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PAPER BY UMWELTBUNDESAMT ON THE RELEVANCE OF PROFESSIONAL LAUNDRY AND MACHINE DISHWASHING ON THE ENTRY OF PHOSPHATE AND OTHER PHOSPHORUS COMPOUNDS (P) INTO WASTEWATER

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Summary:

In June 2021 the German Federal Environment Agency published a research document aimed at determining the relevance of professional laundry and machine dishwashing with regard to the entry of phosphate and other phosphorus compounds (P) into the wastewater.

In a first step, an overview of the various technical processes used in professional laundry and machine dishwashing is given. Further, the question of where phosphates could already be eliminated today or where phosphate is essential for optimal cleaning – taking hygiene, energy, and water consumption into account – is addressed. Based on the quantities of phosphorus used in professional laundry and machine dishwashing, an assessment of the impact of a reduction in the use of phosphorus in the commercial sector on water quality is made.

The assessment shows that the sector contributes circa 0.7 to 1.6% of the total P_{total} inputs to surface waters. This supports that in the upcoming review of the Detergent Regulation the phosphorous restrictions currently applied to consumer laundry and automatic dishwash, should not be extended to other product categories. Such a reduction is not expected to result in a measurable change in water quality or a measurable contribution to the objectives of the Water Framework Directive.

Link to full original document: [Relevanz der gewerblichen Textil- und Geschirrreinigung am Eintrag von Phosphat und anderen Phosphorverbindungen (P) in das Abwasser | Umweltbundesamt]

Below are translations of sections of the document from the original version in German. The original numbering has been retained for reference.

1. Background and objective

The aim of the project is to review the current legal regulation on the phosphorus limit in the Regulation for professional and industrial detergents and cleaning agents. In this context, the state of the art of professional laundry and machine dishwashing, especially regarding the use of phosphates and other phosphorus compounds, is to be presented and processes identified which can cause or avoid phosphorus emissions. The effect of the avoidance potential on the environment (including the expenditures in wastewater treatment plants) is to be presented accordingly.

Against the background of the requirements under EU law for the regulation of national phosphorus limits, the project is intended to provide findings on the question of whether, in order to protect the environment, it is necessary to adapt the current phosphate limit in the regulation for detergents used in professinal textile cleaning to the technical progress and to extend the scope of the regulation to include professional machine dishwashing.

2. Procedure and Method

In work package (WP) 1, the first step consisted of a comprehensive literature and internet research. The aim of the research was to identify the use of phosphates and other phosphorus compounds in the professinal textile and cleaning industry. To present the state of the art regarding the use of phosphates and other phosphorus compounds, the processes of professional laundry and machine dishwashing as well as the respective areas of application and the products used for cleaning were considered.

In WP 2, data was collected from manufacturers of professional detergents and cleaning agents to obtain an estimate of the quantities of phosphates and other phosphorus compounds used in these agents. In addition, the open questions from WP 1 were discussed in dialogue with detergent and cleaning agent manufacturers, machine manufacturers, raw material manufacturers and users to close knowledge gaps. The aim of WP 2 was to quantify the use of phosphates and other phosphorus compounds in the professional laundry and detergent sector and to clarify open questions from WP 1. For the quantification four ways were identified, which can represent the total input quantities:

1. A survey of manufacturers of commercial detergents and cleaners
2. A survey of raw material manufacturers on the quantities of phosphorus compounds sold to commercial detergent manufacturers
3. A calculation of the phosphorus compound content in professional detergents, combined with the production statistics of these products
4. A calculation of the utilization with an estimation of the current German machinery

In WP 3, the wastewater regulations and requirements with regard to the limitation of phosphorus emissions as well as their technical implementation are presented. In addition, it is examined whether a limitation of phosphorus in professional detergents and cleaning agents would result in a reduction of phosphorus emissions to water bodies. Based on the results of WP 1 and WP 2, corresponding freight calculations on a possible reduction of P inputs will be made and the possible cost saving potential for wastewater treatment will be estimated.

In WP 4, the results of the three previous work packages will be combined and discussed against the background of Directive 2000/60/EC (EC Water Framework Directive) and the objectives for the Baltic Sea as they result from the Baltic Sea Action Plan 2007, which was adopted at the HELCOM ministerial meeting in 2007.

Professional dishwashing

3.1 Results of the interviews on professional dishwashing

Table 3-5: Product types, application areas and functions of phosphorus compounds in detergents and cleaning agents

	Phosphoric acid	Phosphates	Phosphonates
Product type	Industrial cleaner Kitchen cleaner Sanitary cleaner Descaler	Kitchen cleaner Industrial cleaner Basic cleaner Dishwashing detergents Parts degreaser	Laundry disinfection Parts degreaser Machine dishwashers Industrial cleaners Detergents
Application area	External train cleaning with water treatment and partial recirculation Decalcification/acid cleaning with simultaneous disinfection, main field of application is swimming pool cleaning	Hospital hygiene for dishwashing with disinfecting effect. Heavily soiled work clothes, so-called "blue man's wash".	Bleach stabilizer Corrosion inhibitor Dispersant Hardness stabilizer
Function	Cleaning booster Limescale remover Corrosion inhibitor	Bleach stabilizer Corrosion inhibitor Dispersant Hardness stabilizer Cleaning booster The only builder that is stable in combination with chlorine as a disinfecting agent (no other disinfecting agent can be used in this application for dishwashing).	Bleach stabilizer Corrosion inhibitor Dispersant Hardness stabilizer Cleaning booster Active ingredient used to stabilize organic disinfectants such as peracetic acid

Source: IHO 2017

6.1 Requirements according to the Wastewater Regulation (AbwV)

The Wastewater Regulation determines the minimum requirements for the discharge of wastewater into water bodies.

Table 6-3: Origin of P_{total} in domestic wastewater in grams per person and day

P-origin	1975	1985	1990	1993	1999	2005
Metabolic products	1,6	1,6	1,6	1,6	1,6	1,6
Textile detergent	2,25	1	0,3	0	0	0
Household cleaner/detergent	0,75	0,6	0,15	0,04	0,2	0,24
Other P sources: laundry soils, drinking water conditioning, food residues	0,4	0,4	0,3	0,2	0,1	0,05
Total	5,0	3,6	2,35	1,84	1,9	1,9

Source: Barjenbruch 2009

6.4 Effects due to a reduced phosphorus entry

It can be assumed that the wastewater treatment plant operators will react to changed effluent values within the framework of control and regulation and reduce the precipitant dosage, since they will now also reliably comply with the discharge values with lower precipitant use. In this case, cost savings for the operation of the wastewater treatment plant would result from the reduced amount of precipitants and the reduced amount of sewage sludge.

6.5 Entries into water bodies

In total, this results in 4,044 t P_{total} from phosphoric acid and phosphates. In addition, 2,000 t of phosphonates were mentioned for all applications. In total, therefore, around 4,800 t of phosphorus are used in professional and industrial detergents and cleaning agents in Germany.

In total, therefore, a maximum of 12,914 t P_{total}. This is compared with the effluent load from non-domestic wastewater of 8,844 t/a P_{total} determined in Chapter 6.2. In this respect, inputs from commercial textile and dish cleaning of more than 8,844 t / a P_{total} can be ruled out.

Rather, it must be considered that, in addition to inputs from professional textile and dish cleaning, other non-domestic inputs also contribute to the total of 8,844 t / a P_{total}. Such inputs may originate, for example, from food processing and beverage bottling plants. The respective local defaults define the requirements for indirect dischargers (i.e., dischargers into the municipal sewer system). The requirements in these local statutes can vary widely. For example, the limit value for discharges into the public sewer system in Darmstadt is 15 mg P_{total} / L, 50 mg P_{total} / L in Berlin and in Freiburg no limit value is specified at all, but only a threshold value above which an increased wastewater fee must be paid for heavily polluted wastewater.

As a result, approx. 1% (corresponding to approx. 40 tons per year) of the P load from phosphates introduced via professional and industrial detergents and cleaning agents could enter water bodies without treatment.

The estimate is conservative (rather too high) in that during the discharge period, a significant portion of the wastewater load still continues to reach the treatment plant and is treated there.

The estimate continues to be conservative (tends to be too high) because the calculations did not take into account that professional indirect dischargers of the professional application of laundry and dish cleaners may have wastewater pre-treatment (with phosphorus removal) prior to discharge to the sewer system. In addition, it can be assumed that very few businesses operate on a 7 day / 24 hour basis, to the extent that the likelihood of the emissions and precipitation events coinciding with combined sewer discharges is reduced. Therefore, it can be assumed that discharges to water bodies from combined sewer overflows tend to be less than 40 t/a.

7. Summary of the results

7.1 Application quantities of phosphorus-containing detergents and cleaning agents

The total phosphorus quantities emitted via commercial and industrial detergents and cleaning agents based on the input quantities of phosphates, phosphonates and phosphoric acid provided by the IHO are shown. In total, this amounts to about 4,800 t per year, of which almost 3,500 t are accounted for by phosphates alone. The remaining approx. 1,300 t are divided between phosphonates (750 t) and phosphoric acid (550 t), whereby the figure for phosphoric acid relates primarily to industrial cleaners.

Calculations based on the machine fleets, the test cleaners (only for dishwashing) and the sales quantities result in a range of 0 to 35,499 t phosphate as well as 318 to 3,524 t phosphonate. This corresponds to an application quantity of 0 to 11,582 t P from phosphate and 120 to 1,332 t from phosphonate. In total, therefore, a maximum of 12,914 t P.

This compares with the influent load from non-domestic wastewater of 8,844 t / a P_{total}. These consist not only of discharges from professional textile and dish washing, but also from food processing including beverage bottling plants to small businesses such as butcher stores that have grease traps but no retention for phosphates. The maximum value of 12,914 t P calculated above is therefore not plausible in this respect, but much lower inputs must be assumed.

Against the background of this overall picture, a range of 3,000 to 5,000 t P from phosphates (and phosphoric acid) originating from cleaners for commercial textile and dishwashing and from industrial cleaners was assumed for the calculations of emissions to water bodies.

A range of 120 to 1,332 t of phosphonates was used for emission calculations from phosphonates.

7.2 Factors influencing the use of detergents and possible applications for phosphorus-free detergents and cleaners

As a result of the complex interrelationships, there is no state of the art that relates exclusively to the use of P-free cleaners. Several influencing factors have common economic and ecological effects as shown in Table 7-1, Table 7-2 and Table 7-3. There, the factors, characteristics and effects of phosphorus-containing detergents and cleaners in different applications are listed according to the literature data, the interviews, and the on-site visits.

Table 7-1: Applications for P-compounds in professional dishwashing

Influencing factors/requirements	Applications and properties of phosphates	Applications and properties of phosphonates
Temperature	Phosphate increases the dirt carrying capacity and thus lowers the necessary maximum temperature. Large parts of the current machinery are designed to save water and energy and must be retrofitted/replaced accordingly if phosphate is not used	
Water quantity	Phosphate increases the dirt carrying capacity and thus reduces the demand for water. Large parts of the current machinery are designed to save water and energy and would have to be retrofitted/replaced accordingly if phosphate were not used.	
time	The cleaning duration is related to temperature, cleaning mechanics and chemistry via Sinner's circle; short cleaning durations mean an increase in temperature or an amplification of chemistry. Such amplification is achieved in practice by the use of phosphates.	
Pollution type	Stubborn soiling (e.g., greasy or protein-containing soiling) combined with short cleaning times, low temperatures and little water can only be removed with strong cleaning agents.	
Dishes quality		Dishes with porous surface (e.g. porcelain of inferior quality) can be cleaned only

		via bleaching agents, which must be stabilized.
Dirt load	High dirt loads can only be dispersed via phosphate, alternatively temperature and water quantity must be increased	
Hygienization/bleaching effect	Only phosphate can stabilize active chlorine compounds and these are necessary in sensitive applications (e.g. hospital tableware)	Disinfectants and bleaching agents must be stabilized, otherwise they will not develop their desired effect
Incorporated metal ions (e.g. rust)		Incorporated metal ions, such as iron or manganese, catalyze the decomposition of disinfectants and bleaches and must be complexed with phosphonates
Incorporated calcium ions (e.g. from dairy products)	Calcium and magnesium must be stabilized, this can be achieved most efficiently with phosphate	
Detergent application quantity	Phosphate increases the dirt carrying capacity and thus reduces the need for cleaning agents	

Source: Summary of results from interviews

Table 7-2: Application cases for P-compounds in commercial textile cleaning

Influencing factors/requirements	Applications and properties of phosphates	Applications and properties of phosphonates
Temperature		The temperature can be used for sanitizing, but this destroys textiles and costs correspondingly more energy.
Pollution	Phosphate-containing detergents are used for special soiling (especially particulate soiling such as road dust, paint pigments, metal abrasion or lipstick).	
Residual moisture/water hardness	Calcium and magnesium must be stabilized. Phosphate is used for this as far as necessary	
Hygienization/bleaching effect		Disinfectants and bleaching agents must be stabilized, otherwise they will not develop their desired effect
Incorporated metal ions (e.g. rust)		Incorporated metal ions, such as iron or manganese, catalyze the decomposition of disinfectants and bleaching agents and must be complexed with phosphonates, otherwise destruction of the textile is to be feared
Application quantity detergent	Due to the industry's switch to phosphate-free basic detergents, the amount of detergent used had to be increased	Application quantity detergent

Source: Summary of results from interviews

Table 7-3: Applications for P compounds in industrial cleaners

Influencing factors/requirements	Applications and properties of phosphates
Corrosion protection	Surface protection is provided by phosphate, substitutes such as organic/mineral acids attack surfaces
Pollution	Protein-rich soiling (e.g. in slaughterhouses) is efficiently removed by the use of phosphoric acid
Dirt load	High dirt loads in closed applications (CIP cleaning) are usually dispersed via phosphate
Application quantity detergent	Due to the change in the industry to phosphate-free basic detergents, the amount of detergent used had to be increased

Source: Summary of results from interviews

According to the statements in the interviews, a formulation for dishwashing detergents with phosphates must contain at least 5 % sodium tripolyphosphate (corresponds to 1.3 % P) or, in the case of phosphonates, at least 2 % phosphonate compounds (corresponds to 0.2 % P) in order to achieve a technically relevant effect. For the textile cleaning sector, these limit values are 2 % sodium tripolyphosphate (corresponds to 0.5 % P) or 2 % phosphonate compounds (corresponds to 0.2 % P). These limit values originate from practice; relevant generally accepted rules of technology or publications on the state of the art are not known to the authors and the interviewed practitioners.

In the area of dishwashing, additional use of water, energy and detergents would be necessary, since phosphates significantly increase the dirt carrying capacity of the liquor and the substitute products do not allow such a high concentration of dirt in the liquor. Large parts of the current machinery are designed to save water and energy and would need to be upgraded/replaced accordingly if phosphates were not used. For the most part, substitution has already taken place for detergents, but it is still necessary to use phosphates in individual cases (particularly stubborn soiling) to achieve the desired cleaning result.

In the field of industrial cleaning, it is mainly the corrosion-inhibiting effect, in addition to water softening, which necessitates the use of phosphates in the form of phosphoric acid. Cleaning can also be realized with alternative mineral acids or carboxylic acids, but with some alternatives this leads to corrosion of surfaces. Phosphonates are important in this case because they also have a corrosion inhibiting effect.

Phosphonates are found in professional detergents and cleaners, but also in industrial cleaners. The most important task of phosphonates is to stabilize bleaching and disinfecting agents by complexing metals that catalytically accelerate the decomposition of these agents, for example iron or manganese. In addition, they have a corrosion-inhibiting effect. Substitution of phosphonates is difficult for various reasons. For example, cleaning performance suffers because bleaching and disinfecting agents are not quite as well stabilized by alternative stabilizers such as EDTA and thus cannot develop their full performance. In the case of disinfectant detergents, this means that disinfection can no longer be realized with the current washing parameters and other processes must therefore be developed. Thermal disinfection is possible, but this would destroy a large part of the laundry used today, as it is not designed for high temperatures. In addition to this weakening of the disinfection effect, some of the phosphonate alternatives are attacked by the bleaching and disinfection agents, which means that both these and the stabilizers have to be overdosed. In addition, the alternatives usually have to be used overstoichiometrically because they can only bind one ion. In the case of EDTA, this is compounded by the fact that it passes through wastewater treatment plants in high proportions and thus enters natural waters.

7.2.1. P-free applications in professional dishwashing

From interviews with the stakeholders, it emerges:

A complete abandonment of P-containing cleaners is currently realized in the cleaning of lightly soiled glasses (without proteins) and the use of fully demineralized water.

Using 5 times the amount of water, energy, and detergent and approximately twice the contact time, cleaning dishes without P compounds would be possible in old 3 to 4 tank machines. However, removal of stubborn soiling such as coffee or tea rims is not always completely possible. However, such an operation is currently not economical compared to the alternatives and is therefore not used in professional practice.

According to the current state of the art, professional dishwashers use only ¼ of the amount of water in the freshwater rinse and the regeneration water of the wash tanks is only 1/10 of the amounts used in 1980. For the same rinsing performance, the detergent solution must therefore carry and disperse more dirt.

Without phosphonate in the detergents, these dirt and hardness components from the water and the dirt (calcium/magnesium) cannot be kept in suspension. This results in fouling and clogging of the washing systems and then also in deposits on the wash ware. Phosphate-containing detergents, on the other hand, can be dispensed with in some current plant configurations.

7.2.2. P-free applications in professional laundry

From interviews with the stakeholders, it emerges:

According to the current state of the art, phosphorus compounds can currently be dispensed with altogether for lightly soiled laundry without blood and food residues. Bed linen from hotels does not fall under this category, as these are bleached and thus require phosphorus compounds. The same applies to hospital laundry, which must also be sanitized.

Phosphates are usually not used in basic detergents, but in additional washing aids such as washing boosters. Phosphonates are difficult to replace as stabilizers of bleaching and disinfecting agents in detergents and would require a change in current washing processes (more water, more temperature, more detergent).

7.3. Reductions in entries to water bodies

Since phosphates in dissolved form ($PO^{4}{}_{3-}$) are already predominantly retained by precipitation in wastewater treatment plants up to a certain concentration, there is a slight minor relief of surface waters due to a theoretically conceivable reduced P_{total} input from phosphates as a result of possible new regulations for professional cleaning agents. As shown in Chapter 6.5, the (conservative, i.e. tending to be too high) estimates result of entry of between 167 and 369

t P_{total} / a, corresponding to about 0.7 to 1.6 % of the total Pges inputs to surface waters.

Such a reduction is not expected to result in a measurable change in water quality or a measurable contribution to the objectives of the Water Framework Directive.

The contribution to the German reduction targets defined in the Baltic Sea Action Plan 2007, according to which a reduction of P_{total} inputs by 240 t / a is to take place in the Baltic Sea catchment area, would only be small. Assuming that emission reductions are proportionate to the 3.3 million inhabitants in the Baltic Sea catchment area (BLANO 2014), this results in a theoretically avoidable P_{total} input of 167 to 369 t / a * 3.3/82.7 = 6.7 to 14.7 t P_{total} per year, corresponding to 2.7 to 6.1 % of the reduction target of 240 t P_{total} per year.

7.4. Resource aspects

With the recovery of phosphorus from sewage sludge, up to 40% of the applied fertilizer quantity of 110,000 to 120,000 t P / a could possibly be covered (Pinnekamp 2013). A complete reduction of phosphates (and phosphoric acid) in cleaners for professional laundry and dishwashing, as well as the additional quantities collected in industrial cleaners, could avoid the consumption of 3,000 to 5,000 t P / a plus up to 1300 t P in phosphonates. This saving in phosphorus resources is offset by a currently unquantifiable additional expenditure of energy and water resulting from the necessary change in washing and cleaning processes. In addition, there is also an additional expenditure of resources for the production of the substitutes.