

# PHYSICO-BIOGEOCHEMICAL PROPERTIES OF SURFACE WATER FROM ETCHE AND ITS ENVIRONS, NIGER DELTA NIGERIA.

1. Uzoegbu, M. U. and 2. Agbo, C. C.

<sup>1,2</sup> Department of Geology, College of Physical and Applied Sciences, Michael Okpara University of Agriculture, Umudike, PMB 7267, Umuahia, Abia State.

<sup>1</sup>GSM: 08030715958; Email: mu.uzoegbu@mouau.edu.ng

## ABSTRACT

A total of twelve water samples of six each were collected during the dry and wet seasons from six sampled localities (Akwa, Odogwa, Obite, Odagwa and Umuebulu) along Etche River. These were to determine the seasonal variation in the quality of surface water and level of pollution. The result of the physico-biogeochemical determination showed variations from one locality to another in both dry and wet seasons for Turbidity, Temperature, DO, TSS, TCC, P, N, Fe and Pb. The values of Conductivity, TDS, BOD, Cl, S, Bi-  $\text{CO}_3^{2-}$ , THC were higher in dry season than wet seasons. The pH values ranged from 5.17-6.50 indicate that almost all the samples were slightly acidic in both seasons. The DO values of some samples are within WHO limit (7.5) whilst others are not. The high values of turbidity, temperature, TSS, TCC, P, N, Fe and Pb in the wet season could be attributed to the influx of sediments from inter-land and waste from dumpsite and human activities. The dilution from overland flow and run-off also attribute to the high values of P and N. Heavy metals concentrations in most of the sampled areas were found to fall below the safe limits of WHO except Fe that is slightly above the recommended limit. The biogeochemical parameter (TCC) in all the localities was higher than the limit for WHO, suggesting the possible contamination of bacteria from industry, human and animal wastes.

**Keywords:** Water, Physico-biogeochemical, Contamination, Seasonal variation, Waste, Etche River.

## INTRODUCTION

Wetlands typically occur in low-lying areas that receive fresh water at the edges of lakes, ponds, streams, and rivers, or salt water from tides in coastal areas protected from waves. In wetlands, the surface of the water, called the water table, is usually at, above, or just below the land surface for enough time to restrict the growth of plants to those that are adapted to wet conditions and promote the development of soils characteristic of a wet environment.

The studied area (Etche) lies within latitudes  $04^{\circ} 45'$  and  $05^{\circ}08'N$  and longitude  $06^{\circ}05'$  and  $07^{\circ}14'E$  and situated in the southern part of the Niger Delta of Nigeria (Fig. 1). In Niger Delta region of Nigeria, the problem of water resources is getting good quality (potable) water because of environmental pollution and degradation. Generally, water resources problems are of three main types such as little water, much water and polluted water. In most cities, in this region, towns and villages, valuable man-hours are spent on searching to fetch water, often of doubtful quality, from distant sources. Studies in Nigeria have shown that surface water resources are easily contaminated from anthropogenic activities in most cities for instance, oil

pollution. This has attracted some considerable public interest since 1970s. Number of communities in the Niger Delta wetland of Nigeria has faced various ecological problems brought by oil industries and lots of paucity on government action (Chokor, 1993). Majority of the inhabitants of the western Niger Delta region such as Etche metropolis (Fig. 1), consume water that has not undergone any form of treatment. Etche is known to have numerable activities such as drilling of sand, agricultural activities. This part of Niger Delta experiences much of oil pipeline leakages and too much dumping of waste which contributed to the contamination of streams and rivers in creeks and subsurface water. The effect of human activities and pipeline leakages affected the microbiological and physicochemical quality of Chukuche River in Etche (Aluyi et al., 2006). These were also observed in the Umuagwu Community in Organs of Okoroagwu where physic-chemical impact affected their ecological and water qualities ((Efe et al., 2006).

Water pollutants result from many human activities. Pollutants from industrial sources may pour out from the outfall pipes of factories or may leak from pipelines and underground storage tanks. Polluted water may flow from mines where the water has leached through mineral-rich rocks or has been contaminated by the chemicals used in processing the ores. Cities and other residential communities contribute mostly sewage, with traces of household chemicals mixed in. Sometimes industries discharge pollutants into city sewers, increasing the variety of pollutants in municipal areas. Pollutants from such agricultural sources as farms, pastures, feedlots, and ranches contribute animal wastes, agricultural chemicals, and sediment from erosion. Water pollution, contamination of streams, lakes, underground water, bays, or oceans by substances harmful to living things; water is necessary to life on earth.

On the water quality, Etche and its environs is lacking information or data on the pollution level of the surface water. It is therefore necessary to investigate the quality of surface water from some selected creeks in the area. This paper deals in determination of physic-biogeochemical properties of surface water from Etche and environs.

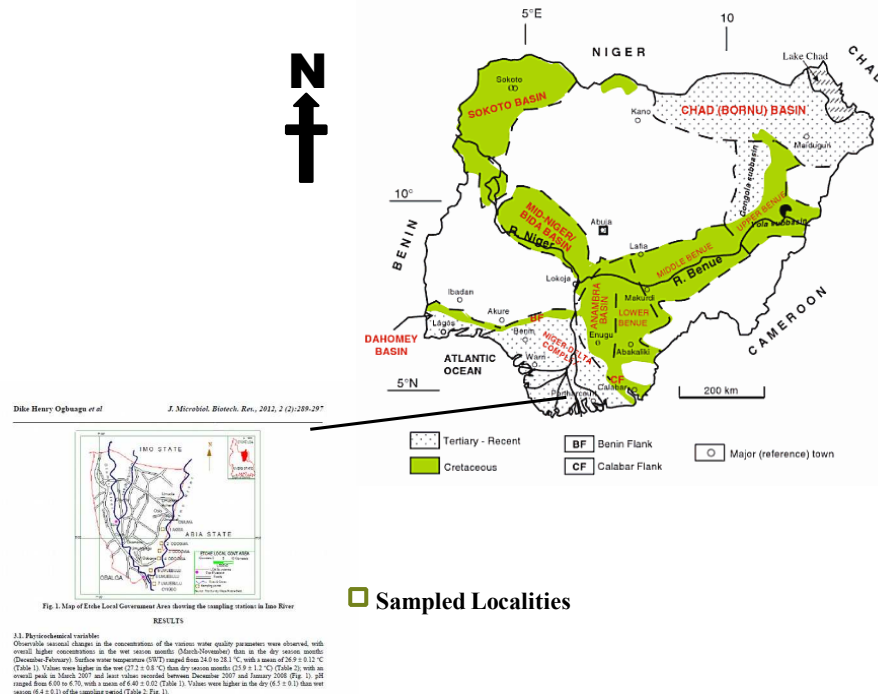


Fig. 1: Map showing the location of the Studied area (In set: Map of Nigeria showing Rivers State and Etche LGA).

## REGIONAL STRATIGRAPHIC SETTING

Three lithostratigraphic units characterized the area. These are the Benin, Agbada, Akata formation in order of increasing age. The Niger-Delta stratigraphic setting (Fig. 2) was modified by Shannon and Naylor (1989) and Doust and Omatsola (1990).

The Benin Formation is predominantly a sand stone sequence with a few shale intercalations which become more abundant towards the base. The sands of the formation are largely deposits of the continental upper deltaic plain environment ranging in age from the Oligocene in the North to their recent equivalents in the modern delta.

This formation is the major aquiferous layer in the study area. It also have the main source of potable groundwater in the Niger Delta region. The Benin Formation is an extensive stratigraphic unit in the southern Nigeria sedimentary basin, with an average of 4667 in meters feet. Due to its high sand percentage, few minor shale streaks and absence of brackish water and marine fauna, the formation is recognized throughout the Delta.

The sand stone are coarse grain, gravelly, locally fine grained, poorly sorted subangular to well rounded, it as acts as cap rock in the Delta, structural units common are points bar, channel fill and finer deposits and ox bow fills (Etu-Efeotor and Akpokodje, 1990).

The Agbada Formation underlines the Benin Formation and forms the second of the three strongly diachronous Niger Delta oil, the formations. As the principal reservoir of Niger Delta oil, the formation has been studied in some detail. The works of Weber (1971) is however, quite classic. The Agbada Formation consists mainly of sands, sand stones and silt-stones. It consists of numerous offlap rhythms, the sandy parts of which constitute the main hydrocarbon reservoirs in delta oil-fields. The sales constitute seals to reservoirs and as such are also important. In the Agbada formation, the sequence is divided into an upper unit consisting of sand stone-shale alternations with the former pre-dominating over the later and a lower unit in which the shales

predominate and in places are thicker than the inter-calculated sand stones or sands. The structural elevation of the base of the Agbada Formation fluctuates widely throughout the delta because of synsedimentary diapirism largely within the Akata shale and the consequent growth fault development. The Agbada Formation contains beds laid down in a variety of sub-environments which can be grouped together under one broad paralic environment. The Agbada Formation occur almost delta wide beneath the Benin Formation on the landward side of the Niger Delta complex. The Ogwashi-Asaba formation of Oligocene to Miocene probably passes into the Agbada Formation in the subsurface. The top of Agbada is drawn on the highest occurrence of shale yielding a brackish or marine fauna.

This is the basal major time transgressive lithologic unit in the Niger Delta complex. This is a marine pre-delta megafacies, comprising mainly of shales with occasional turbidite sand stones and silt stone. The approximate range of thickness is from 0-6000 meters and the formation crops out subsea in the outer delta area but is not seen on shore. The formation consists of dark grey uniform shales, especially in the upper part. In some areas, it is sandy or silty in the upper part of the formation where it grades into the Agbada Formation.

The hydrogeology of the area has been described by several researchers such as Etu-Efeotor, (1981); Amadi et al., (1989); Etu-Efeotor and Akpokodje (1990) and Udom et al. (1998). The Benin Formation is the water bearing zone of the area. It is overlain by Quaternary deposits (40-50cm) thick and generally consists of rapidly alternating sequences of sands and silty clay which later become increasingly prominent seawards (Etu-Efeotor and Akpokodje, 1990). Generally multi-aquifer systems have been identified in the Delta based on strata logs (Etu-Efeotor, 1981). The first aquifer is mostly unconfined, while the rest are confined. The average depths of borehole in Yenagoa are between 20 and 50 metres. In terms of water quality, Udom et al. (1999) have noted that groundwater in most parts of Yenagoa is high in iron content. The static water level in the area ranges from 0-1m during the rainy season and 1-3m during the dry season. Rainfall is the major source of recharge for aquifer in the area.

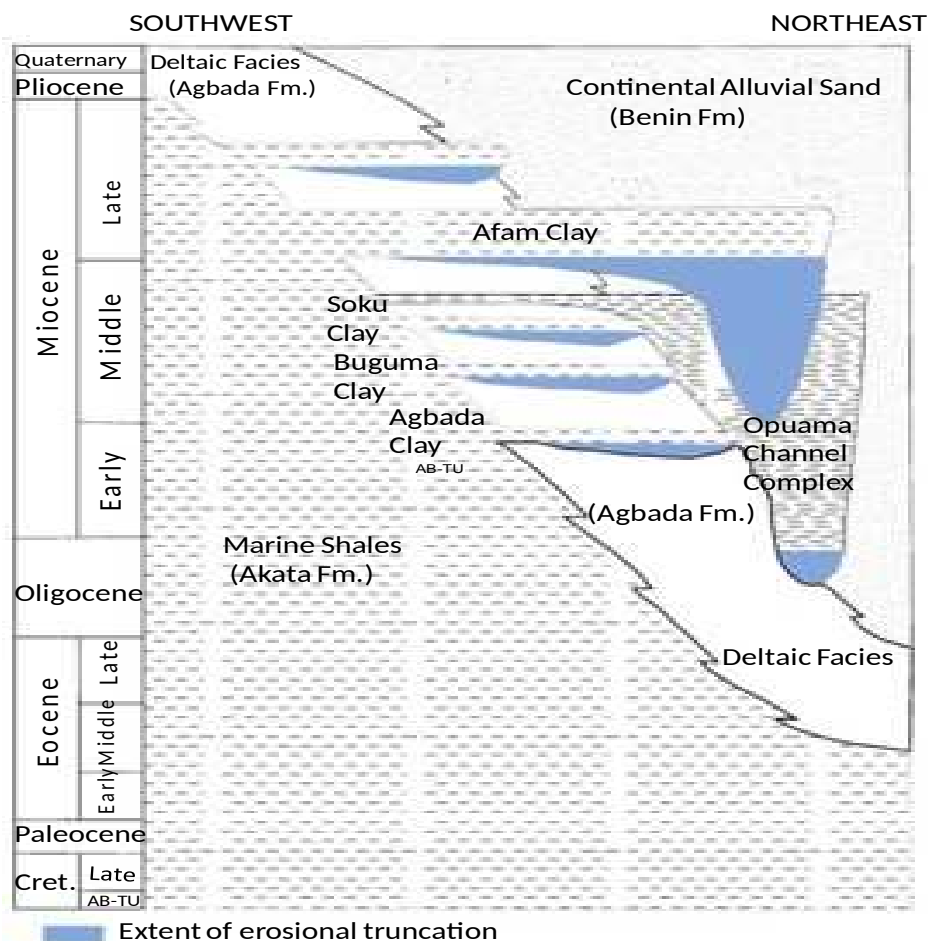


Fig. 2: Stratigraphic column showing the three formations of the Niger Delta. Modified from Shannon and Naylor (1989) and Doust and Omatsola (1990).

## MATERIALS AND METHODS

A total of twelve water samples of six each were during the dry and wet season were collected from six sampled localities (Akwa, Odogwa, Obite, Odagwa and Umuebulu) along Etche River. The localities where the samples were collected are Akwa, Odogwa, Obite and Odagwa for 1, 2, 3 and 4 respectively. While the 5 and 6 localities are from Umuebulu. The samples were collected from 2m away from the river bank and 50cm below water surface.

The pH, Temperature, Total Dissolved solids (TDS), Conductivity, and Turbidity were determined on the field using LaMotte model meters. Other physico-biogeochemical parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Colliform Count (TCC), Total hydrocarbon Content (THC), Phosphorus (P), Nitrogen (N), Iron (Fe) and Lead (Pb) were measured and analyzed in the laboratory.

For all the analyses, analytical reagent (Analar) grade chemicals were used. Laboratory equipment and facilities were decontaminated through proper cleaning and storage similarly, quality control of laboratory air through the use of functional cooling system (below 20°C) was

observed. The equipments were regularly calibrated using standard reference materials and solutions. In all the data verification and validation for ionic balance were carefully carried out.

## RESULTS AND DISSCUSIONS

The individual sampled locations, co-ordinates and site descriptions are shown in table 1, while the statistical summary of results obtained for the six sampled localities during the dry (March) and rainy (July) seasons for the physico-biogeochemical/heavy metals parameters are also shown in table 2.

Table 1: Sampled locations, co-ordinates and site descriptions.

S/ N	Sampled Locations	Latitude (N)	Longitude (E)	Site description
1	Akwa	05°10'24.2"	006° 09'22.9"	Presence of house boats
2	Odogwa	05°11' 00.9"	006° 10' 02.0"	Located just by the Odogwa bridge. Predominant activities at this station including swimming, washing of cloths etc.
3	Obite	05° 15' 26.3"	006° 17'09.7"	Boats and boat yard.
4	Odagwa	05° 18' 28.5"	006° 22' 53.8"	Presence of Trucks loaded with sands, workers carrying sand from water to land.
5	Umuebul u	05° 17'29.4"	006° 20'17.3"	Human activities like swimming, washing of clothes and fishing.
6	Umuebul u	05° 19'59.7"	006° 23' 59.7"	Indiscriminate dumping of wastes, small native boats, and fishing

Water is life. All organisms contain it; some live in it; some drink it. Plants and animals require water that is moderately pure, and they cannot survive if their water is loaded with toxic chemicals or harmful microorganisms. If severe, water pollution can kill large numbers of fish, birds, and other animals, in some cases killing all members of a species in an affected area. Pollution makes streams, lakes, and coastal waters unpleasant to look at, to smell, and to swim in. Fish and shellfish harvested from polluted waters may be unsafe to eat. People who ingest polluted water can become ill, and, with prolonged exposure, may develop cancers or bear children with birth defects (FGDC, 2001).

Oil and chemicals derived from oil are used for fuel, lubrication, plastics manufacturing, and many other purposes. These petroleum products get into water mainly by means of accidental spills from ships, tanker trucks, pipelines, and leaky underground storage tanks (SPDC, 2004). Many petroleum products are poisonous if ingested by animals, and spilled oil damages the feathers of birds or the fur of animals, often causing death. In addition, spilled oil may be contaminated with other harmful substances, such as polychlorinated biphenyls (PCBs).

Chemicals used to kill unwanted animals and plants, for instance on farms or in suburban yards, may be collected by rainwater runoff and carried into streams, especially if these substances are applied too lavishly. Some of these chemicals are biodegradable and quickly decay into harmless or less harmful forms, while others are nonbiodegradable and remain dangerous for a long time.

When animals consume plants that have been treated with certain nonbiodegradable chemicals, such as chlordane and dichlorodiphenyltrichloroethane (DDT), these chemicals are absorbed into the tissues or organs of the animals. When other animals feed on these contaminated animals, the chemicals are passed up the food chain (Montgomery, 2003). With each step up the food chain, the concentration of the pollutant increases. This process is called biomagnification. In one study, DDT levels in ospreys (a family of fish-eating birds) were found to be 10 to 50 times higher than in the fish that they ate, 600 times the level in the plankton that the fish ate, and 10 million times higher than in the water. Animals at the top of food chains may, as a result of these chemical concentrations, suffer cancers, reproductive problems, and death.

Many drinking water supplies are contaminated with pesticides from widespread agricultural use. More than 14 million Americans drink water contaminated with pesticides, and the Environmental Protection Agency (EPA) estimates that 10 percent of wells contain pesticides. Nitrates, a pollutant often derived from fertilizer runoff, can cause methemoglobinemia in infants, a potentially lethal form of anemia that is also called blue baby syndrome (IPCC, 1983). Heavy metals, such as copper, lead, mercury, and selenium, get into water from many sources, including industries, automobile exhaust, mines, and even natural soil. Like pesticides, heavy metals become more concentrated as animals feed on plants and are consumed in turn by other animals. When they reach high levels in the body, heavy metals can be immediately poisonous, or can result in long-term health problems similar to those caused by pesticides and herbicides (UNEP, 1991). For example, cadmium in fertilizer derived from sewage sludge can be absorbed by crops. If these crops are eaten by humans in sufficient amounts, the metal can cause diarrhea and, over time, liver and kidney damage. Lead can get into water from lead pipes and solder in older water systems; children exposed to lead in water can suffer mental retardation (UNU, 1983).

Hazardous wastes are chemical wastes that are either toxic (poisonous), reactive (capable of producing explosive or toxic gases), corrosive (capable of corroding steel), or ignitable (flammable). If improperly treated or stored, hazardous wastes can pollute water supplies. In 1969 the Cuyahoga River in Cleveland, Ohio, was so polluted with hazardous wastes that it caught fire and burned. PCBs, a class of chemicals once widely used in electrical equipment such as transformers, can get into the environment through oil spills and can reach toxic levels as organisms eat one another (IPCC, 1992).

The pH mean value for dry season is 6.32 while that of wet season is 5.76. This meant that water is more slightly acidic in wet than dry seasons. However most of the locations had values below the pH of 6.5 for World Health Organization (WHO) limit indicating weak acidity and could be as a result of leached chemicals or ions from inter-land by run-off. Table 2 shows mean value for turbidity as 23.55NTU for Dry season while 29.50NTU is for Wet season. These values are above the WHO limit of 1 NTU. The possible high values could be attributed to the run-off from inter-land carrying silts and sediments down the river and creeks or probably this may be due to turbulence and agitation due to tidal variation and movement of boats.

The water temperature ranged from 31.9 in the wet season to 30.55 in the dry season (Table 2). Marine and estuarine organisms are very sensitive to thermal changes as they form the tropical levels. Conductivity mean value in the dry season is 780. 1us/cm while the wet season is 48.6 us/cm. The higher values during the dry season could be attributed to the influx of leached ions from inter-land by run-off or materials from the industrial discharges. Just like any other place in Nigerian, in-land water bodies' conductivity was much less than 500  $\mu$ S/cm at the peak of the

dry season when mineralization of organic matter is at maximum and much less than 100  $\mu\text{S}/\text{cm}$  during the rainy season.

Table 2: The statistical summary of results obtained for the six sampled localities.

Locations	1		2		3		4		5		6	
Seasons	Ws	Ds	Ws	Ds	Ws	Ds	Ws	Ds	Ws	Ds	Ws	Ds
pH	5.43		5.58	6.25	5.17	6.45	6.25	6.50	6.10	6.45	6.05	6.45
Turbidity (NTU)	5.86		10.00	22.80	7.00	23.00	50.00	22.70	30.40	22.40	75.00	22.40
TSS (mg/l)	5.00		12.00	10.00	10.00	10.00	29.00	10.00	32.00	20.00	25.00	10.00
DO (mg/l)	28.00		7.50	8.10	7.10	8.00	8.85	7.60	2.20	8.80	7.50	4.60
$\text{NO}_3^-$ (mg/l)	7.00		0.00	5.76	0.02	6.06	0.01	7.46	0.00	6.82	0.00	5.38
Fe (mg/l)	20.00		0.91	1.70	0.48	1.38	0.38	2.88	0.70	2.61	2.06	2.06
TDS (mg/l)	8.80	6.20	16.00	110.00	11.00	120.00	35.00	1030	47.00	480.00	25.00	540.00
CT (mg/l)	0.00	6.92	5.31	58.15	4.49	67.10	4.13	577.02	5.79	210.32	5.31	250.49
$\text{SO}_4^{2-}$ (mg/l)	1.13	0.63	1.00	31.69	1.00	13.65	1.00	90.94	1.00	31.68	1.00	32.16
$\text{HCO}_3^-$ (mg/l)	12.00		6.30	8.00	3.86	12.00	17.08	14.00	13.82	24.00	14.23	16.00
THC (mg/l)	60.00		0.28	0.32	0.12	1.46	0.22	0.56	0.03	0.48	0.18	1.39
Pb (mg/l)	4.14		0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
Cr (mg/l)	14.37		0.01	0.03	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01
CU (mg/l)	1.00		0.01	0.03	0.01	0.00	0.01	0.00	0.01	0.03	0.01	0.00
TCC (MPN/100ml)	13.97		120.0	220.0	40.00	60.00	10.00	20.00	1600	1800	40.00	60.00
Zn (mg/l)	6.10	6.00										
	0.34		0.72	0.88	0.65	0.72	0.70	0.91	0.56	0.49	0.54	0.44
Temp (°C)	0.89		28.80	31.50	34.00	31.30	31.30	29.20	32.50	29.50	33.50	30.20
Cond. $\mu\text{S}/\text{cm}$	0.01		37.00	220.2	38.00	240.0	65.70	2060	86.90	960.0	44.6	1080.0
BOD (mg/l)	0.01		2.20	3.90	2.00	3.00	2.90	2.40	2.40	0.80	2.50	1.80
$\text{PO}_4^{3-}$ (mg/l)	0.01		0.01	0.00	0.01	0.00	0.08	0.00	0.06	0.15	0.18	0.03
	0.00											
	0.01											
	0.00											
	34.00											
	10.00											
	0.54	0.48										
	31.30											
	31.60											
	19.4											
	120.4											
	3.70	2.00										
	0.01											
	0.00											

**Note:** Ws = Wet Season      Ds = Dry Season

The mean value in the dry season was 390mg/l while those for the wet season is 24.3mg/l. Location 6 has TDS of 1030mg/l and is classified as brackish in accordance with the Gorrel (1958) classification. While the rest sampling locations indicated fresh. The value of TSS is higher in the wet season (19.6mg/l) than in the dry season (13.3mg/l). WHO's limit is <10. In relation to this, almost all the locations have values greater than 10 indicated that the water is polluted and unsafe for aquatic organisms. The high values in the wet season could be attributed to the suspended sediments and colloids as well as from dissolved gases in the water.



The DO mean value during dry season is 6.1mg/l while the wet season is 8.09mg/l. DO is higher in the wet season than in the dry season. The value for wet season is not within WHO limit which is 7.5mg/l. The water quality is poor when DO is lower than the standard limit. It has been reported by NCES, (1991) that the quality of water is high when DO value is as close as possible to 9.2mg/l. From the results in Table 2, most of the water samples are not of good quality and unsafe for aquatic organisms. The observed seasonal fluctuation may be due to the effect of temperature on the solubility of oxygen in water. At high temperatures, the solubility of oxygen decreases while at lower temperatures, it increases. Another reason could be that of oxygen-depleting wastes or high BOD. The BOD values were higher in the wet season (2.62mg/l) than in the dry season (2.32mg/l) though they did not fall below the safe limits of WHO. But the disparity in values could be due to the domestic/municipal wastes introduced into the water by run-off.

The concentration of chloride was higher in the dry season (196.22mg/l) than in the wet season (4.86mg/l). The possible high values are indication of salt water intrusion from the Focados River. Phosphate mean value is higher in the wet season (0.05mg/l) than in the dry season (0.03mg/l). Phosphate pollution probably may be due to phosphate containing detergents in waste water from the washing of rugs around the locations. Sulphate obtained high value in the dry season (35.68mg/l) than in the wet season (1mg/l). Recently, studies have shown that Sulphate contribution to free acidity in Warm rainfall water is usually high up to 76%, far higher than that obtained on non-anthropogenically impacted zones (Ogunkoye and Efi,2003). The values are below 250mg/l of WHO limit for sulphate typically of freshwater environment. Nitrate mean value is 0.005mg/l in dry season and 6.39mg/l in wet season. The higher value in wet season could be attributed to run-off contributing to the amount of the constituents (nitrates) in the water body. The mean of values for Bi-carbonate is 13.33mg/l for dry season and 10.23mg/l in the wet season. However, below WHO limit of 200mg/l. Though there were disparities in the range of values for both seasons from one location to another but all values fall below the safe limit thus no pollution with respect to this parameter.

THC mean value is 0.85mg/l in the dry season and 0.2mg/l in the wet season. Thus the higher values in the dry season could be attributed to the bilge water from Houseboats and tug boats or other activities at the Chevron oil company. WHO standard for zinc is 5.0mg/l but the mean values obtained in this studied areas is 0.65mg/l in the dry season and 0.62mg/l in the wet season. These values are below the limit, thus no indication of pollution. Chromium has WHO limit of 0.05mg/l and Copper 0.1 mg/l as the accepted concentration in water. From the results in Table 2, these properties has values below the regulation limits, thus no pollution occurred. Mean values for iron in dry season is 0.61mg/l while in the wet season is 2.01mg/l. WHO limit for iron is 1.0mg/l. From the results, the wet season has higher values than the dry season. Iron is the second most abundant element in nature. It is readily oxidized into the ferric state ( $\text{Fe}^{3+}$ ) in natural waters and a substantial fraction of such is present in the suspended form. Iron actually presents no health hazard even in excess concentration except for imparting a metallic taste to the water. Mean value in the wet season is 0.01mg/l while the dry season is 0.01mg/l. High Pb levels in surface water could be traced to urban and industrial wastes and high petrol-Pb used by vehicles in the area (Arah,1985). WHO limit for Pb are 0.05mg/l. All the samples from both seasons have values below this limit, thus no pollution.

Table 2 shows mean value for TCC in the dry season is 261.7MPN/100ml and 307.3MPN/100ml in the wet season. TCC values were higher in the wet season than in the dry season this could be attributed to the influx of pathogenic bacteria from animal and human wastes introduced by

runoff and increased activities. The presence of TCC in the waste samples during sampling period indicated faecal pollution of the water due to human activities. Akpata and Ekundayo (1978) reported high faecal load with concentration of TCC in the Lagos Lagoon.

## CONCLUSION

The physico-biogeochemical characteristics of selected parameters in the Etche River and its environs western Niger Delta of Nigeria during the dry and wet seasons has been determined in this studied area. Deleterious levels of contamination of surface water in the area were observed which stands as potential health hazards to the inhabitants of the area that uses these water directly for domestic purpose without treatment. The overall observation of the data indicated a fast rate of deterioration of water quality in the available water resources. It is therefore needful that urgent steps be taken to ensure effective water resources management in the area.

A 1994 study by the Centers for Disease Control and Prevention (CDC) estimated that about 900,000 people get sick annually in the United States because of organisms in their drinking water, and around 900 people die. Many disease-causing organisms that are present in small numbers in most natural waters are considered pollutants when found in drinking water. Such parasites as *Giardia lamblia* and *Cryptosporidium parvum* occasionally turn up in urban water supplies. These parasites can cause illness, especially in people who are very old or very young, and in people who are already suffering from other diseases. In 1993 an outbreak of *Cryptosporidium* in the water supply of Milwaukee, Wisconsin, sickened more than 400,000 people and killed more than 100.

Oil spills often occur through accidents, such as the wrecks of the tanker *Amoco Cadiz* off the French coast in 1978 and the *Exxon Valdez* in Alaska in 1992. Routine and deliberate discharges, when tanks are flushed out with seawater, also add a lot of oil to the oceans. Offshore oil platforms also produce spills. The second largest oil spill on record was in the Gulf of Mexico in 1979 when the *Ixtoc 1* well spilled 530 million liters (140 million gallons). The largest oil spill ever was the result of an act of war. During the Gulf War of 1991, Iraqi forces destroyed eight tankers and onshore terminals in Kuwait, releasing a record 910 million liters (240 million gallons). An oil spill has its worst effects when the oil slick encounters a shoreline. Oil in coastal waters kills tidepool life and harms birds and marine mammals by causing feathers and fur to lose their natural waterproof quality, which causes the animals to drown or die of cold. Additionally, these animals can become sick or poisoned when they swallow the oil while preening (grooming their feathers or fur).

## REFERENCES

- Aluyi, H.S.A et al, 2006: Effect of Human activities and Oil pollution on the microbiological and physicochemical quality of Udu river, Warr, Nigeria. *Etud.Biol.v.28*, n. 62, p. 35-43.
- Amadi, P.A., Ofoegbu, C.O and Morrison, T. (1989), Hydrogeochemical Assessment of Groundwater Quality in parts of the Niger Delta, Nigeria. *Environmental Geo/Water Science*, Vol. 14, No 6, pp 195-205.
- Chokor, B.A (1993): Government Policy and Environmental Protection in Developing World, *Environment Management*, Volume 17, Number 1, pp.1 5-30.

- Doust, H., and Omatsola, Eq., 1990, Niger Delta, in, Edwards, J. D., and Santogrossi, P.A., eds., Divergent/Passive Margin Basins, AAPG Memoir 48: Tulsa, American Association of Petroleum Geologists, p.239-248.
- Etu-Efeotor, J. O. and Akpokodje, E. G., 1990. Aquifer systems of the Niger Delta. Journal Mm. Geol. Vol. 26, No.2, pp 279 -284.
- IPCC, 1990. Strategies For Adaption To Sea Level Rise. Report of the Coastal Zone Management Subgroup, Response Strategies Working Group, 12p.
- IPCC Report, 1992. Global Climate Change and the Rising Challenge of the Sea. Report of the Intergovernmental Panel on Climate Change, Response Working Group, Coastal Zone Management Subgroup p. 19.
- FGDC (Federal Geographic Data Committee), (2001). "National Spatial Data Infrastructure".
- Montgomery, C.W (2003): Environmental Geology (sixth edition). 554p. Mc Graw Hill Pub. Boston, USA.
- Nigerian Coastal Erosion and Subsidence, 1991. Technical Report No. 1. Prepared for EEC/Nigerian Coastal Erosion Research Project. Ed. B.I.C Ijeoma. 137p.
- Shannon, P. M., and Naylor N., 1989, Petroleum Basin Studies: London, Graham and Trotman Limited, p 153-169.
- SPDC (2004): Groundwater monitoring at Edjebe restaurant SPDC-West. Final report for the Shell Petroleum Development Company of Nigeria Limited (unpublished). By Devine Concepts Integrated Services limited (DCISL)
- Udom G., Etu-Efeotor, J., and Esu, E. (1999) Hydrogeochemical characteristics of groundwater in parts of Port Harcourt and Tai-Eleme Local Government Areas. Global Journal of Pure and Applied Science 5(5). P. 545-552.
- Udom, G.J., Esu, J.O. and Ekwerre, S.J. (1998). Quality Status of Groundwater in Calabar Municipality, Sutheastern Nigeria. Global Journal of Pure and Applied Sciences. Vol. 4(2):163-169.
- UNEP (1991): Fresh-Water Pollution, UNEP /GEMS Environment Library, No. 6,
- UNU (1983): United Nations University Newsletter, 7(2), 9, Tokyo, Japan.
- Weber, K. J., 1971: Sedimentological aspects of oil fields in the Niger Delta Geologie en Mijnbouw, vol. 50, p. 559-576.

World Health Organization (WHO), (2006). International Standards for Drinking Water and Guidelines for Water quality. World Health Organization, Geneva.