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Detergent phosphates and detergent ecotaxes: a policy assessment.

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Executive Summary

The reason that the use of phosphates in detergents remains an issue is that there is a continuing problem with eutrophication, which is the nutrient enrichment of water, and which can lead to the growth of algae and cyanobacterial blooms in European surface waters. These are unsightly, often have an unpleasant odour and can be toxic. The growth of algae and cyanobacteria also depend on the water temperature and the availability of sunlight for photosynthesis. Warm water temperatures and plenty of sunlight may combine with slow flowing or stationary water to give the conditions under which blooms can grow. Eutrophication is caused by inputs of nutrients, phosphorus and/or nitrogen, into surface water ecosystems that are far higher than the natural level. The main sources of phosphorus in Western Europe are animal manure and fertilisers used in intensive livestock agriculture and human waste in urban waste water. Phosphates used in domestic laundry detergents may make a significant contribution to the phosphate content of urban waste water in some areas.

Phosphates and STPP in particular perform a vital function in modern synthetic detergents, although there are substitutes, of which the most successful is zeolite combined with polycarboxylate. Life cycle analyses suggest that there is little to choose between STPP and zeolite-polycarboxylate formulations in terms of their environmental impact, but STPP remains the most effective ‘builder’ in laundry detergents.

In order to control eutrophication, many countries have acted to control the use of STPP in laundry detergents. Laundry detergent formulations using STPP are no longer sold in Germany, Italy, Switzerland, Austria and Norway in Europe, as well as the US and Japan. More recently, more coherent policy packages regarding eutrophication have been developed, with one of the main actions being the installation of equipment to remove phosphorus from urban waste water.

Another policy tool has been the adoption of ecolabels. There is no clear message to be put across by such a system, as the phosphate content of detergents is often not a significant contributor to eutrophication. This is reflected by the Scandinavian and EU detergent ecolabels, which allow phosphates to be included.

These policies have been partially effective so far. It is now generally accepted that a large reduction in phosphorus loading can enable surface waters to recover from cyanobacterial blooms and turbidity, but each site has to be considered individually. Therefore, the continuing investment in phosphorus removal in sewage plants will eventually control cyanobacterial blooms in many instances, in particular where the main nutrient loading comes from urban waste water. Countries such as Italy, where blooms are still a major problem and there are relatively few phosphorus removal installations will benefit considerably from these policies.

Future policy should be based on local responses to local problems within an overall legal framework, a point insufficiently emphasised in the current literature but clearly developed in the new EU Water Framework Directive. Continuing investment in phosphate removal at sewage plants is the first part of a policy to control eutrophication. The next step, which is much more difficult, is to control phosphorus loading from agriculture. Then there is the question of what to do with the phosphorus when it has been removed. Phosphorus removal in sewage plants produces sludge, which must be used or disposed of. As it has high transport costs, the most economic option is to use the sludge as fertiliser in the area surrounding the sewage treatment plant. However, there are obstacles to sludge spreading. Limits for heavy metal content and the presence of other contaminants such as brominated flame-retardants or pathogens and farmers’ refusal for image/food quality reasons mean that sludge spreading may be insufficient. There are several alternatives. The simplest is to dry and incinerate the sludge, but this requires careful treatment to control combustion products. There are alternative uses, such as drying and using for building materials or paving slabs, as has been practised in Japan. A further possibility is to recover and recycle the phosphorus in a form useable by the phosphate industry or as fertiliser. All these alternatives require investment in some degree. Recycling into industrial processes has the additional complication that phosphate manufacturers would have to alter their production organisation to accept the recycled phosphorus instead of phosphate rock, although since the rock has quite a high heavy metal content, the production process could probably be made cheaper. Regional recycling as a fertiliser, either directly or after simple processing, may offer better logistics and economics.

Any further regulatory controls on phosphates in detergents would be very unlikely to influence the extent of cyanobacterial blooms. Since each local problem has to be resolved by regional action, policies such as a general tax on detergents are not relevant as environmental policies.

This report considers ecotaxation in particular. The fundamental principle of ecotax design is that it should provide an incentive for the polluter to change their behaviour in a way that reduces the undesirable or polluting activity, in this case eutrophication. Smith (1997) argues that the earmarking of tax revenues does not have an economic justification, but is used to make the introduction of a tax more acceptable.

The use of a national tax on detergents containing phosphates is problematic for several reasons. A national tax takes no account of local variations, so a large proportion of taxpayers will be facing extra costs for no environmental gain. In many areas, the main phosphate loading will come from agricultural sources, so a detergent tax does not address the problem. Even if the main problem comes from urban waste water, a reduction in detergent use will not prevent eutrophication in most cases. Consumers will always wish to wash clothes and will not be very sensitive to changes in detergent prices. Household expenditure on detergents is also a small proportion of expenditures, so a significant increase in price of detergents is unlikely to cause consumers to use much less. An impractiably high rate of tax on detergents would be necessary to have any significant impact on the incidence of eutrophication.

In overall environmental terms, given that there is little difference in life cycle impact between the phosphate and non-phosphate detergents, there is not much point in taxing just phosphate detergents as opposed to all detergents. If there is a significant difference in tax levels or only a tax on phosphate detergents, there will be a reduction in demand for phosphate detergents.

The sole example of a tax on detergent phosphates is the French TGAP, which taxes all detergent purchases with a somewhat higher rate of tax applicable to phosphate-containing detergents. The TGAP on detergents will not be successful at addressing the environmental problem of cyanobacterial blooms caused by eutrophication, although it will slightly improve the overall efficiency of the tax system. The impact on social equity is small. It will not change consumer behaviour. Taxing all detergents rather than only those with STPP has no significant environmental implications and will maintain a place for STPP formulations in the French detergent market.

With regards to the phosphate industry, the overall conclusion is that STPP manufacture can remain a relatively small, but significant activity for the chemical industry for the foreseeable future and that effective policies to control eutrophication are entirely compatible with the continued or even expanded use of STPP in laundry detergents. In recent years, there has been innovation in new products such as ‘compact’ powders and tablets. These help to prevent the excessive use of detergents and therefore reduce the environmental impact of detergents. STPP is particularly suitable for use in both of these new types of product and this should contribute to the continuing presence of STPP in the detergent market.

In terms of policies for detergent phosphates, any further controls by regulation or taxation would be very unlikely to influence the extent of cyanobacterial blooms and algae. Since each local problem has to be resolved by regional action, policies such as a general tax on detergents are not relevant as environmental policies.

Future policy should be based on local responses to local problems within an overall legal framework, a point insufficiently emphasised in the current literature, but highlighted in the new EU directive on water treatment. Continuing investment in phosphate removal at sewage plants is the first part of a policy to control eutrophication. The next step, which is much more difficult, is to control phosphorus loading from agriculture. This could be achieved through a combination of improved use of fertilisers and manures and taxes on the use of phosphates in agriculture.

Since phosphate removal will become more widespread, this problem will have to be addressed. For now, recycling technology is being developed and is close to being applicable on an industrial scale. Therefore, policy should encourage the formation of markets for sludge or recycled phosphate products. There are many ways in which this could be achieved: by voluntary agreement with water companies, phosphate manufacturers and agricultural businesses; by legislation to require the removal and disposal of phosphorus and the associated by-products or by taxation on point and diffuse sources of phosphorus.

1. Introduction

Laundry detergents are an item that appears on everybody’s shopping list; they perform one of the basic household functions. An important ingredient of many detergents is phosphate in the form of sodium tripolyphosphate (STPP). Its introduction in synthetic detergents in 1948 heralded a step increase in performance over the soap-based products that had been used before. Subsequently, the markets for synthetic detergents grew rapidly in Europe and the US and the production of STPP became a significant part of the phosphate industry, although it has always remained a relatively small part of the market in comparison to fertilisers, which account for 85% of phosphate production.

One consequence of the use of STPP in the domestic environment can be increased phosphate in household waste water, which may then contribute to the phosphorus load in rivers, lakes and inshore waters. The presence of phosphates in waste water can be an environmental issue because of “eutrophication”, the increase of nutrient levels in water, which can lead to environmental problems such as the formation of large masses of algae or blooms which are unsightly, causing slow moving water to be turbid, and may be toxic. Therefore the use of STPP in detergents has been controlled and its use reduced. The removal of phosphates in sewage treatment plants has been shown to be very effective in reducing the phosphate load in rivers and lakes. However, the presence of cyanobacterial blooms and turbidity is still an important environmental issue in many European countries.

This report considers the potential for further control of STPP use in household detergents as a part of environmental policy for phosphorus, the probable effectiveness of tighter controls for improving the environment and the consequences for the consumer and the STPP industry. Commercial laundry operations and detergents used in industry are not addressed. Although a quantitative economic analysis is beyond the scope of this report, qualitative provisional conclusions are drawn for the probable impact of the different policy instruments on the environment and the phosphate industry. Section 2 explains why phosphates play such an important part in many laundry detergents and briefly surveys the alternative chemicals that can be used. Section 3 covers the environmental issues associated with phosphates in surface waters – the problems which can develop due to eutrophication – and considers whether detergent phosphates play a significant role. Section 4 surveys the history of environmental policy on detergent phosphates, including a discussion of the new French tax (TGAP) and the subsequent reactions in the consumer markets. Section 5 contains a brief qualitative analysis of the current market conditions for STPP. Section 6 proceeds to consider the ways in which environmental policy might effectively address the continuing issue of eutrophication in the future and the economic implications of the policies. Section 7 concludes.

2. The use of phosphates in laundry detergents

The reason why phosphate compounds and in particular STPP are used in detergents is that they turn out to perform several very useful functions. No other single chemical product has been found which performs the same combination of functions as ‘builders’ and contributes so effectively to the performance of modern household detergents, where washing temperatures are low and soiling of the clothes is generally relatively light. STPP performs the following functions (Davidsohn & Milwidsky, 1978):

1. As with all complex phosphates,STPP is alkaline, so it counteracts hardness inwater. ‘Hardness’ means that the water contains salts such as calcium chloride or magnesium chloride, which will leave crusty deposits on the clothes. Dirt and the textiles may also contain calcium and magnesium ions. STPP reacts with these salts to combine them into other phosphate containing compounds which do not precipitate, so avoiding further deposits of precipitated crystals on the clothes. This has the additional advantage of preventing deposition on the heating elements in the washing machine (Merkenich and Gohla, 1979).

2. A combination of 50% detergent and 50% STPP provides a more effective washing performance than using 100% detergent, other factors being equal. Condensed phosphates increase the surface activity of the active washing compounds (Ullmann, 1999). An additional effect is that the alkaline STPP raises the pH value in the wash liquid (i.e. acts as a chemical buffer), which means that the ions in the dirt and textile fibres become more strongly charged. This in turn leads to increased repulsion between the ions in the dirt and in the textile, thus increasing washing performance. Of all the phosphate compounds, STPP has the greatest synergy in these respects.

3. Complex phosphates such as STPP 'deflocculate', which means that they break up large particles of e.g. mud or clay into smaller ones. Furthermore, they keep fine particles in suspension in the washing water and prevent them recombining, thus avoiding redeposition on the clothes. Related to this property of deflocculation, they emulsify oily materials, that is they also break up oily masses into smaller particles.

4. Because of the alkalinity of STPP, it will redissolve Calcium and Magnesium compounds that are present from detergent in previous washes and will reactivate any remaining soap. Therefore, the performance of the detergent is enhanced in this case.

This combination of functions means that phosphates and STPP in particular can play a very important role in the washing process. If phosphates are not used, they must be replaced with some material or combination of materials that performs a similar combination of functions, if the performance of the detergent is to be maintained. In recent years, there has been innovation in new products such as 'compact' powders and tablets. These help to prevent the excessive use of detergents and therefore reduce the environmental impact of detergents. STPP is particularly suitable for use in both of these new types of product.

2.1 Alternatives to Phosphates in Detergents

As will be shown in sections 3 and 4 below, concern about the environmental impact of phosphates in synthetic detergents resulted in the introduction of various controls and restrictions on the use of phosphates in household detergents. This led to a search for alternative builders. Several replacements have been tried:

Sodium citrate

Sodium citrate was utilised as a builder, but it has some disadvantages (Stinson, 1987). It is considerably more expensive than STPP (twice as much at that time) and does not perform as well in removing calcium and magnesium ions. This lower performance is least marked at very low temperatures.

Ethylene diamine tetraacetic acid (EDTA) and Nitrilotriacetic acid (NTA)

Both of these chemicals are effective at abstracting calcium and magnesium ions and NTA in particular can largely replace STPP as a builder (Perry et al, 1984). However, it does not buffer as strongly as STPP and is less effective as a particle disperser. The main problems with NTA are that there has been some evidence that it is carcinogenic and its great strength in combining with metal ions has caused fears that heavy metals in sewage sludge may be taken up and hence mobilised (Perry et al, 1984).

This could then result in peak concentrations of heavy metals in rivers and lakes being above regulated levels. Brouwer and Terpstra (1995) argue that this latter risk is not significant. These environmental concerns have resulted in both EDTA and NTA being excluded from EU Ecolabelable automatic dishwasher and domestic laundry detergents.

Zeolite A and its cobuilders

The most successful alternative has been zeolite A, a relatively inert substance derived from aluminium oxide (Landbank, 1994). It has a reasonable performance in abstracting calcium and magnesium ions but is limited as a builder. It does not buffer during the washing process and does not prevent redeposition of soil particles in the wash liquid, so it has to be used with a cobuilder, usually polycoarboxylic acids.

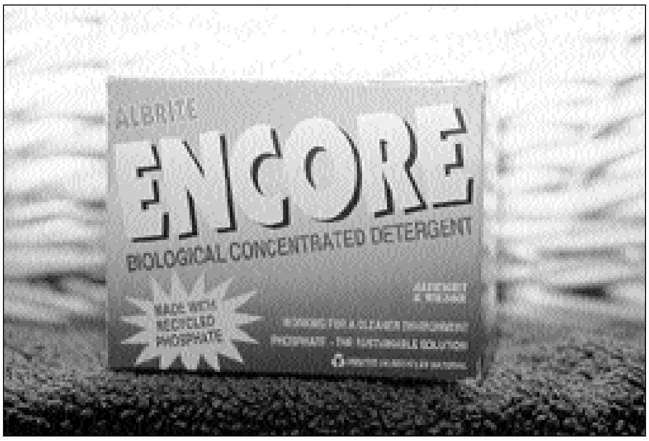
These are oil-based compounds that soften water and keep soil particles in suspension. Zeolite-PCA builders are now used in almost all countries where STPP is no longer used, in particular the USA, Germany and Italy. It is also extensively used in liquid detergents. Its real advantage appears to be that it never been perceived as presenting a serious environmental problem, although concern has been expressed over the impact of PCAs on heavy metals in water sources (CES, 1991) and it provides reasonable performance for modern household detergent powders.

It also results in increased volumes of sludge from sewage treatment plants in comparison to STPP. Zeolites and PCAs contribute significantly to volumes of sludge produced by sewage works, probably generating significantly more sludge than detergent phosphates in cases where either sewage P-removal is not necessary, where P-removal is carried out essentially by biological processes or if P-recycling is installed. The inclusion of zeolites in detergents is estimated to increase sewage works sludge production by 15% (FRWA, 1996).

Comprehensive life-cycle comparisons of STPP and Zeolite A – PCA has been undertaken for European conditions (Landbank, 1994 and Landbank, 1995). They found that the overall environmental impact of the two builder systems was roughly equal in both the UK, which has relatively simple waste water treatment and in Scandinavian countries which have very advanced waste water systems. Landbank (1995) concludes that using STPP exclusively as a builder is the option with the lowest environmental impact in terms of waste water treatment only.

This is mainly because zeolite builders result in a greater volume of sludge from sewage treatment works and because zeolites and PCAs have no recycling value, whereas phosphorus can be usefully recovered and recycled. Although Life Cycle Analysis methodology has evolved since these studies, more recent work (EMPA, 1999) has confirmed the coherence of theses studies' data and conclusions.

In summary, there has been extensive research into alternatives to phosphates and STPP in particular as a builder. For household powder detergents, which are usually required to operate with medium to light soiling of the washing and washing machines utilising relatively low temperatures, STPP is the most appropriate builder taking into account its environmental impact and cost to the detergent producers. It is particularly useful for heavy soiled washes, it is extensively used in industrial laundry detergents as well as in dishwasher detergents, even in countries where it is no longer present in household detergents.



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3. Detergent phosphates in waste water: are they a pollutant?

This question has to be addressed in two stages: firstly, do phosphates in water cause environmental problems and secondly, if there is a problem, what is the contribution of household waste water and in particular detergent phosphates to these problems?

3.1 Phosphates and Eutrophication

The environmental issue associated with phosphates is eutrophication and the subsequent growth of blooms of cyanobacteria and microscopic algae. Eutrophication describes a situation in which a body of water receives an increased supply of plant nutrients which provide the conditions for the rapid growth of these blooms. Both phosphorus and nitrogen are essential chemicals for plant growth, but are only required in very small quantities under 'natural' conditions. Therefore, if the supply of either of these nutrients is suddenly increased, the conditions for plant growth will change and the eco-system will adapt. In particular, given suitable environmental conditions, blooms will form. Jones and Alexander (1989) and Haas et al. (1988) provide empirical evidence that phosphorus can be the limiting nutrient determining the extent of blooms. The growth of algae and cyanobacteria also depend on the water temperature and the availability of sunlight for photosynthesis. Warm water temperatures and plenty of sunlight may combine with slow flowing or stationary water to give the conditions under which blooms can grow.

It is important to note that the size of blooms is governed by these different limiting factors. If the water is warm, there is plenty of sunlight and the requisite minerals, but initially a low level of phosphate, then the introduction of phosphate will cause a growth of the blooms. However, if there is already plenty of phosphate and the growth is limited by, say, nitrogen, then the addition of phosphate will not cause any growth. The relationship between biomass and phosphorus has been statistically estimated in the 'Vollenweider model', but because of the other potentially limiting factors, there is no continuous function between biomass and the quantity of phosphate (Reynolds, 1992). Cranfield et al. (1989) report that while blooms are associated with eutrophication, there is generally a low correlation between cyanobacterial biomass and total phosphorus or total nitrogen. Gde and Gries (1998) consider that biological productivity cannot be accurately predicted by simple phosphorus load approaches.

Algae and cyanobacterial blooms are a problem for the environment. The growth of large masses of these blooms may lead to the deoxygenation of deeper waters, threatening rare fish species and invertebrates. Reeds and other submerged plants may be lost and there can be indirect effects on herbivorous bird species. There is thus a loss of the variety of habitat and hence diversity of species (Lund and Moss, 1990). The blooms may also block water filtration systems. Cyanobacterial blooms in particular may have an offensive odour and colour, forming noxious scums and may be toxic (Howard, 1994). Kelly and Pontefract (1990) report an incident at Rutland Water, UK in 1989 in which a total of 15 dogs and 20 sheep died after drinking contaminated water. Turner et al. (1990) report an incident at Rudyard lake, Staffs., UK where a group of soldiers suffered from gastro-intestinal ailments, one from hallucinations and another from atypical pneumonia. In 1989, 169 water bodies in England and Wales were considered to have problems with cyanobacteria and 68% of 78 sites tested were found to have cyanobacterial toxins (NRA, 1990). However, Lund and Moss (1990) consider that in the UK, the growth of cyanobacterial blooms is localised, rather than a widespread problem across the UK. They also report that the incidence of environmental problems due to eutrophication in the UK was at a similar level in the 1980s compared with the 1970s. Up to 1989, 16 European countries had reported blooms (Lawton and Codd, 1991) and blooms have been reported in Australia, Canada, Japan, South Africa and the USA (Howard, 1994). Morse et al. (1993) summarised the situation in Europe at the beginning of the 1990s in the following table:

Table 1: Extent of waters affected by eutrophication

Country	Extent	Key areas affected
Belgium	High	Most inland waters
Denmark	High	Most inland waters, North Sea, Kattegat, Baltic
France	Low	Loire, Meuse, Saone and possibly other rivers
Germany	High	Many inland waters, Bavaria, Rhine, North Sea, Baltic
Greece	Medium	Potential threat to limited inland and coastal waters
Ireland	Medium	Potential threat to inland waters
Italy	High	Most lakes and reservoirs, Rivers Arno, Tevere, Po, Adriatic
Luxembourg	Medium	
Netherlands	High	All inland waters
Spain	Medium	Many inland waters
Portugal	Low	
UK	Low	Lough Neagh, Anglia, some other local areas
Switzerland	High	Many lowland lakes

Source: Morse et al. (1993)

3.2 Contribution of detergent phosphates to phosphate loading

Detergent phosphates are a significant, but secondary, source of phosphates in rivers and lakes. Humans and animals are by far the most important sources. Morse et al. (1993) state that of phosphorus input to the aquatic environment in the EU, the most important contributors are livestock waste (34%), human waste (24%) and agricultural fertilisers (16%). Detergent phosphates form 10%. UKWIR (1997) state that for waste water input to sewage plants, the most important source is human waste, detergents form between 9% and 50% and that manufacturers' estimates were 40%; a current manufacturers' estimate is 20-25% (Duley, 2000); and industrial processes contribute 9% in the UK. Between 30% and 90% of phosphorus loading in rivers is from non-point sources i.e. agriculture (Sharpley et al., 1995) and this range is confirmed by McCann and Easter (1999) who state that in the Minnesota River, US, non-point sources contribute 35% of phosphate loading with low rainfall up to 90% loading in high rainfall. There are some surface waters in which the phosphorus load is dominated by point sources. In 1989 the river Po, Italy, received 67% of phosphorus from point sources and 29% from agriculture; the German Rhine received 77% from point sources and 23% from agriculture in 1985. For 1989-1992 in all of (West) Germany, 52% came through point sources and 42% from agriculture (EEA, 1998b). UKWIR (1997) make the claim that 'If, as seems probable, this load is dominated by particulate and biologically unavailable forms then it is reasonable to deduce that the soluble and biologically active phosphate fraction discharged to rivers is often 85-90% derived from secondary sewage treatment' (UKWIR, 1997, p19). However, this assertion is not supported by any evidence and is in contradiction to Morse et al. (1993) and McCann and Easter (1999).

The conclusion to be drawn from this evidence is that phosphates may indeed cause serious environmental problems. Kolber (1990) states that detergents led to 40% of water 'over-fertilisation' in Austria. However, the conditions under which these problems arise are limited and inherently site specific. Thus it is not possible to determine in general whether the removal of a certain amount of phosphate will reduce the incidence of blooms or whether an increase in will cause blooms to develop or grow. Furthermore, the contribution of household detergents to the total phosphate load that finds its way into rivers, lakes and reservoirs varies considerably. Where phosphorus loading is dominated by waste water inputs, phosphorus from detergents might contribute up to 25% or so of the phosphorus loading. Therefore, the reduction or removal of phosphates in detergents will only have an environmental impact under very specific and limited conditions and where phosphate removal has not been installed in sewage works.

4. Policies on detergent phosphates and their consequences

In response to the harm being done to the environment, the potential factors causing eutrophication – i.e. increased input of nitrogen and phosphates into watercourses, lakes and seas – were rapidly identified. In the case of detergents, the increase in phosphorus input due to the introduction of synthetic detergents was perceived to be a major contributor to eutrophication. The question then was how to reduce this nutrient loading. Policies in response to the growth of eutrophication as a problem have followed the general course of environmental policy, starting by setting national standards through regulation, through international agreements where necessary.

Most policy on phosphates has been of this nature. There were two relatively obvious courses of action: the restriction of phosphates in household detergents and the treatment of waste water in sewage plants to remove phosphorus. With the more recent trend towards the use of economic instruments, such as taxes and charges, the taxation of phosphates is now being considered and has been enacted for detergents in France in particular. Ecotaxes are considered in detail in section 5 below. A significant aspect of policy formation was the rapid acceptance by industry that changes were necessary; there have been many voluntary agreements to reduce phosphate use in detergents and these have led to significant reductions in phosphate use. The reasons for this are considered in section 6 below.

4.1 Pollution control policies

The three main sources of phosphorus are livestock waste, human waste and agricultural fertilisers. However, the relative contributions will vary significantly, depending on the particular site. Rural areas with intensive agriculture have the highest contributions from agriculture to their surface water resources, while urban water will have the main contribution from waste water.

Therefore, policy mechanisms must be able to take account of local conditions. This suggests that at least implementation of policy should be decentralised, as in the French system of management by river basin (CFEGP, 1999) and as defined by the new EU Water Framework Directive (EUCC, 2000).

A further important consideration is the practicability or simplicity of operation of the policy. It is much easier to implement monitoring, controls and investments for point sources of pollution than for diffuse sources. Urban waste water is collected and discharged through sewage plants which are point sources of phosphorus. In contrast, agricultural manure and fertiliser creates a phosphorus load by leaching into groundwaters which then are washed into rivers and lakes, creating a diffuse source. Because sewage plants can be easily monitored and controlled in contrast to the diffuse sources from agriculture, policy so far has tended to concentrate on urban waste water.

This has the limitation that the most important source of phosphates, human waste from the body's processing of food, is dependent solely on population levels and cannot be limited at source. Detergents have been the other main contributor. Both human and detergent phosphates, along with industrial sources discharged into sewers, can be effectively removed down to very low levels by the installation of sewage collection and of advanced sewage treatment, where public policy requiring this is decided and implemented.

There are several types of policy instruments that have been applied to reducing phosphate input to surface waters:

4.1.1 Command and Control instruments

Phosphate levels in detergents and also in fertiliser input to agriculture can be specified by legislation or administrative instruments. As explained in section 3 above, detergents are not the largest contributor to phosphate input in urban waste water. However, given that the main contributor is human waste, which as a biological function cannot be reduced, controlling phosphates in detergents offered the best way of reducing phosphate input into urban waste water.

The response of individual countries has depended on the severity of the problem and its geographical extent. In 1985, Italy introduced a restriction of 4% STPP content in household detergents (a low enough proportion to prevent effective use of STPP) in negotiation with industry. This was followed by regulatory bans on phosphates in household detergents in Switzerland and Norway and subsequently Austria in 1994.

Many US states introduced bans in the early 1990s and Japan also discontinued the use of STPP in detergents. In the Netherlands, Denmark and Germany the use of STPP was not banned, but particularly in Germany the governments negotiated with the phosphate industry for a voluntary agreement. Furthermore, consumer opinion also turned against phosphates in particular because of high profile environmental claim advertising by phosphate free brands and the demand for detergents with STPP dropped to such an extent that there are now no household detergents using STPP sold in these countries.

However, since cyanobacterial blooms and algae are still a widespread problem in Italian surface and coastal waters, regulating detergents in this way does not seem to be effective. Morse et al. (1993) found that there were no examples of phosphate limits in detergents making any large impact on eutrophication and FEM (1986) concluded that moving to phosphate free detergents would not measurably change phosphorus inputs from the river Redon into Lake Geneva.

This type of blanket instrument also ignores local variations in conditions, for example whether most of the phosphate comes from waste water or agriculture. It is therefore likely to be inefficient in economic terms and in many cases will not solve the problem. One way in which regulation can be effective in the context of phosphates is to specify either treatment standards or emissions standards for waste water treatment.

4.1.2 Waste water treatment

The other obvious possibility is to treat waste water at sewage plants to reduce the phosphorus content of discharges. The technology for waste water treatment is well established, but requires significant investment, which in countries with public water treatment had to come from government budgets. Thus a public perception of a severe problem was necessary for such a policy to be enacted. Treatment of urban waste water to remove phosphorus has the greatest potential to change the output into rivers and lakes, because it works on all the phosphate content of waste water instead of only the small fraction from detergents.

Also, phosphate removal in sewage works is generally installed at the same time as nitrogen removal, thus also reducing the input of this nutrient to surface waters. Denmark, Germany, the Netherlands, Switzerland and Sweden have all installed a large number of phosphate removal systems. Germany and the Netherlands are among the signatories to the Rhine Action programme, which required a 50% reduction in inputs of phosphorus and nitrogen to surface waters (van der Kleij et al., 1991).

A potentially far-reaching step was taken by the EU in 1991 with adoption of the Directive on Urban Waste Water Treatment (Directive 91/271/EEC). The impact of this directive, which came into force in 1991 with the requirements regarding phosphate removal applicable by 31/12/1998, is assessed in IEEP (1999). Progress has been variable in the different member states, both in the designation of sensitive areas that require phosphate removal and in the installation of treatment systems.

While phosphate discharges have been reduced, phosphate concentrations are far above their natural levels in many areas in Europe and eutrophication continues to be a serious problem. Although full compliance with the EU directive still requires far more extensive phosphate removal, policy is now changing towards a water catchment based and hence localised approach, within the context of national and EU policy.

The new Water Framework Directive maintains the requirements of existing Directives (e.g.91/271) as the minimum baseline to be developed at the catchment level. Since the growth of cyanobacterial blooms and algae is very dependent on the local conditions, a more integrated approach to nutrient load at a local level offers the possibility of more efficient and effective action.

The technology exists to remove 95% or more of phosphate from waste water, if the most comprehensive treatment systems are fitted (IEEP, 1999). Consequently, if countries such as Italy (where waste water treatment is relatively limited and there are serious problems with cyanobacterial blooms and algae) move towards compliance with the Directive by installing more treatment plants, eutrophication due to phosphorus should decrease and this might have a considerable effect on the overall problem. Sweden, Switzerland and the Great Lakes region of the USA, for example, have implemented phosphate removal programmes, which have controlled the extent of eutrophication (Landbank, 1995). I

In Sweden they have therefore not considered it necessary to put any controls on phosphates in detergents. EEA (1999) considers that the number of heavily polluted rivers in Western Europe has fallen from 25% in 1975-80 to approximately 5% in 1992-98, especially because of the installation of waste water treatment following the Urban Waste Water Directive.

This will have been very effective where there was a high proportion of the phosphorus load from point sources, as in the river Rhine. It must be emphasised, however, that because cyanobacterial blooms and algae are dependent on the specific local conditions, each incidence has to be analysed and treated individually for a fully effective policy to be developed. Remember also that this does not reduce the problem due to non-point sources of phosphorus from agriculture.

Phosphorus removal through waste water treatment raises two issues. The first is that the operating costs of the sewage plant are increased. While some processes could produce a revenue from selling nutrient rich sludge for use as fertiliser or by recycling to phosphorus to phosphate manufacturers, this is not currently profitable (Driver et al., 1999). Therefore, the finance must be raised either from public sources or through water charges. This will explain the delay in implementing the EU directive in some cases. However, the costs have not prevented countries such as Germany and Switzerland from installing many phosphate removal plants, so the costs are probably not a major barrier where eutrophication is perceived to be a serious problem.

The second issue is that phosphorus removal using the current commercial processes results in the production of phosphorus rich sludge, which must then be disposed of. The simplest solution is to use the sludge as fertiliser, but there are further problems. If the EU directive is implemented fully, there will be more sludge produced than is required for agriculture. Furthermore, most sludge will be produced in urban areas and would have to be distributed to the agricultural areas. This would involve large transportation costs.

There is also a concern that the sludge would also contain a high proportion of heavy metals, which would also be of concern if their use in fertilisers increased the metal concentration in the food chain. The recovery of phosphorus for use by industry, where the metal concentrations are much lower than the raw materials sources now available could solve these problems, but the cost of recycling phosphorus in the quantities required by industrial producers is still much higher than the cost of the raw material. However, if phosphorus has to be removed and the use of sludge is restricted, this may become the most effective solution.

A further possibility is to dry and incinerate the sludge, but this requires careful control over the combustion products, which is potentially difficult because of the large number of different chemicals and constituents of the sludge and therefore expensive if further pollution is to be avoided, as well as the handling of solid by-products. Of concern are the heavy metals, mercury, dioxins and furans, acid gases, as well as NOx and N2O (Werther and Ogada, 1999). Another possible use is to dry the sludge and use it for construction materials. In Tokyo, it is used for pavement construction (Guardian, 1998).

4.1.3 Voluntary agreements between governments and industry

There are several voluntary agreements to limit the use of phosphates in detergents by the detergent industry. In some countries such as Germany and Italy, and more recently Ireland, the voluntary agreement is in effect equivalent to a “ban” of phosphates in household laundry detergents. In most other European countries, and in some EU Accession countries, voluntary agreements are in place limiting detergent phosphate levels to the minimum necessary for phosphates to play an effective role in the detergent. So there is little more that can be achieved here.

4.1.4 Information and ecolabels, education, codes of practice

More information on product content could be provided to the consumer when they purchase detergent products. However, there is no clear message to be put across by such a system, as the phosphate content of detergents is often not a significant contributor to eutrophication. This is reflected by the Scandinavian “White Swan” and EU detergent ecolabels, which allow phosphates to be included (this was confirmed for these ecolabels when the criteria were revised and updated, in both cases in 1999).

Use of detergent phosphates can be reduced by providing accurately sized measuring cups for detergents, while tablets are very effective in that they control the quantity of chemicals for each wash. The main variable then is the amount of washing in the machine. Codes of practice are applicable to the use of manure and fertiliser in agriculture; although currently mainly applied to nitrates, this can reduce over-application of manure and can reduce runoff of phosphate from fertilisers and manure into groundwater.

4.1.5 Recycling phosphates from waste water

A further alternative is to extract the phosphorus from the waste water stream in such a form that it can be reused, either in agriculture as a fertiliser or by phosphate manufacturers as a substitute for the raw material, phosphate rock. Recycling by spreading sludge is the most effective environmental option in many cases (Edge, 1999). However, this possibility may be limited by several factors. Sludge is bulky and therefore has high transport costs, so there must be a demand close to the sewage treatment plant if the economic cost is not to be high.

While this is in general the case in the UK, it is not so in many parts of Europe and the US (Greaves et al., 1999). In some regions where there is a high population density and limited agricultural land, there may be more sludge produced than is suitable for spreading. This has been found to be the case in the Netherlands and in a study in the Lothian region of Scotland (Towers and Horne, 1997). There are also serious concerns about the concentrations of heavy metals in sludge from waste water, to the extent that the European commission has proposed much stricter controls on the composition of sludge used for spreading (CEC, 2000).

The other route is to extract phosphorus from waste water streams in a form suitable for reuse by industry for phosphate or fertiliser manufacture. There are two techniques currently under development: crystallisation of calcium or magnesium phosphate and precipitation of struvite crystals (magnesium/potassium ammonium phosphate). Full scale pilot plants are already running using these process routes in Holland, Italy and Japan. Other technological approaches are also being investigated including ion exchange, membranes, sludge fractioning and biological pathways.

The technology for production of struvite from manure is also being developed (Schuiling and Andrade, 1999). The problem here is one of economic incentives: the manufacturers would have to change their production systems to accept the recycled phosphorus thus incurring extra costs. Given current phosphate rock prices and the reasonable availability of the raw material in at least the short term, recycled phosphorus would be more expensive than the raw material, so some form of regulation or subsidy would be required to create a market for recycled phosphorus. Driver et al. (1999) consider that these techniques will become more widely used when more phosphorus removal systems are installed in sewage works and the problem of what to do with the phosphorus becomes more acute.

4.2 Consumer reactions and trends in phosphate use

Laundry detergents are an essential consumption item, that is used very regularly and purchased frequently. The emergence of eutrophication as an environmental issue together with increased consumer awareness of environmental issues was capitalised upon by certain companies in the 80’s and early 90’s to carry out extensive and aggressive anti-phosphate advertising campaigns for phosphate free detergent brands, increasing the perception of phosphates in detergents as environmentally damaging.

In some countries, this led to phosphates in detergents being banned while in Denmark, Germany and the Netherlands, the importance placed by consumers on environmental issues destroyed the market for detergents containing STPP.

In countries such as France and the UK, there is also a widespread opinion that phosphates are bad for the environment. Since the detergent market is very competitive and marketing oriented, the consequence of this has been that detergent manufacturers have reduced the use of STPP in detergents. In France, detergents contained 24% STPP on average in 1985 which was reduced to 10% in 1998.

The introduction of ‘eco-friendly’ detergent brands in response to this perception was a temporary phenomenon, as the major manufacturers changed their main products to use less STPP anyway (Key Note, 1997).

The consumer choice literature reflects this situation, in which phosphates are mentioned as an environmental issue (Que Choisir, 1999 and Which, 1994; Which, 1999). Both Which articles indicate the presence of STPP in the detergents under test and mention that phosphates can cause an environmental problem, but that fertilisers are more important.

To summarise; in Europe, the USA, Japan and other countries where the environment is a major issue, the use of STPP in detergents has either been stopped or has fallen very considerably and is continuing to be reduced. In other countries such as Russia, China and Latin America, where there are also potentially large consumer markets, the use of detergents is increasing generally and there is little tendency to try and minimise the use of STPP.

5. Ecotaxation of detergent phosphates and other economic instruments

The modern trend in environmental policy has been to move towards the use of ‘economic instruments’. There are two main types of economic instruments: taxes/subsidies and tradeable permit systems.

These types of measures have long been proposed by economists, because under suitable conditions they offer the possibility of taking the costs of pollution abatement into account as well as the pollution reduction and therefore being economically efficient without requiring complicated and expensive administration, in particular taxes and permit trading. The idea is that if there are external costs to society imposed by some activity, such as the use of detergents, then the user of the detergent should face costs that reflect the external costs. In order to set an economically optimal level of permitted pollution by regulation, it is necessary to know the costs to the polluter of meeting the permitted level.

Such information is often not available. Economic instruments do not require detailed knowledge of each polluter’s costs, they use market mechanisms to provide incentives for polluters to reduce pollution at minimum cost to themselves. Thus if a tax is levied on e.g. household detergents by the weight, this provides an incentive for households to use less detergent. They would then in the long run start to prefer washing machines etc. that use less detergent and the industry would change their designs to meet the changed demand.

This does not require detailed knowledge of costs by the lawmaking body, but does require some system to collect the taxes. Therefore, taxes are usually most appropriate where there is a tax collection system already in place.

In the case of taxes for externalities, this is known as a ‘Pigovian’ tax. If the costs to society of the externality and the costs to the user of reducing production or consumption of the polluting activity or good are known, it is possible to calculate a tax that, at equilibrium, equates the marginal external cost and the abatement cost. This is then an optimum position for the society.

The advantage is that the tax provides an economic incentive for polluters to change their behaviour and each individual polluter can choose their level of abatement and hence the amount of tax they pay. Thus it is easy to take account of differences in abatement costs between different polluters. Under a system of regulation, in order to achieve the same level of economic efficiency where polluters have differing abatement costs, each polluter must be regulated separately, leading to large administration costs. In the context of eutrophication, a national tax has the disadvantage that it does not allow for the difference in requirements for the reduction of phosphates between basins, so the effects may be insignificant or appropriate in some areas.

The only example of a tax on detergents is the French TGAP, discussed below. Taxation of polluting activities is much more common, both in Europe and in other OECD countries. Ekins (1999) surveys European environmental taxes. Belgium and the Netherlands have introduced surplus manure charges, which are based on the emissions of phosphorus and/or nitrogen in excess of the environmentally acceptable manure loads per hectare. Norway, Sweden and the USA have introduced fertiliser charges which are taxes on products rather than taxes directly related to the pollution caused.

5.1 Criteria for the design of ecotaxes and their application to detergents

The fundamental principle of ecotax design is that it should provide an incentive for the polluter to change their behaviour in a way that reduces the undesirable or polluting activity. It should address the problem at hand, in this case eutrophication. If a tax is to achieve some desired level of pollution abatement, the first criterion is that it should be set at a level which will provide the requisite economic incentives for the polluters to change their behaviour. It will rarely be practicable to achieve a first best optimum in simple economic terms, because the details of abatement costs for all polluters will not usually be known by the regulator. Smith (1997) considers environmental tax design.

There is a trade-off between low administrative costs and the effective targeting of a tax. Usually, a more effective tax requires more measurement or more complex charging schedules. Another factor is the use of the revenues generated by a tax. The revenues may be designated for use in the same area from which the tax is raised (known as earmarking) e.g. paying for the installation of water treatment or they may be used to reduce other taxes such as employment taxes to improve the overall efficiency of the taxation system. Smith (1997) argues that the earmarking of tax revenues does not have an economic justification, but is used to make the introduction of a tax more acceptable.

Efficiency may also be dependent on the assignment of control over the tax. An environment department is more likely to set a socially optimal level of tax compared to a finance ministry which is concerned with raising revenues. However, the revenues should be assigned to a ministry where environmental taxes generate a small part of the total. This avoids the tendency to use environmental taxes as the main generator of funds for environmental programmes and thus for the tax levels to bet set artificially high.

In the case of detergents, the polluter is the consumer, either household or industrial. Given that the environmental costs are borne through eutrophication, the policy objective should be to reduce the nutrient loading into surface waters where cyanobacterial blooms and algae are a problem. Where the nutrient in question is phosphorus, the main sources of phosphorus should be identified and then policies put in place to reduce the phosphate loading. This makes the use of a national tax on detergents containing phosphates problematic for several reasons.

A national tax takes no account of local variations, so a large proportion of taxpayers will be facing extra costs for no environmental gain. In many areas, the main phosphate loading will come from agricultural sources, so a detergent tax does not address the problem. Even if the main problem comes from urban waste water, since detergents contribute a small proportion of phosphates, a reduction in detergent use will not prevent eutrophication in most cases. It should also be noted that demand for detergents is relatively inelastic; consumers will always wish to wash clothes and will not be very sensitive to changes in detergent prices.

Household expenditure on detergents is also a small proportion of expenditure: EUROSTAT (1992, 1993) shows that expenditure on all cleaning and maintenance products is between 0.5% and 1.5% on average in most EU countries, so a significant increase in price of detergents is unlikely to cause consumers to use much less. Therefore, an extremely high rate of tax on phosphate detergents would be necessary to have any significant impact on the incidence of cyanobacterial blooms and algae.

The impact of a tax on all detergents compared to a tax on phosphate detergents

There are several issues associated with tax differentials between phosphate and non-phosphate detergents. A tax on all detergents partially loses the fundamental point mentioned above of addressing the environmental problem, as non-phosphate detergents do not influence eutrophication. In terms of more general environmental objectives, Landbank (1994, 1995) find that there is no significant difference between the life cycle environmental impact of phosphate and non-phosphate detergents.

So if the policy concern is the environmental impact of detergents in general, a tax on all detergents is logically consistent. If a tax is introduced which differentiates strongly between phosphate and non-phosphate detergents by having a much higher rate of tax on phosphate formulations, then there will be a substitution effect. Non-phosphate detergents are a close substitute for phosphate detergents in the consumer market, since they wash reasonably well under household conditions, so consumers will switch from phosphate to non-phosphate formulations to some extent.

This would have the following impacts: there would be little reduction in overall detergent use (assuming non-phosphate detergents were not taxed heavily), there would be a reduction in phosphate loading in waste water (depending on the relative significance of detergent phosphates) and there would be a large reduction in the revenues from the tax, as consumers switched to the low tax non-phosphate formulations.

The conclusion here is that in overall environmental terms, given that there is little difference between the phosphate and non-phosphate detergents, there is not much point in taxing just phosphate detergents as opposed to all detergents. If there is a significant difference in tax levels or only a tax on phosphate detergents, there will be a reduction in demand for phosphate detergents.

A further consideration, applicable to fiscal policy in general, is welfare or social equity. In most European countries, it is felt that fiscal policy should work to reduce the difference in incomes or expenditures on basic goods across the society. This implies that a tax on consumer expenditure should be borne at least equally by the better off social groups, or that there should be some form of compensation for poorer social groups.

5.2 The French TGAP

The one example of a tax specifically on phosphates in household detergents is the French ‘Taxe Générale sur les Activités Polluantes (TGAP)’, which came into force in January 2000. The TGAP contains several different taxes on various activities which are seen as polluting. These include: activities modifying water movement and flow, gravel extraction, industrial outputs of heated water and radioactivity, pesticides (but not fertilisers) and laundry detergents.

The stated objective of the TGAP is to reduce polluting activities through an improved application of the polluter pays principle and the raising of revenues to finance the 35 hour week and hence employment (CFEGP, 1999). The TGAP is also presented as having the objective of modifying consumer behaviour. The part of the tax applied to detergents is levied on the sales price to the consumer as follows (FMF, 2000):

Detergents with:	
less than 5% STPP	470 FF/tonne
5-30% STPP	520 FF/tonne
more than 30% STPP	570 FF/tonne

This represents 2.35-2.85 FF for a 1 kilo standard detergent packet, which is approximately between 2-3% of the sale price for concentrated powders and 10% for the cheaper powders. The expected revenue for the first year is 500 million FF, out of a total of 4 billion FF for the TGAP. Applying the criteria for efficient taxes outlined above, it can be seen that the TGAP detergent tax does apply directly to the issue of concern i.e. the presence of detergents in urban waste water. Furthermore, the collection of the tax will be relatively simple, because the systems in place for VAT on consumer products can be used. The final rates that have been applied are such that there will probably be a slight reduction in detergent use, because detergents have a low elasticity of demand i.e. sales volumes are not very sensitive to changes in price. The variation in rates of 0.5 FF or between 0.4% and 2% per packet is probably so small that any consequent reduction in sales in not detectable. These price variations are certainly much smaller than price differences between different products and promotions etc.

Assessment of the TGAP on detergents

Applying the criteria outlined above, the TGAP has a few positive aspects. Because the use of phosphates in detergents is taxed, it does address eutrophication directly. Since the revenues are intended to reduce employment costs, it improves the general economic efficiency of the tax system. It is also reasonably effective in political terms: it appears to address eutrophication, but is small enough not to impose large additional costs on the consumer. Because all detergents are taxed at approximately the same level, there will probably be no large extra switch away from detergents with STPP, so the one remaining STPP manufacturer in France will probably continue production.

However, it will not achieve its environmental aims of reducing cyanobacterial blooms and algae in surface waters. As discussed above, STPP is a small part of the phosphate load and so this marginal additional load will only be significant in a small number of cases. As the change in detergent use due to this tax will be small, the change in STPP input into urban waste water will also be small. Detergent STPP forms 9-50% of the phosphate input to waste water and a maximum 25% of the input to rivers, lakes and reservoirs. Assuming the maximum of the range, 50%, if there is a 5% reduction in detergent use, then there would be a 2.5% reduction in STPP input into waste water and a 1.25% reduction in phosphate input to surface waters as a maximum where phosphate loading was dominated by urban waste water. Even for waters sensitive to the phosphate load, this is very unlikely to have any great effect on the growth of cyanobacterial blooms. Given the large proportion of nutrient input from agriculture in many areas, it is necessary to address these inputs in order to have any significant impact.

The result of the political process has been a tax on all detergents at more or less the same level. In so far as the alternative detergent formulations excluding STPP also have undesirable environmental consequences, the slight differentiation between STPP and non-STPP detergents is desirable in terms of the overall environmental impact of the tax. Given that the life cycle analyses (Landbank, 1994 and 1995; EMPA, 1999) do not find much difference in environmental impact between STPP detergents and the zeolite/PCA alternative, this is reasonable. However, it is not clear that the environmental impact of zeolites is addressed by the tax and this was not stated as an objective of the TGAP.

With regards to social equity, the TGAP on detergents applies to all purchases equally. This means that households which wash more, especially large families, will have a higher increase in expenditure. Since low income groups tend to have larger families and the elasticity of expenditure is low, the tax will effect poorer social groups more and is therefore inequitable. This impact is partly offset by the financing of the 35 hour week, which will benefit households where one or more members are in employment. Poor households which are not in employment, or which do not see a reduction in working hours, will face the largest impact. EUROSTAT (1992) shows that the overall average household expenditure on cleaning and maintenance products is 0.88% of total expenditure. The poorest two deciles spend 1.09% and 1.13% of their budgets on this, while the top quartile spends 0.74%. Therefore, it can be concluded that although the tax is inequitable, the effect is slight.

The overall conclusion is that the TGAP on detergents will not be successful at addressing the environmental problem of cyanobacterial blooms and algae, although it will slightly improve the overall efficiency of the tax system. The impact on social equity is small. It will not change consumer behaviour. Taxing all detergents rather than only those with STPP has no significant environmental implications and will maintain a place for STPP formulations in the French detergent market.

5.3 Tradeable permits

Tradeable permit systems operate by issuing a series of permits to engage in a polluting activity. These permits can then be traded on a market, so that polluters with low abatement costs can sell extra permits and polluters with high abatement costs can buy permits. This has several advantages. In particular, with modern IT systems, it is cheap to administer. As with taxes, it allows polluters to optimise their behaviour, without requiring information about each individual polluter. In realistic conditions of limited information about the costs of the different polluters, it provides a simple method of determining how much emissions there will be, because this is set by the number of permits that are issued. Tradeable permit systems have not been widely used in environmental policy so far, but there have been highly successful applications to SO2 and CO2 emissions in the U.S. Tradeable permit systems are most suitable for situations in which there are a discrete but significant number of polluters, so that monitoring is relatively straightforward, and there are plenty of actors wishing to trade. Thus it would be relatively simple to introduce such a system for waste water treatment, where there are a large number of discrete facilities. A system for detergent manufacturers would be more difficult to operate, because the industry is very concentrated and there are only a few manufacturing facilities.

Permit trading is useful in that it allows polluters to trade permissions to pollute, so that they can minimise the combined cost of pollution abatement and buying permits. Thus the overall result is that the combination of the level of pollution and the amount spent on pollution abatement is optimal for a chosen level of pollution, which is set by the quantity of permits available. Permit trading has only been used in a few cases, notably in the US for SO2 emissions from power stations, where the cost of abatement has been found to have been much less in the long run than was initially estimated.

Photo : Chevallier
Bourgoin-Jallieu, France

6. Implications for the detergent phosphate industry

6.1 Position in the supply chain and detergent market conditions; competitive position

Phosphates are an intermediate product in the detergent supply chain. The production of STPP is based on phosphorus rock as the raw material from which phosphoric acid is manufactured. The technology also exists to recycle phosphates. Detergent phosphate forms a relatively small part of overall phosphate production: about 10% of phosphate rock are used for detergent phosphates. The fertiliser industry much bigger with about 80% of raw material demand, so the raw material price is determined by conditions in the fertiliser industry. Raw materials are approximately 75% of the selling price of STPP (Driver, 2000). STPP is sold to detergent manufacturers and detergents are sold through retail outlets, mainly grocery stores/supermarkets.

The consumer detergent market is very concentrated, both in retail and in supply. In 1998, Proctor & Gamble and Unilever had over 75% of the UK powder detergent market (Key Note, 1999). The retail market is large, expenditure on fabric cleaning products in the UK was £1.18 billion in 1998 with a further £98 million on machine dishwashing products (Key Note, 1999). It is mature; overall demand is roughly constant, although there is a slow long term decline in volumes in Europe. This is due to fewer people being employed in manual labour and improved performance of detergents. Required quantities have decreased from 200g detergent/wash to 70-80g/wash, with lower washing temperatures, shorter wash cycles and a lower water use. Therefore, competition is intense with the manufacturers spending heavily on advertising (£76.8 million for fabric detergents in 1998, Key Note (1999)) and innovation in new products such as ‘compact’ powders and tablets.

STPP is particularly suitable for use in both of these new types of product, so some increase in the use of STPP as these product types develop can be expected. The lifetime of a detergent formulation is only of the order of 1 year (Driver, 2000). The market for dishwasher detergents, in which STPP is usually used as the builder, is expanding but was only 22% of the laundry detergent market in 1998 (Key Note, 1999).

The competitive position of STPP manufacturers can be summarised as follows: there is a readily available substitute for the product in zeolite plus the required additional compounds. There is overcapacity in zeolite production, so zeolite prices are relatively low (Gomez, 2000). Since detergent production is highly concentrated and there is a substitute available for phosphates and formulations are changed frequently, market power is in the hands of the detergent manufacturers. Because the detergent retail sector is competitive, margins for the detergent manufacturers are low and because they have market power in buying the intermediate products, margins for STPP manufacturers are also low. There is however, little competition in STPP production from manufacturers outside Europe because of poor quality of STPP from certain non EU producers and because the product does not travel well.

6.2 Structure of the detergent phosphate industry

The STPP industry is also heavily internationally concentrated, with the main manufacturers being part of international industrial chemical companies (CFEGP, 1999). There is also overcapacity in the European phosphate industry. After STPP was introduced by Proctor and Gamble in 1948, the market and production increased rapidly until most countries had at least one manufacturer. The issue of eutrophication and the subsequent bans and restrictions then caused a rapid decline in the industry, with many plants being closed up to 1992 (Driver, 2000). This led to consolidation of the industry into five producers in Europe. Two of the largest companies have recently been combined; Rhodia took over Albright and Wilson plc. and now has roughly 50% of the European manufacturing capacity (Gomez, 2000).

The concentration has been associated with cutbacks in capacity, the latest of which is that Rhodia UK recently announced the closure of 2 of the 3 UK STPP plants with 300 redundancies. The reduction of 140,000T of effective capacity will mean that plants in Europe will improve from operating at 50-55% capacity to over 80% capacity (Chem Eng News, 2000). CFEGP (1999) estimates the turnover of the sole STPP plant in France at 350Mn FF/year, with 150 employees (Gomez, 2000).

Internationally, there are detergent markets which might expand. China is the best example, but there is plenty of recently installed manufacturing capacity. There is a relatively low level of detergent consumption in Russia and Eastern Europe and little use of zeolites as a builder so there is potential for growth there (Gomez, 2000). Latin America and South East Asia are also potential markets, although as STPP and powder detergents are quite difficult to transport, it is more probable that local manufacturing plants will be constructed.

7. Possible future policies for phosphates

Having surveyed the use of STPP in laundry detergents, the environmental issues and the current state of the markets, the possibilities for the future course of environmental policy for phosphates can now be considered. The most recent available evidence demonstrates that eutrophication is still a problem in many parts of the EU, in spite of a considerable history of policy measures over the last 25 years. EEA (1998a) found that only 10% of 1000 river measurement sites across Europe had phosphorus concentrations below 50 g/l (the natural background maximum). It has been found that the cyanobacterial blooms may be extremely stable, especially in shallow waters, so that reduction of phosphorus input alone will not restore the waters (Hosper, 1998). There have been some successes.

For example in Lake Veluwe, the Netherlands, the installation of phosphate removal in the sewage works discharging into the lake in 1979 and additional flushing in 1985 enabled the lake to recover by the early 1990s, 10 years after the reduction in nutrient loading (van der Molen et al., 1998). The Swiss policy of waste water treatment has also had some success in reducing the incidence of cyanobacterial blooms and algae, in particular in Lakes Geneva and Neuchatel (Lang and Reymond, 1996). EEA (1998b) shows that mean phosphorus concentrations in European rivers generally decreased between 1987-91 and 1992-96 in Western Europe and in some countries of eastern Europe. However, there are still many sites with very high phosphate concentrations. EEA (1998b) also states that reductions in phosphorus loading from sewage works now need to be followed by reductions in loading from agriculture, as this is now relatively more important.

7.1 Objectives of future policies on phosphates

The conclusion to be drawn from the above summary is that action on phosphates will remain on the policy agenda in the EU. The objectives of future policy should be twofold:

1. to continue monitoring the extent of cyanobacterial blooms and algae in surface and coastal waters and identify the nutrient loadings that are supporting the growth of cyanobacterial blooms;
2. given that phosphate loading is the determining factor in many cases, to achieve large reductions in phosphate inputs to surface waters where eutrophication is a problem.

7.2 Applicable environmental policies and their economic implications

Reduction in the contribution from detergent STPP (the secondary source of phosphorus in sewage) has a marginal effect on the overall phosphate loading and will have no effect on eutrophication in many cases. If a particular ecosystem is nutrient limited by phosphorus and point sources form the majority of the phosphorus input, a reduction in the loading will have some effect in reducing the extent of cyanobacterial blooms and could conceivably induce a shift in the ecosystem balance which removes blooms as a serious problem. However, this is only true for a small range of conditions. It is much more likely that only a large reduction in phosphorus loading will achieve conditions in which blooms disappear. This is extremely hard to predict, not least because the response time of the ecosystems appears to be of the order of 10 years (van der Molen et al., 1998). The EU Urban Waste Water Directive is therefore an appropriate response to this problem, in that it specifies conditions under which action has to be taken and provides a basis for installing waste water treatment which can drastically reduce phosphate loading.

The implication of these considerations is that waste water treatment should become more widespread and therefore government policy needs to be directed towards dealing with either increased sludge production and disposal via spreading, incineration or other uses or phosphate recycling. Markets for sludge or recycled phosphorus do not currently exist and the economics are still uncertain. Therefore policy should be directed to creating markets on a small scale, so that the technology and market structures can be developed. It is necessary to give phosphate manufacturers and the fertiliser industry an incentive to invest in new equipment to accept recycled phosphate instead of the raw material or phosphoric acid i.e. to create a demand for recycled phosphorus.

Given the uncertainties and variations in local conditions, in particular the transport costs of sludge and the varying demand from potential customers close to sewage works, all the different possibilities should be encouraged. This will enable the most economically efficient methods to be selected in each local area.

7.3 Taxation of domestic phosphate products

Since there is a legislative framework in place requiring phosphorus removal from the waste water stream, there is little benefit in environmental terms in having a general tax on detergent phosphates. The only significant point of such a tax would be to raise revenues for the government. Thus the French TGAP is only partially successful, because it is intended to provide finance for the 35 hour week in France (CFEGP, 1999). It will not contribute towards achieving its stated environmental objectives. The introduction of taxes on detergent phosphates in particular will probably accelerate the decline of STPP manufacture in Europe.

The increase in costs might well cause detergent manufacturers to switch to zeolites, which are both readily available and cheap. Furthermore, detergent manufacturers are consolidating production over the whole of Europe. If they are only running a single manufacturing facility, the requirement to sell into markets where STPP products are not sold will strengthen the tendency to cease using STPP in their detergent formulations (Driver, 2000). While STPP does not employ a very large number of people, because production is very concentrated in large facilities, closing plants has significant effects on the local economy, as can be seen in the case of the Rhodia UK plant at Whitehaven UK, with 300 redundancies in an already economically depressed region.

7.4 Policies for diffuse sources

A detailed examination of diffuse sources of phosphorus loading in surface waters is outside the scope of this paper. However, it is now generally accepted that diffuse sources from agriculture form the most important part of phosphorus loading in many inland surface waters. Since phosphate removal from diffuse sources is impracticable, the approach to controlling these sources has to be one of managing the initial use of fertilisers and the careful use and/or disposal of manure (Parr et al., 1999). Policy can provide incentives by taxing excess fertiliser and manure use, as in Belgium and the Netherlands (Ekins, 1999). A further possibility would be to recycle phosphate from animal manure, which could become economically attractive in areas of intensive livestock production (Greaves et al., 1999). There is a potential synergy with waste water treatment here: if a market for recycled phosphorus from waste water treatment plants is developed, it would be much easier for farms to locate a demand for their recycled phosphorus. Parr et al. (1999) also make the point that since the main problem stems from intensive livestock farming, policies to encourage mixed farming will also reduce the incidence of high phosphorus loading.

8. Summary and Conclusions

The reason that the use of phosphates in detergents remains an issue is that there is a continuing problem with eutrophication, which is the nutrient enrichment of water, and which can lead to the growth of algae and cyanobacterial blooms in European surface waters. These are unsightly, often have an unpleasant odour and can be toxic. These growths are caused by inputs of nutrients, phosphorus and/or nitrogen, into surface water ecosystems that are far higher than the natural level. The main sources of phosphorus in Western Europe are animal manure and fertilisers used in intensive livestock agriculture and human waste in urban waste water. Phosphates used in domestic laundry detergents may make a significant contribution to the phosphate content of urban waste water in some areas.

Phosphates and STPP in particular perform a vital function in modern synthetic detergents, although there are substitutes, of which the most successful is zeolite combined with polycarboxylate. Life cycle analyses suggest that there is little to choose between STPP and zeolite-polycarboxylate formulations in terms of their environmental impact, but STPP remains the most effective ‘builder’ in laundry detergents.

In order to control eutrophication, many countries have acted to control the use of STPP in laundry detergents. These policies have ranged from outright bans in Switzerland and Austria and an almost complete ban in Italy through voluntary agreements with industry in Germany and the Netherlands to taxation of detergent purchases in France. Particularly as a result of extensive and aggressive advertising campaigns by certain “phosphate-free” brands of detergents in the 1980’s, the consumer has often perceived the use of phosphates as environmentally damaging, resulting in the abandonment of STPP detergent formulations in Germany, the Netherlands and Denmark. The response of industry to these changing market conditions has been quite dramatic, because of the highly competitive nature of the detergent industry and the importance of product image and marketing. Laundry detergent formulations using STPP are no longer sold in Germany, Italy, Switzerland, Austria and Norway in Europe, as well as the US and Japan. The amount of STPP in laundry detergents has been reduced significantly in other European countries; for example in France detergents contained 24% STPP in 1985 which was reduced to 10% in 1998.

These policies have formed part of a policy package, of which the other main element has been the installation of equipment to remove phosphorus from urban waste water. This has the potential to be a much more effective approach in reducing phosphorus loadings, because it is possible to remove more than 90% of all phosphate in the waste water stream and detergent phosphates form less than half of the total phosphorus input to urban waste waters. Under the umbrella EU Urban Waste Water Treatment Directive, countries such as Germany and the Netherlands have installed phosphorus stripping equipment extensively. Sweden also has a comprehensive system of sewage treatment.

These policies have been partially effective so far. Phosphate loading has been reduced in many surface waters that were heavily polluted, such as the Rhine and the extent of cyanobacterial blooms and algae has been reduced. However, experience in the Netherlands shows that it can take 10 years or more for surface waters to recover the ecosystem balance that existed before eutrophication. There are factors that can make the eutrophic state very stable; flushing of lakes to prevent release of phosphorus from sediments may also be required. A further complicating factor is that there is no simple linear relationship between phosphate loading and the growth of cyanobacterial blooms. It is now generally accepted that a large reduction in phosphorus loading can enable surface waters to recover from cyanobacterial blooms and algae, but each site has to be considered individually. Therefore, the continuing investment in phosphorus removal in sewage plants will eventually control eutrophication in many instances, in particular where the main loading comes from urban waste water. Countries such as Italy, where cyanobacterial blooms and algae are still a major problem and there are relatively few phosphorus removal installations will benefit considerably from these policies.

As the policies for urban waste water treatment have been put in place, attention has increasingly turned to diffuse sources of nutrients, manure and agricultural fertiliser. Here, the policy problem is more complex, because it is not possible to remove phosphorus at a few point sources. Therefore, policy has to be directed at good farming practice in the use of fertilisers and manure, with possibly taxation of fertilisers to discourage their use.

Future policy should be based on local responses to local problems within an overall legal framework, a point insufficiently emphasised in the current literature, but highlighted in the new EU directive on water treatment. Continuing investment in phosphate removal at sewage plants is the first part of a policy to control eutrophication. The next step, which is much more difficult, is to control phosphorus loading from agriculture. Then there is the question of what to do with the phosphorus when it has been removed. Phosphorus removal in sewage plants produces sludge, which must be used or disposed of. As it has high transport costs, the most economic option is to use the sludge as fertiliser in the area surrounding the sewage treatment plant. However, if there is already a problem with phosphorus loading from agriculture, and in many cases because of increasing concerns about sewage sludge use relating to metal, chemical, pathogen content or other issues, this will not be practicable.

There are several alternatives. The simplest is to dry and incinerate the sludge, but this requires careful treatment to control combustion products. There are alternative uses, such as drying and using for building materials or paving slabs, as has been practised in Japan. A further possibility is to recover and recycle the phosphorus in a form useable by the phosphate industry or as fertiliser. All these alternatives require investment in some degree. Recycling has the additional complication that phosphate manufacturers would have to alter their production organisation to accept the recycled phosphorus instead of phosphate rock, although since the rock has quite a high heavy metal content, the production process could probably be made cheaper.

Since phosphate removal will become more widespread, this problem will have to be addressed. For now, recycling technology is being developed and is close to being applicable on an industrial scale. Therefore, policy should encourage the formation of markets for sludge or recycled phosphate products. There are many ways in which this could be achieved: by voluntary agreement with water companies, phosphate manufacturers and agricultural businesses; by legislation to require the removal and disposal of phosphorus and the associated by-products or by taxation on point and diffuse sources of phosphorus.

Finally, what are the implications for detergent phosphates and the STPP manufacturers? Demand for the various consumer products is predicted to be roughly constant in the short to medium term i.e. the next 10 years, say. If policy on phosphorus follows the course outlined above, there is no reason why STPP should not remain an important part of detergent formulations. Indeed, with the widespread introduction of phosphorus removal, STPP formulations could be reintroduced in the countries where they have been replaced by zeolite. Sweden has comprehensive phosphorus removal systems and therefore permits the unrestricted use of STPP in detergents. They could be marketed as an environmentally friendly alternative, as zeolites produce more sludge and do not have the possibilities for recycling and reuse that phosphates have. There remains considerable overcapacity in STPP manufacturer, so it is probable that some plants will close in the next few years, even with the recent consolidation of Rhodia and Albright & Wilson. The overall conclusion, therefore, is that STPP manufacture can remain a relatively small, but significant activity for the chemical industry for the foreseeable future and that effective policies to control eutrophication are entirely compatible with the continued or even expanded use of STPP in laundry detergents. There is continuous innovation in new products such as ‘compact’ powders and tablets. STPP is particularly suitable for use in both of these new types of product, so some increase in the use of STPP as these product types develop can be expected.

In terms of policies for detergent phosphates, any further controls by regulation or taxation would be very unlikely to influence the extent of cyanobacterial blooms and algae. Since each local problem has to be resolved by regional action, policies such as a general tax on detergents are not relevant as environmental policies.

Photo : Chevallier
Bourgoin-Jallieu, France

9. References

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Photo : Thermphos

STPP (sodium tri poly phosphate) ready for detergent production.