International Journal of Emerging Research in Engineering, Science, and Management
Vol. 4, Issue 3, pp.22-28, Jul-Sep 2025.
www.ijeresm.com eISSN – 2583-4894

Assessment of the Water Quality of the Odugbo River in Benue State, Nigeria for Irrigation Farming

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Abstract: Food insecurity remains a pressing global issue, particularly in rapidly growing communities such as Odugbo, which may face challenges in sustaining food supply due to increasing population pressure. To mitigate this, the adoption of off-season irrigation farming becomes essential. In this study, water samples were collected during the dry season from three points along a river in the Odugbo area: the upper course (P1), middle course (P2), and lower course (P3). Physical parameters, heavy metal concentrations using Atomic Absorption Spectrophotometry (AAS), and anion levels via titration methods were analyzed. The results showed: Temperature 28.20 ± 0.05 – 28.60 ± 0.05 °C, pH 6.12 ± 0.063 – 6.79 ± 0.05, TDS 1022 ± 2.00 – 1026 ± 2.00 mg/L, DO 5.75 ± 0.11 – 7.19 ± 0.09 mg/L, BOD 0.13 ± 0.01 – 0.57 ± 0.05 mg/L, Electrical Conductivity 825 ± 3.00 – 875 ± 4.00 µS/cm, Turbidity 1.7 ± 0.00 – 2.1 ± 0.00 NTU, Pb 0.521 ± 0.852 mg/L, Zn 0.140 ± 0.003 – 0.158 mg/L, Cu 0.212 ± 0.027 – 0.751 ± 0.023 mg/L, Mn 0.141 ± 0.003 – 0.162 ± 0.002 mg/L, Cd 0.221 ± 0.002 – 0.231 ± 0.003 mg/L, Cl^- 80.61 ± 0.010 – 110.58 ± 0.022 mg/L, NO_3^- 25.81 ± 0.01 – 45.33 ± 0.01 mg/L, PO_4^{3-} 0.023 ± 0.0007 – 0.190 ± 0.01 mg/L, and SO_4^{2-} 78.53 ± 0.001 – 115.22 ± 0.02 mg/L. The findings suggest that the river water is generally suitable for irrigation farming, as most of the tested parameters fall within the FAO-recommended limits for irrigation water quality.

Keywords: Anions, Heavy Metals, Irrigation Water, Off-season Farming, Water Quality.

1 Introduction

One of the most vital resources that is necessary to support all life forms is water. Water availability is essential for food production, economic growth, and people's overall well-being [1][2]. Because it has a significant impact on the life and health of people who either directly or indirectly depend on a water source, particularly those who live in rural communities, water pollution and its repercussions cannot be overstated. Therefore, it is reasonable to conclude that life depends on water and that life would not exist without it [3][4]. Otherwise, life wouldn't exist. Even if there are instances of seasonal dryness in some places, which could have a significant detrimental influence on people's lives and activities, water from the streams has become easily accessible to meet people's requirements in the absence of pipe-born water, particularly in rural communities.

For many people worldwide, water has multiple meanings, and access to clean water is essential for economic development because water is required for almost everything, including economic production, agriculture, industry, domestic or household tasks, and life itself [5][6][3]. Food security may be threatened by the influx of people into the town brought about by the opening of a new institution, necessitating the start of irrigation farming. By boosting agricultural output and availability, irrigation farming can significantly increase food security, particularly in areas experiencing water scarcity and climate change. It makes off-season farming possible, which raises crop yields and farmer earnings while promoting food accessibility and stability. Because it offers the human population vital physiological, social, and economic benefits, food security is critical on a global basis.

Therefore, evaluating the state of food security, especially in developing nations, is essential to achieving the Sustainable Development Goal of eradicating hunger (Goal 2) [7]. Considering climate change and growing water shortages, efficient irrigation water management is essential to raising agricultural output and resolving this pressing issue. This is essential for creating a productive workforce, which propels economic expansion. Malnutrition, on the other hand, can reduce productivity. Overnutrition and undernutrition can both result in health problems that make it difficult for a person to work and learn [8]-[10].

The concept of "food security" has evolved in response to primary concerns about food and hunger, as well as the shifting political and economic environment. The four pillars of availability, access, usage, and stability are now widely acknowledged as being part of food security. Putting irrigation plans into place is essential to reducing poverty and improving food security. Farmers' participation in irrigated agriculture is strongly linked to enhanced home conditions and higher annual incomes and food expenditures [11]. This study investigates the quality of water samples from three different locations in the Odugbo River by considering some parameters to determine whether the river is suitable for the off-season farming period.

2 Materials and Methods

2.1. Sample Collection and Preservation

A total of 27 samples of water were collected at three different points, and nine samples each from a particular point were composited into three composite samples, each representing the upper river location (P1), middle river location (P2), and lower river location (P3). To avoid a reaction with the metals in the water sample to be investigated, each sample was kept in a plastic bottle. After a thorough cleaning, the sample bottles were rinsed three times: once with the appropriate sample, once with deionised water, and finally with diluted HNO3 [12]. Samples must be kept after collection to yield the best results. A slurry of ice and water was made and cooled at 4°C to lessen the chance of volatilisation or biodegradation between sample collection and analysis [13]. According to [14], certain metals, including aluminium, cadmium, chromium, copper, lead, silver, and zinc, may lose ions by ion exchange or adsorption on the glass container walls. By mixing 3 millilitres of high analytical grade HNO3 with one litre of sample, samples were acidified below pH 2.0 to test for adsorption and precipitation [15]. The samples were carefully labelled as follows: P1 (upper river course), P2 (middle river course), and P3 (lower river course).

2.2. Sample Preparation for AAS Analysis

Sample preparation is a crucial step in analytical chemistry that must be performed carefully and precisely to ensure accurate results. In the process of preparing water samples for metal ion analysis using an atomic absorption spectrophotometer, the standard method outlined by [12] involves the following steps: First, a 50-millilitre sample of well-mixed, acid-preserved water is placed in a beaker. Next, a few glass beads and 5 millilitres of concentrated HNO3 (nitric acid) are added. The mixture is then heated on a hot plate, gradually evaporating 10-20 millilitres of the liquid. Additional concentrated HNO3 is added until the digestion process is complete, ensuring that the sample does not dry out during the process. Finally, the beaker is washed three times with deionised water to ensure proper cleaning.

2.3. Sample Analysis for the Determination of Heavy Metals

The digested samples were taken to the Central Research Laboratory at Umaru Musa Yar'adua University, Katsina, Katsina State, for AAS analysis of heavy metals, including lead, zinc, copper, manganese, and cadmium. Three repetitions were done for each metal analysis, and the instrument provided the meaning of the results. After digestion, the AAS machine was used to detect the availability and concentration of the metal analyte in the sample. The digested sample is aspirated into an air-acetylene flame, causing evaporation of the solvent and vaporization of free metal atoms. This method is called atomization. A light source (hollow cathode lamp) operating in the UV-visible spectra region is used to cause electronic excitation of the metal, and the absorbance is measured with a conventional UV-visible dispersive spectrometer with a photomultiplier detector.

2.4. Sample Preparation and Determination for Anions

Water samples were collected in three different plastic bottles labelled P1, P2, and P3 from the three composited samples and wrapped in black nylon to prevent light. Water samples for anionic analysis were preserved by refrigerating at 4°C and were supported by an ice block during transport for analysis. The anions ($NO3^-$, SO_4^{2-}, Cl^-, and PO_4^{3-}) were determined by titration.

2.5. Determination of Electrical Conductivity

To measure the electrical conductivity of the water sample, a conductivity meter was used. This instrument measures how well the water allows current to pass through, which directly reflects the number of dissolved ions in the water. The electrode was first cleaned and thoroughly wet, then plugged into the conductivity meter. It was then placed into a 250ml beaker filled with deionized water. Once the meter was switched on, zero errors were corrected. Afterwards, the deionized water was replaced with raw water samples, and the electrode was inserted into each one. The system was given some time to stabilize before the readings were taken twice to ensure accuracy.

2.6. Determination of Acidity or Alkalinity of the Samples (pH)

pH is a measure of how concentrated hydrogen ions (H^+) are in a solution. A solution with a high concentration of hydrogen ions will have a low pH, while a solution with fewer hydrogen ions will have a higher pH. In mathematical terms, pH is calculated as the negative logarithm of the H^+ concentration. To measure pH, a Wag WT 3020 pH meter was used. First, the glass electrode was rinsed with deionized water. Then, the pH meter was turned on and calibrated by connecting the glass electrode to the meter and immersing it in a buffer solution. The reading was allowed to stabilize, and the pH meter showed a value of 4.0, matching the known value for the buffer. The exact process was repeated for buffer solutions with pH values of 7 and 10. After calibration, the buffer solution was replaced with the raw water samples, and the electrode was immersed in each. After allowing the system to stabilize, the pH readings were recorded.

2.7. Determination of Total Dissolved Solids (TDS)

Total solids measure the combined amount of dissolved and suspended solids in a sample. This is a standard assessment in water treatment, as a high total solids level often indicates the presence of a significant amount of solid material in the sample. In some cases, this could mean the sample is contaminated, depending on the standards used. To measure total solids, an empty beaker was first weighed. Then, 50 mL of the water sample was added to the beaker and gently heated to dryness at around 105°C. Once the water had evaporated, the beaker was cooled and weighed again. This process was repeated until the mass remained constant, and the final value was recorded.

$$Total\ Solids = \frac{Wt * 1000}{Volume\ of\ the\ Sample}$$

where 'Wt' is the weight of the residue after drying.

2.8. Determination of Dissolved Oxygen (DO)

Dissolved oxygen refers to the amount of oxygen gas (O_2) that is present in water. Oxygen enters water through two main processes: direct absorption from the air, especially in areas with rapid movement of water, or as a byproduct of photosynthesis by plants. Factors like water temperature and flow rate can influence the level of dissolved oxygen in water. Cold water holds more oxygen than warm water, which is why water temperature plays a role in oxygen levels. Having sufficient dissolved oxygen is essential for maintaining good water quality and is necessary for the survival of all aquatic life. To measure dissolved oxygen, 20 mL of water was taken and pipetted with 1 mL of potassium fluoride. Then, 2 mL of 0.1 M manganese sulfate and 2 mL of alkaline iodine solution were added. Following that, 2 mL of concentrated H_2SO_4 and 5 mL of freshly prepared starch indicator were introduced, causing the solution to turn blue-black. The sample was then titrated with 0.05 M sodium thiosulfate solution until the color changed to colorless, indicating the end point of the titration.

2.9. Determination of Turbidity

The method used in this study involved comparing the intensity of light scattered by the water sample under controlled conditions with that of a standard reference suspension. The principle here is simple: the more light that is scattered, the higher the turbidity in the sample. The readings were taken in Nephelometric Turbidity Units (NTUs) using a nephelometer, which was built according to specific standards. The instrument was first calibrated using a primary standard suspension. Daily, a secondary standard suspension was used for calibration checks, and the condition of the standards was periodically monitored for any deterioration, with the primary standard serving as a reference for this process [16].

3 Results and Discussion

Table 1 presents the mean concentrations of the physical parameter in the water samples P1, P2, and P3. The results from the table showed the temperature of the samples: P_1 (28.50±0.05), P_2 (28.60±0.05), and P_3 (28.20±0.05). Although the FAO (2023) does not recommend a specific temperature, the values obtained in this work are accepted in related literature, indicating that the water pH is suitable for irrigation farming. The pH of the samples was detected as: P_1 (6.12±0.06), P_2 (6.19±0.03), and P_3 (6.79±0.05). All the reported values were found within the threshold set by FAO (6.5-8.4). This is an indication that the pH of the river is suitable for irrigation farming. Results for the analysis of total dissolved solid (TDS) in the samples in mg/L were reported as follows:: P_1 (1022±2.00), P_2 (1026±2.00), and P_3 (1026±2.00).

Table 1. Mean and standard deviation data for the concentrations of some physical parameters in the samples

Parameter	P_1			P_2			P_3			FAO Standard
	Mean	SD	RSD %	Mean	SD	RSD %	Mean	SD	RSD %	
TEMP. ^{O}C	28.50	0.05	0.18	28.60	0.05	0.18	28.20	0.05	0.18	-
pH	6.12	0.06	10.3	6.19	0.03	4.85	6.79	0.05	0.73	6.5-8.4
TDS (mg/L)	1022	2.00	0.20	1026	2.00	0.19	1026	2.00	0.19	2000
DO (mg/L)	5.75	0.11	1.91	6.82	0.02	0.29	7.19	0.09	1.25	1.18-2.98
BOD (mg/L)	0.57	0.05	8.77	0.41	0.01	2.44	0.13	0.01	7.69	40
E.C. (µS/cm)	825	3.00	0.36	815	1.00	0.12	874	4.00	0.46	≤ 3000
Turb. (NTU)	1.70	0,00	0.00	1.80	0.00	0.00	2.10	0.00	0.00	-

These values, compared to the limit set by FAO (2000 mg/L) in Table 1 and Fig. 1, showed that the mean concentrations of the samples analyzed were below the regulatory limit and hence depicted no health risk to the crops; therefore, they were considered fit for farming. Analysis showed the following results for the determination of dissolved oxygen (DO) in mg/L in the water samples: P_1 (5.75±0.11), P_2 (6.82±0.02), and P_3 (7.19±0.09). These values were found to be above the limit set by FAO (1.18-2.98 mg/L), as seen in Fig. 1. These high values detected may have adverse effects on plant growth and soil health, primarily due to the potential for increased oxidation and the creation of a more acidic environment which may not be suitable for plant growth [17].

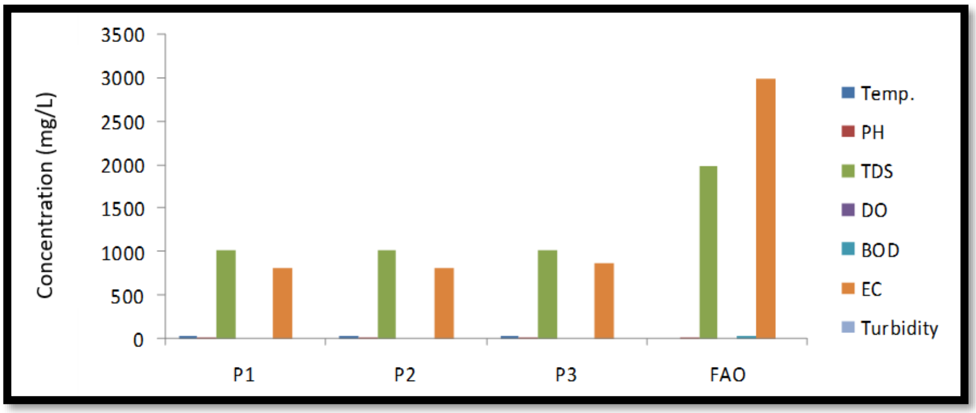

Fig. 1. Comparison of physical parameters with the FAO standard

Analysis to determine the mean concentrations of Biochemical Oxygen Demand (BOD) in the water samples in mg/L were recorded as: P_1 (0.57±0.05), P_2 (0.41±0.01), and P_3 (0.13±0.01). These values are lower compared to the set limit by FAO (40 mg/L) shown in Figure 1. This indicated no health risk to the crops if the river is used for irrigation farming. The electrical conductivity test in µS/cm showed the following results for the samples: P_1 (825±3.00), P_2 (875±4.00), and P_3 (874±4.00). These values, compared to the limit set by FAO (3000 µS/cm), as shown in Fig. 1, indicate that the dissolved ions in the water samples are within the tolerable limits and hence, no fear of health hazard to the crops if used for irrigation. The turbidity of the samples (NTU) was detected as: P_1 (1.7±0.00), P_2 (1.9±0.00), and P_3 (2.1±0.00). Although FAO has not set a specific limit for turbidity, the World Health Organization has established 5 NTU [18] as the standard for drinking water. This value, according to the WHO, can serve as a guide in considering the acceptability of these results for the suitability of the water from this river for irrigation farming.

Table 2 shows the analysis of heavy metals Pb, Zn, Cu, Mn, and Cd in the water samples tested. The mean concentrations of Pb (mg/L) in the sample points were reported as: P_1 (0.852±0.021), P_2 (0.561±0.022), and P_3 (0.521±0.020).

Table 2. Mean and standard deviation data for the heavy metal concentrations in the samples

Metals	**P_1**			**P_2**			**P_3**			**FAO Standard**
	Mean	**SD**	**RSD %**	**Mean**	**SD**	**RSD %**	**Mean**	**SD**	**RSD %**	
Pb (mg/L)	0.852	0.021	2.47	0.561	0.022	3.87	0.521	0.02	3.80	5
Zn (mg/L)	0.158	0.003	1.53	0.140	0.003	1.96	0.140	0.003	1.96	2
Cu (mg/L)	0.751	0.023	1.31	0.212	0.027	1.20	0.212	0.027	1.20	0.2
Mn (mg/L)	0.141	0.003	2.23	0.162	0.002	1.20	0.141	0.003	2.23	0.2
Cd (mg/L)	0.221	0.002	1.96	0.230	0.003	1.11	0.231	0.003	1.10	0.01

These results, compared to the limit set by FAO (5 mg/L) in Table 2 and Fig. 2, were all found below the permissible limit; hence, the river is not harmful to crops. Consequently, based on this report, the water is suitable for irrigation farming regarding the concentration of Pb. The mean concentrations of Zn in the analyzed samples were: P_1 (0.158±0.003), P_2 (0.140±0.003), and P_3 (0.140±0.003). These values were below the threshold of FAO (2 mg/L) shown in Table 2 and Figure 2. This is an assurance of the suitability of the river for irrigation farming. The report of the mean concentrations of Cu was given as: P_1 (0.751±0.023), P_2 (0.212±0.027), and P_3 (0.212±0.027). These values showed that the concentrations of Cu in the river were within the limit as set by FAO (0.2 mg/L) except for the upper river point (P_1). This result suggests that there is a need for moderation to avoid possible health risks to humans through the food chain if the water is used for irrigation farming.

A similar investigation carried out on the water samples showed the mean concentrations of Mn as P_1 (0.141±0.003), P_2 (0.162±0.002), and P_3 (0.141±0.003). These values were found to be lower than the limit (0.2 mg/L) set by the regulatory body shown in Table 2 and Fig. 2. The results from the analysis for the concentrations of Cd in the water samples were reported at P_1 (0.221±0.002), P_2 (0.230±0.003), and P_3 (0.231±0.003). These values were all found above the threshold by FAO (0.10 mg/L) for Cd in water for irrigation. This poses risks to human health through the consumption of contaminated crops and can also affect the ecosystem by impacting soil microbes and other organisms.

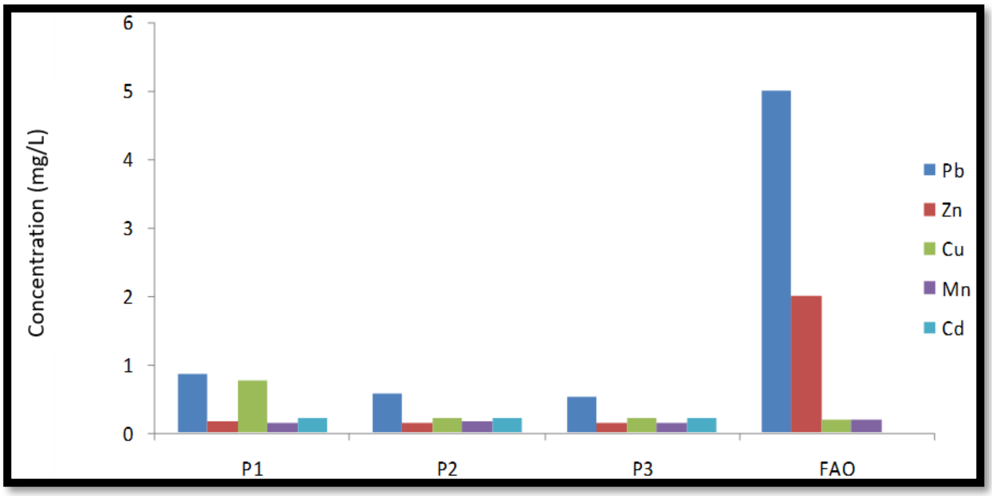

Fig. 2. Comparison of Heavy Metal Concentrations with the FAO standard

Table 3 shows the concentrations (mg/L) of the anions: Cl^-, NO_3^-, PO_4^{3-}, and SO_4^{2-} in the collected water samples analyzed. The mean concentrations of Cl^- were reported as: P1 (110.58±0.022), P2 (95.63±0.025), and P3 (80.61±0.010). These values were found below the permissible limit set by FAO (106.5 mg/L) except for the sample of water from the upper river point. Considering the difference in values between P1 (110.58±0.022 mg/L) and FAO (106.5 mg/L), the water may be regarded as fit for irrigation farming. Results for the analysis of the mean concentrations of NO_3^- were reported as: P1 (45.35±0.010), P2 (34.65±0.026), and P3 (25.81±0.010). These values were all found below the limit set by FAO (50 mg/L); hence, the river is suitable for irrigation farming.

Table 3. Mean and standard deviation data for the concentrations of anions in the samples

Anions	P_1			P_2			P_3			FAO Standard
	Mean	SD	RSD %	Mean	SD	RSD %	Mean	SD	RSD %	
Cl^- (mg/L)	110.56	0.022	0.22	95,63	0.025	0.26	80.61	0.01	0.12	106.5
NO_3^- (mg/L)	45.33	0.01	0.02	34.56	0.026	0.08	25.81	0.01	0.04	50
PO_4^{2-} (mg/L)	0.023	0.001	3.04	0.190	0.01	5.26	0.170	0.01	5.88	0.1
SO_4^{2-} (mg/L)	115.22	0.02	0.02	97.44	0.04	0.04	78.53	0.01	0.01	400

The mean concentrations of PO_4^{3-} were found: P1 (0.023±0.0007), P2 (0.19±0.010), and P3 (0.170±0.010). These values, compared to the 0.10 mg/L set by FAO, are slightly higher than the regulated value except for the upper river water, which was found below the limit. This could be a result of the use of phosphate fertilizer, washed into the river by runoff water [19]. Finally, the results of SO_4^{2-} analysis are reported: P1 (115.22±0.02), P2 (97.44±0.04), and P3 (78.53±0.01).

These were all found below the tolerable limit of 400 mg/L by FAO. Hence, the water from this river is suitable for irrigation farming. The Relative Standard Deviation for all the values is calculated using the Horwitch function, which states that the highest relative standard deviation values acceptable for concentrations of less than or equal to 1000 mg/L are 10% [20]. Fig. 3 plots the concentration of anions at different locations along with the FOA standard.

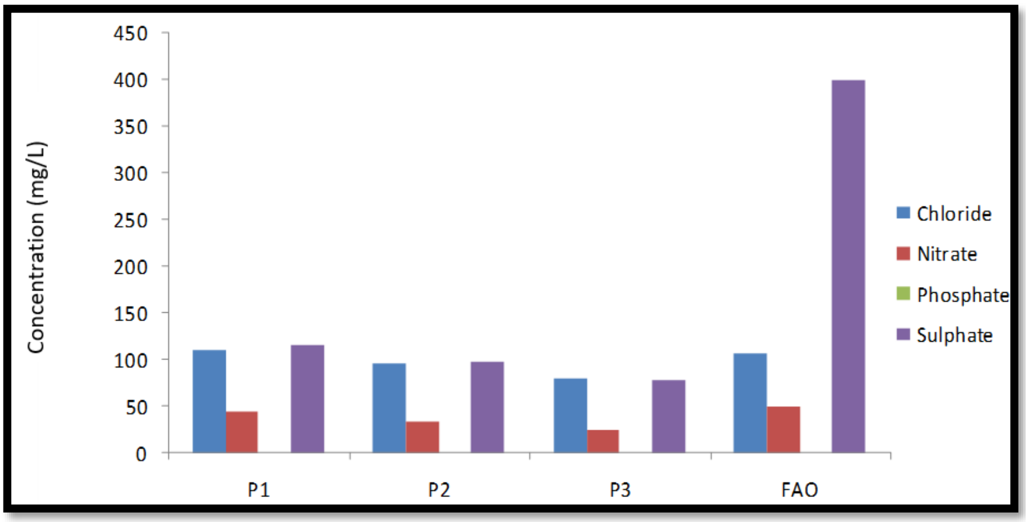

Fig. 3. Comparison of concentrations of anions with FAO standard

4 Conclusions and Recommendations

The water samples' results revealed that the area falls below the desirable limit and is suitable for irrigation during the dry season, as the water quality indices compared with the results didn't show health concerns, except in instances that are not enough to pose a threat to human health. This system of farming, if adopted, can ensure food security, support agricultural diversification, provide opportunities for skills acquisition by students within the community, mitigate drought, and provide employment opportunities for farmers who have fewer farming jobs during the dry season. This study highlights the importance of consistently monitoring the water quality of the Odugbo River to keep track of pollution levels over time. Regular assessments are crucial for implementing timely management measures to reduce the intensity of pollution. Given that some of the parameters examined, like copper and cadmium, are nearing or even exceeding the upper limits, immediate actions need to be taken to address this issue. The remedial measures include:

1) Farmers should be encouraged to adopt biofertilizers and biopesticides as alternatives to prevent contamination of the soil, surface water, and groundwater.
2) A clear action plan needs to be developed for both short-term and long-term management of surface water and other natural resources. This plan should consider factors such as population, agricultural activities, and the availability of water resources.
3) A sustainable watershed management plan should be established to preserve both the quality and quantity of the Odugbo River. During the study, it was observed that several human activities along the riverbank, including the use of agrochemicals like herbicides and pesticides and the unregulated discharge of effluent from cassava processing, are threatening the river's health.
4) The research on the Odugbo River should be extended beyond the scope of this study. This would offer more comprehensive data on the river's suitability for irrigation. Further studies should include an examination of the river's quality during the rainy season to assess its potential to combat drought, which often leads to crop failure.
5) Investigating the quality of Odugbo River during the rainy season is essential to understand its suitability for irrigation, especially in addressing drought issues that threaten crop yields.

FUNDING INFORMATION

This research was sponsored by the administration of the Federal College of Education, Odugbo, through the Tertiary Education Trust Fund (TETFund), Nigeria.

ACKNOWLEDGEMENTS

The authors would like to thank the Central Research Laboratory of Umaru Yar'adua University in Katsina and the Federal University in Lokoja for their support with sample analysis. The authors are also especially grateful to God Almighty for His protection during this work.

ETHICS STATEMENT

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

STATEMENT OF CONFLICT OF INTERESTS

The authors declare no conflicts of interest related to this study.

LICENSING

REFERENCES

[1] Vandana Sharma, Yogesh Kumar Walia, "Water Quality Assessment Using Physico-Chemical Parameters and Heavy Metals of Gobind Sagar Lake, Himachal Pradesh (India)," *Current World Environment*, vol. 10, no. 3, pp. 967-974, 2015. doi: 10.12944/CWE.10.3.28.
[2] E. B. Njoyim and R. M. T. Tamungang, "Evaluation of surface and ground water quality in the Bangangte Municipality, West Cameroon," *International Journal of Research and Reviews in Applied Sciences*, vol. 28, no. 3, pp. 53-64, 2016.
[3] Okwesili Lotanna Chidera, "Water quality assessment of Umuchigbo stream, Abakpa-Nike, Enugu East L.G.A, Enugu," *International Journal of Chemistry Studies*, vol. 7, no. 2, pp. 23-26, 2023.
[4] M. A. Isa, H. S. Bello, I. A. Gulani, M. A. Aisha, and I. Hyelabari, "Prevalence of Malaria Parasite Infection among Pregnant Women Attending Ante-Natal Clinic in State Specialist Hospital," *The Journal of Applied Sciences Research*, vol. 2, no. 1, 2015.
[5] M. N. Alakeh, M. Kenneth, N. E. B. Tamungang, N. F. Biosengazeh, and N. E. Asongafac, "Domestic water quality assessment in Nteingue community, West region of Cameroon," *American Journal of Water Resources*, vol. 11, no. 3, pp. 88–97, Jul. 2023, doi: 10.12691/ajwr-11-3-1.
[6] A. A. Akaho, G. B. Tikeri, and A. O. David, "Physicochemical analysis of potable water in Baham community, Western Region of Cameroon," *Journal of Applied Science Environment Management*, vol. 26, no. 7, pp. 1203-1209, 2022. doi: 10.4314/jasem.v26i7.3.
[7] "Achieving food security: Sustainable Development Goal 2 (SDG 2) - The EU's role in ending hunger and improving nutrition | Think Tank | European Parliament." https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2024)762372.
[8] E. Essien, M. J. Haruna, and P. K. Emebu, "Prevalence of Malnutrition and its Effects on the Academic Performance of Students in Some Selected Secondary Schools in Sokoto Metropolis," *Pakistan Journal of Nutrition*, vol. 11, no. 7, pp. 609–613, Jun. 2012, doi: 10.3923/pjn.2012.609.613.
[9] A. A. Zerga, S. E. Tadesse, F. Y. Ayele, and S. Z. Ayele, "Impact of malnutrition on the academic performance of school children in Ethiopia: A systematic review and meta-analysis," *SAGE Open Medicine*, vol. 10, Jan. 2022, doi: 10.1177/20503121221122398.
[10] F. Hamdan and F. Al-Jarrah, "Nutritional health and its impact on students' academic achievement," *Journal of Educational and Social Research*, vol. 14, no. 6, p. 449, Nov. 2024, doi: 10.36941/jesr-2024-0185.
[11] E. A. Ebrahim and A. Toy, "Impact of irrigation participation on households food security in a rural area of Ethiopia: application of propensity score matching (PSM) method for causal inference," *Frontiers in Sustainable Food Systems*, vol. 8, Nov. 2024, doi: 10.3389/fsufs.2024.1403317.
[12] I. B. Ibrahim, B. Magaji, H. Aisha, and M. S. Zubairu, "Heavy metals analysis on some water samples using atomic absorption spectroscopy," *Food Science & Nutrition Technology*, vol. 8, no. 4, pp. 1-6, 2023. doi: 10.23880/fsnt-16000315.
[13] M. R. Mahananda, B. P. Mohanty, and N. R. Behera, "Physico-Chemical analysis of surface and ground water of Bargarh district, Orissa, India," *International Journal of Research and Reviews in Applied Sciences*, vol. 2, no. 3, pp. 284-295, 2010.
[14] E. A. Godwill, I. C. Jane, I. U. Scholastica, U. Marcellus, A. L. Eugene, and O. A. Gloria, "Determination of some soft drink constituents and contamination by some heavy metals in Nigeria," *Toxicology Reports*, vol. 2, pp. 384–390, Jan. 2015, doi: 10.1016/j.toxrep.2015.01.014.
[15] G. Bruno, "Acid-Alkaline balance and health: An examination of the data," *Supplement Science*, pp. 34-39, 2013.
[16] U.S. Environmental Protection Agency (USEPA), "Determination of turbidity by nephelometer," *USEPA Standard Methods*, 1993. Retrieved from: https://www.epa.org
[17] S. Larance, J. Wang, M. A. Delavar, and M. Fahs, "Assessing water temperature and dissolved oxygen and their potential effects on aquatic ecosystem using a SARIMA model," *Environments*, vol. 12, no. 1, p. 25, Jan. 2025, doi: 10.3390/environments12010025.
[18] *Guidelines for Drinking-water Quality.* 4th Edition, WHO, 2011.
[19] Z. Ouyang and J. Tian, "Effects of water, fertilizer, dissolved oxygen and temperature coupling on the photosynthesis, quality and yield of lettuce," *Ouyang | International Journal of Agricultural and Biological Engineering*, Dec. 2023, doi: 10.25165/ijabe.v16i5.7916.
[20] A. E. Aquism, Z. B. Assim, R. B. Wahi, D. E. Kwabena, and F. W. Festus, "Validation of the Atomic Absorption Spectroscopy (AAS) for heavy metal analysis and geochemical exploration of sediment samples from the Sebangan River," *Advances in Analytical Chemistry*, vol. 9, no. 2, pp. 23-33, 2019. doi: 10.5923/j.aac.20190902.01.