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Evaluation of Heavy Metals and Total Hydrocarbon Concentration in the Qua Iboe River Estuary, Akwa Ibom State, Nigeria

D. Imoke Eni

I. Abam Arikpo

Peter Ereh Oko

*Department of Environmental Resource Management,
University of Calabar, Calabar, Nigeria*

Abstract

The research assessed the concentration level of heavy metals and total hydrocarbon in Qua Iboe River Estuary of Akwa Ibom State, Nigeria during the months of April, May and June. The experimental research design was adopted and a total of 72 water samples were collected on weekly basis from ST1, ST2 and ST3 during high and low tides in thoroughly-rinsed 1-litre plastic containers to avoid adulteration of the samples. Samples were analyzed in-situ and in the laboratory using standard methods. The results of the concentrations of the sampled parameters during high tide included: Cr (0.003-0.21mgl⁻¹), Fe (0.123-0.511mgl⁻¹); Mn (0.018-0.66mgl⁻¹), Pb (0.105-0.603mgl⁻¹), Mg (0.42-0.623mgl⁻¹), Cu (0.00-0.32mgl⁻¹) and THC (0.12-0.88mgl⁻¹)while the low tide concentrations showed: Cr (0.001-0.061mgl⁻¹), Fe (0.56-4.11mgl⁻¹), Mn (0.002-0.13mgl⁻¹), Pb (0.011-0.211mgl⁻¹), Mg (0.108-1.342mgl⁻¹), Cu (0.011-0.076mgl⁻¹) and THC (0.23-0.80mgl⁻¹). The concentrations of Hg and As were negligible throughout the study. Analysis revealed that THC varied significantly across the sampled stations (ANOVA, P <0.001). Pollution Index, PI <1 for Ni, Mn, Na, Hg, As, Mg and Cu, implied that there was no pollution in the estuary. Fe showed that the estuary was slightly polluted with PI 1-2; Cr, V and THC recorded PI 2-3 signifying that the water was moderately polluted; PI >5 for Pb revealed that the estuary was seriously polluted with lead. The oil spills by ExxonMobil's offshore platforms in the area, the heinous practices of waste dumping along the coast have resulted in the high THC and heavy metals concentrations found in the water samples. Hence, the water in Qua Iboe River Estuary is polluted and not safe for personal or domestic uses. The study recommended that Exxon Mobil and other oil companies in Nigeria should adhere strictly to international best practices in oil exploration/exploitation, environmental conservation, maintenance of equipment and safety of their infrastructure should be their priority. Prompt actions should be taken towards clean-up exercises in case of oil spill incidents in the area and proper, modern sewage and solid wastes disposal mechanism should be put in place by the host communities.

Keywords: *Evaluation, heavy metals, total hydrocarbon, pollution level, Qua Iboe River Estuary*

1. Introduction

One of the most essential resources for life in our planet is water. It occupies an extremely important place in nature and in human society; it plays a part in all physical and biological processes that take

place on the earth's surface and in living organism. It constitutes the basic medium of organic life on earth, making possible the exchanges of substances and the development of all living matter (Eze&Abua, 2002). Therefore, the importance of water cannot be overemphasized, as it is generally used for drinking, fishing, general cleaning, washing, cooking etc. All natural water bodies contain dissolved substances; pollutants such as hydrocarbon, heavy metals, bacteria, viruses, salts and nitrateshave contaminated most sources of water supplies due to unregulated activities of man which include oil spills, discharge of untreated effluents and to a large extent unregulated solid wastes disposal into water bodies (Singh & Mosley, 2003 in Akpoveta, Okoh & Osakwe, 2011; Yeboah & Ameyaw, 2012).

There is also a possibility of potential impacts of water contaminants such as harmful chemicals, hydrocarbon and high levels of heavy metals on human health even though no anthropogenic sources of pollution exist (Akpoveta *et al.*, 2011; Atiemo, Dumolga, Adu & Palm, 2012). Based on this, water quality monitoring is important because it forms an integral part of the physical environment and it is a subject of paramount current concern. It is one of the major components that control the disease and healthy states in both animals and humans.

One major source of water available to mankind is the river estuary. Estuaries are referred to as semi-enclosed coastal brackish water bodies, that have unlimited interaction with the ocean or sea and within which saline water mixes readily with fresh water (Pritchard, 1967; Duxbury, Duxbury & Sverdrup, 2002; Mayhew, 2009). In the same vein, as a result of estuary's ability to support a myriad of biological diversity, experts from around the world recognize a growing need to monitor estuarine water quality on a global scale to avert potential health related problems. The Qua Iboe River Estuary (QIRE) contributes immensely to the sustainable economy in that area in terms of fishery resources, navigation, tourism, and thed livelihood of the people is tied to the estuary. The upper section of the estuary is used also by the rural dwellers (especially Upenekang natives) as source of water for bathing and other domestic uses. Unfortunately, as noted by Asuquo, Ogri and Bassey (1999) "the extent to which contamination has occurred in most Nigerian aquatic ecosystems including the QIRE is yet to be thoroughly quantified".

The Mobil Producing Nigeria, MPN (a subsidiary of ExxonMobil) separation plant (fractionating column) in Qua Iboe Terminal (QIT) is situated approximately one (1) kilometer to the Qua Iboe River Estuary. However, oil spillage due to leakages from aging pipelines, accidents, sabotage by hoodlums and aggrieved groups, bunkering activities, instrument failure and so on occur from time to time in the area. Although, massive efforts are usually made by the multi-national company (ExxonMobil) to curtail the situation after the occurrence of oil spills in the area but the laxity shown by the company often leads to environmental pollution. As a result of recurring tidal processes around the ocean-estuary divide, before clean up exercises are carried out, a part of the discharged crude oil may have dispersed to different locations. These locations may include the mangrove swamps, beaches, coast, creeks and most importantly, the river estuary causing a lot of contamination in the area. In the light of this, Udiba*et al.* (2012) have reiterated that, "tidal regimes have caused the widespread distribution of pollutants including oil spills to the length and breadth of the network of adjoining estuaries, rivers and creeks causing unquantifiable pollution".

In addition, improper domestic wastes disposal adds to the severity of the problem of water pollution in the area. The local dwellers especially in Iwuochang, Iwuo-okpom and Mkpanak communities have turned the beaches found along the QIRE into their dumpsites, where they dump their domestic wastes on daily basis. A walk along these beaches is very unpleasant, as heaps of wastes are sited even from afar. These unhealthy practices have contributed significantly to the pollution of QIRE heavy metals, bacteria and viruses. Also, during rainfall and at different tidal cycles these wastes are washed into the estuary seriously contaminating it. In fact, water contamination as stated by Pink (2006), "is the world's leading cause of diseases and it amounts to the deaths of more than 14,000 people daily". It is therefore on these submissions that this research investigated the pollution level of heavy metals and total hydrocarbon (THC) of the water along the QIRE during low and high tides.

2. Materials and Methods

2.1 Description of Study Area

Qua Iboe River Estuary is located in the tropics; it lies between longitudes 07°40'0"E and 7° 50'0"E of the Greenwich Meridian and latitudes 04°21'33"N and 04°30'0"N of the equator. The Qua Iboe River Estuary rises from Umuahia in Abia State and discharges into the Atlantic Ocean through Ibeno LGA of AkwaIbom State. The Qua Iboe River Estuary is situated approximately one (1) kilometer to the ExxonMobil's separation plant (Oze*et al.*, 2005; Dan, Umoh&Osabor, 2014). The Qua Iboe River Estuary to its eastern boundary cuts across the Local Government Headquarters (Upenekang), in Ibeno LGA. It is bounded on the east by Iwuochang, Qua Iboe Terminal jetty, Iwuo-Okpom and Mkpanak communities and to the far-east by the Cross River Estuary, to the south by the Atlantic Ocean. The QIRE is an important source of water for the local population of the area whose main occupation is artisanal fishing (Umoren&Onianwa, 2012). Through tidal swash and backwash, the ocean exchanges organic and inorganic matter with the Qua Iboe River Estuary.

The area is influenced by two wind systems namely the south-westerly wind that brings rain and the north-easterly wind from the Sahara Desert that brings the dry and dusty harmattan wind. The study area is generally humid and characterized by double maxima rainfall. The area is also noted for its humid tropical climate with a total annual precipitation of 2000 mm to 4000 mm, it has a uniform temperature regime with an annual range between 25°C to 28°C (Iloeje, 1991; Esu& Amah, 1999). It has an annual mean relative humidity of about 85 percent. Although, two climatic seasons exist in the study area; the wet season that sets in from April to October and the dry season that takes effect from November to March with high precipitation around July. A short dry period known as "August break" is usually experienced in the last two (2) weeks of August; a brief wet period follows the "August break" from early September to Mid-October, with another peak at the end of September.

The vegetation of the area depicts highly disturbed vegetation following persistent and increasing anthropogenic pressure due to the advent of exploration and exploitation of oil by ExxonMobil. The uncontrolled cutting of the mangroves which is used as fuel-wood by the locals also reduces the vegetation of the area. However, the fresh water swamp forest, saline water swamp forest and the rainforest are the main vegetation found in the area. Furthermore, other abundant species of plants in the area are nipa palm (*Nypafructicans*), white mangrove (*Avicenna africa*) and red mangrove (*Rhizophoraracemosa and R. mangel*) (Ndome, Eteng&Ekanem, 2012).

The study area extends to about 129 kilometers along the Ibeno coastline of AkwaIbom State and forms a part of the creeks, lagoons, sandbars as well as coastal plain characterized by low-lying topography which rises very imperceptibly from 0m on the shoreline to less than 20m at about 10km towards the main land. The shoreline has sand ridges running parallel to the coast with a width of about 200m (Iloeje, 1991; Esu& Amah,1999). The area has a gentle undulating sandy plain heavily incised by numerous creeks, shallow streams and rivers (notably Upenekang, Douglas and Stubb creeks). The major river in this area is the Qua Iboe River Estuary which acts as a confluence to the aforementioned rivers and creeks and their associated distributaries.

The area is drained by many creeks, the Cross River and the Atlantic Ocean. Small creeks of approximate tidal range of 3m and depth of 40m respectively meander strongly, developing branches which form the main channels. Immediate beaches are locally referred to as Ibeno Beachand Itak-Abasi Beach, which are the down-drift and up-drift beaches respectively, adjoining the Qua Iboe River estuary. The estuary is characterized by semi-diurnal tide which ranges between 2 – 4 meters. However, the average height of deposited sand dunes is about 30 meters, rising to 50 meters as one moves toward the beach (Esu& Amah, 1999).

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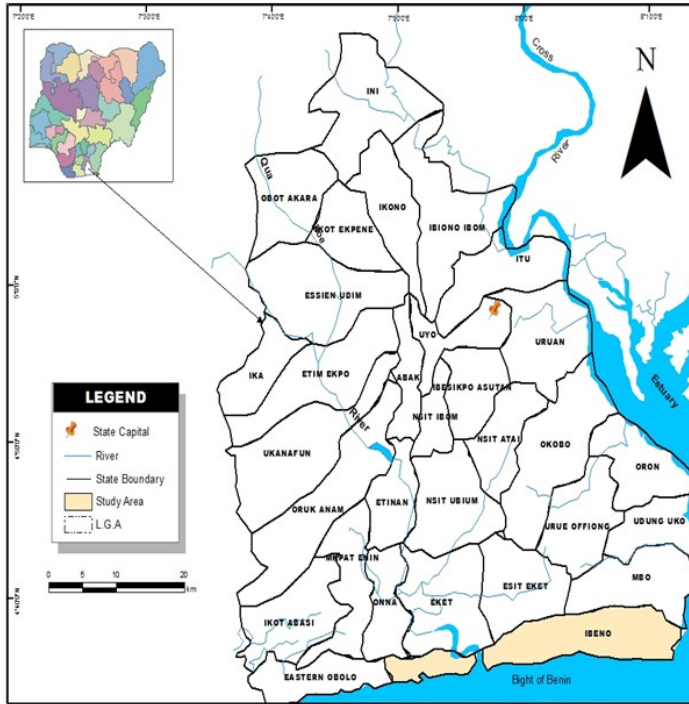*www.richtmann.org*

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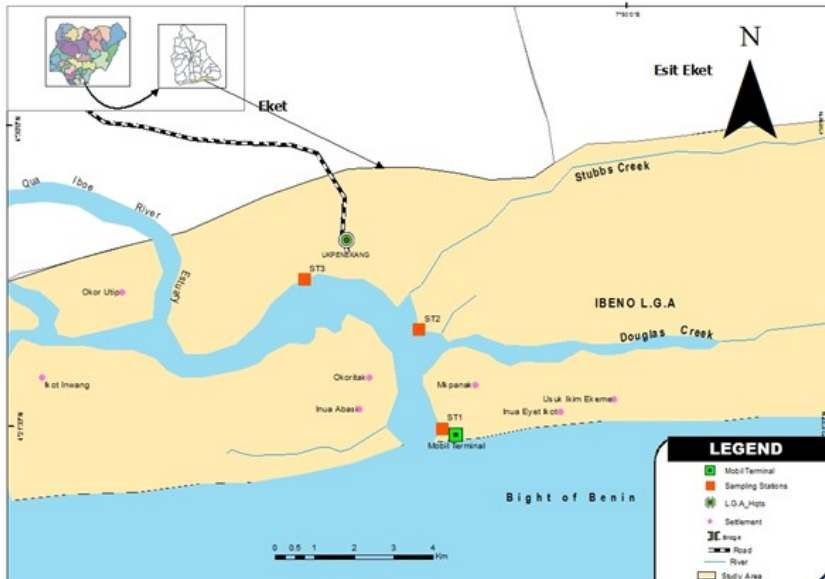**Figure 1.1:** Map of AkwaIbom State showing the study area

Figure 1.2: Profile Map of Ibeno and envrions: The Qua Iboe River Estuary showing sampling stations

The procedure for data collection started with a reconnaissance survey of the study area. This study adopted the experimental research design where the researcher observed a phenomenon and tried to show what caused it. The design enabled three geo-referenced sampling stations: ST1, ST2 and ST3 to be established along the estuary. The distance between sampling stations ST1 and ST2 was 200 meters, and the distance between ST2 and ST3 was also 200 meters; these were delineated using a calibrated tape and a speed boat to establish the sampling stations. The experimental research design helped direct field (in-situ) measurements and experimentation in the laboratory to be carried out for data collection. The data collected were further subjected to inferential statistical analysis.

The study adopted the purposive sampling technique for the establishment of sampling stations along the estuary. Sampling of water quality across the sampling locations was carried out thus; two (2) samples were collected per station, that is, one (1) sample at high tide and one (1) sample at low tide across the three (3) sampling stations. This was done on a weekly basis for twelve (12) weeks (three (3) months). Accordingly, a total of seventy-two (72) samples (36 samples during high tide and 36 samples during low tide) were collected during the study period from the three geo-referenced sampling stations (ST1, ST2 and ST3) with the aid of a rented speed boat. Samples were taken during the rainy season, precisely, between 6th of April, 2015 and 29th of June, 2015, to observe the impacts of tides on heavy metals and hydrocarbon pollution of the area under study. It is important to reiterate here that, although, this study was conducted during the rainy season, the focus of the study was not intended to investigate the variations in the sampled parameters seasonally but to examine the variations in the aforementioned parameters as a result of tidal influence in the estuary.

Before the collection of samples, the containers (1-litre plastic rubbers) were rinsed with diluted HCl acid and rinsed again three times with the sampled water at the site in order to avoid impurities external to the collected water sample which may adulterate the result. After the collection of the water sample at each sampling station, the containers were tightly covered and labeled properly to show the date, sampling station and tidal cycle at where sample was collected. Samples were collected and preserved in an ice-packed cooler (at approximately 4°C) and then transported to the Solz Environmental Central Laboratory (subsidiary of Ines Oceanographic Services) in Port Harcourt for analysis of Chromium (Cr), Nickel (Ni), Iron (Fe), Manganese (Mn), Sodium (Na), Vanadium (V), Mercury (Hg), Lead (Pb), Arsenic (As), Magnesium (Mg), Copper (Cu) and total hydrocarbon (THC)within 24 hours to prevent sample deterioration (APHA, 1995).

2.2 Laboratory analysis of Heavy metals and THC

The Atomic Absorption Spectrophotometer (AAS) HACH model DR 3000 (APHA, 1995) was used in the determination of Chromium (Cr), Nickel (Ni), Iron (Fe), Manganese (Mn), Sodium (Na), Vanadium (V), Mercury (Hg), Lead (Pb), Arsenic (As), Magnesium (Mg), Copper (Cu). The water samples for the aforementioned heavy metals were filtered through Whatman filter paper No. 1, and 1000 ml of the filtered samples were acidified to pH 2 with 20 ml of 6 N HNO_3. Standard solutions for the metals were prepared according to the analytical methods for AAS as described by APHA (1995).

The analysis of THC was carried out in the laboratory with the aid of separating funnel which was determined using HACH spectrophotometer model DR 3000 and full details of this method is given by APHA (1995). Samples for THC were collected in glass bottles; 250 ml of the water was extracted with 100 ml of n-hexane (analar grade) using glass separator funnel. After complete phase separation the n-hexane phase was collected and THC determined spectrophotometrically at 450nm wave length.

3. Results

Table 1: Heavy metals and THC analysis results of Qua Iboe River Estuary forST1: High tide (GPS: 7°46'4.65"E, 4°21'25.2"N)

Parameter	Unit	Sampling Date											
		6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
Cr	mg/l	0.003	0.121	0.112	0.210	0.022	0.043	0.114	0.085	0.147	0.154	0.042	0.117
Ni	mg/l	0.013	0.015	0.011	0.016	0.024	0.023	0.017	0.015	0.017	0.018	0.031	0.019
Fe	mg/l	0.42	0.315	0.407	0.290	0.123	0.311	0.411	0.322	0.359	0.331	0.286	0.411
Mn	mg/l	0.66	0.324	0.048	0.562	0.022	0.026	0.028	0.0352	0.189	0.121	0.162	0.550
Na	mg/l	0.154	1.44	1.054	1.602	1.088	1.022	1.031	0.884	1.232	1.004	1.060	0.960
V	mg/l	0.003	0.062	0.098	0.086	0.094	0.012	0.083	0.004	0.094	0.053	0.066	0.034
Hg	mg/l	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	mg/l	0.205	0.212	0.183	0.176	0.127	0.133	0.108	0.143	0.582	0.445	0.603	0.210
As	mg/l	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	mg/l	0.132	0.421	0.521	0.403	0.087	0.074	0.104	0.061	0.623	0.561	0.441	0.382
Cu	mg/l	0.001	0.042	0.011	0.032	0.320	0.056	0.034	0.024	0.086	0.057	0.081	0.044
THC	mg/l	0.710	0.680	0.880	0.570	0.630	0.610	0.540	0.720	0.490	0.450	0.620	0.580

Source: Researchers' fieldwork (2015)

Table 2: Heavy metals and THC analysis results of Qua Iboe River Estuary for ST1: Low tide (GPS: 7°46'4.65" E, 4°21'25.2" N)

Parameter	Unit	Sampling Date											
		6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
Cr	mg/l	0.001	0.014	0.008	0.115	0.032	0.041	0.053	0.024	0.042	0.041	0.052	0.018
Ni	mg/l	0.044	0.032	0.045	0.055	0.038	0.034	0.043	0.051	0.066	0.041	0.058	0.049
Fe	mg/l	1.440	3.220	2.080	0.910	1.210	1.290	0.770	0.890	1.060	3.010	3.060	3.140
Mn	mg/l	0.008	0.060	0.015	0.019	0.012	0.011	0.104	0.007	0.042	0.107	0.005	0.064
Na	mg/l	0.056	0.055	0.067	0.054	0.034	0.046	0.031	0.028	0.121	0.088	0.101	0.060
V	mg/l	0.004	0.007	0.003	0.014	0.033	0.017	0.011	0.013	0.055	0.051	0.035	0.021
Hg	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	mg/l	0.040	0.021	0.105	0.012	0.067	0.034	0.063	0.020	0.036	0.012	0.122	0.131
As	mg/l	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Mg	mg/l	1.342	0.861	0.501	0.731	1.034	1.011	0.983	1.214	1.023	0.672	0.843	1.013
Cu	mg/l	0.076	0.045	0.055	0.068	0.052	0.049	0.036	0.044	0.039	0.041	0.055	0.011
THC	mg/l	0.540	0.530	0.480	0.420	0.480	0.530	0.460	0.500	0.630	0.600	0.430	0.530

Source: Researchers' fieldwork (2015)

Table 3: Heavy metals and THC analysis results of Qua Iboe River Estuary for ST2: High tide (GPS: 7°45'50.1"E, 4°22'45.1"N)

Parameter	Unit	Sampling Date											
		6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
Cr	mg/l	0.090	0.016	0.050	0.102	0.056	0.040	0.032	0.018	0.134	0.118	0.141	0.014
Ni	mg/l	0.056	0.044	0.053	0.008	0.005	0.022	0.032	0.001	0.003	0.011	0.004	0.061
Fe	mg/l	0.214	0.301	0.441	0.381	0.452	0.433	0.321	0.511	0.217	0.420	0.410	0.266
Mn	mg/l	0.085	0.042	0.018	0.019	0.590	0.071	0.034	0.620	0.122	0.106	0.068	0.124
Na	mg/l	0.543	0.874	1.117	0.461	1.023	1.041	0.981	1.060	1.321	0.618	0.741	0.552
V	mg/l	0.000	0.004	0.006	0.041	0.005	0.011	0.007	0.005	0.065	0.042	0.061	0.008
Hg	mg/l	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Pb	mg/l	0.391	0.189	0.114	0.122	0.213	0.212	0.201	0.162	0.111	0.158	0.125	0.203
As	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000

Parameter	Unit	6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
							Sampling Date						
Mg	mg/l	0.402	0.308	0.069	0.054	0.097	0.207	0.166	0.410	0.093	0.044	0.085	0.076
Cu	mg/l	0.023	0.041	0.012	0.051	0.044	0.032	0.015	0.082	0.079	0.066	0.033	0.057
THC	mg/l	0.560	0.770	0.620	0.540	0.120	0.510	0.660	0.480	0.760	0.650	0.430	0.370

Source: Researchers' fieldwork (2015)

Table 4: Heavy metals and THC analysis results of Qua Iboe River Estuary for ST2: Low tide (GPS: 7°45'50.1" E, 4°22'45.1"N)

Parameter	Unit	6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
							Sampling Date						
Cr	mg/l	0.019	0.011	0.015	0.018	0.045	0.023	0.031	0.042	0.061	0.055	0.048	0.019
Ni	mg/l	0.024	0.014	0.016	0.032	0.077	0.062	0.056	0.061	0.023	0.021	0.022	0.014
Fe	mg/l	0.890	1.530	1.720	4.020	1.050	0.940	0.640	4.110	0.660	2.090	1.510	1.220
Mn	mg/l	0.004	0.006	0.013	0.005	0.004	0.007	0.010	0.008	0.121	0.130	0.003	0.015
Na	mg/l	0.024	0.049	0.013	0.026	0.054	0.072	0.056	0.034	0.166	0.124	0.135	0.118
V	mg/l	0.001	0.014	0.013	0.008	0.054	0.042	0.034	0.021	0.065	0.009	0.011	0.044
Hg	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000
Pb	mg/l	0.060	0.082	0.028	0.078	0.012	0.211	0.054	0.030	0.067	0.021	0.048	0.011
As	mg/l	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
Mg	mg/l	1.034	1.004	1.221	1.041	0.156	0.321	0.413	0.802	1.302	0.912	1.203	0.614
Cu	mg/l	0.064	0.042	0.048	0.055	0.045	0.061	0.051	0.032	0.011	0.038	0.072	0.038
THC	mg/l	0.490	0.530	0.340	0.470	0.710	0.770	0.690	0.580	0.800	0.740	0.690	0.610

Source: Researchers' fieldwork (2015)

Table 5: Heavy metals and THC analysis results of Qua Iboe River Estuary for ST3: High tide (GPS: 7°44'15.73" E, 4°23'30.1" N)

Parameter	Unit	6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
							Sampling Date						
Cr	mg/l	0.025	0.064	0.011	0.123	0.003	0.061	0.082	0.007	0.064	0.041	0.131	0.022
Ni	mg/l	0.012	0.009	0.013	0.010	0.003	0.006	0.008	0.009	0.008	0.004	0.016	0.012
Fe	mg/l	0.312	0.344	0.281	0.480	0.213	0.352	0.226	0.224	0.332	0.231	0.314	0.219
Mn	mg/l	0.008	0.060	0.015	0.019	0.012	0.011	0.104	0.007	0.042	0.107	0.005	0.064
Na	mg/l	0.168	0.121	0.083	0.102	1.001	1.037	1.010	0.581	1.044	0.812	1.023	0.321
V	mg/l	0.012	0.025	0.014	0.016	0.008	0.006	0.004	0.032	0.023	0.038	0.012	0.016
Hg	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	mg/l	0.133	0.121	0.123	0.213	0.121	0.134	0.122	0.105	0.234	0.185	0.154	0.255
As	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	mg/l	0.311	0.266	0.301	0.331	0.067	0.055	0.042	0.073	0.143	0.122	0.109	0.103
Cu	mg/l	0.000	0.058	0.043	0.022	0.012	0.027	0.041	0.018	0.062	0.061	0.049	0.021
THC	mg/l	0.410	0.640	0.440	0.580	0.380	0.410	0.620	0.340	0.380	0.410	0.390	0.620

Source: Researchers' fieldwork (2015)

Table 6: Heavy metals and THC analysis results of Qua Iboe River Estuary for ST3: Low Tide (GPS: 7°44'15.73" E, 4°23'30.1" N)

Parameter	Unit	6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
							Sampling Date						
Cr	mg/l	0.009	0.013	0.012	0.008	0.012	0.018	0.016	0.017	0.021	0.013	0.005	0.009
Ni	mg/l	0.000	0.003	0.005	0.002	0.054	0.044	0.032	0.021	0.009	0.010	0.003	0.006
Fe	mg/l	2.210	0.570	0.760	2.030	0.880	0.740	2.530	1.420	3.340	0.560	2.310	1.880

Parameter	Unit	Sampling Date											
		6/4/15	13/4/15	20/4/15	27/4/15	4/5/15	11/5/15	18/5/15	25/5/15	8/6/15	15/6/15	22/6/15	29/6/15
Mn	mg/l	0.009	0.002	0.008	0.130	0.009	0.012	0.014	0.010	0.021	0.056	0.010	0.026
Na	mg/l	0.045	0.031	0.022	0.041	0.077	0.048	0.073	0.036	0.154	0.011	0.029	0.033
V	mg/l	0.003	0.001	0.000	0.005	0.022	0.031	0.012	0.006	0.023	0.041	0.020	0.016
Hg	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	mg/l	0.023	0.034	0.052	0.021	0.066	0.043	0.013	0.039	0.093	0.052	0.026	0.087
As	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Mg	mg/l	0.124	0.671	0.133	0.521	1.007	1.021	0.462	0.241	1.034	0.228	0.108	0.117
Cu	mg/l	0.023	0.016	0.071	0.026	0.012	0.033	0.041	0.036	0.021	0.020	0.067	0.022
THC	mg/l	0.610	0.440	0.650	0.580	0.230	0.230	0.460	0.520	0.540	0.480	0.630	0.600

Source: Researchers' fieldwork (2015)

Table 7: Descriptive statistics for ST1 – ST3 during high tide

Parameter/Unit	Statistic	N	ST1	Station ST2	ST3
Chromium (mgl⁻¹)	Min.	36	.0030	.0140	.0030
	Max.		.2100	.1410	.1310
	Mean		.097500	.067583	.052833
Nickel (mgl⁻¹)		36	.0110	.0010	.0030
			.0310	.0610	.0160
			.018250	.025000	.009167
Iron (mgl⁻¹)		36	.1230	.2140	.2130
			.4200	.511	.4800
			.33217	.36392	.294000
Manganese (mgl⁻¹)		36	.0220	.0180	.0210
			.6600	.6200	.107
			.227267	.158250	.067583
Sodium (mgl⁻¹)		36	.1540	.4610	.0830
			1.6020	1.3210	1.0440
			1.044250	.861000	.608583
Vanadium (mgl⁻¹)		36	.0030	.000	.0040
			.0980	.065	.038
			.057417	.021250	.017167
Mercury (mgl⁻¹)		36	.00	.00	.00
			.001	.001	.00
			.000	.000	.000
Lead (mgl⁻¹)		36	.108	.1110	.1050
			.603	.3910	.2550
			.260583	.183417	.158333
Arsenic (mgl⁻¹)		36	.00	.00	.00
			.001	.001	.00
			.0002	.0000	.0000
Magnesium (mgl⁻¹)		36	.0610	.0440	.0420
			.6230	.4100	.331
			.317500	.167583	.160250
Copper (mgl⁻¹)		36	.0010	.0120	.0000
			.3200	.0820	.0620
			.065667	.044583	.034500
Total hydrocarbon (mgl⁻¹)		36	.4500	.1200	.3400
			.8800	.7700	.6400
			.623333	.539167	.468333

Source: Researchers' analysis (2015)

Table 8: Descriptive statistics for ST1 – ST3 during low tide

| Parameter/UnitStatistic	Statistic	N	ST1	ST2	ST3
				Station	
Chromium (mgl⁻¹)	Min.	36	.0010	.0110	.0050
	Max.		.1150	.0610	.0210
	Mean		.036750	.032250	.012750
Nickel (mgl⁻¹)		36	.0320	.0140	.0000
			.0660	.0770	.0540
			.046333	.035167	.015750
Iron (mgl⁻¹)		36	.7700	.6400	.5600
			3.2200	4.1100	3.3400
			1.84000	1.698333	1.60250
Manganese (mgl⁻¹)		36	.0050	.0030	.0020
			.1070	.1300	.1300
			.037833	.027167	.025583
Sodium (mgl⁻¹)		36	.013	.121	.0110
			.166	.028	.1540
			.072580	.06175	.050000
Vanadium (mgl⁻¹)		36	.001	.003	.0000
			.065	.0550	.0410
			.026330	.02200	.015000
Mercury (mgl⁻¹)		36	.0000	.0000	.0000
			.0000	.005	.0000
			.000000	.000417	.000000
Lead (mgl⁻¹)		36	.0120	.0120	.0130
			.2110	.1310	.0930
			.060917	.05525	.045750
Arsenic (mgl⁻¹)		36	.00	.00	.00
			.001	.001	.00
			.000	.000	.000
Magnesium (mgl⁻¹)		36	.5010	.1560	.1080
			1.3420	1.3020	1.0340
			.935667	.835250	.472250
Copper (mgl⁻¹)		36	.0110	.0110	.0120
			.0760	.0720	.0710
			.047583	.046417	.032333
Total hydrocarbon (mgl⁻¹)		36	.4200	.2300	.2300
			.6300	.8000	.6500
			.618333	.525000	.510833

Source: Researchers' analysis (2015)
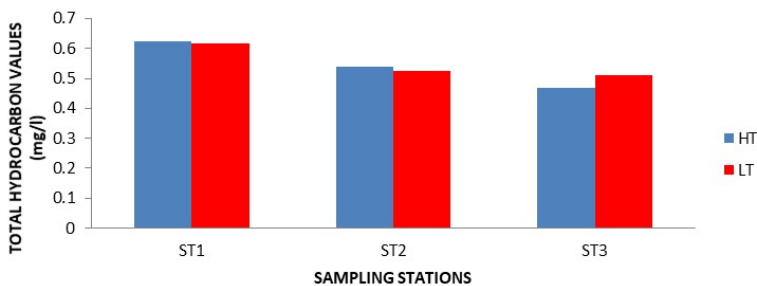
Figure 1.3: Total hydrocarbon, THC (mg/l) variations for T_H and T_L across the sampling stations
Source: Researchers' analysis (2015)

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Table 9: Summary of parameters for high tide (T_h) low tide (T_l) across ST1 – ST3

Parameter	Min.	Max.	Mean	N	Range	Std. Dev.	SE Mean
Cr T_h	.003	.210	.0726	36	.207	.05288	.00881
Cr T_l	.001	.115	.0273	36	.114	.02218	.00370
Ni T_h	.001	.061	.0175	36	.060	.01497	.00250
Ni T_l	.000	.077	.0324	36	.077	.02134	.00356
Fe T_h	.123	.511	.3300	36	.388	.08912	.01485
Fe T_l	.560	4.11	1.7136	36	3.550	1.01281	.16880
MnT_h	.018	.660	.1510	36	.642	.19231	.03205
MnT_l	.002	.130	.0302	36	.128	.03930	.00655
Na T_h	.083	1.602	.8379	36	1.519	.38733	.06455
Na T_l	.011	.166	.0614	36	.155	.03997	.00666
V T_h	.000	.098	.0319	36	.098	.03099	.00517
V T_l	.000	.065	.0211	36	.065	.01755	.00293
Hg T_h	.000	.001	.0001	36	.001	.00023	.00004
Hg T_l	.000	.005	.0001	36	.005	.00083	.00014
PbT_h	.105	.603	.2008	36	.498	.12038	.02006
PbT_l	.011	.211	.0559	36	.200	.04191	.00699
As T_h	.000	.001	.0001	36	.001	.00028	.00005
As T_l	.000	.001	.0002	36	.001	.00040	.00007
Mg T_h	.042	.623	.2151	36	.581	.16981	.02830
Mg T_l	.108	1.342	.7477	36	1.234	.38322	.06387
Cu T_h	.000	.320	.0482	36	.320	.05190	.00865
Cu T_l	.011	.076	.0421	36	.065	.01818	.00303
THC T_h	.120	.880	.5306	36	.760	.13967	.02328
THC T_l	.230	.800	.6658	36	.570	.17703	.02950

Source: Researchers' analysis (2015)

Table 10: Summary of mean values of parameters across stations and tides

Parameter/Unit Statistic	N	Station ST1	Station ST2	Station ST3	Std. Deviation	Std. Error	WHO (2003) Max. limits
Chromium (mgl⁻¹)Mean	72	0.067125	0.049917	0.032792	.0462966	.0054561	0.05
Nickel (mgl⁻¹)	72	0.032292	0.030084	0.012459	.0197911	.0023324	0.07
Iron (mgl⁻¹)	72	1.086085	1.031127	0.94825	.9974450	.1175500	1.0
Manganese (mgl⁻¹)	72	0.13255	0.092709	0.046583	.1506496	.0177542	0.4
Sodium (mgl⁻¹)	72	0.558415	0.461375	0.329292	.4770781	.0562242	50
Vanadium (mgl⁻¹)	72	0.041874	0.021625	0.016084	.0255954	.0030165	0.05
Mercury (mgl⁻¹)	72	0.000	0.000209	0.000	.0006088	.0000718	0.006
Lead (mgl⁻¹)	72	0.16075	0.119334	0.102042	.1154550	.0136065	0.01
Arsenic (mgl⁻¹)	72	0.0001	0.000	0.000	0.000	0.000	0.01
Magnesium (mgl⁻¹)	72	0.626584	0.501417	0.31625	.3981541	.0469229	200
Copper (mgl⁻¹)	72	0.056625	0.0455	0.033417	.0387376	.004565	2.0
THC (mgl⁻¹)	72	0.7342	0.5433	0.5171	.14073	.02873	0.30

Source: Researchers' analysis (2015)

3.1 Statistical Analysis

From table 10, the total hydrocarbon, THC mean concentrations were extracted and subjected to one-way analysis of variance (ANOVA), to assess if there is a significant difference in its concentration across the three (3) sampled locations. The result shows that the between sum of squares for THC is 0.674 while the within sum of squares is 1.435, giving a total sum of squares of 2.109. The result reveals that the variation is significant, $F_{(2, 69)} = 16.198$, $P < 0.001$. Since the probability value is less than the 0.05 level of significance (α) that was set for the study, the null hypothesis was therefore rejected (Table 11).

Table 11: Result of one-way analysis of variance for THC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.674	2	.337	16.198	.000
Within Groups	1.435	69	.021		
Total	2.109	71			

Source: Researchers' analysis (2015)

The statistical technique applied in order to determine the pollution level of water from the estuary, was the pollution index (PI) (see eqn. 1). Data used to achieve this were presented in tables 1 -6, 9 and 10 respectively. Table 13 shows the water quality classification based on pollution index and results of the pollution level of the estuary are presented in table 12. The objective of an index is to turn complex water quality data into information that is usable and understandable by the public. However, "water pollution index based on some very important parameters can provide a simple indicator of water quality which gives the public a general idea about the possible problems with the water in the area" (Mitchell &Stapp, 2001). Pollution Index (PI) is a method of rating that shows the composite influence of individual parameters on the overall quality of water (Abua&Ajake, 2014). The rating has values starting from zero to five and above (table 13), which reflects the relative importance of individual quality parameter and usually divided by the recommended standard (Si) for the maximum plus the minimum values and the summative divided by two as shown on the equation below. Water quality and its suitability for drinking purpose can be examined by determining its quality index (Caerio et al., 2005; Mohamed, Ali &Seliem, 2014).

This concept was adopted in this research because of its applicability in applied hydrological studies (especially water quality).

Pollution Index (PI) is however, given as:

$$PI = \sqrt{\dfrac{\left[\dfrac{Ci}{Si}\right]^2_{max} + \left[\dfrac{Ci}{Si}\right]^2_{min}}{2}} \qquad \text{eqn. 1}$$

Where:
PI = Pollution Index
Ci= Mean concentration
Si = WHO (2003) maximum permissible limit.

Table 12: Summary of results for pollution level of water from the study area

Parameter	Minimum	Maximum	Mean	Who (2003) Maximum Permissible Limits	Pollution Index, Pi	Remark
Chromium (Mg/L)	0.002	0.163	0.049	0.05	2.31	Mp
Nickel (Mg/L)	0.001	0.07	0.03	0.07	0.71	Np
Iron (Mg/L)	0.342	2.311	2.044	1.0	1.65	Sp
Manganese (Mg/L)	0.01	0.40	0.09	0.4	0.71	Np
Sodium (Mg/L)	0.047	0.884	0.899	50	0.014	Np
Vanadium (Mg/L)	0.00	0.163	0.027	0.05	2.31	Mp
Mercury (Mg/L)	0.00	0.003	0.0001	0.006	0.35	Np
Lead (Mg/L)	0.06	0.41	0.13	0.01	29.30	SEp
Arsenic (Mg/L)	0.00	0.001	0.0002	0.01	0.071	Np
Magnesium (Mg/L)	0.08	0.98	0.48	200	0.004	Np
Copper (Mg/L)	0.006	0.20	0.05	2	0.071	Np
Thc (Mg/L)	0.18	0.84	0.60	0.30	2.02	Mp

Note: Sp=slightly polluted, Np=no pollution, Mp=moderately polluted, SEp=seriously polluted

Source: Researchers' analysis (2015)

Table 13: Water quality classification based on pollution index

Class	Pollution Index (PI) value	Status
1	PI <1	No pollution
2	PI 1-2	Slightly polluted
3	PI 2-3	Moderately polluted
4	PI 3-5	Strongly polluted
5	PI >5	Seriously polluted

Source: Caerio et al, 2005; Mohamed, Ali &Seliem, 2014.

4. Discussion of Findings

The aim of this research was to determine the current THC and Heavy metal concentration in the study area. This was however the main focus of the study, as the oil exploration and exploitation activities by ExxonMobil have affected every facet of the livelihood of the people in the study area. Besides, the results found in tables 7 – 9 show that, THC varied between 0.120 – 0.880 mg/l (0.531 mg/l) and 0.230 – 0.800 mg/l (0.666 mg/l) for High tide (T_H) and low tide (T_L) respectively. However, highest mean concentration of 0.623 mg/l for THC was recorded at ST1 during T_H (figure 1.3). These concentrations far exceeded the levels of THC (0.047-0.050 mg/g) and (0.000 mg/l) reported by Andem et al. (2013) in Qua Iboe River Estuary and Udiba et al. (2007) in Calabar River respectively. As shown in table 10, mean values of THC across the three sampling stations show that ST1 recorded the highest mean value of 0.734±0.141 mg/l, this value is higher than the maximum permissible limit of 0.30 mg/l issued by WHO (2003). This result clearly shows that, the recorded oil spills by ExxonMobil in the area readily affects the quality of water of the Qua Iboe Estuary. This study therefore agrees with the study conducted by Andem et al. (2013) in the area which showed significant evidence of bioconcentration of heavy metals (Pb, Fe and Cu) and THC in the tissues of periwinkles.

Similarly, the concentrations of Chromium (Cr) were between 0.003 – 0.210 mg/l (0.073±0.053 mg/l) at T_H and 0.001 – 0.115 mg/l (0.027±0.022 mg/l) during T_L. ST1 recorded the highest value of 0.21 mg/l throughout the study period; this could be as a result of Exxon Mobil's activities in the area, oil leakages from boats at the station's location close to the QIT Jetty, which is mostly used by local boat operators and commercial fishermen and surface runoff. The mean results obtained, were comparable with those reported by Dan, Umoh and Osabor (2014) (9 – 35 µg/l) in the same estuary. But at variance with the study of Umunnakwe et al. (2013) who reported a lesser value (0.0003 mg/l) for Imo River. Result for Cr showed that ST1 (0.07 mgl⁻¹) had a value greater than the 0.05 mgl⁻¹ permissible level given by the WHO (2003), ST2 (0.05 mgl⁻¹) showed a value within the given standard, while the concentration obtained at ST3 (0.03 mgl⁻¹) is below the set limit.

The highest concentrations of Ni (0.061 mg/l and 0.077 mg/l) were recorded at ST2 during T_H and T_L respectively. However, ST3 recorded the least value of 0.000 mg/l during T_L for the entire study duration. The concentration of Ni reduced significantly away from the ocean, values of Ni across the three sampled locations were below the allowable limits (table 10). The higher levels of Ni at ST2 might be related to the cumulative impact of petroleum substances (petrol, engine oil, diesel and kerosene). This also reflects the activities of fishermen along the coast, these substances may have been washed during tidal processes or runoff from the domestic wastes deposited along the beaches into the estuary.

Furthermore, 0.123 – 0.511 mg/l (0.330±0.089 mg/l) and 0.560 - 4.110 mg/l (1.71±1.01 mg/l) show the ranges of Fe recorded during T_H and T_L respectively. Generally, the geology of Ibeno shows that the soils are rich in Fe concentrations. However, highest concentration of Fe was recorded during T_L (4.110 mg/l) at ST2; ST3 (0.94 mgl⁻¹) had Fe concentration slightly below the WHO (2003) limit (1.0 mgl⁻¹), while ST1 (1.09 mgl⁻¹) and ST2 (1.03 mgl⁻¹) recorded values above the acceptable standard, this could be attributed to the reaction of saline water with iron materials found in the wastes in the

presence of oxygen, as water retreats back into the ocean during T_L. Fe contributes significantly to the aesthetics of water in terms of the colour, odour and taste of water. Highest mean value of Fe (1.840 mg/l) was recorded at ST1 during T_L as shown in Figure 4.8. This may be due to the rust of the QIT jetty as saline water reacts with the bridge.

Likewise, the concentrations of Mn varied form 0.018 – 0.660 mg/l (0.150±0.192 mg/l) and 0.002 – 0.130 mg/l (0.030±0.039 mg/l) for T_H and T_L respectively. The highest value of 0.660 mg/l was obtained at ST1 during T_H which may be as a result of the proximity of the station to the ocean. Also, the concentrations of Mn in all the stations, ST1 (0.13 mgl⁻¹), ST2 (0.09 mgl⁻¹) and ST3 (0.05 mgl⁻¹) were less than the 0.4 mgl⁻¹ allowable limits given by WHO (2003).

Na ranged between 0.083 - 1.602 mg/l (0.840±0.387 mg/l) and 0.011 – 0.166 mg/l (0.610±0.039 mg/l) for T_H and T_L respectively. Results show that values of Na were higher during T_H than in T_L. This may be due to salt water intrusion into the estuary at T_H. Lower values of Na recorded during T_L on the other hand, could be as a result of fresh water influence which may have reduced the concentration of Na in the estuary. Moreover, ST1 recorded the highest mean value of 0.558 mg/l. The levels of Na recorded in ST1 – ST3 were below the WHO (2003) standard, but showed a marked reduction from ST1 (0.56 mgl⁻¹) to ST3, with a value of 0.33 mgl⁻¹.

Also, Vanadium, V, varied between 0.000 – 0.098 mg/l (0.032±0.031 mg/l) and 0.000 – 0.065 mg/l (0.021±0.018 mg/l) recorded at T_H and T_L respectively. With a mean value of 0.032 mg/l, it can be seen that higher values of V were observed during T_H. From table 10, it can be observed that with a value of 0.0418 mg/l, ST1 recorded the highest mean of V. Vanadium values were also below the set limit by WHO (2003) in all the stations.

Hg also varied between 0.000 – 0.001 mg/l and 0.000 – 0.005 mg/l which were obtained during T_H and T_L respectively. A negligible concentration of 0.001 mg/l was recorded during T_H at ST1 and ST2 respectively. Similarly, at T_L, a minute quantity of 0.005 mg/l was obtained at ST2. These concentrations seem to be recorded at ST2 due to the fact that the station was located near a dumping site for solid wastes.

The concentrations of Pb were between 0.105 – 0.603 mg/l (0.200±0.12 mg/l) and 0.011 – 0.211 mg/l (0.060±0.042 mg/l) which were obtained during T_H and T_L. ST1 recorded the highest value of 0.603 mg/l during T_H and a high mean value of 0.161±0.115 mg/l (Table 10), which also represented the highest value throughout the study. The presence of Pb in the estuary may be attributed to the resultant effect of refining and manufacturing of lead coating goods, surface runoff and domestic wastes (including automobile wastes from auto-mechanic workshops) in the area. This in turn, resulted in the higher quantity of Pb obtained at ST1. The mean concentrations of Pb decreased markedly away from the ocean (ST1>ST2>ST3). The values of Lead in all the stations, ST1 (0.16 mgl⁻¹), ST2 (0.12 mgl⁻¹) and ST3 (0.10 mgl⁻¹) were far above the maximum allowable level of 0.01 mgl⁻¹ given by WHO (2003), which shows that the wastes dumped along the estuary's beaches negatively affects the estuarine quality. It can be seen that tidal processes in the region, significantly influenced the concentrations of Pb across the stations in the estuary. This is because higher values of Pb were recorded during T_H than in T_L. However, the levels of Pb in this study were above the concentration of 0.060-0.067 mg/g previously reported by Andem et al. (2013) in the same estuary. Similar elevated concentration of Pb (0.53 ppm) was also reported by Onkar et al. (2015) in Harike Wetland, India.

Arsenic (As) on the other hand, ranged between 0.000 – 0.001 mg/l in both T_H and T_L. The concentration of As throughout the study was negligible as these were lower than the 0.01 mgl⁻¹ maximum limit set by WHO (2003). However, Magnesium, Mg varied from 0.042 – 0.623 mg/l (0.220±0.169 mg/l) and 0.108 – 1.342 mg/l (0.750±0.383 mg/l) respectively for T_H and T_L (Table 9). Higher values of Mg were observed during T_L than during T_H. Table 10 showed that highest mean value of 0.627 mg/l was recorded at ST1. Magnesium values in ST1 (0.63 mgl⁻¹), ST2 (0.50 mgl⁻¹) and ST3 (0.32 mgl⁻¹) were far below the limit of 200 mgl⁻¹ prescribed by WHO (2003).

The concentrations of Cu varied between 0.000 – 0.320 mg/l (0.048±0.052 mg/l) and 0.011 – 0.076 mg/l (0.042±0.018 mg/l) for T_H and T_L. Values recorded during T_H were slightly higher than T_L values, although, the highest value of 0.320 mg/l was obtained at ST1 during T_H. This is indicative of

the presence of pollutants traceable to industrial/domestic wastes in the estuary. ST1 also presented the highest mean value of 0.057 mg/l (Table 10). The concentrations of Copper in all the stations, 0.057 mgl^{-1}, 0.046 mgl^{-1} and 0.033 mgl^{-1} for ST1, ST2 and ST3 respectively were beneath 2 mgl^{-1} WHO (2003) set standard. The study agrees with the opinion of Onkar et al. (2015) who stated that "heavy metal pollution is a serious and widespread environmental problem due to its persistent toxicity, bioaccumulation and non-biodegradable characteristics".

Furthermore, results on table 12 show that Ni (PI, 0.71), Mn (PI, 0.71), Sodium (PI, 0.014), Mercury (PI, 0.35), Arsenic (PI, 0.071), Magnesium (PI, 0.004) and Copper (PI, 0.071) recorded PI < 1. Hence, this means that there was no pollution in the Qua Iboe River Estuary in terms of the aforementioned parameters. Also, these parameters had mean concentrations below the WHO (2003) standards. Similarly, Iron (PI, 1.65) had a PI value within PI 1-2 range, which signifies that the estuary was slightly polluted. The PI values for Chromium (PI, 2.31), Vanadium (PI, 2.31) and THC (PI, 2.02) (Table 12) indicate that the water in Qua Iboe River was moderately polluted, as these values fell within PI 2-3 range (Table 13). Comparatively, the parameter that showed marked PI value among the twelve (12) parameters used was Lead (Pb) (PI, 29.30). This value shows that the water is seriously polluted (PI > 5) with very high concentration of Pb. Based on the PI values represented in table 12, it can be observed that the parameters that are seriously causing contamination in the Qua Iboe River Estuary are Chromium, Iron, Vanadium, Lead and THC. This indeed reflects the effects of unwholesome practices in the area. Apart from threat to human life, the pollution poses equal threat to the survival of biodiversity in the area.

Also, as a result of hydrocarbon pollution, vast expanse of mangrove vegetation has been greatly affected in the area, leading to loss of habitat, wildlife exposure to imminent danger, forced migration and subsequent extinction of vulnerable species of both plants and animals. This agrees with the views of the study of Aghalino et al. (2009) who submitted that "the toxicity of the Mobil Qua Iboe oil spill of 1998 showed that 96.5 percent of the mangrove seedlings among other plants on the shoreline died within fourteen (14) days of exposure to oil film". As with the case in the Qua Iboe River Estuary area, previous studies have also shown that "when oil pile up around mangrove roots, it can lead to the suffocation and death of many important species of fishes, turtles, invertebrates and so on", which the people solely depend on for their livelihood and sustenance (ii Aboye, 1983; Sheppard & Price, 1991).

5. Conclusion

There is no contradiction to the fact that water pollution in Ibeno area of Akwa Ibom State and Nigeria at large is of frequent occurrence. Although, views about the sources of water pollution may differ amongst scholars, what cannot be debated is that accidental oil spills and heavy metals discharge are the most common sources of water pollution. The health status of individuals, perhaps, can be determined by the potability of water they use for personal or domestic purposes, which is why various, standards such as WHO, NSDWQ, FMEnv and so on, have been put in place to help control the quality status of water consumed by individuals in order to avert possible health problems.

This research has shown that pollution of Qua Iboe River Estuary by human activities such as the exploration/exploitation of crude oil leading to oil spills and inappropriate waste dumps along the beaches, leads to high concentration of THC and heavy metals especially lead in the estuary. These activities therefore, contravene the tenets established by the concept of sustainable development which encourages economic development through the use of natural resources but not to the detriment of the environment. Since, the main focus in this study has been pollution due to petroleum production activities by ExxonMobil, the THC concentrations found in the water which far exceeded the level given by WHO (2003) and of previous reports as stated earlier, showed that the water is seriously polluted. Based on these findings, the consumption of fisheries (periwinkles, fishes and so on) obtained from this estuary, therefore, exposes the locals to possible health-related

complications as a result of high levels of hydrocarbon, Lead poisoning and other heavy metals in the tissues of these organisms. Lead is a very poisonous metal; in humans, long term exposure to Lead may lead to serious harm of the nervous system and may affect the gastrointestinal tract, kidneys, reproductive system and joints.

Based on the findings of this research, it will be wise to conclude that the oil spills into the water body by ExxonMobil which may have been caused by instrument failure, aging pipelines, accidents and sabotage and waste dumping along the beaches have affected the quality status of the surface water of the Qua Iboe River Estuary. Except these activities are curtailed, the water and fisheries obtained from the estuary are not safe for personal/domestic uses or consumption.

6. Recommendations

The following recommendations are therefore made in view of the findings revealed by this research:

  i. ExxonMobil and other oil companies in Nigeria should adhere strictly to international best practices in oil exploration/exploitation and environmental conservation, the maintenance and safety of their infrastructure should be their utmost priority. This is to bring the scourge of oil spillage to its bare minimum in the area.
  ii. Prompt actions should be taken towards clean-up exercises in case of oil spill incidents in the area to avoid contaminating the environment.
  iii. Robust security strategies should further be developed by ExxonMobil in the area to enhance the protection of their oil facilities (pipelines and the likes) against activities of saboteurs, vandals and so on. This will also curb the incessant oil spills in the region.
  iv. Proper and modern sewage/solid wastes disposal mechanism should be put in place by especially Upenekang, Mkpanak, Iwuo-Okpom and Iwuochang communities.
  v. Regular sanitation in the area should be encouraged by the district's heads, local and state governments, as this area is a tourism hotspot in AkwaIbom State, this will help reduce bacterial and heavy metal contaminations of the estuary.

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