International Research Journal of Environmental Sciences ISSN 2319–1414
Vol. **13(3),** 20-35, July **(2024)** *Int. Res. J. Environmental Sci.*

Environmental Impact Assessment of Trace Metals Contaminated Water, Fish, and Sediments from Riparian Communities in the Niger Delta Region, Nigeria

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Available online at: www.isca.in, www.isca.me
Received 30th January 2024, revised 30th March 2024, accepted 19th May 2024

Abstract

This comprehensive study delves into the Environmental Impact Assessment (EIA) and trace elements present in surface water, sediments, and fish within the riparian communities of the Niger Delta region, Nigeria. The study encompasses three key communities: Tema, Sangama, and Degema. Each community presents unique challenges, from illegal waste processing in Degema to residential waste overflow in Sangama and diverse activities in Tema. Sampling procedures were meticulously designed, considering characteristic features and pollution sites. The study assessed heavy metals such as zinc, lead, copper, cadmium, iron, and arsenic. Sample collection took place monthly from October 2021 to April 2022. Physicochemical parameters measured included pH, dissolved solids, dissolved oxygen, temperature, biological oxygen demand, salinity, and total conductivity. The results highlighted variations across stations, with Sangama exhibiting significantly different values in several parameters compared to Tema and Degema. The temporal analysis from October 2021 to March 2022 revealed fluctuations in physicochemical parameters, providing insights into the dynamic nature of the studied ecosystem. Heavy metal concentrations in sediment, water, and fish varied across stations, with Degema consistently showing the highest values. The results were compared against international standards, emphasising potential environmental concerns. Furthermore, the study explored spatiotemporal variations in heavy metal concentrations, uncovering patterns that contribute to a comprehensive understanding of the ecosystem dynamics. The findings from this study emphasize the critical need for sustainable environmental management practices in the Niger Delta. Informed decision-making is necessary to preserve the delicate balance of these riparian ecosystems based on the data generated.

Keywords Sustainability, Environmental Impact, Niger Delta Region, Trace Elements, Heavy Metals.

Introduction

Environmental concerns about heavy metal accumulation have grown in recent years. The issue has attracted the attention of scholars and regulatory agencies. The increased focus on these contaminants is due to their hazardous nature and persistence in the environment. This results in their accumulation in aquatic plants and animals[1]. The quality of sediments in river and marine systems is crucial to determining the nature and forms of pollution[2]. Sediments serve as both carriers and repositories of environmental pollutants, offering historical insights into pollution sources and patterns. When heavy metal concentrations exceed permissible levels, they can induce toxicological effects in aquatic ecosystems. Water and sediment trace metal concentrations are influenced by several factors, including sediment composition and physicochemical conditions[3,4]. Heavy metals and other pollutants have been discharged into coastal areas due to global economic activity. These pollutants can be stirred up in the water and accumulate in bottom-dwelling organisms, often in close association with water and sediments[5]. There is growing concern about the potential health risks associated with pollutants such as heavy metals, carbon-based compounds, and nutrients found in sediments[6,7].

Environment impact studies on biota, sediment, and water quality assessment methods are widely used to evaluate heavy metal contamination risks in aquatic environments[8,9]. Experimental and numerical approaches have been developed to address ecological concerns and monitor water systems. Water quality preservation is crucial for sustaining and enhancing life quality[4,10,11]. Water is essential in agriculture, industry, domestic use, recreation, and various sectors. Water sources influence land and resource allocation.

Water plays a crucial role in agriculture, industry, domestic use, recreation, and various other sectors, influencing land and resource allocation. Creeks and lagoons in southwestern Nigeria serve as vital ecological and economic assets, yet they have also become repositories for various waste types. These water bodies are susceptible to pollution from industrial and municipal discharges, agricultural runoff, chemical leaks, waste leaching, fishing, transportation, and other human activities[11-14]. The adverse effects of these activities manifest themselves in reduced plankton levels and alterations to creek physical and chemical characteristics. As water quality deteriorates in response to population growth and pollution, comprehensive assessments are needed to gauge contamination.

This study aims to contribute to the understanding of the environmental risk posed by toxic metals in brackish coastal wetlands of the Niger Delta region and to highlight the necessity of sustainable environmental management practices in this region and the significance of informed decision-making and strategic interventions to protect riparian ecosystems by assessing the levels of heavy metal contamination and their potential impacts on the aquatic ecosystem.

Materials and Methods

Study Area: The study areas included three riparian communities in Rivers State, Nigeria, including Abala-ama, Tema, Sangama, Degema, and Krakrama. In Degema, southeast of the Niger Delta, illegal waste processing, dumping, dredging, and fishing are common. Sangama, in the same area, is characterised by residential waste, illegal refining overflow, refuse dumping, and fishing operations. In the same area, Tema is associated with rubbish and human waste disposal, dredging, and fishing. Addressing ecological challenges requires environmental management and sustainable practices. Adaptations for the ecosystem's evolution were necessary in these areas because of complex conditions. Gobies, periwinkles, crabs, and mudskippers inhabit tidal mudflats, including Claroteidae and Cichlidae. These areas have typical Niger Delta mangrove vegetation.

Sample and Sampling Procedure: The sampling stations were chosen in each of the communities based on their characteristic characteristics and importance as pollution sites to represent the various activities in catchments and their importance as pollution sites. Each creek was sampled at least 1000 meters apart to reflect different activities. Based on the nature of industrial and domestic effluents traversing the study area, heavy metals of interest were lead, cadmium, copper, iron, arsenic, and zinc. Biota {Swimming Crab (*Callinectes sapidus*)}, sediment, and water samples were collected. GPS receivers (Magellan GPS 315) were used to georeference all sampling sites (longitudes and latitudes). A sample was taken once a month between October 2021 and April 2022. Every month, the first week of sampling was conducted.

Collection of Samples: The following measurements were taken: conductivity, temperature, dissolved oxygen (DO), hydrogen ion concentration (pH), and total dissolved solids (TDS). For pH, a Milwaukee model pH 600 pocket-sized pH meter was used, with 10 to 15 centimeters of interstitial water. The pH measurement was recorded once the probe stabilised. The Milwaukee MW 600 model was utilized for testing dissolved oxygen (DO), with the DO meter probe placed 10–15 cm below the water surface. Using a hand-held multimeter (EZODO Multi-meter model CTS-406), in situ monitoring included temperature (°C), conductivity, and total dissolved solids (ppm). After a ten-minute warm-up, the meter's probe was placed 10 to 15 centimeters into the interstitial water, and the salinity was determined when the reading stabilized. Biochemical oxygen demand was assessed using a 5-day BOD test[15].

Swimming Crab (*Callinectes sapidus*): Live Swimming Crab (*Callinectes sapidus*) was collected from the catch of local fishermen for six months at 21-day intervals in each community. In each sampling community, fifteen representative fish samples will be obtained over six months (October 2021-March 2022). The test fish was chosen due to its strong association with peri-tidal soft bottom environments and mangroves. In order to ensure the samples accurately represented the actual pollution levels, the samples were collected from the shore. The samples were then transported to the lab in an ice chest with clearly marked contents. After chilling, measurements were taken, and heavy metal analysis was carried out using standard procedures [16].

Sediment: An 'Ekman grab' sampler, stored in a plastic container soaked in a 10% nitric acid for 24 hours, was utilized to gather a combined sediment sample monthly for six months from three different locations in both streams. Upon arrival at the lab, the samples were frozen. Prior to additional examination using the API-RP 45 Atomic Absorption Spectrophotometric Machine, the samples were maintained at 20°C. To ensure the samples precisely represented the pollution hotspots in the study area, they were collected at a distance from the shore.

Water: High-density Schott glass vials were used to collect surface water samples after cleaning. The sampling bottles were washed with detergent, rinsed with tap water, and then immersed in a 50% hydrochloric acid (HCl) for a full day. Before sampling, the bottles were cleaned with tap water and rinsed with triple-distilled water to ensure they were free of metal residue. This was done to prevent metals from sticking to glass surfaces, as acidifying glass promotes metal disintegration. Following collection, samples were carefully wrapped and transported to the lab in an ice pack to maintain their integrity. Each sample was properly marked and sent the same day in an ice chest to the laboratory. The samples were then measured and stored in the fridge for analysis. Standard procedures were used to analyse heavy metal levels[16]. Sampling was conducted at a certain distance from the bank. This was to ensure that the water and sediment samples accurately reflect the distinct and real pollution pockets in the research region.

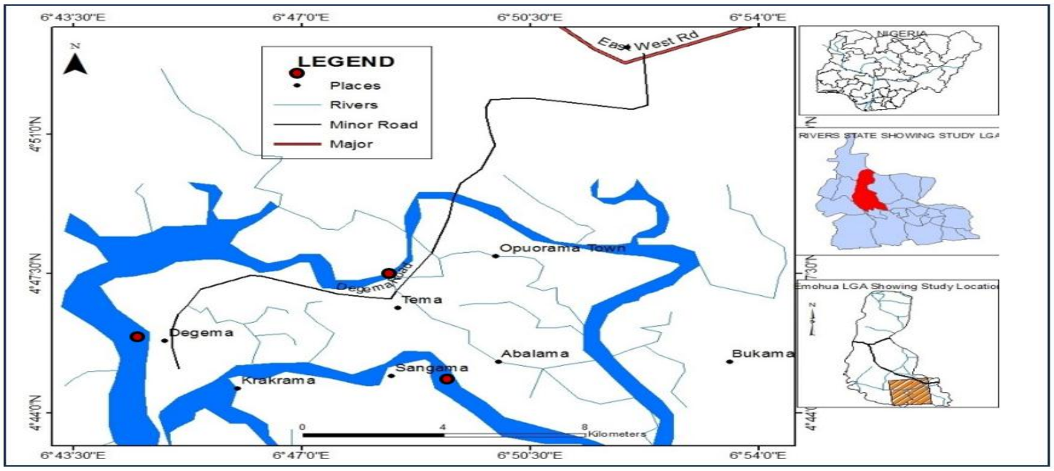

Figure-1: Shows a map of the study Areas along the Creeks showing the three locations.

Procedures for Measuring Physicochemical Parameters of the interstitial water: Water samples were analyzed using handheld multimeters (Milwaukee pH600). The pH, temperature, salinity, conductivity, and total suspended solids (TSS) in the water were determined using a handheld multimeter (Milwaukee pH600 and Laboratory Benchtop Metre 860033). The device was calibrated using a standard buffer, then cleaned with distilled water and reset for self-calibration. A probe was inserted into the river, and measurements were stabilized before recording the data. Dissolved oxygen (DO) was assessed with Winkler's method, while biochemical oxygen demand (BOD) was assessed using 5-day tests (APHA, 2005).
BOD (mg/l) = Initial DO – Final DO.

Determination of Heavy Metals: An atomic absorption spectrophotometer (AAS) was used to estimate iron, arsenic, zinc, lead, copper and cadmium concentrations. As specified by the manufacturers, the instrument was set up and operated.
Sample Preparation: Sediment samples were air dried; fish samples were granulated in a blender; and water was digested with 20 ml conc. H_2SO_4.

Quality Assurance and Control: Using buck-certified atomic absorption standards, a calibration curve was developed for various heavy metals. To counter equipment drift, a reagent blank was conducted after every ten samples. The recovery range was 82% to 110%. Atomic absorption spectrophotometry was used to determine the metal content of soil, water, and biota samples. The methodology and wavelength (nm) used were in line with the parameters specified in 11. These values represent the mean of repeated measurements for each sample. This rigorous quality assurance approach enhances the precision and reliability of the results. All reagents used in the experiment were of analytical grade.

Total Digestion for Heavy Metals: Nitric acid, perchloric acid, and sulfuric acid (APHA 3030I modified) were used in an extraction process. One gramme of sediment and twenty millilitres of digestion solution were mixed in a 250 millilitre Pyrex conical flask. The samples were subjected to an electrical mantle heating to 250°C until the granules became grey, signifying full digestion. Following heating, the digested solution was allowed to cool on the workbench before 20 millilitres of distilled water was added. Using a Whatman 42 ash less filter paper, the digested solution was filtered and transferred into a 100ml glass flask. A volumetric flask was used to create 100ml of filtrate, which was then poured into a sterile 100ml plastic container. The extracts were produced for Pb, As, Cd, Zn, Fe, and Cu AAS analysis.

Statistical Analysis: ANOVA analyses were conducted using SPSS 16. Key indicators were identified using the Duncan Multiple Range Test. Mean values were used to calculate fish tissue, water, and sediment concentrations. Data interpretation was carried out using Microsoft Excel. Pearson's Product Correlation was used to assess the correlation between the parameters under analysis. Means, standard deviations, and standard errors of means were utilized for data management.

Results and Discussion

Special Variations in the Physicochemical Parameters from October 2021 to March 2022: Physicochemical parameters varied across stations in Table-1 and Figure 8 to Figure 13. Sangama exhibited significantly different values for temperature, pH, DO, salinity, BOD, and TDS compared to Tema and Degema. The temperature was notably higher in Sangama (29.50±0.74ºC) and lower in Degema (25.75±0.57ºC), while the pH value was higher at Degema (6.72±0.14) and lower in Sangama (5.68±0.18). The highest Dissolved Oxygen was observed at Degema (3.35±0.11mg/l), followed by Tema (3.27±0.21mg/l), with Sangama recording the lowest at 2.92±0.20mg/l. Salinity peaked at Sangama (15.28±0.71ppm), followed by Tema (12.78±0.81ppm), and was lowest at Degema (11.44±0.45). Moreover, the highest Biological Oxygen demand was seen at Sangama (3.60±0.79mg/l), while the lowest value was at Degema (2.46±0.42mg/l). Additionally, Degema exhibited the highest Electrical conductivity, with Sangama following, and the lowest value was observed at Degema. The highest Total Dissolved Solids were found at Sangama, while the lowest was recorded at Degema. No significant ($p>0.05$) differences were observed in the parameters between the Degema and Tema sampled stations.

Water bodies, like rivers, lakes, and groundwater, are evaluated using physicochemical parameters to guarantee their health and durability[17,18]. A variety of physicochemical parameters is highlighted in this study. Sangama, Tema, and Degema showed significant variations in temperature, pH, DO, salinity, BOD, and TDS. Industrial and domestic waste disposal, overfishing, and dredging activities may have led to substantial physicochemical alterations in water bodies[19]. Sangama exhibited higher temperatures (29.50±0.74ºC) compared to Degema (25.75ºC±0.57ºC). This variation could be attributed to Sangama being situated in a more densely populated area than Degema[20] and the presence of more heat-emitting activities[21]. Additionally, Sangama's potentially higher elevation may result in elevated temperatures due to decreased air pressure at higher altitudes.

Sangama had the lowest pH (5.68±0.18), while Degema had the highest pH (6.72±0.14). Water pH may be impacted by environmental chemicals, such as those from home wastes and artisanal crude oil refining[22]. Sangama's lower pH may be explained by alternative chemical species with lower pH or by fewer of these chemicals. The higher pH of Degema may be caused by larger concentrations of these chemicals. pH may also be impacted by the kind of trash released[23].

At Degema, Tema, and Sangama, dissolved oxygen amounts were under the 2mg/l WHO-permissible range. At the three tested sites, DO may fluctuate and algae growth may be enhanced due to home or industrial waste and artisanal crude oil refining wastewaters[24,25]. Despite this, the BOD in Tema, Degema, and Sangama were less than the 5.0 mg/l WHO acceptable limit. Additionally, industrial wastes can increase temperature, TDS, and BOD[26,27].

Water salinity indicates the concentration of dissolved salt in water[28]. The salinity levels were highest at Sangama (15.28±0.71ppm), followed by Tema (12.78±0.81ppm), and lowest at Degema (11.44±0.45). Dredging activities near Degema and Tema may have contributed to a reduction in salinity. Variations in salinity can also be linked to differences in water sources and human activities[29,30].

The higher salinity in Sangama compared to Degema may be due to industrial discharges, agricultural run-off, or domestic wastewater discharges[31,32]. Dredging activities, by removing sediment from the water body, could also lower salinity levels in Degema and Tema. Furthermore, Akankali and Davies[44] reported that dredging can decrease salt concentration by increasing water flow.

Sangama reported a higher electrical conductivity value (34.07±3.62µS/cm) than Tema (28.78±2.610µS/cm), while Degema recorded the lowest value (25.76±0.47µS/cm). Sangama had the greatest electrical conductivity, whereas Degema had the lowest. This implies that the mineral concentration of the groundwater sources in Sangama is larger than that of the sources in Degema[34]. The quantity of dissolved minerals in groundwater sources is determined by the lithology of underlying geological formations, which accounts for variations in electrical conductivity[35,36]. The changes in electrical conductivity values in Sangama, Tema, and Degema are probably caused by differences in dissolved ions[37.38]. The electrical conductivity of a body of water may be influenced by several factors, including geology, land use, and water management methods[39,40].

Sangama had the greatest Total Dissolved Solids (28.17±3.77 ppt), whereas Degema had the lowest (19.20±2.29 ppt). The tested stations from Degema and Tema did not vary significantly ($p>0.05$)[41], as well as[42], claim that human activity and changes in the water supply may have impacted the total dissolved solids (TDS) at Sangama and Degema. Minerals, salts, and other dissolved particles are among the inorganic and organic materials found in water. The elevated TDS levels in Sangama may be caused by human activity such as industrial discharge, effluents from nearby illegal crude oil refining activities, agricultural runoff, or home wastewater discharge[31-33]. TDS levels in Tema and Degema are comparable, maybe as a result of comparable human activity and water sources. Different human activities in each place may be the cause of the variance in physicochemical properties between stations in Sangama, Tema, and Degema[31,32]. Apart from altering pH and temperature, these activities may also raise the salinity, TDS, and EC of the water, which may have an impact on the overall quality of the water[33,34].

Table-1: Special difference of physicochemical parameters. Results were presented as mean ± SD of triplicate determinations.

Stations	Temperature (^{o}C)	pH	DO (mg/l)	Salinity (ppm)	BOD (mg/l)	Conductivity (µS/cm)	TDS (ppt)
Tema	27.40±0.75^{ab}	6.45±0.18^{b}	3.27±0.21^{a}	12.78±0.8^{b}	2.78±0.5^{ab}	28.78±2.61^{ab}	21.95±2.5^{b}
Degema	25.75±0.57^{b}	6.72±0.14^{a}	3.35±0.11^{a}	11.44±0.5^{b}	2.46±0.4^{b}	25.76±0.47^{b}	19.20±2.3^{c}
Sangama	29.50±0.74^{a}	5.68±0.18^{c}	2.92±0.20^{a}	15.28±0.7^{a}	3.60±0.8^{a}	34.07±3.62^{a}	28.17±3.8^{a}
WHO 2011	30	6.6 - 8.5	6	120	10	600	500

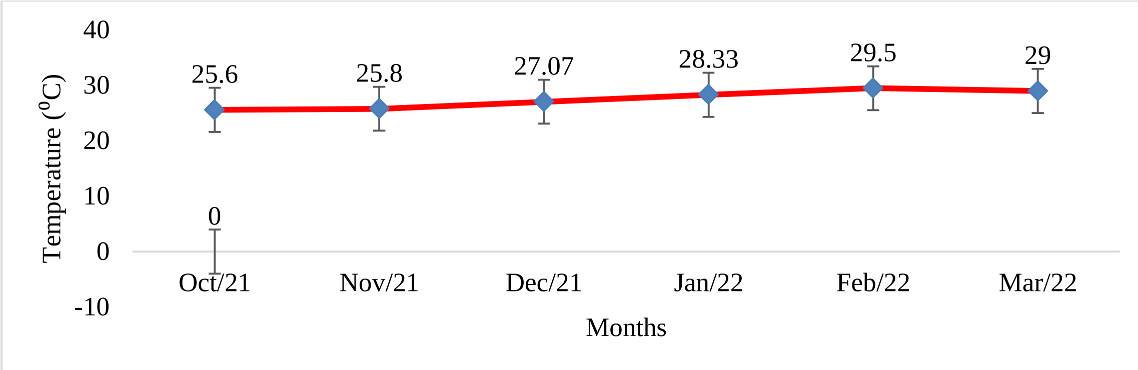

Figure-1: Show the temporal variation of the Temperature (^{0} C).

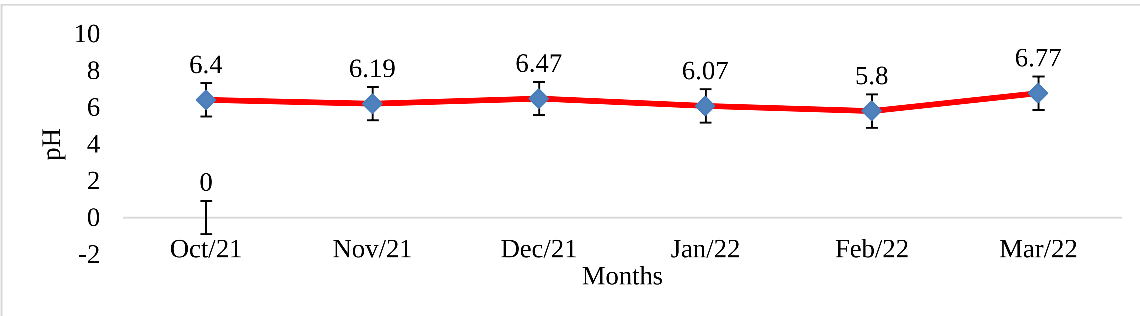

Figure-2: Show the temporal variation of the hydrogen ion concentration (pH).

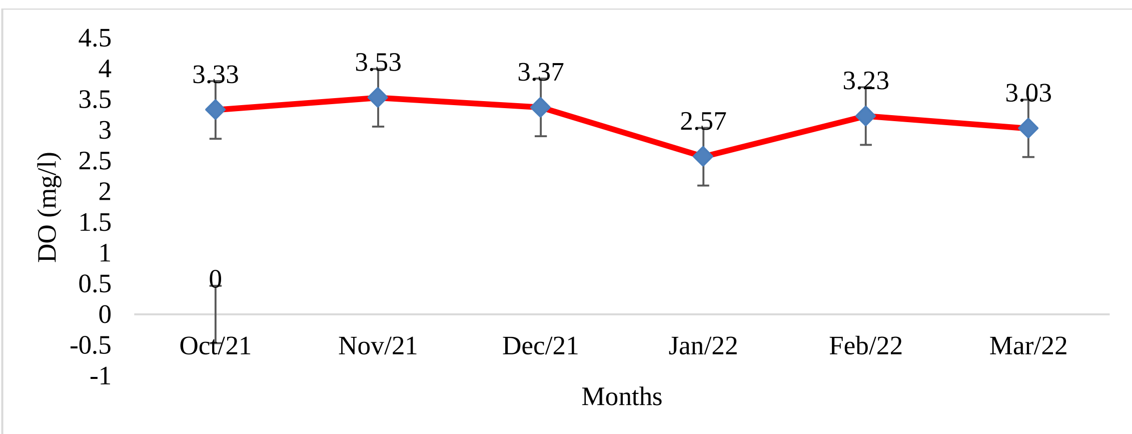

Figure-3: Show the temporal variation of the Dissolved Oxygen (DO mg/l).

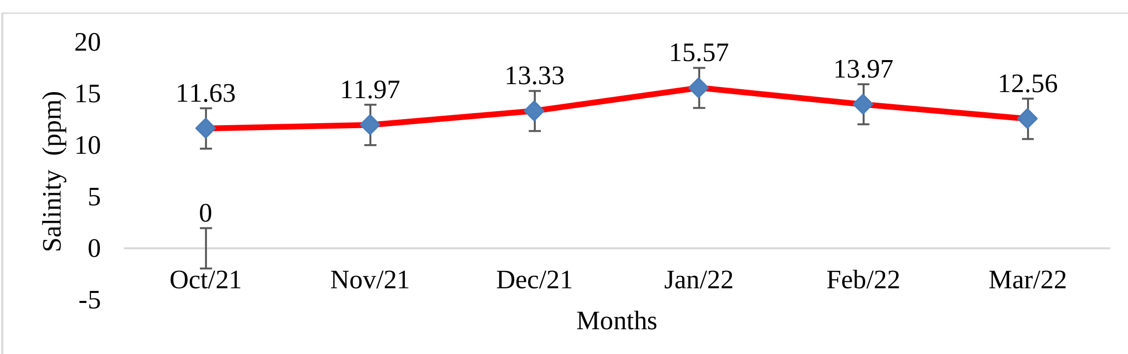

Figure-4: Show the temporal variation of the Salinity (ppm).

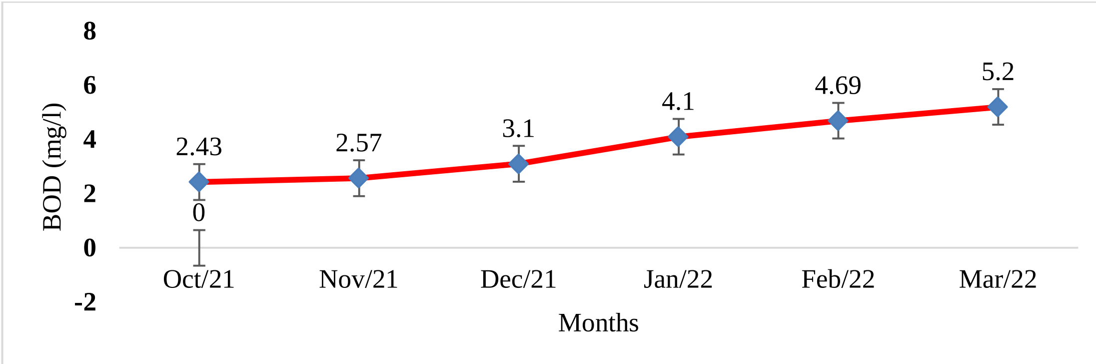

Figure-5: Show the temporal variation of the Biological Oxygen Demand (BOD mg/L).

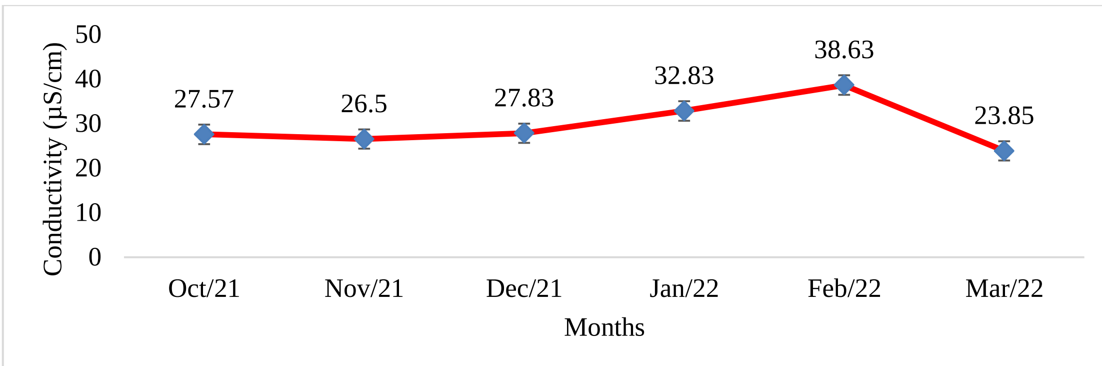

Figure-6: Show the temporal variation of the Conductivity (µS/cm).

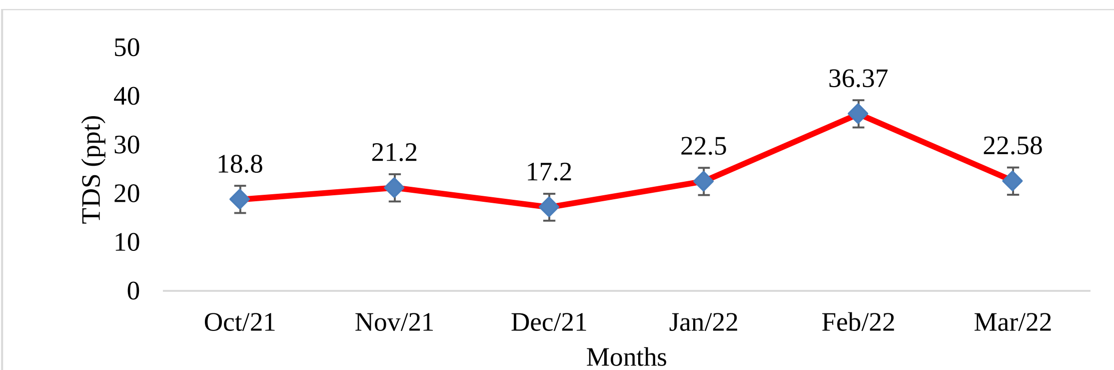

Figure-7: Show the temporal variation of the Total Dissolved Solids (TSS).

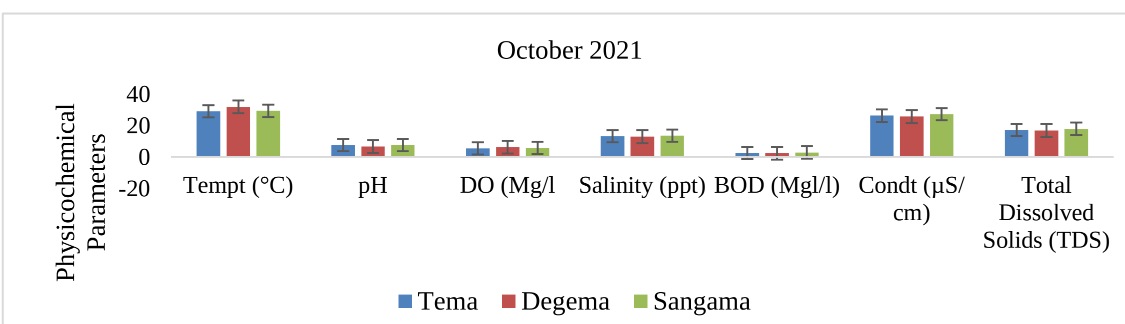

Figure-8: Physicochemical parameter variation across stations in October.

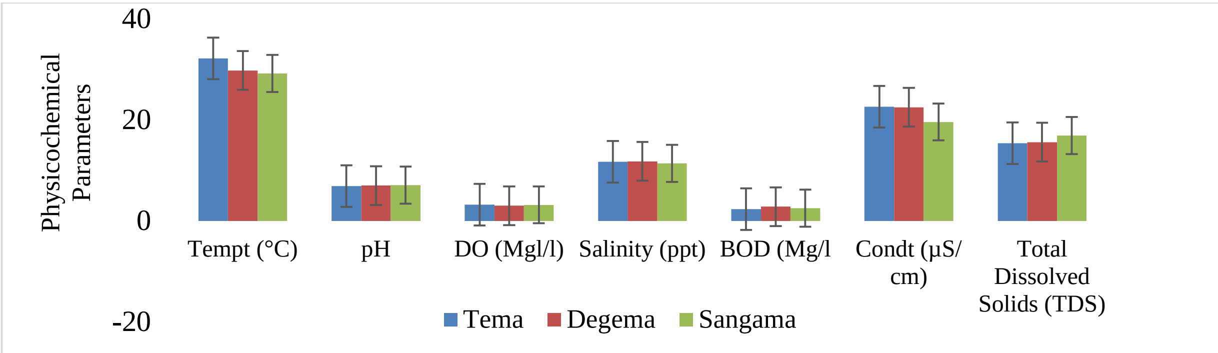

Figure-9: Physicochemical parameter variation across stations in November 2021.

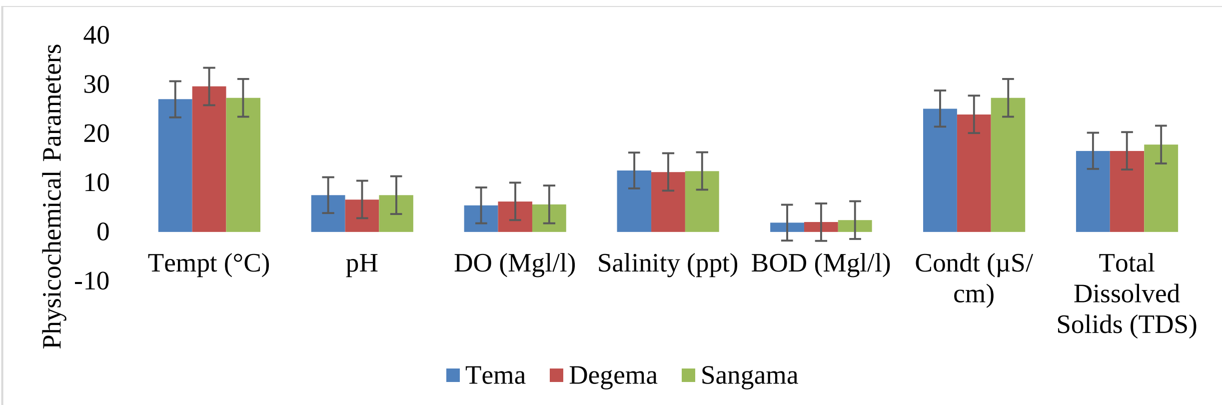

Figure-10: Physicochemical parameter variation across stations in December 2021.

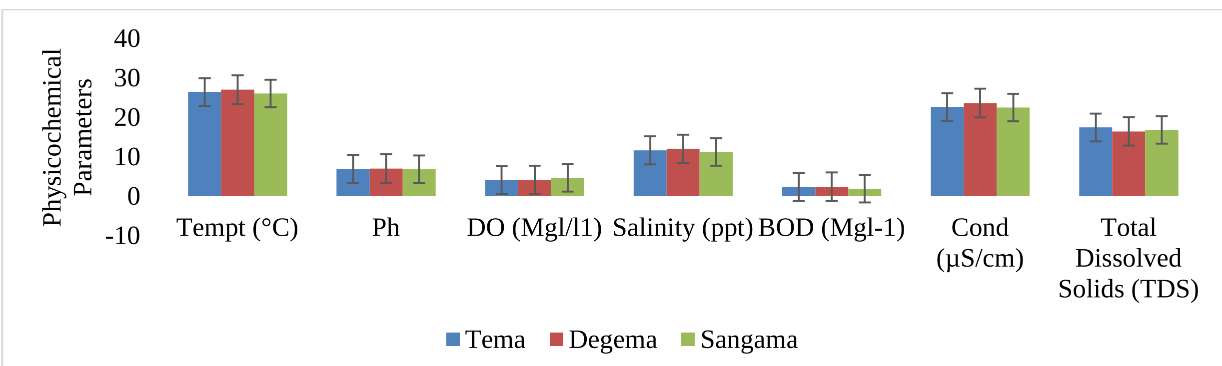

Figure-11: Physicochemical parameter variation across stations in January 2022.

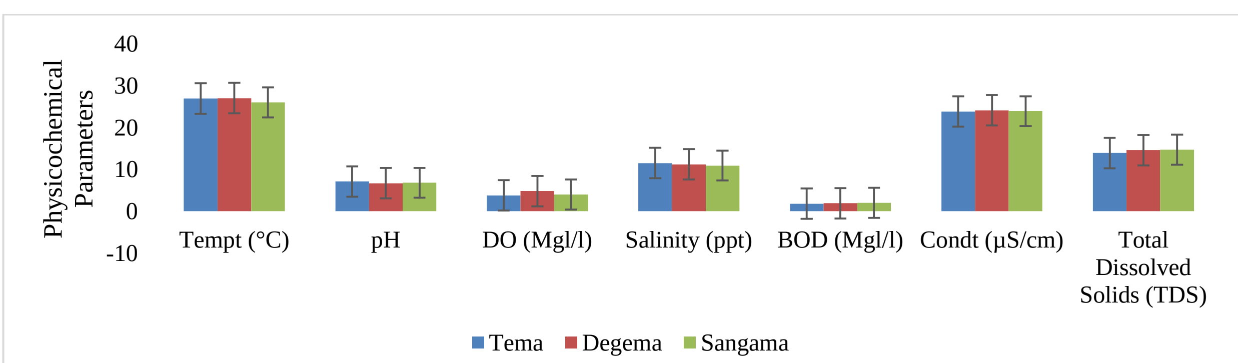

Figure-12: Physicochemical parameter variation across stations in February 2022.

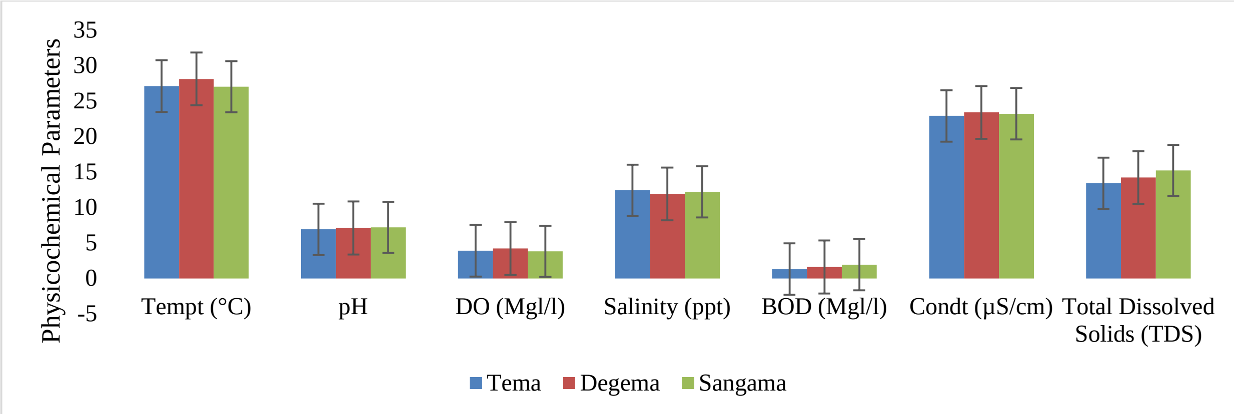

Figure-13: Physicochemical parameter variation across stations in March 2022.

Variation of physicochemical parameters over time from October 2021 to March 2022: Figure-1 to 7 illustrates the temporal fluctuations in various physicochemical parameters (pH, dissolved oxygen, salinity, biological oxygen demand, total dissolved solids, electrical conductivity, and temperature) from October 2021 to March 2022. The temperature ranged from 25.60±0.87°C to 29.50±1.46°C, with mean pH values ranging from 5.80±0.38 to 6.77±0.26. The dissolved oxygen (DO) fluctuated from 2.57 ± 0.33mg/l to 3.53 ± 0.18mg/l. Salinity varied between 11.63±1.00 and 15.57±1.57, and the mean electrical conductivity ranged from 23.85±1.88 to 38.63±6.39. The biological oxygen demand (BOD) varied from 2.43±0.09 to 4.80±0.09, while the total dissolved solids (TDS) ranged from 17.20±0.81 to 36.37±4.55.

The lowest temperature was recorded in October, the lowest pH in February, and the lowest DO in January. Salinity and BOD were lowest in October, while electrical conductivity was lowest in March and TDS in December. The highest temperature, electrical conductivity, and TDS were recorded in February, the highest pH in March, and the highest DO in December. Salinity was highest in January, and BOD was highest in March. The monthly differences in pH, temperature, salinity, biological oxygen demand, electrical conductivity, total dissolved solids, and dissolved oxygen were observed between the stations.

From October 2021 to March 2022, there were changes in the physicochemical parameters, which include pH, temperature, salinity, electrical conductivity, biological oxygen requirement, and total dissolved solids. Water flow and weather are two examples of variables that might cause these characteristics to change[42,43]. The analysis shows that over this time, there was a modest variation in both pH and temperature, ranging from 5.80 to 6.77 and from 25.60°C to 29.50°C and this could be attributed to variation in temperature. Temperatures may fluctuate during the dry and rainy seasons, as stated by[44]. According to Gupta et al.[4] pH values in the range of 6.5 to 8.5 are neutral for aquatic organisms. The same pH range was also observed by de Morais et al.[46] in their investigation of high temperature and high pressure efficiency.

Temperature, photosynthesis, and respiration are some of the variables that affect dissolved oxygen (DO)[47]. The water's capacity to sustain aquatic life is shown by the dissolved oxygen (DO) range of 2.57±0.33mg/l to 3.53±0.18mg/l, which is within the safe range for aquatic life (5–10mg/l). Similar results for the Otamiri River in Owerri, Imo State, Nigeria, were reported by Obiyor[48]. Reduced dissolved oxygen levels may be caused by an excess of organic matter, from sewage discharge or runoff from crude oil refineries[49]. DO levels may also be impacted by variations in temperature, water velocity, and other variables[44].

The slight temperature variation reported in this study is consistent with the findings of Yan et al.[50] and Swain et al.[51], who have noted that evaporation, precipitation, and human activities like dredging and industrial discharge can affect salinity levels. The salinity levels found in this research are within the range that is thought to be safe for aquatic life. Nonetheless, some species could be able to live in this range while others couldn't[52]. Although this range's size could fall within certain saltwater species' typical range, it might be getting close to many freshwater species' top tolerance limit. According to Kibler et al[53] abrupt increases in salinity may also be detrimental to aquatic organisms.

The average electrical conductivity of the water was around 31.2, with oscillations within the range of 23.85±1.88 to 38.63±6.39. These fluctuations could have been caused by human activities such land use changes and pollutant discharge. Increased conductivity may result from elevated quantities of dissolved ions, such as salts[54]. Electrical conductivity readings, which exhibit a modest change from October 2021 to March 2022, are markers of the ionic content of water, according to Elbendary et al.[55].

The levels of TDS and BOD fluctuated somewhat between October 2021 and March 2022. According to Susilowati et al.[56], a high BOD measurement might indicate organic contamination, perhaps from sewage discharge or agricultural runoff. Dissolved solids from the industrial discharges or agricultural runoff may have also contaminate water systems with high TDS levels.

Weather, river movement, and human activity may all affect the quality of water over time[54].

October had the lowest temperatures, February had the lowest pH, and January had the lowest dissolved oxygen (DO). According to Obiyor[48], these characteristics might change seasonally since October has the lowest temperatures, pH, and DO. Elliott et al.[57] claim that seasonal variables that affect temperature include wind, sunshine, and air temperature. Seasonal fluctuations in temperature and precipitation may also have an impact on pH[58].

The water quality may have been impacted by changes in water flow, seasonal variations in aquatic life, and human activity near the sample stations[24]. These factors may have also contributed to seasonal variations in the parameters mentioned. Salinity, BOD, TDS, and electrical conductivity were found to vary seasonally in October, March, and December. Seasonality may be seen in salinity as well as in evaporation, precipitation, and water flow[59]. In water, organic matter is broken down, microorganisms need oxygen, and how much they need depends on a number of variables including temperature, the amount of organic matter present, and the kind of microbe[44]. These fluctuations may also be caused by seasonal influences.

According to Pandey et al.[60], salts and other ionic compounds dissolved in water can affect the conductivity of a liquid. These substances may also change seasonally. Evaporation, precipitation, and water velocity are some of the elements that affect total dissolved solids (TDS) in water. These parameters may also vary seasonally[23].

The highest months were February for temperature and electrical conductivity, March for pH, December for DO, January for salinity, and March for BOD. This suggests that certain factors vary seasonally. Seasonal fluctuations in temperature may be caused by wind, sunshine, and air temperature[57]. Seasonal fluctuation is seen in the effects of temperature and precipitation on pH[58]. Temperature, photosynthesis, and respiration are some of the variables that might affect DO, which is a measurement of the amount of oxygen in water[61]. However, salinity is influenced by several elements, such as water flow, precipitation, and evaporation[62].

The pH readings did not vary substantially ($P > 0.05$) in any of the months, indicating that human and environmental variables may not have as much of an impact on pH as they do on other parameters. Nonetheless, disparities in aquatic species, water flow, and land use at each station may account for geographical variances [44,45]. There are also differences in dredging operations, farming practices, and industrial discharges across the stations.

The Pearson Correlation for Physicochemical parameters: Table-2 shows a positive correlation between temperature and salinity (0.630), dissolved oxygen (0.246), conductivity (0.501), and total dissolved solids (0.695). Dissolved oxygen and pH were positively correlated (0.092), salinity negatively correlated (-0.500), and conductivity and total dissolved solids negatively correlated (-0.917). There was no correlation between dissolved oxygen and other parameters. The salinity was positively correlated with dissolved oxygen (0.675), conductivity (0.645), and total dissolved solids (0.350). The biochemical oxygen demand (0.924) and electrical conductivity (0.546) exhibited strong correlations. Electrical conductivity and total dissolved solids displayed a positive correlation (0.802).

Variations in heavy metal in Concentrations Water: Heavy metal concentrations at different stations and in various media are shown in Table-3. By Sangama stations, heavy metals are distributed as follows: Fish = Zn > Fe > Cu > Pb > As > Cd; Sediment = Fe > Cu > Zn > Pb > Cd > As; Water = Cu > Fe > Zn > Pb > As > Cd). For iron (Fe) content, water from Degema had the highest value (37.92 x 3.95 mg L-1), followed by Tema (36.25x4.01mg L-1), and Sangama (35.90 x 4.12 mg L-1). Additionally, the highest zinc (Zn) concentration was found in Degema (10.99±1.71 mg L-1), followed by Sangama (10.76±1.253 mg L-1), while the lowest was recorded in Tema (9.94±1.25 mg L-1). Lead (Pb) levels were highest in Tema (0.12±0.02 mg L-1) and lowest in Degema (0.07±0.01 mg L-1). In terms of copper (Cu) concentration in water, Degema had the highest reading (149.24±4.89 mg L-1) and Tema the lowest (145.95±3.66 mg L-1). The variation in arsenic (As) concentration in water was less than 0.01 mg L-1.

The Degema, Sangama, and Tema creeks are vital sources of water for food, agriculture, and recreation in the growing oil city of Port Harcourt. However, the increase in artisanal crude oil refining has had a detrimental impact on the creeks and ecosystems they support[34]. The findings show that the three stations' mean amounts of heavy metals in the fish, sediment, and water varied. The highest Fe concentration was observed in the water at Degema (37.92±3.95 mg kg-1), followed by Tema (36.25±4.01 mg kg-1), and the lowest at Sangama (35.90±4.12).

Iron (Fe) is a trace element essential for plant and animal life and occurs naturally in the environment[34]. Human activities such as dredging, crude oil refining, and domestic waste disposal can lead to elevated Fe levels[24]. The high iron content in the water in Degema may be caused by a number of variables, including the local geology, human activity, soil-rich minerals, and closeness to the water source[63].

It's possible that the variations in exposure to these variables account for the variations in iron concentrations seen in Degema, Tema, and Sangama. Differences in the filtration and water quality may be the cause of this. The precise reason for these variations has to be investigated further[44]. With respect to iron (Fe) levels, Degema and Tema had the greatest and lowest values, respectively. Variations in the amount of iron present in the water may have an impact on its quality and can have negative health or environmental effects. Degema may have more iron-rich minerals or other iron sources than Tema and Sangama, or its water supply may be less effective in removing iron.

There is variation in zinc concentration in the water across different locations, with high levels of zinc at all three stations, potentially leading to health issues such as nausea, vomiting, abdominal cramps, and diarrhea, as well as anemia and impaired immune function[34]. It is possible that there are more zinc-rich minerals or other sources of zinc at Degema, or that the water source at Degema is less effective at filtering out zinc than at other locations[64]. Activities like dredging, artisanal crude oil refining, and domestic waste disposal likely impact the environment[63], leading to contamination of nearby water sources with zinc-containing particles. Consequently, soils and sediments may contain higher zinc levels, resulting in elevated zinc levels in water samples[65]. High concentrations of zinc in water may have negative health consequences, including diarrhoea, cramping in the abdomen, nausea, and vomiting. Severe instances may also result in decreased immune system performance and anaemia. From an ecological standpoint, however, excessive zinc concentrations in water bodies may be harmful to aquatic life, having a negative impact on the development, reproduction, and survival of a variety of aquatic species. Zinc can also interfere with the normal functioning of the ecosystem by altering the balance of the food chain[66].

Tema had the highest lead levels in stream water, whereas Degema had the lowest. This implies that the lead contamination in the stream could not be consistent throughout, either because lead pollution comes from various sources in different places or because the pollution is concentrated around Tema. Prolonged exposure to elevated lead levels in water may have detrimental effects on the environment and human health, upsetting the food chain and eventually damaging the ecosystem. High lead concentrations may also have a negative impact on IQ, the reproductive system, and the neurological system[24]. Degema Creek, on the other hand, has lower lead levels, which may indicate less health problems for the surrounding population and animals. Lead concentrations may be impacted by environmental elements including soils and geology. The Federal Government of Nigeria has established a maximum of 0.02 mg/L for lead contamination in drinking water.

Water containing copper may be harmful to young children's health. Natural composition, mining activities, and industrial wastes can all have an impact on the quality of the water. Anthropogenic activity could potentially raise copper concentrations. Long-term use of water tainted with copper increases the risk of neurological and cardiovascular disorders as well as liver and kidney damage. There was little difference in the three stations' water's arsenic concentrations. While prolonged exposure to low levels of arsenic in drinking water has been linked to a number of health issues and may affect aquatic life and ecosystem health, low amounts of arsenic in drinking water are not immediately dangerous.

Heavy metal concentrations in swimming crabs (*Callinectes sapidus*): In Callinectes sapidus, Tema had the lowest Fe content, while Sangama and Degema had the highest concentrations at 22.33±0.80mg kg-1 and 16.11±0.45mg kg-1, respectively. The zinc concentrations were 186.49 ± 3.65 mg kg-1 in Degema and 98.91±1.60mg kg-1 in Tema. Pb and Cd levels in fish samples were consistent at 0.01mg kg-1 across all locations. Tema had the highest Cu concentration (1.77x0.42 mg L-1), while Sangama had the lowest (1.29x0.19mg kg-1). Additionally, there was no difference in As concentration among the three locations as shown in Table 3.

The three stations that were sampled had Fe concentrations arranged as follows: Degema>Sangama>Tema. Sangama, Tema, and Degema have the lowest concentrations of zinc, respectively. The fish samples from each location had comparable Pb and Cd values. Cu concentrations were 1.77±0.42mg L-1 at Tema and 1.29±0.19mg kg-1 in Sangama. Furthermore, the fish samples at all three locations had the same concentration of as (<0.01mg L-1). The findings of this investigation indicate that there is no discernible difference in the three stations that were sampled's water quality. Thus, although there were no levels of as found in any of the fish samples, the quantities of Fe, Zn, Pb, Cd, and Cu in the fish samples did not differ substantially amongst the stations. According to Oujidi et al.[67] and Perumal et al.[68], this indicates that possible environmental contaminants like Pb, Cd, As, and Cu that may arise from industrial activity or agricultural runoff are not having an impact on the fish quality at the three sites. The levels of Fe and Zn in the drinking water above the permitted limits of 0.1-0.3 and 0.1-3.0mg kg-1 established by WHO/USEPA. This suggests that the fish in the region may be able to bioaccumulate these metals, rendering them unfit for human consumption.

Table 2: Pearson Correlation Matrix for Physicochemical Parameters in the Study Area.

Parameters	Tempt	pH	DO	Salinity	BOD	Conduct	TDS
Temperature	1						
pH	-0.199	1					
DO	-0.567	0.092	1				
Salinity	0.630	-0.500	-0.789	1			
BOD	0.246	-0.917*	-0.203	0.675	1		
Conductivity	0.501	-0.901*	-0.263	0.645	0.924**	1	
TDS	0.695	-0.688	-0.114	0.350	0.546	0.802	1

** The correlation is significant at the 0.01 level (2-tailed).* The correlation is significant at the 0.05 level (2-tailed).

The study's findings show that the fish from the three sites had low amounts of arsenic and cadmium and significant levels of iron, zinc, copper, and lead contamination. Those who live close to these sites may be at considerable risk for health problems as a result of long-term exposure to these heavy metals.

Spatial variations in heavy metal Concentrations in Sediment: From Table-3, Degema had the highest Fe concentration in the sediment at 1748.44±88.22mg kg-1, followed by Sangama at 1643.88±83.5mg kg-1, while the lowest was observed in Tema at 1577.60±107.5mg kg-1. Zn was highest in Degema at 225.31±7.83mg kg-1 and lowest in Tema at 205.76±1.88mg kg-1. Pb was highest in Degema at 10.57±0.62mg kg-1 and lowest in Tema at 6.93±1.03mg kg-1. In Tema, Cd concentrations were the lowest (2.4x0.32), and highest in sediments from Degema (3.15x0.33). Tema had the highest sediment Cu contents (563.48±14.82mg kg-1) and the lowest (551.58±40.29mg kg-1). Among the three locations, there were no significant variations in the As concentration (0.01mg kg-1). Tema had the lowest quantities of Fe, Zn, Pb, Cd, and Cu, while Degema and Sangama had the highest concentrations of each element.

In Rivers State, Nigeria, the Degema, Sangama, and Tema creeks are vital to the local residents' way of life. It provides a supply of fish for sustenance as well as a means of transporting wood. The elevated levels of lead, cadmium, zinc, iron, and copper in the sediment of Degema and Sangama may be a sign of environmental contamination brought on by human endeavours like urbanisation and industry. If the pollutants seep into the water supply or were ingested, they may have detrimental impacts on human health in addition to detrimental effects on the ecology and aquatic life. The absence of variation in the levels of arsenic detected in the sediment samples from all three sites implies that arsenic does not play a significant role in the pollution of this region. Sequence of heavy metal dispersion in sediment.

High concentrations of iron, zinc, lead, cadmium, and copper have been found in the sediment of the Degema and Sangama rivers, suggesting environmental contamination most likely caused by industrial and urban activity[11]. They contend that this pollution may be harmful to fish, aquatic life, and other creatures, upsetting the food chain and resulting in long-term ecological imbalances and a reduction in biodiversity[12]. Concerns about the health hazards to the nearby populations, who rely on the creeks for a variety of uses, are also raised by the presence of these heavy metals[69]. The quality of the wood and the lives of individuals who depend on the timber business in the area may be impacted by the pollution seen in the streams, which are used as a transit route for wood. The results emphasise how critical it is to undertake environmental cleanup projects and maintain ongoing water and sediment quality monitoring in order to guarantee local communities continued sustainable usage.

In addition, the concentrations of heavy metals in fish, water, and sediment vary at the three stations; Fe is most prevalent in sediment in Degema, while As is lowest at all three sites. Patel et al.[70] propose that elevated levels of heavy metals in water and sediment could have a detrimental impact on the environment. The buildup of heavy metals in the food chain and the damage they inflict on aquatic life could potentially affect human health[71]. According to Mohtar et al.[72], heavy metals in sediments and water indicate environmental pollution, which may pose a threat to the ecosystem and the nearby populations reliant on the creeks.

Human health may be negatively impacted by high concentrations of heavy metals. Even at modest exposure levels, certain heavy metals, including lead and cadmium, may be hazardous and harm the kidneys, neurological system, and other important organs[12]. According to Rehman et al.[73], there may be a larger danger to health for those who eat fish and water from Degema than for those who drink it from the other two stations due to the increased concentration of heavy metals there. The health of local residents and other living things may be impacted by the levels of heavy metals in the fish, water, and sediment at each station[11]. To reduce the possibility of damage to human health, the amount of heavy metals in the environment should be controlled and monitored.

Pearson correlation of the heavy metal concentration: The Pearson correlation matrix in Table-4 examines the relationships between the concentrations of heavy metals (Pb, Cu, Zn, Cd, and Fe) across three different stations in the study area. The values in the table represent the strength and direction of the correlation between each pair of heavy metals. The off-diagonal elements indicate the correlations between different pairs of heavy metals. The correlation coefficients between Fe and Zn, Fe and Pb, Fe and Cd, and Fe and Cu are all very high, suggesting a strong positive correlation between these metals. Similarly, Zn and Pb, Zn and Cd, Zn and Cu, Pb and Cd, Pb and Cu, and Cd and Cu also show strong positive correlations.

The positive correlations observed among all heavy metals suggest a tendency for these metals to co-occur in the sampled stations. This may suggest that similar sources or environmental processes are affecting the concentrations of these heavy metals in the study area. The positive correlation coefficients show that heavy metal concentrations are positively linked with each other across the three stations. This indicates a consistent pattern of co-occurrence in the study area.

Temporal variation in heavy metals: Table-5 illustrates the temporal fluctuations of heavy metals Fe, Zn, Pb, Cd, and Cu. The range for Fe was 468.17±225.32 to 694.73±330.97 mg/kg, Zn ranged from 112.35±29.7 to 127.72±34.5mg/kg, Pb varied between 1.96±1.12 and 3.91±1.93mg/kg, and Cd showed a range of 0.47±0.30 to 1.27±0.62mg/kg. The Cu value fluctuated between 198.31 and 241.20mg/kg, while the concentration of as remained constant at 0.001mg/kg throughout the month.

In March, the concentrations of Fe, Pb, and Zn peaked, while the highest levels of Cd were recorded in January. The concentration of as remained consistent from October 2021 to March 2022. Additionally, Cu concentrations were at their lowest in March, and July exhibited the lowest concentration of Zn. January to March 2022 and October to December 2021 did not show a significant difference (P>0.05). Zn showed a significant change each month (P>0.05). The variation in Pb between months was statistically significant (P< 0.05). As concentrations remained unchanged from October 2021 to March 2022. The variation in Cu throughout the sample months was statistically significant (P > 0.05).

Table-5 illustrates the fluctuating concentrations of Fe, Cu,Pb, Cd, Zn, and As across different months. The peak concentrations of Fe, Pb, and Zn are observed in March, while the highest concentration of Cd occurs in January. Cu and Zn reach their lowest levels in March and July, respectively. The concentration of as remains stable from October 2021 to March 2022. Between October and December 2021 and January and March 2022, Fe concentrations did not differ significantly. Zinc (Zn) exhibits a notable monthly change, while Pb varies significantly between months. Arsenic (As) concentrations remain unchanged from October 2021 to March 2022, and there is a statistically significant variation in Cu throughout the sample period.

Table-3: Spatial variations in heavy metals in the Water, Crab and Sediment.

Source	Locations	Fe	Zn	Pb	Cd	Cu	As
Water	Tema	36.25±4.01 [a]	9.94±1.25 [b]	0.12±0.02 [a]	0.05±0.01 [a]	145.95±3.66 [a]	0.001±0.0[a]
	Degema	37.92±3.95 [a]	10.99±1.71 [a]	0.07±0.01[b]	0.06±0.01 [a]	149.24±4.89 [a]	0.001±0.0[a]
	Sangama	35.90±4.12[a]	10.76±1.25 [a]	0.08±0.01[b]	0.04±0.01 [a]	146.58±9.50 [a]	0.001±0.0[a]
Fish	Tema	13.34±0.62 [c]	98.91±1.60 [c]	0.001±0.0[a]	0.001±0.01[a]	1.77±0.42 [a]	0.001±0.0[a]
	Degema	22.33±0.80 [a]	186.49±3.65 [a]	0.001±0.0[a]	0.001±0.01[a]	1.46±0.22 [b]	0.001±0.0[a]
	Sangama	16.11±0.45 [b]	113.42±1.21 [b]	0.001±0.0[a]	0.001±0.01[a]	1.29±0.19 [c]	0.001±0.0[a]
Sediment	Tema	1577.6±107.5[c]	205.76±1.88 [b]	6.93±1.03[b]	2. 48±0.32[ab]	451.58±40.29 [b]	0.001±0.0[a]
	Degema	1748.4±88.2 [a]	225.31±7.83 [a]	10.57±0.62[a]	3.15±0.33[a]	563.48±14.82 [a]	0.02±0.01 [a]
	Sangama	1643.8±83.5[b]	221.94±7.16 [a]	7.79±1.28 [ab]	2.50±.055 [ab]	503.81±21.81[a]	0.001±0.0[a]
WHO 2011	Standard	0.3	0.1	0.01	0.003	2.0	0.01
USEPA	limit	0.1	3.0	2.0	2.0	3.0	10

Table-4: Correlation between heavy metals across the three stations in the study area.

	Fe	Zn	Pb	Cd	Cu
Fe	1				
Zn	0.995265	1			
Pb	0.985885	0.99749	1		
Cd	0.911938	0.947503	0.967765	1	
Cu	0.996088	0.982782	0.967233	0.872109	1

Table-5: Temporal changes in heavy metal concentrations in water, fish, and sediment.

	Fe	Zn	Pb	Cd	Cu	As
October 2021	468.17±225.32[b]	112.35±29.7[c]	3.10±1.54 [a]	1.05±0.52 [ab]	198.31±67.78 [b]	0.001[a]
November 2021	509.87±244.98[b]	120.86±31.8 [a]	2.82±1.52 [ab]	0.70±0.34[b]	225.40±83.13 [ab]	0.001[a]
December 2021	557.14±265.26[ab]	119.37±30.3 [b]	1.96±1.12 [b]	1.15±0.58 [ab]	200.90±68.42 [b]	0.001[a]
January 2022	591.66±281.50[a]	118.73±28.91[b]	2.50±1.22[b]	1.27±0.62 [a]	229.26±77.45 [a]	0.001[a]
February 2022	599.60±284.77[a]	123.32±21.7 [a]	2.75±1.47 [ab]	0.88±0.42[b]	215.05±73.43 [ab]	0.001[a]
March 2022	694.73±330.97[a]	127.72±34.5 [a]	3.91±1.93 [a]	0.47±0.30[b]	241.20±86.80 [a]	0.001[a]

Temporal variations suggest that specific months may pose higher risks of heavy metal contamination, emphasizing the importance of targeted monitoring and intervention measures during these periods [11]. Arsenic (As) concentration stability may indicate a consistent input or the absence of significant changes at its source. Significant variations in certain metals, such as Pb and Zn, underscore the need for focused attention to these elements in environmental management strategies. According to [34], the temporal analysis provides valuable information about heavy metal fluctuation, allowing for a better understanding of their dynamics and aiding in the development of effective environmental management and remediation strategies.

Conclusion

The findings of the Environmental Impact Assessment (EIA) conducted in this Niger Delta Region, Nigeria, indicate that surface water, sediments, and fish in three significant communities—Tema, Sangama, and Degemaare contaminated with elevated levels of heavy metals. Consistently, the maximum concentrations are found in Degema, which poses a greater health risk to those who consume resources sourced from this region. Sediment, water, and fish contaminated with high concentrations of heavy metals may contribute to severe health complications, including anaemia, gastrointestinal distress, impaired liver and kidney function, and an increased risk of cardiovascular and neurological ailments. Due to the ecosystem's dynamic character, the study emphasises the necessity of community-specific interventions. The study also emphasizes the urgency of implementing sustainable environmental management practices in this region. Recommendations include regular monitoring of water quality, especially for iron, zinc, and copper, to ensure compliance with safety standards. Further investigations are needed to determine the health and ecological implications of the observed differences in lead levels. Collaborative efforts between local government and environmental organizations are crucial for implementing policies and programs to reduce pollution and promote sustainable river use.

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