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Assessment of Eutrophication Status in Municipal Surface Waters of Kaduna Metropolis, Nigeria

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Abstract—*Eutrophication is a growing environmental concern, particularly in urban water bodies receiving excessive nutrient inputs from anthropogenic sources such as agriculture, domestic wastewater, and industrial runoff. This study assessed the eutrophication status of selected municipal surface water bodies within Kaduna Metropolis, Nigeria. Water samples were collected from Rivers Kaduna, Mando, and Baban Saura and analysed for key nutrients (nitrate, phosphate, and total phosphorus), physicochemical parameters (pH, temperature, total dissolved solids, and electrical conductivity), and the trophic state index (TSI). The results revealed significantly elevated total phosphorus levels at two locations (River Kaduna and River Mando), with the highest concentration recorded in River Kaduna (800.67 mg/L), indicating a hypereutrophic condition. Physicochemical parameters varied slightly among sites but remained within tolerable limits for aquatic life. TSI values classified two out of the three studied water bodies as hypereutrophic, suggesting a high risk of algal bloom and oxygen depletion. Significant correlations were observed between nutrient concentrations and temperatures, underscoring the interconnectedness of these parameters in eutrophication processes. The study concludes that municipal surface waters in Kaduna Metropolis are under considerable eutrophication pressure and recommends regular monitoring, nutrient load control, and inclusion of broader ecological indicators in future assessments to support sustainable water resource management.*

Keywords— *Eutrophication; surface water; River; physicochemical parameters; nutrients; municipal.*

I. INTRODUCTION

Eutrophication refers to the enrichment of water bodies with nutrients, primarily nitrogen and phosphorus, which often leads to excessive algal growth and a decline in water quality. In other words, it is the gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in an ageing aquatic ecosystem, such as a lake (Britannica, 2025). This phenomenon is of particular concern for municipal surface water sources, as it can lead to a host of environmental and health problems, including hypoxia, biodiversity loss, and contaminated drinking water supplies. Eutrophication can be induced by a combination of agricultural runoff, wastewater discharge, and urban stormwater, all of which are common in municipal areas (Akinnawo, 2023; Lukhele and Msagati, 2024).

Human activities and climatic variability have accelerated eutrophication globally. Advances in science and agricultural technology have led to increased use of organic and synthetic fertilisers rich in phosphorus, potassium, and calcium, which further exacerbate nutrient loading in water bodies. In a bid to combat the Malthusian theory of overpopulation and food scarcity, many nations have constructed dams for irrigation and hydroelectric power generation, especially in arid regions. However, water storage reservoirs and artificial lakes are also prone to nutrient enrichment, evaporation losses, and degradation due to biological overgrowth of plankton, insects, fish, and higher aquatic plants (Rashid and Anjum, 1985; Ansari and Gill, 2014; May *et al*., 2021).

In recent years, eutrophication has been identified as a growing threat to the sustainability of urban water sources (Hwang, 2020; Mng'ong'o *et al*., 2022). This study aims to assess the current level of eutrophication in selected municipal surface waters in Kaduna metropolis, focusing on its causes, extent, and impact on local ecosystems. By evaluating the relationship between nutrient inputs and water quality, this research seeks to contribute to the broader understanding of eutrophication dynamics in urban waters.

II. MATERIALS AND METHODS

Study Site

The study focused on selected surface water bodies in Babban Saura, Mando, and Kaduna municipal areas, which serve as municipal water sources. Specific sites were chosen based on their accessibility, significance to the local population, and known eutrophication concerns.

Duration of Research

The research was conducted over a period of three months, from March 2025 to May 2025, to account for seasonal variations in water quality and nutrient concentrations.

Sample Collection and Sampling Method

Water samples were collected at regular intervals, once per month, from designated locations within the water bodies (upstream and downstream). Sampling was done using standard grab sampling techniques, which involve collecting a sample at a specific location and specific point in time to ensure water quality (Danielson, 2014; Tadić *et al*., 2022). Collected water samples were stored at room temperature in a clear plastic bottle (750 ml) that had been pre-cleaned with concentrated hydrochloric acid (conc. HCl).

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Sample Testing

The physical parameters measured include pH, total dissolved solids (TDS), electrical conductivity (EC), and temperature; chemical (nutrient) parameters measured include nitrate, phosphate, and phosphorus. In addition to the nutrient analysis, the Trophic State Index (TSI) was also analysed.

Nutrient Analysis

Nutrient Analysis: Nitrate (NO_3^-), Phosphate (PO_4^{3-}), and Total Phosphorus (TP) were analysed using standard spectrophotometric methods. This method involves adding reagents to the water sample, causing a colour change proportional to the nutrient (element) concentration. The colour intensity was then measured using a spectrophotometer.

Determination of Nitrate

Nitrate Nitrogen was determined using a multiparameter photometer with COD. The phenoldisulphonic acid method was used. 10 mL of the sample was transferred into a clean, dry crucible, and then reagent A (phenol disulfuric acid) was added, and the mixture was swirled uniformly. It was then left to stand for 10 minutes, and 10 mL of distilled water was added. After this, reagent B (5 mL ammonia solution) was added and allowed to cool. Concentration was read when the read button was pressed.

Determination of Phosphate

The Phosphate method was selected using the mode after switching on the photometer and allowing it to stabilise for 5 minutes. The cuvette was rinsed several times with unreacted sample before filling it with 10 mL of sample and capping it. The cuvette was then placed into the holder, and the lid was closed. After that, the Zero key was pressed in order to zero the machine for recalibration. When the meter was zeroed and ready for measurement, one packet of HI736-25 phosphorus reagent was added, the cuvette was capped, and the mixture was shaken gently for about 2 minutes until the powder was completely dissolved. The cuvette was then reinserted into the instrument, and the lid was closed. The timer button was then pressed, and the display showed a countdown of 3 minutes prior to the measurement. The instrument then displays the phosphorus pentoxide (P_2O_5) concentration in mg/L. This value was converted to phosphate PO_4^{3-} in mg/L by multiplying by a factor of 1.366.

Total Phosphorus Determination

The Phosphorous method was selected using the mode after switching on the photometer and allowing it to stabilise for 5 minutes. The Phosphorus React method was selected from the mode, and the 16 mm vial adapter was used. The cap from the HI93758A-0 Reactive Phosphorus reagent vial was remoulded, and 5.0 mL of sample was added to the vial, while keeping the vial at a 45-degree angle. The cap was replaced and inverted several times to mix. The vial was then placed into the holder, and the Zero key was pressed to zero the meter, which indicated the meter was ready for measurement. The vial was then removed, and one packet of HI93758-0 Phosphorus Reagent was added, shaken gently for 2 minutes until most of the powder was dissolved. The vial was then placed into the holder, the Timer button was pressed, and the display indicated a 3-minute countdown prior to the measurement. The instrument then displays the phosphorus (P) concentration in mg/L.

Trophic State Index

Trophic State Index (TSI): Classifies water bodies based on nutrient levels and biological conditions. It uses parameters such as Chlorophyll-a and Total Phosphorus (TP) to determine whether a water body is oligotrophic (low nutrients), mesotrophic (moderate nutrients), or eutrophic (high nutrients, often with algal blooms). This helps assess water quality and ecological health.

Assessment Methods in TSI

The Trophic State Index (TSI), developed by Carlson (1977), is a key tool for assessing water quality by classifying lakes and reservoirs based on nutrient levels and biological productivity. It uses chlorophyll-a concentration, water clarity (Secchi depth), and total phosphorus to determine whether a water body is oligotrophic (low nutrients), mesotrophic (moderate nutrients), or eutrophic (high nutrients with frequent algal blooms). TSI helps monitor eutrophication, identify pollution sources, and guide water management decisions. In this study, TSI, particularly total phosphorus, was used to classify surface water bodies and assess the extent of eutrophication, providing insights for effective pollution control and ecosystem restoration (Carneiro *et al*., 2020).

Physicochemical parameters

Physicochemical parameters, including temperature, pH, total dissolved solids (TDS), and electrical conductivity (EC), were also determined for the water samples.

A multi-parameter photometer from Hanna Instruments (HI83900, USA) was used to determine the concentrations of nitrate, phosphate, and phosphorus in the water samples.

Determination of Temperature

The samples' temperatures were measured using an electroanalytical instrument that had already been calibrated with similar data, and the measurements were recorded in the laboratory before analysis. The temperature was recorded in ^{o}C.

Determination of pH

The pH meter was turned on and allowed to warm up. It was then calibrated before the pH readings of the samples were taken.

Determination of TDS and Electrical Conductivity

These were measured using a Hanna (HI 9813-6), Electrical Conductivity and Total Dissolved Solid meter. This meter is calibrated in mg/L for TDS and micro-Siemens/centimetre (µS/cm) for conductivity. After powering on, the probe was immersed in the water sample in a 200 mL beaker. Each parameter to be checked was selected from the mode button, one after the other, and its respective values were displayed on the screen in less than 30 seconds.

Statistical analysis

Data analysis was carried out using descriptive statistics (bar charts) to summarise nutrient concentrations and water quality parameters. The significance of these relationships was evaluated at the 0.05 level.

III. RESULTS

The results of nutrient analysis were presented in Figures 1 - 4, while the trophic state index was presented in Table 1. Physicochemical parameters of the surface water samples are presented in Figures 5-9.

Nutrients Analysis

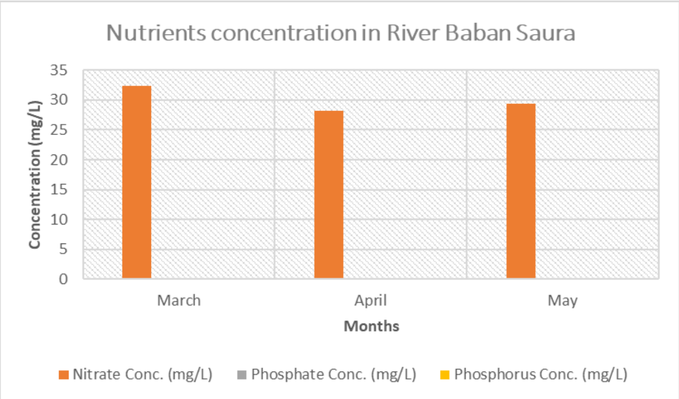

Figure 1. Variation in nutrient concentration within the sampling period at River Baban Saura

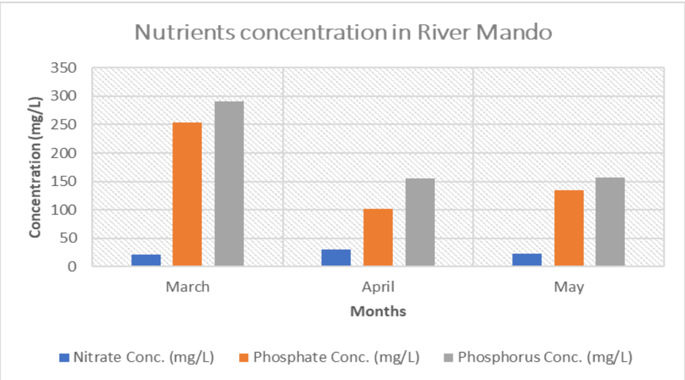

Figure 2. Variation in nutrient concentration within the sampling period at River Mando

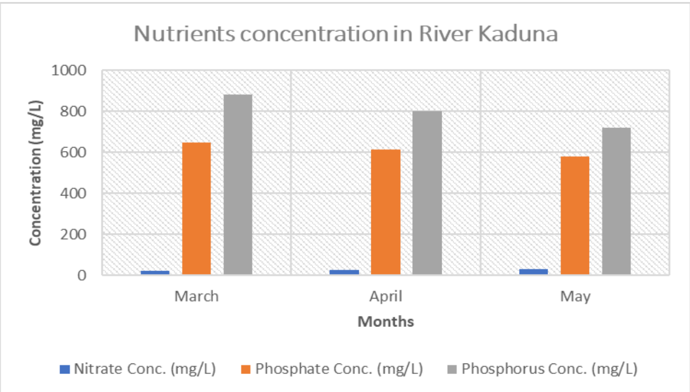

Figure 3. Variation in nutrient concentration within the sampling period at River Kaduna

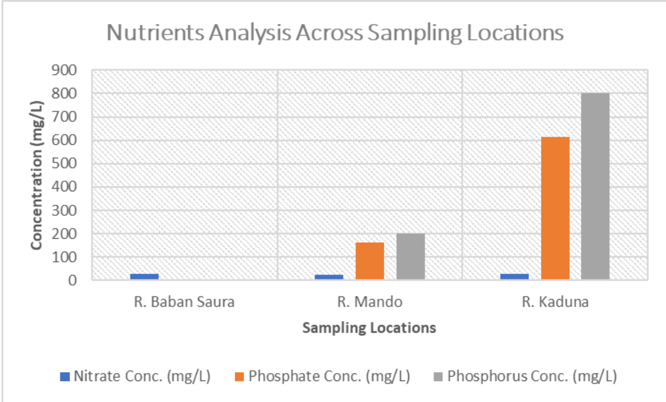

Figure 4. Mean Concentration of Nutrients at Sampling Locations

TABLE 1: Trophic State Index Assessment Using Total Phosphorus

River	TP (mg/m^3)	TSI	Eutrophication State
R. Baban Saura	0	0	Oligotropic
R. Mando	201,330	180.28	Hypereutrophic (TSI>70)
R. Kaduna	800,670	200.18	Hypereutrophic (TSI>70)

Physicochemical Parameters of Rivers

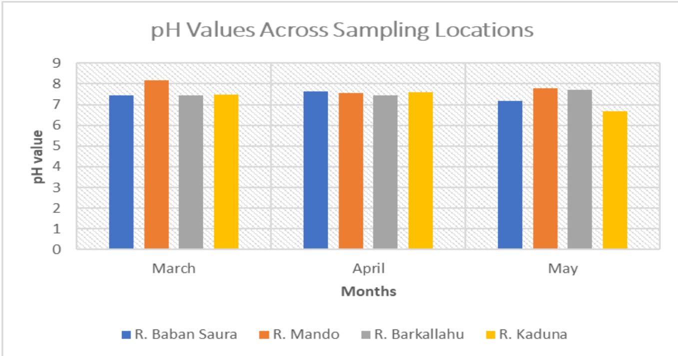

Figure 5. Variation in pH values of sampling rivers within the sampling period

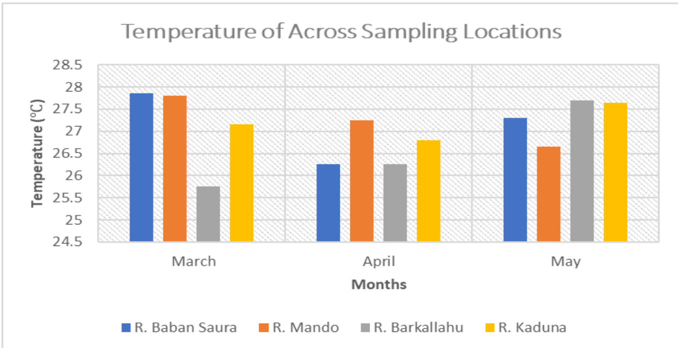

Figure 6. The temperature of the sampling rivers within the sampling period

IV. DISCUSSION

This study evaluated nutrient concentrations and physicochemical parameters in selected rivers within Kaduna Metropolis to assess eutrophication status. Across the sampling period (March to May), River Kaduna exhibited consistently higher nutrient concentrations, particularly total phosphorus, followed by River Mando and River Babban Saura. The elevated phosphorus levels in River Kaduna may be attributed to intense agricultural activities, sewage discharge, and other anthropogenic sources.

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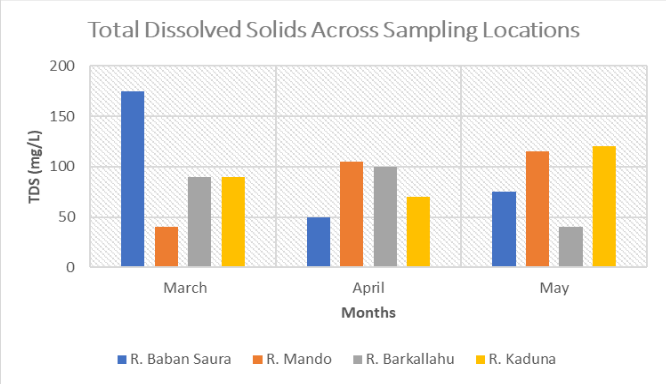

Figure 7. Variation in total dissolved solids of sampling rivers within the sampling period

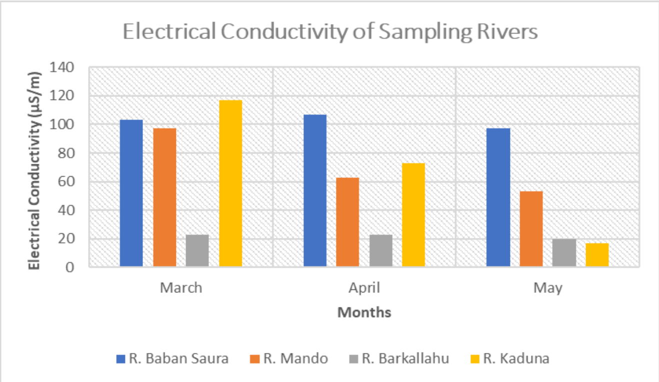

Figure 8. Variation in the electrical conductivity of sampling rivers within the sampling period

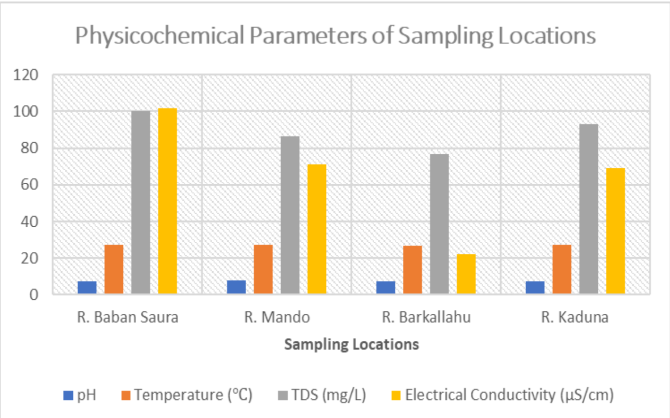

Figure 9. Mean Values of Physicochemical Parameters at Sampling Locations

Phosphate and total phosphorus levels were significantly higher in Rivers Kaduna and Mando, while nitrate concentrations remained relatively low across all sites. The low nitrate levels suggest a potential decline in nitrate-releasing activities, such as fertiliser runoff or wastewater inputs, during the study period. The reduction in phosphorus and phosphate levels toward the rainy season indicates dilution effects and reduced surface runoff, thereby slowing eutrophication and promoting temporary ecological recovery.

The observed phosphorus-dominated nutrient profile aligns with Pinto-Coelho (1998), who emphasised the role of phosphorus, nitrogen, and chlorophyll a as key indicators of eutrophication. The sharp drop in total phosphorus may reflect seasonal shifts in farming practices, such as reduced application of NPK fertilisers with the onset of rains.

Nitrate concentration trends were irregular, likely influenced by spatial rainfall patterns, microbial nitrogen cycling, and sporadic fertiliser use. Natural processes such as atmospheric nitrogen fixation during lightning events may also contribute to nitrate variability. In the absence of rainfall, nitrate inputs are typically derived from fertiliser application and decomposition, both of which are sporadic.

Compared to earlier findings by Akin-Oriola (2003) in Ibadan, nitrate concentrations in the River Kaduna are relatively higher, further highlighting nutrient pollution in the area. This is corroborated by Trophic State Index (TSI) values, which classified Rivers Kaduna and Mando as hypereutrophic. Such conditions pose serious risks, including algal blooms, oxygen depletion, and threats to aquatic biodiversity and human water usage.

Physicochemical parameter analysis revealed a consistent rise in pH values across most sites (except River Kaduna), suggesting a possible transition from synthetic fertilisers, which are often acidic, to organic alternatives. The use of slaked lime by farmers may also neutralise acidic inputs, thereby increasing pH. These observations support the hypothesis that reduced fertiliser use contributed to the declining trend in eutrophication.

Temperature values across sites were relatively stable, ranging from 26.57 to 27.23°C. Minor variations could be linked to biological activity, shading, and localised microclimatic effects. The positive correlation between temperature and nitrate concentration ($p < 0.05$) suggests that warmer conditions may enhance microbial nutrient cycling and support algal proliferation, a key feature of eutrophication.

Total Dissolved Solids (TDS) and Electrical Conductivity (EC) showed clear spatial differences. River Babban Saura recorded the highest TDS (100 mg/L), followed by River Kaduna (93.33 mg/L), while River Barkallahu had the lowest (76.67 mg/L). The March peak in TDS at several sites may be linked to low water volume and higher solute concentrations before the rains began. A general decrease in TDS in April and May supports the theory that rainwater dilutes dissolved solids.

Electrical conductivity followed a similar trend. River Kaduna showed the highest EC (117 µS/cm) in March but dropped to 17 µS/cm by May. This decline may indicate solute migration to deeper layers or reduced ionic concentration due to rainfall dilution. River Barkallahu consistently recorded the lowest EC, indicating minimal anthropogenic input.

Anake *et al.* (2013) noted that EC serves as a proxy for TDS, and the values obtained in this study fall within the permissible range set by the Standards Organisation of Nigeria (SON) of 1000 µS/cm. All EC values in this study were significantly below the upper limit, suggesting that, despite localised eutrophication, the rivers remain within safe limits for conductivity.

The results also align with findings by Moshood (2008), who observed seasonal variations in conductivity due to biological uptake and ion migration. The EC range of 80.4 to

178.8 µS/cm supports diverse aquatic life, and the EC values in this study fall within this range, indicating that the aquatic environments may still support biodiversity.

In summary, while eutrophication is evident especially in Rivers Kaduna and Mando, seasonal rainfall, changes in agricultural practices, and potential policy interventions may be contributing to gradual improvement. Nonetheless, targeted management is essential to prevent long-term degradation.

V. Conclusion

The findings of this study confirm that excessive nutrient concentrations, particularly total phosphorus, are key indicators of eutrophication in the urban surface water bodies of Kaduna Metropolis. Although a decreasing trend in nutrient concentrations was observed as the rainy season approached, eutrophication remains a significant risk. Rivers Kaduna and Mando demonstrated hypereutrophic conditions, likely driven by agricultural runoff, sewage discharge, and industrial effluents.

References

[1]. S. O. Akinnawo, "Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies," *Environmental Challenges*, 12: 100733, 2023.

[2]. G. A. Akin-Oriola, "On the Phytoplankton of Awba Reservoir, Ibadan, Nigeria," *Revista De Biologia Tropica*, vol. 51, issue 1, pp. 99-106, 2003.

[3]. W. U. Anake, C. O. Ehi-Eromosele, T. O. Siyanbola, A. Adobor-Osoh, I. O. Adeniyi, and O. S. Taiwo, "Physico-Chemical and Microbial Assessment of Different water sources in Ota, Ogun State, Nigeria," *International Journal of Current Research*, vol. 5, issue 07, pp. 1797-1801, 2013.

[4]. A. A. Ansari, and S. S. Gill, "Eutrophication: Causes, Consequences and Control," vol. 2, issue XI, 262, 2014. Springer Dordrecht. https://doi.org/10.1007/978-94-007-7814-6

[5]. Britannica, *Eutrophication: Definition, Types, Causes, & Effects*, 2025. Britannica.com/science/eutrophication

[6]. R.E. Carlson, "A Trophic State Index for Lakes. Limnology and Oceanography, vol. 22, pp. 361-369, 1977. http://dx.doi.org/10.4319/lo.1977.22.2.0361

[7]. L. Carneiro, A. Ostroski, and E. G. F. Mercuri, "Trophic state index for heavily impacted watersheds: Modeling the influence of diffuse pollution in water bodies," *Hydrological Sciences Journal*, vol. 65, issue 15, pp. 2548-2560, 2020. https://doi.org/10.1080/02626667.2020.1828588

[8]. T. J. Danielson, "Protocols for Collecting Water Grab Samples, and Freshwater Wetlands: Methods for Collecting Water Grab Samples," Department of Environmental Protection, State of Maine. 4pp, 2014.

[9]. S. J. Hwang, "Eutrophication and the Ecological Health Risk," *International Journal of Environmental Research and Public Health*, vol. 17, issue17, 6332, 2020. https://doi.org/10.3390/ijerph17176332

[10]. Lukhele, T., and Msagati, T. A. M. (2024). "Eutrophication of Inland Surface Waters in South Africa: An Overview," *International Journal of Environmental Research*, vol. 18, 27, 2024. https://doi.org/10.1007/s41742-024-00568-8

[11]. L. May, C. M. Aura, V. Becker, C. L. Briddon, L. R. Carvalho, A. J. Dobel, P. Jamwal, B. Kamphuis, M. M. Marinho, S. McGowan, S. Nandini, C. Nyamweya, C. Ongore, S. S. S. Sarma, M. J. Wishart, "Getting into hot water: Water quality in tropical lakes in relation to their utilization," *IOP Conf. Series: Earth and Environmental Science*, 789, 2021. 012021. https://doi.org/10.1088/1755-1315/789/1/012021

[12]. M. Mng'ong'o, L. K. Munishi, W. Blake, S. Comber, T. H. Hutchinson, and P. A. Ndakidemi, "Towards sustainability: Threat of water quality degradation and eutrophication in Usangu agro-ecosystem Tanzania," *Marine Pollution Bulletin*, vol. 181: 113909, 2022.

[13]. K. M. Moshood, "Assessment of the water Quality of Oyun Reservoir, Offa, Nigeria, Using Selected Physico-Chemical Parameters," *Turkish Journal of Fisheries and Aquatic Sciences*, vol. 8, pp. 309-319, 2008.

[14]. R.M Pinto-Coelho, "Effects of Eutrophication on Seasonal Patterns of Mesozooplankton in a tropical Reservoir: A 4-year study in Pampulha Lake, Brazil," *Fresh Water Biology*, vol. 40, pp. 159-173, 1998.

[15]. S. A. Rashid and A. Anjum, "Preliminary Seasonal Eutrophication studies of Missiriot Dam as influenced by the living organisms and physicochemical characteristics of water," *Pakistan Journal of Agricultural Research*, vol. 6, issue 4, pp. 274-277, 1985.

[16]. Đ. Tadić, R. Manasfi, M. Bertrand, A. Sauvêtre, and S. Chiron, "Use of Passive and Grab Sampling and High-Resolution Mass Spectrometry for Non-Targeted Analysis of Emerging Contaminants and Their Semi-Quantification in Water," *Molecules* (Basel, Switzerland), vol. 27, issue 10, 3167, 2022. https://doi.org/10.3390/molecules27103167

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