DOI: https://dx.doi.org/10.4314/gjpas.v31i1.1

GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 31, 2025: 1-12
COPYRIGHT© BACHUDO SCIENCE CO. LTD PRINTED IN NIGERIA ISSN 1118 – 0579, e-ISSN: 2992 - 4464
www.globaljournalseries.com.ng, Email: globaljournalseries@gmail.com

COMPARATIVE STUDY OF PHYSICO-CHEMICAL PARAMETERS ON NATURAL AND ARTIFICIAL FISH HABITATS IN CALABAR SOUTH, CROSS RIVER STATE, NIGERIA.

INYANG-ETOH, ANIEMA P., AGI-ODEY, EDAK K., EMEKA, VICTORIA I., ODUM, CAROLINE J., TSEGBA, WILFRED M.
Email: aniemainyangetoh@yahoo.com

(Received 7 November 2024; Revision Accepted 5 December 2024)

ABSTRACT

This study was conducted to investigate the physico-chemical parameters of natural and artificial fish habitat in Calabar South. Ten (10) physico-chemical parameters were investigated. Parameters such as temperature, dissolved oxygen, turbidity and hydrogen ion concentration were measured *insitu* from artificial and natural habitats. Results obtained from this study showed that, temperature from the University of Calabar Fish Pond (artificial habitat) were between 28.4-29.3^{0}C, with a mean value of 28.83±5.36^{o}C, while that of the Calabar river (natural habitat) were between 29.44-29.62^{0}C, with a mean value of 29.54±5.44^{o}C. Dissolved oxygen ranged between 3.0-3.9mg/L, with a mean value of 3.83±1.96mg/l from the artificial habitat and between 3.40-3.48mg/L, with a mean value of 3.43±1.85mg/L in the natural habitat. Phosphate concentration was between 0.044-0.075mg/L in the University of Calabar fish pond, with a mean value of 0.063±0.25mg/L, while in the Calabar River, phosphate ranged between 0.029-0.048mg/l, with a mean concentration of 0.041±0.02mg/L. In the Calabar River, sulphates ranged between 0.082-0.088mg/L, with a mean concentration of 0.253±0.16mg/L, while in the University of Calabar fish pond, sulphates ranged between 0.032-0.083mg/L, with a mean concentration of 0.062±0.25mg/L. There was no statistically significant difference ($p<0.05$) in the levels of physico-chemical parameters between the two fish habitats. The ranges of the physico-chemical parameters in this study were within FEPA and WHO permissible limits for aquaculture practices. However, to improve on the ecological status of the habitats, it is recommended that proper management and monitoring of waste that goes into the systems should be undertaken by individuals and the government and their relevant agencies.

KEYWORDS: Comparative study, Physico-Chemical Parameters, Natural, Artificial, Fish Habitat, Calabar South.

INTRODUCTION

Rivers are natural streams of freshwater originating from sources such as rainfall, melting snow or springs that flows in a channel with defined banks, typically moving downhill due to the forces of gravity, and ultimately emptying into other water bodies such as sea, ocean, lake or another river.

Ponds, on the other hand are natural or man-made water bodies with an area that is usually between 1m^2 and 2ha (approximately 5 aces or 20,000 m^2) and holds water for upwards of 4 months in a year (Biggs 2005; Ehiagbonare & Ogunrinde, 2010). Water quality generally refers to the component of water which must be present for optimum growth of aquatic organisms (Ehiagbonare & Ogungiran 2010).

Inyang-Etoh, Aniema P., Department of Mariculture and Marine Fisheries Resources, Faculty of Oceanography, University of Calabar, Calabar, Nigeria.
Agi-Odey, Edak K., Department of Physical Oceanography, Faculty of Oceanography, University of Calabar, Calabar, Nigeria.
Emeka, Victoria I., Department of Physical Oceanography, Faculty of Oceanography, University of Calabar, Calabar, Nigeria.
Odum, Caroline J., Department of Fisheries and Aquaculture, Faculty of Agriculture, University of Calabar, Calabar, Nigeria.
Tsegba, Wilfred M., Department of Science Laboratory Technology, Faculty of Biological Sciences, University of Calabar, Calabar, Nigeria.

Water quality, as a critical aspect of aquatic ecosystems, encompasses the physical, chemical and biological attributes of water bodies (oceans, rivers streams, lakes, ponds or reservoirs) and determines its suitability for various uses such as drinking, swimming and the health of aquatic ecosystems for the culture and growth of organisms (Levin *et al*., 2009).

Physico-chemical parameters, an integral component of ponds and rivers, have the tendency to influence and impair the physiological functions of the organisms that form its biotic community, if their loadings exceed the threshold values (Sharmin *et al.,* 2018). Key parameters, which include temperature, pH, dissolved oxygen (DO), salinity, conductivity, total alkalinity, total hardness, turbidity and the presence of contaminants such as heavy metals, organic and inorganic substances, and nutrients (sulphates, nitrates, ammonium, chlorides, silicates and phosphates) (Mann, 2000), are variables and do not exist independently. Geogenic, anthropogenic and other environmental stressors are the usual culprits for shifts in their levels of concentration especially when there are disturbances like leakage of septic tank into water system, fertilizer and pesticides run-offs, industrial effluents and wastes from various sources which impact aquatic ecosystems and their biotic community (Reese and Voshell, 2002).

A water body, whether ocean, sea, river, stream, lake or pond, is the home of fishes, and its quality is one of the most overlooked aspects of management. They are continuously subjected to the influence of physico-chemical parameters which over time exert effects that endanger the overall wellbeing of living communities. Monitoring them to understand the levels of perturbation by anthropogenic or geogenic activities is very crucial to ensure proper management, ecosystem protection, preservation and sustainability. Using regulations and guidelines set by either national or international bodies, this management could be done by monitoring these parameters to see how deviated they are from their standard values (Reese and Rosenberg 2005).

Since the quality of water plays a vital role in the productivity of aquatic organisms, including fishes (Unanam and Akpan, 2006), an understanding of the water quality serves as a basis for considering whether the water is rich or poor for biological productivity (Ufodike and Garba, 1992) as poor water quality can result in eutrophication and habitat destruction thereby endangering health of aquatic life forms.

This research therefore seeks to compare some physico-chemical parameters of natural and artificial fish habitats in Calabar South, Calabar, Nigeria to determine which conditions are more conducive to fish health, and by extension the ecosystem health, as well as provide insights for habitat management strategies based on findings from this study.

MATERIALS AND METHODS

To conduct this study, one sampling station each was set up at the University of Calabar Fish Pond and the Nsidung sector of the Calabar River in Calabar-South Local Government Area of Cross River State, Nigeria. The study area has a land mass of 264km^2. Geographically, Calabar South lies between latitude 4^0 25' and 5^0 10 of the equator and longitude $8^0$20' and $9^0$08' East of prime meridian (Afangide *et al*. 2010). It has its headquarter in Anantigha. The Local Government is bounded in the north by Calabar municipality, in the South by the Republic of Cameroon, in the east by Akpabuyo Local Government Area and in the West, by the Calabar River (Afangide *et al*. 2010) (Fig. 1). The climate of the area is characterized by a dry season between November to February and rainy season from March to November. During the remaining period of the year, the lower reaches of the river is influenced by semi-diurnal ocean tides (Akpan, 2000). The vegetation of the studied area is generally made of tropical rain forest. Mangroves with major species such as *Avencinia africana* and *Rhizophora racemose* form part of the vegetation in the area especially bordering the Great Kwa and Calabar river flood plains (Holzloehner *et al.,* 2002). The Nypa palm (*Nypa fruticans*) and *Pandamus* constitute among the other trees and shrubs of the mix vegetation of the area (Holzloehner *et al.,* 2002).

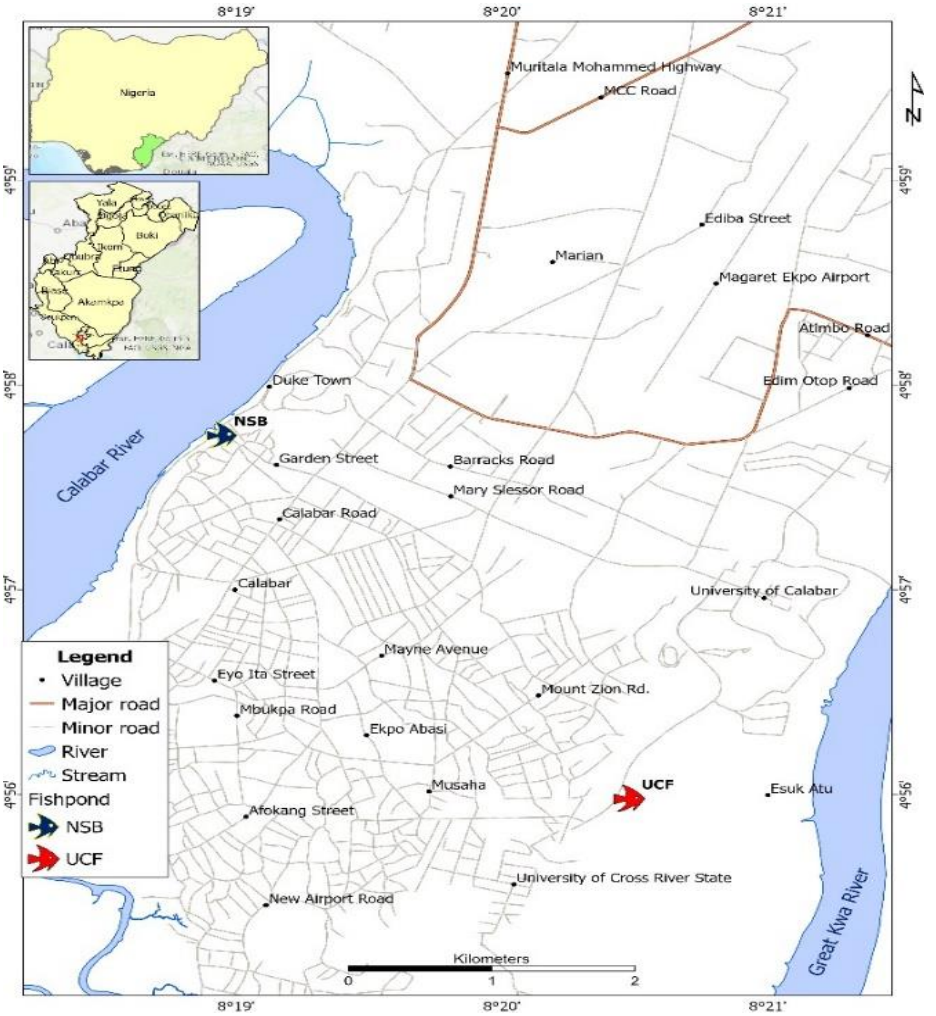

Fig. 1: Map of Calabar South, showing sampling locations

FIELD STUDY

Sampling

For three months of April – June between the hours of 0700 and 0900, 1 litre sterile plastic bottles were used to collect water samples bi-monthly for the analyses of nitrates, phosphates and sulphates from the sampling point set up at the Nsidung beach and the fish pond at the University of Calabar. Collected samples were stored in ice-chest and taken to the Central Analytical laboratory of the Department of Physical Oceanography, University of Calabar, Nigeria, for analysis. Prior to this, fast -changing parameters like pH, DO, temperature, transparency, salinity, and conductivity were measured *in-situ* using their standard measuring equipment. Temperature was measured using mercury-in-glass thermometer. Dissolved oxygen meter, model WTW OX 196 was used to measure the amount of amount of oxygen dissolved in the waters of these habitats. While conductivity was measured using a conductivity meter (model: EHWTWPH 90 meter), salinity was measured using a salinometer (model: WQ P4).

LABORATORY STUDIES

At the laboratory, total alkalinity and concentrations of sulphate, phosphate and nitrates were determined immediately, within 48 hours.

Sulphate

Concentration of sulphate in the surface water, was determined using the following
procedures:

A stock solution was prepared by dissolving 721.8mg (0.722g) of potassium nitrate in 100ml of distilled water. A standard nitrate solution was obtained by evaporating 50ml of the stock solution to dryness in a water bath. The residue was dissolved in 2ml of phenol disulphonic acid, making up to 500ml volume. The prepared solutions (from the 500mL) of various strength ranging from blank 0.0mg/L (distilled water only), 0.1mg/l, 0.2mg/L and 0.4mg/l respectively, was done by diluting 1ml of the prepared solution with 1ml, 2ml and 4ml of distilled water. These give the different strengths of the solution which was used for the test.

These was kept safe at 40°C in a refrigeration prior to the test and evaporated to dryness. 50ml volume of the water sample in a porcelain dish using water bath (a pipette of suitable volume was used to transfer the water sample into the porcelain dish). 2ml of phenol disulphonic acid was added to dissolve the residue with constant stirring with glass rod. Concentrated solution of sodium hydroxide (NaOH) and distilled to the residue containing 2ml of phenol disulphonic acid with constant stirring until an alkaline solution was obtained (red litmus paper turns blue). The solution was filtered into a Nessler's tube using Whatman No. 1 paper and made up the 500ml with distilled water. Final reading of the concentration of nitrate was done using photospectrometer at 410nm wavelength (APHA, 2000).

Phosphate

Phosphate loading in the surface water was determined using a prepared standard stock solution of phosphorus of approximately 100mg of phosphorus/dm^2 (100ml). This was done by accurately measuring and dissolving 0.11g of KH_2PO_4 (Potassium Hydrogen Phosphate) in distilled water and diluting to 250cm^3 volume in a volumetric flask (stock solution A). 10cm^3 of the solution was transferred into a 250cm^3 volumetric flask (stock solution) making up to 100ml with distilled water. Stock solution B was used to prepare standards of approximately 0.2, 0.4, 0.6, 0.8 and 1.0mg P/dm^3 (that is pipetting 5,10,15,20 and 25cm^3) portions of solution B, respectively. This was separated and properly labeled using 100cm^3 volumetric flask. 50cm^3 of distilled water was placed into a 100cm^3 flash as a blank solution. The phosphate concentration was read using spectrometer at a wavelength of 830nm.

Nitrates

For nitrates, samples of water were filtered to remove impurities. 60ml of sample was passed through a cadmium reduction column and 50ml was collected to which 2ml of sulphuric acid reagent was added. It was thoroughly mixed and left to stand for 5 minutes after which 1ml of NED [N(1-nephyl) ethylenediamine dihydrochloride] reagent was added. Upon mixing, the extinction was measured after 20 minutes at 540nm against a blank using UV-visible spectrophotometer.

Alkalinity

Alkalinity was determined by tritration method.

Statistical analysis

Upon the completion of all analyses, calculations were made for all measured indices and their mean values were recorded. Obtained data were analysed using the Pearson correlation statistics at 0.05 level of significance following Ogbeibu (2005).

RESULTS

Physico-chemical parameters of University of Calabar Fish Pond (artificial fish habitat)

The determination of water quality is necessary when baseline conditions and standards are to be set as results from future studies are usually evaluated against these baseline data and standards. The results of the physico-chemical parameters of artificial habitat are shown in Table 1.

Temperature (°C) of the pond ranges from 28.4 - 29.3^{0}C, with an average value of 28.83±5.36°C. Dissolved oxygen (mg/L) was between 3.0 - 4.9mg/L, with a mean value of 3.83±1.96mg/L. Turbidity (transparency), with a mean value of 27.4±5.235cm, ranged between 17.42 - 17.48cm. Salinity ($^0/_{00}$) was 0.0$^0/_{00}$. The Hydrogen ion concentration, pH, was between 7.2 - 7.4, with a mean value of 7.30±2.70 while conductivity (µs/cm) with a mean value of 5.23±2.29µs/cm, ranged from 4.8-5.6µs/cm. Total alkalinity had a mean value of 10.73±3.27mg/L at a range of 10.7-10.8mg/L.

Values between 0.018-0.055mg/L and a mean value of 0.04±02mg/L was obtained for nitrates (NO_3) (mg/L) concentration. Phosphate (PO_4^{3-}) (mg/L) concentration, on the other hand was between 0.044-0.075mg/L with a mean value of 0.063±0.25mg/L. Ranges for sulphate (SO_4^2) (mg/L) loading was between 0.032-0.083mg/L, with a mean value of 0.062±0.25mg/L.

Table 1: Physico-chemical parameters of Artificial fish habitat (University of Calabar Fish Pond, Nigeria) (April-June 2021)

S/N	Parameters	Artificial Fish Habitat: University of Calabar Fish Pond, Nigeria.			
		April	May	June	Mean Value (±SD)
1	Temperature (°C)	28.8	29.3	28.4	28.83±5.36
2	Dissolved oxygen, DO (mg/l)	4.6	3.0	3.9	3.83±1.96
3	Turbidity (Transparency (cm)	17.42	17.45	17.45	27.4±2.23
4	Salinity ($^0/_{00}$)	0.0	0.0	0.0	0.0±0.0
5	Hydrogen ion concentration (pH)	7.4	7.2	7.3	7.30±2.70
6	Total Alkalinity (mg/l)	10.7	10.7	10.8	10.73±3.27
7	Conductivity (µscm)	4.8	5.6	5.3	5.23±2.29
8	Nitrates (NO_3^-) mg/l	0.018	0.046	0.055	0.04±0.2
9	Phosphates (PO_4^{3-}) mg/l	0.044	0.072	0.075	0.063±0.25
10	Sulphates (SO_4^{2-}) mg/l	0.070	0.083	0.032	0.062±0.25

Physico-chemical parameters of the Calabar River, a natural fish habitat.

The results of the physico-chemical parameters of a natural fish habitat are herein presented in Table 2. Temperature of the sampling station at the Calabar River were between 29.44 - 29.62°C, with a mean value of 29.54±5.44°C. Dissolved Oxygen ranged from 3.40-3.48mg/L, with a mean value of 3.43±1.85mg/L. Turbidity ranged between 27.4 - 27.8cm, with a mean value of 27.70±2.26cm. Salinity ranged between 0.31-0.44$^0/_{00}$ with a mean value of 0.39±0.62$^0/_{00}$. Hydrogen ion concentration (pH) was observed to range between 6.21 - 6.29, with a mean value of 6.25±2.5. Recorded total alkalinity mean value stood at 17.57±4.19mg/L at a value range of 17.42 - 17.83mg/L. Conductivity ranged from 144.32-149-4µs/cm, with a mean of 146.75±12.11µs/cm. Nitrate (NO_3) (mg/L) concentration in the Calabar River ranged between 0.028-0.042mg/L, with a mean value of 0.037±019mg/L. Phosphate (PO_4^{3-}) level is between 0.029-0.048mg/L, with a mean value of 0.041±0.02mg/L while sulphate (SO_4^{2-}) loading is between 0.082-0.088mg/L, with a mean value concentration of 0.253±0.16mg/L.

Table 2: Physico-chemical parameters of natural fish habitat of the Calabar River (April-June, 2021)

S/N	Parameters	Natural Fish: The Calabar River, Nigeria.			
		April	May	June	Mean Value (±SD)
1	Temperature (°C)	29.44	29.62	29.55	29.54±5.44
2	Dissolved oxygen, DO (mg/L)	3.42	3.40	3.48	3.43±1.85
3	Turbidity (Transparency (cm)	27.4	27.8	27.8	27.70±5.26
4	Salinity ($^0/_{00}$)	0.42	0.44	0.31	0.39±0.62
5	Hydrogen ion concentration pH	6.21	6.26	6.29	6.25±2.5
6	Total Alkalinity (mg/L)	17.42	17.47	17.83	17.57±4.19
7	Conductivity (µscm)	144.32	146.52	149.41	146.75±12.11
8	Nitrates (NO_3^-) mg/L	0.028	0.042	0.041	0.037±0.19
9	Phosphates (PO_4^{3-}) mg/L	0.029	0.048	0.045	0.041±0.20
10	Sulphates (SO_4^{2-}) mg/L	0.082	0.083	0.088	0.0253±0.16

Mean concentrations comparison of both habitats against recommended standards.

The mean concentrations of the physico-chemical parameters from the respective habitats have been summarized and presented in Tables 3 and 4 and compared with the permissible limits of FEPA (1991) and WHO (2003). Generally, there was no significant difference ($P<0.05$) in the physico-chemical parameters between the two fish habitats.

Temperature (°C)

The mean temperature value was higher (29.54°C) in the Calabar River than in the University of Calabar pond (28.83°C) but were within the permissible limits of FEPA (1991) and WHO (2003).

Dissolved Oxygen (mg/l)

In the University of Calabar pond, DO concentration was higher standing at 3.83mg/L, while the Calabar River's had a mean value of 3.43mg/L was lower. They are however, still within the threshold values of FEPA and WHO.

Turbidity (cm)

Turbidity mean value in the natural fish habitat slightly exceeded that of the artificial pond with mean values of 27.70±2.26cm and 27.40±5.23cm respectively. Nonetheless, they fall within the FEPA/WHO acceptable limits of 1-150cm.

Salinity ($^0/_{00}$)

The pond water of the University of Calabar pond was devoid of any salt. Nevertheless, the Calabar River had a mean salinity of 0.039±0.62$^0/_{00}$ and was higher than the threshold value range of 0.00-0.10$^0/_{00}$ recommended for aquaculture practices.

Hydrogen ion concentration, pH

The mean pH value of 7.30±2.70 was obtained for the University of Calabar fish pond with 6.25±2.5 for the Calabar River which are both within the ranges recommended by FEPA for aquaculture practices of between 5.0-9.0.

Electrical conductivity (µs/cm)

5.23±2.29µs/cm is the mean value of conductivity for the University of Calabar fish pond and 146.75±12.11µs/cm for the Calabar River. As with most of the parameters investigated, these values are within the threshold between 20-1500.0µs/cm set by FEPA/WHO for aquacultural practices.

Nitrates (mg/L)

Nitrates mean values of 0.04±0.2mg/l and 0.37±0.19mg/l have been obtained respectively for the artificial and the natural habitats. These levels are elevated when compared with the guidelines referenced in this research.

Phosphates (mg/L)

Values that are within the tolerable limits (0.01-3.0mg/l) of FEPA (1991) and WHO (2003) for aquaculture practices were recorded for both habitats investigated. For the University of Calabar pond it was 0.063±0.25mg/l and stood at 0.041±0.02mg/l in the Calabar River.

Sulphates (mg/L)

Sulphates mean values of 0.062±0.25mg/l and 0.253±0.16mg/L are herein reported for the University of Calabar pond and the Calabar River respectively. They pale in comparison to the 1000mg/l set by FEPA and WHO for aquaculture practices.

Total Alkalinity (mg/L)

Elevated levels of total alkalinity exceeded FEPA's and WHO's allowable limits of 10.4mg/L with the artificial habitat having a mean value of 10.73±3.27mg/L at a range of 10.7-10.8mg/l while the natural habitat had a mean value that stood at 17.57±4.19mg/L at a value range of 17.42 - 17.83mg/L. These variations have all been pictorially depicted in Figure 2.

Table 3: Summary of the mean values of the physico-chemical parameters in artificial and natural fish habitats (University of Calabar Fish Pond, Nigeria) against two standards.

S/N	Physico-chemical Parameters	Artificial Fish Habitat: University of Calabar Fish Pond	Natural Fish Habitat: The Calabar River	Permeable Limits of FEPA (1991) and WHO (2003)
1	Temperature (°C)	28.83	29.54	20-35
2	Dissolved Oxygen (mg/L)	3.83	3.43	> 1.0
3	Turbidity (Transparency) (cm)	17.45	27.70	1.0-150
4	Salinity (%)	0.0	0.39	0-0.10
5	Hydrogen ion Conc. pH	7.30	6.25	5-9
6	Total alkalinity (mg/L)	10.73	17.57	10.400
7	Conductivity (µs/cm)	5.23	146.75	20-1500
8	Nitrates (NO_3^-) (mg/L)	0.04	0.37	≤ 0.01
9	Phosphates (PO_4^{3-}) (mg/L)	0.063	0.041	0.01-3
10	Sulphates (SO_4^{2-}) (mg/L)	0.062	0.253	1000

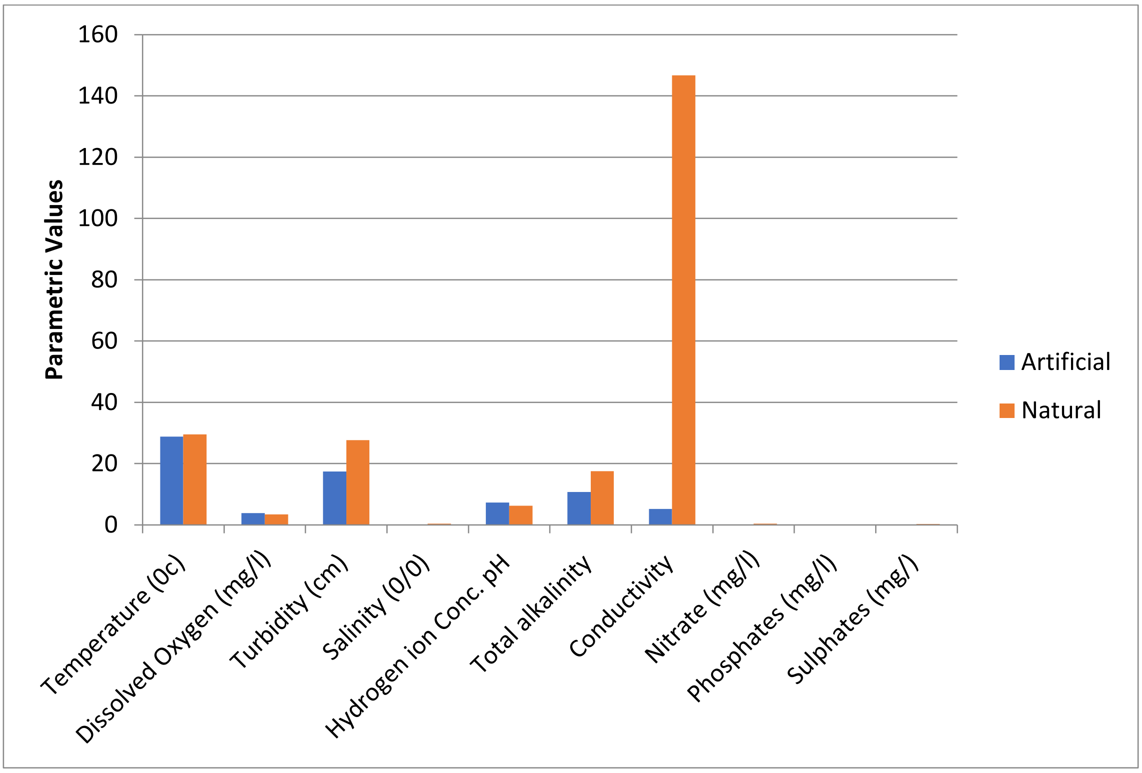

Fig.2: Variations in the mean values of physico-chemical parameters in the fish habitats.

DISCUSSION

Physico-chemical parameters of water bodies, whether artificial or natural, are crucial in defining their health and functionality as they can influence the biological and chemical processes within these systems. Each parameter is known to interplay with one another to enhance the functionality of the system. DO for instance is affected by temperature and salinity *(Belal et al., 2017)*.

Temperature

Temperature is very crucial to the amount of oxygen present in a given water body. The mode of metabolism and other associated mechanisms of thermal adaptation of organisms are dependent on temperature (Ekau *et al*., 2010). It has a direct effect on aquatic life and an indirect influence on the other environmental factors such as dissolved oxygen and nutrients. Fish are ectothermic. As such, water temperature directly affects their metabolic rate, growth and survival (Chibana, 2014). Sudden changes in temperature can stress and/or kill fish.

The result of this study f*alls within the range* with that of Belal *et al*. (2017) who reported a temperature range of 19.0°C – 32.70°C with a mean value of 25.85±5.08°C when studying the effect of water quality on the distribution of macro benthic fauna in Western Lagoon and Timsah Lake in Egypt. Ndome *et al.* in their 2012 study on the ponds in Aquavista, Calabar, Cross River State also reported a temperature range of 20.2°C – 30.0°C. Increase in temperature tends to decrease the solubility of oxygen in water (Abdel-Gawad and Mola, 2014).

The high temperatures in the month of May in University of Calabar fish pond might have been as a result of solar radiation observed on the day of sampling on the pond water. Though the temperature ranges obtained for the pond water surface were within the permissible limits of Federal Environmental Protection Agency (FEPA, 1991) and WHO (2003) for aquaculture practices, the high value in the month of May coincided with the values obtained in the Calabar River throughout the period of study. Several reasons, in addition to solar radiation, have been advanced as a premise for this scenario, notably physical transport processes and biological, chemical, biochemical and physical conversion processes (Uzoigwe and Nnawuihe, 2020). Again, sampling the two water systems was not done on the same sampling day. The occurrence of t*he changes in variation of* the Calabar River throughout the period of sampling, interplayed with the scenarios mentioned above, and might have been the reason for the high temperature in May in the University of Calabar Fish Pond and what was observed in all the months of sampling in the Calabar River. This agrees with Ojikutu *et al*. (2013) in Minna, Niger State Nigeria, and Wang *et al*. (2013) in China.This study agrees with that of (Inyang-Etoh *et al*. (2024) who reported a temperature range of artificial and natural fish habitats to be 26.33 ± 0.57 to 29.00 ± 1.00 and 26.33 ± 0.57 to 29.33 ± 1.15 respectively when studying the physico-chemical parameters in Calabar metropolis. In another study, Inyang-Etoh et al.

(2024) also reported a temperature range of two artificial habitats to be 25.33 ± 0.33 to 25.67 ± 0.33 in Calabar South. Cold weather on the days of sampling might have contributed to the observed slight low temperatures of the surface water of the pond. This phenomenon was previously reported by Ojikutu *et al.* (2013) in artificial water bodies (Dams) in Minna, Niger State, Nigeria.

Dissolved Oxygen

Dissolved oxygen is the measure of the amount of gaseous oxygen that can dissolved in an aqueous solution. Fish require sufficient DO for respiration. The ranges of the dissolved oxygen concentration obtained in this study are also in agreement with those of Haruna and Solomon (2015) who reported that dissolved oxygen concentration of a tropical stream in Abuja, Nigeria, was between 3.6 – 4.8mg/L with a mean of 4.2±2.04mg/L. The amount of dissolved oxygen used up by biological organisms gives rise to biochemical oxygen demand (Clair *et al*., 2003). Inyang-Etoh *et al*., (2024) also reported the dissolved oxygen of both artificial and natural fish habitats to be 3.50 ± 0.26 and 3.46 ± 0.25. These lower concentrations in the dissolved oxygen in the natural fish habitat (the Calabar River) might have been as a result of increased biological activities absorbing more dissolved oxygen than in the artificial habitat (the University of Calabar Fish Pond). Inyang-Etoh *et a*l. (2024), in another study also reported a dissolved oxygen range of two artificial fish habitats in Calabar South to be 3.02 ± 0.33 to 3,90 ± 0.06. Similar observations were made by Haruna and Solomon (2015) in a tropical stream (a natural fish habitat) in Abuja, Nigeria.

Similarly, human activities, photosynthesis, run-offs, respiration, diffusion and decomposition that usually occur differentially in different aquatic habitats might have influenced the concentration of the dissolved oxygen in both habitats during the period of study as previously reported by Uzoigwe and Nnawuihe (2020) in Otamiri River, Imo State, Nigeria, and Haruna and Solomon (2015) in a tropical stream in Abuja, Nigeria.

Turbidity

Turbidity is of great concern in an aquatic ecosystem because an increase within few meters in an open river system implies less penetration of sunlight into the subsurface depths (Williams and Benson, 2009). In both fish habitats, the ranges of turbidity observed in this study were quite high though within acceptable limits. High turbidities of this nature are associated with high dissolved organic matter, run-offs and human activities (Williams and Benson, 2009; Wang *et al*., 2001). Such high turbidities have been observed by Williams and Benson (2009) who reported turbidity ranges of 18.4 – 30.6cm while studying the physico-chemical parameters in Qua Iboe River Estuary, a natural tropical fish habitat in Nigeria.The tubidity in this study does not agree with that of Inyang-Etoh *et al*.,2024) who reported higher turbidities of both artificial and natural fish habitats to be 43.00 ± 11.00 and 74.33 ± 10.40 respectively. Wang *et al.* (2001) also reported a high turbidity range of between 17.6 – 37.4cm in Hanshui River, China. Inyang-Etoh et al. (2024) in a study in Calabar South also reported turbidity of two artificial fish habitats to bebetween 94.93±13.05 and 172 .00 ±33,53 respectively.

Salinity

One of the most variable physico-chemical parameters in the aquatic ecosystem is salinity (Francis *et al.*, 2007). Euryhaline fish are tolerable to wide salinity ranges while stenohaline fish have narrow tolerances (Chibana, 2014). The Calabar River has been reported to have low dissolved chemical content (salinity range < 1.0-7.13 ppt) and that the values usually decrease from January through August (Asuquo, 1989). In the present study, salinity was observed to fluctuate between 0.31 - 0.44$^0/_{00}$ in the Calabar river, with a constant reading of 0.0$^0/_{00}$ in the University of Calabar fish pond throughout the period of study. Similar low salinity values have been previously reported in the Calabar River by Ekpenyong (2009) with a range of 0.38 – 0.57$^0/_{00}$. Thirumola *et al.* (2011) also reported similar salinity ranges of 0.11 – 0.69$^0/_{00}$ in Bhandra reservoir, an artificial fish habitat in India.

In aquatic ecosystems, changes in salinity have the tendency to affect the relative diversity and abundance of organisms (Williams and Benson, 2009). Depending on the geological background of the locality, water level and other prevailing aquatic ecosystems, salinity is known to generally vary from few grams to > 300g/l (> 0.3$^0/_{00}$) (Williams and Benson, 2009). This agrees with the results obtained in the Calabar river during the period of the study. The Calabar river being an open aquatic ecosystem, experiences low tidal dynamics and hence, variability in the chemical constituents (Asuquo, 1989). The ranges of the salinity recorded therefore agrees with the of previous report of Offiong & Edet (1998). The salinity values obtained for the University of Calabar fish pond, agrees with those of Unanam and Akpan (2006) portraying an unpolluted ecosystem with no source of ionic constituents and inputs.

pH and Alkalinity

Hydrogen ion concentration (pH) is one of the most important water quality parameters that has been found to have profound effects on the ecology of biological life in aquatic systems (Hussain and Pandit, 2012). pH is a major factor in all chemical reactions associated with the formation and dissolution of minerals (Williams and Benson, 2009). It affects transformation processes of metal and nutrients and influences the toxicity of pollutants. It may however be affected by the presence of organic acids, biological processes (photosynthesis and respiration) and physical processes (turbulence and aeration), which can alter concentration of dissolved carbon (iv) oxide (CO_2) (Akpan, 2005; Offiong and Edet, 1998; Williams and Benson, 2009).

The sensitivity of biological life to pH is known to vary (Yuan, 2004). Values above 9.0 are considered harmful (Yuan, 2004; Thomsen and Friberg, 2002) as they can disrupt osmoregulation and damage fish gills. Low pH values are associated with lower diversity of organism (Hall et al., 1980; Hussian and Pandit, 2012), and increased toxicity to heavy metals and ammonia (Mishra *et al.,* 2023). High alkalinity results in physiological stress to consumers in the aquatic ecosystem and it is one of the causes of fish mortality (Unanam and Akpan, 2006). The pH of natural water is known to determine the solubility of chemical forms of most substances in water (Unanam and Akpan, 2006). Alkalinity of water is a measure of its capacity to neutralize acids to designated pH. The pH of the artificial fish habitat showed a suitable alkaline condition during the period of study, a condition which agrees with that of Unanam and Akpan (2006) in a fish pond in Essien Udim in Akwa Ibom State, Nigeria. Such alkaline condition is known to be suitable for aquaculture practices (APHA 1980, 1985; Hussain and Pandet, 2012). The results of this study are also in agreement with those of Ndome *et al.* (2009) who reported pH between 5.57 – 6.20 in an urban stream in Cross River State, Nigeria, and those of Unanam and Akpan (2006), who reported pH range of 6.18 – 6.32 in a tropical fish pond in Oruk Anam, Akwa Ibom State, Nigeria. Williams and Benson (2009) reported pH range of between 5.84 – 6.88 in Qua Iboe River Estuary, Nigeria, which also agrees the with the results of the present study.

The ranges of pH recorded (6.21 – 6.29) in the Calabar river (a natural fish habitat) is within the FEPA and WHO permissible limits for aquaculture practices, though the ranges may be indications of slight acidic scenario. The pH values recorded in the Calabar River fluctuated within the acceptable range for unpolluted water (Williams and Benson, 2009).

CONDUCTIVITY

Conductivity is known to increase as the ionic concentrations of water bodies increase (Haruna and Solomon, 2015) and according to Hem (1971) and Williams and Benson (2019), the presence of charged ionic species in solution makes the solution conductive giving rise to high conductivity (Haruna and Solomon, 2015).Conductivity values were generally higher in the natural fish habitat (the Calabar River) (range: 144.32 – 149.41µs/cm) than in the artificial fish habitat (the University of Calabar Fish Pond) (range: 4.8-5.6µs/cm). The conductivity values obtained for the artificial fish habitat (the University of Calabar fish pond) agrees with that of Unanam and Akpan (2006) while studying the physico-chemical characteristics of some freshwater bodies including fish ponds in Essien Udim in Akwa Ibom State, Nigeria. Also, the conductivity value obtained for the Calabar river are in corroboration with the range reported by Haruna and Solomon (2015) when they undertook water quality assessment of tropical freshwater system in Abuja, Nigeria.

Nutrients

The levels of nutrients in both the artificial and natural fish habitats were vari*ed*. Nitrates were generally higher in concentration in June in the University of Calabar fish pond with a value of 0.055mg/*L*. Also, a high nitrate value of 0.042mg/l was recorded in May in the Calabar River. High phosphate value (0.075mg/l) was similarly recorded in June in the University of Calabar Fish Pond with the Calabar River recording a high phosphate value (0.048mg/l) in May. The University of Calabar (artificial fish habitat) recorded a high value (0.083mg/l) of sulphates in May, with a high value (0.088mg/l) recorded in the Calabar River (natural fish habitat). These variabilities of the nutrients concentrations in the two fish habitats are normal and usual in unpolluted tropical fish habitats with disparities in geochemistry and biophysical processes such as drainage from the land of particulate matter, fertilizers, and domestic wastes (Haruna and Solomon, 2015). According to Asuquo (1998), higher levels of nitrates, particularly in an open natural water system like the Calabar river may be caused by faecal matter addition to the river and the inter-conversion (biochemical speciation) of nitrates into other nitrogenous forms, especially $NH^-{}_4$ (ammonium ions) in a chemically reduced environment. Since the levels of nutrients are within accepted limits, the quality of water in both systems are conducive and will support the optimal growth as normal levels of phosphate and sulphate encourage a balanced ecosystem where life forms, including fishes can grow adequately.

CONCLUSION

The results of the physico-chemical parameters in the natural fish habitat (the Calabar River) and the artificial fish habitat (the University of Calabar Fish Pond) were observed to exhibit variabilities during the period of study. These variabilities are common in unpolluted water bodies with differential geochemistry and biophysical processes.

Parameters such as temperature, turbidity, salinity, total alkalinity, conductivity, nitrate and sulphate were generally of lower concentrations in the artificial fish habitat (the University of Calabar Fish Pond) than in the natural fish habitat (the Calabar River). However, dissolved oxygen and phosphate were higher in concentration in the artificial fish habitat than in the natural.

In conclusion, the concentrations of the various physico-chemical parameters though variable, were within the permissible limits of FEPA for aquaculture practices. Nutrient levels are critical indicators of water quality. Their sources primarily stem from geogenic and anthropogenic activities. To sustain the good water quality reported in this work, maintaining a balance in nutrient levels is encouraged so as to maintain the conditions of water in these habitats as normal ranges of physico-chemical properties are crucial for supporting an overall healthy and balanced ecosystem. Deficiencies will limit productivity while excessive nutrient inputs will destabilize the ecosystem and cause eutrophication (algal bloom).

RECOMMENDATIONS

Since each of the fish habitats has different geochemistry, each of the parameters analyzed also showed differential range of values. These maybe due to the approaches of handling the habitats in terms of waste disposal.

Effective management strategies must consider these physicochemical parameters to preserve aquatic habitats. Therefore, to improve on the ecological status of the habitats, it is recommended that proper management of waste that goes into the systems be undertaken by individuals and the government. Monitoring and understanding their dynamics will easily help predict changes in ecosystem health as well as guide remediation and restoration efforts.

ACKNOWLEDGEMENTS

The authors would like to thank the technicians and the farm staff of the Department of Mariculture and Marine Fisheries Resources, University of Calabar and fishermen in Calabar river for their contributions towards the success of this research work.

REFERENCES

Abu-hand, A. S. and El-Moselhy, Kh. I., 2015. Seasonal variations of the physical and chemical properties of seawater at the northern red seas Egypt. Open Journal of Oceanography and Coastal Science, 2(1): 10-15.

Aken, H. M., 2008. Variability of the water temperature in the Western Wadden sea on tidal to centennial time scales. Journal of Sea Research, 60:227 – 234.

Akpan, E. R.., Offem, J. O. and Nya, A. E., 2002. Baseline ecological studies of the Great Kwa River, Nigeria 1: Physico-chemical studies. African Journal of Environmental Pollution and Health, 1(1):83-90

Alam, M. S., 1993. Ecology of the intertidal Macrobenthos of Halishahar coast, Chittagong, Bangladesh. A published Ph.D Thesis Department of Zoology, University of Chittagong, Bangladesh, pp243.

Ali, M.; Salam, A.; Jamshaed, S. and Zahara, T., 2003. Studies of Biodiversity in relation to seasonal variations in water of River Indus at Ghazi Punjab Pakistan. Pakistan Journal of Biological science, 6 (21): 1840 – 1844.

ANZEC, 2000. Australia and New Zealand Guidelines for fresh and Marine water quality. National Water Quality Management strategy. 4, 314.

Asuquo, F. E., 1989. Water quality of the Calabar River, Nigeria. Tropical Ecology, 30(1):31-40.

Asuquo, F. E., Oboho, I. E., Ausquo, E. F. and Udo, P. J., 2004. Fish species used as biomarker for heavy metal and Hydrocarbon Contamination for Cross River, Nigeria. Environmentalist, 24: 29-37.

Belal, A. A., El-Saway, M. A and Dar, M. A., 2017. The effect of water quality on the distribution of macro-benthic fauna in Western Lagoon and Timsah Lake, Egypt. Egyptian Journal of Aquatic Research, 42:437-448.

Biggs, J., Williams, P., Whitfield, M., Nicolet, P., and Weatherby, A., 2005. 15 years of pond assessment in Britain: results and lessons learned from the work of Pond Conservation. Aquatic conservation: marine and freshwater ecosystems, 15(6), 693-714.

Calabar South Local Government Accessed 18th June 20121, from https://www.crossriverhub.com/calabars-south

Chibana, T., 2014. Physicochemical properties of aquatic habitats from ecology and civil engineering perspectives. Landscape and Ecological Engineering, 10, 85-86.

Courtney, L. A. and Clement, W. H., 1998. Effects of acidic pH on benthic macro invertebrate communities. Hydiobiologia, 379:145-152.

Ekau, W., Auel, H., Portner, H. O and Gilbert, D., 2010. Impacts of hypoxia on the structure and processes in pelagic communities (zooplankton, macrobenthos and fish) Biogeosciences, 7:1669-1699.

Ehiagbonare, J. E., and Ogunrinde, Y. O., 2010. Physico-chemical analysis of fish pond water in Okada and its environs, Nigeria. African journal of biotechnology, 9(36).

Ezra, A. G. and Nwankwo, D. I., 2001. Composition of phytoplankton in Gub Reservoir, Bauchi State Nigeria. Journal of Aquatic Sciences, 16(2):115-118.

Faragallah, H. M.; Askar, A. I.; Okbah, M. A. and Moustafa, H. M., 2009. Physico-chemical characteristics of the Open Mediterranean sea water for 60km from Damieta harbor. Egyptian Journal of Ecology and Natural Environment, 1(5): 106 – 119.

FEPA, 1991. Federal Ministry of Environment and Protection Agency, National Environmental Protection (Effluent Limitation) Regulations (Cap 131 FRN), 213p.

Haruna, U. R and Solomon, J. R., 2015. Water quality assessment of a tropical stream, University of Abuja, Nigeria. African Journal of Environmental Pollution and Health,11:39-47.

Hem, J. D., 1971. Solubility and occurrence of lead in surface water. American Water Works Association Journal, 65:562-568.

Hussain, Q. A. and Pandit, A. K., 2012. Macroinvertebrate in streams: A review of some ecological factors. International Journal of Fisheries and Aquaculture, 4(7):114-123.

Inyang-Etoh, A. P., Eteng, S. U., George, U. U. and Edem, B. E., 2024. Comparison of the Intestinal Parasites Content of African Catfish (Clarias gariepinus) Reared in Ponds and the Wild in Calabar Metropolis. Adeleke University Journal of Science (AUJS) Volume 3 Issue 1, pp 99-111

Inyang-Etoh, A. P., Eteng, S. U., George, U. U. and Okwejie, P. W., 2024. Comparative Study of Bacterial Pathogens in the Tissues of African Catfish (Clarias gariepinus) Reared Under Different Culture Media in Calabar South Local Government Area of Cross River State, Nigeria. Adeleke University Journal of Science (AUJS) Volume 3 Issue 1,pp 88-98.

Levin, I. A.; Akau, W.; Gooday, A. J.; Jorissen, F.; Middleburg, J. J.; Naqui, S. W. A; Neira, C.; Rabalais, N. N. and Zhang, J., 2009. Effects of natural and human- induced hypoxia on coastal benthos. Biogeoscience, 6:2063-2098.

Mishra, A. P., Kumar, S., Patra, R., Kumar, A., Sahu, H., Chandra, N., Pande, C. and Alshehri, F., 2023. Physicochemical Parameters of Water and Its Implications On Avifauna And Habitat Quality. Sustainability, 15(12), 9494.

Ndome, C. B., Udo, I. U., Akpan, I. I. and Udom, C., 2012. Effect of water quality and bottom soil properties on the diversity and abudance of macrobenthic Fauna in some tropical Grow-out Earthen Fish Ponds. Ecologia, 2 (1): 12-22

Offiong, O. E. and Edet, A. E., 1998. Surface water quality evaluation in Odukpani, Calabar Flank, South-eastern Nigeria. Environmental Geology,36(3/4):343-348.

Ogbeibu, A. E., 2005. Biostatistics: A Practical Approach to the Research and Data Handling. Mindex publishing company Limited, Benin City, Edi State, Nigeria 264p.

Ogunwenmo, C. A. and Osuala, I. A., 2004. Physico-chemical parameters and macrobenthos of an estuarine creek and artificial Pond in Lagos, Southwestern Nigeria. Journal of life and Physical Sciences, 1(2); 128-132.

Ojikutu, R. O., Ibrahim, A. and Raymond, A., 2013. Assessment of water quality parameters and trace metal contents of drinking water sources in Minna, Niger State, Nigeria. Proceedings of 28th FISON Annual Conference, November 25-30, 2013:192-196.

Olaniyan, C. l. O., 1977. An introduction to West African Animal Ecology, Heinemann Educational Books Limited, London and Ibadan, 167p.

Sharik, A. A. M.; Islam, S. and Islam, M., 2017. Spatial and Temporal Environmental variable effect of the lower Meghna River and its Estuary on Macrobenthic. International Journal of Marin Science, 7 (12): 102 – 113.

Unanam, A. E. and Akpan, A. W., 2006. Analysis of physico-chemical characteristics of some freshwater bodies in EssienUdim Local Government area of Akwa Ibom State, Nigeria. Proceeding of the 21st Annual Conference of the Fisheries Society of Nigeria (FISON) Calabar, 13th – 17th November, 2006:310-312.

Uzoigwe, L. O. and Nnawuihe, C. O., 2020. A water quality study of Otamiri River in Imo State, Nigeria. Nigerian Journal of Hydrological Sciences, 8:79-87

Wang, Q. G., Zhao, X. H., Yang, M. S., Zhao, Y., Liu, K. and Ma, Q., 2001. Water quality model establishment for middle and lower reaches of Hanshuiriver, China. Chinese Geographical Sciences, 21(6):647-655.

WHO, 2003. The World Health Report: Shaping the future World Health Organization, Geneva, Switzerland, 1211p.

WHO, 2003. World Health Organization. International Standard for drinking water, Geneva. 1234pp.

Williams, A. B. and Benson, N. U., 2009. Interseasonal hydrological characteristics and Variabilities in surface water of tropical estuarine ecosystems within Niger Delta, Nigeria. Environmental Monitoring Assessment. 7(1), 61 – 65.