Phosphorus in Detergents: Its Impact on Lake Sevan and Its Regulation

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At the AUA Acopian Center, Armen Danielian led the research and managed the project. The aquatic ecologist Garabet Kazanjian oversaw the data analysis for the chemical testing and implemented modeling to estimate the effect of detergent-originating phosphorus on Lake Sevan. Chemist Hrachya Khachatryan conducted the chemical sampling and provided oversight on the analysis of the detergent samples. Environmental legal experts Olympia Geghamyan and Anna Yeranosyan conducted the legal analysis and recommendations for this study. Breavis Research and Marketing Communications Company collected over 800 telephone interviews and conducted dozens of key informant interviews and three focus group discussions. Project coordinator Arpine Zakaryan provided continuous administrative support throughout the project.

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The chemical laboratory of the Republic of Armenia Hydrometeorology and Monitoring Center tested the detergent samples for phosphorus concentration. It also provided data on river flow rates and water quality. We received additional data from the RA Statistical Committee, the State Revenue Committee, and Veolia Jur. We also held discussions with representatives of the Ministry of Economy and the Ministry of Environment for their feedback and comments regarding the current and proposed legislation. We would like to thank all for your open cooperation and discussions.

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List of Acronyms

CATI -- Computer-Aided Telephone Interviews
EU -- European Union
GIZ – Deutsche Gesellschaft für Internationale Zusammenarbeit (*German International Cooperation Society)*
MEnv -- RA Ministry of Environment
MEcon -- RA Ministry of Economy
MTAI -- RA Ministry of Territorial Administration and Infrastructure
RA -- Republic of Armenia
SME -- Small and Medium Enterprises
UK -- United Kingdom
USA -- United States of America
WWTP -- Wastewater treatment plant

1. Global Overview of Phosphorus in Detergents

Detergents have historically been a significant source of phosphorus pollution in freshwater systems, contributing to eutrophication, a process driven by the excessive growth of algae due to nutrient enrichment. Phosphates, commonly used in detergents for their water-softening and cleaning properties, became a major concern in the mid-20th century as their widespread use coincided with increasing algal blooms in lakes worldwide. Phosphorus is often the limiting factor to algal blooms in temperate lakes[1,2] and this has been the case in Lake Sevan as well since the 1970s. Algal blooms reduce the water clarity, deplete oxygen levels during decomposition, and lead to biodiversity loss.[3]

Policy interventions, such as bans or reductions in the phosphorus content of detergents, have demonstrated remarkable success in mitigating these impacts. For example, a notable decline in phosphorus concentrations and improvements in water quality were observed in the Great Lakes in the United States following the implementation of phosphorus detergent bans in the 1970s.[4] Similarly, in Lake Zurich, Switzerland, stricter regulations on phosphorus emissions, including the removal of phosphates from detergents, resulted in significant improvements in its water quality.

Gabrielyan et al.[5] describe strong fluctuations and an overall increase in phosphorus concentrations within Lake Sevan in the last decades. They argue that these significant changes cannot be fully explained by the use of fertilizers in the lake's catchment. Although internal phosphorus loading (from the sediments) due to anoxic conditions created in the Lake cannot be ignored, additional phosphorus coming from wastewater and detergent usage should also be investigated, especially for their long-term impacts. Presently, about 213,200 inhabitants reside in the Lake Sevan catchment[6] and more than 300 businesses operate directly on the Lake's shores.[7]

The decrease in water clarity and quality as a result of lake eutrophication leads to economic losses, both for residential and commercial sectors. Dozens of studies, globally, starting from the 1960s have consistently demonstrated property values decreasing when nearby water bodies' quality deteriorates, including through eutrophication.[8] In addition to losses in property values, a number of studies have

[1] Vollenweider, R. A. (1968). Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication. OECD Technical Report.
[2] Schindler, D. W. (1977). Evolution of phosphorus limitation in lakes. Science, 195(4275), 260–262.
[3] Correll, D. L. (1998). The role of phosphorus in the eutrophication of receiving waters: A review. Journal of Environmental Quality, 27(2), 261–266.
[4] Makarewicz, J. C. (1993). Phosphorus reduction in Lake Erie: Benefits and constraints. Journal of Great Lakes Research, 19(1), 1–9.
[5] Gabrielyan B, Khosrovyan A, Schultze M. A review of anthropogenic stressors on Lake Sevan, Armenia. J. Limnol. 2022;81(s1):2061
[6] https://armstat.am/file/Map/MARZ_05.pdf
[7] EUWI+ 2021
[8] Nicholls, S., & Crompton, J. (2018). A Comprehensive Review of the Evidence of the Impact of Surface Water Quality on Property Values. Sustainability, 10(2), 500.

estimated loss in recreational and other benefits for many developed economies, such as the US,[9] Canada,[10] UK,[11] and New Zealand,[12] including non-user value (utility derived from the lake's preservation even if the lake itself is not utilized as a resource, e.g. due to cultural or historical significance).[13] While no economic studies on eutrophication costs of Lake Sevan were identified, it is worth noting that both the Armenian diaspora in the US and Armenians domestically have demonstrated a certain willingness to pay in order to increase Lake Sevan's water level and quality.[14,15]

While there is a range of possible options for the treatment of nutrient pollutants once they are in the water body, varying in terms of efficiency and cost,[16] this report focuses on the regulation of the phosphorus concentration in detergents, aiming to reduce the inflow of phosphorus into Lake Sevan. Several jurisdictions worldwide have implemented increasingly strict limitations on phosphates in household detergents, starting in the 1970s with individual US states[17] with EU members following shortly.[18] Nonetheless, such policies (at least in the EU) were made effectively redundant by the requirement to install tertiary treatment plants.[19]

It is critical to note that in the absence of addressing other sources of phosphorus (such as agriculture, fish farming, municipal wastewater, etc.), the effectiveness of such policies in restoring water quality will be limited.[20,21] It could, nonetheless, prove to be a critical step as the country develops its water quality agenda including wastewater treatment, fish-farming standards, and the like. An overview of current international legislation regarding phosphorus concentration in detergents is provided in Section 5 of this report.

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[9] Dodds, W. K., Bouska, W. W., Eitzmann, J. L., Pilger, T. J., Pitts, K. L., Riley, A. J., Schloesser, J. T., & Thornbrugh, D. J. (2009). Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages. Environmental Science & Technology, 43(1), 12–19.

[10] Smith, R. B., Bass, B., Sawyer, D., Depew, D., & Watson, S. B. (2019). Estimating the economic costs of algal blooms in the Canadian Lake Erie Basin. Harmful Algae, 87, 101624.

[11] Pretty, J. N., Mason, C. F., Nedwell, D. B., Hine, R. E., Leaf, S., & Dils, R. (2003). Environmental Costs of Freshwater Eutrophication in England and Wales. Environmental Science & Technology, 37(2), 201–208.

[12] Mueller, H., Hamilton, D. P., & Doole, G. J. (2016). Evaluating services and damage costs of degradation of a major lake ecosystem. Ecosystem Services, 22, 370–380.

[13] Smith, R. B., Bass, B., Sawyer, D., Depew, D., & Watson, S. B. (2019). Estimating the economic costs of algal blooms in the Canadian Lake Erie Basin. Harmful Algae, 87, 101624.

[14] Wang, Hua; Laplante, Benoit; Wu, Xun; Meisner, Craig. (2004) Estimating Willingness-to-Pay with Random Valuation Models: An Application to Lake Sevan, Armenia. Policy Research Working Paper;No.3367. © World Bank, Washington, D.C. http://hdl.handle.net/10986/14158 License: CC BY 3.0 IGO.

[15] Laplante, Benoit & Meisner, Craig & Wang, Hua (2005) Environment as cultural heritage: the Armenian diaspora's willingness-to-pay to protect Armenia's Lake Sevan, Policy Research Working Paper Series 3520, The World Bank.

[16] A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution. US Environmental Protection Agency Office of Water, May 2015

[17] David W. Litke (1999) Review of Phosphorus Control Measures in the United States and Their Effects on Water Quality. US Geological Survey, Water-Resources Investigations Report 99–4007.

[18] Köhler, J. (2006). Detergent Phosphates: an EU Policy Assessment. Journal of Business Chemistry

[19] Köhler, J. (2006). Detergent Phosphates: an EU Policy Assessment. Journal of Business Chemistry

[20] Köhler, J. (2006). Detergent Phosphates: an EU Policy Assessment. Journal of Business Chemistry

[21] David A. Keiser (2020). Policy Brief—The Effectiveness of Phosphate Bans in the United States. Review of Environmental Economics and Policy 14(2).

The industry costs of transitioning to low-phosphorus or phosphorus-free products depend on the particularities of a given market, and little data is available regarding international experience. European Commission's 2010 impact assessment report on the consequences of a total phosphate ban in washing materials in the EU stated that "It can be expected that larger detergent formulators operating in several or all Member States would find it relatively easy to substitute detergents containing phosphates with comparable alternative formulations as they normally already offer phosphate-free detergents in those Member States where phosphates have already been phased out."[22] The report indicated that small and medium-sized enterprises, focused on producing phosphate detergents for the domestic markets, may have a harder time complying with the new regulations, requiring a longer transition period. Product reformulation costs were estimated to average EUR 10,800 per product, and some SMEs could suffer as market share would shift further to large international suppliers. Allowing for a longer transition period would reduce some of the impact on them. Similar effects, but on a smaller scale, would be present in the case of restrictions on phosphates, as opposed to a complete ban.

2. Purpose of this Study

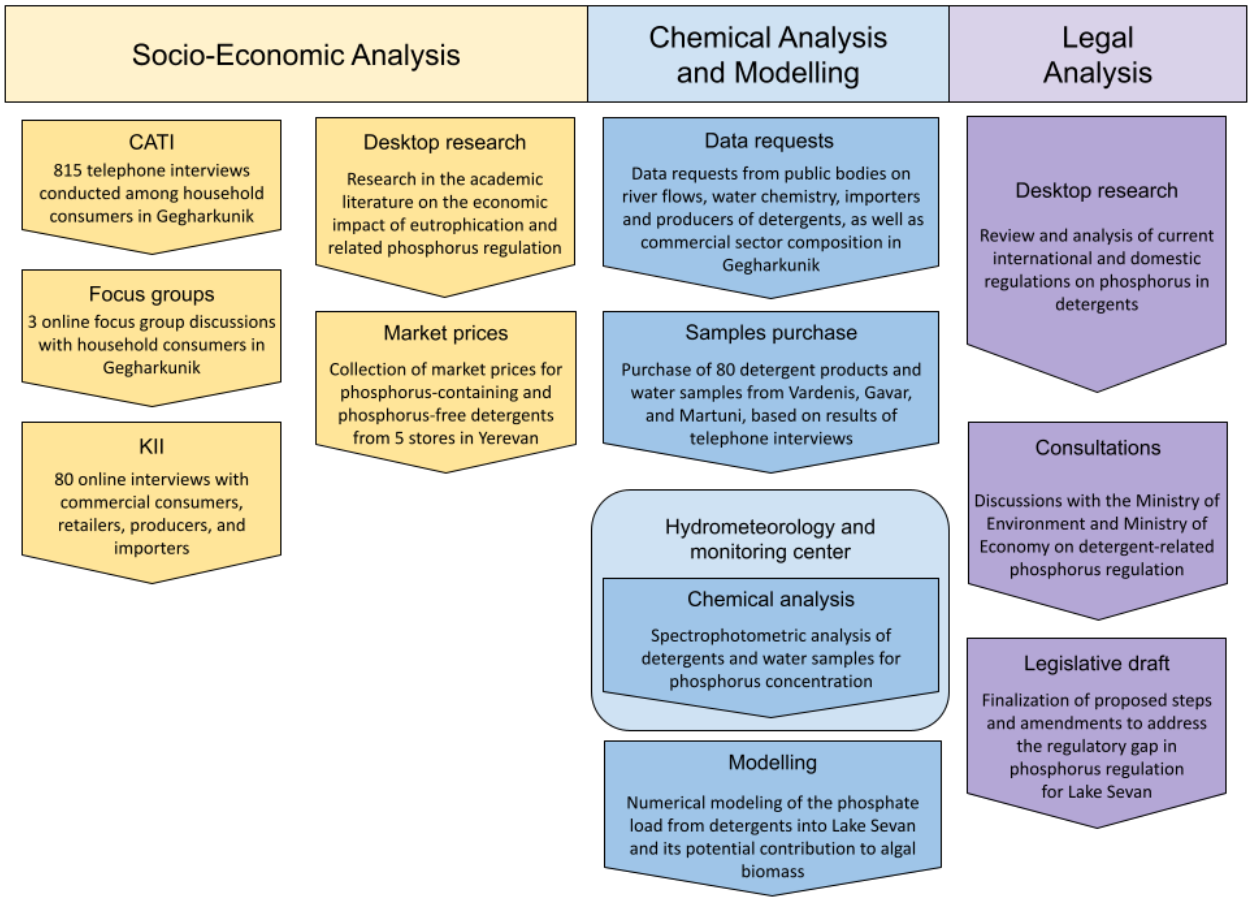
This study is part of the project titled "EU4SEvan - Environmental Protection of Lake Sevan", co-funded by the EU and the German Federal Ministry for Economic Cooperation and Development (BMZ). The overall objective is to gather and analyze the current detergent usage statistics in Armenia (with a focus on the Lake Sevan area), the market situation (including in the case of shifting to phosphorus-free detergents import and production), the existing regulation on phosphorus concentration in detergents, and the legislative changes needed to reduce the pollution from phosphorus in Lake Sevan.

3. Methodology

The study used several approaches to answer its key questions: a) Should Armenia introduce legislation limiting or banning phosphorus content in imported or locally manufactured detergents and b) If yes, what would be the most acceptable way in which such restrictions are introduced? As such, the study examined the social, economic, chemical-environmental impact, and legal dimensions of such reform. Table 1 below presents the multiple methods used to identify pathways forward on the study questions.

[22] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52010SC1277&from=EN

Figure 1. Summary of scope and methods used in this study



Socio-Economic Analysis

The socio-economic analysis consisted of desktop and field research. Computer-assisted telephone interviews (CATI), focus group discussions, and interviews were conducted by *Breavis Research and Marketing Communications Company* to identify the awareness, attitudes, and practices about detergents and their phosphorus concentration. Target groups included residential and commercial consumers of detergents in the Lake Sevan area,[23] retailers (shops, supermarkets) in the Lake Sevan area, and nationwide importers and producers. In addition, data on prices for phosphorus-containing and phosphorus-free detergents was collected from several stores in Yerevan (including the retailers Parma, Rock Four, SAS, Yerevan City, and Gurmenia), to estimate the competitiveness of phosphorus-free products.

[23] The only exception is car washing stations, where, due to lack of responses, businesses outside lake Sevan basin were contacted.

Chemical Analysis and Modeling

Dilutions of powder and liquid detergents were prepared to analyze their phosphate concentrations. Two rounds of samples were sent to the *Hydrometeorology and Monitoring Center* for chemical testing. See Appendix B for details on sampling and testing methodology.

Data on monthly river flow rates and water characteristics was requested from the *Republic of Armenia (RA) Hydrometeorology and Monitoring Center*. Additional data on tap water quality was requested from *Veolia Jur,* the national drinking water supplier serving many of the Lake Sevan basin communities. See Appendix D for details on the data received. Data from the residential consumer surveys conducted by Breavis, see section above on "Socio-Economic Analysis," was used to estimate monthly detergent consumption rates. For the commercial sector, monthly spending rates on detergents were collected through key informant interviews and converted into consumption rates.

Legal Analysis

The purpose of the legal analysis was to assess the legal framework of the Republic of Armenia regarding phosphorus-containing detergents, taking into account the EU and other countries' experience. This assessment formed the basis of providing recommendations to improve the effectiveness of the RA's legislative and institutional framework on regulating phosphorus in detergents.

The study conducts a survey of international and domestic laws on phosphorus in detergents and cleaning products, the history of their development, and current practices. Desktop research included looking at cases of the European Union, the United States, Canada, Australia, Russia, and Ukraine. In addition, the researchers held consultations with the key ministries of the Economy and Environment on the current situation and possibilities of regulating phosphorus in cleaning products.

The legal analysis centers on the RA Government Decision N 1795-N,[24] which addresses the technical requirements for detergents (hygiene, safety, labeling, producer responsibility) and water quality norms for Lake Sevan. Armenia's international obligations under EU and Eurasian frameworks are also considered. Wastewater treatment challenges (including untreated municipal and industrial discharges into Lake Sevan), gaps in sectoral control, and inadequate incentives for wastewater treatment are addressed. Recommendations regarding legislative amendments and broader regulation are given in Section 6. The full text of the legal analysis (in Armenian) is available in Appendix A.

4. Impact of Detergent-sourced Phosphorus Inflow into Lake Sevan

To study the impacts of detergent-derived phosphorus (P) pollution in Lake Sevan we first conducted a survey (n=815) to identify the most commonly used detergents (>5% usage rate), leading to the collection of 72 detergent samples from three towns (Gavar, Martuni, Vardenis) and their preparation in a laboratory setting. Detergents were diluted in distilled water and analyzed for phosphorus content using the Ammonium molybdate spectrometric method (ISO 6878-2004) at the laboratories of Hydrometeorology

[24] https://www.arlis.am/documentview.aspx?docid=185742

and Monitoring Center SNCO. Additionally, tap water samples from the same towns were tested for their phosphate concentration. The study also incorporated household and business surveys to estimate detergent consumption. By integrating these data with regional population distributions, we a) calculated the total amount of phosphates entering the lake from detergents and 2) compared these figures to the overall amount of phosphates discharged into the lake via its eight largest tributaries (Calculated using monthly flow rates and phosphate concentrations received from ArmHydroMet) and total phosphorus loading into Lake Sevan found in the literature.

The chemical analysis revealed variability in phosphorus content among detergent types. Dishwashing liquids had the highest median phosphate concentration (3.29 mg/L), while glass-washing liquids had the lowest (0.015 mg/L). Laundry detergents, both powder and liquid, showed moderate phosphorus levels. We used median values instead of means, which are more sensitive to very high or low numbers that we recorded in a few brands. **Despite the variation, all tested detergents contained phosphate levels below the internationally accepted threshold of 0.5%.** We hypothesize that detergent manufacturers, who also supply markets with phosphate regulations, use similar formulas across all regions to minimize production costs. The study estimated that household detergent use contributed approximately 647 kg of phosphate annually (see the table below), while commercial establishments added another 2.35 kg, resulting in a total detergent-derived phosphate load of 650 kg per year. Tap water was also identified as a significant source of phosphate, particularly in Gavar, where concentrations reached 0.64 mg/L. That entails that for a single laundry wash using 45L of water, detergent-driven phosphate amounts to 0.3 - 0.8 mg PO_4^{3-}, whereas phosphates from the tap water alone would amount to 29.3 mg in Gavar or 9.6 mg in Vardenis. A detailed description of the methodology and results can be found in Appendix B.

Table 1: The number of inhabitants within each river catchment, their estimated total detergent usage based on the interviewed individuals, and the resulting release of P (in kg).

Location	Inhabitants	Number of people surveyed	Monthly detergent usage (all types, in kg or L)	Total monthly P release (kg)
Dzknaget	38748	154	452,800	9.441
Drakhtik	11370	36	103,300	2.058
Pambak	1529	7	14,200	0.296
Masrik	25730	158	286,100	5.711
Karchaghbyur	5784	22	63,190	1.244
Vardenis	22459	67	298,600	6.189
Martuni	26132	73	346,100	7.124
Argichi	15142	28	248,700	5.348
Lichq	5261	14	72,850	1.594

Bakhtak	10451	25	116,300	2.734
Gavaraget	50979	193	525,000	10.339
Sotq	1169	4	9,300	0.181
Shoghvag	8122	24	80,490	1.654

In comparison to other sources of phosphorus in the Lake Sevan Basin, detergent-derived phosphate accounted for <1% of total external loading into the Lake. Our calculations based on monthly flow rates and phosphate concentrations from 2021-2023 in the eight largest tributaries showed a discharge of about 103 tons of phosphates annually. Table 2 below details the annual discharge of phosphates from the different rivers in the basin. The calculated number is comparable but marks an increase compared to the 85 annual tons reported in the decision N 1912 on approval of the management plan of the Sevan basin for 2022-2027 based on concentrations between 2013 - 2017.

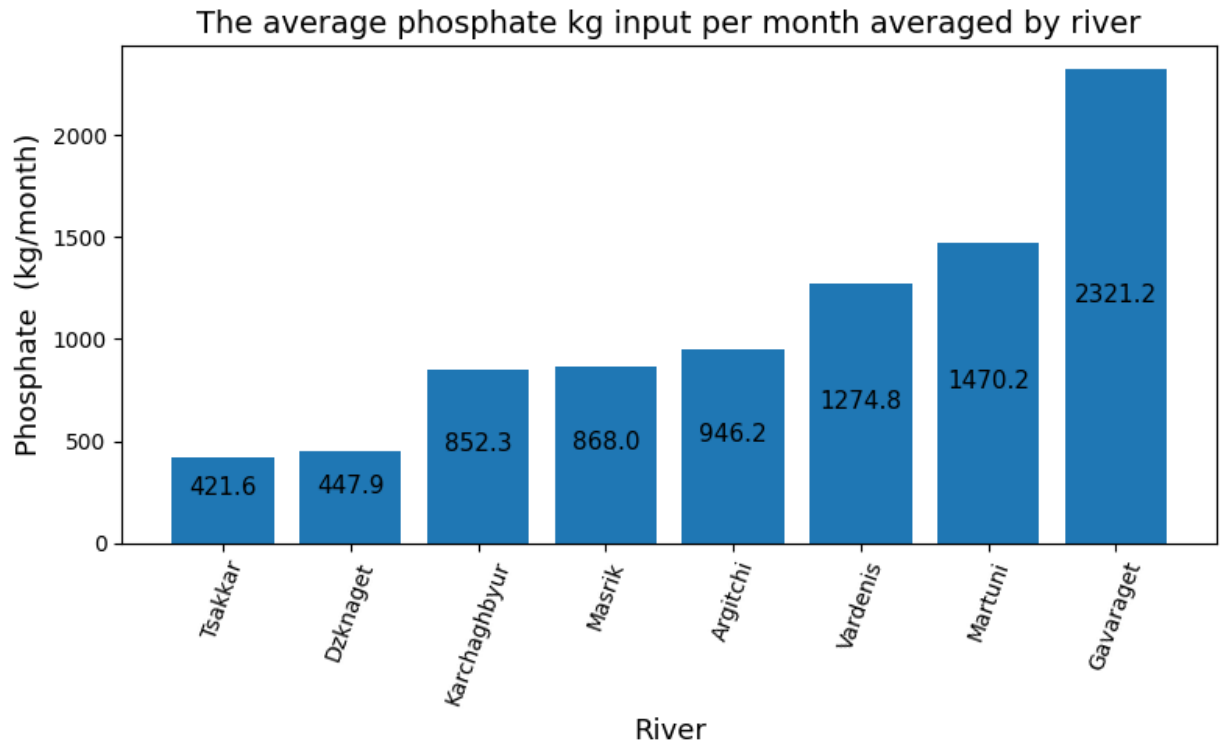


Figure 2: Average monthly load of phosphorus into the rivers

The proportion of detergent-driven phosphate is significantly lower than in past studies from other countries (*e.g.* European reports from the 1990s before the introduction of relevant regulations attributed 10% of phosphates in wastewater to be detergent-driven) due to the lower percentage of phosphates in detergents as aforementioned and the low population size and the lower residential activities compared to agricultural ones in the region. The primary sources of phosphorus in the lake were identified as wastewater (172 tons annually), agricultural fertilizers (1,775 tons used in the basin), and animal manure

(At least 68 tons). The total phosphorus (TP) loading into Lake Sevan was reported to be 264.4 tons annually (EUWI+ Report, 2021). Further analysis of the potential different contributors of phosphorus into the Lake and their impact can be found in Appendix B. Although phosphates released from detergents are highly available for algal uptake and can be used immediately (as opposed to organic phosphorus for example from manure or human waste that needs to be mineralized first), given their low quantities (less than one ton, even if we account for a large confidence interval), detergents do not appear to constitute a major source of phosphorus pollution within the basin. Given the lake's long residence time (~35 years), even small phosphorus inputs can have lasting impacts. However, for more pronounced and quicker outcomes in improving the water quality of the Lake, attention should focus on the sectors that are contributing a much higher percentage of phosphorus loading in Lake Sevan, namely residential wastewater, fertilizers, and animal manure.

5. Awareness and Readiness-to-Change in the Armenian Detergent Market

The 815 computer-aided telephone interviews (CATI) conducted with households in the Gegharkunik Marz were designed to learn about the local population's awareness and attitude towards the environmental impacts of phosphorus on Lake Sevan, particularly due to the use of phosphorus-containing detergents. The findings demonstrate, on one hand, high awareness of the presence of environmental issues related to Lake Sevan, yet a lower understanding of the presence of phosphorus in the products and its negative effects.

Over 90% of the respondents believe that the presence of household cleaning detergents, household waste, and sewage discharge are somewhat or very harmful to the Lake's ecosystem. However, almost half (42.2%) attributed the lake's eutrophication to trash accumulation; about a quarter (25.2%) attributed it to algal bloom, and only 8.7% replied that wastewater and sewage are the cause. Likewise, while the majority of respondents (96%) believe that phosphorus can have negative impacts on the environment, over half (54.7%) do not pay any attention to the phosphorus content in washing materials, and 28.3% pay limited attention.

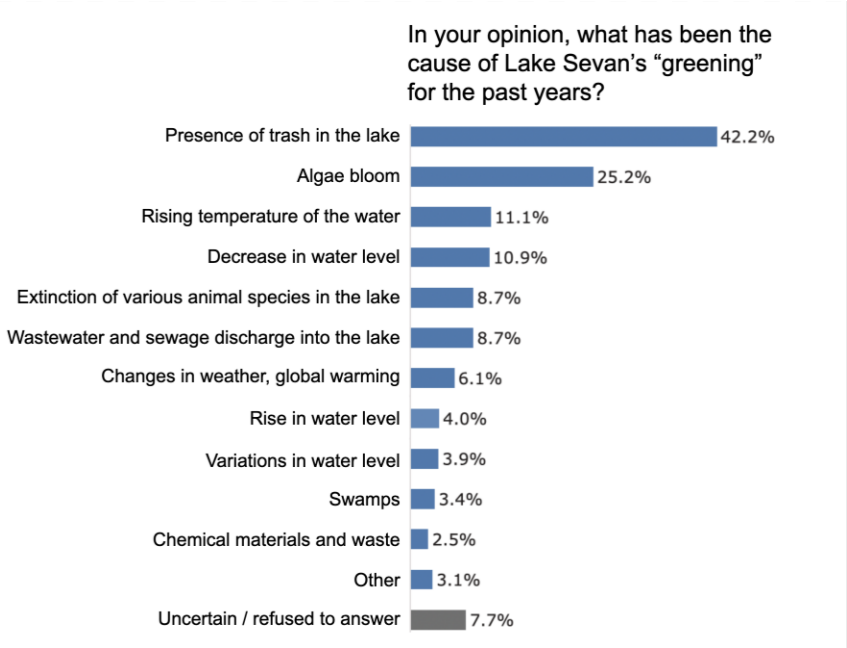


Figure 3. Household respondents on the cause of Lake Sevan's "greening" (only one answer allowed).

At the same time, survey results demonstrate high readiness to change. The majority of respondents (93.7%), when asked, expressed willingness to switch to products that do little to no harm to the ecosystem of Lake Sevan. An even bigger proportion (98-99%) believe that regional and local authorities should raise awareness and develop strategies for the preservation of the Lake Sevan ecosystem.

The focus group discussions conducted with consumers and individual interviews with retailers and suppliers of detergents (both importers and producers) offered more insights into the findings from the CATI. Quality was mentioned by all groups as the most important factor when choosing a product, even at a higher price. However, only the importers and the producers are aware of detergent composition; retailers and consumers (both commercial and household) rarely pay attention to the composition. While many stakeholders are aware that there is a negative impact on nature from excessive anthropogenic phosphorus, there is limited understanding of the specific consequences of phosphorus pollution.

The participants of focus group discussions and interviews demonstrated a high willingness to change when informed about the negative impact of phosphorus. Importers and producers of detergents noted that the phasing out of phosphorus-containing materials would not greatly affect the business and that they would be prepared to shift to phosphorus-free products. Retailers likewise expressed readiness to look for alternative products, while consumers (both residential and commercial) are prepared to shift to phosphorus-free sources even if that has a negative impact on the prices. Participants positively assessed the EU's restrictions and bans on phosphorus concentration in detergents, suggesting that RA can also follow suit.

The summaries of the CATI, focus group discussions, and key interviews are available in Appendix C.

In addition, prices for detergent products were collected in select supermarkets in Yerevan, in order to compare price differences between phosphorus-containing and phosphorus-free products. The results are presented below and demonstrate on average a comparable, if not lower, median price for phosphorus-free products. The prices are available in Appendix E.

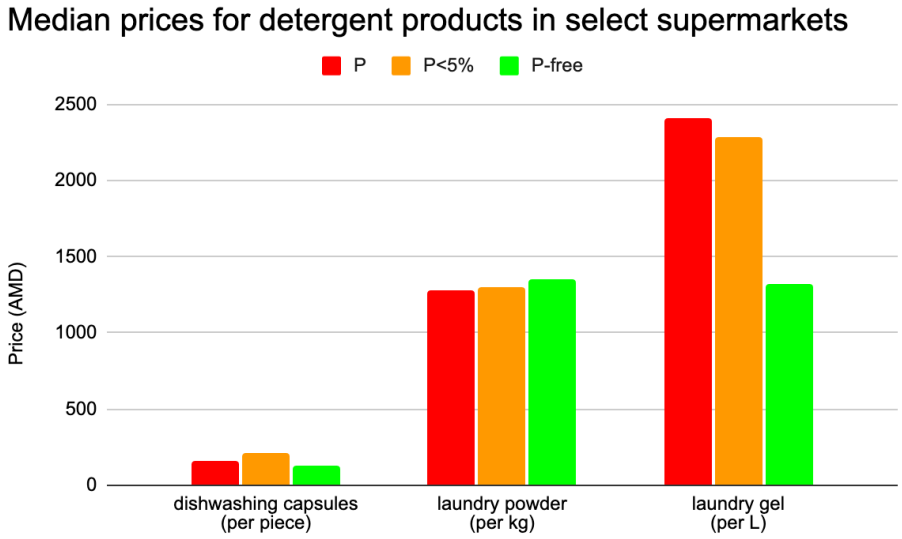


Figure 4. Median prices for phosphorus-containing (P), low-phosphorus (P<5%), and phosphorus-free (P-free) products in select stores in Yerevan - SAS, Gurmenia, Yerevan City, Rock four, Parma.

6. Legal Analysis of the Armenian Jurisdiction

The legal analysis has identified certain gaps in the regulatory framework of Armenia concerning phosphorus-containing detergents and cleaning products. The conclusions and recommendations of the analysis are presented fully in Armenian in Appendix A,[25] and summarized below.

Two pathways for regulatory improvements were identified - reducing phosphorous loading of Lake Sevan through reducing the permissible concentrations in the detergent products and removing it from wastewater through wastewater treatment plants.

As chemical analysis has shown that the concentration of phosphorus in detergents is already low (Section 4), the latter option is prioritized. Moreover, reducing phosphorus through wastewater treatment plants (WWTP) may be the more optimal choice regardless of detergent phosphorus concentration, as there are other sizable sources of phosphorus in wastewater from non-detergent sources. These include human fecal matter and urine.

A review of the RA legislation and resulting issues identified the following key findings:

[25] It is important to note that the full legal analysis as presented in Appendix A was completed prior to the finalization of chemical testing results, and some of its recommendations may not be as relevant.

- The current RA legislation on phosphorus concentration in detergents and cleaning products is not consistent with the regulations defined by the relevant directives of the European Union and the legislation adopted in a number of countries. The government's general (albeit strict) requirements for surface-active agents and cleaning agents containing surface-active substances do not take into account the specific features of dishwashing and laundry detergents, which make up the vast majority of products in this category.

- In contrast to the legal requirements in several countries, the RA law does not mandate consumers to be properly informed about the negative consequences of phosphorus-containing detergents and cleaning products on human health and the environment. The problem is not just specifying the allowable amount of phosphorus in a given detergent. More generally, it is the low level of awareness regarding phosphorus' negative effects and related regulation of the population, and as a result, the negative consequences of the public's actions and inaction on the environment, in this case, on the water quality of Lake Sevan.

- The Lake Sevan basin area is not equipped with biological wastewater treatment plants, which would perform, among other functions, phosphorus purification. In fact, in RA, there is a lack of mechanisms for the treatment of industrial wastewater, its pre-treatment before disposing it into the drainage system, urban wastewater treatment, and limiting the flow of treated wastewater into natural water bodies (including Lake Sevan). In addition, a quality monitoring system implementation is absent for water discharge from the treatment plants. Modernization of WWTPs and construction of new WWTPs in Sevan's basin management area and the Arpa-Sevan tunnel complex river basin remain a huge problem. Some of the problems stem from the fact that the construction of biological treatment plants has costs that are not politically prioritized, while the RA lacks incentive mechanisms. On the other hand, according to the Code of Administrative Offenses of the Republic of Armenia, fairly mild penalties and fines are provided for removing wastewater without treatment, as a result of which businessmen prefer to be subject to an administrative penalty than to take steps to build appropriate infrastructures.

- The low level of environmental control in RA also contributes to the discharge of wastewater into Lake Sevan and the deterioration of the lake's water quality.

While legislation could mitigate phosphorus inflow through detergent regulation and/or abating the phosphorus through wastewater treatment, **taking into account the already low concentration of phosphorus in the detergent products in Armenia, the following legislative and practical recommendations should be prioritized. The proposed solution below also has the advantage of removing excess phosphorus from other sources (human waste) and detergents through well-functioning WWTPs and effective awareness-raising activities.**

1. On the basis of the principle of "reimbursement of polluted water treatment costs by the polluter" established by the RA Water Code, following EU standards,

    a. establish in RA a mechanism for determining the permissible limits for discharging treated wastewater into a water basin,

b. establish a mandatory requirement for the activity of producing entities to provide a drainage network with an appropriate service treatment plant (biochemical treatment plant), which will ensure the process of phosphorus purification,

c. promote the construction and operation of WWTPs operating with alternative technologies,

d. by revising the RA legislation, establish stricter responsibility for the absence of WWTPs and illegal discharges of untreated wastewater.

2. Provision of environmental tax privileges in the Tax Code of RA, provision of low-interest loans for entrepreneurs who construct wastewater treatment plants and carry out phosphorus treatment before it is discharged into the water resource.

3. In all settlements of Gegharkunik and Kotayk marzes, local government bodies organize and implement annual mandatory events and information campaigns to inform all groups of the population about the mitigation and prevention of phosphorus effects on the water quality of Lake Sevan. Basic knowledge about the restoration and protection of Lake Sevan must be included in the courses of various subjects in preschool and school state programs. The suitability of such activities for other regions should also be considered.

Should separate regulatory changes targeting specifically phosphorus concentration in detergents be sought, details on such amendments can be found in Appendix A.

7. Policy Implications and Recommendations

The overall results indicate that detergent products in the Gegharkunik region of Armenia have a low concentration of phosphates, contributing less than 1% to the total flow of phosphorus into Lake Sevan. It is possible that detergent products from the international market already contain low phosphorus due to regulations in advanced economies. While some uncertainties are still present in the analysis of phosphorus concentrations and consumption rates, introducing regulations aimed at reducing phosphorus concentration in detergents is unlikely to have a strong impact. Investments needed to reduce the phosphorous loading of Lake Sevan should be focused elsewhere.

The total inflow of phosphorus into Lake Sevan remains very high. The Vollenweider model applied to Lake Sevan indicates the lake is nutrient-rich and highly susceptible to excessive algal growth. Reducing the total quantity of phosphorus at the inflow points - *e.g.* through building or improving the wastewater treatment plants or nature-based solutions capable of sequestering nutrients (N and P) - may be more effective than regulating phosphorus at the level of detergent products. The presence of other significantly larger sources of phosphorus (such as agricultural chemicals and human waste) warrants a more comprehensive approach that should be prioritized over targeted detergent regulation.

The social surveys conducted, however, revealed a considerable knowledge gap among the population as to the causes of the harmful algal blooms occurring in Lake Sevan. Most people erroneously believed that

littering the Lake with plastic and other household solid waste causes the algal blooms witnessed in Lake Sevan. A concerted awareness-raising campaign should elevate the public's understanding of nutrient overloading (N and P) from multiple sources, which is a key contributing factor explaining the algal blooms and the action needed to reduce the loading.

Further research should be conducted to estimate the quantities of phosphorus from other sources, as existing literature is both scarce and inconsistent (see Appendix B). A more detailed spatio-temporal analysis of phosphorus inflow into the Lake will optimize the decision-making on treatment plant options and locations.

8. List of Appendices (available upon request)

Appendix A - Legal Analysis (in Armenian)
Appendix B - Methodology and Results for the Phosphorus Load from Detergents
Appendix C - Summary of CATI, Focus Group Discussions, and Key Informant Interviews (in Armenian)
Appendix D - Data Requested From Public Bodies (in Armenian)
Appendix E - Prices in Select Yerevan Supermarkets