February 2011
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Environmental protection

Zero-phosphate detergents

A recent WRC-funded study investigated the positive and negative consequences of introducing zero-phosphate detergents into South Africa.

Eutrophication: Role of phosphorus in detergents

There is growing awareness of the role that phosphate contained in powdered laundry detergents plays in the eutrophication of water resources. The introduction of zero-phosphate (zero-PO_4) detergents into the South African market is, therefore, under consideration as an alternative means of controlling eutrophication, especially in view of the apparent failure of the legislated 1 mg/ℓ effluent phosphate concentration standard to control this problem. However, before considering this option, the positive and negative consequences associated with introducing zero-PO_4 detergents have had to be carefully investigated.

The phosphate 'builder component' used in detergents takes the form of pentasodium tri-polyphosphate (STPP), which acts to soften hard water by complexing calcium, ferric and magnesium ions. It also assists in the cleaning process by buffering the pH of the washing solution, preventing rust and corrosion and keeping dirt particles in suspension. STPP, in the presence of water, is easily hydrolysed to bioavailable orthophosphate (PO_4), an important nutrient which, when released into the aquatic environment, contributes to eutrophication in rivers and reservoirs.

Besides the builder component, the element phosphorus (P) is contained also in other components of detergents, such as the fluorescers and optical brighteners. Since there is no known substitute for phosphorus in these components, however, they cannot be removed from formulations. Only the phosphorus contained in the phosphate STPP builder component can thus be targeted for removal.

Investigating consequences of zero-PO_4 introduction

The investigation took the form of:

- Reviewing literature on current local and international practice with regards to the use and restriction of phosphates in detergents;
- Estimating the impact detergent phosphates have on the phosphate loading and efficacy of wastewater treatment works (WWTWs) and their ability to meet the 1 mg/ℓ phosphate standard for effluent;
- Estimating the impact detergent phosphates have on the phosphate loading and the frequency and severity of algal blooms in key dams around the country;
- Estimating the cost savings that may occur at water treatment works (WTWs) and at WWTWs if detergent phosphate were to be eliminated
- Conducting a cost benefit analysis of the introduction of zero-PO_4 detergents across all sectors; and,
- Assessing the impacts of the introduction of zero-PO_4 detergents on the Waste Discharge Charge System.

Data for the investigations were sourced from detergent market statistics, WWTW and WTW records and water quality records. Predictions relating to phosphate loading, algal growth and eutrophication in key dams were made with the help of internationally recognised models and were further based on water quality data and phosphate export coefficients developed for each study catchment. Estimates of costs and benefits to society at large were based on data and information sourced mainly through interviews and from literature.

International regulation of detergent P

Regulation of detergent phosphate was found to be a

widely practised method of addressing eutrophication problems, with many countries in Europe and many states in the USA either banning phosphate in detergents or introducing concentration limits. Many countries and states have undertaken this voluntarily without a legislative requirement.

Detergent P loading on WWTWs

Information gathered mainly but not exclusively from the Darvill WWTW in Pietermatitzburg suggests that the impact of detergent phosphorus on WWTWs' phosphate loading varies significantly between facilities, depending on the contribution made by industrial sources in the WWTW's catchment. In facilities treating predominantly residential sewage, the reduction in total P loading may be as high as 33%. In the event of the detergent component of total P loading being eliminated, a reduction in costs associated with the removal of phosphates is thus possible.

Should the WWTWs continue to strictly target the 1 mg/ℓ standard, the cost reduction would be equivalent to the cost of aluminium sulphate (alum) used for surplus phosphate removal. At the Darvill WWTW this could amount to a saving of R2 million per year. Saving on alum would, however, not pass the benefit of the phosphate loading reduction on to the wider environment. For this to happen, the treatment process ought to remain unchanged, producing a reduction in the effluent concentration by the equivalent of the detergent phosphate contribution. In this way, the more substantial environmental benefits could be realised.

Detergent P loading on dams

The proportion of overall phosphorus loading of dams attributable to detergent PO_4 varied according to the extent of residential land-use in the catchment. Dams with small catchments but high urban land-use show the highest proportions of detergent based phosphorus loading. Phosporus export associated with urban residential areas serviced by relatively efficient WWTWs amounted to about 5 kg/ha.annum^{-1}. Smaller WWTWs are generally less efficient in phosphate removal and will consequently exhibit higher export values.

Contributions to the total phosphorus loading of 24 key dams attributable to detergent PO_4 ranged from 3.2% to 29.3%. The 5 dams found to be most affected were: Roodeplaat – 29.3%; Laing – 28.3%; Hartbeespoort – 28%; Inanda – 28%; and Klipvoor – 26.9%.

Impact of detergent PO_4 elimination on water quality and eutrophication in dams

Model predictions of the reduction of in-dam total P concentration due to the elimination of detergent PO_4 ranged between 3% and 35%. Dams that benefited most were: Inanda – 35%; Roodeplaat – 27%; Laing – 26%; Hartbeespoort – 26%; Shongweni – 26%; and Klipvoor – 25%. The summed reduction for all the 24 priority dams investigated was 11-12%. Corresponding reductions of chlorophyll 'a' concentrations were estimated to range between 2.5% and 30%. Dams that benefited most were: Inanda, 30%; Roodeplaat, 23%; Laing, 23%; Hartbeespoort, 22%, Shongweni, 22%; and Klipvoor 21%. The summed reduction for all the 24 priority dams investigated was 12%.

Impact of zero-PO_4 detergents on water treatment

Based on the modelling of reduced algal concentrations attributable to zero-PO_4 detergents, a total predicted saving of R616 134 per year was estimated for treating water from Hartbeestpoort, Roodeplaat and Klipvoor Dams. This is likely to be conservative estimate of total treatment costs associated with eutrophic water. Projected eutrophication levels in South Africa suggest that treatment costs, although currently relatively small, may be significantly affected by eutrophication in the future.

Cost-benefit analysis

It was not possible to consistently assign monetary values to costs and benefits of introducing zero-phosphate detergents. For this reason, a qualitative assessment of issues within each sector and the summation of cost-benefit products within the sector proved to be the most appropriate approach for gaining an indication of the overall (positive or negligible) impact of zero-phosphate detergents on that sector. Assessed impacts for sectors were as follows:

Positive impacts:

- ***The Environment*** will benefit largely from the significant reduction in phosphorus loading of rivers and dams. This in turn will result in a significant reduction in eutrophication and algal growth. This is anticipated to have benefits for biodiversity conservation, aesthetic and amenity value of water bodies and human and livestock health.

- ***WTWs*** will benefit by being required to spend less on purification chemicals, and by experiencing fewer filter blockages as a result of lower levels of algal growth. They will therefore experience greater operational efficiency.
- ***Detergent manufacturers*** will experience a minor benefit by eliminating the rising cost of phosphate from their production expenses.

Negligible impacts:

- **WWTWs** will experience a benefit where the reduced phosphate load may result in less expenditure on treatment chemicals at certain facilities and a reduction in charges paid according to the WDCS, but this will be largely negated by the fact that non-recyclable zeolite may produce greater volumes of sludge which will need to be disposed of.
- ***Consumers*** will experience a benefit where the use of phosphate alternatives will eliminate the increase in cost of detergents that is likely to occur due to rising phosphate costs. However, that benefit may be negated by the possibility of residue occurring on clothing and a limitation of product choice in the event of phosphate- rich detergents being banned.
- ***The Waste Discharge Charge System*** will see neither significant benefit nor cost.

On balance, the introduction of zero-PO_4 detergents is likely to have a net beneficial effect.

In conclusion...

There can be little argument concerning the impact phosphates have on the water resources in South Africa, and given that a large proportion of WWTWs are struggling to meet even the relatively lenient 1 mg/ℓ effluent phosphate concentration limit, the projected reduction in phosphate loading due to introduction of zero-PO_4 detergents is extremely significant.

This is especially true for small WWTWs where phosphate removal is generally inefficient. This reduction in phosphate loading would not only go a long way to assist WWTWs in achieving effluent concentration targets, but it would also help alleviate problems created by the overflow from WWTWs during heavy rains or because of equipment failure, as well as problems in rural settings where detergent phosphates are introduced directly into water courses.

Downstream of WWTWs, the indications are that phosphorus loading on dams could be reduced by as much as 35% through the elimination of detergent phosphates, resulting in an estimated reduction in algal growth of up to 30%. In dams where algal growth gives rise to significant costs (through reductions in biodiversity, loss in dam-side property values, increased water treatment costs and loss of recreational amenity value) reductions of this nature must be regarded as very important in terms of eutrophication control.

It is important to note that the environmental benefits of eliminating phosphate from detergents will only be fully realised if the resulting reduction in WWTWs' influent phosphate loading is translated into a reduction in their effluent loading. This will not necessarily occur at efficient facilities (where the 1 mg/ℓ standard is routinely achieved) should the reduction in treatment costs be exploited whilst continuing to target the 1 mg/ℓ effluent concentration standard.

However, in cases of WWTWs where the 1 mg/ℓ standard is currently not being attained, the benefit will indeed be transferred to the downstream environment in addition to the facility being better able to comply with the legal standard. In the interests of ensuring that potential environmental benefits are fully realised, the time is probably ripe for a comprehensive review of the relevance and implementation of the 1 mg/ℓ phosphate effluent standard.

Clearly, the elimination of phosphate from detergents is both beneficial and desirable, and it is thus recommended that the replacement of phosphate containing detergents with zero-phosphate alternatives should be carried out as soon as is feasible.

It is also recommended that negotiations be entered into between the Department of Water Affairs and detergent manufacturers to establish a mutually acceptable process for this transition to be achieved. It is further important that the change to zero-phosphate detergents be consolidated through legislation.

Further reading:
To obtain the report *Investigation of the Positive and Negative Consequences Associated with the Introduction of Zero-phosphate Detergents into South Africa* (**Report No: TT 446/10**), contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.