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Research Article

Anthropogenicity, Potential Contamination Index (Cp) and Geo-Accumulation Index (I-geo) Analysis of Sediments of Kaani River, Ogoni Axis, Rivers State, South-South, Nigeria

Anate Sumaila Ganiyu*, Abule Esther Chinyere

Department of Chemistry, Faculty of Natural and Applied Sciences, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Nigeria

Abstract

Modifications in the natural state of the environment brought about by human activity have resulted in pollution or contamination at various degrees. Because of their toxicity and tendency to accumulate, heavy metals are extremely important to the environment. It is critical that their quantities in the marine ecosystem of our surroundings be monitored. Anthropogenicity, possible contamination, and geo-accumulation index were assessed using sediment samples taken from four (4) distinct geographic locations along the Kaani River in the Ogoni axis of Rivers State, Nigeria, in accordance with international standards. Atomic Absorption Spectrophotometric technique (AAS) was used to determine the heavy metal content of the sediments. The sequence of the heavy metal concentrations, according to the analysis's findings, was Fe > Zn > Mn > Cu > Cd > Pb > As. According to the recorded data, Zn > Ni > Cu > Cd > Pb > Cr > As > Mn > Fe was the order of anthropogenic influence or addition of the heavy metals under investigation to the sediments. According to the percentage values, Zn had the largest anthropogenic input in the Kaani River sediments, followed by Ni and Cu. Fe > Zn > Ni > Cu > Cd > Pb > Cr > As > Mn is the order in which the potential contamination index analysis is presented. Sediment heavy metals from Maa di binnise Igbara waterside (station 1), Mann Stream (station 2), Woman Stream (station 3), and Nwii ke ma kor stream (station 4) were found to be extremely contaminated with Zn, slightly contaminated with Cu and Cd (at some stations), and uncontaminated with Fe, Mn, Pb, and As according to Geo-accumulation index values. Even at low concentrations, these observations unequivocally point to an imbalanced state in the ecosystem. In order to restore the aquatic ecosystem's integrity and sufficiently safeguard the quality of its sediment, a controlled effort must be made to limit the detrimental effects of these trace elements.

Keywords

Ecosystem, Potential, Sediments, Heavy Metals, Contamination

1. Introduction

The primary cause of pollution in a given environment is human activity over the background concentration of natural materials. Any ecological environment, whether aquatic or terrestrial, that contains environmental toxicants or pollutants

*Corresponding author: anatesumga24@gmail.com (Anate Sumaila Ganiyu)

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degrades both the quality of the environment and the suitability of the environment for natural inhabitants (plants and animals) in that area [14, 9]. The issue of heavy metal pollution in aquatic habitats has received a lot of attention globally. This is due to its toxicity as well as its environmental persistence and abundance [10]. The concentration or abundance of heavy metals in the environment is influenced by both natural and human influences [13]. The environment now contains higher concentrations of organic pollutants and heavy metals due to the rapid growth of industry and population migration to urban areas [22]. According to studies on public health and aquatic habitats, heavy metals constitute significant pollution intermediates [12]. This is because, in addition to their ability to cause certain illness problems, they can become immobile when released and settle on sediment, depending on the environmental circumstances at the time [17]. There are instances where trace amounts of heavy metals are discovered. Through re-suspension, absorption, precipitation, and co-precipitation with other elements in the form of oxides and hydroxides [17, 3], as well as complicated formation reactions, they can get trapped within the sediment. Because they do not biodegrade, heavy metals can accumulate throughout the food chain.

Heavy metal exposure has been linked to a number of illnesses in humans, animals, and plants, particularly when the metals are present in high quantities [21]. Enough protection of the aquatic system's sediment quality is necessary for the correct monitoring and restoration of any body of water. This will contribute to the preservation of wildlife, aquatic life, and human health [11]. In aquatic systems, sediment is recognized as the last sink for contaminants and as a crucial component of the aquatic environment. For numerous aquatic plants and animals, it functions as a home, a food source, a spawning site, and a place to raise their young [11].

In order to investigate the anthropogenic influence, possible pollution, and geo-accumulation index of sediments in the Kaani River of the Ogoni Axis of Rivers State, Niger Delta, Nigeria, this study was conducted.

2. Experimental Section

2.1. Description of Study Area

A local freshwater river in Kaani, the Ogoni axis of Rivers state, served as the study's site. In the Khana Local Government Area, South-South, Nigeria, Kaani is a 1,050 square kilometer plot of land situated in the southeast senatorial district of Rivers state. Estranged east of Port Harcourt, the region is situated in Rivers State on the Gulf of Guinea coast. It crosses a large portion of Nigeria's Niger Delta region as well as the Khana Local Government Area.

The Kaani settlement is encircled by nearby host communities, including Kor, Kpong, and Yeghe towns, whose residents mostly work as fishermen, sand drillers, and engage in illicit petroleum exploration and exploitation (often referred to as "kpoo fire") for financial gain. The Kaani village is situated at latitude 1.50740S of the equator and longitude 37.37070E of the Prime Meridian, with a relatively humid environment. With a latitude of 4.69200N and a longitude of 7.35270E, the river's GPS data indicates that it is primarily a forest with patches of mosaic grassland and shrub land. The city has an estimated population of 985,860 people as of 2016) [5]. The region experiences tropical monsoon climates during the short dry season. Largely farming and small- and medium-sized business ownership are among the community's occupations. Products of illegal refined petroleum products bunkering activities are sold in the town, despite the absence of any mention of a multinational oil firm. Boat transportation, open defecation, sand dredging, illicit oil enterprises, timber markets, home waste disposal, drainage system effluent disposal, and fabric washing in the water shed are just a few of the human activities that occur in the area. Due to the environmental imbalance they have caused in the ecosystem, these have adversely affected and disturbed the river's natural state and have consequently affected regular human activities that were previously carried out.

2.2. Sampling Methods

Using a grab sampler, samples were taken from the bottom silt during low tide. The samples were taken from four different places at a depth of 10 cm. Three samples were collected from a given area and combined to create an aggregate sample. Six sample collections were made during the sampling year (2022) at intervals of two months. The sediment samples were put in ice-packed containers as soon as possible after being quickly transferred into plastic polythene bags. The samples were moved right away to be stored in the Ignatius Ajuru University of Education's Department of Chemistry Laboratory in Port Harcourt, Rivers State, Nigeria.

2.3. Sample Preparation

Before being weighed, the gathered sediment samples were air-dried to a consistent weight [18]. Using a pestle and a ceramic mortar, the previously dried samples were ground into a powder without shattering the stones and pebbles. Before being ground, the veggies, stones, and pebbles were carefully chosen and disposed of. A polypropylene mesh measuring 0.2 mm was used to sift the grounded samples. 25 cm^3 of deionized water were added to a ceramic crucible containing 5 g of the ground-up sediment samples. Ten milliliters of a concentrated acid combination containing HNO_3, HCl, and H_2SO_4 in a 5:3:2 ratios were used to digest the samples [17]. The samples were then cooked in a steam bath until a clear hue was achieved. After letting the mixture cool, Whatman size 2 filter paper was used to filter the contents into sample vials. After adding deionized water to make up to 25 milliliters of filtrate, it was frozen at -4°C for a whole day before being sent to the lab for metals analysis.

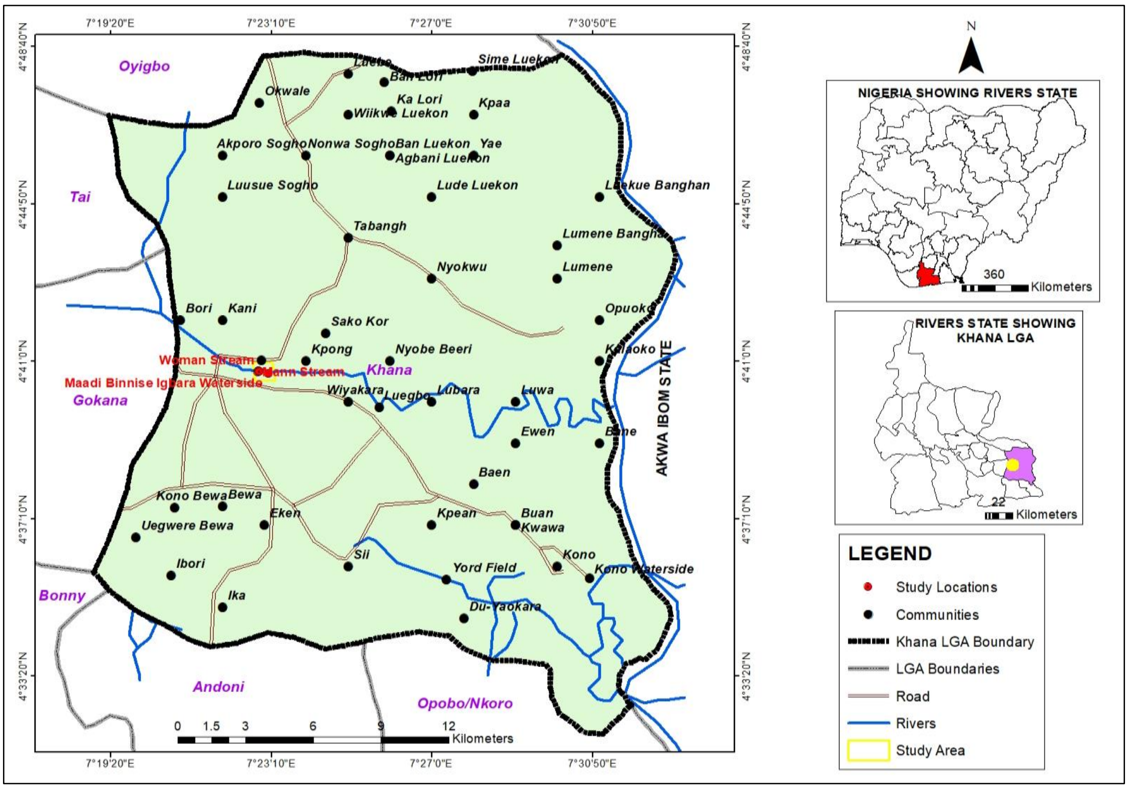

Figure 1. Khana LGA showing the Study Locations.

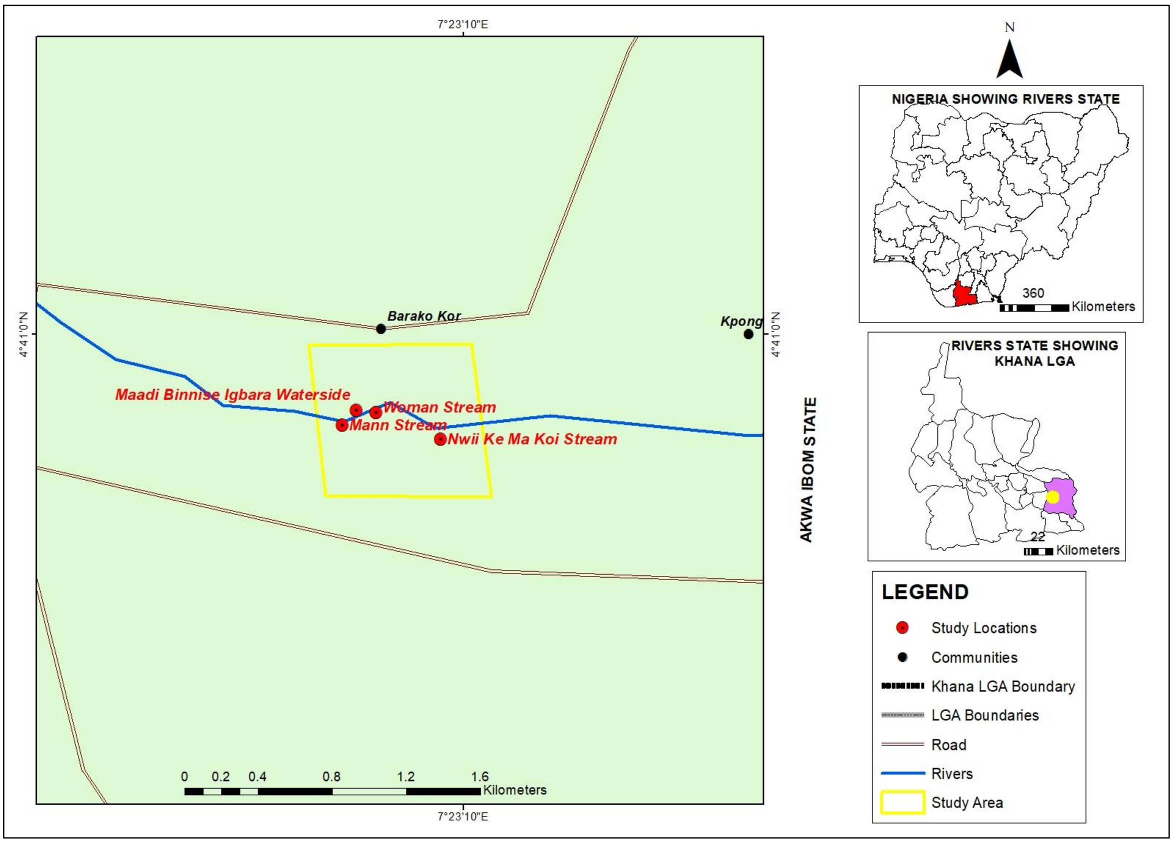

Figure 2. Expanded Study Area and Sampling Locations in Khana LGA.

2.4. Laboratory Analysis of Heavy Metals

With the help of an atomic absorption spectrophotometer (AAS) type SE-71906, UK, heavy metal analysis was performed on the digests. AAS technique makes use of the atomic absorption spectrum of a sample in order to assess the concentration of specific analyte within the sample. It requires using a standard with known analyte concentration to establish the relation between the measured absorbed absorbance and the analyte concentration and relies therefore on the Beer-Lambert Law. Digestion/preparation of the sample and estimation of heavy metals were carried out based on standard methods. The data was further validated using the methodology outlined by Marcus and Edori (2016) [17]. After then, the data were expressed as mean ± SD.

2.5. Model Assessment

In order to establish the degree of contamination or pollution in the sediment as well as its sources, various evaluation models were employed to analyze the concentration of heavy metals in the sediment.

2.5.1. Anthropogenicity

This represents a percentage-based direct measurement of the impact of humans on the level of heavy metals. Lacatusu (2000) [16] provided the mathematical formula used to calculate Anthropogenicity as,

$$APn\% = [\mu/Bn] \times 100$$

Where, μ is the metal concentration and Bn is the background value of the metal.

The Directorate of Petroleum Resources (DPR), (2002) [6], provided background values as target values, measured in mg/kg, which were utilized in this work's computation of the Anthropogenicity of the heavy metals. Target values: Fe = 38,000, Pb = 85, Cu = 36, Zn = 140, Cd = 0.80, Cr = 100, Ni = 35, Mn = 850, and As = 13 are the values employed for the heavy metals under investigation.

2.5.2. Potential Contamination Index

The Dauvalter and Rognerud (2001) [4] equation was used to calculated the Potential contamination index Cp as,

$$Cp = \frac{\text{(Metal) sample Max.}}{\text{(Metal) Background}}$$

Where (Metal) sample Max is the maximum concentration of a metal in sediment, and (Metal) Background is the average value of the same metal in the background level.

2.5.3. Geo-accumulation Index

The I-geo was determined using the Muller (1981) [19] equation, which is I-geo = log 2 (Cn /1.5 Bn). Where Bn = geochemical background concentration in shale (represented in this case by DPR (2002) [6] values for Nigeria) and Cn = measured concentration of heavy metal. Because of the potential for background changes brought forth by lithological variances, the number 1.5 was created. Based on the seven classes of the geo-accumulation index [19] presented in Table 4, the interpretation of the collected data was discussed.

3. Results and Discussion

Table 1. *Anthropogenicity of Heavy Metals contamination of Sediment samples from different stations of Kaani River.*

Heavy metals (%)	Stations			
	1	2	3	4
Mn	0.63	0.43	0.51	0.31
Cd	NA	15.75	NA	8.63
Cu	17.09	17.12	12.96	14.39
Cr	5.37	5.38	8.17	6.53
Pb	8.71	8.69	11.15	7.44
Fe	0.36	0.35	0.31	0.29
Zn	11.51	11.51	70.34	10.51
As	2.79	1.51	0.56	0.72
Ni	20.16	12.64	17.84	14.45

NA (Not Available)

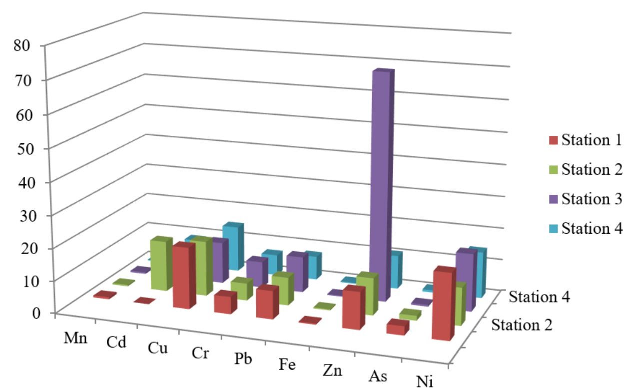

Figure 3. *Heavy Metals contamination of Sediment samples from different stations of Kaani River.*

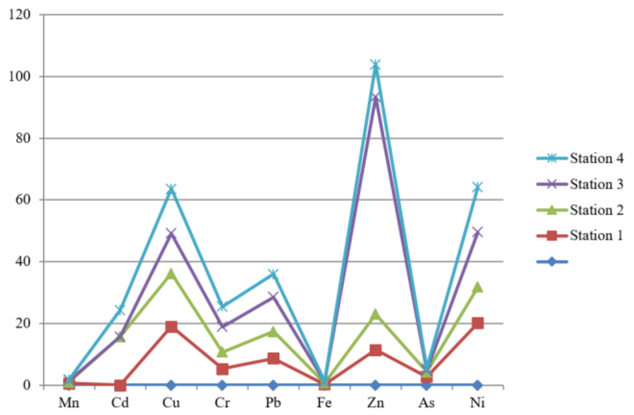

Figure 4. *Heavy Metals contamination of Sediment samples from different stations of Kaani River.*

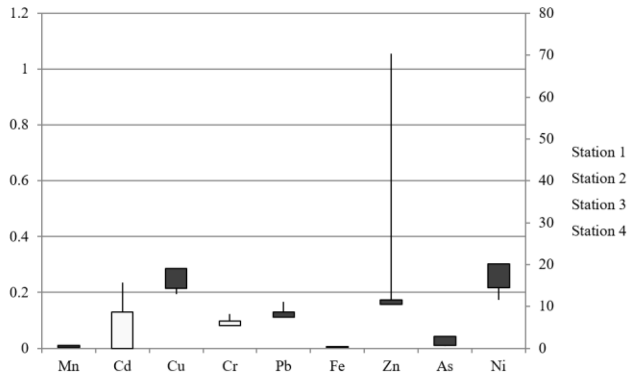

Figure 5. *Heavy Metals contamination of Sediment samples from different stations of Kaani River.*

Table 1, Figures 3, 4 and 5 presents the Anthropogenicity data for the river under study. The acquired results were as follows: Mn: 0.3100-0.6300%; Cd: NA-15.7500%; Cu: 12.9600-17.1200%; Cr: 5.3700-8.1700%; Pb: 7.4400-11.1500%; Fe: 0.2900-0.3600%; Zn: 10.5100-70.3400%; As: 0.5600-2.7900%; Ni: 12.6400-20.1600%. Zn > Ni > Cu > Cd > Pb > Cr > As > Mn > Fe was the order of anthropogenic influence or contribution of the heavy metals under investigation to the sediments. Station 3 has the highest anthropogenic Zn input (70.34%), followed by station 1's (20.16%) and station 2's (17.12%) and station 4's (14.45%) anthropogenic Ni input. The findings of this study demonstrated that adding untreated waste and effluents to bodies of water is one way that humans alter the aquatic ecology by adding more zinc. These results are consistent with those of Nwineewii and Edem (2014) [20], who found that the concentration of the anthropogenic metal in the river under study was identical.

The result recorded for the concentration of heavy metals in sediment samples from Kaani River at the different stations is presented in Table 2 and Figure 6. The concentration of Mn within the year lie within the range of 2.648±0.011 to 5.362±0.054 mg/kg within the stations with a mean value of 4.000 ± 0.021 mg/kg; Cd lie within the range of 0.000±0.000 to 0.126±0.000 mg/kg within the stations with a mean value of 0.049±0.002 mg/kg; Cu lie within the range of 4.666± 0.010 to 6.154±0.014 mg/kg within the stations with a mean value of 5.541±0.071 mg/kg; Cr lie within the range of 5.372±0.217 to 8.166±0.018 mg/kg within the stations with a mean value of 6.361± 0.074 mg/kg; Pb lie within the range of 6.327±0.046 to 9.474±0.198 mg/kg within the stations with a mean value of 7.647±0.081 mg/kg; Fe lie within the range of 111.614±2.278 to 137.348±3.226 mg/kg within the stations with a mean value of 124.981±2.673 mg/kg; Zn lie within the range of 14.707±0.106 to 98.481±5.619 mg/kg within the stations with a mean value of 36.356±1.593 mg/kg; As lie within the range of 0.073±0.004 to 0.363±0.001 mg/kg within the stations with a mean value of 0.182±0.002 mg/kg and Ni lie within the range of 4.423±0.003 to 7.212±0.038 mg/kg within the stations with a mean value of 5.734±0.024 mg/kg respectively. This finding shows the level of contamination of the sediments from different stations of the study location at various levels of concentration as a result of the anthropogenic activities of the region, which is in agreement with the study conducted by Issa et al. (2011) [11] and Ibrahim et al. (2016) [9].

Table 2. *Concentration of Heavy Metals in Sediment samples from Kaani River at various stations.*

Heavy metals (Mg/Kg)	Stations				Mean ± SD	DPR Limit	WASV
	1	2	3	4			
Mn	5.362±0.054	3.675±0.007	4.316±0.011	2.648±0.011	4.000 ± 0.021	850	850
Cd	NA	0.126±0.000	0.000±0.001	0.069±0.005	0.049±0.002	0.8	0.3
Cu	6.154±0.014	6.164±0.049	4.666± 0.010	5.179± 0.212	5.541±0.071	36	45
Cr	5.372±0.217	5.377±0.012	8.166±0.018	6.528±0.047	6.361± 0.074	100	90
Pb	7.403±0.053	7.383±0.028	9.474±0.198	6.327±0.046	7.647±0.081	85	20
Fe	137.348±3.226	132.348±2.505	118.613±2.683	111.614±2.278	124.981±2.673	38T	47T

Heavy metals (Mg/Kg)	Stations				Mean ± SD	DPR Limit	WASV
	1	2	3	4			
Zn	16.118±0.356	16.118±0.291	98.481±5.619	14.707±0.106	36.356±1.593	140	120
As	0.363±0.001	0.196±0.001	0.073±0.004	0.094±0.003	0.182±0.002	13	10
Ni	7.212±0.038	4.423±0.003	6.243±0.019	5.056±0.034	5.734±0.024	35	68

WASV-World Average Shale value of sediment (Turkian and Wedpohl, 1961) [23].
DPR- Department of petroleum Resources (2002) [6]
NA (Not Available)

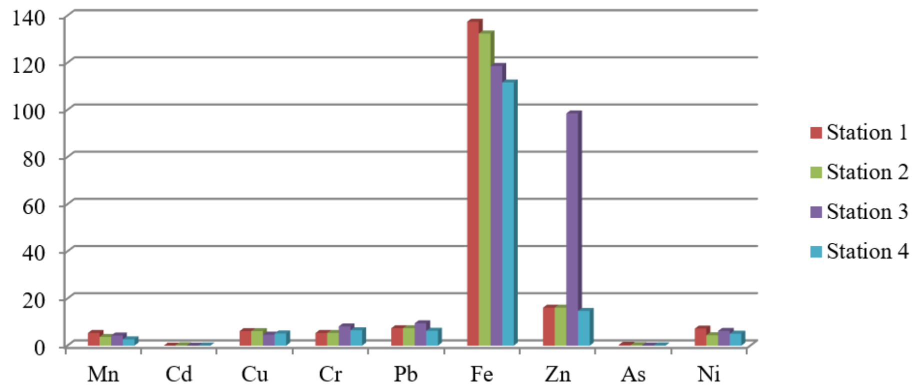

Figure 6. *Concentration of Heavy Metals in Sediment samples from Kaani River at various stations.*

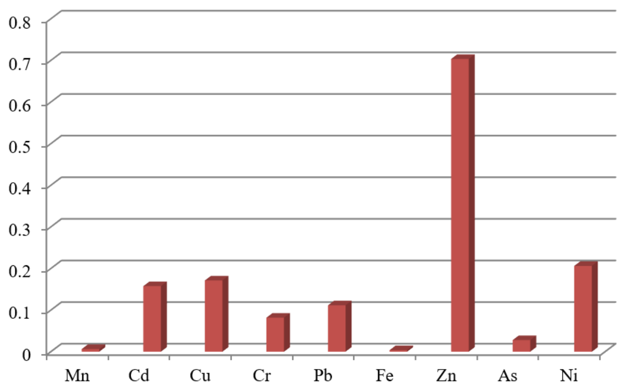

Figure 7. *Metals Potential Contamination Index (Cp) in Sediment samples from Kaani River Stations.*

Table 3. *The Heavy Metals Potential Contamination Index (Cp) in Sediment samples from Kaani River Stations.*

Heavy Metal	Potential Contamination index (Cp)
Mn	0.0063
Cd	0.1575
Cu	0.1712
Cr	0.0817
Pb	0.1115
Fe	0.0036
Zn	0.7034
As	0.0279
Ni	0.2061

Table 3 and Figure 7 displays the finding for the probable contamination index Cp. Manganese (Mn) had a potential contamination index of 0.0063, while the values for Cd, Cu, Cr, Pb, Fe, Zn, and As were 0.1575, 0.1712, 0.0817, 3.6144, and 0.2061, respectively, according to the results of analysis from various stations. Zn > Ni > Cu > Cd > Pb > Cr > As > Mn is the sequence in which the possible contamination index is found. The findings demonstrated that, when compared to the classification intervals provided in Table 4 by Dauvalter & Rognerud (2001) [4], the index value of the heavy metals in sediment samples is low contaminated with all of the heavy metals investigated because the values obtained fall into the Cp < 1 category, which denotes low contamination. These results support those of Kpee et al. (2020)

[15] from Nta-wogba River sediments in the Niger Delta and those of Marcus and Edori (2016) [17] from the Bomu River in the Niger Delta. Therefore, there is little to no impact of the observed human activities in the water body on the sediments that were sampled from the River. Because of the water's continuous flow, particularly during the rainy season, the contaminants were unable to settle or be absorbed by the sediments.

Table 4. Interpretation of Potential Contamination Index (Cp) intervals.

Classification of Cp	Contamination Level
Cp < 1	Low contamination
1 < Cp < 3	Moderate contamination
Cp > 3	Severe contamination

Table 5. The geo-chemical pollution index's contamination intervals and pollution/contamination interpretation.

Classification	Intervals of contamination	Interpretation
0	I-geo ≤ 0	Practically uncontaminated
1	0 < I-geo < 1	Uncontaminated to moderately contaminated
2	1 < I-geo < 2	Moderately contaminated
3	2 < I-geo < 3	Moderately to heavily contaminated
5	3 < I-geo < 4	Heavily contaminated
6	4 < I-geo < 5	Heavily to extremely contaminated
7	5 < I-geo < 6	Extremely contaminated

Table 6. Heavy Metals Contamination of Sediment samples from various stations in the Kaani River: Analysis of the Geo-accumulation Index.

Heavy metals	Stations			
	1	2	3	4
Mn	0.0013	0.0009	0.0010	0.0006
Cd	NA	0.0843	NA	0.0462
Cu	0.0274	0.0275	0.0208	0.0231
Cr	0.0120	0.0120	0.0182	0.0146
Pb	0.0743	0.0741	0.0951	0.0635
Fe	0.0006	0.0006	0.0005	0.0005
Zn	0.0270	0.0270	0.1647	0.0246
As	0.0073	0.0039	0.0015	0.0019
Ni	0.0213	0.0131	0.0184	0.0149

NA (Not Available)

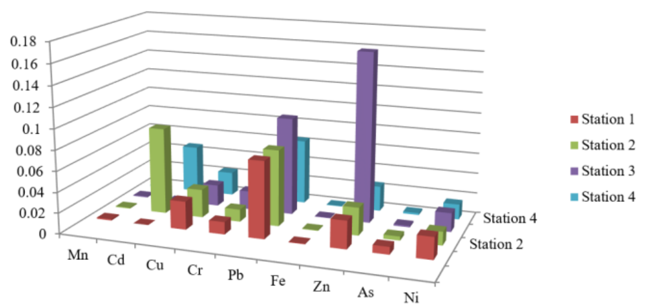

Figure 8. *Heavy Metals Contamination of Sediment samples from various stations in the Kaani River: Analysis of the Geo-accumulation Index.*

Table 6 and Figure 8 presents the findings of the heavy metal contamination of sediment from several sites in the Kaani River using the geo-accumulation index analysis. 0.0006 - 0.0013 for Mn, N/A - 0.0843 for Cd, 0.0208-0.0275 for Cu, 0.0120-0.0182 for Cr, 0.0635-0.0951 for Pb, 0.0005-0.0006 for Fe, 0.0246 -0.1647 for Zn, 0.0015-0.0073 for As, and 0.0131-0.0213 for Ni were among the results that differed. The Kaani River sediments' geo-accumulation index was found to be at the classification level of 0 < I-geo < 1 for every station under investigation. The findings demonstrated that in every station (1-4) under investigation, the sediments were essentially free of metal contamination. When the geo-accumulation assessment results were compared to the virtually uncontaminated sediments from the aquatic environment studied in this work, it became clear that the heavy metal values obtained were solely from background sources, free from interference from anthropogenic activities. These values are different from those found in the sediments of the Asejire Dam in Southwest Nigeria, where the contamination levels were exceptionally high in Fe and moderately high in Pb [2]. Furthermore, Ekpete et al. (2019) [7] found that while Cr was not contaminated in the several tidal creeks in Azuabie, Port Harcourt, Zn, Cd, and Pb were considerably contaminated. According to Ama et al. (2017) [1], sediments from River Nun were only slightly contaminated with Cu and Ni but not with Pb, Cr, Cd, or Zn. Nonetheless, Emoyan et al. (2006) [8] found that heavy metals (Co, Cu, Zn, Mn, and Ni) geo-accumulated similarly in sediment, with the exception of Cd and Pb (which were mildly contaminated) and Fe (which had severe to excessive pollution).

4. Conclusion

The quality or condition of the sediment heavy metals examined in this study was assessed using indicators related to the human (anthropogenic) contribution. The findings of the Anthropogenicity analysis clearly showed that, in the locations under investigation, varying proportions of human activity had disturbed the sediments. The current study's findings demonstrated how human actions, such as the discharge of untreated waste and effluents into bodies of water, increase the amount of zinc in aquatic ecosystems. Human activity in the water body has little to no effect on the sediments that were sampled from the River, according to the detected potential contamination index of the sediment. When compared to geo-accumulation assessment values, the practically uncontaminated nature of the aquatic environment's sediments demonstrated that the heavy metal levels obtained were solely from background sources, free from anthropogenic interference. They were also found to be within the tolerant limit, meaning they currently do not pose a serious risk to human health. However, we are concerned that under the current circumstances, some of these metals—like Pb, As, Cr, and Cd—may eventually find their way into water through the re-suspension process and be readily ingested by aquatic edible animals. This could have a detrimental impact on the food chain. As a result, efforts to address the input sources ought to be made.

Abbreviations

AAS	Atomic Absorption Spectrophotometer
APn%	Percentage Anthropogenicity
Bn	Geochemical Background Concentration in Shale
Cn	Measured Concentration of Heavy Metals
Cp	Contamination Index
DPR	Department of Petroleum Resources
GPS	Global Positioning System
HNO_3	Trioxonitrate (v) Acid
HCl	Hydrochloric Acid
H_2SO_4	Tetraoxosulphate (vi) Acid
I- geo	Geo- Accumulation Index
LGA	Local Government Area
NA	Not Available
SD	Standard Deviation
Wasv	World Average Shale Value of Sediment

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Authors Contributions

Anate Sumaila Ganiyu: Conceptualization, Data curation, Formal Analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing

Abule Esther Chinyere: Funding acquisition, Resources, Software, Validation, Visualization

Data Availability Statement

The data supporting this article have been included as part of the Supplementary Information.

Conflicts of Interest

The authors declare no conflicts of interest.

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