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Profile Of Surface Water Quality At Sapele Section Of Ethiope River, Delta State, Nigeria

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***Abstract:** Human activities, particularly industrial, agricultural, and domestic practices, have increasingly become primary drivers of environmental degradation. The profile of the surface water of the Sapele section of River Ethiope, Delta State of Nigeria was investigated. The study involved the collection of water samples from 10 sampling stations. The physiochemical and heavy metals were analyzed according to standard methods and procedures. The Water quality index was computed using the weight arithmetic method. The results revealed pH in the range 5.80 – 6.80; DO 5.10 – 6.10 mg/L; COD 14.74 – 30.34 mg/L; BOD 2.10 – 4.60 mg/L; Pb 0.002 – 0.021 mg/L; Cd 0.004 – 0.016 mg/L. WAWQI >100 which means the water is unsuitable for drinking. The implications of the PCA results suggest the presence of organic pollution, water hardness, salinity, suspended solids, and metal contamination in the studied area which indicates that sources of pollution emanated from anthropogenic activities such as agricultural runoff, improper waste disposal, and dredging activities.*

***Keywords:** dredging, water quality, Pollution, Heavy metals*

I. INTRODUCTION

Water is an indispensable natural resource that is vital for the existence of life and reigns as one of the most abundant resources on Earth. The globe is composed of an excess of 75% water, encompassing an array of forms such as rivers, lakes, streams, seas, oceans, and subterranean water reservoirs (Georgieva et al., 2018). Despite representing a meager proportion (0.49%) of Earth's surface freshwater, rivers hold significance beyond their size. They serve as a vital drinking water source worldwide and play a pivotal role in facilitating agricultural growth, industrial activities, energy generation, transportation, and providing habitats for numerous organisms. However, a rising number of rivers worldwide are experiencing notable pollution levels, coinciding with projections that global freshwater demand will rise by one-third by the year 2050 (Programme and Raymond, 2018; Thai-Hoang *et al.* 2022). Human activities, particularly industrial, agricultural, and domestic practices, have increasingly become primary drivers of environmental degradation across the globe. These activities introduce a multitude of pollutants into various environmental compartments, including water bodies. Such degradation profoundly affects aquatic ecosystems, leading to a range of negative consequences (Thai-Hoang *et al.* 2022).

Surface water bodies, in particular, act as crucial repositories for various pollutants, including pesticides and heavy metals (Emovin, et al. 2006). Assessing the profile of surface water quality has been an interest since it has been established that the quality of surface water influences the health status of any populace. Water quality encompasses the suitability of water for various purposes or processes, as defined by the World Health Organization (WHO, 2016). Water quality assessment involves the comprehensive evaluation of the physical, chemical, and biological characteristics of a given body of water. Several key indicators are utilized for this assessment, including parameters like Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) (Iyama et al. 2017; Iyama et al .2020). Additionally, metrics such as organic pollution and eutrophication indices can be employed to quantify the extent of water pollution (Liu et al. in 2011; Iyama et al. in 2020).

Heavy metals, due to their highly toxic and persistent nature in the environment, are considered high-priority pollutants. Therefore, monitoring the fluctuations in concentration and distribution of heavy metals and their compounds across various environmental compartments is imperative for effective environmental management (Don-Pedro et al. 2004; Oribhabor and Ogbeibu, (2009). Notably, lead (Pb), Chromium (Cr), Arsenic (As), Cadmium (Cd), Copper (Cu), and Zinc (Zn) are the metals of primary environmental concern in water. It is imperative to possess an understanding of how the concentrations and distribution of heavy metals and their compounds change within various environmental compartments. This understanding is crucial for effective environmental management (Vincent-Akpu and Nwachukwu, 2016).

In aquatic ecosystems, metals typically exist in low concentrations naturally. Some essential metals like copper (Cu) and zinc (Zn) serve regular physiological functions in organisms at standard levels but can become harmful at higher concentrations. The increasing presence of metal contaminants exceeding natural levels has become a growing concern. The proliferation of metal contaminants beyond natural levels has emerged as a growing concern, given metals' persistence in the environment, the potential for bioaccumulation, and biomagnification along food chains, thereby elevating public health risks. (Vincent-Akpu and Nwachukwu, 2016). Principal component analysis (PCA) can simplify complex water quality datasets and help identify underlying patterns and sources of variation in water quality, making it a valuable tool for water quality assessment and management (Lencha et al. 2021). Various studies have successfully applied PCA in the identification of pollution source and for data reduction (Ustalogue and Tepe, 2019; Yang et al. 2020; Lencha et al. 2021).

Ethiope River, a vital water source in the Sapele region of Delta State, Nigeria, holds significance for the local community. It serves as a source of fishery, recreational activities, domestic use, and agricultural practices. Hence, this study aims to assess the surface water quality and to identify the various sources of pollution in the Sapele section of Ethiope River, shedding light on its condition and its implications for the surrounding environment and populace.

II. MATERIALS AND METHOD

STUDY AREA

The area of study is the Sapele section of Ethiope River in Sapele Local Government Area of Delta state, Nigeria. The Ethiope River takes its source from a spring at Umuaja in Ukwuani Local Government Area of Delta State and flows for over 100km to empty into river Benin. The entire length of the river lies between latitude 6^o 31 and 6^o 30 N and longitude 50^o – 60^o E (Omo-Irabor & Olobaniyi, 2007). The river serves as a major source of water for agriculture, transportation, Fishing, and other domestic purposes at various locations as there are different human settlements along the bank of the river.

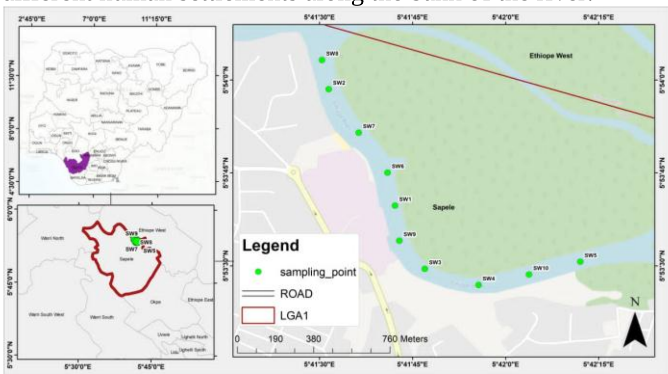

Figure 1: Map of Study Area

SAMPLING

Ten sampling locations were selected along the Sapele section of Ethiope River for this study. The sampling activities were carried out in February 2023. Water samples for general physicochemical parameters were placed in previously cleaned 1-liter containers. sampling containers were meticulously rinsed with water from the respective sampling points before the actual sample collection. The collection and preservation of samples for various parameters followed the guidelines outlined by APHA, (2012). For heavy metal analysis, the samples were placed in prewashed 1-liter containers and acidified to achieve a pH level below 2 through the addition of a 1:1 solution of HNO3. Samples intended for COD analysis were separately stored in prewashed 250 mL brown bottles and acidified to a pH level below 2 using H_2SO_4. Samples designated for BOD determination were placed in pre-cleaned BOD bottles and covered with aluminum foil. The water samples were kept in coolers at a temperature of 4°C until they could be transported to the laboratory. These procedures adhered to the established standard methods for water analysis, as detailed in APHA, (2012) guidelines.

ANALYTICAL METHOD

Parameters	Analytical Methods
Physico-chemical	
Temperature, ^{o}C	Thermometer (APHA, 2550-B)
pH	Electronic method (APHA - 4500-H+)
Temperature, ^{o}C	Thermometer (APHA, 2550-B)
Turbidity, NTU	Nephelometric method (APHA – 2130-B)
Conductivity, µS/cm	APHA 2510 B
Total dissolved solids (TDS), mg/L	APHA 2540-C
Total Suspended Solids (TSS), mg/L	Gravimetric method (APHA-2540-D)
Nitrate, mg/L	Cadmium Reduction method (ASTM, 2016 -D3867)
Phosphate. mg/L	Ascorbic Acid method (APHA-4500 PO43-)
Sulphate, mg/L	Turbidity method (APHA-4500 SO42-E)
DO, mg/L	APHA – 4500-O C
BOD, mg/L	5-day method (APHA 5210B)
COD, mg/L	Dichromate method (Reflux) (APHA – 5300 B)
Calcium, mg/L	Complexometric Titration method
Magnesium, mg/L	Complexometric Titration method
Metals	Atomic Absorption Spectrophotometer (AAS), (APHA 3400)

Source: APHA, (2012)

Table 1: Methods for determination of the physico-chemical parameters

STATISTICAL ANALYSIS

The physicochemical parameters results were subjected to descriptive statistical analysis to determine both the mean and the degree of variation (standard deviation). To assess whether there were notable distinctions among the different sampling stations, a one-way analysis of variance (ANOVA) was employed. Additionally. Principal component analysis was performed to identify specific sources of contamination. All statistical analyses were conducted using Microsoft Excel and Office 365.

III. RESULTS AND DISCUSSION

RESULTS

The physicochemical result of surface water in the Sapele area of the Ethiope River, located in Delta State, Nigeria is presented in Tables 4.1-4.5 and Figures 4.1 – 4.3.

The pH range of 5.80 to 6.80 falls within the slightly acidic to neutral range. The mean pH of 6.13 suggests that the water in the study area is slightly acidic. The temperature values in the range of 27.70 to 29.20 °C indicate a relatively warm water environment. The electrical conductivity range of 16.5 to 25.00µS/cm indicates the presence of dissolved salts and minerals in the water.

The total dissolved solids (TDS) range of 8.10 to 12.60 mg/L with an average value of 10.69 mg/L represents the concentration of inorganic and organic substances dissolved in water. The total suspended solids (TSS) range of 3.00 to 12.00 mg/L indicates the concentration of particles suspended in water. TSS was within WHO, (2011) permissible limits for drinking water quality (Table 2). The turbidity range of 7.10 to 16.20 NTU represents the clarity or cloudiness of water due to suspended particles.

The COD range of 14.74 to 30.34 mg/L represents the amount of oxygen required to chemically oxidize organic and inorganic matter in the water. The BOD range of 2.10 to 4.60 mg/L represents the amount of dissolved oxygen consumed by microorganisms while decomposing organic matter in water. The dissolved oxygen range of 5.10 to 6.10 mg/L represents the concentration of oxygen dissolved in the water.

Sulphate ranged from 0.11 – 0.56 mg/L with an average value of 0.32 ± 0.17 mg/L. Sulphate was within WHO, (2011) acceptable limits for drinking water quality (Table 2). Magnesium values ranged from 2.16 – 7.04 mg/L with a mean value of 4.13 ± 1.25 mg/L. Bicarbonate ranged from 21.96 – 64.66 mg/L with an average value of 34.16 ± 12.21 mg/L. Sodium values ranged from 0.02 – 0.08 mg/L with a mean value of 0.05 ± 0.02 mg/L. Sodium was within WHO, (2011) recommended limits for drinking water quality (Table 2). Potassium ranged from 0.01 – 0.03 mg/L with an average value of 0.02 ± 0.01 mg/L. Nitrate values ranged from 0.01 – 0.08 mg/L with a mean value of 0.04 ± 0.02 mg/L. Nitrate was WHO, (2011) permissible limits for drinking water quality (Table 2). Total Phosphorus values ranged from 0.00 – 0.008 mg/L with a mean value of 0.003 ± 0.00.

Physiochemical Parameters	Range of the study area	Mean ± Standard deviation	P – value	WHO, 2011
pH	5.80 – 6.80	6.13 ± 0.37	P > 0.05	6.5 – 8.5
Temperature (°C)	27.70 – 29.20	28.30 ± 0.51	P > 0.05	
Electrical Conductivity (µS/cm)	16.5 – 25.00	21.25 ± 2.54	P > 0.05	
Total Dissolved Solids (mg/L)	8.10 – 12.60	10.69 ± 1.30	P > 0.05	
Total Suspended Solids (mg/L)	3.00 – 12.00	5.50 ± 2.97	P > 0.05	50
Turbidity (NTU)	7.10 – 16.20	9.81 ± 2.99	P > 0.05	5
Gross organics				
Chemical Oxygen Demand (mg/L)	14.74 – 30.34	20.98 ± 7.16	P > 0.05	
Biological Oxygen Demand (mg/L)	2.10 – 4.60	3.48 ± 0.75	P < 0.05	
Dissolved Oxygen (mg/L)	5.10 – 6.10	5.71 ± 0.38	P < 0.05	
Anions				
Sulphate (mg/L)	0.11 – 0.56	0.32 ± 0.17	P > 0.05	250
Magnesium (mg/L)	2.16 – 7.04	4.13 ± 1.25	P > 0.05	30
Bicarbonate (mg/L)	21.96 – 64.66	34.16 ± 12.21	P > 0.05	
Sodium	0.02 – 0.08	0.05 ± 0.02	P > 0.05	200
Potassium	0.01 – 0.03	0.02 ± 0.01	P > 0.05	
Nitrate (mg/L)	0.01 – 0.08	0.04 ± 0.02	P > 0.05	50
Total Phosphorous (mg/L)	0.00 - 0.008	0.003 ± 0.002	P > 0.05	

Note: P > 0.05 – no significant difference at 95% confidence interval; P< 0.05 – significant difference at 95% confidence interval.

Table 2: Physicochemical characteristics of Surface Water from River Ethiope

Heavy Metals Parameters (mg/L)	Range of the study area	Mean ± SD	P-value	WHO, 2011
Iron	0.06 – 0.26	0.17 ± 0.06	p>0.05	0.3
Copper	0.003 – 0.044	0.02 ± 0.01	p>0.05	2.0
Nickel	<0.001	<0.001	p>0.05	
Lead	0.002 – 0.021	0.01 ± 0.006	p>0.05	0.01
Zinc	0.003 – 0.045	0.02 ± 0.006	p>0.05	
Manganese	0.01 – 0.07	0.03 ± 0.02	p>0.05	
Cadmium	0.004 – 0.016	0.01 ± 0.003	p<0.05	0.003
Chromium	<0.001	<0.001	p>0.05	

Table 3: Heavy Metal Analysis of Surface Water from River Ethiope

The range of 0.06 to 0.26 mg/L for iron suggests the concentration of iron in the water. The mean concentration of 0.17 mg/L indicates the average iron content in the study area. The range of 0.003 to 0.044 mg/L for copper represents the concentration of copper in the water. The mean concentration of 0.02 mg/L suggests the average copper content in the study area.

The value of "<0.001 mg/L" for nickel indicates that the concentration of nickel in the water is below the detection limit of the measurement method. The range of 0.002 to 0.021 mg/L for lead represents the concentration of lead in the water.

The range of 0.003 to 0.045 mg/L for zinc indicates the concentration of zinc in the water. The mean concentration of 0.02 mg/L suggests the average zinc content in the study area. The range of 0.01 to 0.07 mg/L for manganese represents the concentration of manganese in the water. The mean concentration of 0.03 mg/L suggests the average manganese content in the study area.

The range of 0.004 to 0.016 mg/L for cadmium indicates the concentration of cadmium in the water. Cadmium exceeded WHO, (2011) standard limits for drinking water quality. The mean concentration of 0.01 mg/L suggests the average cadmium content in the study area. Chromium was below detection limits of <0.001 mg/L. Lead in the ranged from 0.002 – 0.021 with an average value of 0.01 ± 0.006 mg/L exceeded WHO, 2011 permissible limits for drinking water quality.

IV. WATER QUALITY INDEX (WQI)

In this study, Weight arithmetic water quality index (Equation 1) was used to calculate the surface water quality (Chandra et al. 2017). WAWQI assesses the water quality based on the commonly measured variables (Kizar, 2018; Chidiac et al. 2023). World Health Organization, (2011) and the united State Environmental Protection Agency, (2016) were the standard limits used to compute the water quality index of the study area. The water quality status of the study area was assessed based on classification by Chidiac et al. (2023). Table 4.7 shows the water quality index results of the Ethiope River Delta state, Nigeria.

$$WQI = ((\Sigma w\, n^* \, q\, n)/\Sigma\, w\, n) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Water quality index level	Water quality status
Water quality status 0–25	Excellent
water quality 26–50	Good
water quality 51–75	Poor
water quality 76–100	Very poor
water quality >100	Unsuitable for drinking

Source: (Chidiac et al. 2023)

Table 4: WAWQI and Status of Water Quality

Physicochemical Parameters	1	2	3	4
bicarbonate	**0.986**			0.142
alkalinity	**0.986**			0.142
magnesium	-0.876	-0.229	0.356	-0.231
BOD	**0.848**	0.314	0.406	-0.134
DO	**0.828**	-0.287	0.169	-0.452
EC	-0.783	0.318		-0.531
lead	**0.763**	0.162	-0.624	
TDS	-0.763	0.384		-0.513
turbidity	-0.725	-0.107	0.242	0.636
Cadmium	**0.693**	0.439	-0.353	0.45
ammonia	**0.633**	**0.502**	0.564	-0.17
Total Phosphorus		-0.995		
acidity	-0.123	**0.966**		-0.225
Total Hardness		**0.926**	0.354	0.131
zinc	-0.53	**0.82**		-0.21
calcium	**0.601**	**0.796**		
sulphate	-0.352	**0.778**	-0.383	0.354
COD	**0.682**	**0.723**	0.108	
iron	-0.634	**0.684**		-0.355
Copper	-	0.352	-0.923	0.13
Manganese	-	-0.508	**0.86**	
Chloride	0.352	0.213	**0.811**	0.417
Temperature	**0.646**	-0.122	**0.719**	0.226
potassium	-0.173	-0.437	-0.68	**0.563**
Nitrate	-0.502	0.34	**0.663**	0.439
pH	-	-	**0.625**	-0.778
sodium	-0.416	0.404	0.375	**0.724**
Total suspended solids	-0.676		0.286	**0.678**
Total	10.42	7.57	5,80	4.21
Initial Eigen value % variance	37.20	27.03	20.73	15.03
Cumulative %	37.21	64.24	84.97	100

Note: highlighted bold are the significant loading at 0.05 confidence intervals.

Table 5: Principal Component results of the surface water from River Ethiope

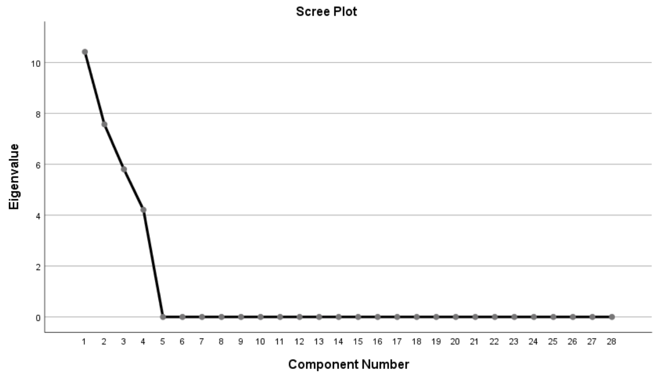

Figure 2: Shows the Screen Plot from the principal component analysis

Sampling station	Water quality index level	Water Quality status
SW1	102.37	Unsuitable for drinking
SW2	153.55	Unsuitable for drinking
SW3	281.51	Unsuitable for drinking
SW4	332.69	Unsuitable for drinking
SW5	255.91	Unsuitable for drinking
SW6	409.46	Unsuitable for drinking
SW7	358.28	Unsuitable for drinking
SW8	409.46	Unsuitable for drinking
SW9	307.09	Unsuitable for drinking
SW10	332.68	Unsuitable for drinking

Table 6: Water Quality Index Level

DISCUSSION

The results of the study conducted on the surface water of the Sapele section of the Ethiope River in Delta State provide valuable insights into the physicochemical parameters and their implications for the study area.

Comparing these results with previous research in the field of water quality assessment, several similarities can be observed. For instance, the slightly acidic pH range falls within the acceptable range for most aquatic organisms, which aligns with previous studies by Erhenhi and Omoigberale, (2020) highlighting the tolerance of many species to this pH range. Similarly, the temperature range indicates a relatively warm water environment, which has been noted in other river systems as well, emphasizing the influence of climate and geographical location on water temperature. The presence of dissolved salts and minerals, indicated by electrical conductivity and TDS, is a common finding in many water bodies and can be attributed to natural geological factors or human activities. Elevated conductivity and TDS levels have been associated with increased ion concentrations, affecting water quality and the suitability of habitats for certain species. This aligns with previous research emphasizing the impact of conductivity and TDS on aquatic ecosystems. The concentration of total suspended solids and turbidity in the water indicates the presence of particles, which can reduce light penetration and affect aquatic plants and organisms. Higher levels of suspended solids and turbidity have been linked to sedimentation, erosion, and pollution sources, consistent with previous studies highlighting the ecological consequences of increased turbidity.

The total hardness values reflect the concentration of calcium and magnesium ions in the water. High hardness levels can affect both ecological and human systems, including impacts on aquatic organisms and the formation of scale in pipes and appliances. Previous research by Smith *et al.* (2019) has extensively examined the effects of hardness on various aspects of water quality and ecosystem health. Dissolved oxygen (DO) is an estimate of the levels of oxygen dissolved in the aqueous system (Trick *et al.* 2018). Water bodies with DO less than 2mg/L are regarded to be very polluted (Ija *et al.* 2022). Fish can die in water bodies if the DO levels drop to 0.3 mg/L for a very long time (Ekubo and Abowei, 2011). DO is directly proportional to atmospheric pressure and has an inverse relationship with salinity, temperature, and microbial activities (Trick *et al.* 2018). High Biological and chemical demand with low DO of an aquatic system indicates polluted water (Ija *et al.* 2022). The average DO concentration observed in this study is considered suitable for the survival of aquatic species in water bodies (Weiner, 2008; Iwegbue *et al.* 2022). Biological oxygen demand (BOD) is a measure of the oxygen required by microorganisms for the decomposition of organic matter in the aqueous system (Aina, 2016). Natural water bodies with BOD < 5mg/L are considered unpolluted (Ioryue *et al.* 2018). The BOD measure in the study area infers unpolluted water. The levels of COD (Chemical Oxygen Demand) found in surface water sources generally vary, with concentrations typically falling below 20 mg/L in clean, uncontaminated waters and exceeding 200 mg/L in waters that receive discharge or effluents (Jain and Singh, 2003). COD values observed in this study exceeded 20 mg/L which indicates pollution.

The ranges provided for iron, copper, nickel, lead, zinc, chromium, cadmium, and manganese represent the concentrations of these heavy metals in the water. Elevated levels of heavy metals can have significant implications for water quality and the health of aquatic ecosystems. Iron, copper, lead, zinc, and cadmium are known to be toxic to aquatic organisms, even at low concentrations. These metals can accumulate in the tissues of organisms, causing various harmful effects such as impaired growth, reproduction, and metabolic functions. They can also disrupt the ecological balance within the river and adversely affect the food chain. Previous research by Smith *et al.* (2018) investigated iron levels in rivers and found similar ranges in different water bodies. They noted that elevated iron levels can affect water aesthetics, taste, and aquatic life. This aligns with the findings of the current study, suggesting that iron concentrations in the study area are within a typical range. Nduka and Orisakwe, (2011) reported similar copper concentrations in various river systems. They emphasized the potential toxicity of copper to aquatic organisms and the importance of monitoring its levels, especially in areas affected by industrial discharges or agricultural runoff.

Nickel and chromium are also heavy metals of concern due to their potential toxicity. Although the provided values for nickel and chromium were below the detection limit, it is important to note that some forms of these metals can be highly toxic to aquatic life and human health. Manganese, in moderate concentrations, is an essential micronutrient for organisms. However, elevated levels can have adverse effects, including neurological disorders in humans and toxicity to aquatic organisms. The average concentration of manganese falls within a range that requires careful monitoring to ensure it does not exceed acceptable limits. Nduka and Orisakwe, (2011) reported similar manganese concentrations in various water sources. They discussed the impacts of elevated manganese levels on water quality, taste, and human health.

The principal component analysis (PCA) results from the study identify potential sources affecting the water quality in the study area. Four principal components (PCs) were identified, which collectively explained 86% of the total variance in the dataset.

The strong positive loading of dissolved oxygen (DO), bicarbonate, chloride, and alkalinity in PC1 is consistent with reports by Hettige et al. (2022) in a study on the effect of dredging on water quality. According to Hettige et al. (2022) dissolved oxygen, turbidity, total suspended solids, calcium, chloride, alkalinity, orthophosphate, and nitrate–nitrogen increased after dredging. The strong loading of bicarbonates may be attributed to natural processes such as the weathering of rocks, atmospheric decomposition, and the decomposition of organic matter into inorganic carbon which alternatively results in bicarbonate ions (Fernandez et al. 2014; Olukemi et al. 2019; Omid et al. 2021). The strong negative correlation of turbidity and electrical conductivity with dissolved oxygen (DO) in Pearson correlation infers that turbidity and electrical conductivity contribute to the reduction in dissolved oxygen in the study area. The strong positive loading of biological oxygen demand and the moderate positive loading of chemical oxygen demand, and ammonia in PC1 indicates the presence of organic waste that may be attributed to anthropogenic activities such as waste from agricultural activities and the dump site close to the sampling stations. According to Dung et al. 2015; Hamed, (2019), the positive loading of biological oxygen demand, chemical oxygen demand, and ammonia may be attributed to domestic waste, industrial waste, or agricultural activities.

The strong positive loading of sulphate, total hardness, calcium, zinc, acidity, and moderate positive loading chemical oxygen demand (COD) observed in PC2 indicates a contribution from domestic waste and natural processes. According to Olukemi et al. (2019) positive loading of magnesium, calcium, sulphate may be due to lithogenic origin. The strong positive loading of manganese, and chloride and the moderate loading of temperature, nitrate, and pH in PC3 suggest influence from domestic waste.

The moderate loading of total suspended solids, sodium, chloride, and potassium in PC4 indicates the influence of surface runoff from farmland and the influence of dredging activities carried out in the study area.

The implications of the PCA results suggest the presence of organic pollution, water hardness, salinity, suspended solids, and metal contamination in the studied surface water. The eigenvalue % variance explained by the first two components (PC1 and PC2) indicates their significant contribution to the overall variability of the dataset. Sources of river pollution can include various anthropogenic activities such as agricultural runoff, improper waste disposal, and dredging activities. The results of the weight arithmetic index of Ethiope River, Delta State, Nigeria (Table 4.7) revealed WAQQI > 100 which is unsuitable for drinking (Table 4.4)

V. CONCLUSION

In this research, the physical and chemical attributes investigated generally fell within the acceptable thresholds set by the World Health Organization for drinking water quality, except for COD (Chemical Oxygen Demand), which showed elevated levels, signifying contamination of the aquatic ecosystem. The analysis of heavy metals demonstrated that lead and cadmium concentrations surpassed the acceptable limits established by the World Health Organization for drinking water quality. The findings from the Principal Component Analysis (PCA) unveiled that the primary sources of pollution affecting the Ethiope River encompass improper waste disposal, agricultural runoff, and dredging activities conducted in the river vicinity. Consequently, the water quality assessments indicate that the water is unsuitable for drinking purposes. Regular investigation of the surface water quality parameters by relevant agencies would be helpful to community dwellers that rely on the water for domestic use and consumption.

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