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To cite this article: I M W Wijaya *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1268** 012002

INCRID 2023 IOP Publishing
IOP Conf. Series: Earth and Environmental Science 1268 (2023) 012002 doi:10.1088/1755-1315/1268/1/012002

Study on Nutrients Concentration Trends in Tukad Badung River Toward Nutrient Recovery Potential

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Abstract. This study addresses the urgent concern of water quality degradation resulting from untreated domestic wastewater discharge, with a specific focus on nutrient trends within an aquatic ecosystem. The investigation centres on ammonium (NH_4^+) as a significant contaminant sourced from residual foods, hygiene practices, and fertilizers, known for its association with eutrophication—characterized by excessive algae growth and oxygen depletion. The study aims to offer comprehensive insights by meticulously analysing water quality parameters across six distinct sampling points. Data collection encompassed total suspended solids (TSS), ammonia (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), total phosphate (PO_4^-), and total nitrogen (TN). Notable variations were observed: TSS concentrations ranged from 9.00 mg/L to 20.00 mg/L, NH_4^+ concentrations spanned 0.00 mg/L to 1.96 mg/L, NO_2- and NO_3^- levels varied from 0.00 mg/L to 0.16 mg/L and 1.19 mg/L to 1.91 mg/L, respectively, PO_4^{3-} content ranged from 0.01 mg/L to 0.65 mg/L, and TN concentrations fluctuated between 1.36 mg/L and 3.31 mg/L. These findings underscore the complexity of water quality dynamics and highlight the need for integrated management strategies to mitigate nutrient pollution's impact on aquatic ecosystems.

1. Introduction

Tukad Badung River is situated in the Badung Regency and Denpasar City on the island of Bali, spans approximately 30 km in length and encompasses a watershed area of 37.7 km^2. The Tukad Badung River presents a valuable water resource that can be effectively harnessed by the neighbouring communities for both domestic and industrial purposes [1]. Nevertheless, the Tukad Badung River is subject to regular influxes of solid and liquid waste originating from various activities conducted within its surrounding watershed. According to a study conducted by Ciawi [2], it was found that the Tukad Badung River experienced a pollutant load of 111.02 kg/day for total suspended solids (TSS) and 92.24 kg/day for biological oxygen demand (BOD) at the upstream location. At the downstream location, the pollutant load increased to 440.92 kg/day. On the other hand, the river's ability to absorb pollutants is limited to 15.43 kg/day for total suspended solids (TSS), 19.69 kg/day for biochemical oxygen demand (BOD), and 7.45 kg/day for chemical oxygen demand (COD). The existence of nitrogen compounds in wastewater poses a noteworthy environmental concern. Nitrogen compounds that are detected in wastewater exist in diverse states, encompassing ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), and organic nitrogen. The organic nitrogen that is found in wastewater undergoes a process of decomposition, leading to the formation of ammonium ions and their subsequent incorporation into bacterial cells. The increased level of pollutants can be attributed to a variety of activities taking place within the Tukad Badung watershed, where untreated wastewater is discharged directly into the river. The presence of nutrient compounds in water can have negative impacts on water quality if their concentrations exceed established standards, in addition to the parameters of total suspended solids (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD).

Nutrient compounds, namely nitrogen (N) and phosphorus (P) compounds, are frequently present in both domestic and industrial wastewater [3]–[5]. Eutrophication can occur because of elevated concentrations of nitrogen and phosphorus compounds derived from aquatic sources. Eutrophication conditions give rise to a swift proliferation of algae, commonly referred to as blooming [6]–[9]. As the population of algae proliferates, a greater amount of dissolved oxygen in the water is consumed for the purpose of algal respiration. When the concentration of dissolved oxygen falls below 2 mg/L, it can result in the mortality of various aquatic organisms, including fish, prawns, clams, and other species.

In accordance with Ministerial Regulation No. 68 of 2016 [10] and Government Regulation No. 22 of 2021 [11], the prescribed thresholds for nutrient compounds in Class 1 water quality are as follows: 0.1 mg/L for ammonium ions (NH_4^+), 10 mg/L for nitrate ions (NO_3^-), 0.06 mg/L for nitrite ions (NO_2^-), 15 mg/L for total nitrogen (Total N), and 0.2 mg/L for phosphate ions (PO_4^{3-}). As a result, the presence of nutrients plays a crucial role in the management of water resources. Based on the findings of Yang [12], it has been determined that eutrophication can be induced by total nitrogen (N) levels ranging from 1 to 2 mg/L and total phosphorus (P) levels ranging from 0.03 to 0.1 mg/L. Hence, the study on nutrient pollutants is still lack and imperative, while it is very important since it plays role to mitigate the occurrence of eutrophication, uphold the integrity of water quality, and ascertain the implementation of suitable management strategies [5], [13]–[19]. The nutrients trend should be monitored accordingly to avoid the risk of eutrophication. This study aims to investigate the spatial and temporal variations of N and P concentrations along the river's course, from its origin in the upstream areas to its discharge point downstream.

2. Methods

The research on nutrient pollutant trends in the Tukad Badung River and its potential recovery will be conducted within the time span of March 2023. The study is divided into two research activities: analysing nutrient pollutant trends, focusing on the Tukad Badung watershed, and investigating nutrient recovery processes with a focus on the efficiency of nutrient compound adsorption using different adsorbents. Research I encompass the entirety of the Tukad Badung watershed, divided to 3 zones: upstream, midstream, and downstream.

2.1 Preparation

In the preparatory stage, necessary permits from relevant authorities were obtained, and requirements for equipment, materials, and personnel were inventoried for data collection throughout the research activities. The required permits were secured from the Provincial Forestry and Environmental Agency of Bali. Equipment essential for the research activities included: sample water containers, laboratory supplies, buckets, 500-mL measuring glasses, plastic test tubes, filter papers, measuring tapes, portable water quality measurement devices, flow metres.

2.2 Sampling Point

The objective of research is to analyse nutrient pollutant (nitrogen and phosphorus) trend patterns along the course of the Tukad Badung River. The section of the Tukad Badung River selected for this study is approximately 18 km long, representing the stretch from upstream to downstream. Sampling will be conducted at 6 points: 2 points representing the upstream area, 2 points in the midstream, and 2 points representing the downstream area. The selection of sampling locations adheres to Ministerial Regulation

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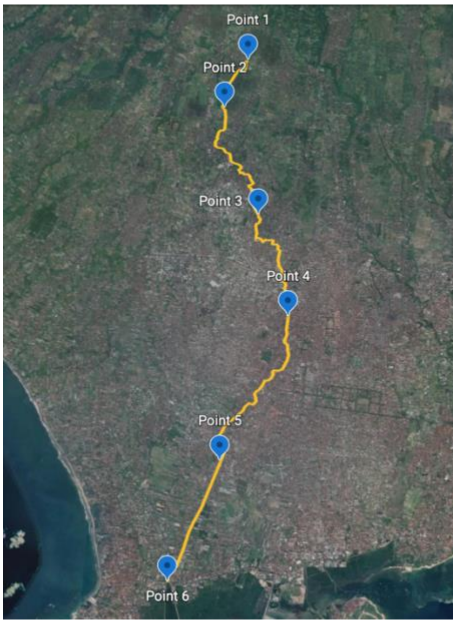
No. 01 of 2007 on Technical Assessment Guidelines for Water Classification. River flow velocity and discharge measurements will be conducted in accordance with the SNI 03-2819-1992 standard for river and open channel discharge measurements. The water sampling locations within the Tukad Badung River are provided in Table 1.

2.3 Sampling Collection and Analysis
Sampling will occur twice daily at each point, specifically at 08:00 to capture peak domestic wastewater production conditions. About 5 litres of water have taken from the sampling point to be analysed. Water quality parameters to be analysed in water samples include TSS, pH, DO, NH_4^+, NO_2^-, NO_3, Total N, PO_4^{3-}, and Total P. Water sampling technique followed the SNI 6989.57-2009 standard for surface water sampling methods.

Table 1. Sampling location and coordinate

No	Sampling location	Coordinates
	Upstream	
1	Point 1	Latitude: -8.5827712° Longitude: 115.1954701°
2	Point 2	Latitude: -8.5977317° Longitude: 115.1909239°
	Midstream	
3	Point 3	Latitude: -8.6244026° Longitude: 115.2020789°
4	Point 4	Latitude: -8.6501397° Longitude: 115.2125346°
	Downstream	
5	Point 5	Latitude: -8.6892022° Longitude: 115.1980685°
6	Point 6	Latitude: -8.7213259° Longitude: 115.1883932°



15 **3. Results and Discussion**

3.1. Nutrient Content in the Stream Water
Domestic wastewater is an environmental concern that demands serious attention due to the diminishing capacity of the environment for self-purification against pollutant loads [20]. Domestic wastewater contains organic matter, nutrients, chemical compounds, and potentially harmful pathogenic microorganisms [21], [22]. The presence of high nitrogen and phosphates in water bodies can lead to eutrophication, a phenomenon where rapid algal growth, also known as blooming, occurs [6], [23]. The primary sources of nitrogen commonly encountered in wastewater are urine, faeces, food residues, dishwater, and fertiliser. Ammonium nitrogen is a compound that is present in wastewater in diverse forms and is considered a pollutant. According to Patterson [24], a significant portion of nitrogen sources in everyday life can be attributed to activities such as food preparation and the disposal of leftovers, the utilisation of chemical products for bathing and cleaning, and the application of chemicals for sanitation purposes. The introduction of nitrogen compounds into aquatic ecosystems can give rise to various
7 ecological concerns, such as eutrophication and diminished levels of dissolved oxygen in water bodies.
6 Typically, the release of ammonium ions into the atmosphere occurs as nitrogen gas via the processes

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of nitrification and denitrification. When ammonia (NH_3) is dissolved in water, it undergoes a chemical reaction where it combines with hydrogen ions derived from water molecules. This reaction results in the formation of ammonium ions and hydroxide ions. Ammonia demonstrates limited basic characteristics, whereas ammonium demonstrates limited acidic characteristics.

This surge in algal populations can lead to a reduction in aquatic species, disrupting the ecosystem. In the N-cycle, plants uptake ammonia and dissolved nitrogen oxides from water through soil pores and convert them into nitrogen compounds such as proteins, DNA, and others. The uptake of fixed nitrogen is relatively low, as bacteria convert it back to N_2 gas, releasing it into the air and eventually re-entering the nutrient sub-cycle [44]. Within this nutrient sub-cycle, nitrogen undergoes reversible oxidation-reduction reactions that convert organic nitrogen molecules, like proteins, into ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3). In aerobic conditions, ammonia is oxidised to nitrite and nitrate using dissolved oxygen [25], [26].

The environmental behaviour of phosphorus is heavily influenced by its low solubility in most inorganic compounds, strong adsorption to soil, and its known that phosphorus is a vital nutrient for nearly all forms of life, including animals, plants, and microorganisms [27]. High concentrations of phosphorus in effluent wastewater are often responsible for the rapid proliferation of algae and other plants, initiating the onset of eutrophication [28]. In surface waters, phosphorus concentration is influenced by sediments, which act as reservoirs for adsorbed and deposited phosphorus. Changes between dissolved and deposited forms, mediated by bacteria, play a pivotal role in making phosphorus available to algae, thus contributing to eutrophication. Dissolved phosphorus concentration in river water bodies generally hovers around 0.1 mg/L. Phosphate solubility increases in low pH conditions, with particulate phosphorus composing 95% of the total phosphorus.

Nitrogen and phosphorus are important nutrients for living organisms, including humans, plants, animals, and microorganisms. The significance of controlling phosphorus and nitrogen parameters in water is to prevent water body eutrophication [29]. Characteristics of eutrophication in water bodies include greenish water colour, unpleasant odour, increasing turbidity, the presence of dense water hyacinth populations covering the water surface, and algal blooms [30], [31]. Cyanobacteria (blue-green algae), which dominate under eutrophic conditions, are known to contain toxins, posing health risks to humans and animals [23].

The oxidation of ammonium by nitrogen bacteria into nitrite and nitrate, commonly referred to as nitrification, occurs subsequently. Nitrification refers to the biochemical process in which autotrophic bacteria, specifically those belonging to the *Nitrosomonas* and *Nitrobacter* genera, oxidise ammonium ions into nitrate. The process of ammonium ion oxidation to nitrite is carried out by Nitrosomonas, which is subsequently followed by the oxidation of nitrite to nitrate by *Nitrobacter*. The process of nitrogen gas (N_2) liberation takes place within the nitrogen cycle. The introduction of nitrogen gas into the atmosphere is attributed to the process of denitrification. During the process of denitrification, bacteria belonging to the *Pseudomonas* genus facilitate the conversion of nitrate into nitrogen gas.

The composition and impact of nitrogen compounds are significant subjects of study in the field of chemistry. Nitrogen compounds are chemical substances that contain nitrogen atoms bonded to other elements, such as carbon, hydrogen, and oxygen. These compounds play a crucial role in various natural and industrial processes. Barber and Stuckey [32] assert that nitrogen compounds found in domestic wastewater predominantly comprise ammonia (60%) and organic nitrogen (40%). Nevertheless, the processes require significant energy sources, specifically oxygen and carbon [33]. Nitrate is widely recognised as the nitrogen compound that poses the greatest environmental concerns. The solubility, mobility, and instability of nitrates in aquatic environments can lead to their facile infiltration into groundwater. In addition, it is worth noting that nitrate serves as a catalyst for the process of eutrophication and has the potential to induce adverse health effects in both humans and animals when it is present in drinking water [24]. Nitrate exhibits inherent instability, thereby facilitating its facile absorption by plants and microorganisms.

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3.2. Nutrient Concentration

This study aims to investigate the intricate patterns of nutrient distribution in aquatic environments to gain a better understanding of the resulting implications for water quality. The widespread and concerning phenomenon of discharging untreated domestic wastewater from residential sources into water bodies introduces a diverse array of pollutants into these ecosystems. The presence of ammonium ions (NH_4^+) in water has a substantial detrimental effect on its overall quality. The sources of ammonium are diverse and encompass a range of factors. These include the disposal of leftover food, household cooking techniques, personal hygiene practices such as bathing and toilet usage, waste materials such as excrement and urine, and the application of fertilisers.

The ramifications of elevated concentrations of ammonium have wide-ranging implications for the occurrence of eutrophication in aquatic systems, a phenomenon predominantly driven by the heightened accumulation of nitrogen (N) and phosphorus (P). The process of accumulation facilitates the accelerated proliferation and expansion of algae. The proliferation of algal growth invariably results in a reduction in dissolved oxygen levels, thereby initiating a contest for oxygen resources among aquatic organisms and microorganisms. When the dissolved oxygen concentration decreases to levels below 2 mg/L, it presents a significant risk to the viability of diverse aquatic organisms, including fish, prawns, molluscs, and other species. The research by Correll [35] emphasizes the significance of nutrient concentrations in eutrophication.

According to this research, total nitrogen (N) concentrations of 1 to 2 mg/L and total phosphorus (P) concentrations of 0.03 to 0.1 mg/L can start eutrophication. On the other hand, the river's ability to absorb pollutants is limited to 15.43 kg/day for total suspended solids (TSS), 19.69 kg/day for biochemical oxygen demand (BOD), and 7.45 kg/day for chemical oxygen demand (COD). The existence of nitrogen compounds in wastewater poses a noteworthy environmental concern. Nitrogen compounds that are detected in wastewater exist in diverse states, encompassing ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), and organic nitrogen. The organic nitrogen found in wastewater undergoes a process of decomposition, leading to the generation of ammonium ions and their subsequent incorporation into bacterial cells. The increased level of pollutants in the Tukad Badung watershed can be attributed to a variety of activities taking place within the area, where untreated wastewater is discharged directly into the river. The exceeding of established water quality standards by the concentrations of nutrient compounds in water can have adverse effects on water quality, in addition to the parameters of TSS, BOD, and COD. The result of nutrient analysis from each sampling point are presented below.

Table 2. Nutrient analysis along the Tukad Badung River

Parameter	Sampling Point					
	1	2	3	4	5	6
Total Suspended Solid (mg/L)	12.00	19.00	20.00	18.00	9.00	12.00
Ammonia (mg/L)	0.57	0.00	0.09	0.25	1.54	1.96
Nitrite (mg/L)	0.09	0.00	0.03	0.13	0.10	0.16
Nitrate (mg/L)	1.22	1.39	1.23	1.91	1.41	1.19
Total Phosphate (mg/L)	0.01	0.07	0.14	0.28	0.65	0.49
Total Nitrogen (mg/L)	1.89	1.39	1.36	2.29	3.06	3.31

To direct our focus towards the provided tabulated data, it is necessary to conduct a thorough examination of the measured parameters at six separate sampling locations within the aquatic environment. The concentrations of total suspended solids (TSS) display significant fluctuations, ranging from 9.00 mg/L to 20.00 mg/L at the sampled locations. The range of ammonia (NH_4^+) concentrations exhibits interesting patterns, varying from minimal amounts at certain locations to notably higher levels at others, specifically at sampling points 5 and 6, where the values reach a

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10 maximum of 1.96 mg/L. The levels of nitrite (NO_2^-) exhibit a relatively restrained range, ranging from 0.00 mg/L to 0.16 mg/L, while the concentrations of nitrate (NO_3^-) demonstrate a similar pattern,
2 oscillating between 1.19 mg/L and 1.91 mg/L. The concentration of total phosphate (PO_4) exhibits
4 considerable variability, spanning a range of 0.01 mg/L to 0.65 mg/L. The concentrations of total
2 nitrogen (TN) display significant variability, ranging from 1.36 mg/L to 3.31 mg/L. The diverse range of findings underscores the intricate relationships and interdependencies among these variables within the aquatic milieu. The comprehensive examination of data obtained from six distinct sampling locations within the aquatic environment yields a profound comprehension of the intricacies associated with multiple parameters. This observation presents a multitude of implications for the aquatic environment and the surrounding ecosystem.

The concentrations of total suspended solids (TSS) observed at different sampling locations
2 demonstrate a significant variation, ranging from 9.00 mg/L to 20.00 mg/L. The observed fluctuations
7 in total suspended solids (TSS) concentrations suggest the heterogeneous composition of suspended particulate matter within the aquatic environment. The observed variation can be attributed to a confluence of multiple factors, including local hydrodynamics, sediment resuspension, and anthropogenic activities that influence sediment influx. Elevated levels of total suspended solids (TSS) may imply the potential occurrence of sediment erosion and disturbances caused by human activities, whereas lower levels may indicate a relatively less disrupted ecological setting.

The concentrations of ammonia (NH_4^+) exhibit noteworthy patterns that bear significant implications for water quality and ecological stability. The observed spectrum, ranging from minimal concentrations to a maximum value of 1.96 mg/L, suggests the existence of spatial discrepancies in nutrient contributions originating from both domestic and agricultural origins. Elevated concentrations of ammonia observed at sampling locations 5 and 6 may suggest heightened nutrient input resulting from anthropogenic sources or agricultural discharge, thereby raising apprehensions regarding the potential amplification of eutrophication mechanisms. On the other hand, decreased levels may indicate the presence of effective natural attenuation or a reduced influence from nutrient sources. The relatively low levels of nitrite (NO_2) and the corresponding pattern observed in nitrate (NO_3) concentrations indicate the possibility of nitrogen transformation processes occurring in the aquatic ecosystem. The observed variations in these parameters may suggest different phases of nitrogen processing, which are significantly impacted by microbial activities, oxidation-reduction conditions, and the prevailing nutrient concentrations. Elevated concentrations of nitrite may indicate incomplete nitrification processes or localised inputs, whereas the variability observed in nitrate levels could potentially signify the presence of multiple nutrient sources and diverse cycling pathways.

2 The range of total phosphate (PO_4) concentration, which varies from 0.01 mg/L to 0.65 mg/L, is of considerable importance in relation to the potential occurrence of eutrophication. Elevated levels of phosphate have the potential to augment the growth of algae, thereby initiating changes in the composition and functioning of aquatic ecosystems. The detection of comparatively higher levels of phosphate concentrations at specific locations may indicate areas of potential concern, potentially associated with the introduction of detergents, agricultural runoff, or industrial discharges.

2 The diverse spectrum of total nitrogen (TN) concentrations, ranging from 1.36 mg/L to 3.31 mg/L, underscores the complex dynamics of nitrogen in aquatic ecosystems. The observed fluctuations in nitrogen concentrations can be attributed to multiple contributing factors, including agricultural runoff, domestic wastewater, and atmospheric deposition. Higher concentrations of total nitrogen (TN) are indicative of greater nutrient inputs, requiring careful management strategies to mitigate the potential risks associated with eutrophication. In summary, the diverse fluctuations in water quality parameters observed at various sampling locations underscore the intricate interplay taking place within the aquatic ecosystem. The trends that have been observed provide significant insights into the diverse sources of pollutants, the mechanisms of their transformation, and the potential consequences they may have on the aquatic ecosystem. A comprehensive understanding of the topic is essential for making informed decisions that prioritise the mitigation of eutrophication, the preservation of water quality, and overall environmental well-being. The findings offer a comprehensive comprehension of the intricate interplay

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among diverse factors that impact the quality of water and the ecological equilibrium of the aquatic milieu. The coexistence of varying nutrient concentrations, particularly ammonium, phosphorus, and nitrogen, underscores the potential for complex and consequential interactions. Moreover, the identification of elevated levels of ammonium in certain sampling sites indicates a concerning possibility of intensifying eutrophication processes. The observed phenomenon involves the swift expansion of algae populations, which has the potential to disturb the balance of ecosystems, diminish oxygen concentrations, and potentially destabilise ecological equilibrium. In order to address these challenges, it is crucial to possess a comprehensive understanding of the intricate nutrient dynamics that exist within aquatic systems. This acquired knowledge will establish a fundamental basis for the formulation of informed management strategies that are capable of efficiently safeguarding water quality and advancing overall ecological welfare.

The concentration of total phosphate (PO_4) exhibits a considerable range, spanning from 0.01 mg/L to 0.65 mg/L. The concentrations of total nitrogen (TN) demonstrate significant variability, ranging from 1.36 mg/L to 3.31 mg/L. The diverse range of findings underscores the intricate relationships and interdependencies among these variables within the aquatic ecosystem. The comprehensive examination of data obtained from six distinct sampling locations within the aquatic environment yields a profound comprehension of the intricacies surrounding diverse parameters. This observation presents a multitude of implications for the aquatic environment and the surrounding ecosystem. The concentrations of Total Suspended Solids (TSS) observed at different sampling points demonstrate a significant variation, ranging from 9.00 mg/L to 20.00 mg/L. Changes in the concentrations of total suspended solids (TSS) can be seen as evidence of the different kinds of particles that make up suspended matter in aquatic environments. The observed variation can be attributed to a confluence of multiple factors, including local hydrodynamics, sediment resuspension, and anthropogenic activities that influence sediment influx. Higher levels of total suspended solids (TSS) may mean that sediment erosion and disturbances caused by humans may be happening, while lower concentrations may mean that the environment is less disturbed. The concentrations of ammonia (NH_4^+) exhibit significant patterns that have significant implications for water quality and ecological stability.

4. Conclusion

This study investigates the various water quality parameters present in aquatic environments, shedding light on the complex dynamics that influence the health and sustainability of water ecosystems over extended periods of time. The examination of data obtained from six distinct sampling points provides insights into the intricate relationships among various contaminants and their implications for both water quality and the overall integrity of the ecosystem. The concentrations of ammonia exhibit spatial variability, with certain regions demonstrating negligible quantities while others display significantly elevated levels. The highest concentrations of ammonia, with a maximum value of 1.96 mg/L, are observed at sampling points 5 and 6. The concentrations of nitrite range from 0.00 mg/L to 0.16 mg/L, while the levels of nitrate exhibit fluctuations between 1.19 mg/L and 1.91 mg/L. The total phosphate concentration demonstrates considerable variability, encompassing a range of values between 0.01 mg/L and 0.65 mg/L. The concentrations of total nitrogen exhibit considerable variability, spanning from 1.36 mg/L to 3.31 mg/L. The significance of the variation in total phosphate concentration is closely linked to the potential occurrence of eutrophication. In the same way, higher concentrations of total nitrogen are a sign of more nutrient inputs. This means that eutrophication needs to be carefully managed to reduce the risks that come with it.

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