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

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Abstract

This study assessed water quality of River Niger Basin during the dry Season. It examines the environmental dynamics of aquatic ecosystems across upstream, midstream, and downstream locations during the dry season. In assessing water quality, a total of seventeen (17) parameters were analyzed in the laboratory of the Federal University of Technology (FUTMINNA), Department of Chemistry. Notably uniform temperature readings (29.6-29.7°C) indicate a stable environment, fostering aquatic life. Turbidity levels showed a slight increase in midstream, possibly indicating particulate matter accumulation, followed by a slight decrease downstream. Water color intensification suggests elevated dissolved organic matter levels, potentially linked to pollution. While dissolved oxygen levels increased downstream, indicating a thriving ecosystem, Biological Oxygen Demand (BOD) and Carbon Dioxide (CO2) concentrations also rose, suggesting heightened organic pollution and respiration. An increase in pH hinted at changes in water chemistry, potentially due to organic matter breakdown. Conversely, alkalinity and hardness declined downstream, highlighting vulnerabilities in chemical buffering and mineral availability for aquatic organisms. The variations in nitrogen compounds, including elevated ammonia upstream and shifting nitrite and nitrate levels, suggest complex ecological interrelations, with phosphorus levels decreasing downstream due to effective biological uptake. H_2S levels fluctuated with water conditions, portraying varying aerobic and anaerobic states. Ultimately, results suggest nutrient increases and organic pollution indicators downstream, likely influenced by human activities, highlighting significant ecological implications for water quality and ecosystem health. Initiatives aimed at reducing agricultural runoff, improving waste management systems, and restoring natural habitats can significantly improve water quality of River Niger Basin of Nigeria.

Keywords: *Assessment, Basin, Dry Season, Quality, River, Water,*

Introduction

According to recent assessments, the global average percentage of rivers with good to fair water quality is relatively low. Only about 20% of the world's rivers are considered to have good quality water, meaning that they can support aquatic life and human use without significant pollution [1]. One of the main factors contributing to river water pollution is agricultural runoff. About 70% of global nitrogen and 40% of global phosphorus inputs come from agricultural sources, leading to significant eutrophication in freshwater ecosystems. Furthermore, approximately 80% of global wastewater is not properly treated, resulting in the release of untreated or inadequately treated sewage into river systems [2]. This not only poses a risk to human health but also impacts the ecological balance of aquatic ecosystems.

The global distribution of river water quality varies significantly across different regions. For instance, Asia and South America have some of the highest proportions of rivers with poor water quality, primarily due to industrial and agricultural activities, as well as inadequate waste management practices. In contrast, European rivers tend to have better water quality, with about 50% considered to be of good to fair quality [3]. However, even in these regions, there are still concerns about pollution and eutrophication. Another critical aspect of river water quality is the presence of chemical pollutants, including pesticides, heavy metals, and pharmaceuticals. About 20-50% of global rivers contain detectable levels of at least one pesticide, while approximately 15-30% contain at least one heavy metal [4]. Additionally, many rivers have been found to contain pharmaceuticals and

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personal care products (PPCPs), which can have adverse effects on human health and aquatic ecosystems.

In terms of specific statistics, according to the UNEP, about 45% of global rivers are considered to be at risk due to climate change [5]. The EEA has reported that 75% of Europe's rivers are at risk of failing to meet good ecological status by 2030, primarily due to pollution, overfishing, and climate change [6]. Furthermore, the Global Environmental Facility (GEF) has estimated that the economic benefits of improving river water quality are likely to be substantial, potentially amounting to tens of billions of dollars annually [7]. These statistics emphasize the importance of addressing river water pollution and promoting sustainable development practices to protect the world's freshwater resources.

The River Niger Basin, one of the most significant river systems in West Africa, plays a critical role in the livelihoods of millions of people across several countries. However, during the dry season, the water quality in this basin often deteriorates, resulting in severe ecological, social, and economic repercussions. Reduced water flow exacerbates the concentration of pollutants, leading to increased salinity and higher levels of harmful substances like heavy metals and agricultural runoff [8]. These changes not only impair the ecosystem but also undermine the health and safety of communities that depend on the river for drinking, bathing, and irrigation.

As the water level recedes in the dry season, the remaining water becomes heavily polluted, affecting the biodiversity in and around the river. Aquatic flora and fauna suffer due to elevated contaminant concentrations, which can lead to mortality among fish populations and disrupt breeding cycles [9]. The decline of fish stocks not only affects local diets rich in protein but also jeopardizes the livelihoods of fishing communities. Additionally, the loss of biodiversity disrupts the natural balance of the river ecosystem, impacting other species that rely on healthy aquatic habitats for survival [10]. These ecological changes have ripple effects on both terrestrial and aquatic food webs.

The social implications of poor water quality in the River Niger Basin during the dry season are equally alarming. Communities reliant on the river for various domestic uses face significant health risks due to exposure to contaminated water. Waterborne diseases such as cholera, dysentery, and typhoid fever become rampant as the availability of safe drinking water dwindles [11]. Vulnerable populations, including children and the elderly, are disproportionately affected, leading to increased morbidity and mortality rates. The health crisis exacerbates existing inequalities, as low-income families lack the resources necessary to access clean water or adequate healthcare [12].

Economically, the consequences of poor water quality are profound. Agriculture, which heavily depends on the river for irrigation, suffers as salinization and pollution degrade soil quality and crop yields. Farmers may experience reduced harvests and, consequently, loss of income, leading to increased food insecurity in the region. Additionally, the decline in fish population’s impacts local markets that rely on this source of income, pushing communities further into poverty. The broader economic implications also extend to sectors like tourism and recreation, as declining water quality can deter visitors and decrease economic investment in the region. It is in this vein that this study has assessed of water quality of River Niger basin during the dry season.

Materials and Method

The chosen communities are situated between latitudes 5°00'N and 14°00'N and longitudes 5°00'E and 15°00'E, as illustrated in Figures 1 and 2. The River Niger Basin spans sections of nine countries in West Africa and ranks as the third largest river basin on the continent. The study area is focused around the River Niger Basin and comprises five local government areas in Kwara and Niger States: Moro, Edu, Pategi, Mokwa, and Edati. This investigation targets the riverine communities along the Niger River, extending from Jebba to Patigi/Muregi, situated within the Guinea Savannah vegetation zone in Nigeria's north central region.

The surface features of the land above sea level, including low-lying areas and highlands, are referred to as relief [14]. In West Africa, the Niger River stands out as the third-longest river on the continent, stretching 2,600 miles (4,200km) and ranking behind the Congo and Nile Rivers. The Niger Basin, which encompasses the region drained by the river and its tributaries, covers a vast area of approximately 2,156,000 km2, making it the ninth-largest watershed globally [15] [16]. Originating in Guinea, the Niger River flows through Mali and the inner Niger Delta before merging with its main tributary, the Benue River, and eventually emptying into the Atlantic Ocean at the Niger Delta in Nigeria. The river's catchment area, including the Kaduna sub-catchment, features fertile land suitable for agriculture, with the Niger River and its tributaries, such as the Benue, Sokoto-Rima, and Anambra Rivers, supporting farming activities along their banks.

The River Niger basin is situated in Nigeria's Guinea Savanna, where the atmospheric weather is shaped by the surrounding mountains and valleys. As a result, the basin experiences temperatures that range from 25°C to 40°C, an annual relative humidity of 85%, and rainfall totals between 250 and 600 mm [17]. The rainy season is typically higher from April to September, although it may extend beyond September in some years. Relative humidity gradually increases from April, peaking between July and September, and then decreases from January to March. March usually sees the highest temperatures and the lowest relative humidity. The variations in climate significantly affect the local population’s activities and the fishing practices in the River Niger basin.

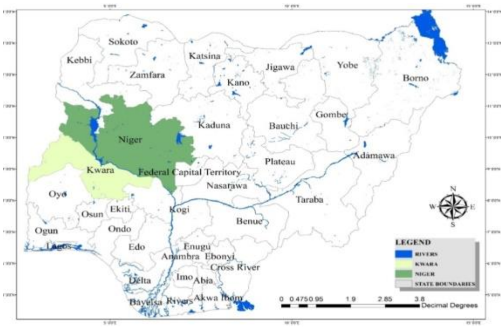

Figure 1: The Study Area in Niger and Kwara States in Nigeria

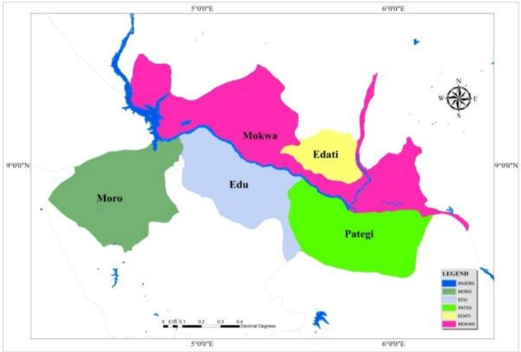

Figure 2: Study Area Location in Five Local Government Areas

In assessing water quality, a total of seventeen (17) parameters were analyzed in the laboratory of the Federal University of Technology (FUTMINNA), Department of Chemistry. The methods employed for each parameter, which include temperature, transparency, turbidity, water color, carbon dioxide, pH, alkalinity, hardness, unionized ammonia, nitrite, nitrate, primary productivity, BOD, and plankton population, are detailed in Table 1.

To gather the necessary raw data for this study, three locations along the river—designated as points A, B, and C, were chosen at various points of the river (upstream, midstream, and downstream) as in Figure 3. Water samples were collected during the dry season in March 2024. At each of the three sampling sites, samples were taken from the surface and from a depth of 2 feet below the water surface. The samples intended for physical and chemical analysis were collected in 1-liter plastic containers, while those for bacteriological testing were collected in sealed, sterilized bottles. The 250 ml plastic bottles were thoroughly cleaned and rinsed with 1-2 ml of 2% industrial HCl. They were then rinsed again with the water sampled before being filled securely and labeled appropriately. The sterilized bottles were submerged in the river, where their seals were removed while still underwater, ensuring they were filled completely, sealed, and wrapped in a black sack with some water to minimize exposure to sunlight. Efforts were made to avoid aeration during the sampling process. The carefully collected water samples were transported to the laboratory for preservation and subsequent physical, biological, and chemical analyses. All samples were taken to the lab within six hours of collection [18]. The total suspended solids and total dissolved solids were analyzed using standard methods involving filtration, evaporation to dryness, and weighing, with the results reported in mg/l. All tested parameters were classified into three categories: physical, chemical, and biological [19].

Table1: Water Quality Parameter and Laboratory Methodology

S/N	Description and Laboratory Methodology
1	**Temperature (0C):** Temperature is a fundamental parameter that measures the water temperature in degrees Celsius. It is measured immediately at the point of collection using a mercury-in-glass thermometer.
2	**Turbidity (NTU):** Turbidity is a measure of water clarity, indicating the presence of suspended particles that scatter light. It is commonly measured in Nephelometric Turbidity Units (NTU) or Formazin Nephelometric Units (FNU) using a digital turbidity meter.
3	**Water color:** Water color is indicative of dissolved and suspended substances in water. It is measured using various methods such as the platinum-cobalt colorimetric method, spectrophotometry, or automated colorimeters to determine its level in Hazen color units (CU) or UV-Vis spectroscopy.
4	**Dissolved oxygen (mg L-1):** Dissolved oxygen is a measure of oxygen present in water, necessary for aquatic life. It is measured using a DO meter after calibration with distilled water and buffer solution.
5	**Biochemical Oxygen Demand (BOD) (mg L-1):** BOD measures the amount of oxygen required for the biological decomposition of organic matter in water. It is measured by incubating samples in BOD bottles for 5 days at 20°C and determining the dissolved oxygen content.
6	**Carbon dioxide (CO2) (mg L-1):** CO2 concentration is measured in milligrams per liter (mg L-1) and is a key parameter in assessing water quality. It can be measured using titration, infrared gas analyzers (IRGA), or the alkalinity-pH method.
7	**pH:** pH is a measure of water acidity or alkalinity. It is measured using a pH meter after calibration with distilled water and buffer solution.
8	**Alkalinity (mg L-1):** Alkalinity measures the ability of water to neutralize acids. It is measured by titrating water samples with H2SO4 until a color change occurs, indicating the endpoint of the titration.

9	**Hardness (mg L-1):** Water hardness is a measure of the amount of calcium and magnesium ions present in water. It is measured using the ethylenediaminetetraacetic acid (EDTA) titration method.
10	**Calcium (mg L-1):** Calcium is a key ion that contributes to water hardness. It is measured using the EDTA titration method.
11	**Ammonia (mg L-1):** Ammonia levels are measured using the Kjeldahl digestion method, followed by distillation and titration with H2SO4 or the Nessler's reagent method to detect its presence in water.
12	**Nitrite (mg L-1):** Nitrite concentration is measured using the Griess reagent method, ion chromatography, or nitrite test strips to detect and quantify its presence in water.
13	**Nitrate (mg L-1):** Nitrate is a parameter that is measured using the brucine method to determine its concentration in water.
14	**Phosphorus (mg L-1):** Phosphorus concentration is measured using the molybdenum blue method, ICP-MS, or colorimetric methods to determine its level in water.
15	**Hydrogen sulfide (H2S) (mg L-1):** H2S concentration is a key parameter that measures the level of toxic hydrogen sulfide gas in water. It is measured using the methylene blue method or gas detection tubes.
16	**Primary productivity (CL-1 D-1):** Primary productivity measures the rate of photosynthesis in aquatic ecosystems. It is measured using the light and dark bottle oxygen method to determine the net oxygen production through photosynthesis.
17	**Plankton (No. L-1):** Plankton abundance is a measure of the number of individual plankton cells or organisms present in a liter of water. It is determined using various methods such as microscopy, fluorescence microscopy, flow cytometry, or DNA-based techniques.

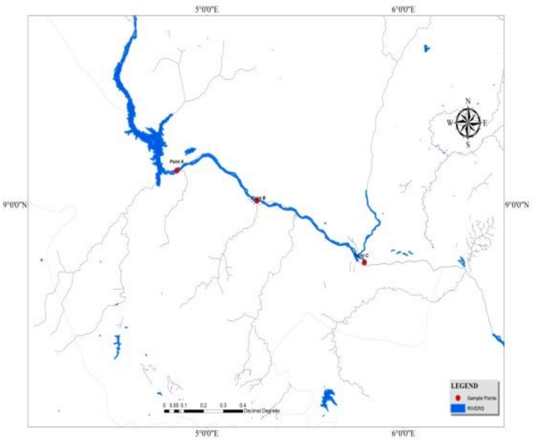

Figure 3: Water Sample Points in the River Niger Basin

Results and Discussion

According to the data presented in Table 2, samples A, B, and C represent various locations in upstream, midstream, and downstream areas during the dry season. The temperature readings across all samples were notably uniform (ranging from 29.6 to 29.7°C), suggesting a stable environment that is generally favorable for aquatic life, as it implies minimal thermal stress. Turbidity showed a slight increase from upstream (0.42 CM) to midstream (0.46 CM) before decreasing slightly downstream (0.43 CM). This pattern may indicate an accumulation of particulate matter or organic material along the flow, with some settling occurring in the downstream region. Water color increased significantly from Sample A (0.00) to Sample B (0.53) but decreased in Sample C (0.37). The increased coloration may imply a higher presence of dissolved organic matter or suspended particles, possibly associated with pollution or biological activity.

Dissolved oxygen levels rose notably from Sample A (753 mg/L) to Sample B (1025 mg/L), reaching a peak in Sample C (1364 mg/L). The higher levels downstream suggest a thriving ecosystem, likely due to increased photosynthesis or reduced organic decay. Biological Oxygen Demand (BOD) values increased from Sample A (638.5 mg/L) to Sample C (913.9 mg/L), indicating a rise in organic pollution or intensified decomposition processes downstream, which heightens the oxygen demand and could create stressful conditions for aquatic organisms. Carbon Dioxide (CO2) concentrations also rose from Sample A (6.12 mg/L) to Sample C (8.14 mg/L), suggesting biological activities like respiration and decomposition dominate, leading to CO2 production that surpasses photosynthetic absorption. The pH level increased slightly from Sample A (0.51) to Sample C (0.74), hinting at changes in water chemistry possibly linked to the breakdown of organic matter and microbial activity.

Alkalinity decreased from upstream (0.00 mg/L) to midstream (0.066 mg/L) and then further declined downstream (0.022 mg/L), indicating low buffering capacity that could make the water more vulnerable to pH fluctuations. Hardness also decreased from Sample A (1.09 mg/L) to Sample C (0.48 mg/L), suggesting a reduction in calcium and magnesium ions, which could affect aquatic organisms that rely on these minerals. Calcium levels dropped from Sample A (4.83 mg/L) to Sample C (2.08 mg/L), which may impact calcifying organisms in the ecosystem. Ammonia levels were higher in Sample A (10 mg/L) compared to B (3 mg/L) and C (4 mg/L). The elevated ammonia upstream may indicate pollution from organic matter or inadequate waste treatment, while the lower levels downstream could suggest dilution or decomposition.

Nitrite was present only in Sample B (0.045 mg/L), indicating ongoing nitrification processes associated with the decomposition of organic matter. Nitrate concentrations were highest in Sample A (43 mg/L), decreased in Sample B (27 mg/L), and slightly increased in Sample C (29 mg/L), suggesting that organisms downstream may be absorbing nitrates. Phosphorus levels sharply decreased from Sample A (24.7 mg/L) to Samples B and C (6.03 mg/L), suggesting biological uptake or sedimentation effectively reduced phosphorus availability downstream. Hydrogen Sulfide (H2S) levels fell from Sample A (114 mg/L) to Sample B (45 mg/L) but rose again in Sample C (59 mg/L). The elevated H2S levels upstream suggest ongoing anaerobic conditions linked to organic decomposition, while the decrease in Sample B could indicate more aerobic conditions, with the slight increase in Sample C hinting at a return to anaerobic conditions downstream.

Productivity steadily increased from Sample A (271.2 CL-1 D -1) to Sample C (460.4 CL-1 D -1), indicating that downstream phytoplankton growth may benefit from increased nutrients, although this could raise concerns about potential eutrophication. Plankton counts decreased from Sample A (195.2 L-1) to Sample B (84.07 L-1) but slightly increased in Sample C (101.1 L-1). The drop in Sample B may reflect limited resources or changes in habitat, while the minor rebound in Sample C indicates a return to conditions that support their growth. The variations observed across these samples illustrate a dynamic ecosystem, with upstream and downstream conditions differing significantly. The findings suggest an increase in nutrients and indicators of organic pollution as water flows downstream, possibly due to human activities. These changes have key implications for aquatic life, highlighting both health and stress levels throughout the basin and indicating the need for management strategies to address any degradation in water quality.

Table 2: Water Quality of River Niger Basin during the Dry Season

Parameter	**Sample A (Upstream)**	**Sample B (Midstream)**	**Sample C (Down Stream)**
Temperature (0C)	29.7	29.6	29.7
Turbidity (CM)	0.42	0.46	0.43
Water color	0.00	0.53	0.37
Dissolved oxygen (mg L1)	753	1025	1364
BOD (mg L-1)	638.5	686.8	913.9
CO_2 (mg L-1)	6.12	7.12	8.14
pH	0.51	0.27	0.74
Alkalinity (mg L-1	0.00 0.	0.066	0.022
Hardness (mg L-1)	1.09	0.72	0.48
Calcium (mg L-1)	4.83	3.12	2.08
Ammonia (mg L-1)	10	3	4
Nitrite (mg L-1)	0.00	0.045	0.00
Nitrate (mg L-1)	43	27	29
Phosphorus (mg L-1)	24.7	6.03	6.03
H_2S (mg L-1)	114	45	59
Primary productivity (CL-1 D -1)	271.2	333.3	460.4
Plankton (No. L-1)	195.2	84.07	101.1

This study's findings are consistent with previous research such as [20] which analyzed water quality factors like hardness and mineral content in different areas along the Nile River, showing similar patterns of water chemistry changes influenced by both natural and human factors from upstream to downstream. Also [21] studied changes in water quality over time and space in the Yangtze River basin, emphasizing the differences in water parameters like mineral content between upstream and downstream locations. [22] further highlighted how urban and agricultural activities impact water chemistry, causing variations in hardness and calcium levels as water travels through a river system. Overall, these studies demonstrate the dynamic nature of water chemistry and suggest that surrounding land use, human activities and natural processes play significant roles.

Research studies have consistently shown that elevated ammonia levels in rivers are often linked to organic pollution, which can have detrimental effects on biodiversity and environmental health. In a similar study, [24] found that ammonia levels upstream of river samples were associated with organic pollution, suggesting potential pollution sources from urban runoff or agricultural inputs. This is consistent with the findings of [25], who reported high ammonia levels in upstream river sites in the Indian Subcontinent affected by agricultural runoff, exceeding 10 mg L-1 and indicating organic pollution sources.

The decrease in ammonia levels downstream, as observed in Sample A and Sample C, is attributed to enhance biological processing and nitrification activities, as supported by [26], who found that upstream areas had higher ammonia concentrations and lesser biological processing due to pollution.

Another study, [27], analyzed nitrogen transformations in river systems across various zones, revealing that upstream locations had the highest ammonia concentrations and notable nitrate levels, while midstream locations showed a pattern of decreased ammonia and varying levels of nitrates and nitrites indicative of biotic activity. Notably, all these studies agree that downstream areas often exhibit high nitrates, consistent with regeneration processes and effective nitrification, supporting the findings from Sample C. Overall, these research studies emphasize the importance of monitoring and mitigating organic pollution in rivers to maintain healthy ecosystems and biodiversity.

Conclusion

Efforts to mitigate the effects of poor water quality during the dry season in the River Niger Basin must prioritize sustainable management and conservation strategies. Initiatives aimed at reducing agricultural runoff, improving waste management systems, and restoring natural habitats can significantly improve water quality. Moreover, community engagement and education on water conservation and hygiene practices are critical for enhancing public health outcomes. Collaborative efforts across governmental and non-governmental organizations are essential to ensure the health of the River Niger Basin and the well-being of the millions who depend on it. Addressing these challenges not only safeguards water quality but also ensures a sustainable future for both human and ecological communities.

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