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Ecosystem impacts of phosphorus and surfactants in consumer products

Prepared for Stewart Investors

ABOUT THE AUTHORS

The Institute for Sustainable Futures (ISF) is an interdisciplinary research and consulting organisation at the University of Technology Sydney. ISF has been setting global benchmarks since 1997 in helping governments, organisations, businesses and communities achieve change towards sustainable futures. We utilise a unique combination of skills and perspectives to offer long term sustainable solutions that protect and enhance the environment, human wellbeing and social equity.

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DISCLAIMER

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Stewart Investors

Contents

Acronyms and abbreviations

ADD	Automatic dishwasher detergents
AEOs	Alcohol ethoxylates
AISE	International Association for Soaps, Detergents and Maintenance Products
APEOs	Alkylphenol ethoxylates
BAS	Branched alkylbenzene sulphonates
CESIO	European Committee of Organic Surfactants and their Intermediates
ERASM	Environment and Health - Risk Assessment & Management
EU	European Union
GHG	Greenhouse gas
HERA	Human and Environmental Risk Assessment on ingredients of household cleaning products
LAS	Linear alkylbenzene sulfonates
QAC	Quaternary ammonium ethoxylates
RSPO	Roundtable on Sustainable Palm Oil
SLES	Sodium laureth ether sulfates
SLS	Sodium laurel sulfates
STPP	Sodium tripolyphosphate
USA	United States of America
WWTP	Wastewater treatment plants

Executive Summary

Stewart Investors commissioned this research to explore the ecosystem impacts of household and personal care consumer products, including laundry detergents, dishwashing detergents, other cleaning products, shampoo and soap.

The research was undertaken by a multi-disciplinary team from the Institute for Sustainable Futures and the Faculty of Science at the University of Technology Sydney.

The research was initially scoped to focus on **phosphate ingredients**, which can contribute to nutrient pollution resulting in algal blooms and poor water quality. Whilst various regulatory, industry and company initiatives have been adopted to limit phosphate levels in consumer products, this is not universal across all countries and ecosystems continue to be impacted. The study was then extended to examine the potential ecosystem impact of **surfactants**.

This research was exploratory in nature, and it did not aim to quantify specific risks nor to rate or rank individual companies. The inquiry was not limited to nor focussed primarily on the companies in Stewart Investors' investment portfolios. Instead, this report provides a "state of evidence" review and synthesis of a wide range of scientific, regulatory, industry and company information about the potential ecosystem impacts of phosphate and surfactant ingredients from consumer products.

Executive Summary continued

A | PHOSPHORUS

ECOSYSTEM IMPACTS OF NUTRIENT POLLUTION

The discharge of excess phosphorous (and nitrogen) into aquatic ecosystems has significant impacts on ecosystem health and the viability of aquatic life.

Excess nutrient loads can lead to eutrophication, encouraging the production of algae and cyanobacteria which can form algal blooms and lead to mass fish kills. Certain ecosystems, such as shallow freshwater lakes and slow flowing rivers, are particularly vulnerable to nutrient pollution. Particular species such as corals are also vulnerable and take a long time to recover. Ongoing eutrophication can lead to long term impacts on ecosystems that have sometimes irreversible impacts on ecosystem health and biodiversity.

PHOSPHATES IN CONSUMER PRODUCTS

PHOSPHATE COMPOUNDS AND FUNCTIONS

Phosphate compounds in consumer products have various functions including as buffering agents to maintain pH; sequestering agents to soften water; and dispersants. Of the many types of phosphate ingredients used in consumer products, sodium tripolyphosphate (STPP) is the most commonly used.

This research focussed on phosphates in laundry detergents and automatic dishwasher detergents.

The contribution of consumer products to nutrient pollution first came to attention in the 1950s and 60s, when high levels of phosphates in laundry detergents were recognised as a significant contributor to eutrophication in surface water bodies in countries such as the USA and Japan. More recently, the growth of automatic dishwasher use has increased attention on phosphates in dishwashing products.

Other types of household consumer products also contain phosphates, but these are not addressed within this research because they are present at low concentrations or, as in the case of toothpaste, the product type is used in relatively small volumes.

In several countries regulatory or voluntary industry initiatives have reduced or eliminated phosphates from laundry and automatic dishwasher detergent products.

Regulatory restrictions (bans or concentration limitations) on phosphate in laundry detergents first emerged in the 1970s and 1980s, including in Canada, Japan, several European countries (EU-wide from 2013) and about half of the states of the USA. Since 2000, other countries such as Brazil and some states of China have also placed regulatory bans or limits on phosphate content. In Australia and in the US states not covered by regulation, voluntary industry agreements to remove phosphate from laundry products are in place.

More recently, in line with the growth in the use of automatic dishwashers, regulatory or voluntary industry initiatives in the EU, some US states, Canada and Australia also restrict phosphate levels in automatic dishwasher detergents. However, there are still countries in which phosphate levels in laundry products are restricted, but those in automatic dishwasher detergents are not.

Many international companies have removed or are in the process of removing phosphates from their products, including for markets where phosphate ingredients are not regulated.

The scope of this research did not include assessment of all products supplied by all companies, however a desktop review indicated that many large international companies supply phosphate-free laundry detergents. However, practices for local manufacturers vary.

The common replacements for phosphate ingredients in laundry detergents do not have known environmental impacts.

The most common replacement for STPP in laundry detergents are zeolites (sodium aluminosilicates) which are not considered an environmental hazard as they are insoluble and made up of aluminium and silicon compounds which are considered non-toxic.

There are still many countries, including in high-population and high-growth markets, where phosphate levels in consumer products are not restricted by regulatory or voluntary initiatives.

For example, in India, a voluntary industry standard actually specifies a minimum percentage of STPP required if the product is to be classified grade 1 or 2. Whilst this is currently under revision to a maximum STPP level of 2.5%, currently many locally manufactured laundry detergents contain phosphate and the standard will remain voluntary. It is evident that phosphate-containing products are available in other high-population countries such as the Philippines, Indonesia and Russia. Whilst this research was conducted primarily in English and not all countries were investigated, it is likely that most countries in Africa, South Asia, Central Asia, south-east Asia, the Pacific and Latin America, phosphate levels in consumer products are not restricted.

CONTRIBUTION OF CONSUMER PRODUCTS TO NUTRIENT POLLUTION

The extent to which phosphates in consumer products result in nutrient pollution depend on:

- consumption levels and rates;
- wastewater collection, disposal and treatment; and
- the relative contribution of other sources of phosphorus.

Consumption rates of detergents varies between countries, but overall consumption for laundry detergents is growing world-wide.

The consumption of detergents depends on many factors including: population size and growth; machine ownership rates; washing frequency; and volumes of detergent used per wash.

The global market for laundry detergents continues to grow, particularly in the Asia-Pacific, Eastern Europe, Latin America, Middle East and Africa. Increased urbanisation and growing rates of washing machine ownership are likely to drive increased demand for laundry detergent.

Dishwasher ownership rates vary significantly by country and there is the potential that growth in ownership may result in increased demand for automatic dishwasher detergent. However, in countries such as China and India, hand-washing of dishes remains the predominant practice.

In most locations, phosphate from consumer products enters the environment without being removed by wastewater treatment processes.

Sophisticated wastewater treatment technologies can remove up to 90% of the phosphate in domestic wastewater streams (contribute by human excreta, food waste and consumer products) however this type of process is rarely used outside of northern Europe, where there is already limited levels of phosphate in products, and in parts of the middle east. Where they are in place, wastewater treatment processes commonly remove from close to nil to at most half of the phosphate in wastewater.

Furthermore, globally more than half of wastewater generated is not treated, and in many countries including where phosphates are used in consumer products, sanitation coverage is significantly lower. Although there is substantial global attention on the need for safely managed sanitation for all, progress in sanitation coverage will not result in a level of wastewater treatment that is effective in removing phosphate from consumer products before it enters the environment.

Executive Summary continued

Consumer products are only one source of phosphorus entering the environment. Agricultural sources are a major source in many river basins. Within domestic wastewater, human excreta, food waste and consumer products (where these contain phosphate) are all major sources of phosphates. In densely-populated urban areas it is likely that consumer products (where these contain phosphates) can can contribute substantially to nutrient pollutant loads. However, few studies attempt to specifically estimate the contribution of nutrient pollution in the environment from consumer products relative to that from all other sources.

The relative contribution of consumer products to phosphate loads varies significantly by location and is difficult to precisely estimate. In contexts where phosphate-containing products are available, analysis of wastewater streams generally indicate 25-50% of the phosphate in domestic wastewater is attributed to consumer products. Global models indicate that domestic sources in turn contribute about half of the phosphorus into the world's river basins. This indicates that in densely-populated urban areas where phosphate-containing products are widely used, it is likely that consumer products contribute substantially to nutrient pollution. However, very few studies attempt to estimate how much of the phosphate in the environment, or at specific environmental sites, is attributable to consumer products compared to all other sources, whether domestic, industrial or agricultural.

LOCATIONS AT RISK OF NUTRIENT POLLUTION AND ECOSYSTEM IMPACTS FROM PHOSPHATE IN CONSUMER PRODUCTS

In any markets where phosphate-containing products continue to be used, densely populated urban centres with limited wastewater treatment are a potential major source of phosphate pollution from consumer products.

There are several relatively recent examples of rivers and lakes in India, Ukraine, the Philippines, Russia and Indonesia where phosphates in consumer products have been linked to nutrient pollution and ecosystem impacts.

Noting that this review was conducted primarily in English, India emerged a key country for which there are several media reports of ecosystems affected by phosphates from consumer products. As outlined above, in India there has historically been a voluntary standard specifying a *miminimum* level of phosphate in laundry detergents, and local manufacturers continue to supply detergents containing phosphates.

Overall there are likely to be many other locations not specifically identified in this review where consumer products containing phosphates are contributing to the risk of ecosystem harm.

B | SURFACTANTS

Surfactants are one of the most important components of detergent products.

Many types of surfactants are used in consumer products, often in combination with each other. Due to their cleaning and foaming properties, surfactants are one of the most important components of detergent products.

Approximately 40% of the synthetic surfactants are used in household consumer products, and personal care products account for approximately 14% of the global surfactants market.

Up to 60% of surfactants produced globally enter the environment, depending on whether there is wastewater treatment.

Wastewater treatment can remove a large portion of surfactants, but removal is not complete unless tertiary treatment is used.

The most visible potential ecosystem impact from surfactants is foaming on waterways.

Biodegradability is an important characteristic because it determines the extent to which a surfactant persists in the environment to create generally localised impacts, such as foaming on rivers.

Some surfactants are also ecotoxic, but the impact depends on the concentrations in the environment and the biodegradability of the surfactants under local environmental conditions. Most surfactants biodegrade into other compounds that are not considered harmful. However, some surfactants biodegrade into more toxic compounds.

Many surfactants are toxic, to various degrees, to plants and animals at high concentrations. If biodegradable, most surfactants will break down into other compounds that are not considered harmful. However, APEOs biodegrade into more toxic compounds.

Many countries regulate surfactant biodegradability (e.g. BAS phased out in countries such as EU, US and replaced with LAS to prevent foaming of rivers). Nevertheless, surfactants that can have potential toxicity to the environment continue to be used.

Oleochemical-derived surfactants (e.g. from palm kernel oil) tend to have higher biodegradability than non-renewable petrochemicals.

Some surfactants can only be derived from petrochemicals, but others can be derived from both. Oleochemical-derived surfactants generally have higher biodegradability than petrochemical-derived surfactants. However, a specific compound's toxicity does not depend on whether it has been it is derived from plant or petroleum sources.

Bio-surfactants (Biologically derived) are a relatively new category of surfactants that are generally superior to chemically-derived surfactants in terms of biodegradability, toxicity and cleaning efficiency.

However, bio-surfactants are only a niche market and often not cost-competitive.

Executive Summary continued

C | COMPANY PRACTICES

The company practices and perspectives on the use of phosphates and surfactants of five companies were reviewed.

The following companies were selected by Stewart Investors and UTS because they supply laundry and dishwasher products: PZ Cussons, Henkel, Unilever, Hindustan Unilever and Colgate-Palmolive.

The review involved a review of publicly available online documentation and interviews.

Of the five companies invited, PZ Cussons, Henkel and Unilever agreed to an interview.

Unilever provided their interview on behalf of Unilever and Unilever Hindustan. There is limited information presented in this report on Colgate-Palmolive as the information found online was not verified through interview.

All three companies interviewed noted that they have removed or are in the process of removing phosphates from all of their products, including for markets where ingredients are not regulated.

PZ Cussons started to remove phosphates from laundry and automatic dishwasher products in 2008 and has now removed from all products. The last remaining laundry product that had some residual phosphates was a brand sold in West Africa, but as of early 2019, phosphate has been removed from the formulations completely.

Henkel removed phosphates from laundry products in the 1980s, and from automatic dishwasher products in 2016. Phosphates were usually removed in all geographies, however, they noted that there may be remaining products in geographies where there is no phosphate ban.

Unilever began removing phosphates from products in 2010, and has removed or significantly reduced phosphates across their products. 95% of laundry powders are now phosphate free, and they are planning to have nil phosphates in laundry powders as quickly as possible.

Phosphates are found in laundry powders in Pakistan and Myanmar, some laundry bars in India and the Philippines and dishwashing bars in Bangladesh, however Unilever has already reduced phosphate use and is working to remove phosphates from these products as soon as possible. The first phosphate free automatic dishwasher detergent (ADD) was launched in Europe in 2008, and phosphates have been removed from all automatic dishwasher products.

Avoiding environmental impacts and regulation of phosphate ingredients influenced companies' decisions to remove phosphate.

The introduction of EU-wide regulation of phosphate as an ingredient in laundry products was a key driver for companies to reformulate products. Companies also noted broader sustainability drivers, for example Unilever noted that reducing lifecycle greenhouse gas emissions was another key driver to remove phosphates.

The challenges faced by companies when reformulating products to remove phosphate included: maintaining product performance, and working with raw material companies on supply; and managing consumer expectations about the performance and appearance of products.

Companies also noted that they were conscious of ensuring that alternative ingredients to phosphates did not introduce new environmental risks.

Companies interviewed noted the importance of biodegradability of surfactants, that this is key to their selection of surfactant ingredients, and that the surfactants they use do not pose environmental toxicity risks. Toxicity of specific surfactants used was not discussed.

All three companies interviewed discussed the sustainability challenges around oleochemical-derived surfactants, in particular palm oil. They are all involved with the Roundtable on Sustainable Palm Oil.

SUMMARY CONCLUSION

PHOSPHATES from consumer products no longer pose a risk to ecosystems in countries or states where these products' ingredient levels are regulated or restricted through voluntary initiatives, such as in Australia, the EU, USA, Canada, Japan and Brazil. The main substitutes (eg. Zeolites) for phosphates are not considered to be harmful to the environment. Many large consumer product manufacturers, including the specific companies interviewed for this research, have eliminated or plan to eliminate phosphate from laundry and dishwashing detergent liquids and powders. Some of these companies have committed to this across all markets, even where there are no restrictions.

Nevertheless, there are many other locally manufactured products containing phosphates which are sold and continue to pose a risk to ecosystems in countries such as: India, Russia, China, Philippines, Indonesia and Bangladesh.

SURFACTANTS can cause frothing in waterways if they are not sufficient biodegradable. The companies interviewed for this research noted that biodegradability is a key factor influencing surfactant ingredient choice, and that standards are regulated in countries such as Australia and the EU.

The companies interviewed for this research noted that surfactants they use are not ecotoxic. There is less comprehensive scientific knowledge about the ecotoxicity of the many types of surfactants used in consumer products, although some specific surfactants that tend to persist when in the environment are known to have ecotoxic properties and others are known to biodegrade into more toxic compounds. Thus some surfactants could possible cause ecosystem harm if present at high concentrations.

The report

1. Introduction

1.1 Background: ecosystem impacts from consumer products

Consumer products containing phosphorus, such as detergents and dishwashing powders and tablets, can contribute to nutrient pollution resulting in algal blooms and poor water quality (Qv and Jiang, 2013).

The contribution of consumer products to nutrient pollution first came to attention in the 1950s and 60s, when phosphates in laundry detergents were recognised as a significant contributor to eutrophication in surface water bodies in countries such as the USA and Japan. Since then a number of countries have adopted measures to control the content of phosphorus ingredients in detergents, and many companies have voluntarily reduced or eliminated phosphorus from their products.

However, there are still several countries around the world where phosphate-containing consumer products, including laundry detergents, continue to be sold. These continue to have major impacts on ecosystems in countries such as India (Kundu et al., 2015), China (Wang et al., 2009) and Russia (Agance France-Presse, 2017) and many other parts of Asia and Africa, including in the many locations where wastewater drains directly into waterways without treatment or nutrient removal (Feisthauer et al., 2002)

Even in countries where phosphate is banned from laundry detergents, other types of consumer products such as automatic dishwasher detergents may still contribute to nutrient pollution as regulatory and industry action has been slower for these products (Richards et al., 2015).

Surfactants are another ingredient of household consumer products, including detergents, shampoos and cleaning products. Surfactants were first identified as a pollutant of concern due to foam on the surface of rivers, such as in Germany in 1959. Since then, high surfactant concentrations in discharge waters have also been linked to other ecotoxicity impacts (Davidson and Milwisdsky, 1972; Schwuger, 1991, Azizullah et al, 2012, Jardak et al. 2016). The environmental impacts of surfactants are currently less well understood than that of phosphates.

1.2 Project objectives and scope

This research project was commissioned by Stewart Investors to explore the contribution to nutrient pollution and resultant ecosystem impacts of household and personal care consumer products, including laundry detergents, dishwashing detergents, other cleaning products, shampoo and soap. The initial scope of the research focussed on phosphorus, and was extended to include surfactants:

- **Phosphorus:** The key ingredient from consumer products that can contribute to nutrient pollution (although nitrogen can contribute to nutrient pollution it is rarely found in consumer products so is not the focus of this research)
- **Surfactants:** A widely used group of ingredients identified as having potential environmental impacts

This research will provide Stewart Investors with a greater understanding of the risk of ecosystem impacts from consumer products, potentially assisting them to support these companies in minimising environmental impacts.

The objectives of the project are to:

- Investigate the extent to which the consumer products industry is impacting nutrient pollution and ecosystems
- Identify countries/locations where ecosystems are currently at risk of nutrient pollution or other environmental impacts from consumer products
- Identify to what extent consumer products companies are addressing the environmental impacts of their products

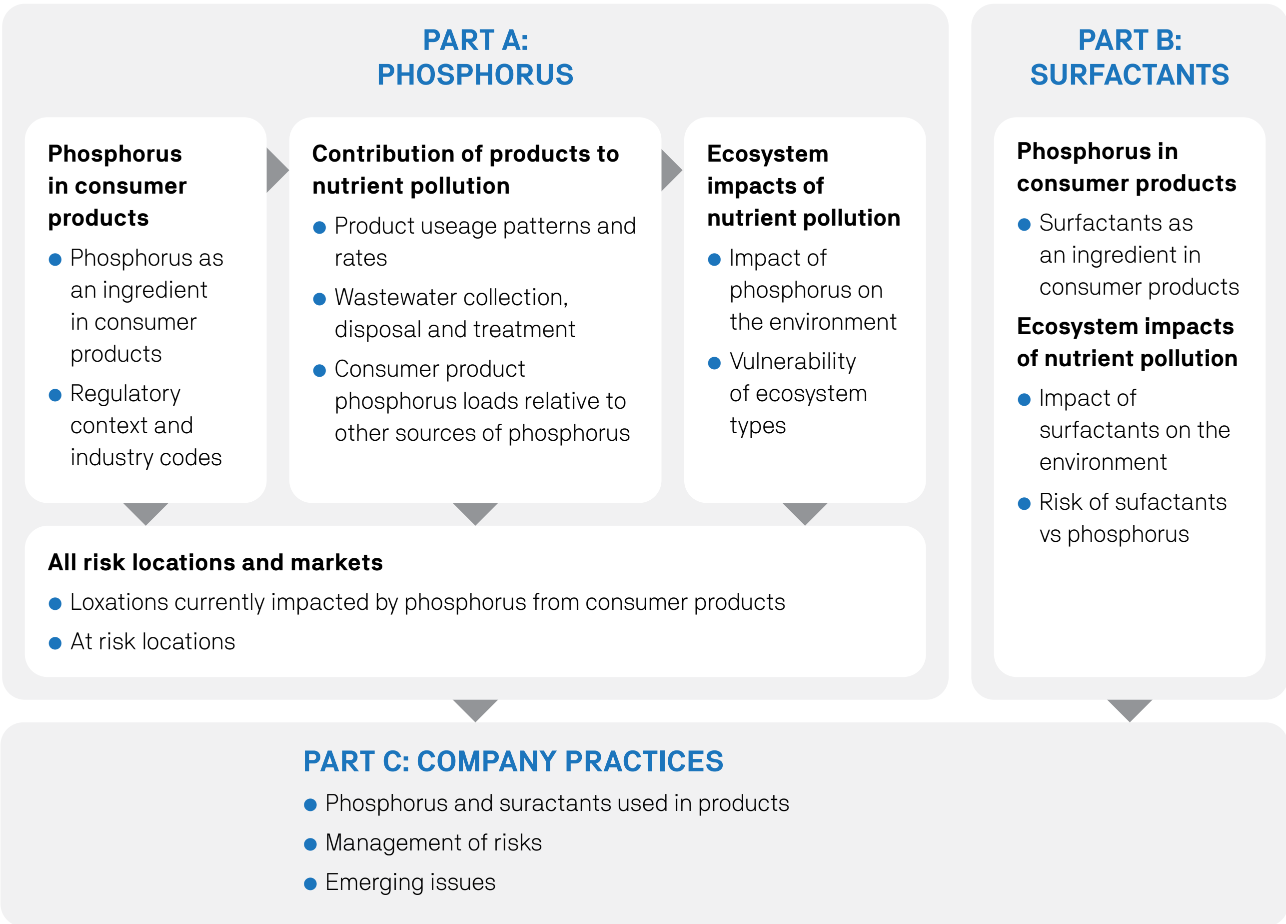
This research was exploratory in nature, and it did not aim to quantify specific risks nor to rate or rank companies. Rather, the research provides a “state of evidence” review and synthesis of a wide range of information about the impact of household consumer products on nutrient pollution of ecosystems.

1. Introduction continued

1.3 Research approach

The project is structured in three parts, which also form the outline of this report (as shown in Figure 1).

Figure 1: Research approach



Part A of the report focuses on phosphorus, beginning with a review of three key areas that contribute to the risk of nutrient pollution from consumer products:

- Phosphorus in consumer products
- Contribution of consumer products to nutrient pollution
- Ecosystem impacts of nutrient pollution

The findings from this initial review, alongside a review of global case studies of nutrient pollution, were used to evaluate the locations and markets at risk of nutrient pollution from consumer products.

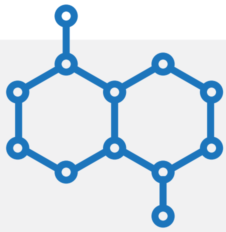
The research was based on a document and information review, commencing with a review of academic literature to gauge the current scientific evidence. Further reading was then undertaken of "grey" literature including news sources, government regulations, consumer reports and company statements. Grey literature was particularly important for this review because there have been many recent changes to consumer products (such as regulations or product formulation), which may not necessarily yet be reflected in scientific studies. This review was conducted almost exclusively in English, and are other information sources in other languages that was not reviewed.

Part B reviews the emerging issue of surfactants. A similar literature review was undertaken, however, as the issue of surfactants is broader and less well known than phosphorus, the approach to evaluating the issue was simplified.

Part C of the report is a summary of company practices. Following Part A and B, five companies were identified by Stewart Investors and UTS ISF for more specific review. This was based on the types of products in their portfolio (particularly laundry and automatic dishwasher products) that can contain phosphorus and surfactants. A review was undertaken of the ingredients used in products, based on company information and additional sources, and verified where possible through interviews. The five companies were invited to participate in a phone interview, and three agreed to participate.

Part A: Phosphorus

2. Phosphorus in consumer products



- Phosphates are the phosphorus-containing chemical compound used in consumer products posing the greatest risk for nutrient pollution, as they are highly water-soluble and assimilate into the phosphorus cycle. The most common phosphate used in consumer products is sodium tripolyphosphate (STPP).
- Laundry and automatic dishwasher powdered detergents are the consumer products most likely to contain high proportions of phosphates and used at quantities which pose a risk of nutrient pollution. Phosphorus is found in many other types of consumer products but at insignificant concentrations and/or rates of use. For example, toothpastes may contain phosphates, but the volume of use and hence contribution to nutrient pollution is insignificant compared to that of laundry and automatic dishwasher detergents.
- In many countries phosphates have been reduced or eliminated from most products through regulation or industry initiatives, or both. Phosphates have been removed from laundry detergents in USA, Canada, EU, Australia, Japan and Brazil. Phosphates have been removed from automatic dishwasher detergents USA in 2010 and Australia and the EU in 2017.
- Major international companies have voluntarily reduced or eliminated phosphates from their products, therefore phosphates may have been removed from a number of detergent brands even where regulation has not been in place.
- There are no regulations limiting phosphates in detergents in several countries of the world, particularly developing and emerging economies. In these countries, detergents containing phosphates may continue to be sold, and it appears this is the situation where there are a high proportion of locally owned and manufactured brands. For example, this is the case in India, where studies have shown that several detergent brands continue to be sold containing high concentrations of STPP, and this may also be the case in other locations.

2.1 Phosphorus as an ingredient in consumer products

Phosphorus (P) is contained in a wide range of chemical compounds used in consumer products, particularly home care and personal care products. Phosphate compounds are the focus of this study, because they are the main way that consumer products can result in phosphorus causing nutrient pollution.

Phosphates are inorganic compounds derived from phosphoric acid, and are named based on the number of phosphorus atoms, as shown in Table 1. Phosphates ingredients function to maintain pH of a product; soften high mineral-content water through sequestration; and dispersants. The most common phosphate used in consumer products is sodium tripolyphosphate (STPP).

Phosphates are very soluble in water but do not biodegrade. Instead, phosphate in its most simple form (orthophosphate) assimilates into the phosphorus cycle and the phosphorus becomes available for plant growth. Other phosphate compounds, such as the common sodium tripolyphosphate compound (STPP), break down in water or soil to orthophosphate.

2. Phosphorus in consumer products continued

Table 1: Typical phosphate-derived ingredients and applications

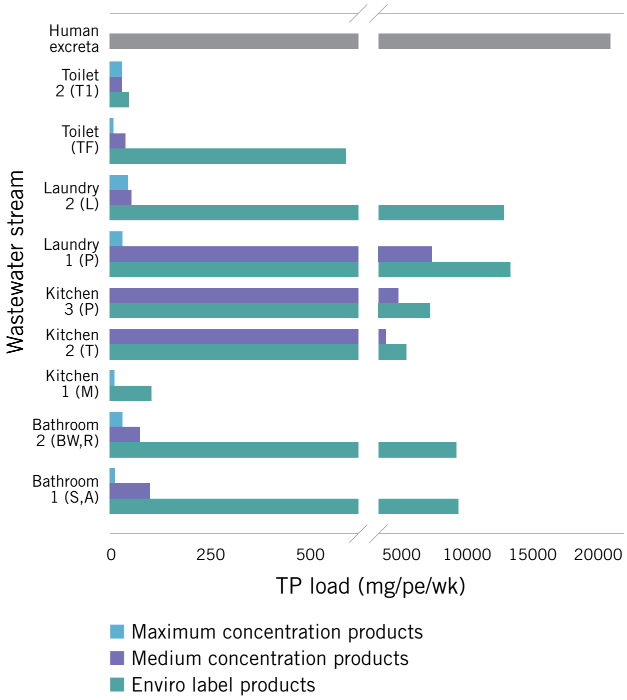
No of P Atoms	Ion	Function	Usual Name	Common applications
1	PO_4^{-3}	Buffering, i.e. to maintain a certain pH	Orthophosphates	Orthophosphates used in some in laundry and automatic dishwasher detergents (most common use is in fertilizers)
2	$P_2O_7^{-4}$	Buffering agent and sequestering builder	Pyrophosphates	Calcium pyrophosphate used as a tartar control agent in toothpastes; Tetrasodium pyrophosphate (TSPP) used in laundry and automatic dishwasher detergents and some toothpastes
3	$P_3O_{10}^{-5}$	Dispersant and sequestering builder	Tripolyphosphates	Sodium tripolyphosphate compound (STPP) used as a builder in laundry and automatic dishwasher detergents
>3	$P_nO_{(3n+1)}^{-(n+2)}$	Dispersant	Polyphosphates	Used in kaolin production

Phosphorus is found in almost all consumer products, but in varying concentrations. A major study undertaken in 2010, which examined 156 common household products sold in Australia detected phosphorus in 97% of the products, including cleaning products, personal care products, cleaning and laundry products (Tjandraatmadja et al., 2010). This study was conducted prior to the removal of phosphate from consumer products in Australia.

The formulations of home and personal care products vary widely based water quality in the end use market (e.g. hard vs soft water), customer segment preferences, cost of manufacture and any national guidelines or regulation which may limit the amount and type of ingredients used.

There is high variability in the phosphorus content within each type of consumer product (Patterson 2008). For example, one study measured between 0.01 to 55g of phosphorus per kg product for 24 different laundry detergents (Tjandrastmadja et al., 2010). Another study found that the phosphorus content of 50 powder and 41 liquid laundry detergents varied from nil to 7.16g phosphorus per wash (Lanfax 2009). The amount of phosphorus that enters wastewater can vary significantly depending on the concentration of phosphorus in products, as shown in Figure 2.

Figure 2. Phosphorus in loads in wastewater (adapted from Tjandraatmadja et al., 2010)



The typical median and maximum values across a range of products are presented in Table 2. The final column shows the estimated total phosphorus that could result from these products, based on the maximum concentrations and average patterns of use. As noted this study was conducted prior to the removal of phosphate from laundry and automatic dishwasher detergents in Australia. It provides an indication of the concentrations and phosphorus loads from products which have not been reformulated to reduce phosphate. Countries where phosphates have not been eliminated by regulation or industry initiatives could have similar levels of phosphates in products as those shown in Table 2.

Table 2: Typical values for phosphorus in consumer products – Australia, 2010 (phosphate ingredients not yet removed) (Tjandraatmadja et al., 2010)

Product	Median concentration of Phosphorus (g/kg)	Maximum concentration of Phosphorus (g/kg)	Mass of product used (frequency x product dose) (g/person/week)	Estimate of Total Phosphorus from product use based on maximum P in product (g/person/week)
Laundry products				
Laundry powder	25 g/kg	55	3 x 126g powder or 80g concentrate	**13.0**
Laundry liquid	8 g/kg	46	3 x 90g	**12.5**
Fabric softener	0.04 g/kg	0.2	3 x 75g	**0.04**
Dishwashing products				
Dishwasher tablet	29 g/kg	98	1.8 x 20g	**3.5**
Dishwasher powder	22 g/kg	53	1.8 x 60g	**5.8**
Dishwashing liquid	0.01 g/kg	1.5	7 x 10.5g	**0.1**
Personal care products				
Toothpaste	10 g/kg	79	14 x 3g	**1.6**
Soaps	0.9 g/kg	2.5	42 x 2g	**0.21**
Shampoo	0.15 g/kg	1.7	5.3 x 5g	**0.05**
All other products	<1 g/kg			

2. Phosphorus in consumer products continued

The specific phosphorus compounds found in consumer products are outlined below:

LAUNDRY DETERGENTS

Sodium tripolyphosphate (STPP)[1], has historically been the most common builder used in laundry detergents (powders, liquids and soap bars). Builders dissolve insoluble metal salts and keep them in solution, improving the performance of the surfactant. STPP has a number of functions including sequestration of "water hardness" enabling surfactants to function effectively, pH buffering, dirt emulsification and prevention of deposition, hydrolysis of grease, and dissolving-dispersing dirt particles (HERA 2003).

Newer formulations have reduced or eliminated phosphates as a builder. The most common replacement are zeolites[2], which can be used as well as, or instead of STPP. Zeolites are often used in combination with other builders, such as polycarboxylate and sodium carbonate (Hauthal 2005). Sodium carbonate and sodium silicate can also be used as builders. These substitutes are considered to have no adverse environmental impacts as they are insoluble and made up of aluminium and silicon compounds which are considered non-toxic (Fruijtier-Pölloth 2009). Other common compounds in detergent formulations include sodium sulphate and sodium perborate, which serve as buffers and auxiliary compounds respectively.

Enzymes are a newer product ingredient and they are generally included for their stain-removal properties rather than as a direct substitute for phosphate. However, some products reformulated without phosphate also include enzymes, to promote overall cleaning effectiveness. Subtilisms are protein-digesting enzymes which are ultimately biodegradeable in the environment. Enzymes are almost completely removed by wastewater treatment, but even where this does not exist enzymes are generally inactivated to a large extent in the washing process. Inactivation is considered to be equivalent to a loss of any ecotoxic properties, and thus enzymes are not considered to be harmful to the environment (HERA 2007).

DISHWASHER DETERGENTS

Sodium tripolyphosphate is the most common builder used in automatic dishwasher detergents (ADD), but it has been reduced or replaced in many products depending on the market. Compact formulations or tablets contain higher concentrations of phosphates than dishwasher powders, however when the amount of product typically used is considered, powders contribute larger loads than tablets Tjandraatmadja et al., 2010, Richards et al., 2014). Liquid handwashing detergents typically have a low phosphate content.

TOOTHPASTE

Toothpaste contains various phosphorus derived ingredients depending on the brand and toothpaste type. This may include calcium pyrophosphate, dicalcium phosphate dihydrate as an abrasive, sodium monofluorophosphate as fluoride. Tetra sodium pyrophosphate (Na4P2O7) or sodium tri-polyphosphate are added in formulations for tartar control (Tjandraatmadja and Diaper 2008). Some toothpastes contain very high concentrations of phosphates, however as they are used in small volumes the resulting contribution to nutrient pollution is low and toothpastes have relatively low impact on nutrient pollution.

OTHER PERSONAL CARE AND CLEANING PRODUCTS

Other personal care products (such as shampoos) and household cleaning products and have only trace amounts of phosphorus. They are also typically used in small amounts, so are not a major contributor of phosphorus in residential wastewater (Tjandraatmadja and Diaper 2006, Tjandraatmadja et al., 2010).

KEY PRODUCTS OF CONCERN

Laundry and automatic dishwasher detergents are the consumer products of highest concern as contributors of phosphorus to the environment through wastewater, as they have higher concentrations of phosphate and volumes of use compared to other personal care and home-care products (Tjandraatmadja et al., 2010, Richards et al., 2015). Therefore, this research is focused on laundry and dishwasher products.

1 ($Na_5P_3O_{10}$); Also known as sodium triphosphate (STP), tripolyphosphate (TPP) or pentasodium triphosphate

2 Zeolites (sodium aluminosilicate) have a silicon-aluminium-oxygen matrix, such as the widely used type A zeolite, $Na_{12}[(AlO_2)_{12}(SiO_2)_{12}]$ $27H_2O$.

2.2 Regulatory context and industry initiatives

2.2.1 GOVERNMENT AND INDUSTRY INITIATIVES TO REDUCE OR ELIMINATE PHOSPHATES

In many countries phosphates have been reduced or eliminated in consumer products, by either regulation or voluntary industry initiatives, or a combination of both. The reduction of phosphates began with laundry detergents, and in more recent years attention has focused on phosphates in automatic dishwasher detergents in countries where dishwasher use is high. Other types of consumer products have not been the subject of regulatory or industry initiatives to limit phosphate levels, because they are either used in low volumes (toothpaste) or have nil or insignificant concentrations of phosphates (other personal care and cleaning products).

Table 3 provides an overview of the current status of regulation and industry codes across the world. Laundry detergents are all phosphate-free (or capped at very low levels) by regulations in the EU, Canada, Japan, Brazil and half of US states, with dishwasher products regulated in the EU and a number of US states. Voluntary industry agreements apply in Australia and nationally across the USA for both laundry and dishwasher detergents.

Table 3: Summary of regulations and industry initiatives by country

Country	Initiative	Products and date
Australia	Voluntary removal by major brands	Maximum of 0.5% P in laundry detergent (2014) and dishwasher detergent (2017)
Brazil	Regulation	Maximum of 4.8% P by weight in laundry detergent (products found to be voluntarily below 0.01%) (2008)
Canada	Regulation	Maximum of 0.5% P in laundry and dishwasher detergents since 2010 (prior to this there was a maximum of 2.2% P in laundry detergent since mid 1970s)
China	Regulation (state)	P in laundry detergent banned in some states
	Voluntary standard	Maximum 1.1% phosphoric anhydride for phosphate free powders and liquids; minimum 8.0% total phosphoric anhydride for P containing detergents (since 2009 for laundry powder and since 2012 for liquid laundry detergents)[3]
European Union	Regulation	Ban (limit of 0.5g/load) on P in laundry detergent (2013) and dishwashing detergent (2017) (many countries already had bans in place since 1980s)
India	Voluntary standard	Minimum of 11% and 7% STPP by weight for grade 1 and 2 laundry detergents, currently under revision to a maximum 2.5% P
Japan	Regulation (prefecture)	Removal of P in laundry detergent beginning in 1979
US	Regulation (state)	Ban on P in laundry detergent in half of states (beginning 1970s) and dishwasher detergent in 16 states (2010)
	Voluntary industry agreement	Voluntary agreement by industry association to remove P across country from laundry (1994) & dishwasher (2010)

3 The Chinese standard is measured in phosphoric anhydride, which is a reacted compound used to measure the amount of P.

2. Phosphorus in consumer products continued

The impact of phosphates from laundry detergents to nutrient pollution was first recognised in the 1950s and 60s, which drove a number of countries to adopt measures to control the phosphate content of detergents. A high number of eutrophication events on lakes and ponds caused by phosphates in detergents in the 1970s in the USA led to restrictions on phosphate use in certain states (Schwuger, 1991). Similarly in Japan, prefectures began requiring the removal of phosphates from laundry detergents from 1979 following several cases of nutrient pollution in lakes (Friedman 2004). This regulation occurred in areas surrounding lakes affected by phosphates, but the result was the removal of phosphate from detergents across Japan (Glennie 2002). (Note that in many cases the “banning” of phosphates or shift to “phosphate-free” products is done through a regulation or standard to limit phosphates to an insignificant concentration.)

Half of US states and Canada have now banned the use of phosphates in laundry detergents, and these states also began regulating phosphates in dishwasher detergents from 2010 (CBC News 2008). The industry voluntarily agreed to extend phosphate restrictions across all US states in 1994 for laundry detergents (even where it is not banned), and in 2010 for dishwasher detergents. This was done through the industry association the American Cleaning Institute, which represents the majority of detergent manufacturers (Walsh 2010).

Since the 1980s many European countries introduced national regulations on phosphates, beginning with Germany, Italy, Switzerland and the Netherlands (Friedman 2004). In 2012 the European Union (EU) introduced a directive to limit phosphates in laundry detergents to 0.5 grams per dose from 2013, followed with a limitation on 0.3 grams per dose for dishwasher detergents from 2017 (Chemical Watch 2011).

In Australia the removal of phosphates occurred comparatively later. The Australian industry association ACCORD (which represents 90% of the industry) has voluntary standards for both low-P and phosphate-free laundry detergents, with a labeling system. Following pressure from an environmental campaign, in 2011 all major manufacturers and supermarkets committed to removing phosphates (up to a maximum of 0.5%) from laundry detergents by 2014 (Barlass 2011). The removal of phosphates from dishwasher detergents began in 2017 following another campaign and it is expected dishwasher detergents will be phosphate free by 2019 (Barlass 2017).

In China some states regulate phosphate in detergents, for example the area around Lake Taihu banned phosphates in 1999 (Wang et al., 2009). However, in many places, both phosphate-containing and phosphate-free laundry products are sold (Zhang et al., 2014).

In certain countries there are minimum standards for phosphates. For example, whilst some states in China regulate maximum phosphate levels, national product standards stipulate a minimum phosphate content for products when they are marketed and sold as “phosphate-containing” (CIRS 2016). India also had a minimum standard for phosphates in grade 1 and 2 detergents, as a way to classify the quality of detergents, which is currently under revision (Kundu et al., 2015).

Regulations may also differ between detergents for commercial and industrial use compared to household use. For example, in Canada commercial or industrial laundry detergents can have up to 2.2% P by weight compared to 0.5% for households (Government of Canada 2019).

Regulations on phosphate concentrations in detergents have often been introduced alongside other initiatives and policies to minimise the impacts of phosphorus in the environment. These include improvements to wastewater treatment systems (to remove all sources of phosphorus from wastewater), and ecosystem management and monitoring (e.g. EU, Japan). Reducing phosphates from detergents is considered one of the cheapest and easiest measures to reduce phosphorus to the environment. Therefore, in some cases regulation has occurred even when detergents may not have been the main reason for pollution.

IMPACTS OF REGULATION

A significant reduction in the phosphorus loads in wastewater has been found in several studies of water quality before and after phosphorus bans in detergents. For example, the introduction of regulation of phosphorus in laundry detergents in Brazil resulted in a reduction of 21.5% in the total phosphorus discharged into the environment from 2005 to 2008 (de Quevedo and da Silva Paganini 2016). Another study in Canada showed an improvement in water quality, particularly in urban areas (Dawe 2006).

However, in many cases the introduction of regulation on phosphates in detergents was found to have little to no effect on reducing nutrient pollution, because of the relatively minor contribution of detergents compared to other sources (Friedman 2004).

Banning phosphates from detergents can generate some improvements for nutrient pollution, but is not sufficient on its own. Case studies in Switzerland, Italy and the USA showed that elimination of phosphates in detergents, combined with upgrade in sewage treatment for phosphorus removal, could reduce nutrient loads enough to substantially improve water quality (Glennie et al., 2002).

2.2.2 COMPANY INITIATIVES TO REDUCE OR ELIMINATE PHOSPHATES

In addition to industry-wide agreements in countries, many companies have undertaken individual action to reduce or eliminate phosphates from their products. However, as there are many suppliers and brands on the markets, in many countries it is unknown whether products containing phosphates are sold. Details on formulations and manufacturing processes are often not readily available due to commercial reasons, and formulations can differ from manufacturer to manufacturer (Nur-E-Alam et al., 2016).

Many multinational companies have removed or are in the process of removing phosphates across their products, including the largest manufacturer of laundry detergents by sales volume.[4] Initially many companies may have needed to reformulate their products to comply with country regulations or agreements, however, in most cases large international companies are now selling phosphate-free detergents to all markets, even into markets where this is not required (Gies 2014).

Some companies also reduce phosphates beyond levels required by regulation. For example in Brazil, a 2016 study of 20 brands of laundry detergents found they all had low concentrations of phosphorus between 0.001% and 0.01% by weight, lower than the amounts allowed under national regulations (de Quevedo and da Silva Paganini 2016).

Many international companies have also removed phosphates from dishwasher powder and tablets. However not all companies specifically label or market their products as phosphate-free. Detailed perspectives of several companies are discussed in Part C of this report.

PHOSPHORUS SCARCITY

The world's main source of phosphorus is mined phosphate rock, which is becoming increasingly scarce (UNEP 2011), and is one of the most under-researched resource policy issues. Although phosphate rock is mined in many countries, just five countries (Morocco, China, Algeria, Syria & Brazil) control 84% of remaining finite high quality reserves (USGS 2018).

90% of the phosphate market is used in fertilizers, as phosphorus is an essential element for growing food for which there is no replacement (Cordell 2009). Phosphorus scarcity has mainly been discussed in relation to food production. However, consumer products manufacturers could also be impacted by changes in the global market for phosphorus, such as the price spike that occurred in 2008 (Cordell & White 2015).

4 P&G

2. Phosphorus in consumer products continued

2.2.3 COUNTRIES WITHOUT PHOSPHORUS INGREDIENT REGULATION

There are many countries, mainly developing and emerging economies, where there are no regulations or industry-wide agreements limiting phosphate content in detergents. In these countries detergents containing phosphates may continue to be sold, alongside phosphate-free options, depending on which companies retail to these markets.

In India, several detergent brands continue to be sold containing high concentrations of phosphates (Government of India 2018). National government standards previously set a *minimum* of 11% and 7% STPP by weight for grade 1 and 2 detergents, however, lab tests conducted in 2008 indicated much higher phosphate content in popular laundry products (Kundu et al., 2015). The detergent standard is in the process of being updated to maximum 2.5% STPP, however this will remain voluntary (Adak 2018). Following several incidents of water pollution linked to phosphates from detergents, there has been calls for legislation to ban phosphate in detergents (Adak 2018).

There is limited information available on phosphate use in consumer products in many locations, including Africa, Latin America, South East Asia, South Asia and the Pacific. Testing of selected detergents brands made in Russia and sold in ex-USSR countries indicated high P-content (Emilsson 2007, EU Neighbours, 2018). Studies have also found phosphates in several detergent brands in Bangladesh (Nur-E-Alam et al., 2016) and Indonesia (Janetasari 2013). A number of studies on Africa have linked the eutrophication of lakes to excess nutrients in wastewater, due to increase in population density and poor wastewater management, which suggests a link to phosphates in detergents (Juma et al., 2014).

In countries without regulation or voluntary agreements, it is most likely that local brands will sell products with high concentrations of phosphate, compared to larger international companies who have predominantly removed phosphates from their products. Therefore phosphate-containing detergents are most likely to be sold in countries without regulation, which have a high proportion of locally owned and manufactured brands.

3. Contribution of products to nutrient pollution

The contribution of consumer products to nutrient pollution varies across countries and markets. Key factors determining the extent to which phosphates in products result in nutrient pollution include:

- product usage patterns and rates (see 3.1)
- wastewater collection, disposal and treatment (see 3.2)
- the relative contribution of other sources of phosphorus (see 3.3)

- The consumption of detergents varies between countries, depending on population size and growth; machine ownership rates; washing frequency; and volumes of detergent used per wash. The increased use of washing machines and dishwashers is a key driver for increases in consumption of phosphate-containing detergents.
- Household wastewater collection and treatment can reduce the amount of phosphates, originating from consumer products, that enters the environment. However, in many countries, wastewater is not collected or treated effectively. Furthermore, in some locations, consumer products are also used directly in waterbodies such as lakes and rivers.
- Primary and secondary wastewater treatment technologies can remove 10-30% of phosphorus, however actual rates are lower where wastewater treatment plants are not designed for phosphorus removal or are operating above capacity. Tertiary treatment can remove up to 90% of phosphorus but is rarely used.
- Although there is substantial global attention on the need for safely managed sanitation for all, progress in sanitation coverage will not result in a level of wastewater treatment that is effective in removing phosphate from consumer products before it enters the environment
- Globally, the total phosphates used in laundry detergents and automatic dishwasher detergents grew between 1970 and 2010. Laundry detergents are generally a larger contributor than automatic dishwasher detergents, except in North America and Europe which have high rates of detergent use and where there are more comprehensive and long-standing limitations on phosphates in laundry detergents.
- It is challenging to determine relative contribution of different sources of phosphorus to nutrient pollution, due to the complexity of the monitoring and modelling required. Some studies attempt to isolate the contribution from consumer products, but the results are specific to location-based and seasonal factors. However:
  - Globally, domestic sources (mostly human excreta, then food waste and consumer products) contribute approximately half of the anthropogenic phosphorus entering the environment.
  - Generally, in rural areas agriculture is the main contributor of phosphorus; in urban areas, wastewater discharges from industry, households and sewage treatment plants are the key source of phosphorus.
  - In locations where phosphate-containing detergents are available, studies generally indicate 25-50% of household domestic wastewater can be attributed to detergents.

3. Contribution of products to nutrient pollution continued

3.1 Product usage patterns and rates

The rate of laundry and dishwasher products used significantly between markets and individual households. In addition to population size and growth, key factors include: whether hand washing or machine washing practices prevail; washing frequency, and manufacturers' recommendations about volumes of detergent to use per wash.

For example, laundry detergent consumption depends on:

- **Washing machine ownership rates:** High rates of 90-100% ownership in EU, Australia and Japan, compared to 45-50% in India, Indonesia and Philippines (Nielsen, 2016). Washing machine ownership generally results in greater detergent use, although in some cases handwashing customs involve multiple types of soap and laundry powders (Retamal and Schandl, 2017). It is expected that increased use of washing machines will occur in many countries, and this will drive increased demand for laundry detergent (Grand View Research 2018).
- **Laundering frequency:** This varies significantly in different countries depending on a range of factors including income, size of washing machine, space for drying, and customs.
- **Dosage per wash:** Recommended doses vary, including due to different product lines available in different countries, and differing rates of front loader or top loader use. For instance, the recommended manufacturer dosage for eight laundry powders and four liquid detergents sold in Australia ranged between 57- 99g per scoop and 60-160g per wash, respectively (Tjandraatmadja et al., 2008).

The market for laundry detergent is growing at a fast rate (between 8 to 14% compound annual growth rate for liquids and 2-10% for powders), particularly in Asia-Pacific, Eastern Europe, Latin America, Middle East & Africa regions (Euromonitor 2011). The positive trend is expected to continue pushed by increased urbanisation in the 2018-2025 period (Research and Markets, Nov. 9, 2018).

Dishwasher ownership will influence the consumption of detergents containing phosphates, as only automatic dishwasher detergents contain phosphates and hand dishwashing detergents contain negligible amounts (see Section 2.1). Ownership rates vary significantly by country – approximately 27% in Japan, 46% in UK and 70% Germany. Hand washing is currently the predominant practice in China and India where dishwasher ownership is only at about 1% (Statistica 2018).

Table 4. Per capita annual consumption of detergents

Country	Annual detergent consumption	Source
India	2.7 kg all detergents (laundry and dishwasher)	Rebello et al., 2014
	2.8 kg in 1994, expected to rise to 4kg for all detergents (laundry and dishwasher)	Kundu et al., 2015
UK	2.0 kg laundry detergents 1.3 kg dishwasher detergents	Rothsidou and Scrimshaw, 2015
Philippines	3.7 kg all detergents (laundry and dishwasher)	Rebello et al., 2014
Malaysia	3.7 kg all detergents (laundry and dishwasher)	Rebello et al., 2014
Vietnam	4.8 kg laundry detergents	Quynh et al., 2005
Brazil	5 kg laundry detergents	de Quevedo and da Silva Paganini, 2015
USA	10 kg all detergents (laundry and dishwasher)	Rebello et al., 2014

As outlined in table 4, from various studies it is evident that the annual consumption of detergents varies within countries, from between 2 and 10kg detergent per person per year. Higher annual use of detergents is usually correlated with higher income countries, however this is not always the case, for example the UK has lower per capita use than several countries in Asia.

Due to the wide range of factors influencing product use, there is not clear cut patterns as to how this influences the consumption of detergents. For example, although laundering frequency tends to increase with income levels, in some European countries such as high-income Norway, laundry powder use has decreased due to increasing awareness of sustainability issues. (Laitala et al., 2012). Overall however, the increased use of washing machines and dishwashers is a key driver for increases in consumption of phosphate containing detergents.

3.2 Wastewater collection, disposal and treatment

Phosphorus in consumer products can result in nutrient pollution if the products are used directly in waterbodies or if wastewater is discharged into the environment. The type and effectiveness of wastewater collection and treatment thus has a significant influence on phosphorus loads resulting from consumer products.

3.2.1 WASTEWATER COLLECTION AND TREATMENT RATES

Wastewater treatment plants (WWTP) have the capacity to reduce wastewater nutrient pollution, including phosphorus from consumer products, but also phosphorus and nitrogen from sewage and other sources (Katukiza et al., 2015).

The rates at which human wastewater is collected and treated vary widely across the globe. In Western Europe, the USA and Australia and New Zealand the majority of households in urban areas are sewered and wastewater from toilets as well as greywater (washing machines, sinks) is conveyed to treatment plants. However, in many countries collection and treatment rates are low (see table 5) and, as at 2015, more than 60% of the world's population do not have access to safely managed sanitation (WHO 2018). Therefore in most markets, phosphorus from products would not be removed by wastewater treatment before it enters the environment.

Table 5: Treated wastewater (%) by region in 2010 (van Puijenbroek et al., 2019)

Region	Treated wastewater (%)
North America	73
Central and South America	44
Middle East and Northern Africa	41
Sub-Saharan Africa	19
Western and Central Europe	83
Russia and Central Asia	47
South Asia	23
China Region	46
Southeast Asia	33
Japan and Oceania	89
Global	42

3.2.2 NUTRIENT REMOVAL THROUGH WASTEWATER TREATMENT

Even where wastewater treatment is in place, not all treatment technologies are equally effective at removing nutrients:

- **Primary treatment** (screening and sedimentation) can remove 5-10% of phosphorus (although not designed for such purpose)
- **Secondary treatment** (biological treatment using trickling filters, rotating biological contactors or activated sludge treatment) can typically remove 10-45% of phosphorus (and 40-53% of nitrogen). Higher levels of phosphate removal are possible, for example 70-90% removal rates are possible through addition of chemicals, e.g. flocculants (iron salts or lime), but this is more costly and also increases the volume of solids that needs to be disposed (Smil 2000). However the removal efficiency is typically much lower, as primary and secondary treatment plants are often not designed for phosphorus removal (Griffin 2017).

3. Contribution of products to nutrient pollution continued

- **Tertiary treatment** (advanced treatment using absorption, ultrafiltration/ microfiltration/ nanofilatration, extended biological nutrient removal) can remove up to 90% of phosphorus. However tertiary treatment is uncommon, and is mainly used in Northern Europe and the Middle East (UNESCO, 2017).

In addition, wastewater treatment plants are often operated beyond their design capacity and hence are unable to cope with the nutrient loads (Popa et al., 2012). For example, the Kisat wastewater treatment plant in Kenya is reported to only provide between 2.8-4.1% removal of nutrients from wastewater due to overloading (Musungu et al., 2014).

Table 6: Wastewater treatment removal efficiency (Drecht et al., 2009)

	Primary	Secondary	Tertiary
Removal of P (%)	10%	45%	90%

3.3 Consumer product phosphorus loads relative to other sources of phosphorus

In many environments consumer products are typically not the main source of nutrients entering the environment in terms of total loads, but nevertheless they can still be a significant contributor to ecosystem impacts.

Where phosphate-containing products are used, their contribution of detergents to phosphorus in wastewater can be significant, especially in densely populated urban areas where wastewater management is limited (Kundu et al., 2015, Nur-E-Alam et al., 2016).

There is significant challenge involved in determining the impacts of consumer products compared to other domestic sources in wastewater, and diffuse sources (de Quevedo and da Silva Paganini 2016).[5] There have been a number of studies that have attempted to identify:

- the relative contribution of consumer products and/or wastewater to the environment (Section 3.3.1)
- the relative contribution of consumer products to wastewater (Section 3.3.2).

3.3.1 CONSUMER PRODUCTS RELATIVE TO ALL OTHER SOURCES OF PHOSPHORUS IN THE ENVIRONMENT

In urban areas direct wastewater discharge from industry, households and sewage treatment plants are the key sources of phosphorus, and in rural areas agriculture is the main contributor.

The relative contribution of different sources to phosphorus in water bodies varies widely depending on the location, the extent of urbanisation, wastewater treatment and the impacts of historical agricultural practices.

Nutrient pollution in surface water systems can arise from point and diffuse sources. Diffuse sources include atmospheric deposition, erosion and run-off from agricultural activities, urban and industrial land use activities. Point sources include industrial and urban wastewater discharges (untreated and from sewage treatment plants) (Hulya and Hayal 2008).

In urban areas direct wastewater discharge from industry and households or effluent discharge from sewage treatment plants are the key source of phosphorus (Carey and Migliaccio 2009). In large cities, with high population density, domestic sources (i.e. human excreta, food and consumer products) are likely to be the highest contributor (rather than industrial sources). Globally domestic sources contribute approximately 54% of phosphorus entering the environment, up to 89% in the Aral Basin (Mekonnen and Hoekstra 2018).

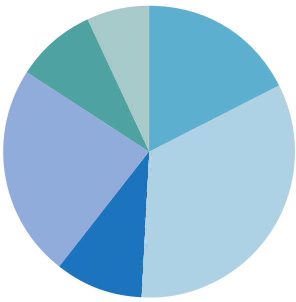
In rural areas agricultural activities are the major source of phosphorus (Carpenter et al., 2005, Anejaetal 2012, Wu et al., 2012). The impact of phosphorus from terrestrial runoff from fertilisers in agriculture is well known; it is estimated four-fifths of phosphorus from the food and agricultural value chains is lost or wasted, most of which gets washed into in rivers and oceans (Cordell et al., 2009, Elser et al., 2007).

5 Many environmental studies address the overall loadings of both nutrient types and their impacts in various types of aquatic systems due to the difficulty in assessing the exact origins of these pollutants. Studies of pollution into the environment are generally based on the modelling of nutrient loads and fluxes from natural and human activities and the sampling of surface waters and discharges points for identification of point and non-point sources within catchments over time.

Nutrient pollution is also impacted by seasonality and localised effects. For instance, in the Jinjiang River, the third largest river in Fujian Province, China, industrial wastewater discharge and localised agricultural activities were the primary source of nutrients in periods of low river flow, whilst agricultural runoff was the main source of nutrients during high river flow (Chen et al., 2013).

There are very few studies that attempt the complex monitoring and modelling required to quantify the phosphate contribution of consumer products relative to all other. An EU study in 2015 attributed 10% of the total phosphorous entering surface waters in the European Union to household detergents (Kundu et al., 2015, see Figure 3). However, this study referenced data from 1993, which is likely to have changed since the introduction of phosphorous restrictions and bans in consumer products in the EU.

Figure 3. Different P sources entering surface waters of the European Union (adapted from Kundu et al., 2015)



3.3.2 CONSUMER PRODUCTS RELATIVE TO OTHER DOMESTIC SOURCES OF PHOSPHORUS IN WASTEWATER

Wastewater is typically the main contributor of phosphorus entering the environment in urban areas. Within wastewater, human excreta contributes the majority of the load of phosphorus, however in markets when phosphate containing detergents are available, detergents can still comprise a significant share of around 25%.

The majority of studies relating to consumer products estimate the contribution of different sources to domestic wastewater in areas with wastewater treatment plants.[6] Inputs from food, in the form human excreta and as well as food scraps, are found to have a much higher input to phosphorous loads relative to the inputs from consumer products.

Residential wastewater is typically the main source of the phosphorus (as well as nitrogen) reaching a wastewater treatment plant (Metcalf and Eddy 1998). In the home, blackwater (from the toilet) is the main contributor to the nutrient load in residential wastewater. For instance, in two Australian studies blackwater generated 78% and 88% of the phosphorus load in a household's wastewater (Tjandraatmadja et al., 2009, Gray and Becker 2002). On average urine contributes 60% of phosphorus load in residential wastewater (and 75% of the nitrogen) (Vinnerås 2001).

Studies have demonstrated a range of contributions of consumer products to phosphorus in wastewater. Prior to the introduction of phosphate-free detergents it was estimated up to 50% of phosphorus in wastewater could be attributed to detergents (Glennie et al., 2002). Recent estimates in locations where phosphate-containing detergents are still available at the time of the study (South Africa, Hungary and Czech Republic) suggest detergents could contribute between 25% to 33% (see Table 7). In Brazil where detergents are phosphate-free, the contribution is less than 1% (de Quevedo and da Silva Paganini 2016).

6 Where wastewater treatment plants (WWTPs) are in operation, it is possible to estimate the relative contributions of domestic sources using a mass balance approach, by estimating loads entering the WWTP (volume of wastewater per person) and calculating the mean concentration of phosphorous in crude sewage.

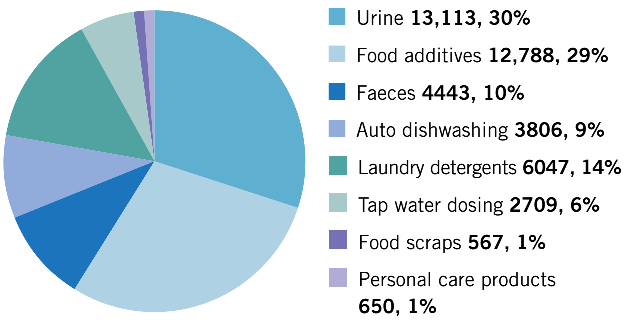
3. Contribution of products to nutrient pollution continued

Table 7: Consumer products relative to other domestic sources of phosphorus in wastewater

Location	Consumer product share of phosphorus to wastewater (%)	Reference
Brazil	0.17% from laundry detergents	de Quevedo and da Silva Paganini 2016
UK	25% from consumer products (14% laundry detergents, 9% auto dishwashing and 1% personal care products)	Comber et al., 2013
Global average for 2010	16% from laundry and dishwasher detergents	van Puijenbroek et al., 2019
South Africa	33% from laundry detergents	Quayle et al., 2010
Hungary and Czech Republic	25% from laundry and dishwasher detergents	Glennie et al., 2002
China	11% from laundry detergents	Liu, 1996
US	Up to 65% from laundry detergents	Devey & Harkness 1973
US and Canada	Up to 50% from detergents in Canada, and up to 70% in the US (Great Lakes Region)	International Joint Commission 1969

A recent study from the UK compares the contribution of different consumer products to other sources in domestic wastewater (see Figure 4). This found that 25% of phosphorus could be attributed to consumer products; 14% was from laundry detergents, which was decreasing over time as regulations were being introduced, and 9% from automatic dishwasher detergents, which could potentially increase. Personal care products (mainly toothpaste) contributed only 1%. Consistent with other studies, human excreta was the main contributor to phosphorus loads, followed by food (Comber et al., 2013).

Figure 4. Tonnes-P/year discharged to sewer from domestic sources and % contribution to total load in the UK (adapted from Comber et al., 2013)



In locations without established wastewater treatment services, it is difficult to determine the magnitude of the impacts of phosphorous inputs from domestic products to the environment. For example, in India the total outflow of phosphorus from detergent to wastewater is somewhere between 41,000 and 145,555 tonnes/year, and in many cases this flows directly to rivers. This also does not capture the direct inputs from washing directly into rivers (Kundu et al., 2015).

CONTRIBUTION OF LAUNDRY AND DISHWASHER DETERGENTS

In the majority of regions laundry detergents contribute far more to phosphorus emissions compared to dishwasher detergents (based on 2010 data, shown in Table 8). The exception to this is North America and Europe, where dishwasher detergents contribute more to total emissions (as phosphorus removal from dishwasher detergents began later, as discussed in Section 2.2). Between 1970 and 2010 emissions from laundry detergents have decreased in North America and Europe, but increased in all other regions of the globe. Emissions from dishwasher detergents have increased in all areas, but remain small in most regions.

Table 8: Total emissions of Phosphorus by laundry and dishwasher detergents (106 kg P/year) (van Puijenbroek et al., 2018)

	Laundry		Dishwasher	
Region	**1970**	**2010**	**1970**	**2010**
North America	69	45	11	51
Central and South America	13	83	0	2
Middle East and Northern Africa	6	51	0	5
Sub-Saharan Africa	3	12	0	0
Western and Central Europe	108	32	14	63
Russia and Central Asia	17	34	0	2
South Asia	2	22	0	0
China Region	4	167	0	2
Southeast Asia	1	5	0	1
Japan and Oceania	19	40	3	26
Total	241	491	29	153

4. Ecosystem impacts of nutrient pollution

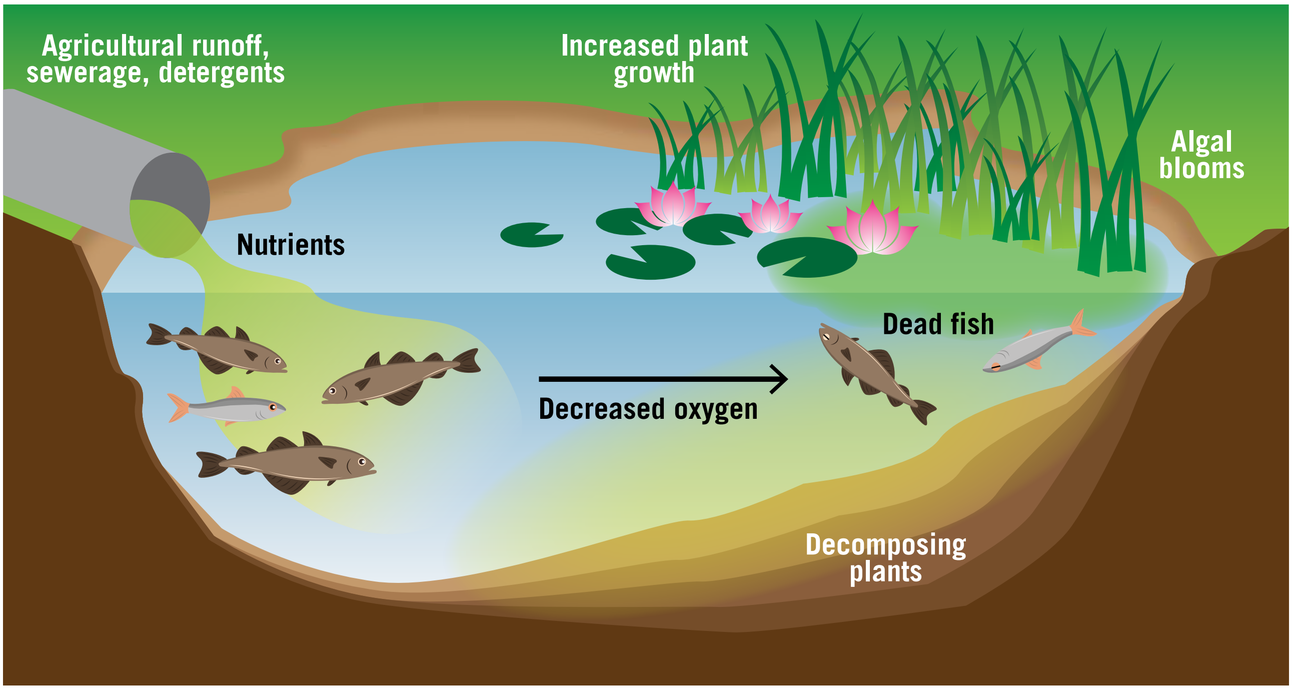
- The discharge of excess phosphorous and nitrogen nutrients into aquatic ecosystems has had significant impacts on ecosystem health and the viability of aquatic life. This can lead to eutrophication, encouraging the production of algae and cyanobacteria which can form algal blooms and lead to mass fish kills.
- Certain ecosystems, such as shallow freshwater lakes and slow flowing rivers, are particularly vulnerable to nutrient pollution. Particular species such as corals are also vulnerable and take a long time to recover.
- Ongoing eutrophication can lead to long term impacts on ecosystems that have sometimes irreversible impacts on ecosystem health and biodiversity.

4.1 Impact of phosphorus on the environment

The discharge of excess nutrients (phosphorus and nitrogen) into the environment, including from wastewater, consumer products and agriculture, poses a significant threat to aquatic ecosystems (Qv and Jiang, 2013).

When discharged in high volumes to the aquatic environment, phosphorous (and nitrogen) pollution can lead to the 'eutrophication effect', resulting in algal blooms, excess aquatic plant growth, reductions in biodiversity and sometimes fish kills (Figure 5). In addition, high nutrient loads impact overall water quality, affecting the availability of water for human use and consumption.

Figure 5. Conceptual depiction of the freshwater eutrophication process



EUTROPHICATION

Excess nutrients (phosphorus and nitrogen) encourages the production of algae and cyanobacteria which can form algal blooms. It can also lead to increased bacterial growth, increasing respiration rates of bacteria and algae and the lowering of dissolved oxygen levels in aquatic systems. The low dissolved oxygen creates an uninhabitable environment for some aquatic species such as fish, and this can lead to mass fish kills (Paerl et al. 2001).

In turn, low oxygen levels can lead to greater quantities phosphorus being released into the water from sediments to which they were formerly chemically bound (Correll, 1998). Nitrogen can also be released from sediments under conditions with low dissolved oxygen (Mueller et al. 2016). The additional release of P and N from sediments reinforces the eutrophication process, creating a feedback loop which is further exacerbated by other environmental factors such as water flow, sunlight, pH changes and increased temperature.

Even low inputs of bioavailable phosphorous can generate 500 times its weight in algae, therefore small increases of the nutrient can produce significant effects (Grzybowski and Szydłowski, 2013). Advanced eutrophication is often marked by blooms in freshwaters of the potentially toxic algae cyanobacteria (scum-forming algae) and, in coastal areas, other toxic blooms such as dinoflagellates and diatoms (Hallegraeff 1993). The eventual decomposition of this phytomass can create a hypoxic (low dissolved oxygen) or anoxic (no dissolved oxygen) conditions towards the bottom or throughout a shallow water column (Smil, 2000).

For most aquatic systems, 100ug total P/Litre is an unacceptably high concentration of phosphorus, and concentrations of 20ug P/L are often a problem (Correll, 1998). As the total concentration of phosphorus in water increases, standing phytomass increases in a linear fashion, but this is also influenced by other factors (such as sunlight and local environmental conditions) (Smil, 2000).

There is still a lack of data relating to these threats and their effects upon whole ecosystems, as opposed to indicator species-focused investigations (Halpern et al., 2007).

Over time, chronic eutrophication can have devastating impacts on aquatic environments. The longer that nutrients remain and accumulate in the ecosystem, the greater the risk of eutrophication (Smil, 2000; Jarvie et al., 2013). Many lakes, rivers and estuaries globally have progressed from previously healthy ecosystems to eutrophic conditions due to nutrient pollution (Correll, 1998). These changes can have significant and, at times, irreversible effects on biodiversity and ecosystem health.

4.2 Vulnerability of ecosystem types

Determining an ecosystem's vulnerability to nutrient pollution requires considering the location and physical characteristics, ecosystem type and specific organisms within the ecosystem (Correll, 1998). Determining the extent of ecosystem vulnerability to nutrient pollution is also challenging due to the lack of 'intact' aquatic ecosystems upon which to base reference sites (Jarvie et al., 2013).

Predicting the level of risk for nutrient pollution in any given ecosystem is complex. Although every ecosystem is different, four key factors can help determine the vulnerability of an ecosystem to nutrient pollution:

4. Ecosystem impacts of nutrient pollution

continued

1. **P or N limited ecosystem:** Nutrient limitation status[7] impacts the type of nutrient (P or N) that will have the most impact in an ecosystem. For example, less phosphorous occurs naturally in rivers and lakes than nitrogen so they are considered "P-limited". As such, when additional inputs of P introduced, excessive primary production commences (in the form of algal blooms) and eutrophication may occur. However, P can also lead to algal blooms and other impacts in N-limited ecosystems, and nitrogen can have impacts in P-limited systems. Once limitation is lifted for one nutrient, say P, then the nitrogen concentration may becoming limiting and influence the amount of algal growth seen.

   Generally speaking, fresh water tends to be P limited and coastal waters tend to be N limited (as shown in **Table 9**). However, this does not always hold and the opposite patterns occur and co-limitation of systems where both P and N are required to increase algal growth can also occur (Müller and Mitrovic, 2015).

   Table 9. Nutrient limitation by aquatic ecosystem type

P-limited	N-limited
Lakes	Oceans
Estuaries/Continental Shelf	Estuaries/Continental Shelf
Rivers/Streams	

2. **Physical characteristics of the ecosystem:** Freshwater systems (streams, lakes and reservoirs) with low flow, low depth and low water clarity are especially vulnerable to eutrophication (Søballe and Kimmel, 1987). In general, however, the consequences for nutrient loading in stream ecosystem functioning remain poorly understood (Woodward et al., 2012).

3. **Sensitivity of organisms:** Some aquatic organisms have much lower thresholds for P inputs than others. For example, corals are particularly vulnerable as P stimulates the growth of algae in coral reefs, which blocks sunlight and result in brittle and stunted coral, as well as being responsible for the inhibition of the calcification process of corals (Smil, 2000). Risk for coastal eutrophication and associated impacts has increased markedly over the last 30 years and is likely to continue to increase in many world regions (Seitzinger et al., 2010).

4. **Resilience to nutrient pollution:** The ability of an ecosystem to recover from nutrient pollution determines if and how long the ecosystem will take to recover. Although slow-flowing freshwater systems tend to be more vulnerable to nutrient pollution, marine ecosystems are considered to be least resistant to point-source organic pollution as well as requiring longer periods to recover from this type of pollution (Halpern et al., 2007).

Therefore, all three of the above points should be considered in assessing the potential risk for nutrient pollution from phosphorus in consumer products.

7 'Nutrient limitation' refers to the particular nutrient that drives primary production (i.e. the production of plant life that can grow) in a given aquatic ecosystem.

5. Locations at risk of nutrient pollution and ecosystem impacts from consumer products

- Several examples from the last 10 years, including in India, Ukraine, the Philippines, Russia, South Africa and Indonesia, link nutrient pollution ecosystem impacts to phosphates in consumer products.
- This review did not consider all countries, but did identify India, Bangladesh, China, Ukraine, Indonesia, Philippines and Russia as high-population countries where phosphate-containing detergents continue to be sold.
- Noting that this review was conducted primarily in English, India is a key country for which there are several media reports of ecosystems affected by phosphates from consumer products.
- Overall there are likely to be many other locations not specifically identified in this review where consumer products containing phosphates are contributing to the risk of ecosystem harm. In particular, in markets where phosphate ingredients are not restricted, any densely populated urban centre with limited wastewater collection or treatment is a potential source of phosphate pollution from consumer products and where local or downstream ecosystems would be at risk.

5.1 EXAMPLES OF LOCATIONS AFFECTED BY PHOSPHATES FROM DETERGENTS

Whilst many hazardous algal bloom outbreaks are linked to agricultural runoff, there are also several recent examples of nutrient pollution where it is suspected that consumer products have contributed significantly, although there are very few scientific studies to verify these. Examples found in the previous 10 years are shown in Table 10.

Table 10: Summary of incidents of nutrient pollution linked to consumer products

Country and location	Year	Contribution	Reference
India (Bellandur Lake, Bangalore, Yamuna River, Delhi)	2018	Suspected detergents linked to many examples of nutrient pollution (and frothing from surfactants)	Adak, 2018
Ukraine (Dnieper River)	2018	Consumers are being encouraged to buy phosphate free detergents, as algae in the Dnieper river are impacting water quality and biodiversity.	EU Neighbours, 2018
Philippines (Laguna da Bay near Manila)	2017	Pollution linked to detergents, untreated sewage and agriculture run-off, recommendation to ban P in detergents	Global Environment Facility, 2017
Russia (Lake Baikal in Siberia)	2017	Suspect detergents may be linked to eutrophication, ecosystem under "significant stress" and decreased fish stocks	Agence France-Presse, 2017
Indonesia (Brantas River)	2000	Phosphates from detergents disposed directly into the river are impacting the growth of phytoplankton in the Brantas River, as well as dissolved oxygen and pH.	Janetasari 2013
South Africa (e.g. Hartbeespoort dam)	2010	Detergents responsible for 3-30% of P in dams, government considered regulation, Main detergent brand removed phosphates. 2017 study found phosphate levels have fallen in South African rivers.	Quayle et al., 2010, Groenwald, 2011, Griffin 2017

5. Locations at risk of nutrient pollution and ecosystem impacts from consumer products

continued

HISTORICAL EXAMPLES OF NUTRIENT POLLUTION FROM DETERGENTS

There are also various historical examples of detergents contributing to nutrient pollution, however in general there have not been more recent documented examples in these locations where subsequent regulatory or voluntary initiatives targeted phosphate levels. In the 1960s 45% of phosphates entering Lake Lugano in Switzerland and Italy were from detergents, which led to rapid eutrophication. In 1965 the Great Lakes in the USA were affected by algal blooms, and it was estimated 50-70% of phosphates entering the lake were from detergents. Other lakes affected by nutrient pollution in the 1970s include Paranoa Lake in Brazil which led to mass fish kills, and Lake Biwa & Lake Kasumigaura in Japan.

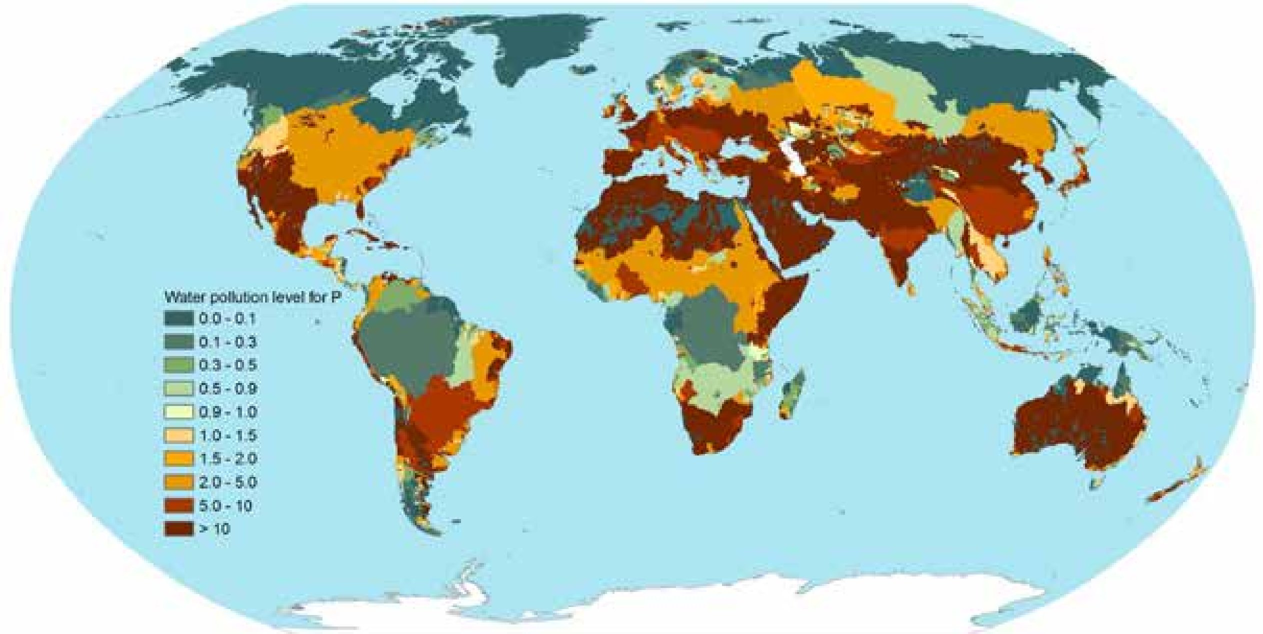
In the 1990s Montevideo, Uruguay was affected by nutrient pollution and it was estimated 58% of phosphates were from detergents. In the 1990s/early 2000s countries affected included Thailand (Lake Nong Hang & Lake Kwan Phayao), Paraguay (Lake Ypakarai), Philippines (Laguna da Bay), India (River Ganga) and many lakes in China (Lake Taihu, Dianchi, Erhai, Bai Huau) (Ministry of Environment Japan 2010). Nutrient pollution from detergents may continue in these locations.

NUTRIENT POLLUTION FROM ALL SOURCES

As discussed in Section 3.3, detergents are only one contributor to nutrient pollution from phosphorus. Locations that are affected by phosphorus, regardless of the source, are at risk of devastating or irreversible impacts. Figure 6 highlights the most affected river basins globally, noting that the main sectors contributing to phosphorus loads vary significantly across these examples (Mekonnen and Hoekstra, 2018)).

The river basin the most severely polluted phosphorus is the Aral Basin in Central Asia. Other severely polluted basins include Huang He (China), Indus (Pakistan and India), Murray-Darling (Australia), Ganges (India), Yangtze (China) and Danube (Central and Eastern Europe), using the metric of water pollution level (WPL)[8].

Figure 6. Water pollution level per river basin relating to human-induced P loads from agricultural, industrial and domestic sectors, 2002-2010 (Mekonnen and Hoekstra, 2018)



8 The metric of water pollution level (WPL) is used to measure the fraction of waste assimilation capacity of a river basin (calculated by diving the grey water footprint (GWF) by the actual river runoff in the basin). It can provide a helpful way of visualising the pressure put by anthropogenic P loads on freshwater resources around the globe.

NUTRIENT POLLUTION FROM DETERGENTS IN INDIA

Detergents containing phosphates are still sold in India and have been linked to examples of pollution of rivers in cities such as Delhi, Pune and Bangalore. There are no regulations that prevent the use of phosphates in detergents. Studies have found that it is mainly local manufacturers that use phosphates in their detergents, and local manufacturers are gaining market share over international brands (Government of India 2018).

Detergent standards set a minimum STPP content for high grade detergents, and in the past some detergents contained up to 35% STPP (Kundu et al., 2015). This standard is currently under revision to be updated to a maximum of 2.5% phosphorus. However, this standard is voluntary and a separate law would be required to make it binding (Adak 2018).

At the same time, the consumption of laundry detergent is increasing. Per capita consumption was 2.8kg per year in 1994 and expected to grow to 4kg per year in 2005 (Pattusamy et al., 2013).

It is estimated that between 41,000 and 145,555 tonnes/year of phosphorus from detergent goes to wastewater. In certain locations, such as the areas around the River Ganga, almost all sewage (2.5 billion litres per day in the case of the Ganga) is discharged directly into the river (Kundu et al., 2015). In addition, these figures do not fully capture the direct inputs from washing in streams and rivers directly.

5.2 AT RISK COUNTRIES

Based on the findings from Chapters 2 to 4, a range of factors have been identified that increase the risk of nutrient pollution linked to consumer products. The locations most at risk of nutrient pollution and ecosystem impact from consumer products are those where:

- **Phosphate containing products are available:**
  - **There are no regulation or voluntary agreements** to ban the use of phosphates in detergents
  - **A high share of local manufacturers,** as major international brands have voluntarily removed phosphates from their products
- **Consumption of detergents is high and/or increasing**
- **Inadequate wastewater treatment** where wastewater is discharged directly into surface waters, or where washing is done directly in rivers
- **Urban centres with high population densities**
- **Vulnerable ecosystems** such as shallow and/or slow moving lakes and rivers, coral reefs, and locations with existing high loads of nutrients due to anthropogenic sources.

It is known that phosphate-containing products continue to be sold in **India, Bangladesh, China, Ukraine, Indonesia and Russia**. There are also recent of examples of nutrient pollution where it is suspected detergents are a contributor in these countries, as well as in the **Philippines**. The EU, USA, Brazil, Japan and Australia have all removed phosphates by regulations, voluntary industry initiatives or a combination of both, so are unlikely to be at risk.

The following regions have low wastewater treatment rates, including Sub-Saharan Africa (19%), South Asia (23%) and Southeast Asia (33%), China (46%) and Russia and Central Asia (47%), so if phosphates are present in detergents they are likely to end up in ecosystems. No country (even with high wastewater treatment rates) has 100% removal of phosphorus from wastewater treatment.

Urban centres in emerging economies are most at risk, as they are most likely to have inadequate wastewater treatment and use significant volumes of detergents. South Asia has already been identified as a significant contributor in forecasts of future nutrient loads (from all sources), as it is a rapidly-growing region in economic transition (Seitzinger et al., 2010).

Part B: Surfactants

6. Surfactants in consumer products

- Many types of surfactants are used in consumer products, often in combination with each other. Due to their cleaning and foaming properties, surfactants are one of the most important components of detergent products.
- Approximately 40% of the surfactants are used in home care products, and personal care products account for approximately 14% of the global surfactants market.
- Up to 60% of surfactants produced globally enter the environment, depending on whether there is wastewater treatment. Wastewater treatment can remove a large portion of surfactants, but removal is not complete unless tertiary treatment is used.

6.1 Surfactants as an ingredient in consumer products

Surfactants[9] are widely used in a range of consumer products due to their ability to clean and foam in water, including personal care products (e.g., shampoos, body wash) and in household cleaning products (e.g., dishwashing and laundry detergents, hard-surface cleaners). The properties of surfactants reduce the surface tension of water in washing and aid penetration of the cleaning solution to lift dirt and grease.

Detergents usually contain surfactants derived from petrochemicals, whilst soaps typically use surfactants derived from vegetable and animal fats.

6.1.1 TYPES OF SURFACTANTS

There are hundreds of compounds that can be used as surfactants, however only ten types of compounds make up 80% of surfactant production. Surfactants are often classified by their ionic 'behaviour' in solution: anionic, cationic, non-ionic or amphoteric.[10]

For most consumer products, the surfactants used are anionic (e.g. linear alkylbenzene sulphonates (LAS)) or non-ionic (the alcohol ethoxylates (AEOs) or alkylphenol ethoxylates (APEOs)). However, there are also disinfectant and other cleaning and conditioning products which contain cationic surfactants such as quaternary ammonium ethoxylate (QAC). Often multiple surfactants are used within one product.

9 Surfactants (surface-active agents) are chemically synthesised compounds made of molecules with a hydrophobic (water-repelling) section that is attracted to oils and fat and a hydrophilic (water-attracting) part which has affinity for water.

10 Amphoteric surfactants are not addressed as part of this study as they are a very small share of surfactant production.

6. Surfactants in consumer products continued

Table 11: Types of surfactants and application in consumer products

Category of surfactant	Type of surfactant	Consumer products
Anionic	Linear alkylbenzene sulfonates (LAS) (petrochemical derived)	Laundry detergents (powders and liquids), dishwashing liquids, detergent tablets, shampoo, soap bars, other personal care products and household cleaners
	Sodium Laurel Sulfates (SLS) (mostly oleochemical, e.g. palm or coconut oil) and Sodium Laureth Ether Sulfates (SLES) (mostly oleochemical/natural or synthetic/petrochemical)	Many shampoos, personal care and home care products
Non-ionic	Alcohol Ethoxylates (AEOs) (either petrochemical or oleochemical derived) and Alkylphenol Ethoxylates (APEOs) (either petrochemical or oleochemical derived)	Laundry detergents, some household cleaners, personal care products (also industrial processes)
	Poloxamers (petrochemical derived)	Cosmetic and home care products, in particular Poloxamer 407 and Poloxamer 124 are present in toothpastes
Cationic	Quaternary ammonium ethoxylates (QAC) (oleochemical derived)	Antimicrobial formulations, fabric softeners and hair conditioners among other domestic products

6.1.2 KEY PRODUCTS THAT USE SURFACTANTS

The total annual global production of surfactants in 2008 was approximately 13 million metric tonnes, and is likely to have grown (Levison 2009). Anionic surfactants (including SLS and SLES) comprise approximately half of the total surfactant market share (Reuters 2018), and non-ionic surfactants (AEOs and APEOs) make up about 45% of total surfactant production (Schmitt et al., 2014). LAS is the most widely used surfactant, and there are at least four million metric tonnes of LAS produced annually as a proportion of the global surfactant market (Hampel et al., 2012).

Asia Pacific is the largest consumer and producer of surfactants, with 40% of market share. The global surfactants market is expected to grow 5% per year from 2018 to 2023 (Reuters 2018).

Home care accounts for approximately 40% of the market of surfactant production (2014 data, Palmer and Hatley, 2018). Surfactants represent one of the most important and largest components of detergent products, comprising 15-40% of the total detergent formulation (Lechuga et al., 2016).

Personal care products accounted for 14% of the global surfactants market in 2017 (Reuters 2018).

6.2 Surfactants entering the environment

6.2.1 VOLUMES AND CONCENTRATIONS SURFACTANTS ENTERING THE ENVIRONMENT

Large volumes of surfactants are used every day, eventually entering the environment where they have the potential to cause ecological damage (Traverso-Soto et al., 2012). The volume and concentrations of surfactants entering aquatic ecosystems varies significantly based on regulations, levels of consumption and wastewater management infrastructure.

Recent studies have suggested that up to 60% of the total surfactant production eventually enters the aquatic environment (Pradhan and Bhattacharyya, 2017; Schmitt et al., 2014; Wang et al., 2015). Other studies suggest in regions with adequate wastewater treatment, surfactants exist at levels below regulatory limits (Cowan-Ellsberry et al., 2014).

Many countries have regulatory limits on the concentrations of surfactants in wastewater. There is also legislation on the biodegradability of surfactants in laundry detergents, which has been around as early as the 1960s in European countries (Schwuger, 1991).

Relying on regulatory limits to curtail the risk of environmental damage may underestimate the potential for harm. Analyses of water bodies around the world found surfactants at concentrations higher than their predicted 'no effect' levels under regulation (Rebello et al., 2014).

6.2.2 SURFACTANT REMOVAL FROM WASTEWATER

Once used, the major fraction of surfactants are disposed down the drain to sewers, where an estimated 50% by volume is degraded, 25% is attached to suspended solids and 25% is dissolved.

Conventional treatment processes in wastewater treatment plants are unable to provide complete removal of surfactant compounds (Jardak et al., 2016). Previous studies suggest only 73% of LAS surfactants are eliminated in wastewater treatment (Scott and Jones, 2000). AEOs and APEOs can be partly removed by activated sewage sludge treatment (>85% removal efficiency). However many surfactants require advanced tertiary treatment (nanofiltration, activated carbon or reverse osmosis) which can achieve removal efficiencies ranging from 70 to >99% based on the technology adopted (Shareef et al., 2008, Traverso-Soto et al., 2012).

Surfactants can enter aquatic ecosystems by other means, such as stormwater discharge and the direct discharge of effluents from industrial and urban areas, completely bypassing any form of wastewater treatment.

Even if 99% of LAS is remediated via wastewater treatment, due to high consumption volumes and the absence of adequate sewage treatment in many cases, important amounts of this compound may reach rivers and coastal waters, and finally the sediment (Hampel et al., 2012).

7. Ecosystem risks from surfactants

- The risk of ecosystem impacts from surfactants depends on the concentrations reaching the environment, the biodegradability of the surfactants under local environmental conditions, and the sensitivity of the ecosystem and its species.
- Biodegradability is an important characteristic because it determines the extent to which a surfactant persists in the environment to create generally localised impacts, such as foaming on rivers. Many surfactants are also toxic (some or highly) to plants and animals at high concentrations, but if biodegradable, most surfactants will break down into other compounds that are not considered harmful. However, some surfactants, e.g. APEOs, biodegrade into more toxic compounds.
- Many countries regulate surfactant biodegradability (e.g. BAS phased out in countries such as EU, US and replaced with LAS to prevent foaming of rivers). Nevertheless, surfactants that can have potential toxicity to the environment continue to be used. Even though many surfactants are considered harmless at low concentrations, they can be found in the environment at potentially harmful concentrations, particularly in countries without wastewater treatment.
- Surfactants often labelled “green” can be chemically-derived, but from oleochemicals (e.g. palm kernel oil) instead of non-renewable petrochemicals. Some surfactants can only be derived from petrochemicals, but others can be derived from both. Oleochemical-derived surfactants generally have higher biodegradability than petrochemical-derived surfactants. However, a specific compound’s toxicity does not depend on it is derived from plant or petroleum sources.
- Bio-surfactants (biologically derived) are a relatively new category of surfactants that are generally superior to chemically-derived surfactants in terms of biodegradability, toxicity and cleaning efficiency. However, these are only a niche market and often not cost-competitive.

7.1 Ecosystem vulnerability to surfactants

In certain ecosystems, surfactant compounds are more likely to accumulate and persist. Non-flowing systems such as shallow lakes, flowing streams and river systems are the most vulnerable to surfactants from urban wastewater discharges, even in locations where wastewater treatment has been in place for some time (based on a global study on LAS, Wang et al., (2012). The risk of surfactants on ecosystems is also increased by high organic matter content in sediments/soil and sensitive ecosystems or organisms (e.g. fish, corals, certain invertebrates).

7.2 Types of surfactant impacts

As well as the sensitivity of the ecosystem, the ecosystem impacts of a surfactant will depend on its:

- **Biodegradability:** how easily the surfactant breaks down in water, which impacts the concentrations that remain in the environment
- **Ecotoxicity:** toxic effects caused by substances on animals and plants, dependent on concentrations in the environment

A summary of the biodegradability and ecotoxicity of common surfactants used in consumer products is given in Table 12.

Table 12: Ecosystem impacts of surfactants

Type of surfactant	Biodegradability	Ecotoxicity
Linear alkylbenzene sulfonates (LAS)	• Biodegradable under aerobic conditions but is persistent in the environment under anaerobic conditions. Once LAS binds to sediments it is slow to degrade. • Longer-chain compounds of LAS are more likely to persist in the environment.	• LAS surfactants may have high acute and chronic toxic effects on aquatic life above certain concentrations (Environmental Working Group, 2019a). • Longer-chain compounds of LAS are the most toxic of these compounds.
Sodium Lauryl Sulfates (SLS) and Sodium Laureth Ether Sulfates (SLES)	• SLS and SLES considered biodegradable as these compounds decompose into simple, non-toxic components after 96 hours in both aerobic and anaerobic environmental conditions.	• Moderately toxic to aquatic life in its raw material form. • Product formulations that contain diluted amounts of the compound are not necessarily toxic, and in fact may be non-toxic to aquatic life (Bondi et al., 2015).
Alcohol Ethoxylates (AEOs) and Alkylphenol Ethoxylates (APEOs)	• AEOs are readily biodegradable, including in anaerobic environments, so despite the acute concerns these compounds appear to involve less longer-term effects compared with other types of surfactants.	• AEO surfactants cause very high acute toxicity to aquatic life (European Union Ecolabel program) (Environmental Working Group, 2019b). • Ecotoxicity risk of APEOs for varies with compounds. APEOs are considering relatively non-toxic but breakdown into nonyl phenol and octyl phenol which are toxic and can cause endocrine disruption in aquatic organisms (Shareef et al., 2008).
Quaternary ammonium ethoxylates (QAC)	• QACs are considered to be aerobically biodegradable, however the degradation is affected by chemical structures, dissolved oxygen concentration, complexing with anionic surfactants.	• QACs are toxic to a number of aquatic organisms including fish, daphnids, algae and microorganisms employed in wastewater treatment systems (Zhang et al., 2015).

7. Ecosystem risks from surfactants continued

7.2.1 BIODEGRADABILITY

The biodegradability of surfactants is important as it prevents surfactants from remaining in the environment, and determines how much of a surfactant may have toxic effects on the environment.

In the past branched alkylbenzene sulphonates (BAS) were the most common surfactant used in laundry detergents, but these are being phased out because of their impacts to waterways (such as foaming on rivers). From 1965, branched chain surfactants were substituted with LAS because of its biodegradability in the USA and EU (Davidson and Milwisdsky, 1972, Schwuger, 1991). In some countries, particularly in the Asia-Pacific region and Latin America, branched alkylbenzene sulphonates are still in use and could have detrimental ecosystem impacts (Shafir et al., 2013).

Biodegradability depends on the type of surfactant and also whether it ends up in an aerobic or anaerobic environment. Generally, surfactants that enter the aquatic environment following adequate wastewater treatment undergo rapid degradation by microorganisms. However once they enter anaerobic conditions (such as river or lake sediments), they can accumulate and cause toxicity in the medium to long-term (Wang et al., 2015). For example, even though LAS has high biodegradability in aerobic conditions, it is slower to biodegrade in aquatic environments and once it reaches sediments and can accumulate (Shafir et al., 2014).

In locations where wastewater is treated effectively, by the time cleaning product ingredients reach natural waters, they are mostly degraded. Ecotoxicity studies have determined that a surfactant concentration of 0.5 mg/L of natural water would be essentially nontoxic to fish and other aquatic life under most conditions. However, it has been suggested that chronic toxicity of anionic and non-ionic surfactants occurs at concentrations as low as 0.1 mg/L (Bondi et al., 2015), and even at low concentrations, surfactants appear to alter soil physics, chemistry and biology (Rebello et al., 2014). For instance, SLS at 0.1 mg/mL causes inhibition of asexual and sexual reproduction in some bacteria (Matsui and Park 2000).

While some research has suggested that the concentrations of surfactants reaching receiving waters is below the threshold of causing any acute or chronic impact (Cowan-Ellsberry et al., 2014), such conclusions are often applicable where there is a high level of wastewater treatment in the location of interest, and no direct washing in the water body.

7.2.2 ECOTOXICITY

The toxicity of surfactants depends on the type of compound, the concentration and the characteristics of the receiving environment. The risk of ecotoxicity from surfactants is not comprehensively understood, but there is increasing concerns environmental harm toxicity for aquatic organisms (Palmer and Hatley 2018). The molecular structure of any given surfactant compound also has a significant impact on its toxicity potential (Lechuga et al., 2016).

Many studies have suggested varying levels of ecotoxicity risk associated with different types of surfactants (Azizullah et al., 2012; Cserháti et al., 2002; Jardak et al., 2016; Pradhan and Bhattacharyya, 2017; Wang et al., 2015; Warne and Schifko, 1999). On the other hand, others present evidence that with adequate wastewater treatment and compliance with regulation, the environmental concentrations of surfactants have insignificant effects on aquatic life (Cowan-Ellsberry et al., 2014). Ecotoxicity is dependent on dosage, length of exposure and biological species, making the study of surfactant impacts on aquatic environments particularly complex.

Exposures to surfactants may not be immediately lethal, but may induce chronic effects in aquatic organisms' vital functions and processes, such as resistance to environmental and competitive stress, reproduction, and growth, and thus have knock-on ecological effects (Jardak et al, 2016). Exposure to sublethal concentrations of surfactants causes gill damage in fish and can expose them to microbial attack or interfere with functions in microbial species (Rebello et al., 2014). These effects have detrimental effects on populations and flow-on effects to whole ecosystems.

SURFACTANT METABOLITES

While the toxicity risk of some surfactants in environmentally-relevant concentrations may be relatively low, there is increasing attention being given to the possible toxicity of the metabolites (degradation products) of surfactants after they enter the environment. For example, although APEOs are considered relatively non-toxic compounds, the metabolites from some APEO compounds (nonyl-phenol and octylphenol) have been investigated due to higher toxicity and persistence than the parent compounds toxicity (Jardak et al., 2016, Shareef et al., 2008).

There is some evidence to suggest that metabolites of surfactants could persist in these types of environments (Jardak et al., 2016). The there have been studies that suggest morphological and reproductive effects upon aquatic species due to the deposition of surfactant metabolites in waterways (Shareef et al., 2008).

"GREEN SURFACTANTS"

Consumer demand for more naturally-derived and sustainable products for the home has driven the emergence 'green' alternatives to synthetic surfactants. 'Green surfactants' are obtained from nature or synthesised from renewable raw materials. 'Green surfactants' refers to two types of products, and can be derived through chemical processes or through biochemical processes.

Chemically derived "green" surfactants are synthesised by chemical processes from natural oleochemicals (e.g. palm oil or animal fats) rather than non-renewable petrochemicals. Some types of surfactants, such as AEOs, can be derived from either petrochemical or oleochemicals (Shah et al., 2016). Other surfactants, such as LAS, can only be derived from petrochemicals, but different surfactants with similar properties can be used as an alternative. For example, two green surfactants that are used commercially are methyl ester sulfonate, a naturally derived alternative to LAS that is more biodegradable, and alkyl polyglucosides, used in many for personal care products (Rebello et al., 2014, Euromonitor International 2018). Green surfactants derived from oleochemicals are generally more biodegradable than petrochemical surfactants. However, a specific compound's toxicity level does not depend on whether it is derived from plant or petroleum sources.

Biosurfactants are biological compounds with high surface active properties produced by microorganisms, plants and fungi. Biosurfactants are an emerging field of research and not widely commercially produced. Some biosurfactants make use of a plant-based natural surfactant such as 'soap berries' (such as those extracted from the plant Sapindus mukorossi). One experiment into the efficacy of extracts from plant species such as Zephyranthes carinata and Sapindus mukorossi suggest 'remarkable' surface active properties (Pradhan and Bhattacharyya, 2017). Other emerging bio-surfactants of interest include sophorolipids and rahmnolipids surfactants (produced by fermentation of either fats and oils, glycerin or soy molasses) for use in household and auto dish washing products. These compounds under examination by Henkel and partners were promising in regards to low toxicity and surfactant activity compared to alkyl polyglucosides, but required increased uptake to be price competitive (De Guzman 2010). Biosurfactants have several potential advantages over chemical surfactants, including higher biodegradability, lower toxicity and greater efficiency in terms of the volume required (Rebello et al., 2014).

Part C: Companies

8. Company practices and perspectives

A review of company practices and perspectives on the use of phosphates and surfactants was undertaken for four companies:

- PZ Cussons
- Henkel
- Unilever / Hindustan Unilever
- Colgate-Palmolive

These companies were identified by Stewart Investors and UTS ISF following Parts A and B of the research. These companies were selected based on the types of products in their portfolio (particularly laundry and dishwasher products).

The review involved two methods:

Desktop review of the ingredients in consumer products, based on company reports and additional sources such as consumer affairs reports, academic studies and retail websites.

Interviews with company representatives to understand practices and perspectives, and to verify ingredient information found in the desktop review. A copy of the interview questions is in Appendix A. All four companies were individually contacted for an interview and three (PZ Cussons, Henkel and Unilever) agreed to participate. Unilever provided their interview on behalf of Unilever as a whole, including Hindustan Unilever.

Interviews took place between December 2018 and January 2019. The summary of the findings is presented below.

8.1 Phosphates

PHOSPHATE CONTAINING PRODUCTS:

The three companies interviewed have removed or are in the process of removing phosphates from all of their products.

PZ Cussons started to remove phosphates from laundry and dishwasher products in 2008 and has now removed from all products. The last remaining laundry product that had some residual phosphates was a brand sold in West Africa, but PZ Cussons reports as of early 2019, phosphate has been removed from the formulations completely. (Note: in the desktop review one product (sold in Australia) was found to contain phosphates, but in the interview PZ Cussons confirmed this product no longer contained them.)

Henkel removed phosphates from laundry products in the 1980s, and from dishwasher products in 2016. Phosphates were usually removed in all geographies, however, they noted that there may be remaining products in geographies where there is no phosphate ban.

Unilever began removing phosphates from products in 2010, and has removed or significantly reduced phosphates across their products. 95% of powders are now phosphate free, and they are planning to have nil phosphates in laundry powders as quickly as possible. Phosphates are found in laundry powders are in Pakistan and Myanmar where a business was acquired by Unilever that used STPP as part of the formulations, but Unilever is working on complete removal. (Note the desktop review found phosphates in laundry powders in Indonesia (on a retail website)[11], in Bangladesh (Nur-E-Alam et al., 2016) and in India (Government of India, 2018) sold under Hindustan Unilever. However, Unilever clarified that these products do not contain phosphates.)

Phosphates remain in some laundry bars in India and the Philippines, but are in the process of being removed. There has already been significant reduction of phosphate use, by approximately 40%, and Unilever are working to remove phosphates from laundry bars. Phosphates are a particular challenge for removal in laundry bars as they contribute to the structure of the product. Laundry bars are typically sold to low-income consumers in developing and emerging markets (e.g. India and parts of Africa).

Dishwashing bars containing 2% STPP are sold in Bangladesh, but Unilever is working to remove this as soon as possible[12]. The first phosphate free automatic dishwasher detergent (ADD) was launched in Europe in 2008, and phosphates have been removed from all dishwasher products.

Phosphates were found in three Colgate-Palmolive toothpaste products; however this was not able to be verified with the company. As noted in Section 2.1, toothpaste products are of low concern for nutrient pollution due to their small volumes.

11 https://www.monotaro.id/corp_id/s000001477.html

12 http://www.unileverbrandsinfo.com/products/vim/bar/

8. Company practices and perspectives

continued

DRIVER TO REMOVE PHOSPHATES:

All three companies interviewed noted that avoiding environmental impact as well as regulation influenced their removal of phosphates from products.

PZ Cussons notes that avoiding the environmental impact of phosphates was the main driver, and that removal was prioritised in European products first because of impending EU legislation. Phosphates were removed next in Australia because it was the second largest business unit. Africa was the last market, and there is now one brand remaining containing phosphate, which is being removed voluntarily even though there are no regulatory limits on phosphates in products.

Henkel removed phosphates in the 1980s, ahead of legislation in Europe (although legislation was already in place in Germany). Phosphates were taken out of ADD in early 2016, a year prior to date on which regulations banning phosphates throughout the European Union came into force.

Unilever noted that the main sustainability drivers for removing phosphates are documented in their company-wide Sustainable Living Plan. Unilever is in the process of removing phosphates from products in India in the absence of regulations. Reducing greenhouse gas emissions (GHG) were also a driver to remove phosphates. Unilever found that phosphates were a relatively big contributor to lifecycle GHG and by removing phosphates were able to reduce GHG per wash by 50%.

CHALLENGES TO REMOVING PHOSPHATES:

Technical challenges to maintain the performance of the product were the main challenge reported by the companies. Additional challenges included working with raw material companies and consumer expectations about the performance and appearance of the products.

PZ Cussons noted that the main challenge was the performance of the products in terms of stain removal. In reformulating the product they found none of the direct substitutes were as effective, but they were able to address overall efficiencies in other areas, for example through utilising higher levels of enzymes. They also noted the challenge was helped by the fact that sector-wide many other companies were also simultaneously reformulating their products to remove phosphates, so performance against competitors was maintained.

PZ Cussons used a phased approach to manage change and performance with consumers, starting with reduction and then moving to removal. Alternatives were looked at in terms of performance, cost effectiveness, supply chain logistics, as well as environmental fate and risk assessment.

Henkel began look for alternative builder to phosphates in the 1980s, and registered several patents for zeolites. They noted the significant investment in time, effort and money with the raw material manufacturers to find a suitable replacement.

Changing the formulation was particularly challenging for automatic dishwasher detergents; 40% of the entire formulation had to be reformulated, to make sure all the properties that the former tablets had are still in place. The change in formulation had positive outcomes for the company as they received the highest rating in a review of performance in a German state owned consumer magazine.

For removal of phosphates in liquid laundry detergents in Australia, Henkel noted that they had to maintain consumer satisfaction with the new products by matching viscosity.

Unilever noted substantial investment and time for research and development was required to find right technical solutions, and it was easier to remove phosphates from some products than from others. Powders were less challenging than bars as the main function of phosphates in powders is water softening and alternatives were available to fill this function. However, for bars phosphates have two functions: softening the water and giving the bar structure. The biggest technical challenge is how to structure a bar cost effectively whilst maintaining its properties, as moving to different ingredients results in bars with different wear rates. Alternatives are in development that maintain the structure of the bar.

REMAINING MARKETS WITHOUT PHOSPHATE INGREDIENT REGULATION:

All three companies sell consumer products into markets where phosphate levels in consumer products are not regulated. **PZ Cussons** supplies into West Africa and **Unilever** into India and Indonesia (and likely others not mentioned). Henkel did not mention the regions they sell into outside of Europe and Australia. **PZ Cussons** and **Unilever** noted that they are in the process of phasing out phosphates voluntarily in these markets.

PZ Cussons noted that phosphates were not generally used in markets that PZ Cussons operates in, except for West Africa. Phosphates are still used in West Africa but generally by smaller companies, not by multinationals.

PZ Cussons do not retail in China, South and Southeast Asia but noted there are still a prevalence of phosphates in these markets. They noted that ultimately regulation would be needed to remove phosphates from, as phosphates are a very effective ingredient in detergents, and they can understand why smaller companies have chosen not to move away.

Unilever noted that when supplying to markets without phosphate ingredient regulations, this does not affect their decision to remove phosphates. Unilever also noted that in some countries phosphates are required in a product in order to be able to market and sell it as a laundry detergent.

INGREDIENT DISCLOSURE:

All companies disclose the ingredients in their products when required to by local regulation (e.g. in the EU). They tend to disclose general ingredients on packs, but PZ Cussons and Unilever also have detailed ingredients available on their website.

In terms of the declaration of ingredients, in the EU where ingredient disclosure is mandatory, **PZ Cussons** disclose general ingredient types on the pack as defined by regulation, but disclose full ingredients on their website. In Australia and West Africa they give a general ingredient listing on packs. PZ Cussons noted they usually do not disclose a full list of specific ingredients unless required by regulations.

Henkel noted in the EU all ingredients above 0.2% are disclosed.

Unilever has an initiative to improve transparency which makes detailed ingredients for home, beauty and personal care products available on websites in the US and EU.

MARKETING AS PHOSPHATE-FREE:

The three companies generally do not market their products as “P-free”, but do label their products as P-free in Australia in line with the national labelling standards.

PZ Cussons noted that they are mindful when companies claim to be P-free. They noted that phosphates were widely used for some products such as automatic dishwashing detergents, so it is valid to claim P-free for these products. However, they noted that they would not claim a product is P-free when phosphate wouldn’t have been there in the first place, such as hand dishwashing products.

Henkel commented that the industry generally does not make claims about P-free or biodegradability. Henkel noted they would only make a claim if they had a really green product such as 100% biodegradable, but they usually don’t claim this.

Unilever commented that they do not generally market their products as phosphate-free unless required by national labelling standards. They have provided information on the website on the GHG improvements from phosphate removal.

ENVIRONMENTAL IMPACTS OF ALTERNATIVES AND HOW TESTING IS DONE:

All the companies interviewed undertake their own research and development for alternative product formulations, and PZ Cussons and Henkel detailed their internal risk assessment process. Both PZ Cussons initially reformulated with zeolites, but have since moved to other ingredients.

PZ Cussons noted that their first reformulation of laundry powders used zeolites and polycarboxalytes. They use the HERA project for guidance around ingredients which concluded zeolites pose no significant environmental risk. PZ Cussons commented they wanted to ensure that alternative to phosphates did not create new issues. Ingredient choices are made by an internal “Materials of Concern Committee”, made up mainly of technical experts but also commercial staff. This committee drives strategies for certain materials, looks at scientific evidence, overlaid with commercial and consumer information.

8. Company practices and perspectives

continued

Henkel initially used zeolites in laundry detergents, and switched to silicate in laundry powders. For ADD the ingredients were switched partly to MGDA (Sold by BSF sells under the name Telon). Internal testing to get approval for raw material and ingredients is done looking at ecological impact, toxicological impact and dermatology. Performance tests are also done in comparison with competitors.

Unilever noted their ultimate goal is to find a solution that meets consumer needs, is cost effective and has sustainability benefit. Unilever have an internal "Safety and Environmental Assurance Centre" to ensure all products and ingredients are assessed for safety to consumers, workers and environment before they go to market. This team works closely with the Science and Technology team early on and in an ongoing manner to ensure the use of the material is safe. Environmental risk assessments are undertaken to look at environmental fate, biodegradability, aquatic toxicity and exposure in the environment to ensure safety can be demonstrated.

8.2 Surfactants

USE OF SURFACTANTS AND REASONS FOR SURFACTANT CHOICE:

All the companies use a mix of surfactants. **PZ Cussons** noted they use a relatively small portfolio of surfactants, which makes it easier to manage technical issues and supply chain procurement. They mainly focus on commoditized surfactants such as ethyl sulphates and betaines. They use linear alkylbenzene sulphonic acid (LAS), mainly in laundry and dishwasher detergents. **Henkel** noted they use all of the 3 main kinds of surfactants including in combination: anionic, non-ionic and cationic; cationic surfactants are used in fabric finisher. **Unilever** use anionic, non-ionic and cationic surfactants in their portfolio.

BIODEGRADABILITY:

The three companies noted the importance of biodegradable surfactants, and that is regulated in the EU and Australia (AS4351).

PZ Cussons noted that the biodegradability was key to selection of surfactants and they specify a low C14 content in linear alkylbenzene sulphonic acid. They noted that they could source cheaper surfactants but biodegradability would be impaired. They specify that they cannot use BAS as it has poor biodegradability, and instead use LAS. They noted that there are still products on the market from other companies that use BAS.

Henkel noted that all surfactants they use are biodegradable. The anionic and non-ionic surfactants are all biodegradable according OECD Standard 301, and are labelled with this standard in Germany. Henkel noted that in the 1980s cationic were not biodegradable and there was public concern around this, so they looked for alternatives along with surfactant manufacturers. In the 1990s switched to alternatives that were biodegradable by the time they get to wastewater treatment plants.

Unilever noted that all anionic and non-ionic surfactants used in home care and beauty and personal care are readily biodegradable according to OECD methodologies. This is required in EU but applied across the business. Their internal standard on biodegradability has been in place for decades. It should be noted that Unilever has one minor cationic surfactant in use (<1%) which is slower to biodegrade and does not meet their internal standard. This is used in a few countries because of a technical issue on product stability, but they are actively working on removing it.

TOXICITY:

The companies interviewed noted that the surfactants do not generally pose environmental toxicity risks. They did not discuss information about the toxicity of specific surfactants. **Unilever** noted that the toxicity of any specific ingredient does not by itself reflect a "level of concern" posed by that ingredient, as environmental risk assessment needs to consider both hazard properties, like toxicity, with assessment of the environmental exposure of the ingredient, for example whether the ingredient biodegrades rapidly.

All the companies use LAS (which is used widely for laundry powders as the primary surfactant in majority of the world). **PZ Cussons** noted that in terms of environmental impacts, LAS has recently received the most attention, as millions of tonnes of LAS are produced each year and most is used in the manufacture of laundry products. PZ Cussons permit use LAS based on guidance from HERA, but noted they would consider alternatives if they were available.

RISK ASSESSMENT:

All three companies have a similar risk assessment process to that used for phosophates and alternatives. In addition, **PZ Cussons** noted that having a small portfolio of surfactants has benefits from a procurement standpoint, and for internal specifications on products and materials. **PZ Cussons** and **Unilever** noted that the HERA are useful and informative assessments. **Unilever** noted they use more up-to-date information to guide ingredient selection including internal safety assessment. **Henkel** also mentioned the ERASM research program jointly launched 20 years ago by AISE with CESIO (surfactant manufacturers association) to undertake research on surfactants and their impact on the environment and human health.

DERIVATION OF SURFACTANTS (PETROCHEMICAL AND OLEOCHEMICAL) AND CONSIDERATIONS

All three companies use both petrochemical and oleochemical (plant based) sources as the feedstocks for their surfactants, dependent on availability and product application.

PZ Cussons noted that their laundry powders use LAB which is petrochemical derived and sulfates are used for liquid applications which are generally derived from palm kernel oil. The majority of their surfactants are oleochemical based, with either palm kernel oil or coconut oil. The choice is dependent on application and cost effectiveness, as both petrochemical and oleochemical feedstocks are commoditized and therefore quite volatile.

Henkel noted that the feedstock depends on geography and availability. They are aiming to have more oleochemical based surfactants in their products. They have some green products which have the EU Ecolabel or Blue Angel label in Germany, and in the ratio must be greater than 60% naturally derived surfactants in these products.

Unilever have a mix of both petrochemical and oleochemical sources of surfactants. Their oleochemcials are dominated by palm kernel oil (generally anionic and non-ionic), with some small amount of palm oil (cationic). They noted the feedstock is not determined by product type but by brand and geography.

SUSTAINABILITY OF PETROCHEMICALS AND OLEOCHEMICALS

All three companies discussed the sustainability debates around oleochemicals, in particular palm oil, and all are involved in international sustainability initiatives.

PZ Cussons noted that palm oil has had negative press around deforestation and agricultural practices, but it also has high yields compared to other alternative feedstocks e.g. coconut oil. PZ Cussons recently released their internal approach to responsibility and sustainability of palm oil called Palm Promise. They are involved with Roundtable on Sustainable Palm Oil (RSPO) but see this as going further. They are implementing a mechanism to trace supply back to the mills so they can better understand the sustainability of what they are sourcing, They noted that they are ongoing debates within the broader industry around the sustainability of oleochemicals compared to petrochemicals In addition shale gas from north America has shifted the conversation as it has lowered the cost of petrochemicals.

Henkel also noted the public discussion about oleochemicals, and public demonstrations were held protesting against other companies who sourced palm oil but did not have sustainability certificates. Henkel is part of the RSPO and noted their needs to be balanced discussion on the benefits of oleochemical and petrochemical feedstocks.

Unilever noted that they were involved with the formation of the RSPO. They were involved with making sure the organisation built robust approaches in certification scheme, for example to make sure land-use change, avoiding deforestation and use of peat-lands was included in certification.

8.3 Company risks

Companies are most at risk if they sell phosphate containing products, particularly in regions with inadequate wastewater treatment. The companies reviewed in Section 8.1 above have removed or are in the process of removing phosphates, even in markets where not required by regulation.

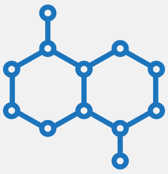
For companies who have not removed phosphates, continuing to manufacture these products is a company risk. Even where consumer products are not the main contributor to nutrient pollution compared to other sources, there is a still a risk of public attention on consumer product companies which could lead to calls for removal.

All the companies interviewed use majority biodegradable surfactants. As noted above, the environmental impact of any one surfactant depends on its environmental fate. However, there are many types of surfactants used overall by the sector in large volumes, entering different environments. The overall impact of surfactants is not known, because it is not comprehensively understood what or how these multiple types of surfactants might interact in different environments. There is furthermore a risk for other companies who continue to use surfactants that have poor biodegradability.

8. Company practices and perspectives

continued

Summary conclusion:



PHOSPHATES from consumer products no longer pose a risk to ecosystems in countries or states where these products' ingredient levels are regulated or restricted through voluntary initiatives, such as in Australia, the EU, USA, Canada, Japan and Brazil. The main substitutes (e.g. Zeolites) for phosphates are not considered to be harmful to the environment. Many large consumer product manufacturers, including the specific companies interviewed for this research, have eliminated or plan to eliminate phosphate from laundry and dishwasher detergent liquids and powders. Some of these companies have committed to this across all markets, even where there are no restrictions.

Nevertheless, there are many other locally manufactured products containing phosphates which are sold and continue to pose a risk to ecosystems in countries such as: India, Russia, China, Philippines, Indonesia and Bangladesh.

SURFACTANTS can cause frothing in waterways if they are not sufficiently biodegradable. The companies interviewed for this research noted that biodegradability is a key factor influencing surfactant ingredient choice, and that standards are regulated in countries such as Australia and the EU.

The companies interviewed for this research noted that surfactants they use are not ecotoxic. There is less comprehensive scientific knowledge about the ecotoxicity of the many types of surfactants used in consumer products, although some specific surfactants that tend to persist when in the environment are known to have ecotoxic properties and others are known to biodegrade into more toxic compounds. Thus some surfactants could possible cause ecosystem harm if present at high concentrations.

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Appendix: Interview questions

Phosphorus

1. Does your company sell any household products containing phosphorus (P), e.g. laundry or dishwasher powders? If yes:

   a. Which products/brands contain P?

   b. In what concentration?

   c. Which state/country/region are these sold in?

2. Did your company previously sell products with P (and now no longer does)? If yes:

   a. When was it removed from which product and why?

   b. What were the implications of removing P (e.g. change in alternative ingredients/ formulations)

   c. What kind of testing/analyses has been carried out to assess the environmental impact of these substitutes?

3. What, if any, barriers previously existed or currently exist to substituting the P ingredients in your products?

4. Does your company go beyond any regulations or industry agreements on the use of P in household and personal care products? (If yes, specify product and state/country)

5. Does your company have an official policy with regard to the use of P in your household products?

6. Does your company disclose ingredients and concentrations?

   a. Are you required to do this or is it voluntary?

   b. Does your company specifically market any products as "low-phosphorus" or "phosphorus-free"?

Surfactants

1. Can you please provide details of the type of surface active agents / surfactants used in your products? (please supply additional documentation/ingredients lists if available).

2. Are there any known environmental impacts from these surfactants?

   a. Are they known to degrade in the environment?

   b. What kind of assessments and/or testing is carried out to assess the environmental impacts of surfactant ingredients?

3. Which of your products use plant-derived surfactants versus petroleum derived, or other? (% share of products if known)

   a. What source are the plant-derived surfactants derived from? (e.g. palm kernel?)

Sustainability of the industry

1. What steps should the industry as a whole be taking to reduce the environmental or health impacts from household products?

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