INLAND WATERS BRANCH

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Detergents, Phosphates, and Water Pollution

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Foreword

This report was prepared to provide the general public with technical information on detergents and the effects of phosphates on the water environment. It answers some of the more commonly-asked questions regarding phosphate-based detergents -- what they are, what they contain, how they work and how they affect the quality of our water resources. The property of biodegradability as it applies to detergents is explained.

During the past few months, scientists of the Inland Waters Branch have been studying and chemically analysing detergent products from many sources. Similar studies were carried out some time ago by Pollution Probe, University of Toronto. The data on phosphate content published by Pollution Probe were compared with what information the Inland Waters Branch had available at that time. Although differences of a few percent phosphate were noted in some of the products, there was in general close agreement.

The Inland Waters Branch analyses were carried out in the Ottawa laboratories of the Water Quality Division under the supervision of Mr. W.J. Traversy. Dr. P.D. Goulden, Mr. G. Kerr and the undersigned collaborated in the preparation of the report.

A. T. Prince,
Director, Inland Waters Branch,
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Detergents, Phosphates, and Water Pollution

The current battle to stem the continuing deterioration of the quality of Canada's fresh-water resources is being fought on many fronts. The problem of control is complex -- as complex as the range of pollution sources is wide. Many of our once beautiful waterways are slowly being stifled by the injurious effects of bacteria-laden human wastes, by massive quantities of organic industrial wastes and by toxic pesticides and chemical effluents.

Adding further to the growing burden carried by our lakes and rivers is the special form of pollution caused by phosphates and nitrates. While these compounds do not in themselves pose any threat to health at the concentrations involved after diffusion in receiving waters, they do possess nutritive properties which encourage the excessive growth of algae and other forms of undesirable aquatic vegetation. When large amounts of this vegetation decompose at the end of the growing period, depletion of the vital life-sustaining dissolved oxygen in water occurs. This form of pollution, which is caused by excess nutrient enrichment, is also referred to as eutrophication and in its extreme form results in the accelerated aging or dying of lakes.

Origin of Nutrients

Phosphates and nitrates are both released to water by the breakdown of human and animal wastes and other organic matter. They are found also in chemical fertilizers and industrial wastes. But scientists have now shown that a substantial part of the increasing nutrient load in our lakes and rivers can be traced directly to the phosphate-based detergents used extensively in home and industry. Since household use accounts for most of the consumption of detergent phosphate in Canada, it is clear that the household detergent, which has revolutionized washday for the modern housewife, is contributing substantially to the problem of nutrient enrichment.

Phosphates and Eutrophication

To understand the role of phosphates in water pollution, one must first look at the process of eutrophication. Briefly, eutrophication can be regarded as the progressive increase in biological productivity in a body of water, supported by a continuing abnormally-high input of nutrients which stimulate growth. Many other factors are also involved which contribute to excessive aquatic plant growth, such as availability of carbon dioxide for photosynthesis, abundant sunlight, clarity of water for light penetration, warm temperatures and other conditions. While some of these factors can be controlled, the phosphate nutrient factor is considered to be one of the most critical and one that can be controlled in such a way as to restrict excessive growth.

Under natural conditions, moderate amounts of nutrient material found in water and in lake and river beds encourage the growth of aquatic vegetation. This vegetation is a food source for fish and for the small organisms on which many fish feed. Left to its own resources, nature provides an ecological balance which may change but little over a long period of time.

The addition of even small quantities of nutrients, particularly phosphates, upsets the ecological balance and triggers an abnormal growth of aquatic vegetation, the most troublesome form of which is algae. Abnormal growths of algae can clog municipal water intakes and destroy the value of a lake for boating, swimming and other forms of recreation. Decaying algae use up oxygen which is vital to the survival of fish and other organisms -- oxygen which is essential also to the growth of *aerobic* (oxygen-using) micro-organisms which destroy solid and liquid organic wastes in water. Gradually, with the depletion of dissolved oxygen, *anaerobic* micro-organisms which thrive in the absence of dissolved oxygen become predominant, giving rise to the malodorous by-products of decomposition generally associated with gross pollution.

As the process of eutrophication proceeds, lake shores and beaches become fouled by the evil-smelling accumulations of decaying algae which have drifted in from open water. If the process is allowed to continue, the condition of a lake can deteriorate to the point where the quality of the water and the shore environment is, to all intents and purposes, destroyed.

Surfactant and Builder

The housewife of an older generation got by on washday with scrub-boards, copper boilers and soap. The soap she used was made from animal or vegetable fats and caustic soda (lye). In the 1930's the first synthetic soap-like products appeared on the market. The principal ingredients were derived from petro-chemicals produced by the petroleum industry.

The soaps and the synthetic soap-like products both suffered from disadvantages which reduced their effectiveness as cleaning agents. With soaps the main problem is the fact that in most water supplies, the hardness constituents (ions of calcium, magnesium, iron, etc.) react with the soap, forming a curd or precipitate. Soap is wasted in forming the precipitate and to compensate for this, more soap must be added before washing can take place. Also, the precipitate so formed tends to become re-deposited on the fabric as soap scum. The synthetic soap-like materials do not form a scum with the hardness salts, but their effectiveness is nevertheless much reduced by the presence of hardness constituents in the water. Today, these synthetic soap-like materials such as *LAS (linear alkylate sulphonate)*, are commonly referred to as "surfactants".

In the 1940's, it was found that combining surfactant materials with a special type of phosphate yielded a product with considerably improved performance. It was this discovery that led to the development of today's detergents.*

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*The term "detergent" was used by chemists to denote the synthetic soap-like products developed in the 1930's and this practice still persists to some extent today. The synthetic soaps gradually became known also as surface active agents (this has now been shortened to "surfactant"). It is now common practice to use the term "detergent" to denote the complete washing product, which contains surfactant, phosphate builder, and the other additives. The term "soap" is still reserved, as in the past, to indicate the product derived from natural oils and fats.

Modern laundry detergents contain a variety of chemicals introduced for specific purposes. There are chemicals for brightening and whitening clothes, protecting washing machines against corrosion, stabilizing suds in top-loading machines and for suppressing suds in tumbler machines. These ingredients, however, make up only a small fraction of the packaged detergent. The two most important ingredients are the *surfactant* and the *builder*.

The *surfactant*, which is the suds-producing ingredient, is soluble in both oil and water, a property which helps the water wet the individual fibres thoroughly and permits the effective removal of oil and grease. In the packaged product, the surfactant comprises up to 20% by weight of the mixture.

The *builder*, the agent which works with the surfactant to give the detergent its tremendous cleaning power, is usually sodium tripolyphosphate (STP). It helps remove oil and dirt from cloth fibres and holds them in suspension once they have been removed. The builder prevents the hardness constituents from interfering with the action of the surfactant by combining with these constituents to form a soluble chemical complex. It further assists the cleaning process by making the wash water alkaline.

Amount of Phosphate Builder in Detergents

There is considerable variation in the amount of phosphate builder used in the preparation of detergent products. Recent tests on a variety of washing and cleaning products by scientists of the Inland Waters Branch showed a range of from less than one percent to as high as 66 percent expressed as the compound STP. At the upper end of the scale were the heavy-duty laundry detergents and automatic dishwasher products with phosphate content between 28 and 66 percent. Liquid all-purpose cleaners ranged from less than one percent to about 10 percent. Testing generally less than one percent were the liquid detergents for manual dishwashing and the fabric softeners.

The phosphate level is high in products used specifically for softening and conditioning water for laundry and washing purposes.

Enzyme Additives

Today, many detergents contain enzymes which have been added for the specific purpose of removing stubborn stains. The enzymes are bacteria-produced chemicals which can break down proteins to form soluble amino-acids. When they are used to launder cloth on which there are protein stains such as those caused by blood or chocolate, the enzymes convert the normally-insoluble stain to soluble derivatives which are then removed in the washing process.

Phosphates and Biodegradability

For many years, the surfactant used in detergents was the petroleum industry product called *alkyl benzene sulphonate (ABS)*. This was the foaming ingredient which produced large quantities of suds when it was mixed with water and agitated. Since ABS was non-biodegradable, that is, it was not broken down to harmless end products such as water and carbon dioxide by the action of bacteria in sewage treatment plants or in open waters, it retained its surfactant properties and continued to produce unsightly foam in rivers and lakes. Research in the early 1960's produced a new surfactant called *linear alkylate sulphonate (LAS)* which is biodegradable and, since 1966, all detergents produced in Canada use this material.

The question of biodegradability, however, has no bearing whatever on the problem of nutrient enrichment caused by the phosphate. The fact that a box of detergent is labelled "biodegradable" is no indication that the contents will not contribute to nutrient enrichment and the resulting pollution problem. Biodegradability as represented on these labels refers only to the surfactant (LAS) which constitutes no more than about 20 percent of the material in the package. The builder (STP), is not biodegradable and on that basis the packaged product cannot properly be considered biodegradable.

Solution to the Problem

In modern detergents, science has offered the housewife a powerful and effective cleaning agent but the cost, measured in terms of a gradual deterioration in the quality of our water resources, is frighteningly high. A workable solution to the problem becomes daily more urgent.

Much controversy has arisen in recent months among scientists and industrialists as to the effectiveness of phosphate removal from detergents as a means of controlling the growth of algae and the consequent deterioration of water quality in our lakes and rivers. Debate has been stimulated by the recent report of the Advisory Boards to the International Joint Commission, on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, Volume 1 - Summary, September 1969. This report, based on exhaustive research and investigation during the past four years by government scientists in Canada and the United States, makes many recommendations, among them a strong recommendation for the immediate decrease of phosphates in detergents to minimum practical levels and complete elimination by 1972. Also recommended is the removal of nutrients from sewage treatment plant effluent as rapidly as effective processes and plants can be installed.

Data provided in the report to the International Joint Commission indicate that nearly 40 percent of the phosphates entering Lake Erie are detergent phosphates and most of these originate in the United States. Government scientists believe that the removal of this very significant source of phosphates may be effective in starting Lake Erie on the road to recovery. In the case of Lake Ontario, where eutrophication is serious but less advanced than in Lake Erie, the direct input of phosphates from municipal and industrial sources in Canada is almost equal to that coming from the United States. According to information provided by the soap and chemical industries, detergent phosphates in wastes from Canadian sources are much lower on a per capita basis than those from United States sources. They are nevertheless a significant source of phosphate contribution to Lake Ontario and must be controlled.

Restricting the amount of phosphate used in detergents throughout the country as an immediate measure, would reduce the quantity of algae-producing nutrients being discharged into many of our lakes and rivers. It would also stimulate the industrial development and production of harmless substitutes for phosphates. The next logical step would be an outright ban on the use of detergent phosphates.

Of the various complete or partial substitutes for phosphates which have been investigated, the best hope at present is sodium nitrilotriacetate

(NTA). Although NTA does not contain phosphates, it does contain a small amount of nitrogen which is also a plant nutrient. The nutrient effects of nitrogen, however, are in most cases much less potent that those of phosphates. In Sweden, one detergent manufacturer has replaced 70 percent of the phosphates in some products with NTA. The products involved account for approximately 15 percent of Sweden's total detergent sales. Over the two-year period during which NTA has been in use, no undesirable environmental effects have appeared.

On February 6, 1970, the Hon. J.J. Greene, Minister of Energy, Mines and Resources, announced a proposal to limit the use of phosphates in detergents by mid-1970 and ban phosphates completely as soon as possible. The proposal involves a control plan that would be mutually acceptable to the Government of Canada and the Governments of the Provinces and would be coordinated with a similar plan now being considered by the United States Goverment.

Restricting the phosphate content of detergents or even banning detergent phosphates completely would not, however, be sufficient to prevent the growth of algae, although a marked improvement may be anticipated as a result of this action. Municipal sewage, even without the heavy burden of detergent phosphates, is still a significant source of phosphates and other nutrients and to remove them will require the building of special treatment facilities, particularly for the larger cities. Restricting or banning the use of detergent phosphates, therefore, is only a first step. The technology of phosphate removal from municipal sewage is under development and action is being taken by pollution control agencies of government to move forward from the pilot plant scale of testing to full-scale operational plants. The construction of suitable plants, however, will take many years and the cost will be high.

Summary

The legislation proposed by the Minister of Energy, Mines and Resources would require all detergent manufacturers to limit the phosphate content of their products to a specified level by mid-1970 and would introduce a complete ban as soon thereafter as feasible.

It may be one or two years before harmless substitutes for phosphates are available -- or available in sufficient quantities -- to provide the same level of cleaning effectiveness offered by existing phosphate detergents. If this is so, the consumer, in the interests of reversing the stifling process of eutrophication, may be called upon to accept detergents that are somewhat less effective, until such time as a satisfactory substitute for phosphates is available in quantity.

This report has emphasized the significance of detergents as a source of nutrients for aquatic vegetation and has referred also to the contribution of nutrients from human wastes in municipal sewage. Another source that should not be overlooked is the chemical or organic fertilizer used extensively in agricultural operations. Normally, when fertilizers have been worked into the top few inches of soil, they will not easily wash out. But under certain conditions, such as extensive soil erosion or as a result of runoff due to snowmelt or prolonged, heavy rain, the fertilizer may be released from the soil and carried by drainage to lake or river. The problem presented by the use of fertilizers in agriculture, however, is considered to be much less serious than the problem caused by nutrients from the other two main sources.

In summary, therefore, the program to control nutrients involves first of all a restriction and later a ban on the use of phosphates in detergents, in the expectation that this will help to reverse the process of eutrophication. Next, the building of special waste treatment facilities will decrease even further the quantity of nutrients being discharged from municipal sewage. The third step will involve minimizing, through improved farming practice, the amount of agricultural fertilizers washed from the land.

Current Technical Bulletins

No. 12 Sediment surveys in Canada. W. Stichling and T.F. Smith, 1969

An outline of the Sediment Survey Program of the Water Survey of Canada, including methods, instrumentation and data available.

No. 13 Climatology studies of Baffin Island, Northwest Territories. R.G. Barry and S. Fogarasi, 1969.

A report of the results of a program of climatological investigations in Baffin Island.

No. 14 Hydrology of the Good Spirit Lake Drainage Basin, Saskatchewan: A preliminary analysis. R.A. Freeze, 1969.

A report on the first water balance for the Good Spirit Lake Drainage Basin and a discussion of the methods used in the investigations.

No. 15 Digitizing hydrographs and barographs. T.W. Maxim and J.A. Gilliland, 1969.

A discussion of the conversion of analogue water level recorder graphs and barographs to digital form using a pencil follower and key punch.

No. 16 The computation and interpretation of the power spectra of water quality data. A. Demayo, 1969.

A discussion of the concept of spectral analysis and the method of calculating power spectra of water quality data, including a practical example and the computer program used to perform this type of calculation.

No. 17 Groundwater Investigation - Mount Kobau, British Columbia. E.C. Halstead, 1969.

A report of the results obtained from a study of the groundwater storage system at the summit of Mount Kobau, British Columbia.

No. 18 The effects of the W.A.C. Bennett Dam on downstream levels and flows. A. Coulson and R.J. Adamcyk, 1969.

A report summarizing the expected effects of the W.A.C. Bennett Dam on levels and flows in the Mackenzie River basin.

No. 19 Airborne techniques in climatology; oasis effects above prairie surface features. R.M. Holmes, 1970.

A report describing a pilot study of oasis effects in southern Alberta using a specially-instrumented aircraft and a mobile ground station.

No. 20 Hydrogeological Reconnaissance of the North Nashwaaksis River Basin, New Brunswick. J.E. Charron, 1969.

A description of a hydrogeological reconnaissance carried out as part of an International Hydrological Decade study of the hydrology of the North Nashwaaksis Basin.

No. 21 An instrumented experimental site for the investigation of soil moisture, frost and groundwater discharge. R.A. Freeze and J.A. Banner, 1970.

A report describing an instrumented experimental site at Calgary, Alberta, to provide integrated measurements of the subsurface moisture regime in saturated and unsaturated zones. A summary of the first year's operation is included.

A complete list of titles in the Technical Bulletin Series and copies of these publications may be obtained from the Director, Inland Waters Branch, Department of Energy, Mines and Resources, 588 Booth Street, Ottawa, Ontario.