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2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM



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EDITORS

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
Ms. Nurul Nazwa Mohammad
Ms. Rozaina Saleh

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PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
Ms. Nurul Nazwa Mohammad
Ms. Rozaina Saleh

ISETC 2025 Proceedings Editors

PHOSPHATE CONTENT IN MALAYSIAN LIQUID LAUNDRY DETERGENTS: ASSESSING COMPLIANCE AND ECOLOGICAL RISKS

Nurfarisha Farhana Mohd Ainul Hakeem, Nurfarahanis Hadhirah Roslan, Farah Adiba Zawawi, Marissa Dania Mohd Familzall, Nur Dini Damia Mohd Amran, Siti Nur Faizah Ismail, Kim-Fatt Low*

Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, Tapah Road, 35400 Perak, Malaysia

**Corresponding author: lowkimfatt@uitm.edu.my*

Abstract: Phosphates are commonly used in laundry detergents as water softening agents, but their excessive discharge into aquatic environments has been linked to eutrophication and the deterioration of water quality. Despite international efforts to regulate phosphate use, phosphate-based detergents remain prevalent in regions like Malaysia, where regulatory oversight is limited. This study aimed to quantify phosphate concentrations in selected commercial liquid laundry detergents available in the Malaysian market and evaluate their potential environmental impact using the molybdenum blue method. Five detergent brands (A to E) were analyzed following a 1:500 dilution protocol. Phosphate levels were determined based on a calibration curve constructed from standard solutions (0–5 mg/L as PO_4^{3-}), with absorbance measured at 650 nm. The method showed excellent linearity ($R^2 = 0.9885$) and good precision, with relative standard deviations (RSD) below 10% for both standard and sample measurements. Phosphate concentrations in the detergent samples ranged from 0.411 mg/L to 1.390 mg/L, with Brand E showing the highest level. When translated to estimated phosphate discharge per laundry cycle, values ranged from 20.6 mg to 69.5 mg per 50-liter wash—well below the European Union's threshold of 500 mg per standard dose. However, the cumulative environmental impact of frequent detergent use, particularly from products with higher phosphate content, remains a concern. These findings highlight the need for increased awareness, stronger regulatory measures, and reformulation of detergent products to minimize phosphate pollution in aquatic ecosystems.

Keywords: *Phosphate pollution, laundry detergents, water quality, environmental impact, spectrophotometry*

INTRODUCTION

Phosphorus is an essential nutrient that supports the growth and metabolic functions of plants and animals, contributing significantly to overall ecosystem productivity (Wang et al., 2023). However, excessive amounts of phosphorus, particularly in the form of orthophosphate, can lead to serious environmental problems when released into aquatic environments (Duhamel, 2025). One of the major sources of phosphorus pollution is the widespread use of phosphate-based compounds in household detergents. These phosphates, such as sodium tripolyphosphate (STPP), are commonly added to detergent formulations to soften hard water and enhance cleaning efficiency (Agbazue et al., 2015). Once discharged through domestic wastewater, phosphate compounds may enter rivers, lakes, and other water bodies, increasing nutrient loads and triggering eutrophication, a condition caused by elevated nutrient levels that promote the excessive growth of algae and aquatic plants (Jin et al., 2024).

The environmental impacts of eutrophication are well documented. Excessive algal growth disrupts aquatic ecosystems by reducing light penetration, depleting dissolved oxygen during decomposition, and creating hypoxic or "dead zones" where aquatic life cannot survive (OSPAR, 2023). These conditions degrade water quality, harm biodiversity, interfere with recreational activities, and may introduce toxins that pose risks to human and animal health. Phosphate pollution is therefore considered a critical threat to freshwater environments, especially in regions where wastewater treatment facilities are limited or inadequate (Duhamel, 2025).

In response to these environmental concerns, many countries have introduced regulations to limit the use of phosphates in household cleaning products. For example, the European Union and Canada have adopted strict phosphate restrictions, leading to the widespread adoption of phosphate-free or phosphate-reduced detergents (Environment and climate change Canada, 2020; European commission, 2012). Despite these efforts, phosphate-based detergents

continue to be used in several parts of the world where regulatory enforcement is lacking. In Southeast Asia, including Malaysia, phosphate-containing detergents remain prevalent, underscoring the importance of regional studies that evaluate the phosphate content of commercial products and their potential environmental effects (Low et al., 2021).
Monitoring phosphate concentrations in detergents is essential for understanding their environmental contribution and ensuring compliance with environmental standards. Among the various analytical techniques available, the molybdenum blue method is widely used due to its simplicity, affordability, and sensitivity (Zhai, 2023). In this method, phosphate reacts with ammonium molybdate under acidic conditions to form a phosphomolybdate complex. This complex is then reduced, typically using stannous chloride or hydrazine hydrate, to produce a blue-colored compound. The intensity of the resulting color, which is measured at a wavelength of 650 nm, is directly proportional to the phosphate concentration. This technique is suitable for analyzing phosphate levels in both natural water and detergent samples, and it provides reliable results even at low concentrations (Ismail, 2023).

This study applies the molybdenum blue method to determine phosphate concentrations in selected commercial liquid laundry detergents available in the Malaysian market. The objective is to assess whether these products meet international standards for phosphate discharge and to evaluate their potential environmental impact. Although detergent compositions have been studied in various regions (Chong et al., 2019), there is a lack of published data focusing on detergent phosphate levels in Malaysia and other parts of Southeast Asia (Agbazue et al., 2015; Thapa et al., 2023), where regulations remain limited (Chong et al., 2019).

By providing a detailed analysis of phosphate concentrations in commonly used detergent brands, this research aims to contribute to more effective regulatory strategies and raise public awareness about the environmental consequences of phosphate use. The findings may also support detergent manufacturers in improving product formulations and help policymakers develop appropriate standards for reducing phosphate pollution. Ultimately, the study contributes to broader efforts to protect water quality and maintain the health of aquatic ecosystems in Malaysia.

MATERIALS AND METHODS

Chemicals

All chemicals, including ammonium molybdate tetrahydrate ($(NH_4)_6Mo_7O_{24}\cdot 4H_2O$), stannous chloride dihydrate ($SnCl_2\cdot 2H_2O$), potassium dihydrogen phosphate (KH_2PO_4), sulfuric acid (H_2SO_4), and glycerine, were sourced from Sigma-Aldrich (Missouri, USA). Solutions were prepared as follows: ammonium molybdate reagent (2.5% w/v $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ in 5 M aqueous H_2SO_4), stannous chloride solution (2.5% w/v $SnCl_2\cdot 2H_2O$ in glycerine), and phosphate stock solution (20 mg/L as PO_4^{3-} from KH_2PO_4 in aqueous solution). All aqueous solutions were prepared using sterilized deionized water (deH_2O) produced by a Sartorius Arium® Pro ultrapure water system (Göttingen, Germany).

Instruments

A PerkinElmer Lambda 25 UV-Visible spectrophotometer (Massachusetts, USA), equipped with 1 cm path-length quartz cuvettes, was used for absorbance measurements.

Research Design

This study employed a quantitative, laboratory-based experimental design to quantify phosphate content in commercial liquid laundry detergents. The molybdenum blue method, a colorimetric technique, was selected for its high sensitivity and specificity in detecting phosphate in aqueous solutions. The method is based on the formation of a blue-colored molybdophosphate complex, with absorbance measured at 650 nm using UV-Visible spectrophotometry.

Sample Selection

Five liquid laundry detergent brands (labeled A to E) were selected from the Malaysian market. The selection was based on widespread availability and representation across major household detergent categories to ensure relevance and comparability. Only liquid formulations were included to maintain consistency in sample preparation and analysis. To maintain ethical neutrality and avoid any perception of commercial bias or endorsement, the identities of the detergent brands are anonymized in this study. This approach is consistent with standard academic practice, especially when brand identity is not essential to the research objectives.

Preparation of Standard Phosphate Solutions

Standard phosphate solutions were prepared by serial dilution of the phosphate stock solution using deH_2O. Six working standards with concentrations of 0, 1, 2, 3, 4, and 5 mg/L as PO_4^{3-} were prepared to generate a calibration curve.

Preparation of Detergent Samples

Each detergent sample was diluted at a ratio of 1:500 (1 mL detergent to 500 mL tap water) to simulate typical laundry usage and to ensure that phosphate concentrations remained within the measurable range of the molybdenum blue method. Diluted samples were thoroughly mixed to ensure homogeneity.

Color Development Procedure

For both standard and detergent samples, 25 mL of solution was transferred into a clean container. To each sample, 1.0 mL of ammonium molybdate reagent and two drops of stannous chloride solution were added sequentially. The mixtures were gently stirred and allowed to stand for exactly 10 minutes to ensure consistent and complete color development of the molybdophosphate complex. The 0 mg/L standard solution was used as a blank to correct for potential reagent-related absorbance.

Absorbance Measurement and Calibration Curve Construction

Absorbance readings were taken at 650 nm using the UV-Visible spectrophotometer. Each measurement was performed in triplicate, and mean absorbance values were recorded. Standard deviations of the triplicate measurements were calculated to assess precision. A linear calibration curve was constructed by plotting mean absorbance values against their corresponding phosphate concentrations using Microsoft Excel. The coefficient of determination (R^2) was evaluated to confirm linearity, with R^2 values ≥ 0.98 accepted as valid.

Phosphate Determination in Detergent Samples

Phosphate concentrations in detergent samples were calculated by referencing their absorbance values to the calibration curve. Final results were expressed in mg/L, based on the linear relationship established from the standard phosphate solutions.

RESULTS AND DISCUSSION

Phosphate Calibration Curve and Analytical Performance

The calibration curve for phosphate quantification was generated using standard solutions ranging from 0 to 5 mg/L of phosphate (as PO_4^{3-}), analyzed via the molybdenum blue method at 650 nm. As shown in Figure 1, the calibration curve demonstrated a strong linear relationship between absorbance and phosphate concentration, with a coefficient of determination (R^2) of 0.9885. This confirms the reliability of the method for quantitative phosphate determination within the tested range.

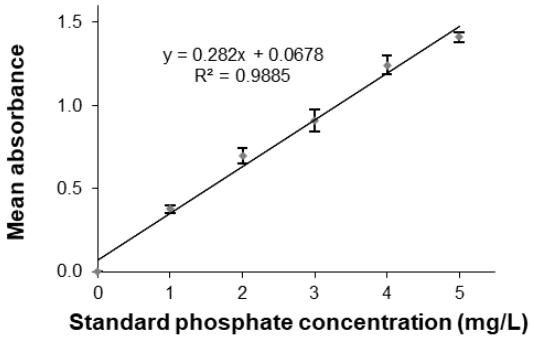


Figure 1. Linear calibration curve of mean absorbance for phosphate quantification using the molybdenum blue method. The error bars indicate the standard deviation from triplicate experiments (n = 3).

The relative standard deviation (RSD) for triplicate absorbance readings across the standards ranged from 2.23% to 7.33%, all below the 10% threshold, indicating excellent precision and consistency. These results affirm the analytical suitability of the molybdenum blue method for detecting phosphate in aqueous detergent matrices.

Phosphate Quantification in Laundry Detergent Samples

The phosphate content of five commercial liquid laundry detergents, labeled A through E, was determined using the same colorimetric approach. Each detergent was diluted at a 1:500 ratio prior to analysis to simulate typical household usage conditions and ensure phosphate concentrations remained within the linear detection range.

Absorbance measurements for each sample were conducted in triplicate, and the results are presented in Figure 2. The RSD for these measurements ranged from 3.57% to 8.80%, indicating acceptable reproducibility. Variations in absorbance values between the brands reflect differing phosphate contents in their formulations.

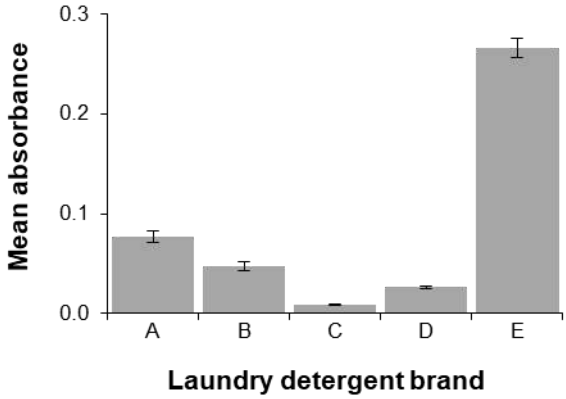


Figure 2. Mean absorbance for laundry detergent phosphate quantification using the molybdenum blue method. The error bars indicate the standard deviation from triplicate experiments (n = 3).

Using the calibration curve from Figure 1, phosphate concentrations were calculated from the average absorbance readings. As summarized in Table 1, Brand E exhibited the highest phosphate concentration at 1.390 mg/L, followed by Brand A at 0.669 mg/L and Brand B at 0.555 mg/L. Brands C and D recorded the lowest phosphate levels, at 0.411 mg/L and 0.476 mg/L, respectively.

Table 1. Calculated phosphate concentrations in laundry detergent samples using the molybdenum blue method

Laundry detergent brand	Calculated phosphate concentration (mg/L)
A	**0.669**
B	**0.555**
C	**0.411**
D	**0.476**
E	**1.390**

Note: Phosphate concentrations (mg/L as PO_4^{3-}) are for 1:500 diluted laundry detergent samples. They were calculated using the calibration curve (Figure 1) from standard solutions (0–5 mg/L) and average absorbance from three measurements at 650 nm (Figure 2).

Estimated Phosphate Discharge Per Laundry Cycle

To better assess the environmental implications of the measured concentrations, the phosphate discharge per single laundry cycle was estimated based on a commonly used household washing machine volume of 50 liters. By multiplying each sample's phosphate concentration by 50 L, the amount of phosphate released per wash was approximated.

For Brand E, the estimated phosphate release was 69.5 mg per wash, reflecting its notably high concentration. Brand A released approximately 33.5 mg, followed by Brand B at 27.8 mg, Brand D at 23.8 mg, and Brand C at 20.6 mg per wash cycle. These values are all well below the European Union's regulatory limit of 0.5 g (500 mg) of phosphate per standard detergent dose (European commission, 2012). Nonetheless, while individually compliant, repeated use of phosphate-containing detergents—particularly those with higher levels like Brand E—can contribute significantly to cumulative phosphate pollution.

Environmental Implications

Phosphate is a critical nutrient that, when present in excess, accelerates eutrophication in freshwater ecosystems. This process promotes the overgrowth of algae and aquatic plants, leading to oxygen depletion, habitat degradation, and in severe cases, the formation of hypoxic "dead zones." In addition, harmful algal blooms may produce toxins that pose risks to both aquatic organisms and human health.

Although all tested detergent brands remain below the EU's 0.5 g phosphate per dose threshold (European commission, 2012), the estimated discharge values suggest that certain products, particularly Brand E, could still pose environmental risks through repeated domestic use. Brands A and B, with moderate concentrations, may also contribute to this burden over time, while Brands C and D appear to have comparatively lower impact.

Many regulatory agencies have imposed limits on phosphate levels in detergents to address these environmental concerns. The EU and several U.S. states have implemented strict standards to phase out or limit phosphate in household cleaning products. The findings of this study reinforce the value of such regulations and highlight the ongoing need for formulation reform, particularly for brands with elevated phosphate levels.

CONCLUSIONS

This study demonstrated the effective application of the molybdenum blue method for quantifying phosphate concentrations in commercial liquid laundry detergents. The calibration curve showed excellent linearity and reproducibility, and the detergent samples exhibited a range of phosphate concentrations reflective of differences in product formulations. When translated to estimated discharge per household wash cycle, all brands were within international regulatory limits, though the cumulative environmental effects of repeated use remain a concern.

To reduce the ecological footprint of phosphate-based detergents, manufacturers are encouraged to adopt phosphate-free formulations or reduce phosphate levels in line with global environmental standards. Public awareness, policy enforcement, and further research into detergent composition and wastewater outcomes will be essential for promoting sustainable household practices and protecting aquatic ecosystems.

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Sekian, terima kasih.

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Setuju.

27.1.2023

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