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ASSESSMENT OF THE PHYSICOCHEMICAL CHARACTERISTICS AND WATER QUALITY INDEX OF NKISA RIVER IN THE NIGER DELTA, NIGERIA

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Abstract: **The study evaluated the physicochemical characteristics of Nkisa River, Niger Delta, Nigeria. Also, the water quality index of the river was determined. The data needs, for the study, were sourced through extensive literature review, field work covering wet and dry seasons, laboratory analysis of field samples. Water samples from 7 sampling stations, each 250m apart, were collected and analyzed every two months for physicochemical and heavy metal content. The results indicated crude oil and other anthropogenic activities impacted on the River water quality. DO (1.10 to 8.1 mg L^{-1}), BOD_5 (2.8 to 8.7 mg L^{-1}), COD (4.18–17.93mgL^{-1}), PO_4 (0.05 to 2.6 mg L^{-1}) and TPH (0.01-13.64 mg L^{-1}) were out of the range of WHO standards and their maximum violations were recorded in Stations 2, 5, 5, 3 and 4 in March, September, May, July and March respectively. Heavy metal concentrations for Fe, Pb, Cd, Cr and Mn were higher than the WHO standards also indicating that Nkisa River is contaminated. The heavy metal concentrations were ranged (0.01 to 1.84), (0.001 to 0.07), (0.001 to 0.74), (0.001 to 0.59), (0.01 to 0.64), (0.01 to 0.45) and (0.003 to 0.57) mg L^{-1} for Fe, Cu, Zn, Mn, Pb, Cd and Cr respectively. The calculated WQI fell within the range of 31.37 – 167.13, indicating water quality status tending from “good water quality” to “unsuitable for drinking”. HPI values ranged from 260.16 to 5697.44 indicating “high class” pollution. HEI (0.39 to 13.27) and Cd (-6.65 to 4.60) fell under “low degree” pollution.**

Keywords: **Degree of Contamination, Heavy Metals, Heavy Metal Evaluation Index, Heavy Metal Pollution Index, Physicochemical parameters, Water Quality Index.**

I. INTRODUCTION

The importance of rivers to the local population of Nigeria, particularly Rivers state, can never be over emphasized. Rivers State's rural prosperity has been attributed largely to its rivers. Its numerous rivers are extremely valuable because they play a larger role in the region's economy, geography, culture, and religion. Nkisa River is an important part of the Niger Delta river system, serving as the region's only surface drinking water supply as well as a nursery and breeding habitat for a variety of fish species. The crude oil pipelines owned by an operating oil exploration and exploitation company run alongside the Nkisa River. Oil pipeline leaks and pipeline vandalism by crude oil thieves have occurred frequently in the area. The river is impacted whenever there is an oil leak or spill. The Nkisa River is rapidly deteriorating as a result of nearby metal works and crude oil extraction.

Surface water pollution has been a problem in developing countries, particularly Nigeria, as a result of increased industrialization, leisure activities, oil spills, flared gases, open defecation, agricultural activities, and solid waste disposal [1]. Incidences of oil spills in the aquatic environment from pipe leaks, vandalization, runoffs etc. pollute water bodies [2] by changing their physical, chemical, and biological properties to the point where the water is unfit for its intended use. Surface water pollution, which threatens ecosystems and human health, is one of the most serious environmental issues currently confronting the Niger Delta Area [3]. Thus, it is essential to monitor and manage surface water through evaluations, regulations, and responsible use.

There have been more cases of water pollution and contamination, fish migration, and shrinkage of the wetland area of the Nkisa River in Egbema community, River State, as a result of various human activities, such as the extraction of oil and gas, dredging, invasion of invasive plants, and restoration of wetlands, in addition to increased industrialization, population growth, and inadequate governance. Fish populations have decreased as a result of oil pollution and poor water quality. The availability of potable, high-quality water is a problem in the Egbema community due to environmental degradation and pollution. Due to abundant gas and crude oil reserves, the Niger Delta Region of Nigeria is becoming more urbanized and industrialized, which is having a negative impact on the environment.

Many nations have created water quality management programs, which include assessment, monitoring, mitigation, and prevention of water pollution in order to ensure safe and healthy water resources, in an effort to reduce challenges related to water quality. It is possible to evaluate the chemical, physical, and microbiological qualities of water before drinking it. To determine how the physicochemical parameters of surface water quality relate to one another and to understand the trends in water quality in the River, a general statistical study and analysis of these parameters have been conducted.

Massive volumes of data on water quality are compiled into a single number called the Water Quality Index (WQI), which is a mathematical tool that indicates the level of water quality [4]. Additionally, the Water Quality Index helps to consistently report large amounts of data on water quality to management, the public, and authorities by condensing complex information into simple terms e.g., "Good," "Bad," "Clean," or "Contaminated." The two categories of indicating drinking water parameters in this study are physicochemical parameters and heavy metals. [4] and [5] analyzed and reported on the water quality index (WQI) of water bodies in Nigeria's southern states. [6] investigated the WQI and HPI of subterranean water sources in Nasarawa State, Nigeria to determine if the water was safe for household applications. The purpose of this study was to analyze the Nkisa River's water quality in Egbema, Rivers State.

STUDY AREA

This study concentrated on sections of the Nkisa River in Egbema, Rivers State, Nigeria's Niger Delta (Figure 1). The region is unique in that there is a significant amount of watercourse connectivity. With 2% of Nigeria's surface area; it is the most important drainage feature of the Niger-Basin rivers system [5]. Three Rivers state local government areas are traversed by the river: Ogba/Egbema/Ndoni between latitudes 6^{o} 30' and 7^{o} 0'E and longitudes 4^{o} 12' and 6^{o} 37' N. The river narrows and steepens as it moves south, and starting in the middle reaches, the steepness gradually lessens. Some characteristics of the sample stations along the Nkisa River are as follows:

Sample Stations 1 to 3: Human activities recorded along these stations include cleaning, bathing, washing and other domestic uses. People fetch and drink water from these parts of Nkisa River. The river bed is composed of stones and gravels, with a sandy middle zone that transition to a muddy one as the river flows downstream. These sample stations are surrounded by riverine forest.

Sample Stations 4 to 6: Several human activities occur here, including illegal crude oil refinery, excavation of sand from the riverbed for building, farming, fishing, dredging, mangrove cutting, timber logging, fishing and transportation. These could be possible pollution sources for the environment [7]. These are the most contaminated part of the river stretch where oil discharges from bunker activities enter the river. The effluent is a hydrocarbon form of pollution (crude oil) that physically colors the river and leaves black oily patches on the skin when it comes into touch with it. It has significantly diminished the population of aquatic life in these regions where it contaminates the Nkisa River. The vegetation consisted of terrestrial and riverine vegetation while the the bed is composed mainly of stones and gravels.

Control Station: The final station was designated as the control station and was positioned at the confluence of two rivers (Nkisa and Orashi). A tributary of the Nkisa River flows into the River Orashi at this station. This aims to provide an overview of the environmental conditions away from significant pollution sources. The water was generally clear with increased velocity.

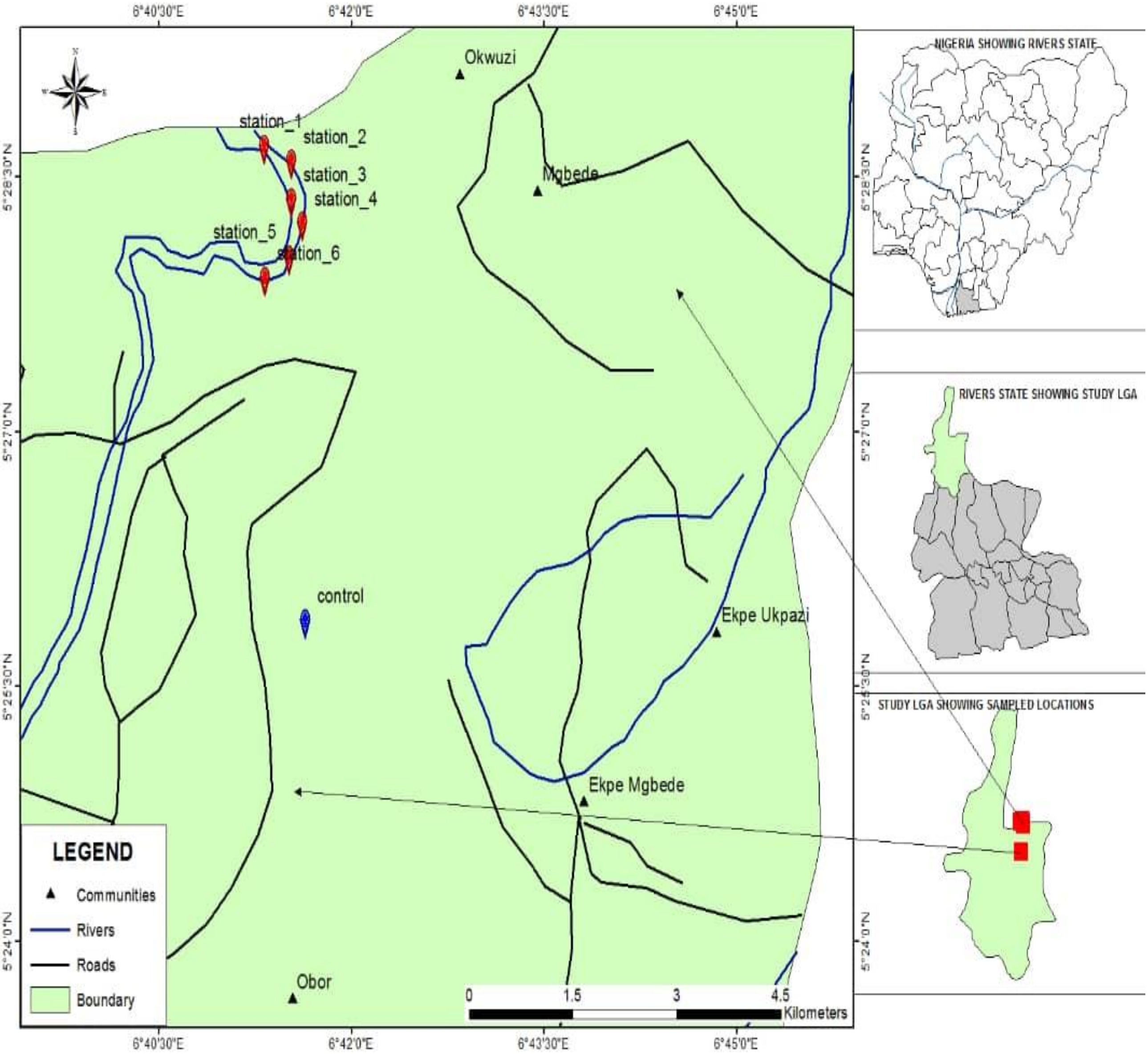

Fig. 1 Map showing the study area

II. BODY OF ARTICLE

DATA COLLECTION AND ANALYSIS

The gathering, organizing, analyzing, interpreting, and presenting of sample data is known as water quality analysis. It also refers to a group of techniques for processing vast amounts of data and reporting general trends. It covers every facet of data, including organizing the gathering of sample data.

For the entire year, field and laboratory work was done every two months to capture the typical conditions of the dry and rainy seasons. Field sample visits and field observation visits were the two categories into which the field activities were separated. Along with getting to know the river itself, the field observation tour also aimed to familiarize participants with the surrounding community and environment. During the field sampling visits phase, data was collected at each of the seven sampling stations spaced 250 meters between stations. Surface water samples collections for physicochemical parameters were done once every two months for one year from (January to November 2021) and a total of 42 samples were collected during the six months of sampling. To preserve the integrity of some unstable physicochemical parameters, water samples were collected for analysis of Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Petroleum Hydrocarbon (TPH), Nitrate, Sulphate, Phosphate, and heavy metals from the location where the mid-stream velocity was measured. Hanna multimeters were used for in-situ measurements of temperature, pH, dissolved oxygen (DO), electrical conductivity, salinity, turbidity, and total dissolved solids in the field. Every substance used and every application technique used in the field followed accepted practices. In order to preserve the organic materials, water samples were brought to the lab in an ice-cooler. The sample analyses were conducted using conventional laboratory techniques [8].

Physiochemical parameters and heavy metal pollution are used in the Water Quality Index (WQI), a useful method for assessing surface water quality for drinking water consumption [9]. For this study, the weighted arithmetic water quality index (WAWQI) method was used in calculating WQI. The total quality of the measured water is determined using the index, which yields a single value. To evaluate the quality of drinking water, three pollution indices were used: degree of contamination (Cd), heavy metal pollution index (HPI), and heavy metal evaluation index (HEI). The heavy metal content of the water is evaluated overall using the (HPI) and (HEI) protocols. On the other hand, the (Cd) technique assesses the quality of water by calculating the level of contamination.

Equations (1), (3), and (4) were used, respectively, to calculate the WQI/HPI, HEI, and Cd [8].

$$\mathrm{WQI/HPI} = \frac{\sum_1^n \mathrm{WiQi}}{\sum_1^n \mathrm{Wi}} \qquad (1)$$

Where Qi = i-th parameter's sub-index; n = the number of parameters taken into consideration and wi = the unit weightage of the i-th parameter. Equation (2) was used to calculate the sub-index (Qi).

$$\mathrm{Qi} = \sum_{\mathrm{I}=1}^{\mathrm{n}} \frac{\mathrm{Mi}}{\mathrm{Si}} \times 100 \qquad (2)$$

Where Mi, Ii, and Si = the i-th parameter's monitored heavy metal value, desirable standard value, and allowable standard value, respectively. Ignoring the algebraic sign, the sign (-) denotes the algebraic differences between the two values.

$$\mathrm{HEI} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \frac{\mathrm{Hci}}{\mathrm{Hmaci}} \qquad (3)$$

Where Hmaci = maximum appropriate concentration of the i-th parameter and Hci = observed value of the i-th parameter. The HEI was used by [10] to make the pollution index and level of pollution easy to interpret.

$$\mathrm{Cd} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{Cfi} \qquad (4)$$

Cfi, or contamination factor, is computed as $\mathrm{Cfi} = \frac{CAi}{CNi} - 1$, where CAi and CNi = the analytical value and maximum allowable concentration of the i-th component, respectively.

III. RESULTS

Tables I, II, III, IV, and V present the results of the physicochemical, heavy metals characteristics, pollution indices, and correlation matrix among the physicochemical parameters and pollution indices of the Nkisa River, respectively.

Table I. Physicochemical Parameters

Physico-chemicals parameters	**MIN**	**MAX**	**Monthly Mean (Dry Season)**			**Monthly Mean (Rainy Season)**			**Standards**		
			Nov.	**Jan.**	**Mar.**	**May**	**Jul.**	**Sept.**	**WHO**	**USEPA**	**FMEnv**
pH	4.53	6.38	5.46	5.77	4.896	6.11	5.994	5.82	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Temp (o^C)	25.9	29.5	27	26.829	28.271	27.7	27.24	26.7	30	-	-
Salinity (%)	0.01	6.3	2.43	1.529	0.013	0.01	0.02	0.02	250	250	250
Cond. (Us/cm)	8	111	41.1	33.543	90.429	21	36.86	10.6	400	-	1000

Turb. (NTU)	0.05	4.9	1.74	1.229	0.149	1.29	2.9	1.47	5	4	5
TDS (mg/l)	4	56	20.4	23.1	45.286	10.4	25.71	5.29	500– 1000	500	500
DO (mg/l)	1.10	8.1	4.96	4.989	1.29	5.51	5.457	7.42	4.0 - 6.0	1	5
BOD5 (mg/l)	2.8	8.7	3.6	3.723	5.003	6.79	5.959	5.47	<3	-	5
COD (mg/l)	4.18	17.93	5.16	5.96	6.281	13.3	9.536	11.8	10	-	-
NO_3 (mg/l)	0.05	7.15	0.12	0.379	0.56	3	5.213	3.91	10	10	50
PO_4 (mg/l)	0.05	2.6	0.12	0.259	0.266	1.12	1.403	1.28	1	1	1
SO_4(mg/l)	<0.01	0.62	0.13	0.102	0.1	0.11	0.28	0.1	250	250	100
TPH (mg/l)	0.01	13.64	1.17	1.606	5.866	4.71	0.681	7.54	3	3	3

Table II. Heavy metals

Heavy Metals	**MIN**	**MAX**	**Monthly Mean (Dry Season)**			**Monthly Mean (Rainy Season)**			**Standards**		
			Nov.	**Jan.**	**Mar.**	**May**	**Jul.**	**Sept.**	**WHO**	**USEPA**	**FMEnv**
Fe (mg/l)	0.01	1.84	0.67	0.173	0.182	0.12	0.144	0.11	0.3	0.3	0.3
Cd (mg/l)	0.01	0.45	0.05	0.017	0.165	0.01	0.01	0.01	0.003	0.005	0.003
Cu (mg/l)	0.001	0.07	0.03	0.013	0.024	0.01	0.003	0.01	2	1	1
Cr (mg/l)	0.003	0.57	0.01	0.010	0.269	0.01	0.003	0.01	0.05	0.01	0.05
Pb (mg/l)	0.01	0.64	0.21	0.074	0.173	0.01	0.01	0.01	0.01	1	0.01
Mn (mg/l)	0.001	0.59	0.01	0.110	0.388	0.01	0.01	0.01	0.1	0.05	0.2
Zn (mg/l)	0.001	0.74	0.13	0.088	0.431	0.06	0.013	0.03	3	5	3

Table III. Categories and Pollution Indices during the periods of study

Index method	**Category**	**Degree of polution**	**Sources**	**MIN**	**MAX**	**Monthly Mean (dry season)**			**Monthly Mean (rainy season)**			**Mean of both seasons**
						Nov.	**Jan.**	**Mar.**	**May**	**Jul.**	**Sept.**	
WQI	0 – 25	Excellent	Aigberua and Tarawou (2019)	31.37	167.13	41.223	64.500	52.908	84.49	133.20	97.96	79.049
	26 – 50	Good										
	51 – 75	Poor										
	76 – 100	Very poor										
	> 100	Unsuitable										
HPI	<15	Low	Edet and Offiong (2002); Giri and Singh (2014)	259.6	10696.5	1651.3	568.43	4290.9	260.4	259.87	260.4	1215.2
	15-30	Medium										
	>30	High										
HEI	<10	Low	Edet and Offiong (2002)	0.39	13.27	6.539	2.193	7.279	0.968	1.048	0.909	3.156
	10-20	Medium										
	>20	High										
Cd	<1	Low	Edet and Offiong (2002; Goher *et al.* (2014)	-6.65	4.60	-3.488	-5.584	-0.537	-6.59	-6.599	-6.59	-4.90
	1-3	Medium										
	>3	High										

Table IV. Correlation matrix among the physicochemical parameters and water quality index

	WQI	**TEMP**	**TURB**	**pH**	**EC**	**SAL.**	**DO**	**BOD**	**COD**	**TDS**	**NO_3**	**PO_4**	**SO_4**	**TPH**
WQI	1													
TEMP	**-0.692**	1												
TURB	**-0.925**	**0.743**	1											
Ph	-0.159	0.199	0.043	1										
EC	-0.342	0.304	**0.569**	-0.032	1									
SAL	-0.638	**0.566**	**0.751**	0.393	**0.856**	1								
DO	0.107	-0.009	-0.122	-0.163	**-0.696**	**-0.607**	1							
BOD	0.391	-0.339	-0.43	-0.126	**-0.748**	**-0.733**	**0.919**	1						
COD	0.418	-0.434	**-0.551**	-0.14	**-0.929**	**-0.894**	**0.839**	**0.909**	1					
TDS	-0.452	0.381	**0.652**	0.046	**0.99**	**0.912**	**-0.669**	**-0.743**	**-0.936**	1				
NO_3	**0.87**	**-0.799**	**-0.724**	-0.105	-0.102	-0.412	0.08	0.383	0.309	-0.2	1			
PO_4	**0.695**	**-0.622**	**-0.627**	-0.004	0.224	-0.065	-0.439	-0.077	-0.171	0.146	**0.727**	1		
SO_4	**0.562**	-0.385	**-0.453**	**-0.886**	-0.206	**-0.652**	0.272	0.352	0.359	-0.308	0.402	0.268	1	
TPH	0.412	-0.069	-0.4	-0.194	**-0.645**	**-0.679**	**0.521**	0.415	**0.627**	**-0.7**	0.157	-0.349	0.367	1

Table V. Correlation analysis of heavy metals and pollution indices

	Cd	**HEI**	**HPI**	**Fe**	**Cu**	**Zn**	**Pb**	**Cd**	**Cr**	**Mn**
Cd	**1**									
HEI	**0.820**	**1**								
HPI	**0.755**	**0.744**	**1**							
Fe	0.192	**0.719**	0.359	**1**						
Cu	0.415	0.267	**0.752**	-0.045	1					
Zn	0.408	0.181	0.231	-0.184	**0.514**	**1**				
Pb	**0.589**	0.252	-0.066	-0.283	-0.282	0.287	**1**			
Cd	**0.610**	**0.666**	**0.979**	0.402	**0.784**	0.164	-0.266	**1**		
Cr	0.465	**0.761**	**0.559**	**0.741**	0.418	0.282	-0.139	**0.565**	**1**	
Mn	0.172	-0.158	0.162	-0.480	**0.706**	**0.753**	0.045	0.147	0.166	**1**

IV. DISCUSSION OF FINDINGS

The bi-monthly results of the Nkisa River's physiochemical characteristics at each station are displayed in Table 1. The Nkisa River's average monthly temperature readings varied from 26.7 to 28.3 ^{O}C. The temperature range at the different sampling stations and months falls within the 30 ^{O}C WHO (2017) acceptable limit. The slight variations in the sampling time at each station and the seasonal dynamics of the weather in the study area may be the cause of these recorded temperature variations. On the other hand, March's mean temperature of 28.3 ^{O}C was higher than the other months', and [11] discovered similar findings. This may result in an increase in the rate of chemical reaction and biological activities in March. Temperature regulates the hydrochemistry of parameters such as DO, BOD_5, solubility, pH, conductivity, etc. The lowest temperature in September may be caused by high water levels and reduced solar radiation, while the maximum temperature in March may be caused by low water levels, increased solar radiation, and a clear atmosphere [12].

The WHO (2017) and FMEnv recommend a mean value of 5 NTU for turbidity, but the mean monthly turbidity ranged from 0.15 to 2.9 NTU. The study area's rainy season, July, yielded the highest turbidity values. This might be because rain falls during the wet season more frequently. The rainy season typically results in increased water turbulence and mixing, which raises the amount of suspended particulate matter. The turbidity of water affects not only the color but also the chemical parameters that determine the quality of the water. High turbidity levels are caused by silt, clay, and other suspended particles during the rainy season, while low turbidity is caused by silt and clay settlement during the dry season. Therefore, it is possible to link the high turbidity levels seen in July to increased erosion and surface runoff that carried a large number of suspended particulates into the river due to heavy rainfall and sand washing.

The pH of the Nkisa River varied from 4.9 to 6.11 on a monthly average. These values could be the result of acidic runoffs and are suggestive of acidic conditions. The lowest pH value of 4.53 was recorded in March, and the highest pH value of May could be related to rainfall, which may dilute the alkaline compounds, or to the dissolution of atmospheric carbon dioxide [13]. All of the measured pH values fell outside of the advised range of 6.5 to 8.5 when compared to drinking water quality standards. The high acidity may have resulted from burning fossil fuels, precipitation, or petroleum spills. The acidic nature of the river water may have resulted from the presence of higher concentrations of carbon dioxide, nitrogen oxides, sulfur oxides, and various other acidic compounds in the research area.

The monthly average EC values varied between 10.6 and 90.43 µS cm^{-1}. The dilution effect of rainfall was responsible for the lowest value (8 µS cm^{-1}) found in September, while high temperature and ionic concentration in March led to the highest value (111 µS cm^{-1}). The massive amounts of hazardous petroleum and home and agricultural waste that are dumped into the river are another factor contributing to the mean EC values' fluctuations. As of right now [14], there is no official guideline defining a safe conductivity level. Nonetheless, most freshwaters had conductivities between 10 and 1000 µS cm^{-1} (Chapman, 1992). Many countries estimate that the EC of natural water is between 170 and 2700 µS cm^{-1}. Since EC was mostly within allowable bounds, other natural processes and the dilution effect were blamed. The salinity range varied between 0.01 to 6.3 mg L^{-1}, with November having the highest monthly mean salinity (2.43 mg L^{-1}) and May having the lowest mean (0.01 mg L^{-1}). Every measurement was within the 1000 mg L^{-1} WHO limit.

The range of the monthly mean DO values was 1.29 to 7.42 mg L^{-1}. A DO level of 3 mg L^{-1} is generally stressful to the majority of aquatic life. There were months when DO did not follow the WHO (2017) recommended minimum limit of 5.00 mg L^{-1}. Because of the high-water turbulence that promotes atmospheric oxygen diffusion and the increased solubility of oxygen at lower temperatures, September saw the highest amount of 8.1 mg L^{-1} [15]. The lowest result was 1.10 mg L^{-1} in March, which may have been brought on by the warm weather and the addition of other wastes and sewage, which accelerate the breakdown of DO in water during the warm months.

The range of the monthly mean BOD values was 3.60 to 6.79 mg L^{-1}. According to the results of [16], the highest mean value (6.79 mg L^{-1}) was recorded in the rainy season of May, while the lowest value (3.60 mg L^{-1}) was discovered in November. In certain months, BOD was over the WHO (2017) limit of 5 mg L^{-1}, but it was within it in others. An increase in BOD during the rainy season may have been brought on by increased runoff carrying sediments and organic matter from the catchment into the river. There is little to no movement of organic matter from the soil during the dry season, as indicated by the lower mean BOD. Additionally, the River's self-purification process made it possible for BOD concentrations to drop.

COD samples collected along the Nkisa River were found to range from 4.18 to 17.93 mg L^{-1}, with the rainy season recording higher average monthly COD levels. As indicated by Table 1, the COD values exceeded the WHO (2017) limit of 10 mg L^{-1} in May and September, but were within it in other months. Given that COD quantifies the oxygen demand resulting from both organic and inorganic compounds, as well as biodegradable ones, it can be inferred that regions susceptible to oil-related activities, such as gas flaring and oil spills, have higher COD levels than regions not affected by these activities. The trend indicates that the impact of the oil spill and gas flaring may be the cause of increased chemical activity. Therefore, the pollution from the adjacent Oil Company's operations and the bunkers was the cause of the rise in COD values. Then, it could be proven that rainy seasons have a greater impact on COD than dry seasons.

TDS ranged in mean monthly values from 5.29 to 45.29 mg L^{-1}. March's high TDS values could have been caused by the combination of high temperature and high ionic concentration. September's lower TDS reading may have been caused by suspended solids sedimenting and a sluggish rate of decomposition. Table 3 shows that the observed values fell within the allowable range. High TDS concentrations can be caused by a variety of factors, including agricultural practices, land fertilization, geological salinity from natural sources, runoff from petroleum, storm water, human input into aquatic ecosystems, and excessive water evaporation.

The range of the mean monthly values for NO_3 was 0.12 to 5.21 mg L^{-1}. In contrast, the highest amount of nitrate was found in July due to high vegetation during the rainy season, which supported the growth of plankton, or the effects of agriculture. The lowest amount of nitrate was found in November due to the utilization of nitrate by plankton and aquatic plants, or due to low surrounding runoff and high microbial activity in the rivers. [17] revealed a comparable result. The WHO (2017) standard guidelines permissible limits for nitrate levels were well within the Nkisa River's levels (10 mg L^{-1}).

PO_4 concentrations varied from 0.12 to 1.4 mg L^{-1} on a monthly mean basis. When compared to the dry season, high phosphorus values were found during the rainy season. This could be because of surface water runoff and rainfall, particularly since the Nkisa River flows through an agricultural region. The monthly average SO_4 varied between 0.11 and 0.28 mg L^{-1}, falling within the recommended sulfate limit for drinking water standards. Since the rainy season is typically when agricultural activity peaks in the Egbema community, there was a higher concentration of SO_4 during that time. Sulfate concentrations are also significantly impacted by biochemical and human sources.

The range of TPH concentrations was 0.01–13.64 mg L^{-1}. The average TPH concentration across all sampling stations was 3.60 mg L^{-1}, which is higher than the WHO (2017) suggested threshold of 3 mg L^{-1} for petroleum hydrocarbons in rivers. The operational oil company's actions as well as other activities like bunkery and inadequate cleanup following an oil spill could be the cause of this high TPH.

Table 2 displays the heavy metal concentrations for Fe, Cu, Zn, Mn, Pb, Cd, and Cr. The monthly average of Fe varied between 0.11 and 0.67 mg L^{-1}. Even though iron is known to be necessary for nutrition in trace amounts and surface water typically has < 1 mg L^{-1} of Fe, iron is still a fairly common concern in drinking water and is closely related to water hardness. Due to substantial evaporation and intense anthropogenic activities (agricultural, petroleum, and high levels of human activity) during the dry season, there was a higher concentration of Fe during this time. Fe concentrations ranged from 0.01 mg L^{-1} in March to 1.84 mg L^{-1} in November, with the highest value recorded in November. This is consistent with [11]'s result.

Copper monthly mean varied between 0.01 and 0.027 mg L^{-1}. While higher copper concentrations make water unpleasant to drink and extremely toxic to aquatic life, copper is necessary for the nutrition of all plants and animals. The study's concentration of Cu was within the permissible limit for drinking water quality standards, and the findings corroborated those of [18]. The concentration of copper that was observed may have resulted from a spill of oil, fertilizers mixed with home sewage water, pesticides, fungicides, or runoff from large agricultural areas.

Pb concentrations ranged from 0.01 to 0.21 mg L^{-1} in the mean monthly concentration. It was discovered that the Pb concentrations during the dry season exceeded the acceptable limits. The study's findings concurred with those of [13]. The increased amount of petroleum oil, agricultural, untreated household and urban wastewaters discharged into rivers may be the cause of the abnormal concentration of lead ions. This could be dangerous for humans who depend on water for domestic and drinking needs, as lead can cause cancer. Fertilizers incorporated into agricultural soil also contribute significantly to Pb levels.

The range of the mean monthly Cd concentration was 0.01 to 0.16 mg L^{-1}. The amount of cadmium in the research was greater than what was considered safe for drinking water. The same outcomes were found by [19]. Because of the Cd contents of the rocks and soils as well as additional petroleum oil inputs from bunker site spills, the concentrations of Cd remain at relatively high levels in the Nkisa River. Because cadmium is toxic to fish and other aquatic organisms, it is an important component of aquatic monitoring studies [20]. Cr's monthly mean value varied between 0.003 and 0.27 mg L^{-1}. The maximum allowable limit for Cr values was exceeded in March, indicating that the aquatic life and users of the Nkisa River were at risk of adverse toxic and health effects.

The range of the monthly mean Mn values was 0.01 to 0.39 mg L^{-1}. In March of the dry season, the maximum concentration of Mn was detected, and it was higher than what was permitted for the quality of drinking water. While most surfacewater and soils that may erode into water bodies naturally contain manganese, the high concentration of manganese in the Nkisa River may be due to nearby petroleum extraction and agricultural practices. Furthermore, the minimal fluctuations in the Mn concentrations measured during the rainy season suggest that there aren't many outside sources of Mn entering the water.

According to Table 3, the computed water quality index (WQI) was between 31.37 and 167.13. These findings are consistent with those of [21] and show that the water quality status ranges from "good water quality" to "unsuitable for drinking." One possible explanation for the observed decline in water quality status during the rainy season is leaching brought on by an abundance of precipitation. Agricultural runoff, leachate, human activity, land runoff, and the disposal of solid waste are all possible causes of higher WQI levels during the rainy season.

The results of the three established heavy metal pollution indices used in this study—the Degree of Contamination (Cd), the Heavy Metal Pollution Index (HPI), and the Heavy Metal Evaluation Index (HEI)—are displayed in Table 3. These indices are useful for assessing the quality of water. The combined impact of metals on water quality is indicated by the monthly mean of HPI, which varied from 427.91 to 2257.66. Comparable outcomes were noted by [22]. The findings demonstrated that in every month under study, the HPI was significantly higher than the suggested critical limit of 100 for drinking water. When it comes to metals, the water quality is classified as high-class pollution (HPI > 30). This finding suggests that the seven metals under investigation have a concerning impact on the quality of river water due to soil erosion, farmland waste discharge, landfill waste, and petroleum product discharges. The HEI's monthly mean ranged from 0.91 to 7.28, with March recording the highest mean value of 7.28 due to elevated metal concentrations. Using the methodology from [10], the current HEI level indicates that the water quality is in the low zone of pollution (HEI < 10), and similar findings were reported by [23]. The range of the mean monthly Cd values was -6.60 to -0.54. The Nkisa River was therefore determined to have a low level of contamination, as shown by Table 4's Cd average value (-4.90).

The correlation matrix between the Nkisa River's physicochemical parameters during the study period is displayed in Table 4. The degree of association between two variables, one of which is considered the dependent variable, is measured by the correlation coefficient (r). Temperature and NO_3 (r=0.87), EC and Salinity (r=0.856), EC and TDS (r=0.99), Salinity and TDS (r=0.912), DO and BOD (r=0.919), DO and COD (r=0.839), as well as BOD and COD (r=0.909) all showed extremely strong positive correlations. Temperature and turbidity (r=0.743), turbidity and salinity (r=0.751), alongside $NO_3$and PO_4 (r=0.727) showed positive, moderate correlations. Temperature and salinity (r=-0.163), pH and COD (r=-0.027), pH and TPH (r = s-0.092), temperature and NO_3 (r=-0.151), temperature and PO_4 (r=-0.1), temperature and SO_4 (r=-0.090), and other parameters were found to have weak negative correlations (Table 4). According to the correlation matrix, WQI had negative correlations with salinity, turbidity, and temperature (-0.692, -0.925, -0.638) and positive correlations with NO_3, PO_4, and SO_4 (0.870, 0.695, 0.562). Additionally, dissolved oxygen exhibited a strong positive correlation with COD (0.839) and BOD (0.919). According to the negative correlations, a rise in one causes a fall in the other.

The correlation analysis between different metal concentrations and index values is displayed in Table 5. Fe, Cu, Cd, and Cr were the most significant contributing elements. Positive correlations have been observed between Cd, HEI, and HPI and Cd (0.610, 0.667, and 0.979), HEI and HPI and Cr (0.761, and 0.559), HEI and Iron (0.719), and HPI and copper (0.752). Similar outcomes were reported by [22]. The observed correlation suggests that Fe, Cu, Cd, and Cr have had a greater impact on the concentration of heavy metals in the various samples analyzed than other metals. Additionally, these heavy metals are accountable for the Cd, HEI, and HPI values obtained in this study for the various locations in the area. HPI has a strong positive and significant correlation with both HEI and Cd (0.744 and 0.755), according to the results of the correlation study between various metal concentrations and index values. In a similar vein, HEI and Cd have a strong correlation (0.820). Positive relationships between metal concentrations can be observed, such as Cr/Fe, Cd/cu, Mn/Cu, and, Mn/Zn, Cd/Cr, Cu/Zn.

V. CONCLUSION

According to the results of this thorough water quality analysis of samples taken from the Nkisa river, the DO, BOD_5, COD, PO_4, and TPH values were outside of the normal range when compared to the WHO standard. This suggests that the Nkisa River is contaminated, particularly in the months of March, May, July, and September. These values may have been caused by the influence of crude oil and other anthropogenic activities. Every other physicochemical and hydrological parameter under study was within the acceptable range at every station and month.

In certain stations, the levels of Fe, Pb, Cd, Cr, and Mn in water samples exceeded the WHO's guidelines for heavy metals. This suggests that the river is contaminated with these metals, which may have resulted from the impact of crude oil and human activities, especially in the months of January, March, September, and November. Although the concentrations of

Cu and Zn metals were within the allowable limits for drinking water, this indicates that these metals were obtained from the natural processes.

The Nkisa River's water quality status is shown by the computed WQI, which ranges 31.37 and 167, indicating a range of water quality conditions from "good water quality" to "unsuitable for drinking". Based on the HPI values observed during the study period, HPI values ranged from 259.66 to 10696.53 which were higher than the suggested critical limit of 100 for drinking water and fell in high class pollution (HPI > 30). The HEI values ranged from 0.39 to 13.27, thereby falling within low zone of pollution (HEI < 10). The Cd values ranged from -6.65 to 4.60 which fell in the class of low degree of contamination. This indicates that the river is heavily impacted by the use of crude oil and other human activities, making it unfit for human consumption until it is properly treated.

REFERENCES

[1] J. Alinnor and A. F. Alagoa, Trace Metal Distribution in Fish, Sediment and Water Samples from Nkisa River, Nigeria. British Journal of Applied Science & Technology 4(20): 2901-2913, 2014 SCIENCEDOMAIN international. www.sciencedomain.org.

[2] R. M. Olalekan, A. O. Omidiji, D.Nimisngha, O. E. Odipe and A. S. Olalekan, Health Risk Assessment on Heavy Metals Ingestion through Groundwater Drinking Pathway for Residents in an Oil and Gas Producing Area of Rivers State, Nigeria. Open Journal of Yangtze Gas and Oil, 3, 191-206. https://doi.org/10.4236/ojogas.2018.

[3] M.C. Onojake, O. Omokheyeke and J.O Osakwe, Petroleum Hydrocarbon Contamination of the Environment: A Case Study. Bulletin of Earth Sciences of Thailand Vol. 6, No. 1, 67-79, 2014.

[4] M.O Raimi, T.K. Pigha and E.O Ochayi, Water-Related Problems and Health Conditions in the Oil Producing Communities in Central Senatorial District of Bayelsa State. Imperial Journal of Interdisciplinary Research (IJIR), 3, 2017.

[5] U. Ochuko, O. Thaddeus, O.A. Oghenero, E.E. John, A comparative assessment of water quality index (WQI) and suitability of river Ase for Domestic Water Supply in Urban and Rural Communities in Southern Nigeria. International Journal of Humanities and Social Science. 4:1, 2014.

[6] O.D. Opaluwa, Y. Mohammed, S. Mamman, A.T. Ogah, D. Ali, Assessment of water quality index and heavy metal contents of underground water sources in Doma Local Government Area, Nasarawa State, Nigeria. *Asian J. Appl. Chem. Res.*, 6(3): 27 – 40, 2020.

[7] R. Morufu and E. Clinton, Assessment of Trace Elements in Surface and GroundWater Quality, LAP Lambert Academic Publishing. Mauritius. ISBN: 978-3-659-38813-2, 2017.

[8] APHA, America Public Health Association, standard methods for the examination of water and wastewater 13th Edition, 1998.

[9] F. Liu, Z. Zhao, L. Yang, Y. Ma, B. Li, L. Gong, H. Liu, Phreatic Water Quality Assessment and Associated Hydrogeochemical Processes in an Irrigated Region Along the Upper Yellow River, Northwestern China Water, 12, 463, 2020.

[10] Z. He, Y. Hu and Z. Yin, 'Microbial diversity of chromium-contaminated soils and Characterization of six chromium-removing bacteria', Environmental Management, 57(6): pp.1319–1328, 2016.

[11] S.M.A. Goran, Ecological Study on Dukan Lake with Particular Reference to Bioaccumulation of Some Heavy Metals and PAHs in Fish and Gull Tissues- Sulaymaniyah, Kurdistan Region of Iraq. Doctorate of Philosophy. Dissertation, Salahaddin University-College of Science, Erbil-Iraq, 2014.

[12] B. Zhang, E.J. Matchinski, B. Chen, X. Ye, L. Jing, K. Lee.K, Marine oil spills – Oil pollution, sources and effects. World seas: an environmental evaluation. 391-406, 2019.

[13] E.O. Nwaichi and S.A. Ntorgbo.S.A, Assessment of PAHs levels in some fish and seafood from different coastal waters in the Niger Delta. Toxicology reports. 3, 167-172, 2016.

[14] J. Curtis and E. Morgenroth, 'Estimating the effects of land-use and catchment characteristics on lake water quality: Irish lakes 2004-2009', Journal of the Statistical and Social Inquiry Society of Ireland, XLII: pp.64-80, 2013.

[15] N.S. Yadav, A. Kumar and M.P. Sharma, 'Ecological Health Assessment of Chambal River using Water Quality Parameters', Journal of Integrated Science and technology, 2(2): pp.52-56, 2014.

[16] Y.A. Shekha, H.M. Ismael and A.A. Ahmed, 'Bacteriological and Mycological Assessment for Water Quality of Duhok Reservoir Jordan', Journal of Biological Sciences, (JJBS), 6(4): pp.1-10, 2013.

[17] A.K. Rasul, Hydrochemistry and geochemistry of recent sediments of lesser Zab River and Dokan reservoir, Kurdistan region-NE Iraq. Doctorate of Philosophy. Dissertation, Salahaddin University-Erbil, 2013.

[18] E. Hesse, S. O'Brien and N. Tromas, 'Ecological selection of siderophore-producing microbial taxa in response to heavy metal contamination', Ecology Letters, 21(1): pp.117–127, 2018.

[19] M.H.J. Carlos, P.V.Y Stefani and A.M. Janettea, 'Assessing the effects of heavy metals in ACC deaminase and IAA production on plant growth-promoting bacteria', Microbiological Research, 8(1): p188–189, 2016.

[20] A.A. Godwin, K. Singh, S. Balerea and S. Kokot, Exploratory multivariate modeling of the physicochemical properties of surface water and groundwater', Journal of Hydrology, 336(1-2): pp.115-124, 2007.

[21] O. Oshurhe, T. Origho, O. Ohwohere-Asuma, J. Ewhuwhe-Ezo, A Comparative Assessment of Water Quality Index (WQI) and Suitability of River Ase for Domestic Water Supply in Urban and Rural Communities in Southern Nigeria. International Journal of Humanities and Social Science, 4(1): 234-245, 2014.

[22] M.A Hoaghia, C. Roman, W.D. Kovacs, C. Tanaselia and D. Ristoiu, 'The Evaluation of the Metal Contamination of Drinking Water Sources from Medias Town, Romania Using the Metal Pollution Indices', Studia Ubb Chemical, LXI, 3, Tom II: p. 461-471, 2016.

[23] R. Herojeet, M.S. Rishi and N. Kishore, 'Integrated approach of heavy metal pollution indices and complexity quantification using chemometric models in the Sirsa Basin, Nalagarh valley, Himachal Pradesh, India', China Journal of Geochemistry, 34(4): pp.620–633, 2015.