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ASSESSMENT OF PHYSICOCHEMICAL AND MICROBIOLOGICAL QUALITY OF RIVER ETHIOPE, NIGER DELTA, NIGERIA: IMPACTS OF OIL EXPLORATION AND ANTHROPOGENIC ACTIVITIES”

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ABSTRACT

Oil exploration and exploitation in Nigeria have a long history, yet they have left significant environmental footprints, impacting ecosystems and human health in affected regions. This study investigated the effects of petroleum exploration and production activities on the physicochemical and microbiological quality of the River Ethiope, Niger Delta, with the aim of characterizing its geochemistry and assessing water quality for human use. Thirteen water samples were collected from seven communities along the river (Sapele, Okpara, Igun, Abraka, Obiaruku, Ebedei, and Umutu/Umuaja) and analyzed for key parameters, including pH, conductivity, total dissolved solids (TDS), total hardness, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), sulphate, phosphate, nitrate, oil and grease, and coliform count. The results were compared with World Health Organization (WHO, 1993/1996) standards for drinking water. Most physicochemical parameters, including conductivity, TDS, hardness, salinity, calcium, magnesium, nitrate, phosphate, and BOD/COD values, fell within WHO permissible limits. However, deviations were observed in pH, turbidity, DO, oil and grease, and coliform counts, indicating contamination from oil spillage, gas flaring, and anthropogenic activities. Notably, the communities of Umutu/Umuaja, Obiaruku, and Sapele were more severely impacted. The study highlights that while portions of the River Ethiope remain suitable for irrigation and domestic use, the water is unsafe for direct consumption without treatment. It underscores the urgent need for effective environmental management, continuous monitoring, and public awareness campaigns targeting oil operators, transporters, and local communities. Regulatory enforcement, pollution mitigation, and reduced reliance on crude oil as a primary energy source are recommended to safeguard water quality and protect aquatic ecosystems.

KEYWORDS: River Ethiope, Water Quality, Physicochemical Parameters, Microbiological Contamination, Oil Exploration, Environmental Pollution.

INTRODUCTION

The Ethiope River, located in Delta State, Nigeria, is a unique and ecologically significant waterway celebrated for its exceptional purity and deep-rooted cultural heritage. Unlike many rivers in the Niger Delta that originate from swampy headwaters, the Ethiope River springs from the base of a giant cotton tree in Umuaja and flows through several oil-producing communities before emptying into the Benin River (Efe, 2010). However, this "natural wonder" is situated within the heart of the Niger Delta, one of the most prolific hydrocarbon basins in the world. The river serves as a primary source of water for domestic use, transportation, and traditional worship for the people of Umutu, Abraka, and Sapele, making its geochemical integrity a matter of both environmental and public health urgency.

For decades, petroleum exploration and production have been the backbone of the Nigerian economy. However, the lithological and hydrogeological characteristics of the Niger Delta make its surface waters particularly vulnerable to industrial pollutants. In the Lower Ethiope River region, the intensity of oil operations -ranging from seismic surveys and wellbore drilling to the transport of crude via aged pipeline networks-poses a continuous threat to the river's pristine geochemical balance. The geochemistry of a river system serves as a "health record" of its environment, reflecting the interaction between the underlying geology and the chemicals introduced by human activity.

The geochemical landscape of the Lower Ethiope is being increasingly altered by the introduction of Polycyclic Aromatic Hydrocarbons (PAHs) and heavy metals such as Lead (Pb), Cadmium (Cd), and Nickel (Ni) (Olobaniyi & Efe, 2007). These contaminants often enter the river system through oil spills, gas flaring precipitates, and the illegal discharge of "produced water" a mineral-rich, saline by-product of oil extraction. Once introduced, these elements can become sequestered in the river sediments, where they undergo various chemical transformations and may eventually enter the aquatic food chain through bioaccumulation in fish and benthic organisms (Nduka & Orisakwe, 2009).

Furthermore, the discharge of drilling muds and refinery effluents further alters the physicochemical properties of the water, such as pH, electrical conductivity, and dissolved oxygen levels. Despite the river's vital importance for domestic use, fishing, and tourism, there is a significant data gap regarding the long-term cumulative impact of the surrounding oil industry on the specific geochemical facies of the Lower Ethiope.

This study, therefore, aims to assess the physicochemical and microbiological quality of the River Ethiope to evaluate the impact of oil exploration and production activities on its geochemistry. By analyzing water samples from key communities along the river and comparing the results with the World Health Organization (WHO, 1993/1996) standards for drinking water, this research seeks to quantify the environmental and anthropogenic pressures exerted by petroleum operations. Understanding these impacts is crucial for informing effective pollution mitigation strategies, safeguarding aquatic ecosystems, and protecting the water resources of one of Delta State's most important and sensitive rivers.

2.0 MATERIALS AND METHODS

2.1 STUDY AREA

2.2.1 Tectonics

The tectonic framework of the continental margin along the West Coast of equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic. The fracture zone ridges sub-divide the margin into individual basins, and, in Nigeria, form the boundary faults of the Cretaceous Benue-Abakaliki trough, which cuts far into the West African shield. The trough represents a failed arm of a rift triple junction associated with the opening of the South Atlantic. In this region, rifting started in the Late Jurassic and persisted into the Middle Cretaceous (Lehner and De Ruiter, 1977). In the region of the Niger Delta, rifting diminished altogether in the Late Cretaceous.

After rifting ceased, gravity tectonism became the primary deformational process. Shale mobility induced internal deformation and occurred in response to two processes (Kulke, 1995). First, shale diapirs formed from loading of poorly compacted, over-pressured, prodelta and delta-slope clays (Akata Fm.) by the higher density delta-front sands (Agbada Fm.). Second, slope instability occurred due to a lack of lateral, basin ward, support for the under-compacted delta-slope clays (Akata Fm.)

2.2.2 DEPOBELTS

Deposition of the three formations occurred in each of the five offlapping siliciclastic sedimentation cycles that comprise the Niger Delta. These cycles (depobelts) are 30-60 kilometres wide, prograde southwestward 250 kilometres over oceanic crust into the Gulf of Guinea (Stacher, 1995). The interplay of subsidence and supply rates resulted in deposition of discrete depobelts--when further crustal and are defined by synsedimentary faulting that occurred in response to variable rates of subsidence and sediment supply (Doust and Omatsola, 1990).

Five major depobelts are generally recognized, each with its own sedimentation, deformation, and petroleum history. Doust and Omatsola (1990) describe three depobelt provinces based on structure.

-The northern delta province, which overlies relatively shallow basement, has the oldest growth faults.

-The central delta province has depobelts with well-defined structures such as successively deeper rollover crests that shift seaward for any given growth fault.

-The distal delta province is the most structurally complex.

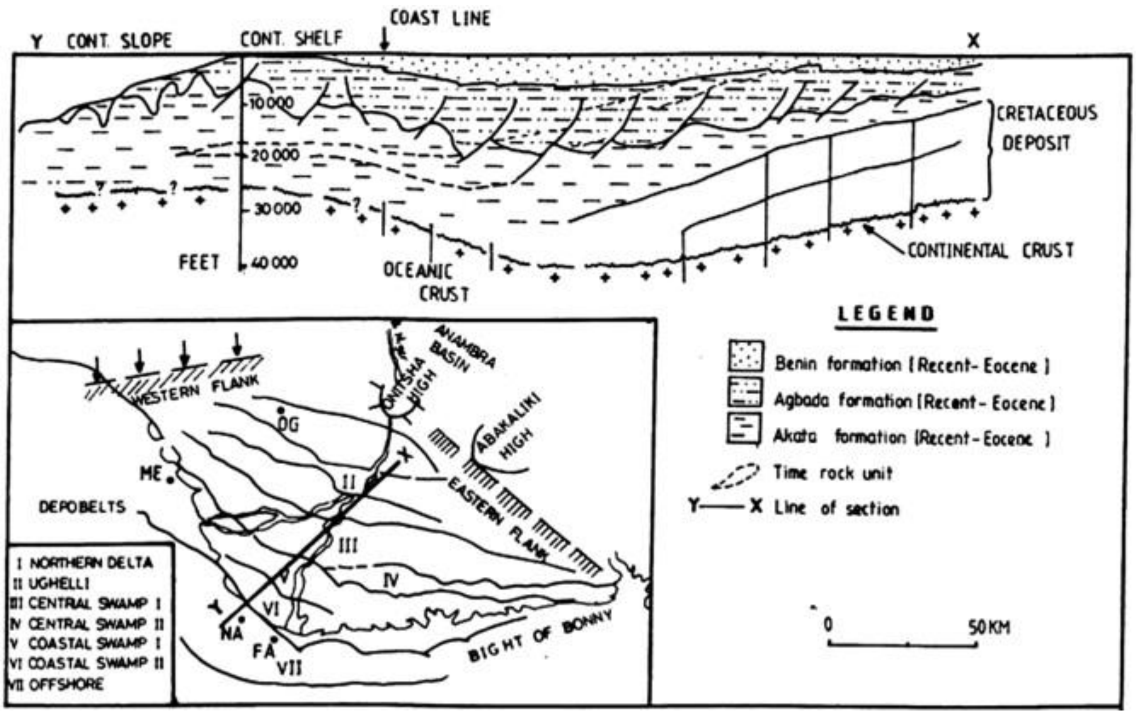

Figure 1: Depobelts in Niger delta.

2.2.3 STRATIGRAPHY

Short and Stauble recognized three subsurface stratigraphic unit in the Niger delta-Benin, Agbada and Akata.

THE BENIN FORMATION

The top most Benin formation extends from the West across the whole Niger delta region and southward beyond the coastline.

It is over 90% sandstone with shale intercalations. It is coarse grained, gravelly, locally fine grained, poorly sorted, sub angular to well-rounded with lignite streaks and wood fragments. It ranges from Miocene-Recent. The thickness is variable but exceeds 6000ft. and is a continental deposit of probable upper deltaic depositional environment.

Very little hydrocarbon accumulations have been associated with this formation.

AGBADA FORMATION

The underlying Agbada formation consists of an upper predominantly sandy unit with minor shale intercalations and lower shale which is thicker than the upper sandy unit. The formation is rich in microfauna at the base decreasing upward and thus indicating an increased rate of deposition in the delta front. A fluviatile origin is indicated by the coarseness of the grains and poor sorting.

The Agbada Formation occurs in the subsurface of the entire delta and may be continuous with the Ogwashi Asaba and Ameki formations of Eocene-Oligocene age. It is over 1000ft thick and ranges from Eocene in the north to Pliocene/Pleistocene in the south and recent in the surface. Major hydrocarbon accumulations are found in the Agbada formation.

AKATA FORMATION

The lowermost Akata Formation is a uniform shale development consisting of dark grey, sandy silty shale with plant remains at the top. Thin sandstone lenses occur near the top particularly near the contact with the overlying Agbada formation.

Planktonic foraminifera may account for over 50% of the rich microfauna and the benthonic assemblage indicates shallow marine shelf depositional environment. It is over 4000ft and ranges from Eocene to Recent.

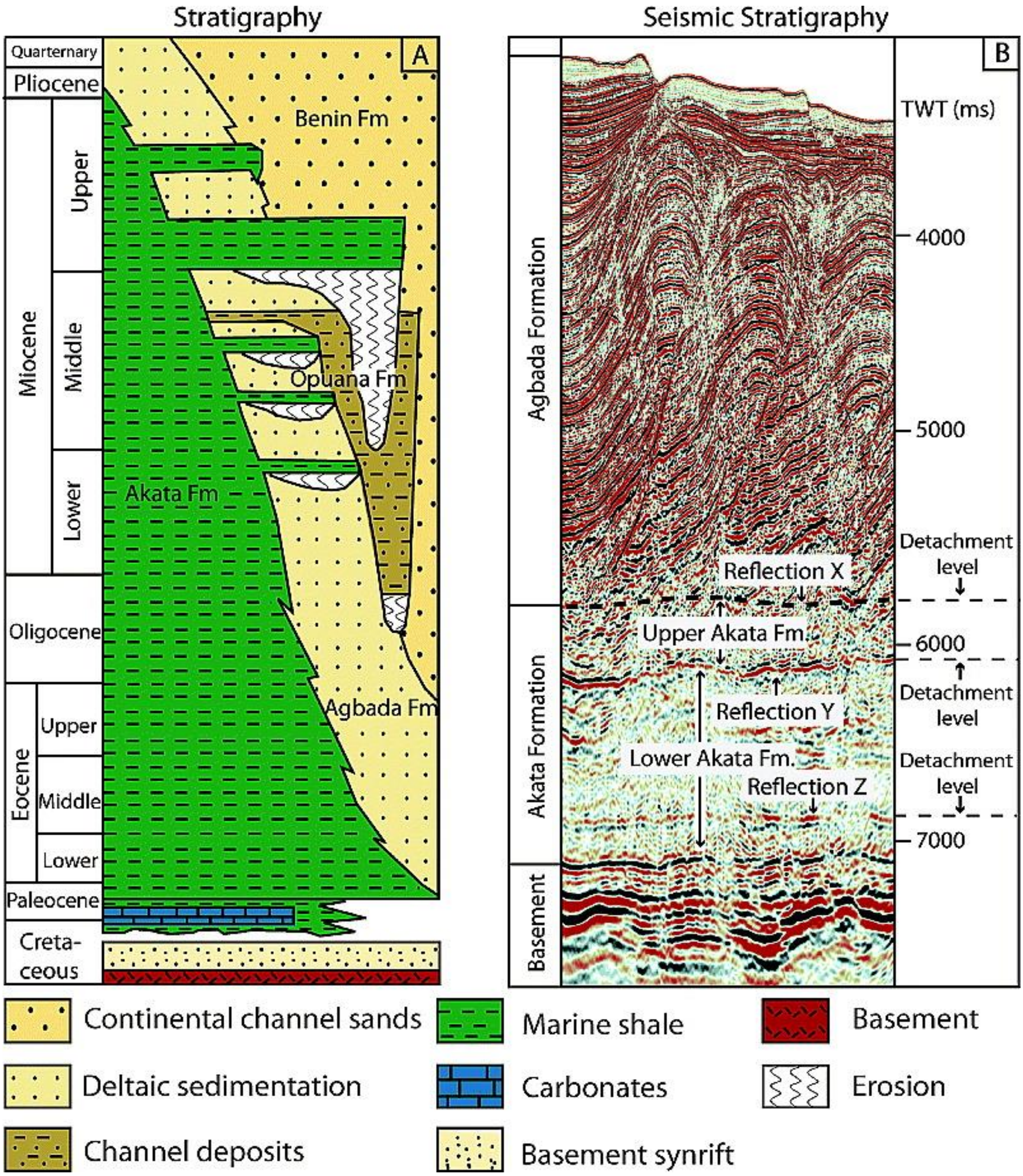

Figure 2: Stratigraphic sequence of the Niger delta

2.2.4 Geology of study area

The sedimentary environments and morphological features of the Niger Delta have been described by (Short and Stauble, 1967; Allen, 1964, 1965, 1967; Oomkens, 1974; Durotoye, 1989; Odemerho and Ejemeyovwi (2007). Specifically, the study area is underlain by the deposits of the modern and Holocene delta top deposits that result in the various physiographic landforms described in the foregoing. The aerial distribution of the deposits thus coincides with the physiographic subdivisions and Short and Stauble's (1967, pp. 766) depositional environments. The combined Ase River/River Niger flood plain is the Freshwater Swamps, the north central plain is the Sombreiro-Warri Deltaic Plain, and both of which contain deposits that conformably overlie and mask the Benin Formation whose outcrop forms the undulating hills in the north and north east. The deposits of the Freshwater Swamps and the Sombreiro-Warri Deltaic Plain are universally considered to be recent expressions of a continuation of the Benin Formation. They result from the sediment laden discharges of the River Niger that is spread on the delta by its various tributaries. The sediment is generally a mixture of medium to coarse-grained sands, sandy clays, silts and clays that eventually settle in fluvial/tidal channel, tidal flat and mangrove swamp environments, a process that has been ongoing since the late Quaternary and is related to interglacial marine transgressions (Allen, 1964, Oomkens, 1974, Durotoye, 1989). The described deposits are exploited for glass sands and quarried extensively for building purposes (Bam, 2007; Akpokodje and Etu-Efeotor, 1987; Ministry of Commerce and Industry, 2001; Atakpo and Akpoborie, 2011). Together, the deposits also constitute the shallow aquifer that is exploited by shallow (<30m) boreholes and dug wells that serve as the primary water supply source for rural as well as many semi-urban and urban communities in the study area and in the Niger Delta region in general (Amajor, 1991). The Benin Formation, the youngest of the three important formations that constitute the sedimentary fill of the Niger Delta Basin is usually described as consisting of massive continental/fluvial sands and gravels. The older formations, which are encountered only in the subsurface in the study area are the Agbada Formation of paralic sands and shales and the basal Akata Formation, which consists of holomarine shales, silts and clays. The lateral equivalents at the surface are the Ogwashi-Asaba Formation and Ameki Formation of Eocene - Oligocene age (Short and Stauble, 1967; Asseez, 1989).

2.2.5 Relief and Drainage

The study area is a low-lying plain underlain by recent unconsolidated Quaternary sediments of both marine and fluvial origin. Land elevation generally remains below 50 m above mean sea level, with no prominent hills, giving the area a relatively flat relief. Numerous flat-floored rivers traverse the region and drain southwards into the Atlantic Ocean. Drainage is dominated by the River Niger, which drains the eastern part of the state and empties into the sea through major distributaries such as the Forcados, Escravos, and Warri rivers, as well as associated creeks including the Bomadi Creek. Rivers Jamieson and Ethiope originate from the northeastern part of the area and flow westwards into the sea. The River Ethiope rises from a spring at Umuaja and flows for over 100 km before discharging into the Benin River. It serves as the main outlet for storm runoff in the area and is an important resource for surrounding communities, supporting domestic water supply, fishing, sand mining, and inter-village transportation.

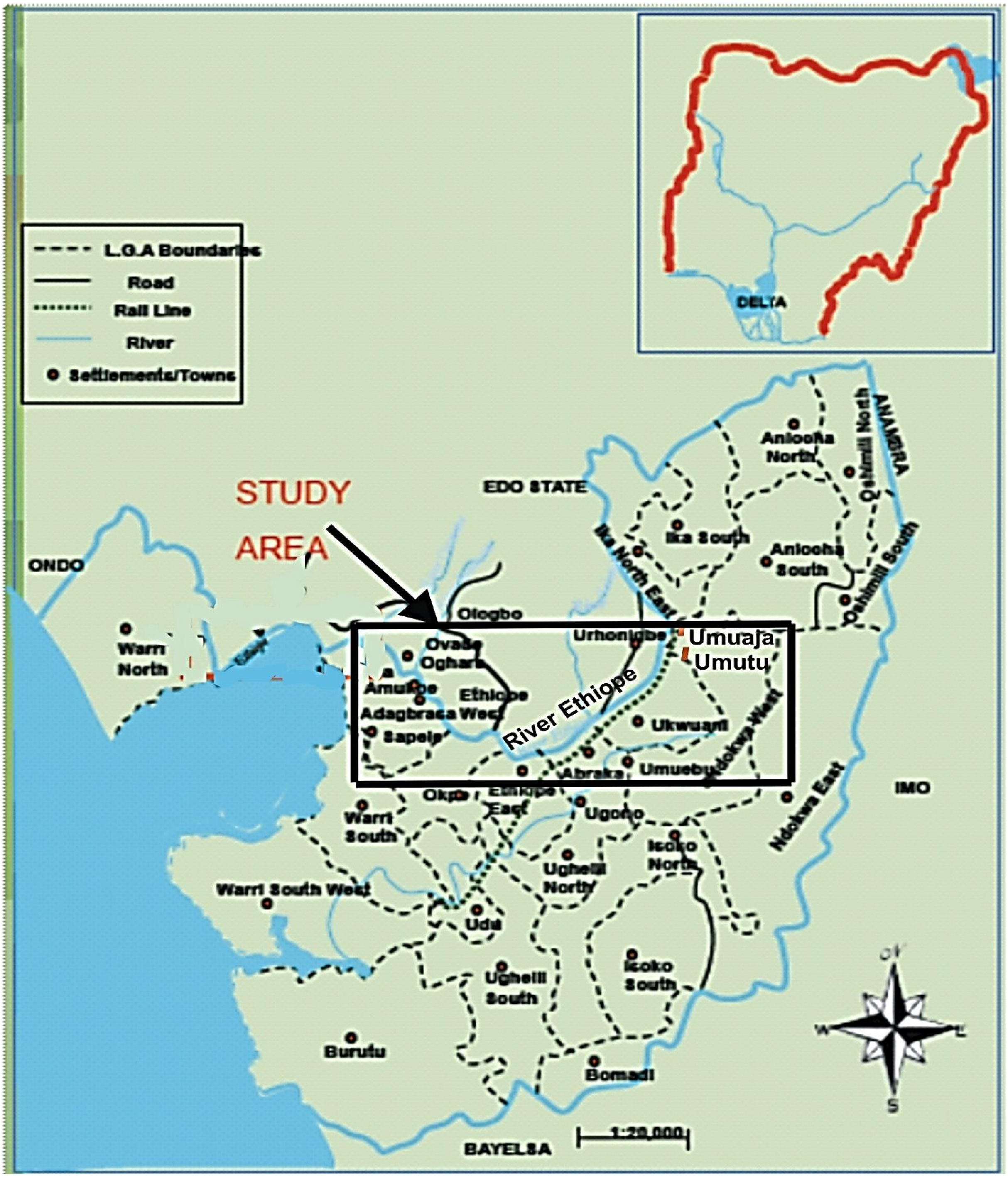

Figure 3: Map of Delta State showing study area. (Inset: Map of Nigeria showing Delta State).

2.3 RESEARCH METHODOLOGY

2.3.1 Field procedures

The success of the research procedure is anchored to various activities that were embarked upon. In order to have an overview and thorough understanding of the research topic, related literatures were reviewed. This in a way broadened my scope on the research topic and gave me an insight to the likely challenges to be encountered.

After this was done, a field journey was embarked upon with the aim of collecting water samples. The samples were collected at different locations in order to depict to a level of fairness the geochemistry of the Ethiope River.

The samples were collected with the aid of plastic bottles (2 litres) from the surface of the River. After this was done, the bottle was capped and a brief description of the sampling point and identification details was attached to the sampling can.

The collected samples were thus preserved and taken to a laboratory where some series of chemical analysis was carried out on it. The results of the analysis were then used to depict the geochemistry of the river. The impacts of petroleum exploration and production activities were then drawn from the laboratory result.

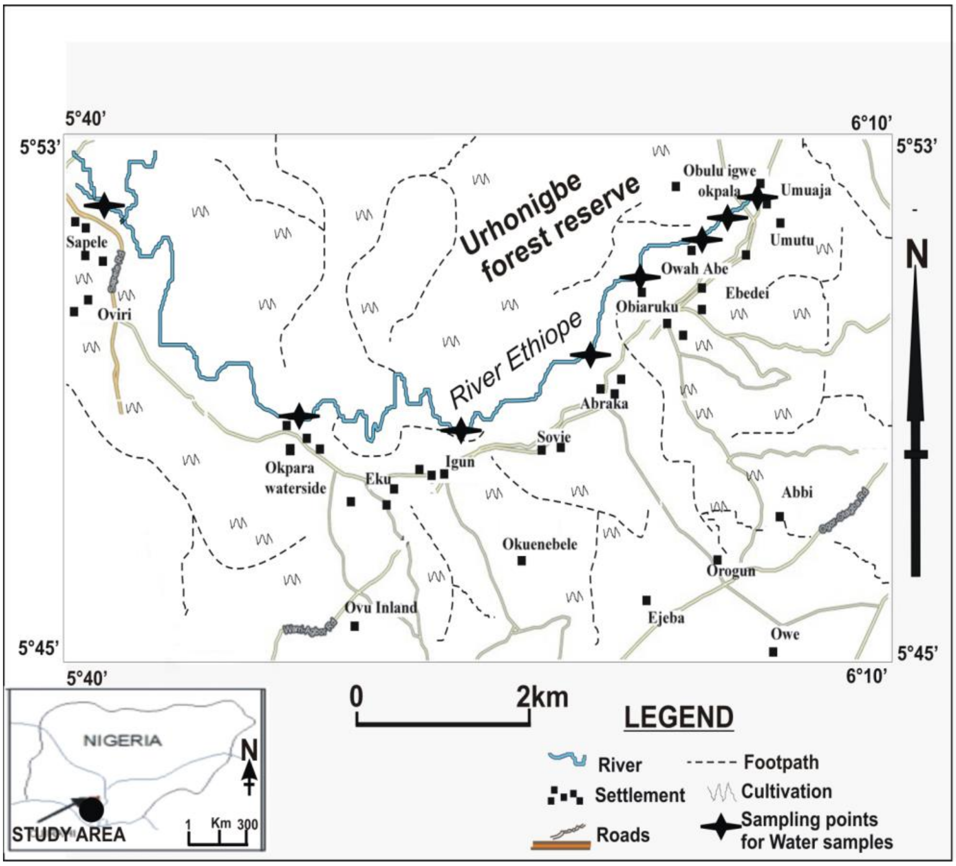

Figure 4: Map of study area showing sampling points.

2.3.1 Sampling Materials

Equipments (materials) that were used during the collection of samples include:

1. **Sampling Bottles**: Plastic bottles (2 litres) were used for the collection of the water samples.
2. **Global Positioning System (G.P.S):** This was used for taking the geographical coordinate of the location from which a sample was taken. It was also helpful in locating oneself in the field.
3. **Cutlass:** This was used for clearing bush paths as the need may arise.
4. **Field Note**: This was used for record keeping. The various locations and G.P.S readings of the area were noted.
5. **Marker and cellotape**: These were used for sample identification. Each sample was given a label in order to differentiate it from the other with the aid of the marker and cellotape.

2.3.2 Sampling Method

Water samples were collected at various communities associated with the Ethiope River. Samples were collected from different locations so as to depict the geochemistry of the Ethiope River to a fair level of accuracy.

The water samples were collected from the surface of the River with the aid of plastic bottles. However, the bottles were rinsed about two or three times with the water to be sampled before the actual collection. After the sample was collected, the bottle was covered air tight and properly labelled.

Two water samples were collected at each location; one of which intended as control measure during the laboratory analyses.

2.3.3 Sample preservation and storage

Plastic bottles (2 litres each) were used to collect the water samples. After this was done, they were then stored in ice packed coolers of which few drops of HCl acid was later added. By doing this, the water sample becomes a little acidic thus preventing microbial reaction in the water.

2.3.4 Laboratory Analysis

The following parameters were determined, TDS, TSS, pH, BOD, COD, DO conductivity, coliform count, total hardness, salinity, oil and grease, turbidity, ammonia, phosphate, anions ($SO4^{2-}$, $NO^{2-}{}_{3)}$ and cations (Ca^{2+}, Mg^{2+}).

The analytical procedures for the physicochemical parameters were done in accordance with the specification of the American Public Health Association (APHA) Standards 1992.

3.0 RESULT

Table 1: Showing the result of the analysed water samples in the study area.

Locations	**Sapele**		**Okpara W/S**		**Igun**		**Abraka**		**Obiaruku**		**Ebedei**	**Umutu/Umuaja**	
Parameters	A	B	C	D	E	F	G	H	I	J	K	L	M
Conductivity us/cm	40.50±0.40	39.3±0.65	38.40±0.30	37.80±0.5	39.80±0.40	40.90±0.40	38.85±0.50	38.75±0.40	39.40±0.40	39.30±0.30	40.70±0.30	40.50±0.50	41.10±0.50
Ph	5.2±0.2	6.3±0.8	5.7±0.4	5.55±0.6	6.4±0.5	5.15±0.17	5.4±0.5	6.1±0.7	5.9±0.6	5.3±0.80	5.60±0.30	5.40±0.50	6.40±0.20
Total hardness mg/l	10.00±0.40	8.00±0.50	5.00±0.40	12.00±0.60	14.00±0.50	11.00±0.30	6.0±0.40	7.00±0.50	8.00±0.50	5.00±0.50	4.00±0.60	10.00±0.20	7.00±0.30
TDS mg/l	28.10±0.50	27.80±0.50	24.60±0.50	25.20±0.40	28.30±0.60	27.50±0.50	27.20±0.40	28.05±0.50	27.90±0.30	28.10±0.50	26.90±0.60	27.40±0.60	28.04±0.40
Turbidity NTU	24.00±1.20	14.00±0.80	6.50±0.40	6.20±0.90	4.00±0.80	12.00±0.90	4.20±0.80	10.00±0.60	4.80±0.50	5.20±0.80	7.20±0.60	16.40±0.40	6.40±0.60
Oil and grease mg/l	12.50±0.80	6.70±0.70	4.70±0.20	4.30±0.40	7.20±1.00	11.70±0.60	5.40±0.60	4.20±0.50	8.30±0.80	6.30±0.30	17.70±0.70	14.20±0.60	8.80±1.20
DO mg/l	5.60±0.12	6.70±0.03	5.25±0.70	5.80±0.80	3.70±0.50	3.78±1.10	6.20±0.40	5.90±0.25	5.80±0.60	6.10±0.50	5.20±0.70	4.60±0.40	3.20±0.20
BOD mg/l	4.10±0.70	5.40±0.90	4.40±0.70	5.30±0.50	3.70±0.80	2.80±0.2	4.50±0.40	5.20±0.50	6.60±0.80	4.90±0.60	5.30±0.70	2.30±0.20	3.20±0.20
COD mg/l	6.40±0.30	5.10±0.20	3.50±0.40	2.90±0.20	3.20±0.20	2.20±0.10	3.70±0.20	3.20±0.25	2.80±0.10	2.40±0.30	1.70±0.10	1.30±0.20	1.50±0.15
Coliform count Coliforms/10	454±25	120±14	340±22	850±60	762±56	605±32	258±17	187±11	65±5.4	145±13	80±15	47±8.8	89±4.9

0cm^3													
Calcium mg/l	4.40±0.16	3.00±0.10	3.20±0.05	2.70±0.20	3.10±0.15	3.00±0.70	4.40±0.90	4.70±0.50	5.10±0.50	4.30±0.40	4.80±0.30	2.61±0.20	2.34±0.30
Magnesium Mg/l	2.00±0.1	3.80±0.1	1.80±0.1	2.30±0.2	1.40±0.1	1.70±0.2	2.15±0.2	1.75±0.2	1.82±0.1	2.20±0.1	1.90±0.2	1.60±0.1	1.85±0.1
Ammonia Mg/l	0.13±0.03	0.02±0.05	0.10±0.05	0.11±0.07	0.20±0.04	0.15±0.02	0.20±0.02	0.16±0.01	0.20±0.02	0.18±0.01	0.14±0.01	0.12±0.01	0.12±0.01
Sulphate Mg/l	6.72±1.20	9.50±0.80	5.20±0.60	4.30±0.40	3.60±0.40	5.70±0.50	7.6±0.3	8.90±0.75	26.80±1.40	22.40±1.12	16.45±1.30	15.80±1.00	20.40±1.50
Phosphate Mg/l	0.07±0.1	0.06±0.001	0.05±0.001	0.03±0.001	0.04±0.001	0.04±0.001	0.03±0.001	0.07±0.001	0.05±0.001	0.08±0.001	0.04±0.001	0.06±0.001	0.06±0.001
Salinity Mg/l	0.70±0.2	0.90±0.1	0.83±0.1	0.78±0.1	0.65±0.4	0.80±0.3	0.90±0.5	0.70±0.2	0.80±0.2	0.70±0.2	0.75±0.2	0.88±0.2	0.60±0.1
Nitrate Mg/l	<0.01	0.02	<0.01	0.02	0.03	0.02	<0.01	0.02	0.02	0.03	0.03	0.01	0.01

Table 2: Mean Concentration of the physiochemical parameters in the study area.

Location	**Sapele**	**Okpara**	**Igun**	**Abraka**	**Obiaruku**	**Ebedei**	**Umutu/ Umuaja**
PARAMETER							
Conductivity us/cm	39.90	38.10	40.35	38.80	39.30	40.70	40.80
Ph	5.75	5.63	5.77	5.75	5.60	5.60	5.9
Total hardness (mg/l)	9.00	8.50	12.5	6.5	6.5	4.0	8.5
TDS (mg/l)	27.95	24.9	27.90	27.63	28.00	26.90	27.72
TSS (mg/l)	12..42	13.33	12.67	12.77	13.95	13.24	13.8
Turbidity, (NTU)	19.00	6.35	8.00	7.10	5.00	7.20	11.4
Oil and grease, (mg/l)	9.6	4.5	9.45	4.80	7.30	17.70	11.5
DO (mg/l)	6.15	5.53	3.74	6.05	5.95	5.2	3.9
BOD (mg/l)	4.75	4.85	3.25	4.85	5.75	5.30	2.75
COD (mg/l)	5.75	3.2	2.70	3.45	2.6	1.7	1.4
Coliform (count coliforms/100	287	595	683.50	222.50	105	80	68

cm^3)							
Calcium (mg/l)	3.70	2.95	3.05	4.55	4.20	4.80	2.48
Magnesium (mg/l)	2.90	2.05	1.55	1.95	2.01	1.90	1.73
Ammonia (mg/l)	0.075	0.11	0.18	0.18	0.19	0.14	0.12
Sulphate (mg/l)	8.11	4.75	4.65	8.25	24.6	16.45	18.10
Phosphate (mg/l)	0.07	0.04	0.04	0.05	0.07	0.04	0.06
Salinity (mg/l)	0.80	0.79	0.73	0.80	0.75	0.75	0.74
Nitrate (mg/l)	<0.02	<0.02	0.03	<0.02	0.03	0.03	0.01

Table 3: Comparison of the analysed water samples with the World Health Organization (WHO) standard for drinking water (1993/1996).

Location / Parameter	**Sapele**	**Okpara**	**Igun**	**Abraka**	**Obiaruku**	**Ebedei**	**Umutu/Umuaja**	**WHO Standard (1993/1996)**	**Inference**
Conductivity	9.02	8.93	9.00	8.90	9.40	8.80	8.3	250-1500	Meets standard
Ph	5.75	5.63	5.77	5.75	5.60	5.60	5.9	6.5-8.5	Below standard
Total hardness Mg/l	9.00	8.50	12.5	6.5	6.5	4.0	8.5	500	Meets standard
TDS Mg/l	312.50	282.50	309.00	135.00	214.00	116.00	419.50	1000	Meets standard
TSS Mg/l	12.42	13.33	12.67	12.77	13.95	13.24	13.8	NA	
Turbidity NTU	19.00	6.35	8.00	7.10	5.00	7.20	11.4	5	Most values exceed standard
Oil and grease Mg/l	9.6	4.5	9.45	4.80	7.30	17.70	11.5	NA	
DO Mg/l	6.15	5.53	3.74	6.05	5.95	5.2	3.9	5	Most values exceed

									standard
BOD Mg/l	4.75	4.85	3.25	4.85	5.75	5.30	2.75	10	Meets standard
COD Mg/l	5.75	3.2	2.70	3.45	2.6	1.7	1.4	10	Meets standard
Calcium Mg/l	3.70	2.95	3.05	4.55	4.20	4.80	2.48	75-200	Meets standard
Coliform (count coliform/100cm^3)	287	595	683.50	222.50	105.00	80	68	Nil	
Magnesium Mg/l	2.90	2.05	1.55	1.95	2.01	1.90	1.73	50-150	Meets standard
Ammonia Mg/l	0.075	0.11	0.18	0.18	0.19	0.14	0.12	NA	
Sulphate Mg/l	8.11	4.75	4.65	8.25	24.60	16.45	18.10	200-400	Meets standard
Phosphate Mg/l	0.07	0.04	0.04	0.05	0.07	0.04	0.06	10	Meets standard
Salinity Mg/l	0.80	0.79	0.73	0.80	0.75	0.75	0.74	200-600	Meets standard
Nitrate Mg/l	<0.02	<0.02	0.03	<0.02	0.03	0.03	0.01	10	Meets standard

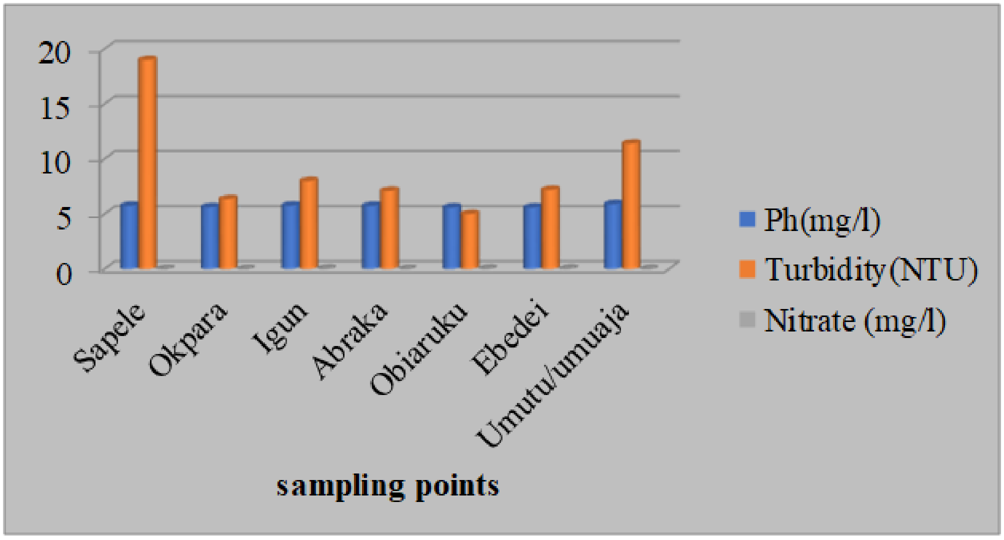

Figure 5: pH, turbidity and Nitrate concentration in the study area.

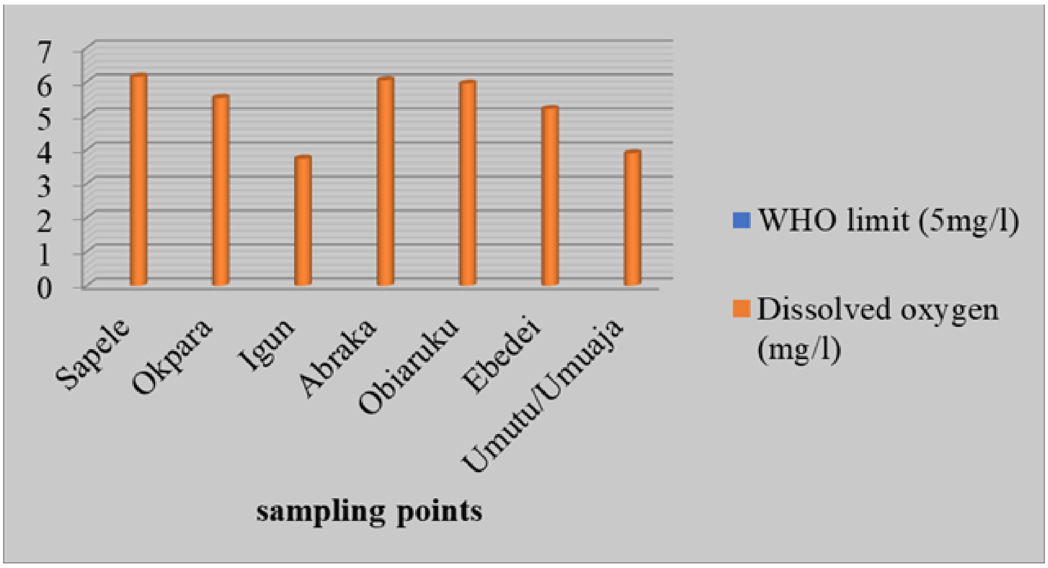

Figure 6: Comparing Dissolved oxygen in the study area with WHO standard for Drinking Water (1993/1996).

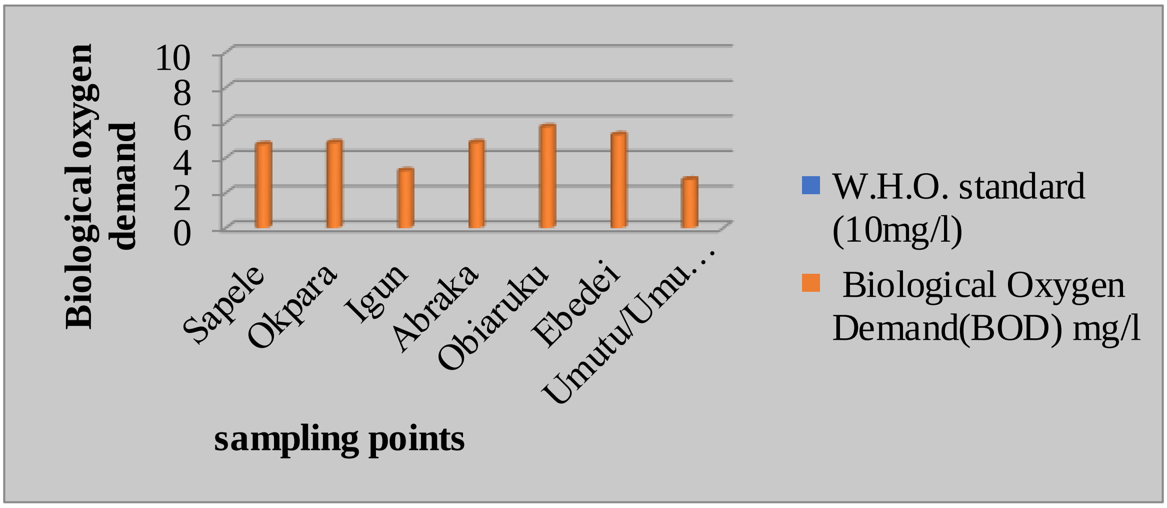

Figure 7: Comparing BOD concentration in study area with WHO standard for Drinking water (1993/1996).

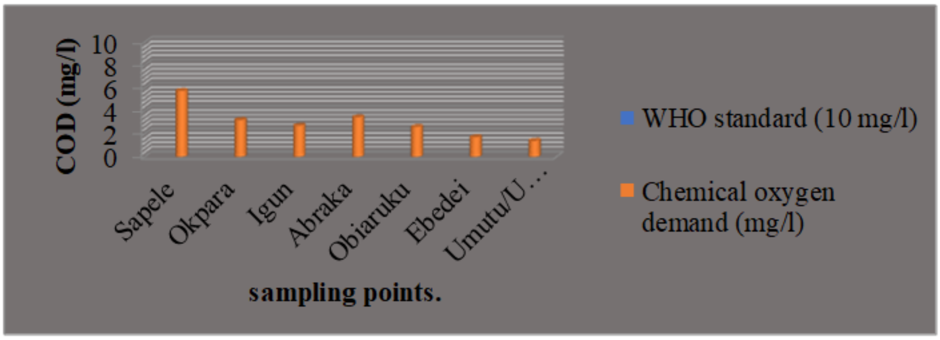

Figure 8; Comparing COD concentration in study area with WHO standard for Drinking water. (1993/1996)

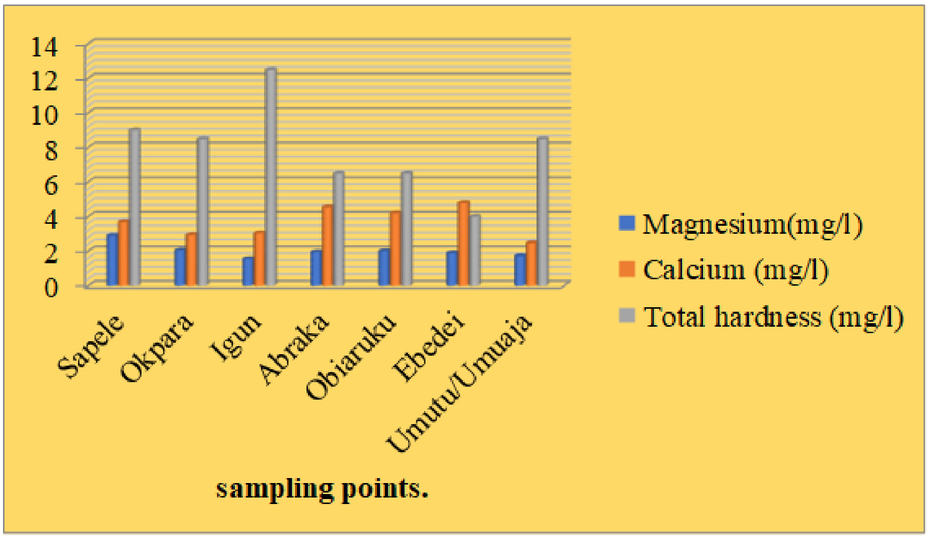

Figure 9: Magnesium, calcium and total hardness concentration in the study area.

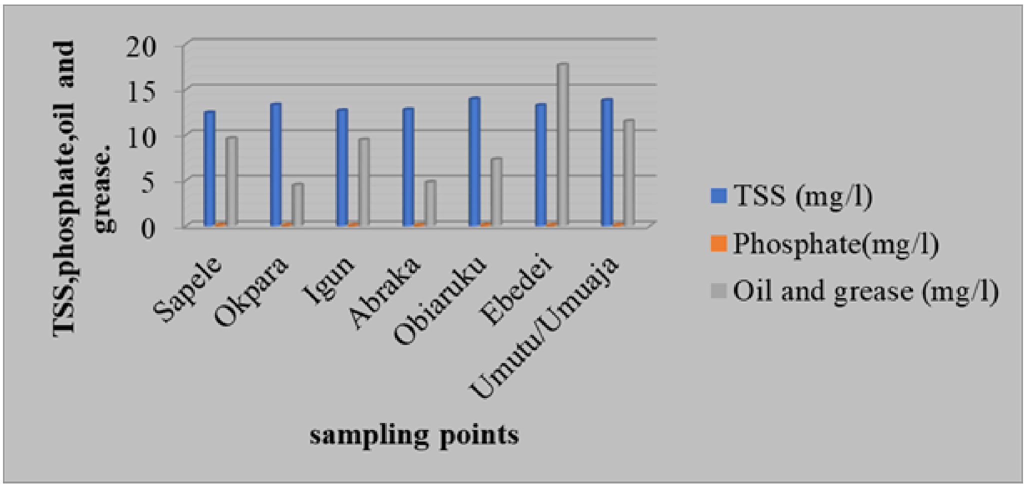

Figure 10: TSS, oil and grease and phosphate concentration in the study area.

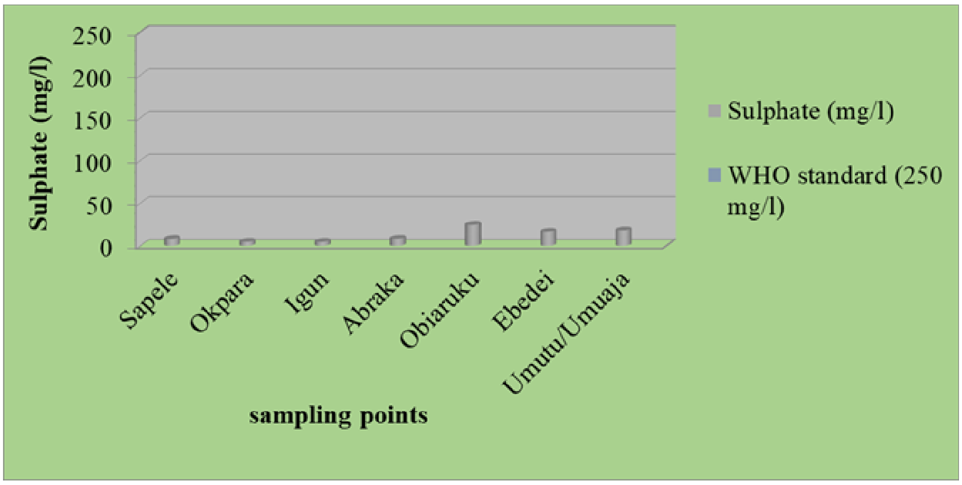

Figure 11: Comparing Sulphate concentration in the study area with WHO standard for Drinking water (1993/1996).

4.0 DISCUSSION

From Table 3 above, all the parameters except pH, turbidity, Dissolved Oxygen (DO), and **coliform count** meet the WHO standard for drinking water. This observation supports earlier findings by **Nwankwo & Ifeadi (1988)**, who noted that although oil-producing environments are impacted by petroleum activities, not all physicochemical parameters exceed international standards simultaneously, especially in river systems with high dilution capacity.

The conductivity, salinity, and ammonia concentration meet the WHO standards for drinking water. The low salinity values (<1) indicate freshwater conditions. This is consistent with reports by **Nwokoma & Dagde (2024)**, who found that Niger Delta oilfield waters generally retain freshwater characteristics despite prolonged oil exploration activities Science Publishing Group. The ammonia concentration is negligible and may be attributed to the dumping of human or animal waste in very small quantities, in agreement with **Angaye et al. (2017)**, who reported that household solid waste contributes marginally to nutrient loading in Niger Delta communities Science Publishing Group.

The nitrate content of the water meets the WHO standard for drinking water. Nitrate in water usually originates from fertilizers or animal/human waste. However, the bar plot indicates that agricultural wastes are disposed into the river in very minute quantities. This finding aligns with **Nwankwo & Ifeadi (1988)**, who observed that nutrient enrichment in Niger Delta surface waters is more strongly influenced by domestic and industrial activities than by intensive agricultural practices.

The pH values (5.75–5.9) fall below the WHO standard for drinking water (6.5–8.5), indicating slightly acidic conditions. This acidity may have originated from gas flaring by oil firms in the study area. When sulphur dioxide (SO_2) from gas flaring ascends into the atmosphere, it may return to the earth as acid rain. Similar acidic conditions associated with oil exploitation and gas flaring have been documented by **Amadi (2014)** and **Adeoye (2022)**, who reported that gas flaring significantly lowers the pH of rainwater and surface waters in the Niger Delta ResearchGate Science and Education Publishing. The acidic nature of the water suggests that acidic wastes are sometimes discharged into the River Ethiope, making the water unsuitable for direct drinking and potentially affecting aquatic organisms.

Turbidity values (5.00–19.00 NTU) indicate polluted and unclear water. Elevated turbidity has been identified by **Nwankwo & Ifeadi (1988)** as a key pollution indicator in oil-producing areas, often resulting from drilling muds, cuttings, suspended solids, and surface runoff. High turbidity reduces light penetration and can act as a carrier for hydrocarbons and pathogenic microorganisms, thereby compounding water quality deterioration.

The Dissolved Oxygen (DO) values show that some locations fall below the WHO recommended minimum of 5 mg/L. Low DO values observed in Igun (3.74 mg/L) and Umutu/Umuaja (3.9 mg/L) may be attributed to continuous oil spillage in the area. Oil films on the water surface inhibit oxygen diffusion into the water, as earlier reported by **Amadi (2014)** Science and Education Publishing. Such conditions stress aquatic organisms and may force their migration to better-oxygenated portions of the river.

Although Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values meet WHO standards, relatively higher BOD values in Sapele, Okpara, Abraka, Obiaruku, and Ebedei indicate increased organic pollution in these areas. According to **Nwankwo & Ifeadi (1988)**, elevated BOD and COD values in Niger Delta waters are often linked to oil residues and organic wastes, confirming the influence of anthropogenic activities on water quality.

Calcium, magnesium, and total hardness values fall within WHO limits, confirming that the River Ethiope is characterized by soft water. This observation agrees with earlier studies in the Niger Delta, which reported generally low hardness due to unconsolidated sediments and minimal carbonate mineral contribution (**Nwankwo & Ifeadi, 1988**).

The coliform count recorded across all sampling locations far exceeds the WHO recommended limit of zero coliform per 100 cm³, indicating significant bacteriological contamination of the river water. The presence of coliform bacteria suggests contamination from human and animal faecal matter, likely resulting from improper sewage disposal, open defecation, and runoff from nearby settlements. This finding is consistent with **Angaye et al. (2017)**, who reported widespread domestic waste pollution in Niger Delta communities Science Publishing Group. High coliform counts pose serious public health risks, including the transmission of water-borne diseases such as cholera, typhoid, and dysentery, thereby rendering the water unsafe for direct consumption without adequate treatment.

Sulphate, phosphate, and total suspended solids (TSS) generally fall within acceptable limits. However, WHO has no specified guideline for oil and grease. Elevated oil and grease concentrations in Ebedei, Umutu/Umuaja, and Sapele indicate oil waste disposal and spillage in these areas, corroborating earlier reports by **Adeoye (2022)** and **Amadi (2014)** ResearchGate Science and Education Publishing. Sulphate concentrations were relatively higher in Obiaruku, Umutu/Umuaja, Ebedei, Sapele, and Abraka, suggesting more intense gas flaring activities. Phosphate concentrations were negligible (<1 mg/L), indicating minimal nutrient enrichment. Total dissolved solids (TDS) were higher in Umutu/Umuaja, Sapele, and Igun, suggesting greater accumulation of dissolved materials associated with oil-related activities.

5.0 CONCLUSION

This study assessed the physicochemical and bacteriological quality of surface water from selected locations along the River Ethiope and compared the results with World Health Organization (WHO, 1993/1996) drinking water standards. The findings reveal that most physicochemical parameters, including conductivity, total dissolved solids, salinity, total hardness, calcium, magnesium, sulphate, phosphate, nitrate, biochemical oxygen demand (BOD), and chemical oxygen demand (COD), fall within permissible limits, indicating that the river water is generally fresh, soft, and weakly mineralized.

However, deviations from WHO standards were observed in pH, turbidity, dissolved oxygen (DO), and coliform count. The slightly acidic nature of the water suggests the influence of gas flaring, acid rain, and intermittent discharge of acidic wastes associated with oil exploration activities in the study area. Elevated turbidity values indicate the presence of suspended solids and pollutants, likely arising from drilling activities, surface runoff, and improper waste disposal. Low dissolved oxygen levels in some locations reflect organic pollution and oil contamination, which can impair oxygen diffusion and negatively affect aquatic life.

Of particular concern is the high coliform count recorded across all sampling locations, which far exceeds the WHO guideline of zero coliform per 100 cm^3. This indicates significant faecal contamination and poses serious public health risks, rendering the river water unsafe for direct human consumption without adequate treatment. The presence of oil and grease in several locations further confirms the influence of oil spillage and petroleum-related activities on water quality.

Overall, although the River Ethiope water may be suitable for irrigation, recreation, and some domestic uses, it is not fit for drinking without proper treatment. The study highlights the cumulative impacts of oil exploration activities, domestic waste disposal, and poor environmental management practices on surface water quality in the Niger Delta. Continuous monitoring, strict regulation of oil industry operations, improved waste management, and provision of potable water supply are therefore recommended to safeguard public health and protect the aquatic ecosystem.

5.2 Recommendation

The following recommendations are proffered in order to reduce the pollution and ensure that the River meets certain acceptable standards

1) **Education**

Making people aware of a problem is the first step to solving it. The Federal Ministry of Environment and Department of Petroleum Resources should formally enlighten oil companies and tank drivers on why they should embrace caution and safety in order to avoid/ reduce pollution. This can be further enhanced by constant advertisement on media and organising seminars. Continued reminder on the need to maintain balance in nature is very essential.

2) Imposing fines on defaulters

Most environmental experts agree that the best way to tackle pollution is through something called the polluter pay principle. This means that whoever causes pollution should have to pay to clean it up, one way or another. Polluter pay principle can operate in all kinds of ways. It could mean that tanker owners should have to take out insurance that covers the cost of oil spill clean -ups. It could mean that factories that use rivers must have their water inlet pipes downstream of their effluent outflow pipes, so that if they cause pollution, they themselves are the first people to suffer. Ultimately, the polluter pay principle is designed to deter people from polluting by making it less expensive for them to behave in an environmentally responsible way.

3) Alternative Fuels

Focussing on Petroleum as the major energy source in Nigeria has made us neglect other energy sources. If we continue like this, we will continue to pollute our immediate marine environment with crude waste. It is therefore necessary to divert our attention to other sources of fuel.

4) Constant Monitoring of the Rivers Geochemistry

The Federal Ministry of Environment should constantly monitor the physicochemical parameters of the River in order to ensure that it meets the WHO acceptable limits,

REFERENCES

1. Adeniye, E. O., Olu-Sule, R., & Anyaye, A. (1983). Environmental and socioeconomic impacts of oil spillage in the petroleum producing riverine area of Nigeria: *The petroleum industry and the Nigerian environment*. Proceedings of the 1983 International Oil Seminar, NNPC, 3, 130– 135.

2. Ake, C. (1979). The oil boom and its problems. *Nigeria Institute of Journalism, 8th Annual Oil Seminar*, 158–161.
3. Amadi, A. N. (2014). Impact of gas flaring on the quality of rain water, groundwater and surface water in parts of Eastern Niger Delta, Nigeria. *Journal of Geosciences and Geomatics, 2*(3), 114–121.
4. Angaye, T. C., Daokoru-Olukole, C., & Abowei, J. F. N. (2017). Characterization of household solid wastes in the Niger Delta: A case study of Yenagoa Metropolis. *International Journal of Sustainable Development Research, 3*(5), 50–57.
5. APHA. (1992). *Standard methods for the examination of water and wastewater* (16th ed.). American Public Health Association.
6. Asseez, L. O. (1979). Review of the stratigraphy, sedimentation and structure of the Niger Delta. In C. A. Kogbe (Ed.), *Geology of Nigeria* (pp. 311–324). Elizabethan Press.
7. Awobajo, A. O. (1981). An analysis of oil spill incidents in Nigeria: 1976–1980. *Proceedings of an International Seminar, Warri, Nigeria*, 57–63.
8. Efe, S. I. (2010). Physicochemical characteristics of surface water of Ethiope River, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, *2*(2), 17–22.
9. Etu-Efeotor, J. O. (1998). Hydrochemical analysis of surface and ground waters of Gwagwalada area of Central Nigeria. *Global Journal of Pure and Applied Sciences, 4*(2), 153–162.
10. Hem, J. D. (1984). *Study and interpretation of chemical characteristics of natural water* (USGS Water Supply Paper No. 1473). U.S. Geological Survey.
11. Ikomi, R. B. (1992). Some aspects of the biology of the dwarf cichlid *Pelvicachromis pulcher* (Boulenger, 1901) in River Ethiope, Nigeria. *Abraka Journal of Agriculture, 1*, 125–1454.
12. Ikomi, R. B. (1996). The biology of the African leaf fish *Polycentropsis abbreviata* (Boulenger, 1905) in the River Ethiope, Nigeria. *Acta Ichthyologica et Piscatoria, 26*(1), 1–14.
13. Nduka, J. K., & Orisakwe, O. E. (2009). Environmental pollution of an oil- producing community in the Niger Delta region of Nigeria. *Scientific Research and Essays, 4*(6), 591–598.
14. Nwankwo, J. N., & Ifeadi, C. N. (1988). Case studies on the environmental impact of oil production and marketing in Nigeria. In *Environmental issues and management in Nigerian development*. Evans Brothers.

15. Nwokoma, D. B., & Dagde, K. K. (2024). Niger Delta oilfields produced water characteristics and treatment technologies. *American Journal of Chemical Engineering, 12*(4), 97–108.
16. Ojeifo, S. N. (2009). *Gas flaring in Nigeria and its impact on the environment*. Robinson Publishing Press.
17. Olobaniyi, S. B., & Efe, S. I. (2007). Comparative assessment of rainwater and groundwater quality in an oil producing area of Nigeria: Case study of Ethiope West LGA, Delta State. *African Journal of Environmental Science and Technology, 1*(4), 76–81.
18. Rim-Rukeh, A., Ikhifa, G., & Okokoyo, P. A. (2013). Physicochemical characteristics of the sediments of Ethiope River, Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences, 4*(2), 333–338.
19. Sawyer, C. N., & McCarthy, P. L. (1967). *Chemistry for sanitary engineers* (2nd ed.). McGraw-Hill.
20. Short, K. C., & Stauble, A. J. (1967). Outline of geology of Niger Delta. *American Association of Petroleum Geologists Bulletin, 51*(5), 761–779.
21. Tebbutt, T. H. Y. (2013). *Principles of water quality control*. Elsevier Science.
22. World Health Organization. (1996). *Guidelines for drinking-water quality: Volume 2, Health criteria and other supporting information*. WHO.
23. World Health Organization. (2017). *Guidelines for drinking-water quality* (4th ed.). WHO.
24. Adeoye, A. E. (2022). A review of the environmental impact of gas flaring on the physiochemical properties of water, soil and air quality in the Niger Delta region of Nigeria. *Earthline Journal of Chemical Sciences, 7*(1), 35–52.
25. Wikipedia contributors. (2007). Petroleum study. In *Wikipedia*. Retrieved from http://en.wikipedia.org/wiki/petroleum