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Environmental Impact of Trace Metals and Total Petroleum Hydrocarbon (TPH) in the Okrika Stretch of Bonny River: A Seasonal Variation Study

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ABSTRACT

The accumulation of TPH and effect of metal contamination in aquatic environments has direct consequences to man and to the ecosystem which tends to bioaccumulate in the food chain. This study investigates the seasonal variations in trace metal and TPH levels in the Okrika section of the Bonny River's water and sediment, assessing their potential environmental impact. Water and sediment samples were collected during the dry and wet seasons and analyzed for trace metals and TPH using standard analytical techniques. The result shows the values recorded for zinc in water at all the sites, and the wastewater/effluent was found to be below the DPR/FMENV allowable limit of 1 mg/L. Significant seasonal fluctuation was observed ($p < 0.05$). Zinc levels in all monitoring sites, including the sediment effluent sample, were found to be far below the USEPA regulatory limit of 121 mg/kg. This implies that the creeks sediment is not contaminated by zinc at present. There was no significant seasonal variation ($p <0.05$). Results revealed notable seasonal fluctuations, with higher concentrations of trace metals and TPH observed in various seasons likely due to reduced dilution and increased anthropogenic inputs. The findings highlight the need for continuous environmental monitoring, regulatory enforcement, and remediation efforts to mitigate pollution in the Bonny River.

KEYWORDS: Environment, pollution, Bonny River, Dry season, heavy metals.

1. INTRODUCTION

Urbanization and industrialization have had a detrimental impact on Bonny River over time. The toxicity, persistence, and bioaccumulation of heavy metals in sediments make them one of the most dangerous environmental contaminants.[1] In order to detect and manage metal pollution in estuaries, sediment analyses offer certain advantages over surface water. This is because the rate at which the concentration of metals in sediment changes is slower than that of water. The capacity of sediment to retain, absorb, and release a various range of pollutants, such as nutrients and heavy metals, over a long duration makes it a perfect archive. The Bonny River, which flows through the center of Nigeria's Niger Delta, is essential to the local inhabitants' economic and ecological well-being. As an aquatic ecosystem, the Okrika portion is the most significant and complex of its many components. This ecosystem's state is intimately related to the physical and the surface water's chemical properties.[2] The Bonny River's Okrika portion experiences separate rainy and dry seasons, each with its own set of natural characteristics. Water quality and, by consequently, the aquatic ecosystems health can be greatly impacted by these seasonal variations.[3] The study aims to evaluate the environmental impact of Total Petroleum Hydrocarbon (TPH) and trace metals in the Okrika Stretch of Bonny River.

2. MATERIALS AND METHODS

2.1 Study area and sample location

The research was carried out in Okrika Local Government Area, situated in Rivers State, Nigeria. Okrika, positioned within the Niger Delta region, is a wetland about 56km upstream from the Bight of Benin is the Bonny River. The sampling point include PREW, EKC, OKC, KOC and the control site, located in Ogoloma Creek, remains unaffected by Ekerekana creeks' activities, jetty, and oil bunkering.

2.2 Collecting Samples

2.2.1 Collecting of surface water samples

The samples were collected using pre-washed 1-liter plastic containers. 2mL of Nitric acid that had been concentrated was added to each surface water sample. During BOD sample collection, care was taken to avoid air entrapment, and bottles were wrapped in dark polyethylene bags, and to get rid of light, they were incubated for five days, preventing potential algae-induced DO production. The

tetraoxosulphate (VI) acid was used to acidify the COD samples and DO measurements were conducted in situ in the field.

2.2.2 Collection of sediment samples

At low tide, sediment samples were gathered with the aid of Eckmann grab sampler.[4] The samples were taken to the laboratory in pre-acid rinsed polyethene bags and stored by freezing. Sediment samples for total petroleum hydrocarbons were kept in a plain clear glass bottles previously washed to avoid contamination at 4^{o}C in an ice pack and transported to the laboratory.

2.3 Determination of trace metal ions in water

For digestion, 100mL of each water sample were put into a conical flask. In a fume hood, 5 mL of HNO_3 was added to the sample. After gradually heating the samples, they were evaporated to the smallest volume (about 20 mL) on a hot plate. 5mL of strong nitric acid were added to the conical flasks after they had cooled. A light-colored, transparent solution indicated that digestion was complete, therefore heating was continued and strong nitric acid was added as needed. After that, the filtrate was brought up to mark in a 100 ml volumetric flask. A Buck Scientific model 200A Atomic Absorption Spectrometer (AAS) with an air acetylene flame was used to measure the absorbance of the sample extract solution in comparison to the reference solutions. The preconcentrated sample extracts were also used to determine the principal cations. A 250 mL standard flask was filled with a serially diluted mixed standard solution that contained 1 mg of the metal ion in 1 mL of the stock solution made by pipetting the proper amounts of commercially purchased stock solutions (BDH chemicals). A Buck Scientific model 200A Atomic Absorption Spectrometer (AAS) with an air-acetylene flame was used to measure the amounts of each metal ion in comparison to the standards solution. As previously mentioned, the concentrations of metals, including the main cations, in wastewater and effluent were measured.

2.4 Determination of trace metal ions in sediments

To analyze for trace metals, sediment samples were ground up, allowed to air dry at room temperature, and then sieved through a 0.5 mm sieve. A 100 mL conical flask was filled with one gram of the sieved sediment samples, which were weighed using a high precision weighing scale. For digestion, 1g of the weighted sediment sample was put into a 100mL conical flask. In a fume hood, 10mL of a 1:1 mixture of hydrogen peroxide and HNO_3 were applied to the sample. On a hot plate, it was cooked to 950C. 3mL of hydrogen peroxide and two more mL of water were added, covered, and heated until the effervescence stopped. After letting it cool, Whatman No. 1 filter paper was used to filter it into a 50 mL volumetric flask, and additional distilled water was added to make up the difference. A Buck Scientific model 200A Spectrophotometer fitted with an air-acetylene flame (AAS) was used to measure the amounts of heavy metals.

3. RESULTS AND DISCUSSION

The concentrations of selected trace metals in water samples collected from different locations within the Okrika region of the Bonny River during the dry season are presented in Table 1

Table 1: During the dry season, mean levels of trace metals (mg/l) in the Okrika region of the Bonny River

Metal	DPR	WHO	CSOC	PREW	EKC	OKC	KOC

Iron (mg/l)	1	0.3	1.659±0.257	2.170±0.052	1.620±0.164	1.226±0.079	2.232±0.083
Zinc (mg/l)	1	3.0	0.071±0.00	0.071±0.00	0.071±0.00	0.071±0.00	0.071±0.00
Nickel (mg/l)	0.015	0.02	0.395±0.031	0.071±0.002	0.056±0.0065	0.228±0.031	0.245±0.032
Lead (mg/l)	0.01	0.01	0.071±0.012	0.035±0.012	0.037±0.0055	0.023±0.003	0.072±0.003
Copper (mg/l)	0.01	0.5	0.044±0.009	0.025±0.006	0.026±0.00308	0.122±0.017	0.049±0.0033

Table 2: During the wet season, mean trace metal levels (mg/l) in water of the Okrika region of Bonny River in wet season

Metal	DPR	WHO	CSOC	PREW	EKC	OKC	KOC
Zinc (mg/l)	1	3.0	0.071±0.045	0.0705±0.0027	0.071±0.045	0.037±0.0032	0.071±0.045
Iron (mg/l)	1	0.3	1.178±0.095	2.9156±0.155	2.916±0.098	2.274±0.072	2.155±0.015
Nickel (mg/l)	0.015	0.02	0.221±0.006	0.0705±0.0031	0.071±0.003	0.037±0.011	0.159±0.043
Lead (mg/l)	0.01	0.01	0.038±0.015	0.012±0.001	0.012±0.004	0.023±0.0021	0.071±0.004
Copper (mg/l)	0.01	0.5	0.027±0.004	0.020±0.001	0.033±0.006	0.037±0.002	0.036±0.005

DPR: Department of Petroleum Resources. WHO: World Health Organization. CSOC: Control Station Ogoloma creek PREW: Port Harcourt Refinery effluent/waste water outfall. EKC: Ekerekana creek. OKC: Okochiri creek. KOC: Kalio/Okpoka creek.

Tables 1 and 2 above show the findings of the trace metal analysis of the surface water of the Okrika section of the Bonny River. While the range in the wet season was between 0.037±0.003 and 0.071±0.045 mg/L, with 0.0705±0.0027 mg/L found in the effluent/waste water sample and 0.071±0.045 mg/L found in the control location, zinc recorded the same mean concentration of 0.071 mg/l in all sampled locations during the dry season, including the effluent samples and the control location. The average iron concentration during the dry season was between 1.226±0.079 and 2.232±0.083 mg/l; location 3 (KOC) had the highest concentration, while location 2 (OKC) had the lowest; effluent/wastewater had 2.170±0.052 mg/L, while the control location had 1.781±0.419 mg/L.

During the wet season, it varied between 2.155±0.015 and 2.916±0.098 mg/L; site 1 (EKC) had the greatest value, while location 3 (KOC) had the lowest. The effluent/wastewater sample had a concentration of 2.916±0.155 mg/L, while the control location had a concentration of 1.178±0.095 mg/L.

During the dry season, the mean nickel concentrations varied between 0.056 ± 0.0065 and 0.245 ± 0.032 mg/L. The values at site 1 (EKC) and location 3 (KOC) were the lowest and highest, respectively. The wastewater/effluent sample had a concentration of 0.071 ± 0.002 mg/L, while the control site had a concentration of 0.199 ± 0.140 mg/L. The concentration varied between 0.037±0.011 and 0.159±0.043 mg/L over the rainy season. The highest value was observed at location 3 (KOC), while the lowest value was observed at location 2 (OKC). Specifically, 0.071±0.003 mg/L was obtained in the effluent/wastewater sample, and 0.221±0.006 mg/L was obtained in the control location.

Table 3: Average levels of TPH and trace metals (mg/kg) in the sediments of the Bonny River's Okrika portion during the dry season

Parameter	FMENV	CSOC	PREW	EKC	OKC	KOC
TPH (mg/kg)	50-5000	65.652±1.61	1689.00±19.85	866.867±7.83	1846.500±28.76	84.668±6.4
Calcium (mg/kg)	N/A	2.117±0.046	16.373±0.386	4.405±0.243	5.354±0.372	1.645±0.03
Magnesium (mg/kg)	N/A	3.288±0.226	5.406±0.363	3.529±0.172	5.163±0.102	4.158±0.07

Sodium (mg/kg)	N/A	65.976±2.161	5.175±0.111	34.504±1.333	64.401±2.627	64.288±3.3
Potassium (mg/kg)	N/A	24.138±1.317	2.283±0.316	3.344±0.376	7.466±3.061	19.231±1.0
Zinc (mg/kg)	N/A	2.235±0.080	3.154±1.636	1.265±0.013	0.394±0.079	0.214±0.01
Iron (mg/kg)	N/A	80.389±1.592	77.113±32.100	55.892±12.716	92.764±8.474	83.830±4.9
Nickel (mg/kg)	140	0.248±0.017	0.268±0.017	0.123±0.023	0.268±0.0163	0.240±0.03
Lead (mg/kg)	35	0.069±0.006	0.041±0.006	0.115±0.017	0.073±0.0037	0.042±0.00
Copper (mg/kg)	0.3	0.119±0.056	0.061±0.015	0.127±0.010	0.072±0.035	0.111±0.01

Table 4: Average levels of TPH and trace metals (mg/kg) in the sediments of the Okrika portion of the Bonny River during the rainy season

Parameters	DPR/FMENV	CSOC	PREW	EKC	OKC	KOC
TPH (mg/kg)	50-5000	73.825±24.1	1244.500±22761	67.522±18.29	690.833±9.57	70.815±6.33
Calcium (mg/kg)	N/A	2.597±0.085	11.470±0.777	3.284±0.275	4.583±0.153	2.282±0.143
Magnesium (mg/kg)	N/A	4.416±0.081	3.212±0.102	625.580±124768	5.050±0.146	4.948±0.218
Sodium (mg/kg)	N/A	73.427±2.186	6.997±0.137	30.218±1.940	50.726±6.806	75.027±6.161
Potassium (mg/kg)	N/A	11.930±0.439	1.702±0.161	410.624±68.768	2.498±0.305	13.676±0.520
Zinc (mg/kg)	N/A	1.475±0.60	1.722±0.198	0.703±0.100	0.761±0.125	1.316±0.197
Iron (mg/kg)	N/A	73.720±3.357	71.723±6.665	45.185±2.630	148.500±14.03 9	62.700±3.24
Nickel (mg/kg)	140	0.230±0.015	0.188±0.015	0.191±0.269	0.219±0.021	0.199±0.011
Lead (mg/kg)	35	0.033±0.003	0.049±0.004	0.075±0.005	0.045±0.006	0.042±0.004
Copper	0.3	0.0700.009	0.068±0.030	0.090±0.0036	0.040±0.003	0.081±0.003

The analytical findings of the trace metals in the sediments of the Okrika section of the Bonny River are displayed in Tables 3 and 4. During the dry season, the average calcium concentration was between 1.645±0.035 and 5.354±0.372 mg/kg; the effluent/waste water sample had 16.373±0.386 mg/kg, while the control location had 2.117±0.046 mg/kg. The effluent/waste water sample had a value of 11.470±0.777 mg/kg during the wet season, whereas the control location had 2.597±0.085 mg/kg. The range was 2.282±0.143 to 4.583±0.153 mg/kg. Between 3.529±0.172 and 5.163±0.102 mg/kg were the mean magnesium concentrations measured throughout the dry season. The effluent/waste water sample had a value of 5.406±0.363 mg/kg, whereas the control location had 3.288±0226 mg/kg. The effluent/waste water sample contained 3.212±0.102 mg/l during the wet season, whereas the control location had 4.416±0.081 mg/kg. The values varied from 4.948±0.218 to 625.580±124.768 mg/kg. During the dry season, the amount of potassium in the sediments ranged from 3.344±0.376 to 19.231±1.045 mg/kg, whereas the control location had 24.138±1.317 mg/kg and the effluent/waste water had 2.283±0.316 mg/kg. The effluent/waste water had 1.722±0.161 mg/kg during the wet season, while the control location had 11.930±0.439 mg/kg. The range was 2.498±0.305 to 410.624±68.768 mg/kg. The dry season sodium levels from the different sediments ranged from 34.504±1.333 to 64.401±2.627 mg/kg, whereas the control location had 65.976±2.161 mg/kg and the effluent/waste water had 5.175±0.111 mg/kg. The effluent/waste water had 6.997±0.137 mg/kg during the wet season, while the control location had 73.427±2.186 mg/kg. It varied between 30.218±1.940 and 75.027±6.161 mg/kg. Copper concentrations in dry-season sediment samples varied from 0.072±0.035 to

0.127±0.010 mg/kg, whereas the control location had 0.119±0.056 mg/kg and the effluent/waste water had 0.061±0.015 mg/kg. The effluent/waste water had 0.068±0.030 mg/kg during the wet season, compared to 0.070±0.009 at the control location, with a range of 0.040±0.003 to 0.090±0.0036 mg/kg. Site 1 (EKC) had the highest copper concentration during the dry and wet seasons, while site 2 (OKC) had the lowest concentration.

4. CONCLUSION

The Okrika stretch of Bonny River is an important resource for many people. The health of this ecosystem is therefore essential to the wellbeing of the communities, hence this study to determine the status of the water bodies. The results revealed that some of the trace metals (Fe, Ni, Pb and Cu) in some locations were higher than DPR/FMENV recommended standard while some locations were within the DPR/FMENV limit. Concentrations of Zn at all the sampled locations were within the DPR/FMENV permissible limit. Levels of Zn, Fe, Ni, Pb and Cu in sediment were all within the USEPA and WHO permissible limit. Further research should focus on the continuous monitoring and proactive measures to mitigate pollution and protect the aquatic environment.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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