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Full Length Research Paper

The impact of makeshift oil refineries on the physio-chemistry of the sediments of the Nun river estuary, Niger Delta, Nigeria

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Physio-chemical parameters of the sediments of the Nun river estuary were analyzed in September, 2014 and January, 2015, after the estuary had been subjected to over three years of chronic pollution as a result of makeshift oil refinery activities. The Total Hydrocarbon Content (THB) and Total Organic Carbon (TOC) of the sediments were high, ranging from 17.8 mg/kg to 1125.9 mg/kg and 0.34 mg/kg to 51.4 mg/kg, respectively. The pH values of the sediments were also very acidic, ranging from 5.11 to 6.32. However, the Temperature was moderate. The high concentration of THC and TOC of the sediments, coupled with the acidic pH indicate the unhealthy state of the Nun River estuary.

Key words: Physio-chemical parameters, sediments, pollution, makeshift oil refineries.

INTRODUCTION

Sediments (soils) are highly valuable. The nature of sedimentary deposits or sediment particles carried in suspension and deposited over time influences the assemblage of benthos. The deposited material forms the substrate upon and within which many of the estuarine organisms live either permanently or temporarily, from which food resources are also obtained (Buller and McManus, 1979). Sediments also influence the growth of the benthos and other organisms that depend of them (Newell and Hidu, 1982). The range of sediment sizes present at a given site determines the packing of the particles and the availability of pore spaces through which interstitial fluids may pass (Buller and McManus, 1979). Sandier and less silty sediments have greater heterogeneity of particle sizes, and this, in turn, presents greater variety of ecological niches leading to higher biodiversity (Ward, 1975). Rhoads (1974) states that soft and silty sediments make it difficult for invertebrates to adapt. The packing degree of the sediment potentially determines the stability of the bed which is vital for the kind of benthic invertebrates that will inhabit an area, particularly the burrowers and filter feeders. Particle sizes and the degree of sorting influence physio-chemical characteristics of the sediments, which will in turn reflect the kind of biota occupying the deposits and their densities.

Hydrocarbons are the principal constituents of petroleum and natural gas. Hydrocarbons are a class of organic chemical compounds composed only of the elements carbon and hydrogen. The carbon atoms join together to form the framework of the compound; the hydrogen atoms attach to them in many different configurations.

In a crude oil polluted environment, the heavier fractions of petroleum hydrocarbon typically pass through the water column and settle to the bottom (Hanson et al., 2003) while others mix with water and penetrates to the underlying sediment (Partin, 1999). Generally, the lighter fractions of aromatic hydrocarbons evaporate rapidly, particularly during periods of high wind and wave activity

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(Hanson et al., 2003). This therefore confirms the submission of Ibigoni et al. (2009) that sediments are better indicators of pollution than water.

High hydrocarbon content negatively affects soil-gaseous diffusion which has far reaching implications for biotic community of affected ecosystem and soil fertility (Osuji and Ezebuiro, 2006). The crude oil adversely affected the benthic community in the estuary, causing a drastic decline in the population of some and some benthic macro invertebrates were completely destroyed. Intertidal organisms such as periwinkles and mudskipper are very vulnerable to oil pollution since their habitat are susceptible to coating with oil and may be smothered in the event of heavy oil drifting ashore (Ibigoni et al., 2009). With the high level of THC in the environment both water and sediment is likely to be ingested or absorbed by pelagic and benthic organisms (such as crabs, periwinkles and fish) respectively, which can easily ingest or absorb it, and pass it on (with its attendant health risk) along the food chain to top predators including man. Similarly, the elevated values of THC in sediments recorded in this investigation may be responsible for the observed- moribund state of mangrove vegetation in the study area, and is in agreement with the record of National Research Council (NRC), 2003, that oil (spills) can have adverse effects to both sub- tidal and intertidal vegetation. This therefore calls for proactive action from environmental regulators and or oil industry players to save the aquatic biota, maintain desirable water qualities as well as enthrone environmental sustainability.

Overcoming the detrimental effects of the contamination of soil, air and water is a serious challenge. Large-scale crude oil spills on soil, leakages from pipelines, underground and surface fuel storage tanks, indiscriminate spills and careless disposal and mismanagement of waste and other petroleum by-products of the society, constitute the major sources of petroleum contamination in our environment. High concentration levels of hydrocarbons present in contaminated sites pose a health risk to humans, plants and animal lives.

The mangrove ecosystems of the Nun river estuary have been subjected to oil spills resulting from the activities that are directly or indirectly related to makeshift crude oil refineries (locally called, Kpo fire) from 2011 till date, which has seriously polluted the soil (sediments) in the area. In spite of this life threatening situation, no research has been conducted in the area to ascertain the level of impact of this heinous crime on the vulnerable mangrove ecosystems and the inhabitants of Akassa kingdom.

This work was conducted in the mangrove environments of the Nun River Estuary. Total organic carbon (TOC), Total Hydrocarbon content, soil particle size and the textural class of the substratum of the estuary were also investigated and ascertained. Six sampling stations were established along a main transect.

The aim of this project was to determine the impacts of makeshift oil refining activities, including their dispersants and spills on the physio-chemistry of the sediment, in comparison with less polluted locations. The above aim was addressed by meeting the following specific objective:

1. To determine the sediment characteristics of the area.

MATERIALS AND METHODS

Description of study area

The Nun River estuary is situated in the area around Akassa in Brass Government Area of Bayelsa State in the Niger Delta Region of Nigeria. Akassa encompasses an area of 120km^2 and is situated on both sides of the Nun River estuary. The estuary is located on latitude of 4^0:20”and 4^0: 17”N longitude of 6^0: 49” and 4^0: 55”E. The Nun River estuary is not an exclusively separate system, but is linked to neighbouring estuaries by tidal creeks and channels. It is bordered by the Brass river estuary and to the west by the Sangana River estuary. It opens up into the Atlantic Ocean at its Southern part. The habitats of the estuary are generally narrow and steep- sided in contrast to their relatively broadened and flattened nature stream. Throughout the course of the river, these habitats are by dense mangrove vegetation.

Designation of sampling stations

Six sampling stations were chosen. The randomized block experimental design was used during the research. Two of the sampling stations were established exactly on the makeshift oil refinery camps, which were designated the “highly impacted zones” and one of the sampling stations was established in an area that is adjacent to one of the makeshift oil refinery camps, which was designated as “partially impacted zone”. The remaining sampling stations were the three sampling stations (Stations 1, 2, and 3) that were sampled during the base line study that was conducted on the estuary from 2009 to 2010 (Gijo, 2011).

Sampling station 1 (Apparanbie makeshift refinery camp 1)

This sampling station was established on one of the makeshift oil refineries in Apparanbie Creek; a tributary of the Nun River Estuary. The site is supposed to have red mangrove vegetation. The site is highly polluted by crude oil and mangroves are massively destroyed. The soil was completely laden with crude oil, both at the surface and absorbed by the sediments.

Table 1. Results of soil analysis for September, 2014.

Parameters	Sampling stations											
	STN. 1	STN. 2	STN. 3	STN. 4			STN. 5			STN. 6		
				HTL	MTL	LTL	HTL	MTL	LTL	HTL	MTL	LTL
THC (mg/kg)	1125.9	51.7	1078.3	31.45	35.09	29.33	19.11	21.42	20.78	25.91	20.43	28.18
TOC (%)	88.56	75.81	86.43	47.21	40.63	42.81	30.02	28.14	34.89	41.62	36.28	50.07
pH	5.11	5.13	5.22	5.78	5.89	5.56	6.03	5.97	6.01	6.32	5.86	6.04
TEMPERATURE (°C)	25.2	24.7	24.5	24.2	24.1	24.0	24.4	24.3	24.2	22.3	22.4	22.2

Keys: STN: Station; THC: Total Hydrocarbon Content; TOC: Total Organic Carbon; HTL: High Intertidal Level; MTL: Mid Intertidal Level; LTL: Low Intertidal Level; mg/kg: milligrams per killogram.

Sampling station 2 (Apparanbie 2)

This sampling station is situated adjacent to sampling station 1, still in Apparanbie Creek. This sampling station has both red and black mangrove species and an inhabited area that is without mangrove vegetation. This area is less polluted.

Sampling station 3 (Apparanbia makeshift refinery camp 2)

This sampling station was also established on one of the makeshift oil refineries in Apparanbie Creek; a tributary of the Nun River Estuary. The site is supposed to have red mangrove vegetation. The site is highly polluted by crude oil and mangroves are massively destroyed. The soil was completely laden with crude oil, both at the surface and absorbed by the sediments.

Sampling station 4 (Akahapolo)

This sampling station is characterized by mangrove vegetation and a relatively short intertidal zone. The vegetation consists mainly of red mangroves.

Sampling station 5 (Erewei- kongho)

This station is around Erewei- kongho community, downstream. In this station the low intertidal zone is muddy, the middle intertidal zone is a mixture of sand and clay and the high intertidal zone is sandy. This station does not have mangrove vegetation. The fringes of this station are dominated by grasses.

Sampling station 6 (Ogbokiri)

The station is situated on a mud flat towards the Atlantic Ocean. It has vegetation that is dominated by the white mangroves.

Field sampling

Soil samples were obtained from the six sampling stations with the aid of a soil auger. The collected samples were kept in polythene bags with appropriate labels, and taken to the laboratory for analysis. Soil and atmospheric temperatures were also measured in situ with mercury in glass thermometer.

RESULTS

The results of the analysis of the sediments of the 6 sampling stations are presented in Tables 1 and 2 and Figures 1 - 4.

Discussion

The sediment characteristics that were investigated in this research include soil particle size, total hydrocarbon content (THC), total organic carbon (TOC), pH, and temperature.

Total hydrocarbon content (THC)

The Results of the analysis of the THC of the soil of the highly polluted Nun River estuary varied both spatially and temporally. The THC values were higher in September, 2014 than January, 2015. This can be attributed to the decline and eventual termination of illegal oil refining activities in the estuary. The results revealed that stations 1 and 3 (the illegal refinery camps) had very high values compared to the other sampling stations (Tables 1 and 2). The THC values ranged from 17.8 mg/kg to 1125.9 mg/kg. The THC values of Station 1 were 1125.9mg/kg and 1118.5mg/kg while those of station 3 were 1078.3 mg/kg and 948 mg/kg for September, 2014 and January, 2015, respectively. These sampling stations (station 1 and 3) were seriously laden with crude oil to the point that the crude oil was still very visible throughout the duration of the study and all life forms, including mangroves and macro zoobenthos were completely destroyed. Next to stations 1 and 3 (in terms of the value of THC) was station 2, which was sited adjacent to station 1. This sampling station had THC values of 51.7 mg/kg and 48.5mg/kg in September, 2014 and January 2015, respectively. Next to station 2, in

Table 2. Results of soil analysis for January, 2015.

Parameters	Sampling stations											
	STN. 1	STN. 2	STN. 3	STN. 4			STN. 5			STN. 6		
				HTL	MTL	LTL	HTL	MTL	LTL	HTL	MTL	LTL
THC (mg/kg)	1118.5	48.5	948	25.40	22.53	24.64	17.80	18.50	19.65	24.76	20.38	25.84
TOC (%)	89.34	77.57	86.73	48.72	40.86	45.38	32.84	30.40	36.70	44.56	40.74	51.48
pH	5.13	5.10	5.43	5.98	5.87	5.68	6.08	6.02	6.04	5.97	6.23	6.10
Temperature (^{O}C)	25.1	25.3	24.9	24.8	24.3	24.0	24.3	25.2	24.4	24.1	22.7	22.5

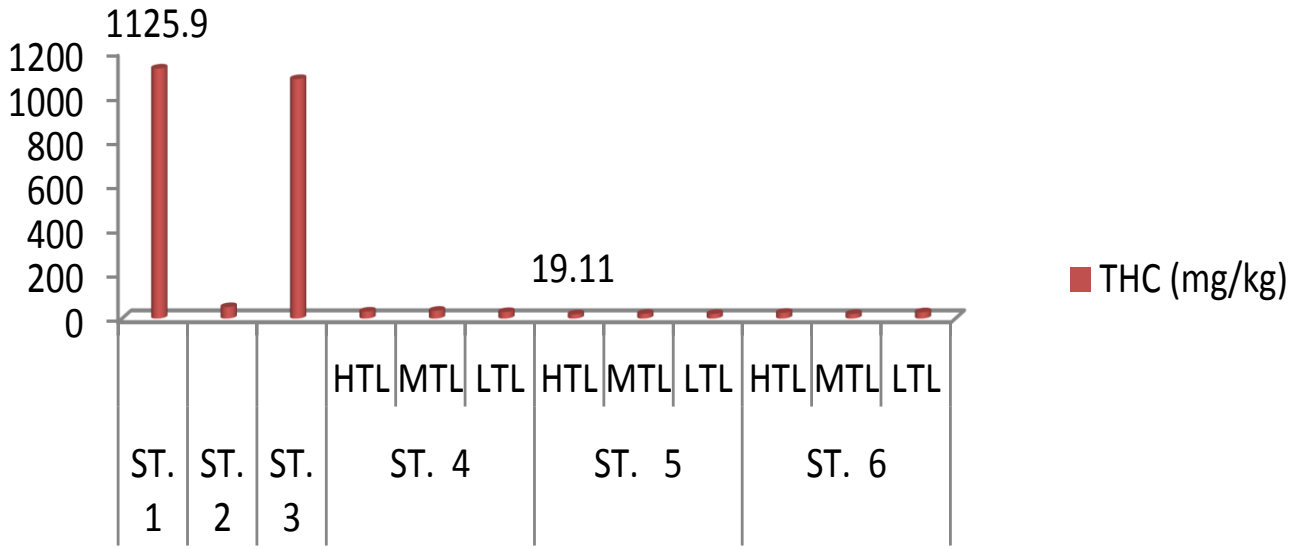

Figure 1. Total Hydrocarbon Content (THC) of the soil in the six sampling stations of the Nun River estuary (September, 2014).

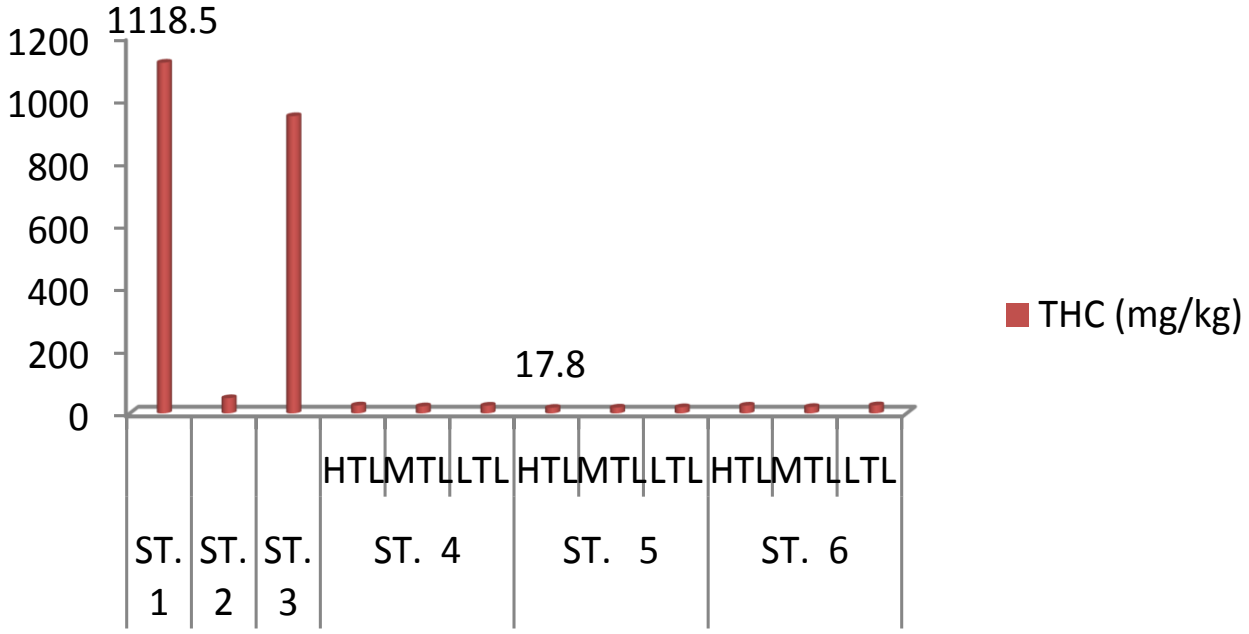

Figure 2. Total Hydrocarbon Content (THC) of the soil in the six sampling stations of the Nun river estuary (January, 2015).

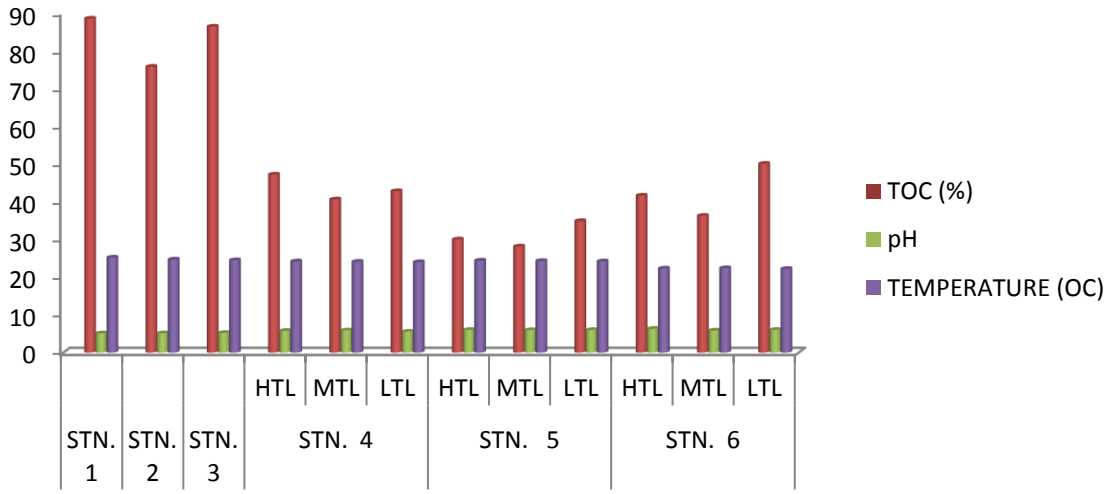

Figure 3. Total Organic Carbon (TOC) content, pH, and temperature of the Soil in the six sampling stations of the Nun river estuary (September, 2014).

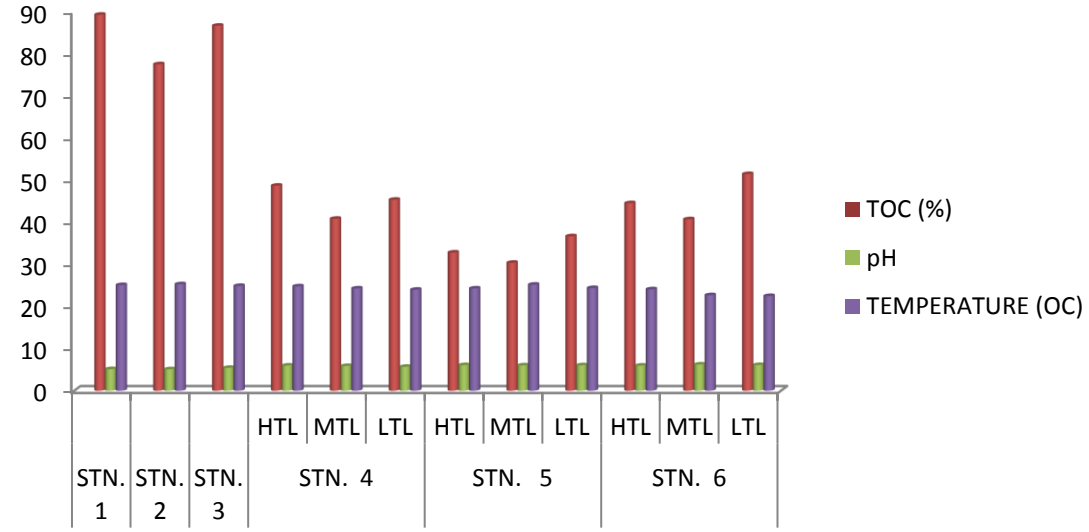

Figure 4. Total Organic Carbon (TOC) content, pH, and Temperature of the soil in the six sampling stations of the Nun river Estuary (January, 2015).

terms of the value of THC, were stations 4, 5, and 6, which had THC values ranging from 17.80 mg/kg at the high intertidal level of station 5 (in January, 2015) to 35.09 mg/kg at the mid intertidal level of station 4 in September, 2014. The relatively low THC values of stations 4, 5, and 6 (compared to stations 1, 2, and 3) could be as a result of the fact that these sampling stations are a little bit distant from the illegal oil refineries (though they serve as loading points of refined crude oil products such as diesel and kerosene) and much of the crude oil may have been washed off and physically transported to the sea, since these stations are a little bit downstream, compared to stations 1, 2, and 3.

The THC values of the sediments, obtained during this study, are within the range reported in the Niger Delta and other parts of the world. Imeh and Sunday (2012) reported THC values ranging from 54 ± 7- 345 ± 4 mg/kg in soil after a petroleum spillage at Ikot Ada Udo, Ikot Abasi in Akwa Ibom State, South- South of the Niger Delta region of Nigeria. Ibigoni *et al.* (2009) recorded THC values ranging from 190.49 ± 15.13 µg/g to 657.31 ± 95.14 µg/g in a study that was conducted on the sediments in a mangrove wetland of the New Calablar River. They also reported that there were significant differences between sampling stations. Wokoma (2014) reported that the concentration of THC in the sediments

of a polluted Tidal creek in Bonny River varied from 1403 ± 80.61 to 3775 ± 113.14 mg/kg. This is closely related but slightly lower than the 400 – 6205 mg/kg reported by Howard et al. (2012) from the Upper reaches of the Sombreiro River, another seriously impacted area, hosting flow-stations, manifolds and wellheads and a network of pipelines that transport petroleum products. Results from another oil impacted area- the New Calabar River revealed a much lower but elevated value of THC ranging from 112.30 ± 17.07mg/kg - 657.30±95.14 mg/kg (Ibigoni et al., 2009). Eja and Ogri (2003) reported mean THC concentration values of 339.2±245.7µg/g in the South Eastern Nigeria. Ideriah *et al.* (2006) reported mean THC concentration values of 528.25 µg/g in the Upper Bonny River. In the streams of Ibadan a non- oil producing area Onianwu and Essien (1999) reported a mean THC value of 219±229 mg/kg for six different streams and river sediments. Mohd. Tahir et al. (1997) recorded a much lower range of THC 0.79 - 20.0 mg/kg in the east coast of Peninsular, Malaysia.

Total organic carbon (TOC)

The results of the analysis of the total organic carbon (TOC) contents of the sediments revealed that stations 1, 2, and 3 (the highly contaminated areas) had higher total organic carbon (TOC) compared to stations 4, 5, and 6 (the less contaminated areas). The TOC values ranged from 28.14%- 89.34%. The lowest TOC value (28.14%) was recorded at the mid intertidal level of station 5 in September, 2014 while the highest TOC (89.34%) was recorded in station 1 in January, 2015. This observation clearly shows that a significant quantity of the oil has undergone appreciable decomposition or a degradation process. Organic matter content should normally increase following the addition of carbonaceous substances, hydrocarbon fuels or condensates. Two decomposition processes are significant to the current research: the decomposition of the soil organic matter and the decomposition of the added petroleum hydrocarbons. Both decompositions are, however, the prerogative of heterotrophic organisms (Osuji and Nwoye, 2007). This implies that significant decomposition of the petroleum hydrocarbons has taken place with different factors of decomposition enhancing the process. The results also indicated that the high and low intertidal zones of stations 4, 5, and 6 had higher TOC than the mid intertidal zones.

Similar values of TOC have been recorded in the Niger Delta and elsewhere, though, the values obtained during this study is relatively high (especially in stations 1, 2, and 3). Okon (2005) recorded mean TOC values ranging from 6.89 ± 3.83% to 11.84 ± 0.36%. Lazăr et al. (2012), recorded mean TOC values of 14.94 ± 2.7%. Also, Okoro et al. (2011) reported TOC values ranging from 1.86 - 147.00% during a study on soil quality assessment 33 months after crude oil spillage and clean-up in Orere-Oluba, in Delta State, Nigeria. They also reported that total organic carbon increased significantly in the contaminated area with a mean level of 41.8%, while the control averaged 3.57%.

pH

The sediments of the Nun River had acidic pH. The mean pH values of the sediments for September, 2014 and January, 2015 were 5.7 4± 0.40 and 5.78 ± 0.39, respectively. The highest pH value (6.32) was recorded in the high intertidal zone of station 6 while the lowest (5.11) was recorded in station 1 in September, 2014. In January, 2015, the highest pH value (6.23) was recorded at the mid intertidal zone of station 6 while the lowest pH value (5.10) was recorded in station 2. Okon (2005) in a study that was conducted on the sediments from Eastern Obolo reported that the pH values of the sediments (in the wet state) tended toward neutrality, with mean values of 6.72 ± 0.147; 6.65 ± 0.362; and 6.81 ± 0.323 for stations 1, 2, and 3, respectively. Shubhanath and Mukesh (2012) recorded soil pH values ranging from 6.34 - 6.69 in a proposed coal mine area at Latehar in Jharkhand, India. Furthermore, Okoro et al. (2011) reported pH values ranging from 5.05 - 6.65 in Orere-Oluba, Delta State, Nigeria.

Temperature

Results from the analysis of the sediments revealed that they had mean temperatures of 24.03 ± 0.89°C and 24.47 ± 0.74°C in September, 2014 and January, 2015, respectively. The results also showed temporal and spatial variations in temperature. The highest temperature (25.3°C) was recorded in station 2 in January, 2015 (dry season), while the lowest temperature (22.2°C) was recorded in the low intertidal zone of station 6 in September, 2014- rainy season. The mean atmospheric temperature of the estuary in September, 2014 was 25.3 ± 0.25°C while that of January, 2015 was 25.6 ± 0.25°C. When compared with pH, it was observed that the temperature of the sediments decreased as the pH increases.

REFERENCES

Buller AT, McManus J (1979). Sediment Sampling and analysis. In; Dyer, K. R. (ed.), Esturine hydrography and sedimentation. University Press, Cambridge UK. pp. 87- 130.

Eja EM, Ogri OR (2003). Evaluation of Total Hydrocarbon (THC) levels in oil polluted coastal areas of South Eastern Nigeria. *Global J. Environ Sci.*, 2:1: 1- 9.

Hanson J, Helvey M, Strach R, eds. (2003). Non- fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region, Version 1, pp. 1- 75.

Howard IC, Briggs AO, Nduka JO, Uzomba NI (2012). Total Hydrocarbon levels of surface sediment and water from the Upper reaches of Sombreiro River, Niger Delta, Nig. J. of Nig. Environ. Society, 7 (3): 16- 22.

http://1.bp.blogspot.com/_DeabNDTNx68/SVPr7EKXy6I/AAAAAAAAAlY/162HX8mmP-4/s1600/NigerDelta.gif.

Ibigoni CH, Gabriel UU, Horsfall M Jnr (2009). Evaluation of total hydrocarbon levels in some aquatic media in an oil polluted mangrove wetland in the Niger Delta. Appl. Ecol. and Environ. Res., 7(2): 111- 120.

Ideriah TJK, Braide AS, Brigg, AO (2006). Distribution of lead and total hydrocarbon in tissues of periwinkles (*Tympanotomus fuscatus* and *Pachymelania aurita*) in the Upper Bonny River, Nigeria. J. Appl. Sci. Environ. Mgt. 10 (2). pp. 145- 150.

Imeh JO, Sunday CE (2012). Determination of Total Hydrocarbon Content in Soil after Petroleum Spillage. Proceedings of the World Congress on Engineering (July 4- 6, 2012), London, U. K. Pp 3.

Lazăr L, GOmOiu MT., BOiCEnCO L, VaSiLiu D (2012). Total organic carbon (toc) of the surface layer sediments covering the seafloor of the Romanian Black Sea coast. Geo-Eco-Marina. 18 (2) 121pp.

Mohd. Tahir N, Abdulah AR, Shanmugam S (1997). Determination of Total hydrocarbon in coastal waters and sediments off the east coast of Peninsular, Malaysia. Environ. Geochem. and Health 19(2): 67- 71.

National Research Council (NRC) (2003). Oil in the sea III: inputs, fates and effects. Washington (DC): Department of Biology, Ignatius Ajuru University of Education P. M. B. 5047, Port Harcourt, Nigeria. National Academy Press.

Newell CR, Hidu H (1982). Production, abundance, and biomass of mobile epibenthic marine fauna in shallow waters, Western Sweden. J. Exp. Mar. Biol. Ecol., 57: 273-30.

Okon MU (2005). Studies on the impact of Nipa Palm (*Nypa fructicans wurmb*) on the epibenthic community of mangrove swamps of Eastern Obolo L. G. A., Akwa Ibom State, Nigeria. PhD Dissertation, Department of Animal and Environmental Biology, University of Port Harcourt, Nigeria. pp. 18- 84.

Okoro D, Oviasogie PO, Oviasogie FE (2011). Soil quality assessment 33 months after crude oil spillage and clean-up, Chemical Speciation & Bioavailability, 23:1, 1-6.

Onianwu PC, Essien CA (1999). Petroleum Hydrocarbon levels in sediment of streams and rivers within Ibadan City, Nigeria. Bull. Chem. Soc. Ethiop. 13(1): 83- 85.

Osuji LC, Ezebuiro PE (2006). Hydrocarbon contamination of atypical mangrove floor in Niger Delta, Nigeria. Int. J. Environ. Sci. Tech. 3(3):313-320.Osuji, L. C. and Nwoye, I. (2007). An Appraisal of the impact of petroleum hydrocarbons on soil fertility: Owaza experience. Afr. J. Agric. Res. 2(7): 318-324.

Osuji LC, Nwoye I (2007). An appraisal of the impact of petroleum hydrocarbons on soil fertility: the Owaza experience. Afr. J. Agric. Res., 2(7), 318– 324.

Partin S (1999). Environmental Impact of the offshore oil and gas industry. Eco-Monitor East Northport, New York. p. 425.

Rhoads DC (1974). Organism-sediment relations on the muddy sea floor. Oceanography and Marine, an Annual review 12: 236- 300.

Shubhanath B, Mukesh G (2012). Physico-chemical and microbial analysis of water and soil samples in proposed coal mine area at Latehar. A thesis submitted in partial fulfillment of the requirement for the degree of bachelor of technology in biotechnology. Department of Biotechnology and Medical Engineering National Institute of Technology Rourkela, Orissa. Pp. 37- 38.

Ward AR (1975). Studies on the sub- littoral nemadodes of Loverpool Bay II. Influence of sediment composition on the distribution of marine nematodes. Mar. Biol. 39: 217-225.

Ward JV (1974). A temperature stressed stream ecosystem below hypolimnal biotope of an urban stream in Nigeria. *Trop. Zool.* 4: 1- 12.

Wokoma OAF (2014). Levels of Total Hydrocarbon in Water and Sediment of a Polluted Tidal Creek, Bonny River, Niger Delta, Nigeria. *Int. J. of Sci. & Technol. Res.,* 3 (12): 354.