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RAINY SEASON DISTRIBUTION OF HEAVY-METAL POLLUTION INDEX ALONG OKULU RIVERS IN ELEME LGA OF RIVERS STATE, NIGERIA

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ABSTRACT

This study was conducted in order to determine the rainy season distribution of heavy metal pollution index (HPI) along Okulu rivers in Eleme local government area of Rivers State. Water samples were collected from distances of 100, 200, 300, 400 and 500m away from petrochemical effluent discharge point into the river using well-washed and rinsed bottles. Heavy metal contents of the water samples were analyzed specifically for cadmium, chromium, copper, lead, Iron, Nickel and Zinc. The heavy-metal pollution indices of the various samples were evaluated using the weighted average formula based on WHO and FME surface water standards. The results revealed that the HPI for the water samples at distances of 100, 200, 300, 400 and 500m away from effluent discharge point based on FME standards were 9771, 6325, 10681 and 5814 which indicated that the water samples were unfit for both domestic, Irrigation and industrial purposes while the HPI for the water samples at distances of 100, 200, 300, 400 and 500m away from effluent discharge point based on WHO standards were 35.06, 45,95, 95.30 109.87 and 205.43 which showed that water sample from distances of 100 and 200m away from discharge point are suitable for industrial and irrigation purposes but not for domestic purposes while water samples beyond 200m are not suitable for both domestic, industrial and irrigation purposes. The model of the distribution of the HPI along the sampled area revealed that there is non-linear sinusoidal relationship between HPI and distances along the sampled points. It was concluded that the river is highly polluted with heavy metals and the heavy metals are unevenly distributed along the river. It was recommended that communities along the Okulu rivers should not use the water from this river for both domestic, irrigation and industrial purposes due to high level of heavy-metal contents that could pose serious threat to their health.

KEYWORDS

Heavy-metals, Pollution Index, Rainy Season, Okulu River

Introduction

Heavy metals are constituent of petroleum hydrocarbon, and heavy metal content of petroleum is associated with porphyrins which is the pyrrolic structure (Srivastava *et al.,* 2019). The exploration of petroleum and its associated industries such as petrochemical industry, contaminates the environment and also exposes humans to heavy metals; unlike organic pollutants, heavy metals do not decay or biodegrade. Heavy metals, occur naturally or from anthropogenic activities such as mineral resources development, metal processing and smelting, chemical production, factory emissions and sewage irrigation, has been established to be the principal sources of heavy metal pollution (Zhang *et al.,* 2015). The impact of heavy metals could either be positive or negative to human health and the environment depending on the level of exposure and the species of heavy metals involved. This concept has been demonstrated by various research reports of heavy metals (Zang *et al.,* 2015; *Chen et al*., 2018)

According to (Abata et al., 2016), some heavy metals are dangerous to health or to the environment (e.g. mercury, cadmium, lead, chromium), some may cause corrosion (e.g. zinc, lead), some are harmful in other ways (e.g. arsenic may pollute catalysts) while some of these elements are essential for humans in minute quantities (cobalt, copper, chromium, manganese, nickel) while others are carcinogenic or toxic, affecting among others, the central nervous system (manganese, mercury, lead, arsenic), the kidneys or liver (mercury, lead, cadmium, copper) or skin, bones, or teeth (nickel, cadmium, copper, chromium). For example, exposure to cadmium and arsenic would result in disorders of the cardiovascular and other systems, which may eventually result to cancer (Zang *et al.,* 2015). In the last five decades, thirty thousand (30,000) tons of Cr and eight hundred thousand (800,000) tons of Pb was released into the environment globally, most of which accumulate in soil and water bodies and thus caused serious heavy metal pollution (*Chen et al*., 2018).

The harmful effects of bioaccumulation of heavy metals across the food chain make them a significant environmental concern. Heavy metal contamination primarily originates mainly from activities and wastes from chemical and petrochemical industries (Zahir & Mohamed 2013). It is essential for human health to have trace amounts of certain heavy-metal in our metabolism because they are present in such minute concentrations, however, excessive amount of these heavy metals pose serious threat to humans and the environment. Thus, the positive functions of these heavy-metals shift to a negative one when their concentrations exceed what is considered safe for human health. According to Venkata et al. (2014), heavy metal ions can be found in food and water as direct sources, and in more indirect forms in industrial processes and vehicular traffic. Plants, animals, and bacteria all require trace amounts of heavy metals like copper, iron, nickel, and zinc act as micronutrients.

Though necessary for human survival, most heavy metals are poisonous and are mostly associated with increased risk of cancer in workers who inhale or ingest them (Ramesh, & Thirumangai 2014). For instant, copper deficiency is associated with anemia, stunted growth, and circulatory issues (Balakrishnan et al., 2014) but excessive copper poisoning can cause symptoms such as unconsciousness, Wilson's disease, nephropathy, liver necrosis, and widespread homolysis. Death could result from failure to cure it. The dangers of lead poisoning in the workplace have been known for ages, and the disease has long been associated with serious Lead poisoning and other neurological problems can occur in the brain and blood cells when lead levels in drinking water are high enough (Ponnusamy et al., 2014). In nature, chromium is found in minute amounts. Compared to rocks of the silica type, it is more abundant in rocks. The physicochemical form of chromium determines its toxicity; hexavalent salts are the most harmful (Abdul-Jameel et al., 2012). Nickel, like chromium, is not poisonous, but at extremely high concentrations it can influence physiological processes (Zahir & Mohamed 2013). Automobile repair shops, electroplating units, the manufacturing process of utensils, sewage, and agricultural runoff are among the many sources of the high levels of nickel in waters.

In most communities in Nigeria including Rivers State, surface water bodies are utilized for several purposes ranging from domestic uses, agricultural and industrial purposes. However, these surface water bodies are polluted due to pollutions from human activities (Kamble et al., 2011). Industrial effluent disposal and water runoff from polluted soil surface into the surface water bodies are the major culprit responsible for the high concentration of heavy metals in most surface water in Rivers State. Therefore, it is necessary to conduct this study to investigate heavy-metal pollution index of Okulu river; a surface water body in River State with known source of pollution, in order to ascertain the likelihood of excessive heavy metals in the water based on Federal Ministry of Environment (FME) permissible standards for heavy metals in surface water bodies in Nigeria

Heavy-metal pollution index is a water quality index evaluated based on pollution level of the heavy metal. It is defined as a rating that reflects the composite influence of different heavy metal in water sampled (Allison et al. 2020.) It is considered as one of the most effective and reliable method of measuring water quality because it simplifies data into information that can easily be understood by concern citizens, researchers and policy makers. In this study heavy-metal pollution index based on conventional method for evaluation of water quality index was used to ascertain the distribution of heavy metal pollution level arising from activities of sand mining, petrochemical and abattoir effluent on Okulu River particularly in the rainy season.

1.0 Materials and Methods

2.1 Research Design

This study adopted Experimental design. The design is suitable for this study because it involves carrying out empirical study in which the researcher has room to control and manipulate the independent variable based on the limitations and scope of this study. In this study, the independent variables which are at the disposal of the researcher are distant of point of water sample collection from point of effluent deposition in the river while the dependent variable is the concentration of heavy metals in the water sample

2.2 Study Area

The study area is Eleme LGA, River state. Okulu river flowing through Agboonchie and Aleta community in Eleme LGA was the focal point of the study see Figure 2.1. Okulu river is a freshwater system used for domestic, economic and recreational purposes. However, the river is polluted by activities of petrochemical fertilizer operation, sand mining, and abattoir processing facilities. Okulu River takes it course from Ogale meandering through Agbonchia and Aleto before emptying into Bonny River through Okrika creeks. Five different data collection point were considered in the River; Point 1 (100m from effluent discharge point) is located at latitude 04.807900N and longitude 007.098740E. Activities around this location are sand mining, fishing and farming. Point 2 ((200m from effluent discharge point) is located at latitude 04.806860N and longitude 007.100990E. Activities around this location are abattoir processing facility, car wash and auto mechanic. Point 3 (300m from effluent discharge point) is located at latitude 04.807860N and longitude 007.101880E. Activities around this location is farming and dredging. Point 4 (400m from effluent discharge point) is located at latitude 04.808470N and longitude 007.103070E. Activities around this location are fishing and NNPC pipeline right of way. Point 5 (500m from effluent discharge point) is located at latitude 04.808910N and longitude 007.105560E. see Figure 2.2

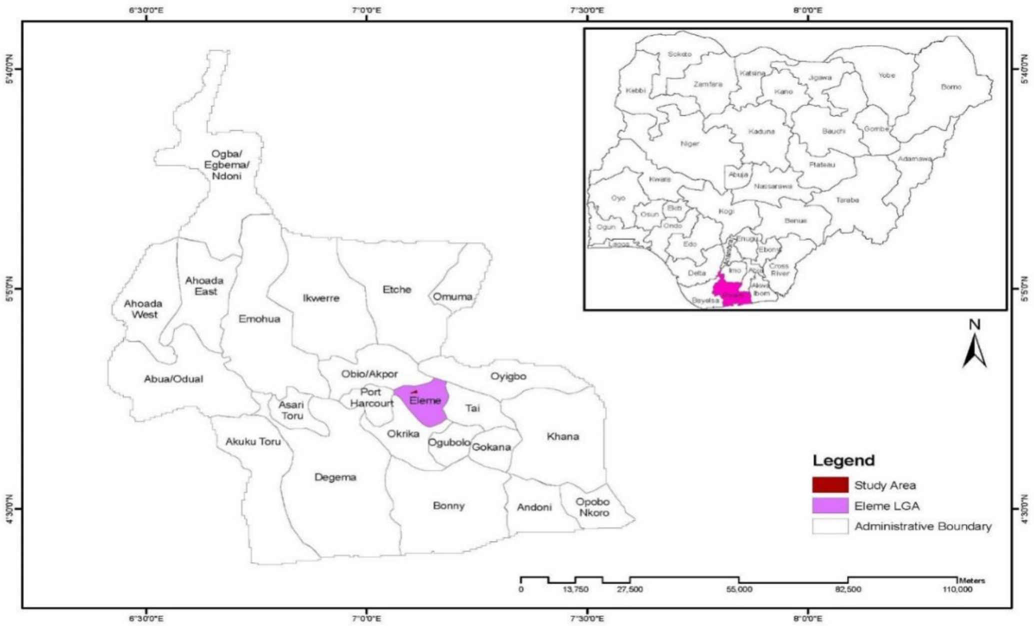

Figure 1. Map Rivers State showing Eleme LGA

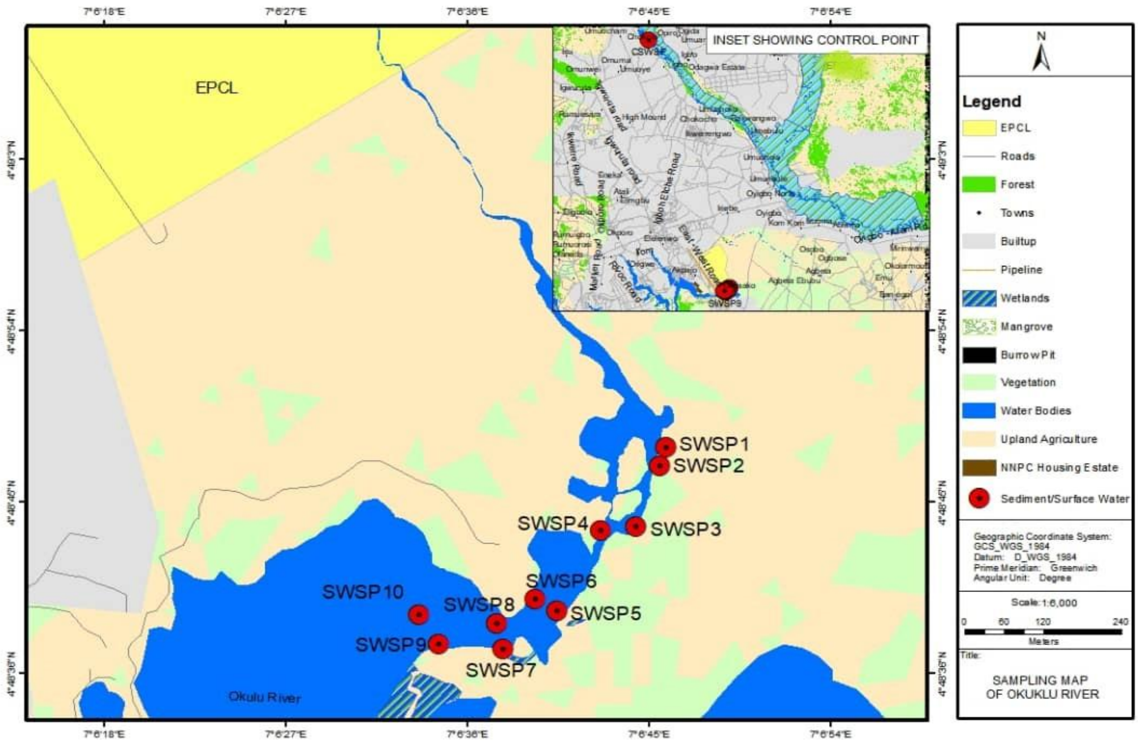

Figure 2.2. Map of Okulu River in Eleme LGA showing the sample collection points

2.3 Sample Collection procedures

2.3.1 Pre-Field Activities.

An investigation tour of the study area was done and sampling stations were located and mapped using Global Positioning System (GPS). Sampling containers were obtained, washed, rinsed and labelled. Reagents for sample analysis were prepared and all the instrument to be used for the analysis were properly calibrated.

2.3.2 Main Field Activities

Five sampling point were established along the Okulu River at distances interval of 100m such that the first sampling point is approximately 100m from point of discharge of petrochemical effluent in the river. Two water samples were collected from each sampling points for a period of in the peak of the rainy season (July, 2024). Glass bottles were used to collect water sample for heavy metals and stored in ice-chest and transferred to the laboratory for analyses.

2.3.3 Laboratory Activities

The chemical analysis of the heavy metal in the water samples was done using standard laboratory methods as established by American Public Health Association (APHA). The suitability of Okulu River for domestic and other purposes were determined by comparing the values of the heavy metal concentration obtained with FME (2018) and WHO (2004) standard for surface water see Table 2.1

Table 2.1 The FME and WHO standard limit of some heavy metal in surface water body

Parameter	FME limit	WHO limit
Cadmium, Cd (mg/l)	0.005	0.005
Chromium, Cr (mg/l)	0.001	0.05
Copper, Cu (mg/l)	0.1	1.0
Iron, Fe (mg/l)	0.05	0.3
Lead, Pb (mg/l)	0.5	0.05
Nickel, Ni (mg/l)	0.01	0.1
Zinc, Zn (mg/l)	0.05	5.0

2.4 Heavy-metal Pollution Index

In evaluation the heavy metal pollution index in this study, seven heavy metals namely, cadmium, chromium, copper, lead, Iron, Nickel and Zinc were considered. The weighted arithmetic mean method was used to classify the water quality according to the degree of purity using the most commonly measured water quality variables (Shweta et al. 2013.) using the procedures expressed as follows;

1. Parameter weightage calculation Wi. Where Wi is the unit weightage and Si is the suggested standard for the parameter, the weightage parameter is given by Wi = 1/Si.
2. Determine how each heavy metal Qi is rated in terms of quality. The formula for determining an individual's quality rating is Qi = Vi/Si.
3. Here, Qi is the parameter's sub-index, Vi is the parameter's monitored value, and Si is the parameter's standard or allowable limit.
4. Then HPI model is computed using the following equation

$$\frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi}$$

2.1 HPI rating (Onyeugbo et al 2021)

S/N	HPI Level	Status	Possible Usage
1	0-25	Excellent	Drinking, Irrigation and industrial
2	26-50	Good	Domestic Irrigation and Industrial
3	51-75	Fair	Irrigation and industrial
4	76-100	poor	irrigation
5	101-150	very poor	Restricted use for irrigation
6	above 150	Excessively polluted	Proper treatment required

2.0 Results and Discussion

3.1 The concentration of the sampled heavy metal in the various location compares to standard limits

Table 3.1 showed the concentrations of the seven heavy metals in the water sample collected from the five different locations along Okulu river. The results revealed that the concentrations of all the seven heavy metals sampled from the five locations are exceed both the national and international standards for the various heavy metal in surface water body. This is a confirmation of the fact that the river is highly polluted. These results aligned with works of Samuel, (2015) and Kamble et al., (2011) who stated that heavy metal presence in water bodies occurs mainly due to anthropogenic activities such as industrial processes, agricultural activities and disposal of wastes

Table 3.1 Concentration of the sampled heavy metals at different distances from effluent discharge point

Distance M)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Iron (mg/l)	Lead (mg/l)	Nickel (mg/l)	Zinc (mg/l)
100	0.0178	13.189	15.491	7.1383	6.8428	1.2164	11.142
200	0.1387	8.4537	11.788	5.2226	5.4579	0.8569	8.8279
300	0.3642	14.419	14.632	4.9841	8.8167	0.1154	8.7128
400	0.5688	7.7549	9.3744	7.5931	4.9987	0.7539	10.321
500	1.0261	16.959	14.29	5.8911	11.109	0.6628	16.187
FME	0.005	0.001	0.1	0.05	0.5	0.01	0.05
WHO	0.005	0.05	0.1	0.3	0.05	0.1	5.00

3.2 Distribution of heavy metal pollution index along the rivers based on FME standard limit

Table 3.2 showed the heavy metal pollution index calculated for the various distances from effluent discharge point based on federal ministry of environment standard. The results revealed that the entire length of the river considered in this study are excessively polluted with heavy metal such that location 5 which is 500m from the point of effluent discharge is the most polluted point (HPI = 12,630) followed by point 400m from the point of effluent discharge (HPI = 10681) while point 300m from effluent discharge point is the least polluted (HPI = 5814). The high heavy metal pollution observed in this study could be attributed to the disposal of petrochemical and abattoir effluents into the rivers as well as massive sand mining activities carried in the rivers. This results aligned with the outcome of study carried out by Onueugbo et al (2021) who confirmed that water quality index of Okulu river is very high and unfit for domestic and industrial use.

Table 3.2 The Heavy metal pollution index at different distances from effluent discharge point based on FME standards

Distance (m)	Heavy metals	Concentration (mg/l)	Wi	Qi	Wi.Qi	HPI	Remark
100	Cadmium	0.0178	200	3.560	712	9771	Excessively polluted
	Chromium	13.189	1000	13189	13,189,000		
	Copper	15.491	10	154.91	1541		
	Iron	7.1383	20	142.77	2855		
	Lead	6.8428	2	13.686	27		
	Nickel	1.2164	100	121.64	12164		
	Zinc	11.142	20	222.8	4456		
200	Cadmium	0.1387	200	27.74	5548	6325	Excessively polluted
	Chromium	8.4537	1000	8453.7	8,453,700		
	Copper	11.788	10	110.79	1107.8		
	Iron	5.2226	20	104.44	2088.8		
	Lead	5.4579	2	10.916	21.832		
	Nickel	0.8569	100	856.9	85690		
	Zinc	8.8279	20	176.58	3531.6		
300	Cadmium	0.3642	200	72.84	14568	10681	Excessively polluted
	Chromium	14.419	1000	14419	14,419,000		
	Copper	14.632	10	146.32	1463		
	Iron	4.9841	20	99.68	1994		
	Lead	8.8167	2	17.633	35.00		
	Nickel	0.1154	100	11.54	1154		
	Zinc	8.7128	20	174.26	3485		
400	Cadmium	0.5688	200	113,76	22752	5814	Excessively polluted
	Chromium	7.7549	1000	7754.9	7754900		
	Copper	9.3744	10	93.744	937		
	Iron	7.5931	20	151.86	3037		
	Lead	4.9987	2	9.997	20		
	Nickel	0.7539	100	753.9	75390		
	Zinc	10.321	20	206.24	4125		
500	Cadmium	1.0261	200	205.22	41044	12630	Excessively polluted
	Chromium	16.959	1000	16959	16959000		
	Copper	14.290	10	142.90	1429		
	Iron	5.8911	20	117.4	2348		
	Lead	11.109	2	22.22	44.00		
	Nickel	0.6628	100	662.80	66280		
	Zinc	16.187	20	323.74	6474		

Figure 3.1 showed the graphical representation of the relationship between HPI and distance from effluent discharge point based on FME. The graph showed that there is non-linear and sinusoidal relationship between HPI and distance from effluent discharge point. The model is presented as Equation 1. The uneven distribution of the HPI in the river could be attributed to uneven water current, river depth, water flow rate and two-directional flow of the rivers which changes due to change in tide.

$$\mathbf{HPI = 2E\text{-}05D^4 - 0.0186D^3 + 7.6242D^2 - 1253.8D + 75975} \qquad \mathbf{1}$$

Where HPI is the heavy-metal pollution index along the rivers and D is the distance from effluent discharge point. Hence the model can be used to predict the HPI along any distance from the effluent discharge point based on FME standard

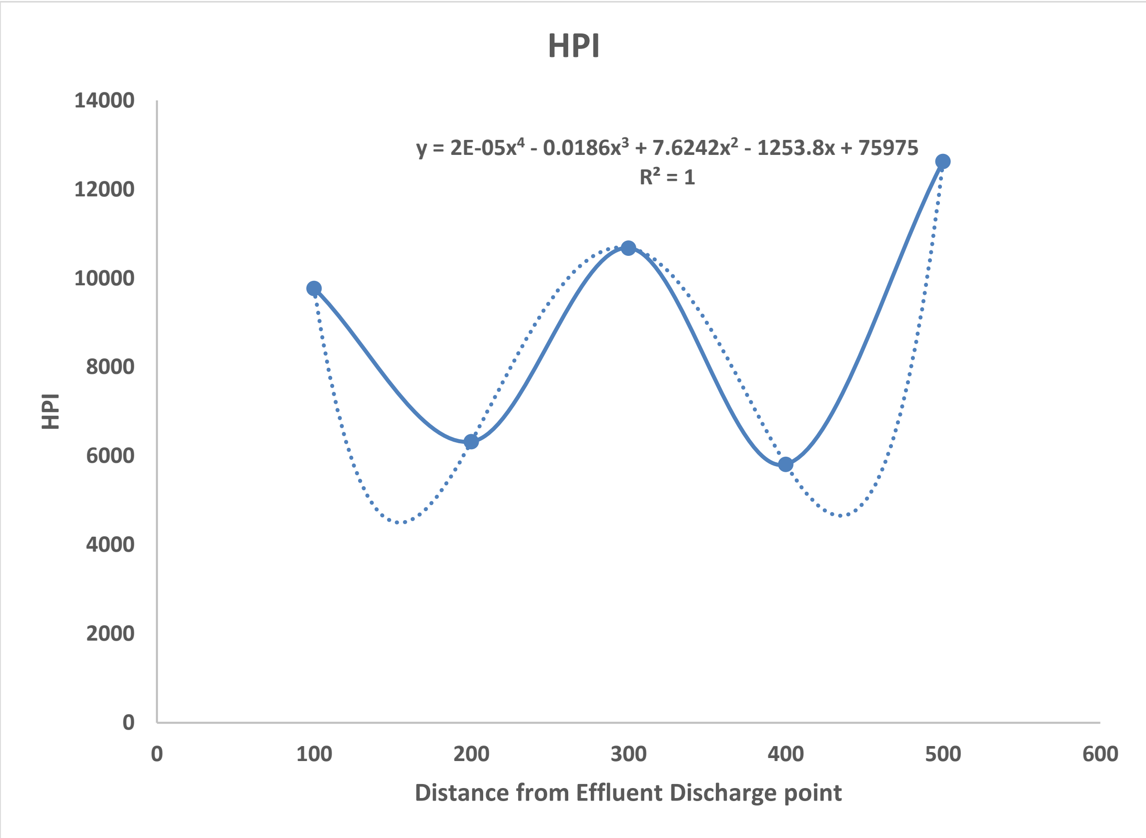

Figure 3.1 The relationship between HPI and distance from effluent discharge point based on FME standard

3.2 Distribution of heavy metal pollution index along the rivers based on WHO standard limit

Table 3.3 showed the heavy metal pollution index calculated for the various distances from effluent discharge point based on WHO standard. The results showed that the HPI at distance 100 and 200 meter from effluent discharge point are good, 300m away from effluent discharge point is poor, 400 meter from discharge point is very poor while 500m from discharge point is excessive polluted This mean that location 5 which is 500m from the point of effluent discharge has the highest pollution index (HPI = 205.43) followed by point 400m from the point of effluent discharge (HPI = 109.87) while point 100m from effluent discharge point is the least polluted (HPI = 35.06). The high heavy metal pollution observed in this study could also be attributed to the disposal of petrochemical and abattoir effluents into the rivers as well as massive sand mining activities carried in the rivers. This results partially aligned with the outcome of study carried out by Onueugbo et al (2021) who confirmed that water quality index of Okulu river is very high and unfit for domestic and industrial use.

Table 3.3 The Heavy metal pollution index at different distances from effluent discharge point based on WHO standard

Distance (m)	Heavy metals	Concentration (mg/l)	Wi	Qi	Wi.Qi	HPI	Remark
100	Cadmium	0.0178	200	3.560	712	35.06	Good
	Chromium	13.189	20	263.8	5276		
	Copper	15.491	1	15.49	15.49		
	Iron	7.1383	3.33	23.78	79.20		
	Lead	6.8428	20	136.9	2738		
	Nickel	1.2164	10	12.16	121.64		
	Zinc	11.142	0.2	2.230	0.446		
200	Cadmium	0.1387	200	27.74	5548	45,95	Good
	Chromium	8.4537	20	169.07	3381		
	Copper	11.788	1	11.79	11.79		
	Iron	5.2226	3.33	17.40	57.94		
	Lead	5.4579	20	109.16	2180		
	Nickel	0.8569	10	8.569	85.69		
	Zinc	8.8279	0.2	1.766	0.353		
300	Cadmium	0.3642	200	72.84	14568	95.30	Poor
	Chromium	14.419	20	288.38	5767.6		
	Copper	14.632	1	14.632	14.63		
	Iron	4.9841	3.33	16.597	55.27		
	Lead	8.8167	20	176.33	3527		
	Nickel	0.1154	10	11.54	115.4		
	Zinc	8.7128	0.2	1.742	0.35		
400	Cadmium	0.5688	200	113,76	22752	109.87	Very Poor
	Chromium	7.7549	20	155.10	3102		
	Copper	9.3744	1	9.374	9.37		
	Iron	7.5931	3.33	25.27	84.15		
	Lead	4.9987	20	99.80	1996		
	Nickel	0.7539	10	7.539	75.39		
	Zinc	10.321	0.2	2.064	0.412		
500	Cadmium	1.0261	200	205.22	41044	205.43	Excessively polluted
	Chromium	16.959	20	339.18	6783.6		
	Copper	14.290	1	14.29	14.783		
	Iron	5.8911	3.33	19.614	32.01		
	Lead	11.109	20	222.2	4444		
	Nickel	0.6628	10	6.63	66.30		
	Zinc	16.187	0.2	3.24	0.648		

Figure 3.2 showed the graphical representation of the relationship between HPI and distance from effluent discharge point based on WHO standards. The graph also showed that there is non-linear sinusoidal relationship between HPI and distance from effluent discharge point. And the model is expressed in Equation 2. The uneven distribution of the HPI in the river could be attributed to uneven river depth, water current, water flow rate and two-directional flow of the rivers which changes abstractly due to change in tide

$$\mathbf{HPI = 8E\text{-}08D^4 - 9E\text{-}05D^3 + 0.0368D^2 - 5.7484D + 324.88} \qquad \mathbf{2}$$

Where HPI is the heavy-metal pollution index along the rivers and D is the distance from effluent discharge point. Hence the model can be used to predict the HPI along any distance from the effluent discharge point based on WHO standard

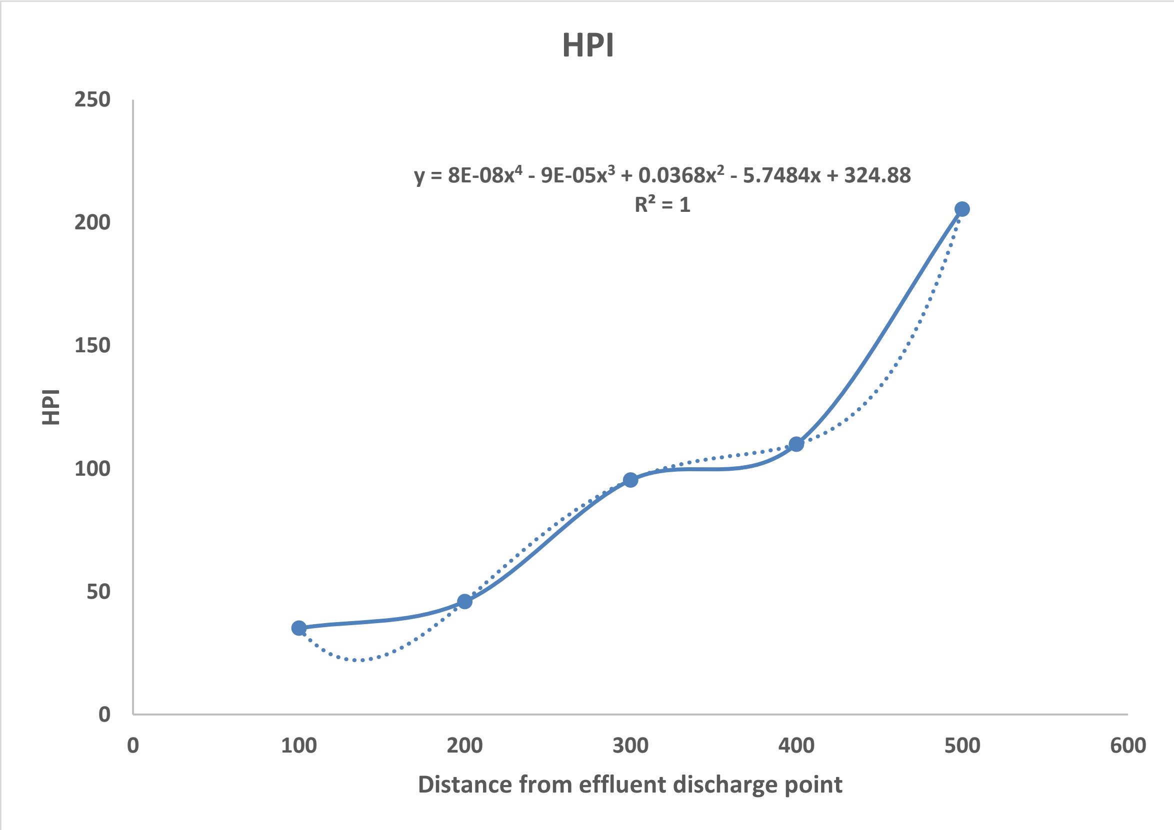

Figure 3.2 The relationship between HPI and distance from effluent discharge point based on WHO standards

4.0 CONCLUSIONS

Based on the findings of this study, it was concluded that; one, there is high level of heavy metal pollution in Okulu rivers which could be attributed to petrochemical effluents, sand mining and other activities along the coast of the rivers, two, the heavy-metal pollution index is a function of the concentrations of the heavy metal and the recommended standard limits of the heavy metals based on different national and international standards and three, there is non-linear sinusoidal distribution of the heavy-metal pollution index along the rivers which could be predicted using appropriate polynomial models developed based on heavy metal recommended standards.

3.0 RECOMMENDATION

Based on the conclusions above, it was recommended that;

1. The communities along the Okulu rivers should be not to use the water from this river for both domestic, irrigation and industrial purposes due to high level of heavy-metal contents that could pose serious threat to their health.
2. Rivers state government should ensure that petrochemical companies and other firms that uses the rivers as effluent discharge point should treat their effluent to required standard before disposal
3. Other activities in the rivers such as sand mining should be regulated

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