



ASSESSMENT OF THE LEVELS OF PHOSPHATE IN DETERGENTS SAMPLES

V. E. AGBAZUE*, N. R. EKERE and Y. SHAIBU^a

Department of Pure and Industrial Chemistry, University of Nigeria, NSUKKA, NIGERIA

^aDepartment of Pure and Industrial Chemistry, Bayero University, KANO, NIGERIA

ABSTRACT

The concentration of phosphate in some commercial detergents commonly used in homes, laundry services, schools and offices in Kano Metropolis have been determined. The analyses were carried out on both local and foreign detergents using a spectrophotometric method. The method was based on the formation of phosphomolybdate with added molybdate ion followed by its reduction with sodium sulphide in aqueous tetraoxosulphate (VI) acid medium. The system obeys Lambert-Beer's law at 715 nm in the concentration range 0.30-12.24 mg dm⁻³ and the data were computed using percentage and t-test. The values obtained for local detergent brand samples were: Bn (0.041%), Om (0.066%), Gn (0.013%), Bb (0.046%), Br (0.046%), Kl (0.035%), Bp (0.053%), Ep (0.010%), Zp (0.025%), Jb (0.014%), and Ar (0.042%) while those of the foreign detergents were Ps (0.005%), Td (0.042%), Lk (0.027%), Ta (0.022%), Dm (0.007%), Bg (0.005%), Bs (0.026%), Kn (0.031%), and Lb (0.006%). The internationally accepted level of phosphate in detergents is 0.5%. Thus, the concentration of these detergent samples fall within the set limit. This study has revealed that continuous use of these products could result in an increase in the phosphate levels in laundry discharges into soil, ponds, lakes and rivers. Excessive amount of phosphate has long been implicated in the eutrophication of surface water bodies, as such, to promote lake/river recovery and improve trophic status. It is imperative that phosphate loads in surface waters are reduced.

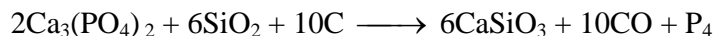
Key words: Phosphate, Detergent, Local, Foreign, Pollution, Standard.

INTRODUCTION

Phosphorus is the eleventh most abundant element on the surface of the earth and is most commonly found as phosphate. In nature, phosphate rocks include fluoroapatite, 3Ca₃(PO₄).CaF₂, chloroapatite, 2Ca₃(PO₄).CaCl₂ and hydroxyapatite, 3Ca₃(PO₄)₂.Ca(OH)₂, calcium iron phosphate Ca₂Fe(PO₄).4H₂O. Fluoroapatite, 3Ca₃(PO₄).CaF₂ is the chief

* Author for correspondence; E-mail: agbazuestars05@yahoo.com; Ph.: +2348068283058

ore of phosphorus. The phosphorus is removed from the ore by first grinding it to remove large lumps, and then heating it in a mixture with sand (silica, SiO₂) and coke (carbon). The reactions take place at around 1500°C using an electric arc furnace. The key reaction is –



The product, which is white can be converted into red phosphorus by heating at 400°C for some hours¹.

Phosphates are added to detergents as builders in the form of sodium tripolyphosphate and sodium pyrophosphate. The excessive use of phosphate as water softeners is criticized by environmentalists, since it contributes to water pollution. The phosphates in domestic waste water pass through sewage disposal systems into rivers and lakes. There they nourish bacteria, which grow excessively and deplete the water of dissolved oxygen, thus killing fish. The phosphates may also produce massive overgrowth of water plants. When this crop of plant dies, there will be excessive decay and putrefaction, which may also kill the fish¹.

In addition, excessive phosphates are known to accelerate the natural aging of lakes (eutrophication). They enter water ways as run off from agricultural lands as fertilizer and as human and animal waste. The largest source of phosphorus entering the environment is synthetic detergent, which contains phosphate compounds to soften water, increase the pH of water, and increase surfactant efficiency.

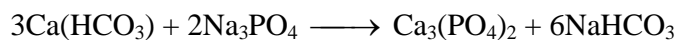
In the mid 1960s, many of the nations' rivers and lakes were rapidly turning green and choking with aquatic plant growth. It was later observed that the primary reason for these deleterious changes in water quality was the high levels of phosphorus, one of the several major plant nutrients, found in domestic and municipal sewage effluents. The principal source of effluent phosphorus was from phosphates used in laundry detergents².

The general feeling around the late 1960s was that many nations' lakes and streams were getting more polluted each day, and phosphate detergents were the primary reason. Half the phosphorus input to lakes Erie and Ontario came from municipal and industrial sources of which 50% to 70% came from detergents. Over half of the phosphorus input to the Potomac estuary also came from detergents in municipal and industrial effluents³. It was generally agreed that detergents accounted for about 50% of the waste water nationwide⁴. There was a

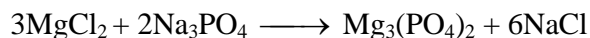
growing public consensus that in order to save lakes (like Lake Erie), phosphates must be banned from detergents.

Detergent is an substance, which has the ability to clean an object. A detergent may be regarded as a surface active agent (surfactant) particularly effective in dislodging foreign matter from soiled surfaces and retaining it in suspension. The term usually denotes a synthetic substance that is not prepared by saponifying fats and oils⁵. The most important advantage of the synthetic detergents is better wetting and cleansing action and no consumption by hard water because of higher solubility of their Ca^{2+} and Mg^{2+} ions⁶.

Phosphates perform many functions in washing powders and detergent. They soften hard water by binding with calcium ions and magnesium ions. In this way they prevent the lime in water from depositing or settling on the textile fibre. If the water is hard and contains dissolved lime, its ability to dissolve soap decreases and the cleansing powder deteriorates. Treating hard water with trisodium phosphate leads to a highly soft water of approximately 0.03 mg eq/dm^3 ; with the chemical reactions as shown below⁷.



From hard water



From hard water

Moreover phosphates stabilize the alkalinity of the surfactants. They keep the dissolved dirt in the water and prevent it from penetrating back into clothes⁶.

Soon after World War II, the soap industry began to develop synthetic detergent as a way to deal with the dual problems of –

- (i) Competing with food and feed industries for a limited supply of natural fats and oils, and
- (ii) Poor cleaning performance in areas with hard waters⁸.

In some brands of detergents, as much as half the total weight consists of inorganic phosphates such as $\text{Na}_5\text{P}_3\text{O}_{10}$, which form very stable complexes with cations such as Ca^{2+} , Mg^{2+} and Fe^{2+} that would otherwise interfere with the cleansing action of detergents. In addition, detergents containing phosphates pose a serious threat to the environment.

Phosphorus, which is an important plant nutrient, occurs widely in the environment and in the aqueous environment the phosphorus greatly encourages microbial growth which is undesirable. The determination of phosphorus is therefore of importance to chemical analysts and limnologists. Detergents, sewage and fertilizers are known to be the major sources of phosphorus and the level of 0.03-0.40 mg dm⁻³ of total inorganic phosphate had become the maximum acceptable level in water⁹.

Typically, the formulation of synthetic laundry detergents consists of a surfactant, a builder, and other miscellaneous ingredients including brighteners, perfumes, antiredeposition agents and sometimes enzymes¹⁰. The surfactant is a surface active agent, which dissolves partly in water and partly in organic solvent because of its dual hydrocarbon and polar character. As a wetting agent, it enables dirt to float off the fabric surfaces. Alkyl benzene sulphonates (ABS) are considered as the most commonly used surfactants. Surfactants decreased the surface tension of water, so that, they penetrate the surface and interstices of the object being cleaned and thus removes the dirt. Release of ABS into streams and rivers resulted in floating flotillas of foam, which is a public nuisance. Through public pressure, however, manufacturers have changed to the biodegradable Linear Alkyl Benzene Sulphonates (LABS)¹¹.

The builders in detergents are usually sodium phosphate (poly phosphate) of the type Na₅P₃O₁₀ or Na₄P₂O₇ acting as a sequestering agent. The builders have the ability to form chelated complexes with polyvalent cations such as calcium and magnesium ions, which otherwise interfere with the surfactant. The builder is particularly necessary in hard waters⁴, without which, manufacturers would have to add more surfactants to the detergent formulation with subsequent increase in the product price.

Phosphates are also known to help peptize and suspended certain types of particulate matter, and aid in killing germs¹⁰. Phosphates detergents are generally safe to use with minimal toxicity problems. The major drawback is that secondary waste water treatment removes only a small percentage of phosphorus from the effluent, so a considerable amount of phosphorus is released to streams, rivers, lakes and estuaries through waste water effluent².

Phytoplanktons are microscopic, free-floating algae, which live in all surface waters. Algae are plants, which utilize sun-light together with soluble nutrients extracted from the water for their growth and reproduction. Algae require primarily carbon, nitrogen and phosphorus to grow. Following Leibig's law of the minimum, the rate of algae growth (i.e. productivity) is controlled or limited by the nutrient in least supply relative to demand¹². Although algae are about 50% carbons, the relative abundance of dissolved carbon (IV)

oxide and carbonates in natural waters rarely makes carbon the limiting nutrient. In most temperate fresh water, phosphorus is the limiting nutrient even though algal cells are less than 1% phosphorus¹². Thus, the rate of algal growth is proportional to the supply or input of phosphorus.

In itself, phosphate is not harmful but is a natural and essential macronutrient for all living organisms. Normally, the phosphate concentration of surface waters is so low that it is a limiting factor for growth of algae and higher plants. Consequently, when excess phosphate is released into the aquatic environment, the resulting over fertilization, leads to increased growth of algae.

Lakes naturally receive carbon, nitrogen, phosphorus and other algal nutrients from rainfall and runoff. Overtime, as lakes receive more nutrients they naturally become more productive. Eventually lakes will be filled with organic matter, turn into bogs, and develop into dry land. This natural process of nutrient enrichment, or eutrophication, can easily take tens of thousands of years³. In the 1960s the term “cultural eutrophication” was coined to describe the accelerated nutrient enrichment of lakes and rivers from man-made origins, including industrial, agricultural and municipal sources¹³.

Eutrophication is the process by which the nutrients in a water body increase resulting in an increased rate of productivity, generally of phytoplankton and of macrophytes in shallow waters. The algae content increase in the water and the subsequent death of algae bloom leads to consumption of the oxygen dissolved in water, creating hypoxic and at times, near anoxic situation. This excess eutrophication kills aquatic life and causes odour and increase in pathogenic organisms⁶.

There are many detrimental effects when a lake goes from pristine clear to pea soup green. If the lake serves as a source of drinking water, excessive algal growth clogs intakes, makes filtration more expensive, increases corrosion of pipes, and often cause taste and odour problems^{11,13}. Algae removal also increases filtration costs for industries using eutrophic waters. Anoxic bottom waters in turn produce hydrogen sulphide, releasing a rotten egg odour and negatively impacting on recreational use of water¹³.

The detergent regulations at the European Union level address exclusively the surfactant and their biodegradability. However, at national levels, regulations or voluntary agreements on the phosphate content of detergents in many countries, e.g. Austria, Germany, Italy, The Netherlands, Norway, Sweden, Switzerland, USA, Canada and Japan¹⁴.

Due to the concomitant secondary processes (organic load of waters, oxygen depletion after the organic bio-mass is microbially degraded), the overall water quality may be considerably reduced. Detergent phosphates released with laundry waste water are quickly converted into orthophosphate. Thus, the use of sodium triphosphate in detergent came under critical scrutiny although many other phosphate sources exist that contribute to eutrophication of surface waters¹⁴.

According to a study on phosphates in Germany in 1975, some 60% of the phosphate contained in municipal sewage originated from detergents and cleansers¹⁴. As a consequence of the partial removal of phosphate in sewage treatment plants and the input of phosphates by other sources (human excretion, food industry, agricultural fertilizers), the share of detergent phosphates in surface waters was estimated to be about 40%. This balance showed already that the reduction of phosphates in detergent is an important but not the sole factor in solving the eutrophication problem of surface waters¹⁵.

The most comprehensive approach involves chemical elimination of phosphates in the sewage treatment plant (tertiary treatment), removing the total phosphorus content of the wastewater. This approach is realized in some countries to a greater or lesser extent. Nevertheless, phosphate reduction in detergents, i.e. at its source, provides immediate relief to receiving waters and, ultimately, also to the coastal areas of the seas, which are increasingly confronted with eutrophication problems. The phosphate regulation of 1980 implementing the pertinent authorization of the German Detergent law of 1975 had a considerable impact on the development of the phosphate loads in German rivers. The phosphate reduction in detergents was enforced in a two-step decree starting with an overall relative decrease of 25% of the detergents' phosphate in 1981 and around 50% in late 1983. The second step required the availability of suitable phosphate substitutes for detergent. Their good performance in phosphate-reduced and free detergents and the acceptance of nonphosphate detergents by the customer has meanwhile led to a complete substitution of phosphate-containing detergents by phosphate free ones in many countries, for example in Europe, in Germany, the Scandinavian countries, Italy, Australia, the Netherlands, and Switzerland. Thus, the legal requirements on reduction or banning phosphates in detergents have been suspended in many cases by the industrial supply of efficient phosphate-free detergents and their acceptance by the consumer¹⁴.

The legislative pressure towards phosphate reduction in detergents accompanied by the availability of suitable substitutes has resulted in a noticeable quality improvement of a number of surface waters today¹⁶. Phosphate balances of the river Rhine in 1979 and 1989

showed that the measured phosphorus load reduction of about 28400^{t/a} within this period corresponded very well with the expected phosphorus reduction due to the use of phosphate-reduced or free detergents (26700^{t/a})¹⁷.

Several phosphate determination procedures have been reported, which include titrimetry, complexogravimetry, colorimetry, atomic absorption spectroscopy, flow injection analysis, HPLC and spectrophotometry methods. Among such methods, spectrophotometry involving molybdovanadate and ammonium molybdate are most commonly used. In ammonium molybdate spectrophotometric method, different reductants have been employed such as tin (II) chloride, ascorbic acid and 1-amino-2-naphthol-4-sulfonic acid¹⁸.

The major break through with respect to phosphate-reduced and nonphosphate detergents was the development and introduction of inorganic water insoluble sodium aluminium silicates of the zeolites A type. The ecological behaviour of this ion exchanger had been investigated in a comprehensive research program that was started in 1973. It covered laboratory tests and field trials conducted by experts from industry, water authorities, and academic¹⁴. It was shown that no excessive sedimentation of the insoluble particulate matter occurred in the household sewer systems and communal sewage systems. A major part of the load of zeolite A (about 60%) is already eliminated in the mechanical stage of sewage treatment plants (sand trap and primary settler) while total elimination is around 95% after passing the biological stage and the secondary settler. Although the mass of the sewage sludge is increased due to zeolite, no negative effects on the purification performance of the activated sludge and on the anaerobic amenability of the sludge in digester was found; no decreased retention of heavy metals in sewage plants has been detected in the presence of zeolite either. Investigations in the 1990s showed that zeolite A is quickly transformed into an extremely insoluble amorphous complex of basic calcium aluminium silicate phosphate under usual sewage treatment plant conditions¹⁹.

The main objective of this research is to determine and compare the levels of phosphates in detergents produced locally with those of foreign origin, relate the levels to world acceptable standard and hence assess pollutant impacts.

EXPERIMENTAL

Materials and methods

In the preparation of reagents, chemicals of analytical grade purity and distilled water were used.

Cleaning of apparatus

All glasswares as well as plastic containers including crucibles and pipettes were thoroughly washed using a detergent solution followed by rinsing in tap water and distilled water. The cleaned glasswares were finally dried in an oven overnight at 30°C.

Sampling

Different brands of powdered detergent samples were purchased from retail outlets, stores and open market in Kano, Northern Nigeria. The representative samples that were purchased and used for the purpose of this work include: Bp(Polythene), Bn(Carton), Jb(Polythene), Zp(Polythene), Ep(Polythene), Br (Polythene), Kl (Polythene), Gn(Polythene), Om (Polythene), Bb(Polythene), Ar (Polythene), Dm (Carton), Ps(Carton), Ta(Carton), Bs (Carton), Td (Carton), Bg (Polythene), Lk (Polythene), Kn (Polythene), Lb (Carton).

Sample preparation

5 g of each of the powdered sample was weighed into porcelain crucibles and placed in a muffle furnace set at 350°C for half an hour; fume was released and the obtained ash was transferred into a 150 cm³ beaker. It was dissolved with 50 cm³ water and the solution was made acidic by adding dilute tetraoxosulphate (VI) acid. It was then heated on a water bath at 99.9°C for about 10 minutes to expel the hydrogen sulphide and nitrite. The resulting solution was filtered into a 100 cm³ volumetric flask and diluted to the mark with water. The solution was used for its phosphate content analysis¹⁸.

Reagents

5.9 x 10⁻³ M Ammonium molybdate: 1.7081 g of ammonium molybdate ((NH₄)₆Mo₇O₂₄) was weighed and dissolved in a beaker containing 150 cm³ of warm water and solution cooled to room temperature. It was then transferred into a 250 cm³ volumetric flask and diluted to the mark with water¹⁸.

6.4 x 10⁻³ M Sodium Sulphide: 0.05 g of sodium sulphide was weighed and transferred into a clean 100 cm³ beaker. It was then dissolved with about 50 cm³ of water and the solution was transferred into a 100 cm³ volumetric flask. The beaker was washed 3-4 times with 5.0 cm³ water and washings were also added into the flask and the resulting solution diluted to the mark with water¹⁸.

0.125 M Tetraoxosulphate (VI) Acid: Tetraoxosulphate (VI) acid (0.125 M) was prepared by adding 6.9 cm³ of the concentrated tetraoxosulphate (VI) acid (S.G. 1.84, 98%)

to 500 cm³ of water in 1000 cm³ volumetric flask and the resulting solution diluted to the mark with water.

Standard solution of phosphate

0.3738 g of disodium hydrogen phosphate was weighed using a watch glass and transferred into a 150 cm³ beaker. 50 cm³ of water was added; the solution was transferred into a 250 cm³ volumetric flask and diluted to mark with more water. This was labelled as the stock solution and from which working standard solution was prepared by diluting 10 cm³ of the solution to 100 cm³ with water¹⁸.

Procedure for the determination of phosphate

A series of ten 10 cm³ volumetric flasks were labelled. To each flask was added 0.5 cm³ of 5.9 x 10⁻³ M ammonium molybdate, 3 cm³ of 0.125 M tetraoxosulphate (VI) acid and aliquots of disodium hydrogen phosphate, which ranged from 0.30-12 mgdm⁻³ (i.e. 0.10, 0.20, 0.30, 0.50, 1.00, 2.00, 2.50, 3.00, 3.50 and 4.00 cm³.) were added. Finally, to each flask, 1 cm³ of 6.4 x 10⁻³ M sodium sulphide solution was added as a reducing agent. Each solution was allowed to set at room temperature for about 20 minutes to enable full colour development. The absorbances of the solutions were taken at 715 nm¹⁸.

Instrumentation

Spectrophotometer

Visible spectrophotometer cell model 7400 with 1 cm matched quartz cells and a digital balance readable 0.001 was used. The spectrophotometer was turned on and allowed to warm up for 15 minutes. The wavelength was set to 715 nm. A cuvette containing the blank was inserted into the reference chamber, and the absorbance adjusted to zero.

The absorbance reading of each of the standard solution was measured, one after the other in ascending order to avoid interference. These were followed by the measurement of the absorbance of the detergent sample solutions.

Procedure for the measurement of the effect of ionic strength on the absorption properties of phosphate

Three sets of five 10 cm³ volumetric flasks were labelled. To each flask was added 0.5 cm³ of 5.9 x 10⁻³ M ammonium molybdate, 3 cm³ of 0.125 M tetraoxosulphate (VI) acid, aliquots of disodium hydrogen phosphate corresponding to 1.5 cm³ was added and 2 cm³ of

sodium trioxonitrate (V), sodium chloride and sodium iodide, which have a concentration range from 0.2 M to 0.8 M were added separately to each of the three sets. Finally, to each flask, 1 cm³ of 6.4 x 10⁻³ M sodium sulphide solution was added as a reducing agent. Each solution was allowed to set at room temperature for about 20 minutes to enable full colour development. The absorbances of the solutions were taken at 715 nm.

Procedure for the measurement of the effects of pH on the absorption

Properties of phosphate

A series of nine 10 cm³ volumetric flasks were labelled. To each flask was added 0.5 cm³ of 5.9 x 10⁻³ M ammonium molybdate, 3 cm³ of 0.125 M tetraoxosulphate (VI) acid, 1 cm³ of disodium hydrogen phosphate and 2 cm³ of a buffer solution with pH ranging from 3 to 11 was added separately to each flask. Finally, to each flask, 1 cm³ of 6.4 x 10⁻³ M sodium sulphide solution was added as a reducing agent. Each solution was allowed to set at room temperature for about 20 minutes to enable full colour development. The absorbances of the solutions were taken at 715 nm.

RESULTS AND DISCUSSION

Plot of the standard solution of phosphate

A linear relationship was found to exist between the absorbance of the system and concentration of phosphate (0.30-7.50 mgdm⁻³) with a straight line passing through the origin. The equation of the straight line has a correlation of 0.9997.

The effect of the changes of ionic strength of the solution on the absorption process of the technique was under-taken and it was noted that ionic strength does not affect the methodology. This can be seen from the graph of absorbance/ionic strength. Also the study on the effect of pH gave the plot as shown in Figure 1. This shows that there is no need for strict pH control when an analysis of this nature is being carried out.

On estimating the phosphate concentrations in each detergent samples from both local and foreign brands, it was discovered that there were inconsistent variations in the phosphates levels from one company to another and from country to country.

The phosphate levels in the locally available detergents ranged between 0.0100 ± 0.001-0.0662 ± 0.001 and those of foreign detergents ranged between 0.0047 ± 0.001-0.0305 ± 0.000. A critical examination of Table 1 and 2 revealed that local detergents like Om, Bb, Br, Bp, and Ar with percentage phosphate content corresponding to 0.0662%, 0.0462%,

0.0460%, 0.0529% and 0.0415%, respectively have a higher phosphate content than the foreign ones like Ps, Td, Lk, Ta, Dm, Bg, Bs, Kn, and Lb having percentage phosphate content corresponding to 0.00473%, 0.0423%, 0.0272%, 0.00680%, 0.00491%, 0.0255%, 0.0305% and 0.0064%, respectively.

Table 1: Percentage phosphate content determined in local detergent samples

S. No.	Sample brand	Phosphate mg dm ⁻³	Phosphate in %/ Std. deviation
1.	Bn	4.12	0.0412 ± 0.001
2.	Om	6.62	0.0662 ± 0.001
3.	Gn	1.30	0.0130 ± 0.000
4.	Bb	4.26	0.0462 ± 0.001
5.	Br	4.60	0.0460 ± 0.001
6.	Kl	3.54	0.0354 ± 0.002
7.	Bp	5.29	0.0529 ± 0.003
8.	Ep	1.00	0.0100 ± 0.001
9.	Zp	2.52	0.0252 ± 0.002
10.	Jb	1.35	0.0135 ± 0.001
11.	Ar	4.15	0.0415 ± 0.001

Table 2: Percentage phosphate content determined in foreign detergent samples

S. No.	Sample brand	Phosphate mg dm ⁻³	Phosphate in % / Std. deviation
1.	Ps	0.473	0.0047 ± 0.001
2.	Td	4.230	0.0423 ± 0.001
3.	Lk	2.720	0.0272 ± 0.001
4.	Ta	2.180	0.0218 ± 0.001
5.	Dm	0.680	0.0068 ± 0.000
6.	Bg	0.491	0.0049 ± 0.000
7.	Bs	2.550	0.0255 ± 0.000
8.	Kn	3.050	0.0305 ± 0.000
9.	Lb	0.640	0.0064 ± 0.000

However, Ar of local brand with percentage phosphate content as 0.0415% almost have the same concentration of phosphate as Td of the foreign product with percentage composition of phosphate as 0.0423%. In the local detergents analysed Ep has the lowest concentration of 0.010% with a standard deviation of ± 0.000 . It was observed that Ps of foreign origin with phosphate content of $0.0047\% \pm 0.001$ has the least concentration of all the detergent used for this study.

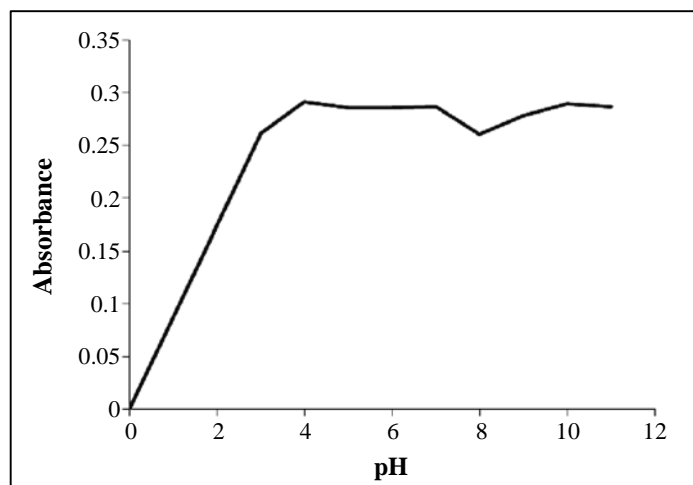


Fig. 1: Effect of pH on the absorption properties of phosphate

In addition, the mean standard deviation of the local detergents were ± 0.001 , ± 0.002 and ± 0.003 whereas those of the foreign detergents was ± 0.001 . This shows that the mean deviation of the foreign detergents agree among themselves more than those of the local detergents. This means that the foreign companies are keeping to the set standards.

It was observed that the mean percentage phosphate in the local and in the foreign detergents analysed were 0.039% and 0.019%, respectively indicating that local detergents contained approximately twice phosphate as builder than foreign detergents. Since the washing capacities of the foreign and local detergents are similar, it indicates that foreign detergents are using other builders in addition to phosphates.

After computing the t-test for both the local and foreign detergents analysed, it was observed that at 5% probability and 18 degrees of freedom, the value is 2.101 and the calculated t-value is 2.378. This indicates that the calculated t-value (2.378) is greater than the table t-value, thus one can conclude that there is a significant difference between the concentration of phosphate in the local and in the foreign detergents analysed.

The present study indicated that detergents available locally contain higher levels of phosphate in comparison to the ones obtained from other parts of the world. Thus, higher amounts of phosphate are released into the sewers, lakes, ponds and rivers, via laundry services, hand washings, kitchen utensils washings etc., by the use of local detergents when compared to the contribution of phosphate from foreign detergents.

Many countries in Europe, for example, Germany, the Scandinavian countries, Italy, Austria, the Netherlands and Switzerland have banned the use of phosphate in detergents¹⁴. The European Union set an overall limit of 0.5% maximum by weight for the content of phosphorus in household laundry detergents²⁰. The U.S. and Canada also set 0.5% maximum limit for phosphorus in automatic dishwashing detergents. On comparing this set limit for phosphates with the mean percentage phosphate contents in the local and foreign detergents as contained in Table 1 and in Table 2, it was observed that, the concentrations of both foreign and local products fall within the set limit. The levels of phosphates in these detergents could be due to compliance with standards sets by regulatory bodies, which apparently signify that, the local and foreign detergents analysed are safe for use in the environment.

CONCLUSION

The results indicated that local detergents contain higher percentage of phosphate than the foreign ones. The results however, indicated that there is a significant variation in terms of the phosphate levels between the local and foreign detergents.

This study has revealed that continuous use of these products could result in an increase in the phosphate levels in laundry discharges into soil, ponds, lakes and rivers.

An excessive amount of phosphorus has long been implicated in the eutrophication of surface water bodies. Therefore, to promote lake/river recovery and improve trophic status, it is recommended that phosphorus loads entering surface waters are reduced.

REFERENCES

1. M. Philip, *Advanced Chemistry (Physical and Industrial)* Published in South Asia by Foundation Books New Delhi (2003) p. 168.
2. Chris Knud-Hansen, *Conflict Research Consortium* (1994).

3. Congressional Report HR 91-1004 April 14, Phosphates in Detergents and the Eutrophication of America's Waters, Committee on Government Operations, **3** (1970).
4. A. L. Hammond, Phosphate Replacement Problems with the Washday Miracle, *Science*, **172**, 361-363 (1971).
5. The New Encyclopedia Britannica, **4**, 39 (2003).
6. B. K. Sharma, Industrial Chemistry (Including Chemical Engineering 5th Ed., Goel Publishing House, Meerut (2006).
7. Agbazue, Vitus E. 95793, Fundamentals of Environmental Chemistry (2012).
8. Chemical and Engineering News, In our Chemical Environment, 1972 (J. C. Giddings and M. B. Monroe Eds). Canfield Press, San Francisco (1970) pp. 120-122.
9. C. Abha and V. K. Gupta, Spectrophotometric Determination of Phosphate in Polluted Water by Solvent Extraction of Molybdenum Blue, *Analyst*, **108**, 1141-1144 (1983).
10. J. R. Duthie, Detergents: Nutrient Consideration and Total Assessment (1972).
11. P. Revelle and C. Revelle, The Environmental Issues and Choices for Society, 3rd Edition Jones and Bartlett Publisher, Boston (1988) p. 749.
12. R. G. Wetzel, Limnology, 2nd Edition Saunders College Publishing, Philadelphia (1983).
13. R. A. Vollenweider, Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication Paris, 192 (1968).
14. E. Smulders, Laundry Detergent, Wiley-VCH Verlag GmbH Weinheim, Germany (2002) p. 172.
15. J. A. Finch and G. W. Smith, Anionic Surfactants, Marcel Dekker, New York (1981) pp. 98-99.
16. P. Gerike, K. Winkler and W. Jakob, *Tenside Surf, Detergent*, **26**, 270-275 (1989).
17. P. Gerike, K. Winkler and W. Schneider, *Tenside Surf, Detergent*, **28**, 86-89 (1991).
18. M. L. Leo, Handbook of Water Analysis, 2nd Ed.; Vollständige Rezension Lesen, New York (2007) pp. 273-283.
19. C. P. Kurzendorfer, P. Kurhm and J. Steber, Zeolite in the Environment in M. J. Schwuger (Ed), Detergents in the Environment, Marcel Dekker Inc., New York, **127** (1997).

20. Malta Standard Authority, Second Floor, Evans Building Merchants Street Valletta VLT03 Malta, 3 (2010).

Revised : 06.11.2014

Accepted : 09.11.2014