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Use of *In situ* water quality parameters for pollution status assessment of Ibeno dark brown water marine environment, Niger delta, Nigeria

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Abstract

Dark brown water zone of Ibeno marine environment was assessed for pollution status using highly sensitive, calibrated portable meters. The onsite-measured parameters were pH, DO, TDS, temperature, salinity and conductivity. The results obtained were compared with standards prescribed by WHO (2008) guidelines in order to determine the quality of the water/it's pollution status. The area that constituted the sampling points of this study is the zone on the continental shelf up to a depth of around 20meters off the shorelines. In this area salinities are much lower at around 18 psu (practical salinity unit) in comparison to other contiguous zones. The Ibeno dark brown water zone is considered the most productive water body of the entire continental shelf of the area, exhibiting the highest chlorophyllous activity. In cases of significant or extreme pollution, the physico-chemical water quality parameters measured as in this study would have generally been at extremely high levels, but the reverse was the case, judging from the results of the study. Therefore, the results generally conformed to recommend global standards by WHO (2008). Therefore, it can reasonably be concluded from the results of this study, that though Ibeno marine environment is a dark brown water zone, pollution impacts on it's water quality are not significant. Specific further studies such as heavy metal analysis in water, biota and sediments that will further profile the pollution status of the environment is recommended.

Keywords: In Situ; Water Quality Parameters; Pollution Status; Dark-Brown Water Zone; Ibeno Marine Environment; Niger Delta; Nigeria

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1. Introduction

Several studies of the ocean are adjudged beneficial to mankind in various ways, the ocean being an environment that supports different biotic and abiotic components that are of immense socio-economic value to society. This assertion has been indicated by several researches. A good example is UCMSPO, 2005a that stated thus; "The study of the ocean is a valuable undertaking in that it provides a greater understanding about the world and how all things living and non-living are dependent on the stability of the marine environment. A complementary relationship occurs between humans, biotic organisms over and above abiotic organisms and when toxic components are appended the effects are extensively circulated. The oceans occupy over seventy percent of the earth's surface.

Similarly, UCMSPO, 2005b reported that the major water bodies that make up the aquatic ecosystem include lakes, rivers, streams, estuaries and wetlands. The report further noted that while an ecosystem describes the interrelationship between biotic and abiotic organisms, operating on a daily basis through energy exchange. Thus in an ecosystem it's energy exchange cycle is essentially between the physical and biological entities that constitutes the system, creating a co-dependence relationship, where each component relies on one another for continuity.

Despite the seemingly independence of the aquatic ecosystem like all other component systems of the bios-sphere in terms of it's natural dynamics, anthropogenic activities of humans, often times interferes with this cycle. This interference is a part of the ecosystem, as human existence and survival is an integral part of the ecosystem. Consequently, UCMSPO, 2005b further opined that human beings have a linkage to all biotic organisms in the ocean, from the tiny afloat flora that supply them with the oxygen they inhale, to the large blue whale that stuffs its abdomen with a ton of very small creatures. However, in some instances where the interference of human in the ecosystem it's the natural balance, it often times results in what is generally termed pollution.

Similarly, Canter (1985) reported that phytoplankton, which are minute forms of plants that usually float in water, constitutes the base of the food chain; requiring sunlight, nutrients and CO_2 to photosynthesize. It is on this phytoplankton that the lower herbivores and omnivores feed on, which are then in turn fed upon by other carnivores and omnivores up the food chain. Thus giving rise to sustenance of the biodiversity of the aquatic environment. It is therefore important to note that one of the most important reasons for protecting the ocean is to maintain biodiversity of the earth. Biodiversity is the number of different species of organisms (plants and animals) that are contained and supported in a particular environment. The oceanic biosphere is quite rich and one of the most diverse in nature, hence protecting it against pollution inducing activities, indirectly means protecting its bio-diverse resource environment.

Mba and Ugbuagu (2012) opined that the environment can be considered as the global life support platform that surrounds the biosphere that all living organisms eke out a living from, thereby making it the inevitable life line or fuel of the global life dynamics of all living organisms. According to Rabie et al. (1994), there are various anthropogenic activities by man such as processes of prospecting, extracting, concentrating, refining and transporting minerals that have great capability for impacting the natural environment. Furthermore these anthropogenic activities often lead to wastes and these wastes often end up in the natural environment, such as the marine areas. Based on the nature of the waste and or how they are handled cum treated before discharging into the aquatic environment, these wastes which can be in the form of solid, liquid or even gracious effluent, may lead to pollution or the degradation of the natural environment.

The Niger Delta region though very rich in flora, fauna and mineral resources; essentially oil is notorious for the various high pollution incidents, especially from crude oil that has ravaged it's marine resources in particular. Highly implicated in this regard is pollution arising from crude oil exploration and exploitation activities (Akankali and Abowei, 2010). Isedu et al. (2004); Mba and Ugbuagu (2012) amongst several other authors reported that the Niger Delta region is a unique Delta in terms of complex and diverse environment; consisting of of distinct ecological zones within the tropical region, that is largely characterized by a dominant deltaic river, called the river Niger. The Deltaic area of the Niger Delta is typically made up of mainly coastal ridge barriers, mangroves, fresh water swamp forest and low land rain forest, covering a total land area of about 70,000 km^2.

The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. Natural water contains some types of impurities whose nature and amount vary with source of water. Water quality might be seen as the chemical, metabolic activities, growth, feeding, and reproduction, physical and biological contents of water. Lawson (2011) reported that seasonal variation and geographic areas have adverse effect on water quality of rivers and lakes, even when there is no pollution presents, while Chitmanat and Traichaiyaporn (2010) implicated low water velocity, municipal effluents and industrial discharges to be the factors that predispose the water of an environment to be of poor water quality. Incidentally, the Niger Dleta marine environment cannot be devoid of all of these factors playing a role in affecting it's water quality.

According to GESAMP (1993) pollution is defined as the introduction of substances into the marine environment (including estuaries) either directly and indirectly, resulting in such deleterious effects as harm to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater, and reduction of amenities.

Pollution in the marine environment poses a serious threat to the various life forms within the different zones of the aquatic environment- shorelines, continental shelf (upwelling zones) and even open Seas. These pollutants emanates from the very many activities that goes on in the marine environment. According to United Nations (2005), ocean going vessels contribute 10 percent to marine pollution. Other offshore sources include industrial activities, such as oil extraction (which is the main source of pollution of the study area) and the extraction of mineral resources. Globally, and within the Niger Delta Marine Environment in particular, hydrocarbon oil which include Premium Motor Spirit (PMS), Automotive Motor Oil (AGO) Dual Purpose Kerosene (DPK) and unprocessed crude oil constitutes the most common polluting substances in the marine environment. In addition Gas flaring, Industrial Pollution, Thermal pollution, Erosion, Siltation, Physical obstruction of waterways by waste and equipment, Sewage pollution & Flooding were reported by Akankali (2016) in order of their rate or frequency of occurrence as shown in table 1. Clearly, incidence of oil pollution was found to be the most common occurring by the report.

Table 1. Ranking of Environmental Pollutant sources within the Niger Delta, Nigeria

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Score**	***Rank**
1	Incidence of oil pollution	304	220	206	85	75					2073	1
2	Gas Flaring	301	240	186	103	70					2101	2
3	Industrial pollution	220	201	200	171	108					2446	3
4	Thermal pollution	75	119	122	150	160	224				3423	4
5	Erosion		120	120	160	230	260				3950	5
6	Siltation			66	130	134	140	200	230		5468	6
7	Physical obstruction of waterways by waste and equipment				60	67	116	196	221	240	6571	8
8	Sewage pollution				44	50	150	200	221	235	6550	7
9	Flooding					4	10	233	228	425	7360	9

**The pollutant source with the lowest number (1) is considered most frequently occurring source of pollution on aquatic resources in the region, while the one with the highest number (9) is considered the least. Source: Akankali (2015)*

Jerzy and Doerffer (1992) in grouping hydrocarbons reported four main categories: alkanes, naphthenes, aromatics and alkenes. Crude oil in it's natural form i.e. unrefined, constitutes the original form of oil. The natural crude is often refined through various chemical treatment processes to produce other products like petrol, diesel and kerosene, which individually contains a complex mixture of the four main categories of hydrocarbons. It is further reported that, sulphur, nitrogen, oxygen and vanadium compounds may also be present; these and other compounds making up about 25% of crude oil.

Crude oil pollution incidence has very severe and wide ranging impacts on the marine environment. Consequently, TITOPFL (1985) reported that oil spill do have serious economic impact on coastal economic ventures and sources of lively hood, for those who depend on the exploitation of natural resources form the sea for their livelihood. Particularly implicated in this category of persons are artisanal fishermen across the various region of the marine environment, where oil pollution incidents are significantly prevalent The adverse effects that crude oil pollution has on marine flora and fauna is compounded by toxicity effects and tainting or distortion of natural taste of food organisms from such environment. These phenomenons are largely due to effects resulting from the various chemical constituents of crude oil, as well as by the diversity and variability of biological systems and their sensitivity to higly persistent compounds that make up the crude oil.

Nybakken, and Bertness, (2005) reported that when there is crude oil spillage, it affects the marine or aquatic environment and the constituent organisms through various pathways; it may either form sheens or slicks on the water surface, parts of it may eventually get to the bottom via adsorption and absorption by organisms and particulates matters, while other fractions that are volatile may vaporize into the atmosphere.

Nybakken, and Bertness (2005) further reported that pollution of marine environment from atmospheric sources is mainly from Air craft emissions from planes. Some of the gases released into the atmosphere get diffused into the marine environment as their ultimate sink, there by constituting a source pollution of the marine environment. Interestingly, atmospheric pollutants have similar characteristics as pollutants originating from either land-based or offshore sources: Virtually all of them have a high probability of being distributed over large surface areas of marine waters, depending on prevailing local or regional winds and weather conditions. However, with respect to pollutants that are deposited through the atmosphere, two main distinctions may be affirmed. In the first scenario the material pollutants are observed to remain in the atmosphere for either a short time or a long duration. The former case results mostly in pollutants being deposited close to their sources; whereas for the latter case, the pollutants becomes distributed on a regional or even a global scale. Secondly, polluting substances usually enter the marine environment through rainwater – in contrast, particulate matter may also just fall out.

It was affirmed been noted by Nybakken, and Bertness (2005) "that it is very difficult to estimate precisely how atmospheric pollutants contributes to the pollution of the marine environment".

However, atmospheric pollutants in particular have been largely implicated as one of the most likely marine environment gets inundated with persistent organic pollutants (POPs), many of which are volatile and considered to be highly toxic (GESAMP, 1993).

Froidefond et al. (2002) described dark brown water zone as a zone on the continental shelf from deep water to a depth of around 20m, where the salinities are much lower at around 18 psu (practical salinity unit). It is the most productive water body, exhibiting the highest chlorophyllous activity. This description matches essentially the Ibeno Marine environment of Akwa Ibom state, Nigeria, where this study is based. This study therefore aims at using *In situ* water parameters to determine the pollution status of Ibeno marine environment; specifically dark brown water zone of the study area based on the criteria given by Froidefond et al. (2002) as cited in the preceding paragraph.

1.1. Geographical setting of the study area

Ibeno Local Government Area is situated at the extreme south of Akwa Ibom State, just at the bank of the Atlantic Ocean, covering an area of about 16,000 square kilometers and the population census figure for 2006 is 74,840 people of which 53.46% are male and 46.54% are female (NBS, 2007). Ibeno is the host community of Most International Oil and Gas Companies (IOC's) operating within Akwa Ibom State, Nigeria. Ibenao community local cumindeginous residents are mainly artisal fishermen that utilize the extensive shoreline bothering the adjourning contental shelf marine waters and the community land areas for extensive artianla fishing. Artisal fishing is the major occupation of the indegenes of the study area.

In terms of it's geo-political boundary, Ibeno town is situated on the eastern side of the Kwa Ibo River about 3 kilometres from the river mouth, and is one of the largest fishing settlements on the Nigerian coast, lying in the mangrove Forest Belt of the Niger Delta region of Nigeria. It is bounded in the West by Eastern Obolo local Government area,to the North by Onna,Esit Eket and Eket,to the South by the Atlantic Ocean (Nigerian Fisheries and Aquaculture Department, 2011)

The study area is located within the equatorial belt of West Africa, which comprises the region lying between latitudes 04^0 41' North of the equator and between longitudes 07^o41' on the Atlantic Coast of Africa. Akankali et al. (2017) described the described the climate of this region of study to be of two main seasons; rainy or wet and dry seasons, spanning between March to October and November to February respectively. The rainy seasons are often characterized by intermittent high solar radiation that is mostly diffused due to cloud cover, which often leads to precipitations upon saturation. Rain therefore falls sparingly even during the dry season months, however there is usually a clearly dry spell between the months of January to March in some parts of this region. The harmattan wind, which is usually cold, dry and hazy, is usually experienced around the months of November to December.

The characteristics of near shore marine waters, especially in terms of colours are often determined by several factors as a result of the different reactions of the constituents of the water in either scattering or absorbing certain sunlight wavelengths. Therefore, in coastal areas like the Ibeno dark brown water zone of Akwa Ibom state, Niger Delta, Nigeria factors such as Feeder-Rivers run-offs, Re-suspension of sand, sediments and silts from the bottom due to tides, waves and storms and a number of other substances can change the color of the near-shore waters.

Microscopic marine algae, known as phytoplankton, has the natural potential to absorb light in the blue and red region of the spectrum due to it's specific pigments contents like chlorophyll. Therefore, as the concentration of phytoplankton increases in the water, the colour of the water tends toward the green part of the spectrum. Alternatively, fine mineral particles like sediments absorb light in the blue part of the spectrum, causing the water to turn brownish in case of massive sediment load (Wikipedia, 2017). It can therefore be reasoned that the dark brown colouration of the Ibeno shore line marine water is mostly as result of the high sediments loads of fine mineral particles absorbing light absorbing light in the blue range of the spectrum, which causes the water to be brownish. The very "dark" brown colouration of the Ibeno near shore marine water can further be attributed to the dark colour of the putrefactive effective of decaying/decayed tropical flora/fauna that often inundates most of the streams and Kwa Ibo river in the area, which finally drains into the near shore waters of Ibeno. Being in the mangrove belt as reported by Nigerian Fisheries and Aquaculture Department (2011), Ibeno occupies the largest Atlantic coastline of more than 129 km in Akwa Ibom State and has rain throughout the year with the peak between May and September. The climatic condition in Ibeno is therefore favorable all year round for fishing and farming, justifying the assertion of high putrefactive effects contributing to the dark brown water colouration of the near shore waters.

2. Materials and procedure

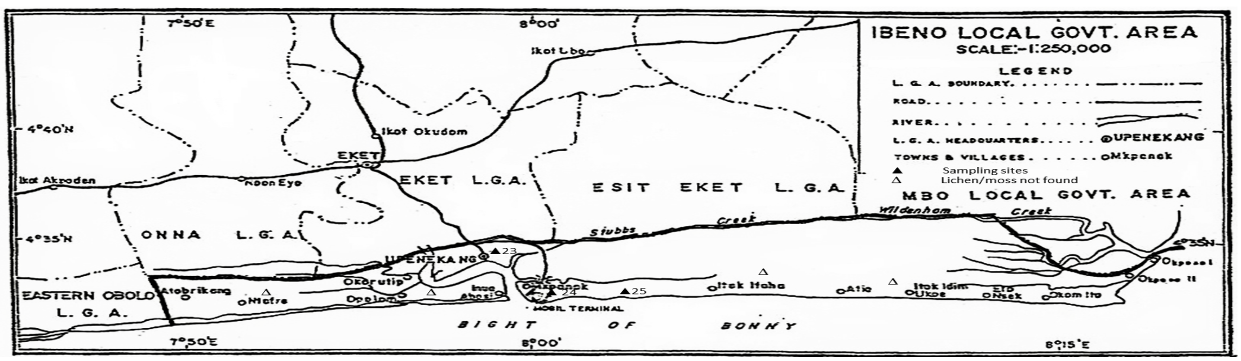

Figure 1. Map of Ibeno Local Government Area

2.1. Sample collection

A total of twenty-five points within Ibeno coastal marine water constituted the *In situ* water quality parameters sampling stations. Prior to measurement, each probe was first rinsed with the sample water. pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), temperature, salinity, Turbidity and electrical conductivity (EC) were measured *In situ* using calibrated instruments (Jenway Hand Held Meter Model 430 and 970 MK II and Horiba Water Quality Meter Model W-2000S/W-23XD).

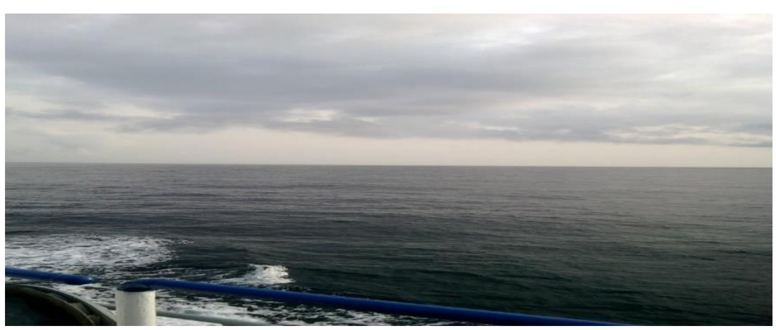

Plate 1. Dark brown water zone of marine environment sampled

3. Results and discussions

Table 2. *In situ* water parameter Measurements

Location	pH	Temp. (°C)	Salinity (mg/l)	DO (mg/l)	TDS (mg/l)	EC (µS/cm)	Turbidity (NTU)	Depth (m)
LT_1	7.24	28.4	76.1	8.5	1662	3308	0.57	69
LT_2	7.93	27.3	93.6	7.27	1730	1752	0.9	67
LT_3	7.98	27.3	87.8	7.69	1131	2240	0.22	71
LT_4	8.24	27.6	71.7	6.74	1611	3256	1.15	68
LT_5	7.63	27.3	87.8	8.46	1536	3052	0.75	73
LT_6	8.36	28	70.2	7.95	1331	2640	0.6	68
LT_7	7.62	28.1	71.7	6.84	1331	2608	0.73	63
LT_8	7.77	28.7	81.9	6.68	1679	3296	0.96	68
LT_9	8.49	28.7	76.1	8.46	1581	3189	1.5	74
LT_{10}	7.97	28.7	52.7	6.66	1441	2873	1.02	79
LT_{11}	6.26	28.5	52.7	8.26	1589	3213	4.25	71
LT_{12}	6.97	28.2	41.1	6.17	1469	2930	4.59	68
LT_{13}	7.87	28.5	46.8	7.98	1195	2394	0.9	62
LT_{14}	7.63	28.6	58.5	6.69	1477	1949	0.8	65
LT_{15}	7.08	28.8	76.1	7.72	1562	3137	0.75	69
LT_{16}	7.95	28.7	41	7.88	1536	3069	1.3	81
LT_{17}	7.99	30.8	58.5	7.57	1396	2792	1.2	67
LT_{18}	5.76	28.3	58.5	6.7	1746	3485	5.63	72
LT_{19}	5.92	28.5	93.6	6.89	1392	2787	5.67	68
LT_{20}	8.08	28.8	52.7	7.55	1615	3231	0.9	69
LT_{21}	7.78	29	52.7	8.11	1423	2828	0.75	75
LT_{22}	7.63	29.3	58.5	6.72	1254	2509	0.53	73
LT_{23}	7.78	29.5	76.1	6.61	1582	3165	0.67	69
LT_{24}	7.95	29.4	64.4	7.81	1386	2759	0.7	72
LT_{25}	7.32	29.4	58.5	7.35	1638	3271	0.8	63
Mean	**7.568**	**28.576**	**66.372**	**7.41**	**1491.72**	**2869.32**	**1.5136**	**69.76**
Min	**5.76**	**27.3**	**41**	**6.17**	**1131**	**1752**	**0.22**	**62**
Max	**8.49**	**30.8**	**93.6**	**8.5**	**1746**	**3485**	**5.67**	**81**
SD	**0.701**	**0.78**	**15.57**	**0.7**	**162.71**	**439.99**	**1.61**	**4.56**
CV	**0.09**	**0.03**	**0.23**	**0.09**	**0.11**	**0.15**	**1.06**	**0.07**

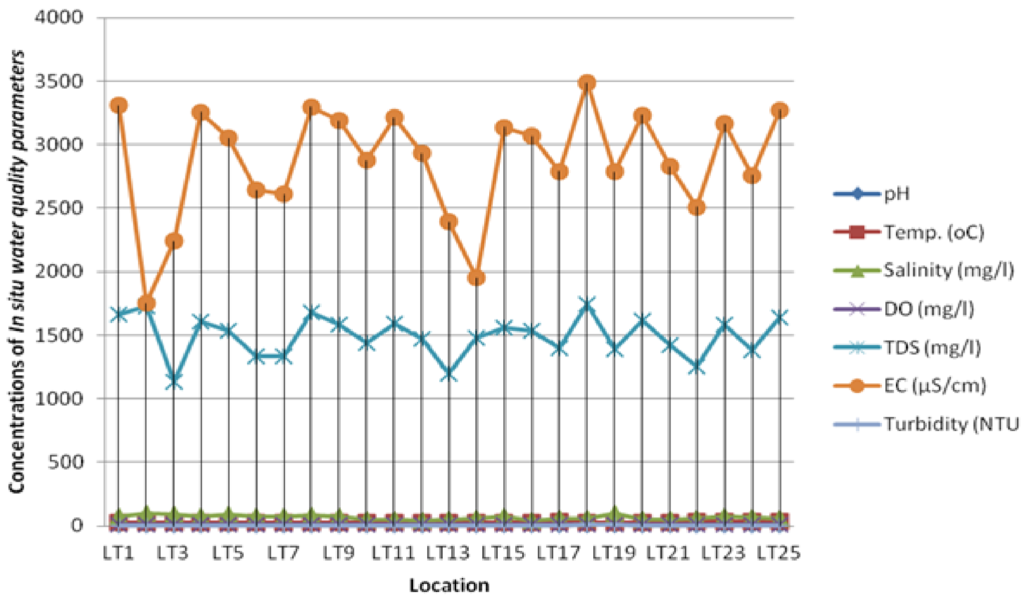

Figure 2. Combined readings recorded for all *In situ* water quality parameters measured

Temperature: Water temperature ranged from 27.3°C – 30.8°C with the mean of 28.576±0.78, which is an ideal temperature for the thriving of flora and fauna of similar ecological zones within the equatorial region of West Africa. This temperature enhances growth rate of marine organisms as confirmed by Boyd et al. (2013). Optimal temperature range requirement studies elswhere carried out on distribution and abundance of marine flora and fauna species showed that they survive optimally under temperature range of the dark brown zone similar to the results recorded for the Ibeno dark brown waters.

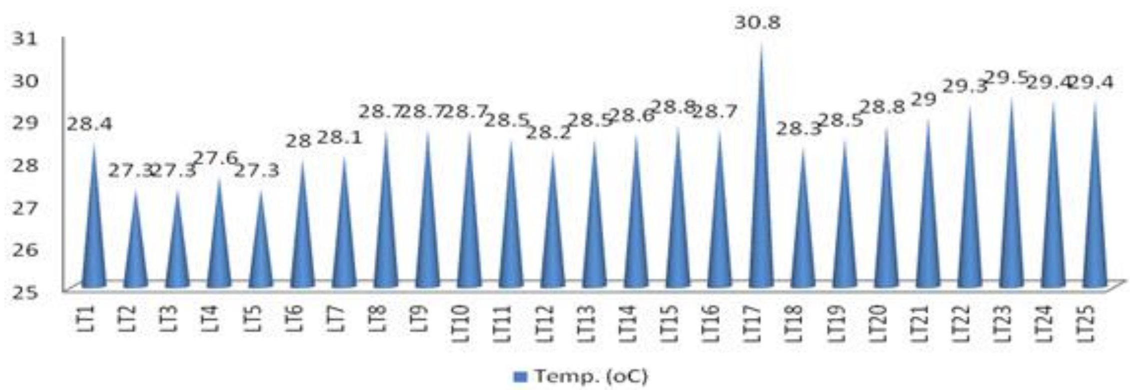

Figure 3. Water temperature within the equatorial region of West Africa

pH: pH ranged from 5.76 – 8.49 with the average of 7.568±0.70. The results showed mostly alkaline pH except at two locations. The minimum pH was found in LT_{18} while highest concentration was found in LT_9. The recorded values of pH did not comply with the WHO standard of 6.5 – 9.0 at locations 11, 18 and 19. The factors like air temperature bring about changes in the pH values of water. The mean recorded pH can regulate algal abundance and distribution in marine environment as supported by Chen and Durbin (1994).

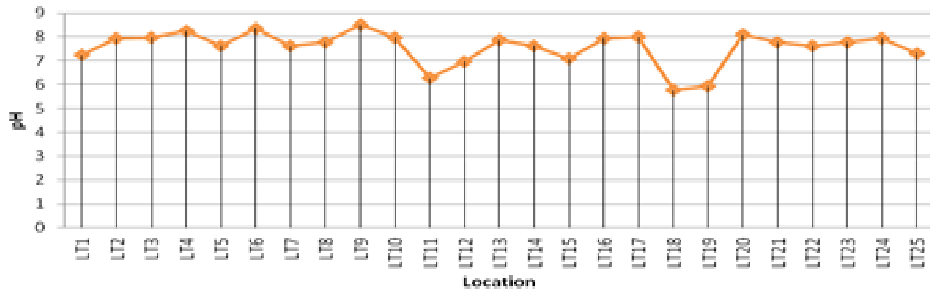

Figure 4. pH ranged from 5.76–8.49 with the average of 7.568±0.70

Electrical conductivity (EC) [μS/cm]: The conductivity in dark brown water samples ranged from 1752 - 3485 μS/cm with the mean of 2869.32±439.99. The minimum conductivity value was found in LT_2 (1752μS/cm) whereas maximum value is found in LT_{18} (3485 μS/cm) sample. The conductivity values obtained from dark brown water analysis did not meet the WHO guideline values of conductivity of safe drinking water (WHO, 2006; Chughtai et al., 2014).

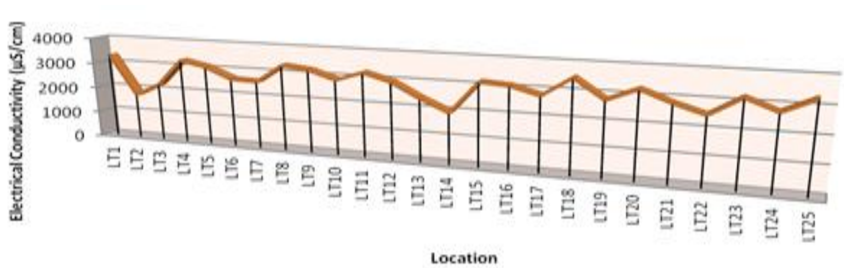

Figure 5. Electrical conductivity (EC) [μS/cm]

Turbidity (NTU): Turbidity is a measure of the appearance of a water body in terms of colour, as a result of suspended substances-essentially colloidal and particulate matter, which ultimately reduce the growth rate of marine life. The measured turbidity values of the dark brown water of the study area varied between 0.22 and 5.67 NTU with the mean of 1.5136±1.61. This water body of the study area is therefore adjudged considerably clearer or less as compared with a similar environment in Penang Island, Malaysia, as reported by Gasim et al. (2013).

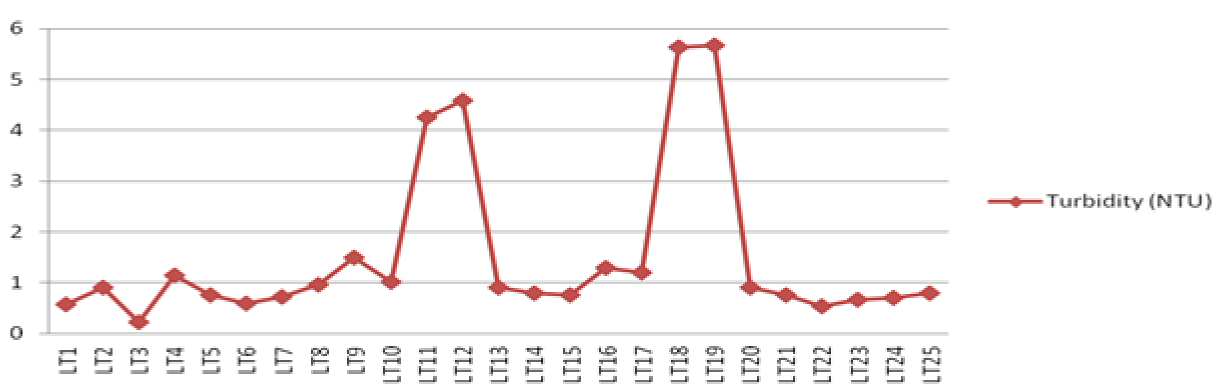

Figure 6. The measured turbidity values of the dark brown water of the study area

Dissolved oxygen (DO) [mg/l]: The values of dissolved oxygen ranged from recorded for the study area ranged between 6.17 - 8.50 mg/l for the 25 stations, with an average value of 7.41±0.7mg/l. The lowest value was observed in LT_{12} sample and the highest value was observed in LT_1 sample. The recorded values of DO were in line with New York State Department of Environmental Conservation (NYSDEC) [2008] recommended values for the optimal biological conditions for similar environments elsewhere in the World.

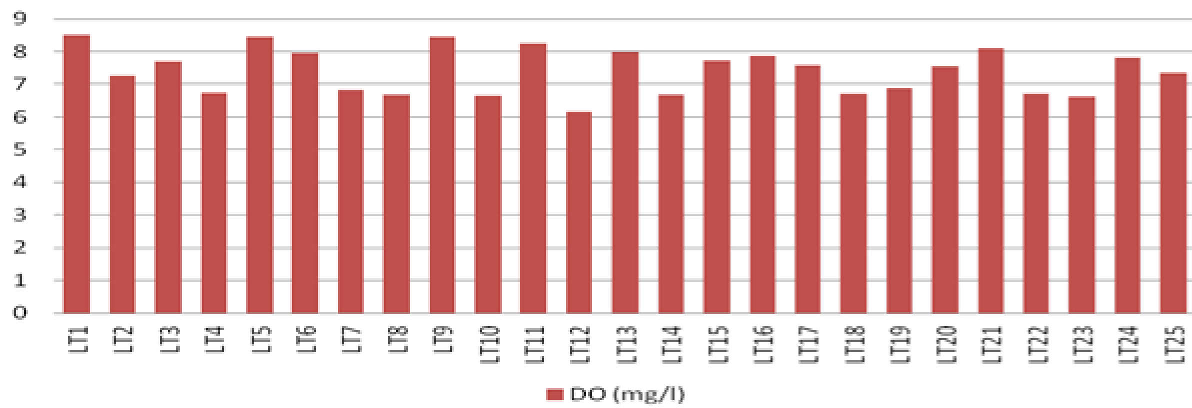

Figure 7. The values of dissolved oxygen recorded for the study area

Total Dissolved Solids (TDS): The recorded values TDS ranged between 1131 and 1746 mg/l with the mean of 1491.72±162.71 and were found to be higher than the WHO limit. The minimum concentration found in LT_3 whereas maximum concentration was found in LT_{18} sample. Total suspended solids play a vital role in determining transparency values of natural water bodies. There is usually an inverse relationship between the TDS and transparency. This implies that high TDS results in lowered transparency, which in turn reduces the extent of sunlight penetration in such waters. Ultimately, this results indirectly to low primary productivity, as there will be less sunlight energy for the phytoplanktons to carry out photosynthesis.

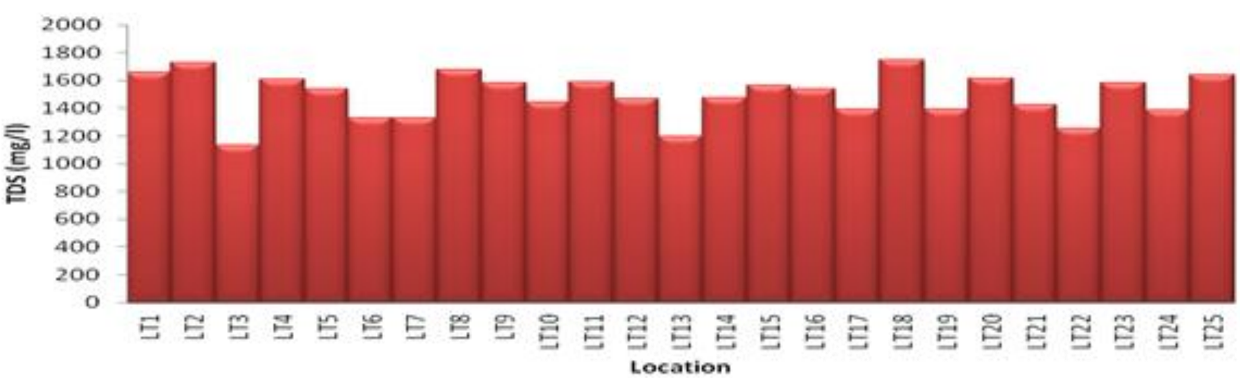

Figure 8. Total Dissolved Solids (TDS) in the study area

Salinity: The recorded values of salinity ranged from 41.0 and 93.6 mg/l with the average of 66.372±15.57, which is within the WHO limits for similar environment. The minimum concentration found in LT_{16} whereas maximum concentrations were found in LT_2 and LT_{19} samples. Salinity essentially is a measure of the amount salt dissolved in water. Several factors which essentially include the amount of fresh water inflow into the marine environment either from rainfall, fresh river systems or melting glaciers for the temperate regions are major determinants of the salinity levels of most marine waters. Evaporation/evapotranspiration could also play a role.

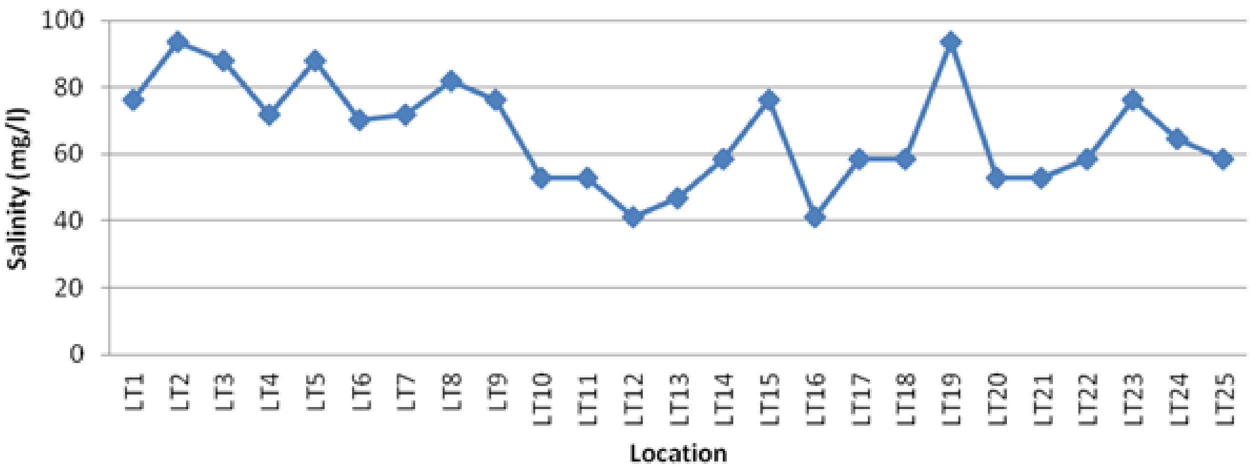

Figure 9. Total recorded values of salinity

Effects of changes in salinity on aquatic organisms osmotic balance and by extension metabolic rates, such as fish has been proven experimentally. Barton (1987) reported such an experiment conducted with the Sheepshead minnow (*Cyprinodon varuegatus*), which is euryhaline in nature; meaning it is able to adapt to a wide range of salinities. This research has demonstrated the extent to which changes in osmotic regulation based on salinity regulation can be tolerated by changes in metabolic rates (measured by changes in oxygen consumption). In the specific experiment as reported by Barton (1987), it was noted that by placing the minnows in water of varying salinity (10% and 35%) and measuring changes in dissolved oxygen content to determine the amount of oxygen consumed, the result showed that the fishes (minnows) exposed to a lower salinity of 10% had the greatest oxygen consumption. It is therefore realistic to conclude that reduced salinities are associated with increased metabolic rates, as these elevated rates are required for osmotic adjustment. This study is of importance as it quantifiably demonstrates how changes in salinity can affect the metabolism of marine organisms such as minnows.

4. Conclusion

In situ physico-chemical water quality parameter measurements of any water body that is a habitat for aquatic organisms, like the Ibeno marine dark brown water zone of Akwa Ibom state, Niger Delta Nigeria, constitutes one of the basis for rapidly and indirectly assessing the pollution status of such environment. This is because the results of the parameters measured are largely influenced by the nature and volume of extraneous physical and chemical substances (pollutants) materials that impacts on the water. In cases of significant or extreme pollution, the physico-chemical water quality parameters measured as in this study would have generally been at extremely high levels, but the reverse was the case, judging from the results of the study. Therefore, the results generally conformed recommend global standards by WHO (2008). Therefore, it can reasonably be concluded from the results of this study, that though Ibeno is a dark brown water zone due to obvious pollutant effects; pollution impacts on it's water quality are not overwhelming. Consequently, the Ibeno dark brown water zone of Akwa Ibom state, Niger Delta Nigeria is not significantly polluted. However, further studies are recommended to complement the findings of this study. Specifically, aspects of such studies may include heavy metal analysis in water, biota and sediments in order to adequately profile the pollution status of the environment and be able to improve knowledge about future environmental and human health impacts in the water.

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