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Full Length Research

Ecological analysis of heavy metals contamination in water from Kaani River, Ogoni, Rivers State, South-South, Nigeria

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ABSTRACT: Ecological evaluation was carried out to study the surface water of the Kaani River, Ogoni axis, Rivers State, South-South, Nigeria, for contamination factor (Cf), degree of contamination (Cd), and modified contamination degree (mCd). Over the course of a year, surface water samples were taken from the Kaani River at four separate locations every two months. The atomic absorption spectrophotometry (AAS) method was used to determine the amounts of heavy metals in the samples after they had been prepared according to normal procedures. The metals analyzed were manganese (Mn), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), iron (Fe), zinc (Zn), arsenic (As), and nickel (Ni) respectively. The result of the metal concentrations in all stations and months showed the order as As < Cd < Pb < Mn < Cr < Ni < Zn < Fe < Cu. A contamination factor test on the various heavy metals based on their concentrations and the WHO standard revealed that the studied heavy metals were at different levels of contamination and pollution classification in the River at different stations. The values observed for all the trace elements studied, with the exception of Fe, were less than the WHO and NAFDAC requirements for drinking water. The River showed no contamination–moderate pollution with Fe, while that of Mn indicated slight contamination- severe contamination range, Cd fell within no contamination to slight contamination range, slight contamination –slight pollution with Cu, no contamination – slight contamination with Zn, slight contamination – very severe contamination with Cr, moderate contamination- very severe contamination with Pb. As and Ni were at the range of slight contamination – moderate contamination. The analysis results from the River indicated that the water should be treated adequately before consumption. The pollution index analysis showed that the River was not polluted with heavy metals. Contamination degree values showed that the River is at different levels of heavy metal contamination. Modified contamination degree indicated that the River experienced nil to very low degree of contamination by the metals examined.

Keywords: Ecological Analysis, contamination, heavy metals, pollution.

INTRODUCTION

The assessment, management, and legislative processes for the renewal, restoration, safety, and protection of the aquatic environment all depend heavily on the ongoing monitoring of any aquatic medium. Together, these activities contribute to the establishment of the integrity of aquatic biota and the general environmental geochemistry, as documented evidence demonstrates that increased levels of heavy metals in the environment are caused by industrial and agricultural activities (Ghosh and Singh, 2005).

According to Hogstrand and Haux (1991), anthropogenic activities like bush burning, indiscriminate waste disposal into our water bodies, and flared gases from industrial sites have all been linked to the pollution of aquatic environments, which includes lakes, streams, rivers, creeks, reservoirs, seas, and even rainwater. Similarly, other pollution agents are natural sources such as precipitation and runoff (Damek and Sawicka, 2003). A rise in population has resulted in a surge in waste production; higher rates of waste discharge, bunkering, illicit petroleum product refining, and fertilizer and pesticide application on agricultural farms have all been linked to population growth (Edori and Marcus, 2017).

Creeks and rivers were the only portable water sources (from rainwater and well water) for home and industrial applications before the current age when private individuals and businesses began drilling boreholes. Water bodies have been utilized for waste transportation and fishing, particularly for residential and commercial purposes, up until now (Ekpete *et al*., 2019).

The anthropogenic activities that are predominant in the Kaani community include dumping of refuse waste into the River, the use of the River for boat transportation, and the use of Agro chemicals on farmland to enhance crop production. These practices are major sources of Heavy metal contamination.

Heavy metals are classified as transition elements and are found in water, food, soil, and air at varying concentrations that pose a risk to human health and are regarded as pollutants and toxicants at higher concentrations. However, some heavy metals are essential to both plants and animals at lower concentrations (Sehgal *et al*., 2012). Because of their toxicity and ability to interact with animal physiological systems, certain of these metals (such as mercury, lead, and cadmium) are not necessary for the environment or the human body, even in extremely low quantities (Lacatusu, 2000). Though some elements, like iron, copper, zinc, manganese, and selenium, are necessary at trace levels for healthy physiological and biochemical body functions (Håkanson, 1980), Haxhibeqiri *et al*. (2015) state that the ongoing degradation of various water bodies and sources is a concern and is turning into a social problem that needs to be addressed immediately, which is why this study was conducted to find out how much heavy metal was present in the Kaani River, a significant river in Ogoni, Rivers State, Nigeria.

MATERIALS AND METHODS

Study area

The study was conducted in a local river (freshwater) in Kaani, Ogoni axis of Rivers state. Kaani is 1,050 sq. Km area of land located in the Rivers south-east senatorial district of Rivers state in Khana Local Government Area, south-south, Nigeria. The territory is located in Rivers State, east of the city of Port Harcourt. It extends across the Local Government Areas of Khana and a major part of the Niger Delta region of Nigeria. Kaani community is surrounded by neighboring host communities such as Kor, Kpong, and Yege communities whose inhabitants predominantly engaged in sand drilling and farming.

Geographically, the Kaani community is relatively humid in climate, located at latitude 1.5074°S of the equator and longitude 37.3707°E of the Prime Meridian. The GPS of the river revealed that the river occupies a latitude of 4.6920°N and a longitude of 7.3527°E. It is mostly forest in nature and covered with mosaic grassland/shrubland, tropically of a monsoon climate of the short dry season.

Plate 1 shows one of the sampling locations (Nwii ke ma kor stream) in Kaani River (station 4)

Methods

Sampling was done bi-monthly for a period of one year (wet and dry season) from July 2022 to June 2023. The geographic locations of the four (4) sampling spots were established by the use of GPS software installed in Infinity mobile handset and then the locations were obtained (Table 1). Water samples were taken from the River in both seasons at a frequency of once in two months from 7. 00 am and 9.00 am with pre-acid washed plastic sample vials. Samples of water were taken between twenty and twenty-five centimeters down. Following their transportation to the laboratory for analysis, the samples were placed in ice-cold packs.

Water samples with a known volume of 50 cm^3 were digested in a steam bath using mixtures of concentrated acids in a 5:3:2 ratio (HNO_3, HCl, and H_2SO_4); the digestion was stopped when the mixture turned clear or colorless. The samples were filtered, and the filtrate was raised to a volume of 50 cm^3 using deionized water.

The Thermal Atomic Elemental Absorption Spectrophotometer (model SE-71906) was used to examine the final filtered digest for heavy metals. For every ten sample runs in the machine, a blank run was performed to lower errors in the analytical data. Every sample underwent three separate analyses for each particular metal, with the findings expressed as mean ± standard deviation (Edori *et al*., 2019). The amount of pollution caused by the heavy metals in the River was assessed using the following metrics: contamination factor (CF), pollution index (PLI), contamination degree (CD), and modified contamination degree (mCD). Proposed contamination intervals and pollutant descriptions served as the foundation for the interpretations of the various assessment equations. The Lacatusu (2000) equation was used to compute the Contamination Factor.

$$\text{Contamination Factor (CF)} = Cm/C_b$$

The Pollution Index (PI) was obtained using the equation

Plate 1 Map showing one of the sampling locations (Nwii ke ma kor stream) (station 4).

Table 1. Sample locations' geographic positions along the Kaani River.

River	Sample identity	Location	Geographic location (Coordinates)
Kaani.	1	Maa di binnise Igbara waterside	Lat. 4.6793^{0}N
Kaani.	2	Mann Stream	Long. 7.3809^{0}E
Kaani.	3	Woman Stream.	Lat. 4.6791^{0}N
Kaani	4	Nwii ke ma kor stream	Long. 7.3850^{0}E

Pollution Index (PLI) = n√(CF1 X CF2 X CF3 X… X CFn)

(CF = contamination factor, n = number of metals, Cm = metal concentration in polluted water or sediments, Cb = background value of the metal or maximum recommended value of the metal in water, sediment, or soil).

The Hakanson (1980) equation was used to determine the contamination degree (CD), which represents the overall impact of heavy metal contamination in an ecosystem. This is how the contamination degree equation was used:

$$\mathrm{Cd} = \sum_{i=1}^{n} C\,F$$

and the modified contamination degree equation applied was

$$\mathrm{mCd} = \frac{1}{N}\sum_{i=1}^{N} CF$$

Where: CD = the degree of contamination, CF = contamination factor of the individual metal, and n = the number of heavy metals investigated.

RESULTS AND DISCUSSION

The results of analysis of the investigated heavy metals from Kaani River is shown in Tables 2, 3 and 4. It revealed the concentration levels of the trace metals. Figure 1 shows the average change in heavy metal concentrations in the Kaani River's surface water during the dry and rainy seasons

Manganese (Mn)

According to the study, at the river's sampling locations, the mean manganese concentration in the surface water of the Kaani River was 0.0189 mg/l. This result was between the NAFDAC (2007) and WHO (2007) permitted level of 0.05 mg/l for potable water. This result conflicts with that of Dibofori *et al.* (2019) in Woji Creek, Port Harcourt, but it is consistent with that of Ama *et al.* (2017), Abdulhamid *et al.* (2015), Kpee *et al*. (2020), Dibofori-Orji and Marcus (2012), and Edori *et al*. (2020).

In natural settings including soil, silt, and water, manganese is a plentiful metal. There are two types of Mn sources in water: natural and man-made. As the river runs its course, boulders are swept along and release manganese into the water. Additional sources include soil

Table 2. Concentrations of heavy metals in water samples taken during the dry season at various stations along the Kaani River.

Heavy metals (Mg/l)	Stations				
	1	2	3	4	Control
Mn	2.374±0.007	0.768±0.001	1.348±0.005	2.069±0.006	0.003±0.000
Cd	0.010±0.000	<0.001±0.000	0.124±0.001	<0.001±0.000	0.000±0.000
Cu	2.972±0.008	1.897±0.003	3.548±0.010	0.694±0.003	0.003±0.000
Cr	2.614±0.007	4.106±0.020	3.418±0.015	3.067±0.011	0.522±0.032
Pb	1.474±0.002	3.291±0.012	2.478±0.009	0.892±0.006	0.031±0.004
Fe	2.694±0.008	1.169±0.005	2.894±0.009	3.248±0.014	0.091±0.002
Zn	5.914±0.017	2.586±0.009	3.321±0.015	4.569±0.016	0.674±0.230
As	1.384±0.006	0.493±0.002	2.167±0.005	1.436±0.003	0.036±0.022
Ni	3.724±0.012	4.691±0.012	2.913±0.007	5.301±0.017	0.853±0.463

<0.001 below detectable limit (BDL).

Table 3. Concentrations of heavy metals in water samples from the Kaani River at several stations during the rainy season.

Heavy metals (Mg/L)	Stations				
	1	2	3	4	Control
Mn	2.174±0.008	0.734±0.002	1.346±0.005	2.049±0.006	0.002±0.001
Cd	0.010±0.000	<0.001±0.000	0.124±0.001	<0.001±0.000	0.000±0.000
Cu	2.272±0.010	1.837±0.007	3.248±0.009	0.674±0.001	0.003±0.001
Cr	2.314±0.008	4.100±0.016	3.118±0.013	3.060±0.009	0.005±0.001
Pb	1.174±0.007	2.291±0.014	2.448±0.011	0.592±0.006	0.005±0.002
Fe	2.601±0.009	1.129±0.001	2.694±0.006	3.144±0.011	0.006±0.002
Zn	5.014±0.225	2.526±0.008	3.021±0.011	4.329±0.201	0.086±0.005
As	1.484±0.002	0.433±0.001	2.117±0.007	1.236±0.008	0.001±0.000
Ni	3.424±0.011	4.592±0.022	2.613±0.009	5.101±0.023	0.042±0.003

<0.001 below detectable limit (BDL).

Table 4. Average heavy metal concentration in water samples from the Kaani River at various sample stations.

Heavy metals (Mg/l)	Stations					
	1	2	3	4	Mean±SD	WHO limit
Mn	0.0274±0.008	0.0075±0.002	0.0347±0.005	0.0059±0.006	0.0189±0.005	0.05
Cd	0.0100±0.000	<0.0010±0.000	0.0124±0.001	<0.0010±0.000	0.0056±0.000	0.03
Cu	2.6220±0.009	1.8670±0.005	0.3980±0.010	0.6840±0.002	1.3928±0.007	2.0
Cr	0.0464±0.008	0.0103±0.018	0.0268±0.014	0.0064±0.010	0.0225±0.013	0.05
Pb	0.0032±0.005	0.0079±0.013	0.0046±0.010	0.0074±0.006	0.0058±0.009	0.01
Fe	0.6480±0.009	1.1480±0.003	0.7940±0.008	0.0196±0.013	0.6524±0.008	0.3
Zn	0.4640±0.121	0.5560±0.009	0.1710±0.013	0.4490±0.109	0.4100±0.063	5.0
As	0.0043±0.004	0.0046±0.002	0.0014±0.005	0.0036±0.002	0.0035±0.003	0.01
Ni	0.0574±0.012	0.0642±0.017	0.0630±0.008	0.0201±0.020	0.0512±0.014	0.15

<0.001 below detectable limit (BDL).

weathering, flow into rivers, and discharges of home and commercial wastewater (Nádaská *et al*., 2010).

Cadmium (Cd)

The study found that at the river's sampling locations, the average cadmium concentration in the surface water of the Kaani River was 0.0056 mg/l. This amount fell within the 0.03 mg/l maximum that NAFDAC (2007) and WHO (2007) permitted for portable water. This result conflicts with that of Dibofori *et al*. (2019) in Woji Creek, Port Harcourt, but it is consistent with that of Ama *et al.* (2017), Abdulhamid *et*

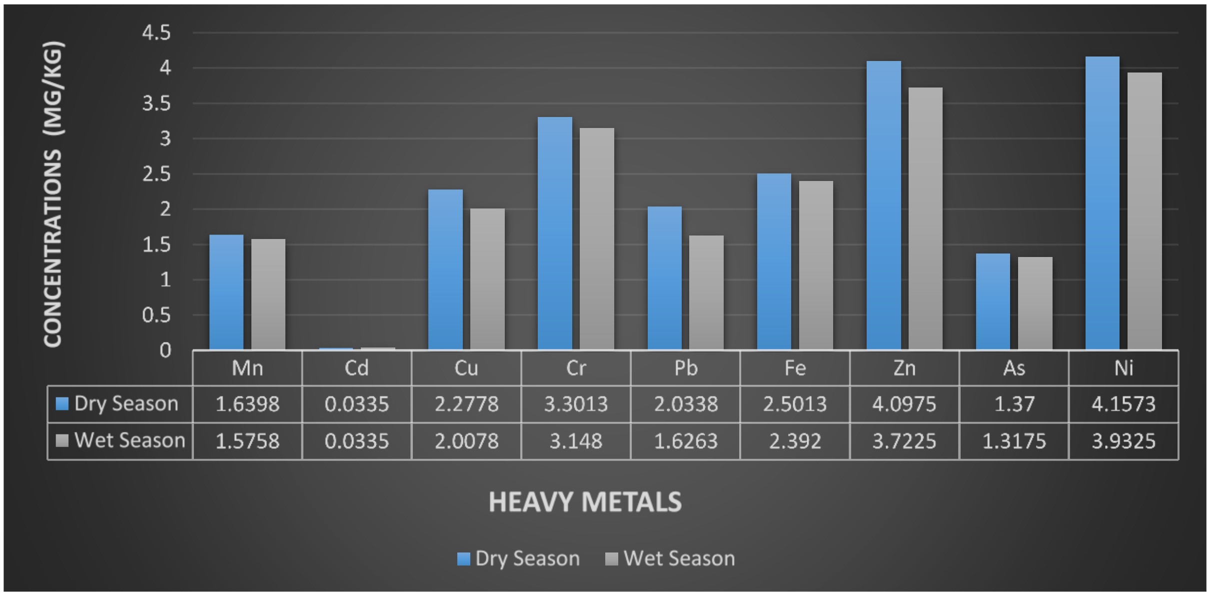

Figure 1. Average change in heavy metal concentrations in the Kaani River's surface water during the dry and rainy seasons.

al. (2015), Kpee *et al*. (2020), Dibofori-Orji and Marcus (2012), and Edori *et al*. (2020). The tendency of Cd to infect essential amino acids and accumulate in very high quantities in proximal tubular cells in human, animal, or plant tissue results in brittle bones and changes in the shape and structure of the kidney and lung. High levels of Cd can cause premature births in pregnant women, liver dysfunction, and a decrease in the weight of newborns (Asonye *et al*., 2007). Procreative disorders, behavior, cardiac and vascular neurology, hematological and kidney dysfunction, injury to hepatocytes and other essential bodily organs, and other medical disorders are also linked to consumption of Cd (Tirkey *et al*., 2012; Sutherland *et al*., 2000).

Copper (Cu)

According to the study, the average copper concentration in the Kaani River's surface water at the river's sampling locations was 1.3928 mg/l. This result was less than the 2.0 mg/l maximum that NAFDAC (2007) and WHO (2007) permitted for portable water. This result conflicts with those of Dibofori *et al.* (2019) in Woji Creek, Port Harcourt, but it supports the findings of Ama *et al.* (2017), Abdulhamid *et al*. (2015), Kpee *et al*. (2020), Dibofori-Orji and Marcus (2012), and Edori *et al.* (2020). Cu is a well-known essential mineral required for efficient cell breakdown and synthesis, but high concentrations in food and water can lead to dejection, necrosis in renal and hepatic cells, and exacerbation of the nervous system (Tepe, 2014). Cu helps animals and systems maintain efficient metabolic processes. Its presence in the human body also prevents certain diseases that interfere with DNA functions in humans (Damek and Sawicka, 2003). These diseases can cause damage to the heart muscle, myelination of the spinal cord, skin discolorations, abnormal bone and connective tissue formation, and skin spots. A deficiency of copper in faunae can have negative effects on the central nervous system (CNS), hepatocytes, renal nerves, tissue enzymes, and blood vessels. Cu can, however, be overindulged in and retained in the human body (Rajappa *et al*., 2010). This is due to the fact that elevated Cu concentrations impede enzyme function, resulting in anemia, and dilute blood. Peptides, aldolases, alkaline phosphodiesterase, lipase adenosine triphosphate, and aminoacyl RNA are among the enzymes in the human body that are impacted by excess Cu (Hossain *et al*., 2020; Owens, 1981).

Chromium (Cr)

The study found that at the river's sampling locations, the average concentration of chromium in the surface water of the Kaani River was 0.0225 mg/l. This amount was less than the 0.05 mg/l maximum that NAFDAC (2007) and WHO (2007) permitted for portable water. This result conflicts with that of Dibofori-Orji *et al.* (2019) in Woji Creek, Port Harcourt, but it is consistent with that of Ama *et al*. (2017), Abdulhamid et al. (2015), Kpee *et al*. (2020), Dibofori-Orji and Marcus (2012), and Edori *et al*. (2020). When the Cr levels in the river were compared to those in previous studies conducted in comparable environments, they were found to be lower than those in other rivers in Nigeria's Niger Delta (Adelekan and Alawode, 2011). It has been determined that chromium (Cr) causes a variety of hematological issues in fish. Reduced serum hemoglobin, erythrocyte count, and thrombocyte count are among the effects. Additional ones include the breakdown of glycogen, lipids, sterols, and proteins (Kaizer and Osakwe, 2010)). Even though chromium (Cr) is a micronutrient that is vital to all living things, including plants and animals, it can be harmful to the environment if it is present in large enough quantities to exceed recommended levels (Waziri *et al*., 2009). The concentration of Cr in the environment has not been significantly increased by anthropogenic activities; these activities have only affected the geologic compositions of rocks where human interference may have occurred and the extraction processes where Cr deposits are located. At high quantities, chromium (Cr) disturbs fish physiology and behavior, yet most of the time it does not result in fish death. Effluents from quarrying and manufacturing operations are likely to have an impact on any environment with high values (Ekpete *et al*., 2019).

Lead (Pb)

According to the study, the average lead concentration in the Kaani River's surface water at the river's sampling locations was 0.0058 mg/l. This figure was between the NAFDAC (2007) and WHO (2007) permitted limit of 0.01 mg/l for potable water. This research supports the findings of Dibofori-Orji and Marcus (2012), Edori *et al.* (2020), Kpee *et al.* (2020), Ama *et al.* (2017), Abdulhamid *et al*. (2015), and Dibofori-Orji *et al*. (2012), but it disagrees with Dibofori-Orji *et al*. (2019) in Woji Creek, Port Harcourt. The amounts of lead (Pb) in this work are less than those reported by Odoemelam *et al*. (2019), but they are still within the range reported in related investigations by Haxhibeqiri *et al*. (2015). In human systems, lead (Pb) is a hazardous metal. when ingested causes changes in various cell pathways, such as those that control the body's transportation of electrolytes, the bonding of cells, the release of information by neurons, the transmission of information within and between cells, the compactness of protein cells, the time at which cells mature, and the regulation of the efficiency of enzymes (Vershima *et al*., 2015). High Pb exposure in humans can cause long-term neuronal death in infants and children (Elinge *et al*., 2012). Lead (Pb) is solely recognized for its detrimental effects on biological organisms' metabolism in their environment (Adebanjo and Adedeji, 2019). Pb is found in the environment as a result of both natural and human-caused sources, but mostly from human-engineered sources (Marcus and Edori, 2016). Fossil fuels, elastic tools, batteries, paints and coatings, amalgams, pesticides, particle emission inhibition devices, polyvinyl chloride conduits, cable concealments, and other materials are some of the human sources of lead (Pb) (Benson *et al*. 2016).

Iron (Fe)

The study found that at the river's sampling locations, the average iron concentration in the surface water of the Kaani River was 0.6524 mg/l. This number was far higher than the 0.3 mg/l NAFDAC (2007) and WHO (2007) allowable limit for portable water. Therefore, to lessen the connected effects of excessive pollution in the aquatic medium, responsible government bodies must intervene. These results support those of Ama *et al.* (2017), Dibofori-Orji and Marcus (2012), Kpee *et al.* (2020), Abdulhamid *et al*. (2015), Edori *et al.* (2020), and Dibofori-Orji *et al*. (2019) in Woji Creek. These are most likely caused by large amounts of industrial effluents that are released into the riverbed. Iron (Fe) is essential for several natural metabolic processes in humans. Fe is toxic to humans if it is found in large enough concentrations in the tissues and organs, even if it helps certain enzyme activities in plants and animals (Benson *et al*. 2016). According to Vosyliene and Jankaite (2006), iron (Fe) damages fish gills and decreases oxygen intake when it is present in water as Fe^{3+} oxide (Buck, 1978), therefore interfering with the fish's normal respiratory processes. Because of its hemolytic properties, iron (Fe) helps mammals transport oxygen throughout their bodies. Additionally, it aids in the biomolecules that are extremely helpful in supporting the various blood processes. The two species of iron in water are Fe^{2+} and Fe^{3+}, and they differ in strength, stability, and solubility. As a result, the rate at which these elements are absorbed into various biotic organism tissues is determined by these three characteristics as well as other favorable environmental conditions, according to (Mesıas *et al*., 2013) and (Nambatingar *et al*., 2017).

Zinc (Zn)

According to the research, the Kaani River's surface water had an average zinc concentration of 0.4100 mg/l at the river's sampling locations. This figure fell between the 5.0 mg/l that NAFDAC (2007) and WHO (2007) approved for potable water. The present study's results are consistent with those of Ama *et al*. (2017), Abdulhamid *et al.* (2015), Kpee *et al*. (2020), Dibofori-Orji and Marcus (2012), and Edori *et al.* (2020), however, they differ from the findings of Dibofori-Orji *et al.* (2019) published in Woji Creek, Port Harcourt. Zinc is an essential element in the human system due to its various metabolic and biochemical functions in bodily tissues and cell division. However, these effects are transient, intestinal irritation, queasiness, depression, illness, and coughing may result from the presence of concentrated Zn values (Hogstrand and Haux, 1991). While there isn't any scientific or experimental evidence of any physiological issues resulting from zinc absorption at values greater than 5 mg/L, zinc is known to provide a bitter taste in water and increase opacity, particularly in home water with an alkaline pH (Edori and Marcus, 2017). Runoffs, washing of the soil's surface by the sea, and Zn-containing riverbanks are some of the sources of Zn input or discharge into rivers. It modifies the way that other significant trace metals are distributed by the liver in fish kept in contaminated water environments. If detected as a deficiency in the human system, it may lead to hypogonadism, which is linked to impaired reproductive capacity, developmental hindrance, dermatitis, anorexia, and delayed wound healing (Hanser and Marrion, 2009).

Arsenic (As)

At the river's sampling locations, the study found that the average amount of arsenic in the surface water of the Kaani River was 0.0035 mg/l. This concentration was less than the 0.01 mg/l portable water acceptable level set by NAFDAC (2007) and WHO (2007). In Woji Creek, Port Harcourt, this conclusion differs from that of Dibofori-Orji *et al.* (2019), but it is consistent with that of Ama *et al.* (2017), Abdulhamid *et al.* (2015), Kpee *et al.* (2020), Dibofori-Orji and Marcus (2012), and Edori *et al*. (2020). Arsenic exposure in the aquatic environment causes bioaccumulation in aquatic organisms and can lead to diseases of the body's physiology and metabolism, including poisoning, liver damage, reduced fertility, and cell death. Both short- and long-term effects are caused by arsenic compounds in populations and communities of organisms as well as in individual plants and animals. In aquatic animals, for instance, these effects are noticeable at concentrations ranging from a few micrograms to milligrams per litre (Nambatingar *et al*. 2017).

Nickel (Ni)

The investigation showed that at the river's sampling locations, the average nickel concentration in the surface water of the Kaani River was 0.0512 mg/l. According to NAFDAC (2007) and WHO (2007), the permitted level for portable water was 0.15 mg/l. This result conflicts with that of Dibofori-Orji *et al*. (2019) in Woji Creek, Port Harcourt, but it is consistent with that of Ama *et al.* (2017), Abdulhamid *et al.* (2015), Kpee *et al.* (2020), Dibofori-Orji and Marcus (2012), and Edori *et al*. (2020). The current study's reported Ni concentrations are lower than those found in the New Calabar River by Nwineewii *et al*. (2019) and in Silver River, Bayelsa State, Nigeria, by Ekpete *et al*. (2019). As colorants and catalysts in various chemical processes, nickel compounds are highly valuable to the battery manufacturing and battery production industries. In laboratory test animals, high levels of Ni intake can result in a fatal lung infection and have varying physiological effects (Ashraj, 2005). It is likely to facilitate dying in settings where breathing is becoming more difficult and reducing the amount of gases entering and leaving the lungs. Due to Ni dust from the production process, those in the metallurgical industries are particularly vulnerable to Ni damage during extended periods of employment. Ni equivalents in human exposures have been regulated to not surpass 0.05 mg/cm³ over 40 hours each week. Ni dust and its constituents are thought to be carcinogenic (Sutherland *et al*., 2000). The order of concentrations of the investigated heavy metals in the surface water sample was Cu > Fe > Zn > Ni > Cr > Mn > Pb > Cd > As.

Water pollution indices for determining heavy metal pollution

Contamination factor

Table 5 displays the heavy metal contamination factor for the River. According to Lacatusu (2000) proposed intervals of contamination (Table 6), the contamination data from the various Kaani River stations when compared with the intervals of classification as shown in Table 7, indicated that the water samples were slightly contaminated in stations 1 and 2, moderately contaminated in station 4, and severely contaminated in station 3 with Mn. In stations 1, 2, and 4, the samples were essentially Hg-free, however in station 3, there is very little contamination. The results of the Cd measurements at each station showed that there was no contamination at number one, but there was moderate contamination at number two and minor contamination at numbers three and four. Pb levels revealed negligible contamination at station 2, moderate contamination at station 4, and little contamination at stations 1 and 3. The results for Cu and Zn in all four sites (1-4) demonstrated that there was essentially no Cu and Zn pollution in the water. The examination of the Ni values found in the water samples from the various stations (1-4) revealed moderate Ni contamination in the samples. According to the analysis of the Fe values found in the tested water samples, station 3 was found to be completely free of pollution, while stations 1, 2, and 4 had very mild levels of Fe contamination. The values obtained for Cr showed that station 4 was non-contaminated, station 2 was somewhat contaminated, and stations 1 and 3 were moderately contaminated (Table 8).

Water samples' pollution index, contamination degree, and modified contamination degree

Table 5 displays the degrees of contamination, pollution index, and modified degree of contamination of the water from the various Kaani River stations. When the pollution

Table 5. Contamination Factor (Cf), Pollution Load Index (PLI), Contamination Degree (Cd) and Modified Contamination Degree (mCd) analysis of heavy metals contamination of water samples from Different Stations in Kaani River.

Heavy metals	Stations			
	1	2	3	4
Mn	0.5480	0.1500	0.6970	0.1180
Cd	0.3330	NA	0.4133	NA
Cu	1.3110	0.9335	0.1990	0.3420
Cr	0.9280	0.2060	0.5360	0.1820
Pb	0.3200	0.7900	0.4600	0.7400
Fe	2.1660	3.8267	2.6467	0.0653
Zn	0.0928	0.1112	0.0342	0.0898
As	0.4300	0.4600	0.1400	0.3600
Ni	0.3827	0.4280	0.4200	0.1340
PLI	0.5459	0.5347	0.3294	0.2622
CD	6.5115	6.9054	5.7462	2.0311
mCd	0.6512	0.6905	0.5746	0.2031

Table 6. The importance and intervals of the pollution/ contamination index.

CF/PI	Significance
<0.1	Very slight contamination
0.10-0.25	Slight contamination
0.26-0.5	Moderate contamination
0.51-0.75	Severe contamination

Adapted from Lacatusu (2000).

Table 7. Interpretation of the contamination degree intervals (Cd).

Classification of Cd	Contamination Level
Cd < 8	Low contamination degree
8 ≤ Cd < 16	Moderate contamination degree
16 ≤ Cd < 32	Considerable contamination degree
Cd > 32	Very high contamination degree

Adapted from Hakanson (1980).

Table 8. Categorization and explanation of mCd.

Classification	Description/interpretation
mCd < 1.5	Nil to very low degree of contamination
1.5 ≤ mCd < 2	Low degree of contamination
2 ≤ mCd < 4	Moderate degree of contamination
4 ≤ mCd <8	High degree of contamination
8 ≤ mCd < 16	Very high degree of contamination
16 ≤ mCd < 32	Extremely high degree of contamination
mCd ≤ 32	Ultra-high degree of contamination

Adapted from Hakanson (1980).

index findings from the stations were compared to the intervals of pollution index evaluation suggested by Zhang *et al.* (2011), they showed that none of the stations had heavy metal pollution. This is because every result falls into the category of (0 < PLI ≤ 1), which denotes a heavy metal-free, unpolluted environment. Based on Hakanson's recommended contamination degree evaluation, the findings of heavy metal analysis in water samples showed that, in the Kaani River, stations 1, 2, and 4 demonstrated low levels of pollution, whereas station 3 showed moderate levels of contamination. All of the values gathered from the various stations examined fall into the range of zero to extremely low degree of contamination (mCD < 1.5), according to the Hakanson (1980) classification for the interpretation and description of modified contamination degree (Table 8).

Conclusion

The measured results showed that some of the metals in the water were contaminated above safe consumption levels. Consequently, not much treatment is needed for the water to be suitable for human consumption. There were minor variations in both space and time, as evidenced by the heavy metal concentrations in the river. In order to restore the water's usability to its original state, it is pertinent that adequate awareness from private and government agencies and remedial efforts be implemented so as to protect the integrity of the ecosystem.

Recommendation

It is recommended that adequate monitoring of the River and education of the rural population be implemented to enhance the portability of the River and the integrity of the aquatic body.

CONFLICT OF INTEREST

The authors declare the they have no conflict of interest.

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