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EVALUATION OF RIVER WATER QUALITY THROUGH TOTAL SUSPENDED SOLIDS AND TOTAL PHOSPHATE ANALYSIS

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Abstract

River water quality is increasingly threatened by anthropogenic activities that contribute suspended solids and nutrient pollution to aquatic environments. However, site-specific information on the concurrent status of TSS and total phosphate is limited for the investigated river, particularly regarding their compliance with Indonesian water-quality standards. This study aimed to evaluate river water quality through the determination of Total Suspended Solids (TSS) and total phosphate concentrations. TSS was analyzed using the gravimetric method in accordance with SNI 6989.3:2019, while total phosphate was determined by UV–Visible spectrophotometry following SNI 6989.31:2021. The results showed that TSS concentrations ranged from 30–34 mg L^{-1} in the upstream section and 21–24 mg L^{-1} in the downstream section. These values complied with the Class II water quality standards established under Government Regulation No. 22 of 2021. In contrast, total phosphate concentrations ranged from 0.795–0.802 mg L^{-1} upstream and 0.746–0.768 mg L^{-1} downstream, exceeding the limits for both Class I and Class II waters. The elevated phosphate concentrations are consistent with nutrient enrichment and may reflect inputs associated with agricultural runoff, domestic wastewater, detergents, and/or other anthropogenic activities, although the present study did not identify individual sources. Quality control evaluation demonstrated satisfactory analytical performance, with acceptable CRM results, recovery of 109.4%, calibration linearity of R^2 = 0.9991, and precision values within the established acceptance criteria. Overall, the findings indicate that while suspended solids remained within the applicable Class II limit, phosphate concentrations exceeded the applicable standards, highlighting the need for continued monitoring and source-oriented nutrient management in the studied river.

Keywords: River Water Quality, Total Suspended Solids, Total Phosphate, Gravimetric Method, UV–Vis Spectrophotometry, Eutrophication

Abstrak

Kualitas air sungai semakin terancam akibat aktivitas antropogenik yang berkontribusi terhadap peningkatan padatan tersuspensi dan pencemaran nutrien di lingkungan perairan. Penelitian ini bertujuan untuk mengevaluasi kualitas air sungai melalui penentuan kadar Total Suspended Solids (TSS) dan total fosfat. Analisis TSS dilakukan menggunakan metode gravimetri berdasarkan SNI 6989.3:2019, sedangkan total fosfat dianalisis menggunakan spektrofotometri UV-Vis sesuai SNI 6989.31:2021. Hasil penelitian menunjukkan bahwa konsentrasi TSS pada bagian hulu berkisar antara 30–34 mg/L dan pada bagian hilir berkisar antara 21–24 mg/L. Nilai tersebut masih memenuhi baku mutu air Kelas II berdasarkan Peraturan Pemerintah Nomor 22 Tahun 2021. Sebaliknya, konsentrasi total fosfat pada bagian hulu berkisar antara 0,795–0,802 mg/L dan pada bagian hilir berkisar antara 0,746–0,768 mg/L, yang telah melampaui baku mutu untuk perairan Kelas I maupun Kelas II. Tingginya kadar fosfat menunjukkan adanya pengayaan nutrien yang berpotensi memicu eutrofikasi. Evaluasi kendali mutu menunjukkan kinerja analisis yang baik, ditunjukkan oleh hasil CRM yang memenuhi batas keberterimaan, nilai recovery sebesar 109,4%, linearitas kurva kalibrasi yang sangat baik (R^2 = 0,9991), serta nilai presisi yang memenuhi kriteria penerimaan metode. Secara keseluruhan, hasil penelitian menunjukkan bahwa meskipun kadar TSS masih berada dalam batas yang diperbolehkan, pencemaran fosfat menjadi perhatian utama dalam pengelolaan kualitas air sungai sehingga diperlukan pemantauan berkelanjutan dan pengendalian sumber pencemar nutrien.

Kata Kunci: Eutrofikasi, Kualitas Air Sungai, Metode Gravimetri, Spektrofotometri UV-Vis, Total Fosfat, Total Padatan Tersuspensi

1. Introduction

River water is a critical freshwater resource supporting domestic, agricultural, industrial, fisheries, and ecological functions. In the investigated river, evaluating both suspended solids and nutrient contamination is important because these parameters represent complementary aspects of water quality: particulate pollution can affect light availability and aquatic habitats, whereas excessive phosphate can promote nutrient enrichment. Increasing urbanization, industrial activity, and agricultural pressure can intensify pollutant inputs to river systems (Hamidah et al., 2025; Kurniawati, 2023; Sinaga et al., 2024). Consequently, site-specific measurements are needed to determine whether the studied river remains within applicable environmental standards and to identify which water-quality parameter requires greater management attention.

Assessment of river water quality requires the evaluation of physical, chemical, and biological parameters (Nadir et al., 2019; Sinaga et al., 2024). Total Suspended Solids (TSS) is a practical physical indicator because it quantifies suspended particulate matter that can influence water clarity, light penetration, sediment transport, and the mobility of particle-associated contaminants (Majoro et al., 2020; West & Scott, 2016). Its measurement is therefore useful for determining the physical condition of the river and for comparing spatial differences between sampling locations. In the present study, TSS is used specifically as a standardized indicator to assess upstream–downstream differences and compliance with the applicable water-quality standard.

In addition to physical parameters, chemical indicators are important for evaluating nutrient enrichment in aquatic systems. Phosphate is an essential nutrient, but excessive inputs from agricultural runoff, domestic wastewater, detergents, livestock activities, and industrial effluents can increase nutrient availability and contribute to eutrophication (Hamidah et al., 2025; Nadir et al., 2019; Putra et al., 2021). Eutrophication may stimulate excessive algal and aquatic plant growth and, following biomass decomposition, contribute to oxygen depletion. Therefore, monitoring total phosphate is particularly relevant for the investigated river because concentrations above regulatory limits can indicate a nutrient-pollution concern even when TSS remains within the applicable standard.

The simultaneous determination of TSS and total phosphate provides complementary information on the physical and chemical condition of river water. Nevertheless, the present study addresses a practical knowledge gap by combining these two standardized measurements with analytical quality-control evaluation and direct comparison against the Indonesian regulatory framework for the investigated river. The study therefore aims to (i) quantify TSS and total phosphate at upstream and downstream locations, (ii) evaluate their compliance with Government Regulation No. 22 of 2021, and (iii) assess the reliability of the analytical results using the available QA/QC indicators. This approach provides a focused site-specific assessment that can support subsequent river monitoring and nutrient-management efforts.

2. Methodology

2.1 Analytical Methods

River water samples were analyzed to determine two important water quality parameters, namely Total Suspended Solids (TSS) and total phosphate concentration. TSS analysis was conducted using the gravimetric method in accordance with SNI 6989.3:2019, while total phosphate determination was performed using the UV–Visible spectrophotometric method based on SNI 6989.31:2021. These standardized analytical methods were selected to ensure the accuracy, precision, and reliability of the obtained results.

2.2 Total Suspended Solids (TSS) Analysis

The concentration of Total Suspended Solids (TSS) was determined using a gravimetric procedure. A known volume of the water sample was filtered through a pre-weighed membrane filter to retain suspended particulate matter. The filter containing the retained solids was subsequently dried in an oven at 105°C until a constant mass was achieved. After cooling in a desiccator, the filter was weighed using an analytical balance. The TSS concentration was calculated from the difference between the initial and final filter masses relative to the volume of sample filtered and expressed as mg L^{-1}.

2.3 Total Phosphate Analysis

Total phosphate concentration was determined using the UV–Visible spectrophotometric method. Prior to analysis, the water samples underwent a digestion process using potassium peroxodisulfate ($K_2S_2O_8$) to convert all phosphorus-containing compounds into orthophosphate. The resulting orthophosphate then reacted with molybdate reagents to form a blue-colored phosphomolybdenum complex. The absorbance of the developed color was measured at a wavelength of 880 nm using a UV–Vis spectrophotometer. Phosphate concentrations were quantified using a calibration curve prepared from standard phosphate solutions and reported as mg L^{-1}.

2.4 Data Analysis

The analytical results for TSS and total phosphate were evaluated descriptively using the individual replicate concentrations and the corresponding upstream/downstream means and ranges. TSS and total phosphate concentrations were compared with the water-quality classifications specified in Government Regulation of the Republic of Indonesia No. 22 of 2021, with particular attention to the Class I and Class II limits reported for the investigated parameters. Analytical quality was assessed using the available blank, duplicate, certified reference material (CRM), laboratory control sample (LCS), matrix-spike recovery, calibration linearity, and relative percent difference (%RPD) results. These evaluations were used to support interpretation of the environmental measurements rather than to claim complete method validation.

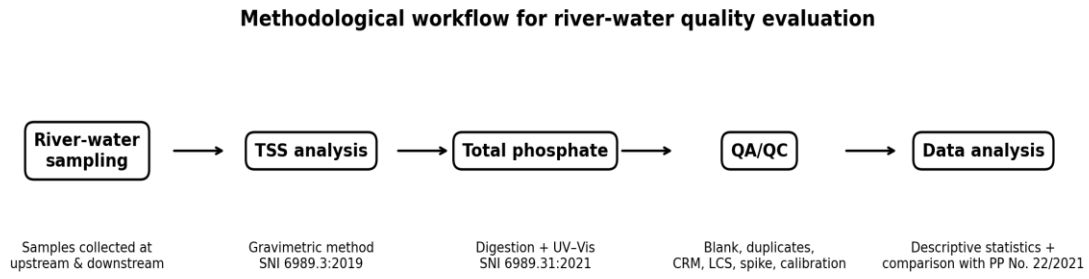


Figure 1. Methodological workflow for the evaluation of TSS and total phosphate in river water.

3. Results and Discussion

3.1 Total Suspended Solids (TSS)

Table 1 shows that TSS concentrations were higher at the upstream stations (34 and 30 mg L^{-1}; mean 32.0 mg L^{-1}) than at the downstream stations (24 and 21 mg L^{-1}; mean 22.5 mg L^{-1}). A downstream decrease in suspended material is consistent with the general understanding that suspended solids in rivers reflect a combination of (i) catchment inputs from erosion and runoff and (ii) in-stream retention or deposition processes that can reduce concentrations along transport pathways (Dewey et al., 2020; Filoso et al., 2015; Law et al., 2020; Mackenzie et al., 2024). Comparable field and modeling studies emphasize that sediment (often operationalized as TSS) is strongly affected by land-use-mediated erosion and hydrological connectivity, while downstream reaches may show attenuation where deposition/retention dominates (e.g., lowland "sediment bottlenecks," wetlands, or impoundments) (Datok et al., 2021; Filoso et al., 2015; Mackenzie et al., 2024; Shrestha et al., 2016).

The higher upstream TSS in Table 1 is plausibly associated with stronger sediment supply from watershed erosion and storm-driven runoff, which mobilize soil particles and organic debris into channels—processes widely reported as key controls on suspended solids in diverse basins (Begg et al., 2022; Dewey et al., 2020; Mackenzie et al., 2024). Catchment studies further show that erosion-control measures and conservation practices can substantially reduce TSS export, implying that where such controls are absent or less effective, event-driven mobilization can elevate TSS in upstream reaches (Law et al., 2020; Mackenzie et al., 2024; McCrary et al., 2024). Empirical work across agricultural and urbanizing watersheds similarly links increased sediment availability and transport to land disturbance and runoff generation, supporting the interpretation

that upstream catchment processes can yield higher TSS than downstream locations when inputs are concentrated upstream (Begg et al., 2022; Dewey et al., 2020; Mackenzie et al., 2024).

Table 1. Results of Total Suspended Solids (TSS) Analysis and Quality Control Evaluation

No.	Sample	TSS Concentration (mg L^{-1})	Certified Value ± Uncertainty (mg L^{-1})	QC Performance Acceptance Limits (mg L^{-1})
1	Downstream Replicate 1	24	–	–
2	Downstream Replicate 2	21	–	–
3	Upstream Replicate 1	34	–	–
4	Upstream Replicate 2	30	–	–
5	CRM S333-5152	80	89.3–107.7	76.3–102
6	Blank	0	–	–

The lower downstream TSS concentrations in Table 1 are consistent with natural attenuation during downstream transport, particularly through deposition and retention in low-gradient reaches, wetlands, and/or impounded sections that can behave as sinks for suspended material (Datok et al., 2021; Filoso et al., 2015; Mereta et al., 2020; Shrestha et al., 2016). For example, wetlands can retain substantial amounts of TSS depending on hydrology and local disturbance pressures (Mereta et al., 2020), while large lowland river–valley settings can trap sediment and reduce downstream fluxes (i.e., functioning as sinks) (Datok et al., 2021). River systems can also show counterintuitive downstream declines in suspended solids where channel conditions favor deposition ("deposition-dominated" behavior), as noted for the Lower Mekong when comparing upstream and downstream stations (Shrestha et al., 2016). In addition, stream–wetland complexes and lowland valley reaches may variably trap suspended solids, with retention dependent on upstream loads and event magnitude, which aligns with a plausible mechanism for downstream reduction observed in Table 1 (Filoso et al., 2015).

Nuance: Not all systems exhibit decreasing TSS downstream; satellite-based work in the Senegal River Basin reported that TSS can increase from upstream to downstream in some river sections, with reductions in specific downstream zones linked to dam effects or deltaic/estuarine conditions (Grippa et al., 2020). Therefore, the downstream decrease observed here should be interpreted as site-specific and contingent on the local balance of sediment sources versus in-stream retention/deposition (Filoso et al., 2015; Grippa et al., 2020; Shrestha et al., 2016).

TSS is widely used as an indicator of physical water-quality condition because suspended particles influence optical properties (e.g., clarity/turbidity and light attenuation) and can therefore affect ecological functioning (Majoro et al., 2020; Tošić et al., 2019; West & Scott, 2016). Elevated suspended sediments reduce light penetration, which can impair primary production and sensitive aquatic habitats; coral reef studies, for example, emphasize that excessive suspended sediments restrict light and can transport associated nutrients with sediments (Tošić et al., 2019). River studies likewise highlight that suspended sediment is a major cause of impairment and can alter habitats and food webs while degrading optical water quality (West & Scott, 2016). The concentrations in Table 1 (21–34 mg L^{-1}) are far lower than the extreme values reported in some highly impacted systems (e.g., multi-hundred to multi-thousand mg L^{-1} ranges reported in other basins), indicating comparatively moderate suspended-solids conditions in the present dataset (Dunea et al., 2020; Majoro et al., 2020); however, even moderate suspended sediments can be important because suspended particles can serve as vectors for contaminants and microorganisms.

Specifically, multiple lines of evidence show that suspended particles can transport sorbed pollutants such as nutrients and metals and can be associated with microbial contamination. Studies demonstrate that suspended sediments can carry adsorbed pollutants and metals in rivers, and that relationships between TSS and bulk metal concentrations can be robust and catchment-specific (Nasrabadi et al., 2018; West & Scott, 2016). Work in artisanal gold-mining-impacted watersheds further shows that total mercury and other trace elements can increase with suspended solids, underscoring the contaminant-carrier role of particles (Diringer et al., 2019). In tropical monitoring, *E. coli* concentrations were reported to correlate with suspended sediment

concentrations, consistent with particle-associated transport of microorganisms during hydrologically connected periods (Nakhle et al., 2021). Taken together, these findings support the interpretation that the TSS levels in Table 1 provide not only a measure of physical condition (clarity/light) but also an informative proxy for the potential transport of particle-associated chemical and microbial stressors (Diringer et al., 2019; Nakhle et al., 2021; Nasrabadi et al., 2018; West & Scott, 2016).

The gravimetric basis of TSS determination described in the literature relies on filtration through a fine-pore filter followed by drying and weighing, which is consistent with widely used laboratory approaches for TSS measurement (Gootman & Hubbart, 2022; Johnson et al., 2018; Kamarudin et al., 2020; Shrestha et al., 2016). Reported protocols commonly include drying at ~105 °C and quantifying mass retained on filters, reflecting the standard gravimetric principle used in many river and lake studies (Gootman & Hubbart, 2022; Johnson et al., 2018; Shrestha et al., 2016). This methodological consistency supports the general comparability of the TSS results in Table 1 to other monitoring contexts that use gravimetric TSS procedures (Gootman & Hubbart, 2022; Johnson et al., 2018; Shrestha et al., 2016).

Quality assurance/quality control (QA/QC) elements reported in Table 1 (certified reference material, procedural blanks, and duplicates) align with established monitoring practice emphasizing the importance of blanks and duplicates to evaluate contamination and analytical variability. For instance, watershed tracing and monitoring efforts have explicitly leveraged blank and duplicate samples to evaluate data quality and guide interpretation, demonstrating the centrality of these QC samples in water-quality datasets (Laceby et al., 2021). In Table 1, the procedural blank result of 0 mg L^{-1} indicates no detectable laboratory-introduced suspended residue for that QC sample, supporting that measured masses in environmental samples are not explained by blank contamination (as evaluated through the blank itself) (Laceby et al., 2021). The duplicate results yielding low relative differences (as summarized in Table 1) similarly indicate good repeatability for the reported dataset, consistent with the role of duplicates in quantifying analytical precision in monitoring programs (Laceby et al., 2021). Finally, the CRM result in Table 1 falls within the laboratory's stated acceptance limits (Table 1), which—by the laboratory's own QC criteria—supports acceptable analytical performance for this batch (interpretation constrained to the acceptance framework reported in Table 1 rather than an external standard) (Laceby et al., 2021).

Overall, Table 1 shows that TSS was 30–34 mg L^{-1} upstream and 21–24 mg L^{-1} downstream, with lower concentrations downstream. This is a measured spatial pattern rather than direct evidence of a specific pollution source. The difference may reflect the balance between local sediment inputs, runoff, hydrological conditions, and in-stream retention or deposition; however, these mechanisms were not independently measured in the present study. Importantly, all observed TSS values were below the applicable Class II limit under Government Regulation No. 22 of 2021. Thus, within the spatial and sampling conditions examined, TSS did not indicate non-compliance, while the upstream–downstream contrast demonstrates that suspended-material conditions were not uniform along the river.

3.2 Total Phosphate

The results of total phosphate analysis are presented in Table 2. Upstream samples contained 0.795–0.802 mg L^{-1} (mean 0.799 mg L^{-1}), whereas downstream samples contained 0.746–0.768 mg L^{-1} (mean 0.757 mg L^{-1}). The downstream concentration was therefore slightly lower than the upstream concentration, but phosphate remained elevated at both locations. These results indicate a persistent concentration of phosphate in the sampled river reaches. Because the study measured concentrations at only the selected locations and did not characterize source-specific inputs, the data do not allow attribution to a particular agricultural, domestic, detergent, livestock, or industrial source.

The elevated phosphate concentrations reported in Table 2 suggest the influence of both natural and anthropogenic nutrient sources. Phosphorus compounds commonly enter river systems through agricultural runoff containing fertilizers, domestic wastewater discharges, livestock activities, detergent residues, and industrial effluents. In watersheds affected by human activities, phosphate enrichment frequently occurs due to inadequate wastewater treatment and uncontrolled nutrient inputs. The relatively high concentrations observed in both upstream and

downstream locations indicate that nutrient loading may be occurring throughout the river catchment rather than being restricted to a single pollution source.

According to Government Regulation of the Republic of Indonesia No. 22 of 2021, the measured total phosphate concentrations exceeded the reported water-quality standards for both Class I waters (0.1 mg L^{-1}) and Class II waters (0.2 mg L^{-1}). The observed concentrations were approximately four times the Class II limit and approximately eight times the Class I limit. This comparison demonstrates regulatory non-compliance for phosphate at both sampling locations and provides a stronger basis for identifying nutrient pollution as the principal water-quality concern observed in this dataset.

Excessive phosphate concentrations are of particular environmental concern because phosphorus is often the limiting nutrient controlling primary productivity in freshwater ecosystems. Elevated phosphate levels can stimulate rapid growth of algae and aquatic plants, leading to eutrophication. During eutrophication events, dense algal blooms may reduce water transparency and disrupt ecological balance. The subsequent decomposition of excessive algal biomass consumes dissolved oxygen, potentially resulting in hypoxic or anoxic conditions that threaten fish populations and other aquatic organisms. Therefore, the phosphate concentrations presented in Table 2 suggest a potential risk of eutrophication within the studied river system and highlight the need for effective nutrient management strategies.

Table 2. Total Phosphate Concentrations and Quality Control Results

Sample Code	Absorbance (Y)	Calculated Concentration (X) (mg L^{-1})	Dilution Factor	Actual Concentration (mg L^{-1})	QC Performance Acceptance Limits (mg L^{-1})
Blank	0.0010	0.013	1	0.013	–
LCS (0.7 mg L^{-1})	0.1236	0.766	1	0.766	–
CRM 920523m	0.1950	1.204	4	4.816	4.78–4.89
Upstream Replicate 1	0.1295	0.802	1	0.802	–
Upstream Replicate 2	0.1283	0.795	1	0.795	–
Matrix Spike (+0.1 mg L^{-1})	0.1457	0.902	1	0.902	–

The calibration curve used for phosphate quantification demonstrated excellent linearity across the concentration range investigated. As shown in Figure 2, the calibration equation exhibited a coefficient of determination (R^2) of 0.9991, indicating a very strong linear relationship between phosphate concentration and absorbance. The high R^2 value confirms that the spectrophotometric method provides reliable quantitative measurements and that the analytical response is proportional to phosphate concentration within the working range of the method.

The calibration curve showed strong linearity, with $R^2 = 0.9991$ (Figure 2), indicating a consistent relationship between phosphate concentration and absorbance over the working range. This result supports the use of the calibration for quantification within the tested range, but R^2 alone was not interpreted as proof of complete analytical accuracy or method validation. Accuracy and precision were evaluated using the available QC results. The matrix-spike recovery was 109.4%, which is within the 85–115% acceptance range applied in this study, although the value represents a slight positive bias relative to 100%. The CRM result (4.816 mg L^{-1}) also fell within its stated laboratory acceptance interval of 4.78–4.89 mg L^{-1}, while duplicate measurements produced %RPD values below 10%. Together, these results support satisfactory batch-level analytical performance under the laboratory QC criteria used in this study.

In addition to the recovery assessment, analysis of the Certified Reference Material (CRM) produced results that complied with the established laboratory quality control limits, confirming the accuracy and traceability of the analytical procedure. Furthermore, duplicate analyses yielded Relative Percent Difference (%RPD) values below 10%, indicating excellent precision and repeatability of the method. The low %RPD values demonstrate consistent analytical performance and minimal variability between replicate measurements.

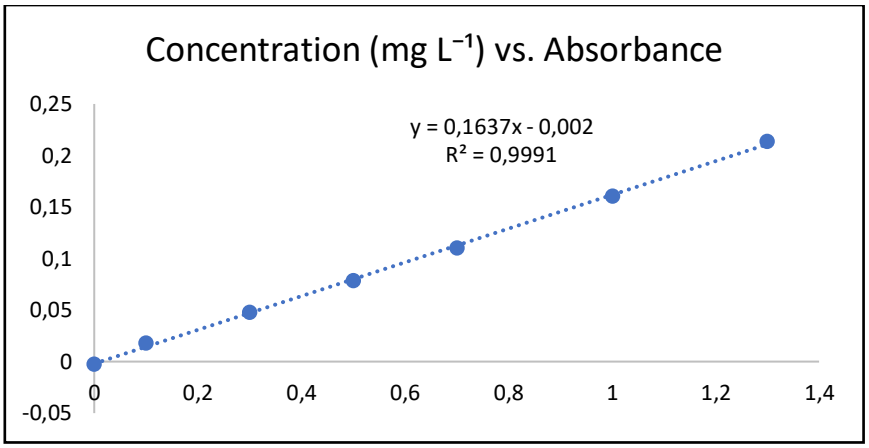


Figure 2. Calibration curve showing the relationship between phosphate concentration and absorbance measured at 880 nm.

Overall, the results presented in Table 2 indicate that phosphate concentrations in the studied river substantially exceed the applicable water quality standards and may pose a risk of eutrophication if nutrient inputs are not properly controlled. The excellent calibration linearity (R^2 = 0.9991), acceptable recovery value (109.4%), satisfactory CRM performance, and low %RPD values collectively demonstrate that the analytical data are reliable and suitable for environmental assessment purposes. These findings emphasize the importance of continuous monitoring and nutrient management programs to reduce phosphorus loading and protect the ecological integrity of the river ecosystem.

4. Conclusion

The present study assessed river water quality through standardized determination of Total Suspended Solids (TSS) and total phosphate using gravimetric and UV–Vis spectrophotometric methods. TSS concentrations ranged from 21–34 mg L^{-1} and remained within the Class II water-quality standard of Government Regulation No. 22 of 2021. In contrast, total phosphate concentrations ranged from 0.746–0.802 mg L^{-1} and exceeded the reported limits for both Class I and Class II waters. The analytical QC results—including CRM performance within the laboratory acceptance interval, 109.4% matrix-spike recovery, R^2 = 0.9991 calibration linearity, and %RPD values below 10%—support the reliability of the reported batch measurements, while the slight positive recovery bias should be acknowledged. The principal finding is therefore that phosphate, rather than TSS, represents the main water-quality concern in the investigated river under the sampling conditions of this study. Continued spatial and temporal monitoring, together with investigation of potential nutrient sources, is warranted to determine the persistence and origin of the observed phosphate enrichment.

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