. These per capita annual estimates include capital investment, operation, and maintenance.

[17] R. D. Grundy, *supra* note 15.

[18] D. Mitchell, "Eutrophication of Lake Water Microcosms: Phosphate vs. Non-phosphate Detergent," SCIENCE 174, 827–29 (1971).

[19] *Id.*

[20] Incidentally, because of the persistent foams that exacerbated pollution problems throughout the United States, public and congressional pressure on the detergent industry in 1965 resulted in a major change in the formulation of the surface active agent. It was converted from an alkyl benzene sulphorate (ABS), which is only slowly biodegradable, "hard," to "soft" linear alkyl sulfonate (LAS), which is more rapidly biodegradable in properly operating wastewater treatment plants. The elimination of phosphates is unfortunately not nearly so straightforward.

[21] W. S. Ruckeyser, "Fact and Foam in the Row over Phosphates," FORTUNE 71 (Jan. 1972).

[22] J. L. Steinfeld, in testimony before the Federal Trade Commission (Apr. 26, 1971).

[23] Similarly, the replacement of synthetic detergents with soap would increase the organic load on wastewater treatment plants by 10 to 20%, increasing treatment costs.

[24] Ministry of Technology (Britain), Notes on Water Pollution, No. 49 (June 1970).

[25] The British were the first to introduce biodegradable, "soft," detergents on a large scale. See *supra* note 20.

[26] As reported in ENVIRONMENT REPORTER published by the Bureau of National Affairs, Inc., 2:28 (Nov. 12, 1971).

[27] R. E. Gosselin, in testimony before the Federal Trade Commission (Apr. 26, 1971).

[28] J. L. Steinfeld, *supra* note 22.

[29] J. L. Steinfeld, at press conference (Sep. 16, 1971).