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Assessment of Water Quality of River Niger Basin during the Wet Season

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ABSTRACT

This study investigates water quality trends in the River Niger Basin by analyzing samples collected from upstream (Sample A), midstream (Sample B), and downstream (Sample C) sites during the wet season. The water samples were analyzed at the Federal University of Technology (FUTMINNA), Chemistry Department laboratory. Key parameters, including temperature, turbidity, dissolved oxygen, and nutrient concentrations, exhibited notable variations along the river flow. Temperature decreased by 2.5 °C from upstream to downstream, while turbidity remained low despite slight fluctuations. Dissolved oxygen levels increased downstream, suggesting enhanced photosynthesis and aeration, whereas Biological Oxygen Demand (BOD) showed an initial decrease followed by a rise at the downstream site, indicating potential organic pollution. The pH level decreased significantly, indicating an increased acidification, while alkalinity rose, reflecting possible buffering effects. Nutrient levels exhibited complex dynamics, with variations in ammonia, nitrate, and phosphorus suggesting influences from urban runoff and nutrient cycling. These findings underscore the River Niger's dynamic ecosystem and the need for continuous monitoring to manage water quality sustainably, highlighting the interplay of natural and anthropogenic factors affecting the aquatic environment.

Keywords: Basin, Quality, River, Season, Water, Wet

1. INTRODUCTION

River water quality is a critical concern globally, influenced by various anthropogenic activities and environmental factors. According to the United Nations Environment Programme

(UNEP), approximately 80% of the world's wastewater is discharged into water bodies without adequate treatment, significantly deteriorating water quality [1]. Common pollutants include nutrients, heavy metals, plastic debris, and pathogens. A comprehensive analysis by the World Bank estimates that 2 billion people experience water pollution, affecting not only human health but also aquatic ecosystems and biodiversity [2]. For example, the degradation of freshwater habitats due to pollution has led to a decline in fish populations and other aquatic life, which are vital for food security and livelihoods in many regions.

Regional data shows that water quality can vary significantly, with developed countries typically reporting better quality metrics than developing nations. In low-income countries, nearly 40% of rivers surveyed failed to meet acceptable water quality standards due to untreated sewage disposal and industrial effluents [3]. In contrast, higher-income countries have implemented stringent environmental regulations that have improved water quality trends over the last few decades. Nevertheless, emerging contaminants, such as microplastics and pharmaceuticals, pose new challenges for water quality management worldwide, necessitating ongoing research and policy adjustments to protect these critical resources for future generations [4].

River water quality is influenced by a variety of natural and anthropogenic factors. One primary natural cause is the geology of the area through which the river flows. The weathering of rocks and soils releases minerals and nutrients into the water, which can either enhance or degrade water quality depending on their concentrations and types. For instance, an increase in natural mineral content can benefit aquatic life; however, it can also lead to excess nutrient runoff, particularly nitrogen and phosphorus which can cause eutrophication [5]. Additionally, seasonal variations such as rainfall and temperature can impact river flow rates, sediment transport, and the dilution of pollutants, further influencing water quality [6].

On the anthropogenic side, human activities such as agriculture, urbanization, and industrialization significantly contribute to river water quality issues. Agricultural practices often involve the use of fertilizers and pesticides which can run off into rivers during rainfall, leading to elevated nutrient levels and chemical pollutants [7]. Urbanization contributes to increased impervious surfaces, which enhance stormwater runoff and can introduce contaminants like heavy metals and hydrocarbons into water bodies [8]. Industrial discharges, often regulated but sometimes poorly managed, may release toxic substances into rivers, further deteriorating water quality. Collectively, these factors underscore the complex interplay between natural processes and human impact on river ecosystems.

The River Niger Basin, which stretches across several West African nations, experiences significant variations in water quality, particularly during the wet season. Poor water quality during this period can severely impact aquatic ecosystems, as increased rainfall often leads to higher runoff that carries pollutants into the river [9]. These pollutants may include agricultural fertilizers, pesticides, and other contaminants from urban and industrial sources. Research indicates that the influx of these substances can lead to eutrophication, depleting oxygen levels in the water and disrupting aquatic life [10]. The resulting decline in biodiversity not only affects fish populations but also threatens the livelihoods of communities that depend on these resources for food and income.

Additionally, poor water quality affects human populations that rely on the River Niger for drinking water and sanitation. During the wet season, the river often becomes a conduit for pathogens and harmful microorganisms from overflowing sewage systems and rampant deforestation, which diminishes natural filtration processes. Consequently, residents are at

heightened risk for waterborne diseases, such as cholera and dysentery, which can lead to severe health crises, particularly among vulnerable populations like children and the elderly [3].

Moreover, the economic consequences of deteriorating water quality during the wet season extend beyond public health issues to affect agricultural productivity and fishing. Fluctuating water quality can inhibit crop growth and reduce fish catch, exacerbating food insecurity in a region where millions rely on agriculture and fisheries for their livelihood. As highlighted by a study conducted by [11], declining water quality ultimately undermines local economies and can lead to increased poverty rates. It emphasizes the urgent need for policymakers to implement integrated water resource management strategies to protect this vital aquatic system, ensuring both ecological integrity and community well-being are preserved for future generations. It is with this objective that study has to assess water quality of River Niger basin during the wet season for sustainable agricultural practice.

2. METHODOLOGY

The study targeted communities located between latitudes 5°00'N and 14°00'N, and longitudes 5°00'E and 15°00'E.

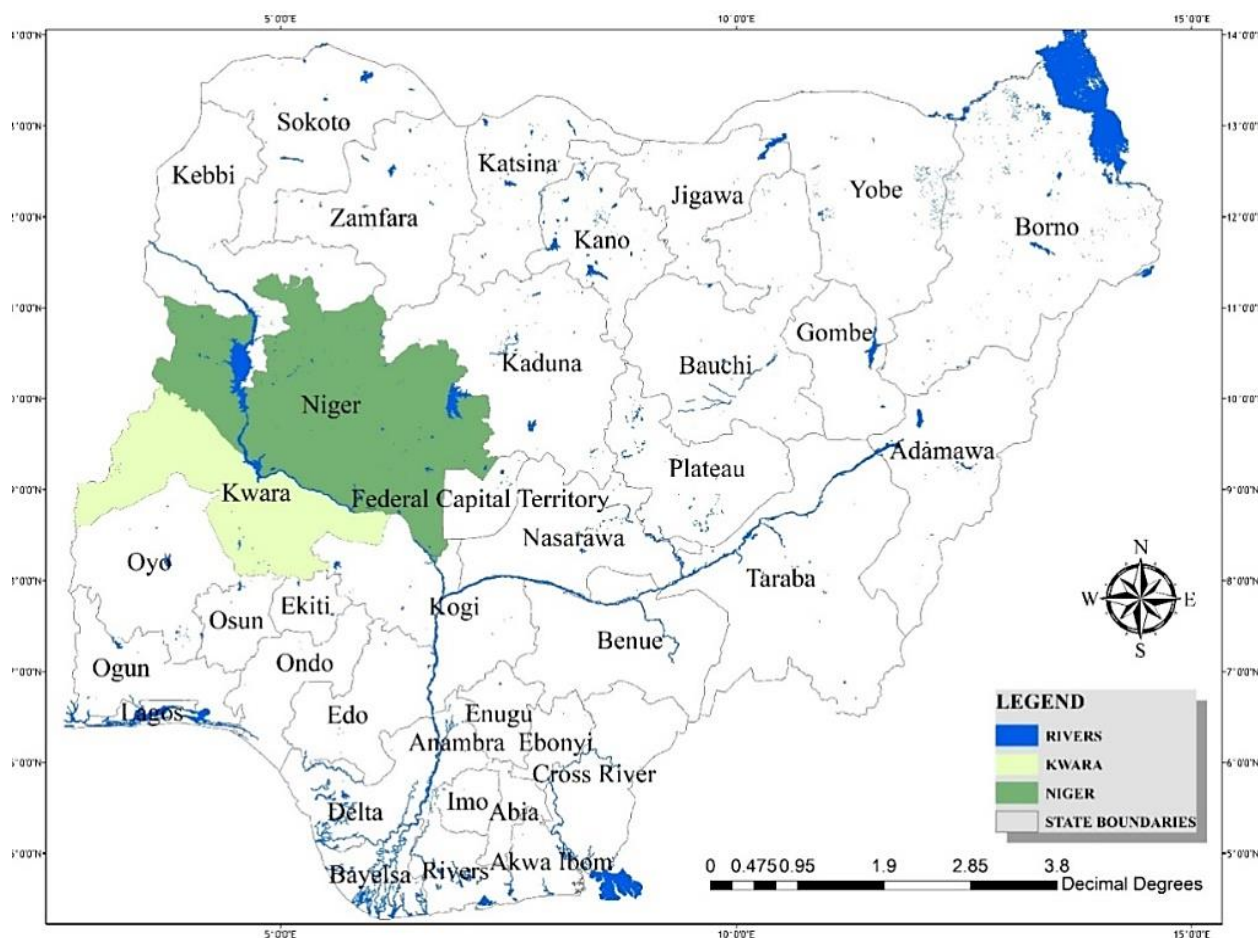


Figure 1. The Study Area in Niger and Kwara States in Nigeria

The Niger River Basin, covering areas of nine West African countries, is Africa's third-largest river basin. Focused within this region are five local governments in Kwara and Niger States - Moro, Edu, Pategi, Mokwa, and Edati. The study primarily targets riverine communities extending from Jebba to Patigi/Muregi, located within Nigeria's Guinea Savannah region in the north-central area of Nigeria (Figures 1 and 2).

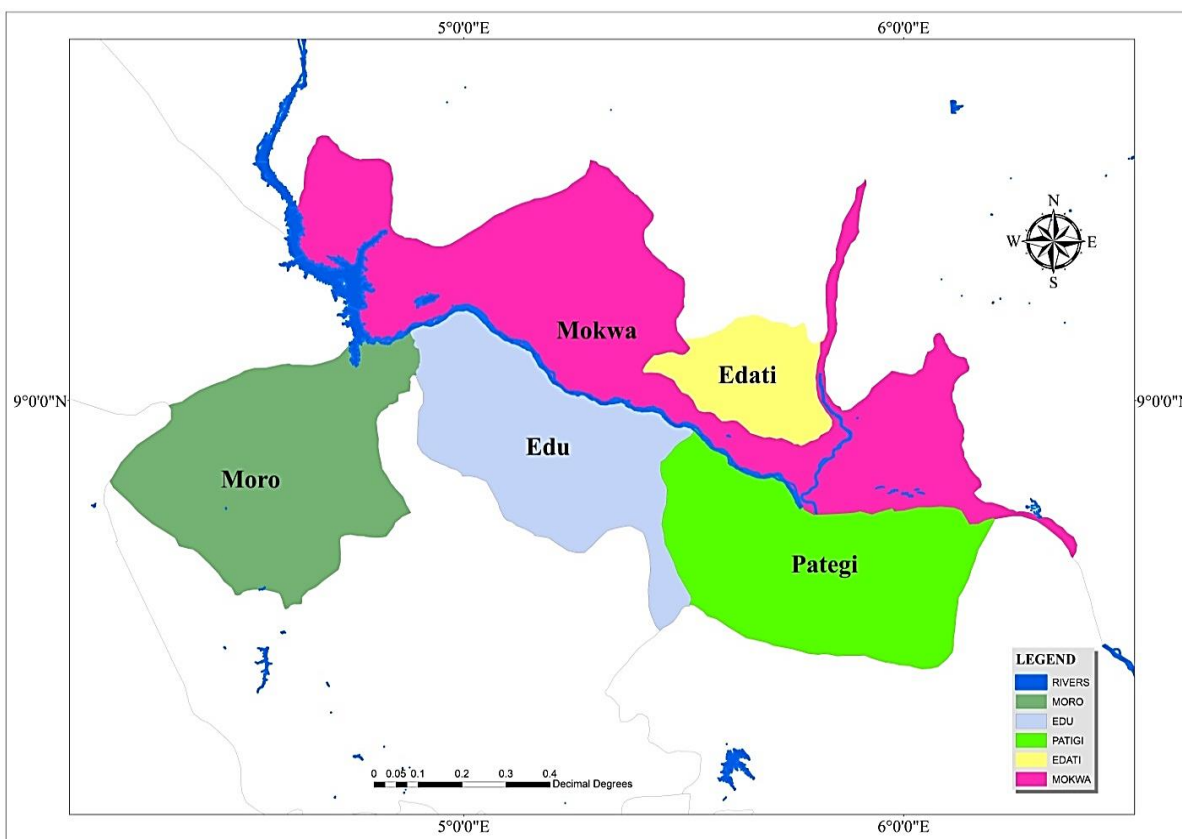


Figure 2. Study Area Location in Five Local Government Areas

Relief refers to the land's surface features that lie above sea level, encompassing both lowlands and highlands [12]. The Niger River, the main river in West Africa, is the third longest river on the continent, measuring 2,600 miles (4,200 km) in length, following the Congo and Nile rivers. The Niger basin is the area that is primarily drained by this river and its tributaries [13] characterized by low-lying, naturally depressed areas. The Niger River Basin has a drainage area of roughly 2,156,000 km², ranking it as the ninth largest watershed globally [14].

The river's source is found in Guinea, and it flows through Mali and the inner Niger Delta before emptying into the Atlantic Ocean along Nigeria's Niger Delta, where it is joined by its major tributary, the Benue River. The Niger and its Kaduna sub-catchments are fertile regions where agriculture is practiced alongside the rivers. Key tributaries of the Niger River include the Benue, Sokoto-Rima, Kaduna, Gongola, Katsina-Ala, Donga, Tarabe, Hawal, and Anambra Rivers. The River Niger basin, situated in Nigeria's Guinea Savanna, has a climate shaped by its mountainous and valley-filled hinterland. As a result, the region experiences a temperature

range of 25-40 °C, an average relative humidity of 85% annually, and rainfall of 250-600 mm [15]. The rainy season typically runs from April to September, with peak relative humidity occurring between July and September.

In contrast, March usually records the highest temperatures and lowest relative humidity. The local climate has a significant impact on the daily activities of the people living in the River Niger basin, as well as the fishing industry in the area. The varying climate conditions throughout the year, particularly the distinct wet and dry seasons, influence the level of fishing activity and the overall lifestyle of the region's inhabitants.

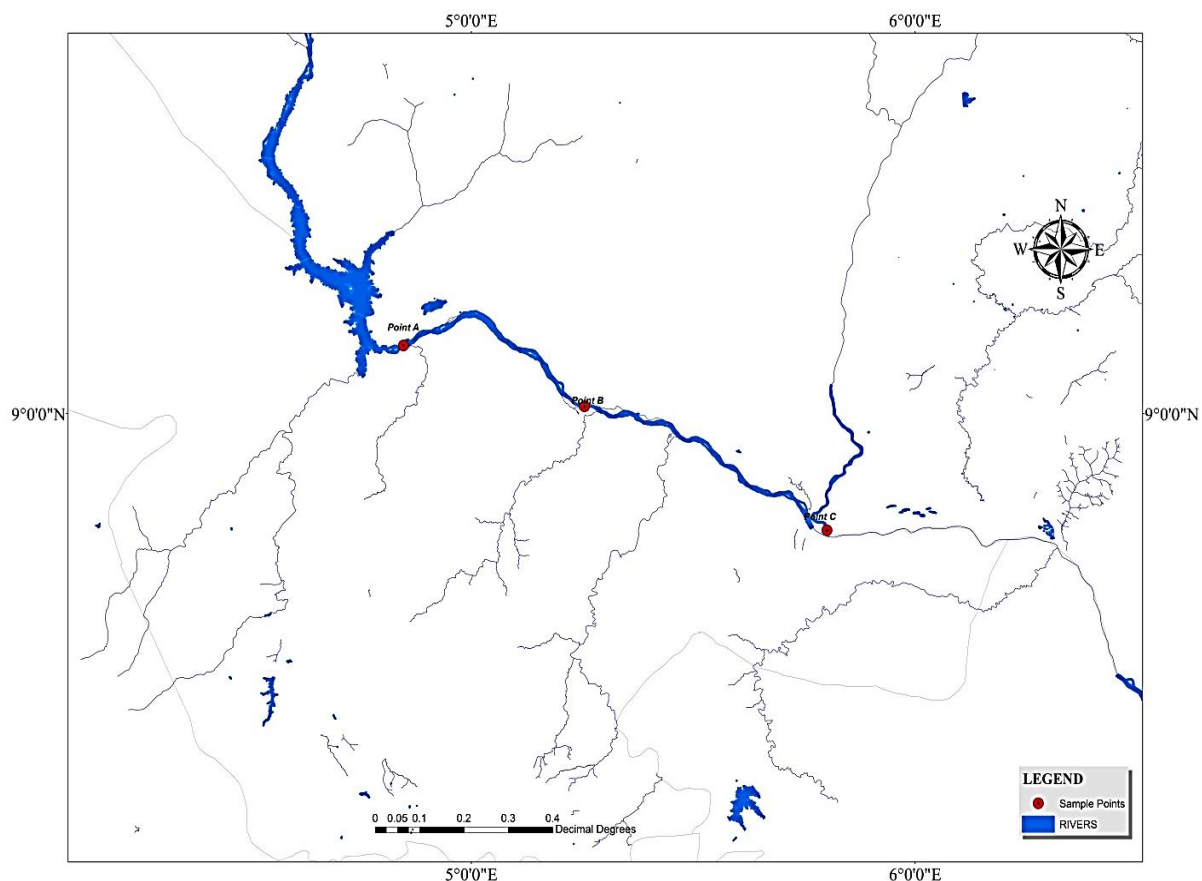


Figure 3. Water Sample Points in the River Niger Basin

Seventeen water quality parameters were examined at the Federal University of Technology's (FUTMINNA) Chemistry Department laboratory, where they were compared with established water quality standards. The parameters evaluated included temperature, clarity, turbidity, water color, carbon dioxide levels, pH, alkalinity, hardness, unionized ammonia, nitrite, nitrate, primary productivity, Biochemical Oxygen Demand (BOD), and plankton populations, among others, using a systematic experimental approach. To gather the necessary raw data for this study, three sampling points (A, B, and C) were chosen along the river's length, representing upstream, midstream, and downstream locations, as illustrated in Figure 3. Water samples were collected during the wet season in August 2024.

At each of the three sampling points, samples were taken from both the surface and 2 feet below the surface. For physical and chemical analysis, 1-liter plastic containers were used, while sterilized and sealed bottles were employed for bacteriological analysis. The sampling bottles were prepared by washing and rinsing them with hydrochloric acid and then with sample water. The bottles were then filled with water, sealed, and protected from sunlight. To prevent aeration, the bottles were filled underwater, and care was taken to minimize exposure to air.

The samples were transported to the laboratory within 6 hours of collection and stored for further analysis, which included physical, biological, and chemical tests. The total suspended and dissolved solids were measured using standard filtration and evaporation methods, with results expressed in milligrams per liter. The parameters tested were categorized into physical, chemical, and biological groups, following established protocols [16] [17].

3. RESULTS AND DISCUSSION

Table 1 presents the water quality trends of the River Niger Basin, comparing samples taken from various locations—Sample A (upstream), Sample B (midstream), and Sample C (downstream). The analysis of water quality parameters across these sites revealed a decrease in temperature from Sample A (26.4 °C) to Sample C (23.9 °C), representing a 2.5 °C drop that may be influenced by factors such as increased water flow or shaded areas downstream. Turbidity experienced minor fluctuations with Sample A recording 0.39 CM, Sample B at 0.35 CM, and Sample C at 0.41 CM. Overall, these low values indicate relatively clear water, although there is a slight increase in turbidity downstream. Water color also diminished from Sample A (0.81) to Sample C (0.58), suggesting a reduction in suspended solids or organic matter as one moves downstream.

Dissolved oxygen levels rose from Sample A (691 mg L⁻¹) to Sample C (871 mg L⁻¹), with the higher oxygen concentration downstream likely resulting from aquatic plant photosynthesis or enhanced aeration. Biological Oxygen Demand (BOD) displayed a small decline from Sample A (661.1 mg L⁻¹) to Sample B (642.4 mg L⁻¹) but increased in Sample C (771.6 mg L⁻¹), indicating possible organic pollution or decomposition activities along the river. Carbon Dioxide (CO₂) concentrations also rose from Sample A (8.21 mg L⁻¹) to Sample C (8.99 mg L⁻¹), likely due to biological respiration or the breakdown of organic materials.

The pH levels in the water showed a significant decrease from Sample A (0.44) to Sample C (0.29), suggesting a potential increase in acidification or contributions from organic materials leading to lower pH downstream. Alkalinity, on the other hand, increased from Sample A (0.071 mg L⁻¹) to Sample C (0.22 mg L⁻¹), which may reflect the presence of buffering compounds or reduced acid inputs further downstream. Hardness varied slightly, with Sample A at 3.12 mg L⁻¹, Sample B at 3.77 mg L⁻¹, and Sample C dropping to 2.98 mg L⁻¹. Calcium levels also rose, starting at 3.02 mg L⁻¹, increasing to 3.78 mg L⁻¹, then slightly declining to 3.11 mg L⁻¹. These minor fluctuations could indicate changes in mineral content, possibly influenced by geological factors or industrial runoff.

Ammonia levels varied, with Sample A at 13 mg L⁻¹, Sample B decreasing to 9 mg L⁻¹, and Sample C rising slightly to 11 mg L⁻¹. This suggests nutrient dynamics may be impacted by urban runoff or decomposition processes. Nitrite levels dropped from Sample A (0.72 mg L⁻¹) to Sample C (0.08 mg L⁻¹), with a notably low measurement in Sample B (0.011 mg L⁻¹), indicating potential bacterial conversion from nitrite to nitrate downstream.

Nitrate concentrations decreased from Sample A (21 mg L⁻¹) to Sample B (19 mg L⁻¹) but then rose significantly in Sample C (32 mg L⁻¹), potentially due to runoff or re-mineralization processes. Phosphorus levels decreased from Sample A (18.5 mg L⁻¹) to Sample B (9.07 mg L⁻¹), followed by a slight increase in Sample C (10.1 mg L⁻¹), indicating nutrient cycling or varying sources throughout the river.

Hydrogen sulfide (H₂S) levels decreased from Sample A (78 mg L⁻¹) to Sample C (61 mg L⁻¹), suggesting less anaerobic conditions downstream. Primary productivity increased from Sample A (201.1 CL⁻¹ D⁻¹) to Sample B (298.7 CL⁻¹ D⁻¹), before slightly decreasing in Sample C (289.66 CL⁻¹ D⁻¹), indicating favorable midstream conditions for aquatic plant growth followed by stabilization downstream. Plankton counts showed a decrease from Sample A (161.7 no. L⁻¹) to Sample B (101.6 no. L⁻¹), then a slight rise in Sample C (113.6 no. L⁻¹), signaling variations in nutrient availability and habitat conditions. Overall, the analysis highlighted a dynamic ecosystem with varying water quality parameters along the river's course. These changes may stem from fluctuations in nutrient dynamics, organic matter decomposition, and differing hydrologic conditions from upstream to downstream. Each parameter shed light on the health and stability of the aquatic environment, emphasizing the importance of ongoing monitoring for sustainable water quality management.

Table 1. Water Quality of River Niger Basin during the Wet Season.

Parameter	Sample A (Upstream)	Sample B (Midstream)	Sample C (Down Stream)
Temperature (°C)	26.4	24.2	23.9
Turbidity (CM)	0.39	0.35	0.41
Water color	0.81	0.77	0.58
Dissolved oxygen (mg L ⁻¹)	691	786	871
BOD (mg L ⁻¹)	661.1	642.4	771.6
CO ₂ (mg L ⁻¹)	8.21	8.33	8.99
pH	0.44	0.31	0.29
Alkalinity (mg L ⁻¹)	0.071	0.098	0.22
Hardness (mg L ⁻¹)	3.12	3.77	2.98
Calcium (mg L ⁻¹)	3.02	3.78	3.11
Ammonia (mg L ⁻¹)	13	09	11
Nitrite (mg L ⁻¹)	0.72	0.011	0.08
Nitrate (mg L ⁻¹)	21	19	32

Phosphorus (mg L ⁻¹)	18.5	9.07	10.1
H ₂ S (mg L ⁻¹)	78	66	61
Primary productivity (CL ⁻¹ D ⁻¹)	201.1	298.7	289.66
Plankton (No. L ⁻¹)	161.7	101.6	113.6

The analysis of water quality parameters across these sites revealed a decrease in temperature from Sample A (26.4 °C) to Sample C (23.9 °C), representing a 2.5 °C drop that may be influenced by factors such as increased water flow or shaded areas downstream. This trend is generally expected, as upstream waters can be more influenced by sunlight and warming effects, while downstream areas can see cooler temperatures, particularly if there is more flow and turbulence or shading from vegetation.

This is similar to the findings of [18] who investigated the influence of riparian vegetation shading on water temperature during low flow conditions in a medium sized river. The study showed that maximum water temperatures, a downstream warming of 3.9 °C was observed in unshaded areas, followed by a downstream cooling of 3.5 °C in shaded reaches. Also, water temperature directly responded to air temperature and cloudiness from upstream to downstream sections of the river channel.

Turbidity experienced minor fluctuations with Sample A recording 0.39 CM, Sample B at 0.35 CM, and Sample C at 0.41 CM. Turbidity is often an indicator of sediment and particulate matter in water, which can affect aquatic life by blocking sunlight and carrying pollutants. This is identical with the findings of [19] who determined that aquatic organisms mainly rely on vision, and that factors such as water transparency and turbidity play a significant role in aquatic environments. Visual clarity underwater diminishes quickly as turbidity rises. Turbidity serves as a key indicator for assessing sediment levels in water, posing numerous detrimental impacts on aquatic life. Suspended sediments that contribute to turbidity can obstruct light from reaching aquatic plants.

Dissolved oxygen levels rose from Sample A (691 mg L⁻¹) to Sample C (871 mg L⁻¹), with the higher oxygen concentration downstream likely resulting from aquatic plant photosynthesis or enhanced aeration. Significantly, the average levels of dissolved oxygen rose from 905.5 mg L⁻¹ at the upstream point to 1117.5 mg L⁻¹ downstream, implying greater microbial or photosynthetic activity in the downstream area. This finding is consistent with [20] which indicated that pollution from major sources exacerbates water quality issues downstream, even when accounting for pollution levels upstream and other location-specific factors.

Biological Oxygen Demand (BOD) displayed a small decline from Sample A (661.1 mg L⁻¹) to Sample B (642.4 mg L⁻¹) but increased in Sample C (771.6 mg L⁻¹), indicating possible organic pollution or decomposition activities along the river. The progressive rise in BOD from upstream to downstream emphasizes the persistent environmental pressure. This observation aligns with the research conducted by [21] who analyzed the pollution levels in rivers that flow into the Caspian Sea by utilizing water quality indices and remote sensing metrics.

Their findings indicated that the Babolroud River exhibited the highest levels of pollution in terms of the Dissolved Oxygen Deficit Index (DODI) at 84.12 and Dissolved Oxygen Saturation (Dosat) at 7.45. The Talar River had the highest measurement at 18, while both the

Talar and Haraz rivers were identified as the most polluted based on the Pollution Load Index (PLI) at 26.21 and Eutrophication Index (EI) at 120.68 from upstream to downstream segments respectively.

4. CONCLUSION

The analysis of water quality trends across the River Niger Basin offers critical insights into the ecological dynamics influencing the aquatic ecosystem. Observations indicate a distinct variation in parameters such as temperature, turbidity, and dissolved oxygen, which collectively highlight the impact of environmental conditions along the river's course. The rising dissolved oxygen levels downstream suggest that photosynthesis and aeration processes are effectively enriching the water, while the contrasting trends in biological oxygen demand and carbon dioxide concentrations warrant further investigation into potential pollution sources and organic decay. Additionally, slight fluctuations in pH and alkalinity underscore the complexity of chemical interactions occurring in this waterway.

Furthermore, nutrient dynamics marked by changes in ammonia, nitrate, and phosphorus concentrations point to intricate relationships between agricultural runoff, urban influences, and organic matter processes. The decline in nitrite levels and the moderate changes in hardness and calcium suggest a shifting mineral landscape affected by both natural and anthropogenic factors. The productivity metrics and plankton populations reflect an ecosystem in flux, capable of supporting varying levels of biological activity, yet exhibiting signs that necessitate careful observation and management. Collectively, these findings illuminate the necessity for ongoing monitoring to preserve the health and sustainability of the River Niger Basin, ensuring that both ecological balance and water quality are maintained in the face of environmental pressures.

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