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CONCENTRATIONS OF SELECTED HEAVY METALS AND PHYSICOCHEMICAL PROPERTIES IN FORCADOS RIVER, SAGBAMA LOCAL GOVERNMENT AREA, BAYELSA STATE, NIGERIA

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Abstract
The concentration of selected heavy metals in water collected from eight different locations from the Forcados River in Sagbama Local Government Area of Bayelsa State, Nigeria was determined using AAS and the physicochemical properties were analysed using standard methods. The concentrations of heavy metals obtained in the water samples were in the order Ni> Cr> Zn> Cu> Pb> Cd. The concentrations(mg/l) of physicochemical properties in the water samples ranged from 5.76 to 6.76 for pH, 15.22 to 16.55 for NO_3^-, 146.23 to 206.39 for SO^3_4, 715.62 to 817.66 for EC, 2.31 to 2.31 to 4.20 for TDS and 197.21 to 198. 50 for TOC. The concentrations(mg/l) of heavy metals in the water samples ranged from 2.25 to 4.76 for Pb, 5.77 to 6.90 for Cr, 1.03 to 2.17 for Cd, 2.25 to 3.87 for Cu, 4.09 to 6.15 for Zn and 6.08 to 7.99 for Ni. These results were within or lower than the permissible limits except pH, sulphates, and electrical conductivity. The result recorded for heavy metals were all higher than the permissible limits of WHO and NESREA. The result also indicated that the river water was contaminated/ polluted with heavy metals in the following order Cr >Pb > Ni>Cd. The study indicated that the heavy metals studied do not pose an environmental risk considering their low concentrations. It is recommended among others that all the activities contributing to the increased pollution of the river in the area be brought under control, to keep the environment safe for water organisms and people living in the area who depend on it for their livelihood.

Keywords: Concentrations, Heavy Metals, Physicochemical Properties, Forcados River, Sagbama

Introduction

Several researchers have investigated the concentration of heavy metals in the waters of coastal rivers in Nigeria. Egborge (2001) related the heavy metal pollution of the water of Warri River to the industrialization of Warri Town. Oluwande et al.(2003) reported on the general levels of contamination/pollution in some rivers in Nigeria. The concentrations of heavy metals in the water bodies in Nigerian rivers had been reported to be low by earlier researchers, amongst whom are Obire et al.(2003) on Elechi River, Chindah & Braide (2004) who reported on Bonny River. Fufeyin (2008) investigated heavy metal concentration in some dominant fish in the river and found that the fish species showed higher mean levels, with variable contamination factors and bioaccumulation quotient among stations. The importance of water and other natural resources to plants and animals cannot be overemphasized, taking into its use in various forms of life, which might be domestic, economic and industrial applications (Madvi, (2002), Ekpete, (2002). When water is misused, it constitutes a threat to the continuous maintenance or development and growth of natural aquatic organisms and consequently provides avenues for the aquatic environment destruction of the environment (Herman & Zaslow, 2006). The well-being of humans, which includes health, welfare, food security, industrial development and growth and the ecosystem depends on the availability of water that falls within the requirement for usage, if not, then they are at risk (Montgomery, 2000).

Due to the incessant increase in population growth, which is accompanied by rapid urbanization and industrial activities, discharges of wastes into lands and which subsequently are discharged into the rivers are on the increase.

Aquatic plants and animals are continuously in contact with water, indicating that any change in water quality would affect them directly. Also, the aquatic food is consequent on those organisms which feed and forage in the environment (Luoma, 2009) and thus accumulate heavy metals, PAHs and other pollutants within the environment. The contamination of the aquatic environment with heavy metals is of global concern, because of their nature, bioaccumulation and toxicological problems associated with them (Islam et al., 2015). Heavy metals input into the aquatic environment is a consequence of both natural and anthropogenic activities (Khan et al., 2008), which pollute both water and sediment to levels that will pose adverse health effects to aquatic vertebrates and humans (Islam et al.,, 2015).

Naturally, the concentrations of heavy metals in aquatic media are very small and therefore do not constitute toxicity to the environment, but at very high and undesirable levels, may be hazardous to man and the environment. Heavy metals are important biologically as trace elements but, the toxicity of many of them in human biochemistry is a thing of great concern. The term "heavy metal" refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentrations (Lissy & Madhu, 2010). Heavy metals penetrate the body system of humans in small measures via food, air, and water and accumulate after some time (Athalye et al., 2001). Heavy metals include lead (Pb), cadmium (Cd), zinc (Zn), manganese (Mn), cobalt (Co), nickel (Ni), silver (Ag), arsenic (As), chromium (Cr), copper (Cu), Iron (Fe) and (Pt) platinum (Upadhyay et al., 2007).

Aim and Objectives of the Study

The aim and objectives of this study were to assess the concentrations of selected heavy metals and physicochemical properties in the water of the Forcados River.

The specific objectives of the study are to:

1. determine some physicochemical properties such as pH, Total organic carbon (TOC), Total dissolved solids (TDS) nitrates, sulphates and electrical conductivity of the water samples.
2. assess the levels of selected heavy metals (Ni, Cu, Cd, Zn, Cr, Pb) in the water samples.
3. evaluate the contamination/pollution status of the water samples concerning each metal.
4. calculate the ecological risk of the heavy metals in the water samples.

Materials and Methods

Sagbama Local Government Area is found in Bayelsa state, Nigeria. The Local Government Area comprises several towns and villages such as Adagbabiri, Bulou-Orua, Tungbo, Ofoni, Elemebiri, Ebedebiri, Toru-Orua, etc. The estimated population of the Local Government Area is put at 241,603 inhabitants according to the 2006 census. Sagbama LGA spans an area measuring 945 square kilometres and with a temperature averaging 25 degrees Celsius. The Local Government Area is covered with water with the LGA hosting the Focardos River and other tributaries of the River Niger. The area is heavily forested, and host part of the Bayelsa National Forest. The area experiences heavy rainfall and high humidity for most of the year. Sagbama LGA experience two major seasons, the rainy and dry seasons which are characteristics of the equatorial climate. The dry season is from November to April with the 'harmattan' which comes briefly during this period. The rainy season spans April to October with a brief dry spell in August, but it frequently rains even in the dry season. The LGA experiences an annual rainfall amounting to 2673.8mm and a mean temperature of 32.8 ^{0}C and is also marked by a tropical equatorial climate. The water samples were collected from eight (8) sampling locations. That is two (2) locations each from Sagbama (SAG), Adagbabiri (ADA), Tungbo (TUG), and Toru-Orua (TOR). The water samples were collected from either side of the Forcados River in each town. The collected surface water samples were stored in pre-cleaned plastic bottles, sealed, labelled and moved to the laboratory for preparation and Atomic Absorption Spectroscopic analysis. The water sample (100cm$^{3)}$ was well mixed, acidified and transferred into a conical flask for digestion. A volume of 5ml of HNO^3 was added to the sample in the fume hood. It was brought to a slow boiling and evaporated on a hot plate to the lowest volume possible (about 1-2ml) before precipitation occurs. Continued heating was done until digestion was complete to a light-coloured clear solution. The content was filtered and the filtrate was transferred to a 100-volumetric flask and diluted to 50ml mark. This solution was taken to the laboratory for heavy metals determination. The water pH was determined in water suspension using a glass electrode pH meter. 10cm^3 of the water sample was weighed into a beaker and 5mL of HNO_3 in water was added and stirred and allowed to stand for five minutes. Thereafter, the pH meter was inserted and the pH was read.

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Using filter paper number (41), a known volume of the sample is measured (50ml- 100ml), using a pipette to be more accurate. Then empty the evaporating dish into a clean, dried flask, and thereafter evaporate almost to dryness on a hot plate and then dry completely in the oven. After drying, cool in discretions and weigh.
TDS (mgl/) = weight of dried sample in an evaporating dish.
TDS (mg/l) = Dish/Conical Flask x 100
Volume of sample poured into the evaporating dish

In the determination of Nitrates. The procedures are given below:

i. Five (5) drops of the water sample were placed in an evaporating dish
ii. To a conical flask, two (2) drops of diphenylamine were added to sulphuric acid
iii. The solution in the flask was then added to the evaporating dish and the content of the dish was heated up. Thereafter blue colouration (was observed) is indicative of the presence of nitrate, thereafter the absorbance of the mixture was read at the wavelength of 520nm in a spectrophotometer.

In the determination of sulphate. The sulphate ions of the water sample were determined using the turbidimetric method. 20ml of five different water samples were measured with a measuring cylinder in a different conical flask that was previously rinsed with distilled water. 5.0ml of a conditioning reagent which contains 30ml of concentrated hydrochloric acid, 100ml alcohol, 75g of sodium chloride and 300ml distilled water, was added until all the sulphate was precipitated. It was digested in water until the precipitate had settled, and the precipitate was filtered, and washed with hot water several times until it was free from chloride. Two-way analysis of variance (ANOVA) was used to determine whether the concentrations of metals varied significantly among sampling locations, with a p-value less than 0.05 ($p<0.05$) considered statistically significant. Pearson's correlation coefficient was used to determine the relationship between physicochemical properties and heavy metals. The statistical analysis was performed using SPSS version 22.

Results

Table 1:Mean of concentrations and physicochemical properties of heavy metals in Forcados River.

SAMPLE PROPERTIES(mg/l)	SAGBAMA	ADAGBABIRI	TUNGBO	TORU-ORUA	WHO (2011)	NESREA (2009)
PH	5.73±0.01	5.75±0.01	5.68±0.01	5.67±0.00	6.5-8.5	6.0-8.5
Nitrate	15.24±0.01	16.55±0.01	15.27±0.08	16.54±0.00	200	500
Sulphate	146.23±0.00	154.30±0.00	156.48±0.08	205.84±0.77	0.05	<0.05
EC	815.91±0.71	720.63±7.08	717.28±0.79	817.59±0.09	600	400
TDS	2.31±0.01	3.86±0.01	4.18±0.03	2.41±0.01	2000	2100
TOC	198.06±0.63	196.77±0.63	198.29±0.12	198.27±0.02	-	-
Lead	2.58±0.71	4.76±0.01	2.25±0.00	2.75±0.02	0.05	<0.01
Chromium	6.09±0.01	6.52±0.52	5.89±0.00	5.78±0.01	0.05	<0.05
Cadmium	2.17±0.00	2.74±0.01	1.04±0.01	1.98±0.02	0.05	<0.10
Copper	3.80±0.07	2.26±0.01	3.87±0.00	2.63±0.51	1.5	0.01
Zinc	5.89±0.01	4.09±0.00	4.90±0.05	6.15±0.00	0.05	<1.00
Nickel	7.04±0.01	6.08±0.01	6.83±0.09	7.93±0.08	0.03	<1.00

Table 1 shows summary of descriptive statistics of physicochemical properties of water of Forcados River in the sampling locations. The result show that pH has a mean and standard deviation values of 5.73±0.01 in Sagbama, 5.75±0.01 in Adagbabiri, 5.67±0.00 in Tungbo, 5.67±0.00 in Toru-Orua and 2.69±0.00 as the control. The result also shows that nitrates has a mean and standard deviation values of 15.24±0.01 in Sagbama, 16.55±0.01 in

Adagbabiri, 15.27±0.08 in Tungbo, 16.54±0.00 in Toru-Orua and 3.47±0.00 as the control. The result further shows that Sulphates has mean and standard deviation values of 146.23±0.00 in Sagbama, 154.30±0.00 in Adagbabiri, 156.48±0.08 in Tungbo, 205.84±0.77 in Toru-Orua and 2.98±0.00 as the control. The result indicated that EC(electrical conductivity) recorded a mean and standard deviation values of 815.91±0.71 in Sagbama, 720.63±7.08 in Adagbabiri, 717.28±0.79 in Tungbo, 817.59±0.09 in Toru-Orua and 2.77±0.00 as the control. The result also outlined that TDS(total dissolved solids) has a mean and standard deviation values of 2.31±0.01 in Sagbama, 3.86±0.01 in Adagbabiri, 4.18±0.03 in Tungbo, 2.41±0.01 in 198.27±0.02 and 2.68±0.00 as the control. Finally, the result shows that TOC(total organic carbon) had a mean and standard deviation values of 198.06±0.63 in Sagbama, 196.77±0.63 in Adagbabiri, 198.29±0.12 in Tungbo, 198.27±0.02 in Toru-Orua and 3.53±0.00 as the control. The result further shows that lead has a mean value of 2.58±0.71 in Sagbama, 4.76±0.01 in Adagbabiri, 2.25±0.00 Tungbo, 2.75±0.02 in Toru-Orua and 3.09±0.00 as the control. The result also shows that chromium has a mean value of 6.09±0.01 in Sagbama, 6.52±0.52 in Adagbabiri, 5.89±0.00 in Tungbo, 5.78±0.01 in Toru-Orua and 2.57±0.00 as the control. The result indicated that cadmium has a mean value of 2.17±0.00 in Sagbama, 2.74±0.01 in Adagbabiri, 1.04±0.01 in Tungbo 1.98±0.02 in Toru-Orua and 1.41±0.00 as the control. The result also shows that copper has a mean value of 3.80±0.07 in Sagbama, 2.26±0.01 in Adagbabiri, 3.87±0.00 in Tungbo, 2.63±0.51 in Toru-Orua and 2.56±0.00 as the control. The result further outlined that zinc has a mean value of 5.89±0.01 in Sagbama, 4.09±0.00 in Adagbabiri, 4.90±0.05 in Tungbo, 6.15±0.00 in Toru-Orua and 2.69±0.00 as the control. The result indicated that nickel has a mean value of 7.04±0.01 in Sagbama, 6.08±0.01 in Adagbabiri, 6.83±0.09 in Tungbo, 7.93±0.08 in Toru-Orua and 1.51±0.00 as the control. The statistical analysis shows a p-value less than 0.05 therefore there is a significant difference in the concentrations of heavy metals in surface water among sampling locations.

Table 2:Summary of Pearson's correlation of physicochemical properties and heavy metals concentrations in water of Forcados River in the sampling locations.

		PH	$N0_3$	$S0_4$	EC	TDS	TOC	Pb	Cr	Cd	Cu	Zn	Ni
PH	R	1											
	p-value												
Nitrate	R	.993**	1										
	p-value	.000											
Sulphate	R	.946**	.967**	1									
	p-value	.000	.000										
EC	R	.989**	.983**	.962**	1								
	p-value	.000	.000	.000									
TDS	R	.263	.255	.133	.124	1							
	p-value	.463	.476	.714	.733								
TOC	R	.999**	.993**	.952**	.990**	.259	1						
	p-value	.000	.000	.000	.000	.469							
Pb	R	.017	.075	-.051	-.057	.282	-.009	1					
	p-value	.962	.837	.890	.876	.430	.980						
Cr	R	.981**	.976**	.898**	.955**	.313	.976**	.156	1				
	p-value	.000	.000	.000	.000	.378	.000	.668					
Cd	R	.403	.447	.348	.403	-.152	.380	.730*	.503	1			
	p-value	.248	.195	.325	.248	.675	.279	.016	.138				
Cu	R	.324	.225	.189	.338	.066	.335	-.723*	.247	-.468	1		
	p-value	.361	.532	.602	.339	.857	.343	.018	.491	.172			
Zn	R	.807**	.797**	.868**	.882**	-.272	.818**	-.398	.717*	.195	.438	1	
	p-value	.005	.006	.001	.001	.446	.004	.255	.020	.589	.206		
Ni	R	.960**	.960**	.982**	.984**	.077	.967**	-.170	.902**	.292	.352	.926**	**1**
	p-value	.000	.000	.000	.000	.834	.000	.638	.000	.412	.318	.000	
	N	10	10	10	10	10	10	10	10	10	10	10	**10**

****. Correlation is significant at the 0.01 level (2-tailed).**

***. Correlation is significant at the 0.05 level (2-tailed).**

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Correlation analysis

Table 2 shows the statistical analysis of Pearson correlation for physicochemical properties and heavy metals of water of Forcados River in the sampling locations. The result shows that Pb has a positive correlation with pH, $N0_3$ and TDS and a negative correlation with $S0_4$, EC and TOC. The sig. (2-tailed) also shows that there is no significant difference in the correlation. The result also indicated that Cr has a positive correlation with all the physicochemical parameters. The sig.(2-tailed) shows that there is a significant difference with all the physicochemical properties except TDS. The result further shows that Cu has a positive correlation with all the physicochemical properties. The sig.(2-tailed) shows that there is no significant difference with all the physicochemical properties. The result also outlined that Zn has a positive correlation with all the physicochemical properties except TDS. The sig.(2-tailed) shows that there is a significant difference with all the physicochemical properties except TDS. The result finally shows that Ni has a positive correlation with all the physicochemical properties except TDS. The sig.(2-tailed) shows that there is a significant difference with all the physicochemical properties except TDS.

Table 3; Significance of intervals of contamination/pollution index (C/PI) C/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
0.75-1.00 Very severe contamination
1.1-2.0 Slight pollution
2.1-4.0 Moderate pollution
4.1-8.0 Severe pollution
8.1-16.0 Very severe pollution
>16.0 Excessive pollution

Table 4: Summary of contamination/pollution index of heavy metals in water of Forcados River.

	Sagbama	Adagbabiri	Tungbo	Toru-Orua	Control
Heavy metals	**HPI**	**HPI**	**HPI**	**HPI**	**HPI**
Pb	1.19	4.98	2.12	0.71	0.25
Cr	0.48	0.45	0.40	0.39	0.13
Cd	47.15	60.13	21.41	42.82	29.84
Cu	0.00	0.00	0.00	0.00	0.00
Zn	0.00	0.00	0.00	0.00	0.00
Ni	3.39	2.91	3.28	3.84	0.61
HPI <total>	52.21	68.46	27.21	47.75	30.83

HPI=Heavy Metal Pollution Index,

Contamination/ pollution index of metals in water of Forcados River.

The contamination/ pollution index of metals in water samples in this study is displayed in Table 4.

The contamination/ pollution index of metals in surface water samples ranges from 0.25 to 4.98 for Pb, 0.13 to 0.48 for Cr, 21.41, to 60.13 for Cd, 0.00 for Cu, 0.00 for Zn and 0.61 to 3.84 for Ni. The contamination/pollution index for Pb ranges from moderate contamination to severe pollution, for Cr it ranges from moderate contamination to excessive pollution, for Cd it is very severe contamination and excessive pollution, for Cu and Zn it was zero contamination/pollution, and for Ni, it ranges from severe contamination to moderate pollution

Table 5.:Summary of ecological risk assessment of heavy metals in water of Forcados River.

	Sagbama	Adagbabiri	Tungbo	Toru-Orua	Control
Heavy metals	**ER**	**ER**	**ER**	**ER**	**ER**
Pb	5.98	3.25	6.87	5.62	5.00
Cr	12.66	11.83	13.09	13.34	30.00
Cd	1.30	1.03	2.71	1.42	2.00
Cu	0.67	1.13	0.66	0.97	1.00
Zn	2.29	3.29	2.74	2.19	5.00
Ni	1.07	1.24	1.11	0.95	5.00
RI<total>	23.97	21.76	27.18	24.49	48.00

RI=Risk Index, ER=Ecological Risk, RI<150=low risk

Ecological risk assessment of heavy metals in water of Forcados River.

The potential ecological risk of metals in the water of Forcados River is shown in Table 5.

The potential ecological risk of the metals in the water is in the order of Cu < Cd <Ni < Zn <Pb < Cr. The potential ecological risk of the metals was in the low ecological categories (i.e. <150). The RI values of these water samples range from 0.66 to 13.34. The highest and lowest values were observed at Toru-Orua and Tungbo sampling locations. The ecological risk index (RI) for Pb ranges from 3.25 to 6.85, for Cr, it ranges from 11.83 to 13.34, for Cd it ranges from1.03 from 2.00, for Cu it ranges from 0.66 to 1.13, for Zn it ranges from 2.19 to 5.00 and for Ni it ranges from 1.07 to 5.00. Below are the heavy metal risk index (Low ecological risk of metals (RI value < 150), moderate ecological risk of metals (> 150 < 300), and strong ecological risk of metals (RI value ≥ 300 > 600). From the table above the potential ecological risk of the metals in water of Forcados River are at the low ecological risk level.

Discussion

Physicochemical properties of water in Forcados River

The pH of water affects most chemical and biological processes in it. It is one of the most important environmental factors limiting species distribution in aquatic habitats. The normal range for pH in surface water systems is 6.5 to 8.5 and that of groundwater systems is 6 and 8.5 WHO, (2011). The pH values in this study ranged between 5.67 to 5.76 with a mean value of 5.58±0.01. The highest and lowest pH were recorded in Adagbabiri 1 sampling location and Tungbo 2 sampling locations respectively. The pH of the sampled surface waters is within the recommended value of the World Health Organization (2011). Some compounds are more toxic to aquatic organisms at different pH values, for instance, nickel cyanide toxicity increases about the decrease of the pH value (Shallcross et al., 2014).

The electrical conductivity values in this study ranged from 816.40 to 715.62 with mean values of 817.59 ±717.29. The highest and lowest EC was observed in Tungbo 2 and Adagbabiri 1 sampling locations respectively. These values are above the permissible limit of the World Health Organization, (2011) and National Environmental Standard Enforcement Agency, (2009), with values of 600 and 400 respectively. These high values of EC imply that there is a significant presence of trace metal ions or ionizable materials in the water of Forcados River. .Nitrate is a form of nitrogen. It can readily dissolve in water and can travel easily through the soil to the water table. Nitrate is common in groundwater, streams, rivers and surface water, it causes increased growth of plants and algae. (Edward, 2018). The nitrates values in the sampled location ranged from 15.22 to 16.56 with a mean value of 16.55±0.01. The highest and lowest nitrates values were observed in Adagbabiri 2 sampling location and in Sagbama 1 sampling location respectively. These values are within or lower than the permissible limits of the National Environmental Standard and Regulations Enforcement Agency, (2009) and WHO, (2011) . These nitrates level in the water samples is as a result of human and environmental activities around Forcados River around the sampled locations.

Sulphate is one of the oxides of sulphur. It is found at very high concentrations in many groundwater and surface water system.(Sharma & Kumar, 2019). The sulphate values in sampled locations ranged from 146.23 to 206.39 with a mean value of 156.48±0.08. The highest and lowest sulphates values were recorded in Tungbo 2 and Sagbama 1 sampling locations respectively. These levels are below the acceptable limits of the National Environmental Standard and Regulations Enforcement Agency (NESREA), (2009)), acceptable limits of 500mg/l. These levels of sulphate are a result of environmental and anthropogenic activities.±.79 and 815.91+0.71. The highest and lowest EC were observed in Tungbo 2 sampling locations and Adagbabiri 1 sampling locations respectively. These values are above the permissible limit of the World Health Organization, (2011) and the National Environmental Standard Enforcement Agency, (2009). These high values of EC imply that there is a significant presence of trace metal ions or ionizable materials in the water of Forcados River. (Arias et al., 2005)**.**

A very high TDS value raises the content of salt in water and can make it unfit for drinking and irrigation purposes. The total dissolved solids in the water samples ranged from 2.30 to 4.20 with a mean value of 2.41±0.01. The lowest and highest TDS values were recorded in Sagbama 2 sampling location and Toru-Orua 1 sampling location respectively. The TDS values are lower than the permissible limits of the (WHO, 2011) and (NESREA, 2009) cited. These low TDS values suggest very low anthropogenic activities in the Forcados River. The measure of total organic carbon (TOC) indicates the level of contaminants or organic molecules present in water. The measurement of TOC in water enables organizations to know whether the water is safe for their specific needs. The TOC in the surface water samples in this study ranged from 197.21 to 198.50 with a mean value of 198.06±0.63. The highest and lowest TOC values were observed in Sagbama 1 sampling location and Adagbabiri 1 sampling location. The high values of TOC in the sampled water indicate the high level of contaminants or organic molecules present in the water of River Forcados, hence it is very unsafe for human consumption but safe for irrigation purposes.

Heavy metal concentrations in the water of Forcados River

Lead

In this study, lead was detected in all sampling locations. The concentration of lead ranged from 2.25 to 4.76mg/l with a mean value of 4.76±0.01. The highest and lowest concentrations of Pb were observed at Adagbabiri 2 sampling location and Tungbo 1 sampling location respectively. These concentrations of Pb were however higher than the permissible limits of WHO, (2011) and NESREA, (2009) which are 0.05 and <0.10mg/l respectively. These concentrations of lead were slightly higher than those reported by Ogboru and Ekpete, (2021), observed to be 2.65 to 3.25mg/l. Lead occurs in the earth's crust, it is the most abundant heavy metal and it is toxic to plants. Its exposure to young children has been linked with learning disabilities. (Pearce, 2001).

Chromium

The concentrations of chromium in this study ranged from 5.765 to 6.895mg/l with a mean value of 6.52±0.52. The lowest and highest Cr concentration were observed in Toru-Orua 2 and Adagbabiri 2 sampling locations respectively. These concentrations of Cr were however higher than the permissible limits set by WHO, (2011) and NESREA, (2009), which are 0.05 and <0.05mg/l respectively. The concentrations of Cr in this study are higher than those reported by Ogboru and Ekpete, (2021), observed to be 2.35 to 3.95mg/l with mean values of 3.75+1.476. No evidence exists that chromium is essential to plants, but traces of it is useful to plants and animals. Generally, there are little problems associated with discharge to land by wastewater containing chromium (III)

Cadmium

Cadmium was detected in the water samples at concentrations ranging from 1.04 to 2.74 mg/l with a mean value of 2.74±0.01. The highest and lowest concentration of Cd was found at Adagbabiri 1 and Tungbo 1 sampling locations respectively. The concentrations of Cd in this study were higher than the maximum permissible limits set by WHO, (2011) and NESREA, (2009), which are 0.05 and <0.10mg/l.

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Copper

Copper was detected at concentrations ranging from 2.247 to 3.868mg/l with a mean value of 3.87±0.05. The highest and lowest Cu concentrations were observed at Tungbo 1 and Adagbabiri 1 sampling locations. These concentrations of Cu observed in this study were however higher than the acceptable values set by WHO, (2011) and NESREA,(2009), which are 1.5 and 0.01mg/l. The concentrations in this study were lower than those reported by Ogboru and Ekpete, (2021) observed to be 3.20 to 5.70mg/l and also lower than those reported by Ekpete and Festus, (2013) observed as 1.24±0.672.

Zinc

The concentrations of zinc in the water samples in this study ranged from 4.085 to 6.148 with a mean value of 6.15±0.01. The concentrations of zinc in this study were higher than the permissible limits set by WHO, (2011) and NESREA, (2009), of 0.05 and <1.00mg/l. However, the concentrations of Zn observed in this study were within the range of that reported by Ekpete and Festus (2013) observed values of 2.670 to 6.417mg/l. The concentrations were however higher than that reported by Ogboru and Ekpete, (2021) observed values of 2.30 to 4.95mg/l. Zinc occurs naturally in the earth's crust, and most of its compounds found naturally are water-soluble. The metal is essential for plants and animals but poisonous in high concentrations. It irritates the intestine and during zinc poisoning, intestinal discomforts like vomiting, stomach cramps, diarrhoea, and nausea are early signs, other symptoms of zinc poisoning are fever, cough, low blood pressure, urinary retention, etc.

Nickel

Nickel was detected at concentrations ranging from 6.076 to 7.986mg/l with a mean value of 7.93±0.08. The highest and lowest values were observed at Toru-Orua 1 and Adagbabiri 2 sampling locations respectively. These concentrations of Ni observed in this study were higher than the acceptable limits set by WHO, (2011) and NESREA, (2009), of 0.03 and <1.00. The concentrations of Ni observed in this study were higher than those reported by Ogboru and Ekpete, (2021) observed was 1.50 to 3.10mg/l. The concentration of Ni in this study is however lower than that reported by Marcus and Ekpete, (2014) observed as 57.19±6.929.

Conclusion

The concentration of heavy metals and physicochemical properties of water of Forcados River in the Sagbama local government area (Sagbama, Aagbabiri, Tungbo and Toru-Orua) of Bayelsa State were carried out. The result showed that heavy metals contamination in the water of Forcados River followed the order Cr >Pb > Ni>Cd. The study indicated that the heavy metals studied do not pose an environmental risk considering their low concentrations.

Recommendation

It is however, recommended that all the activities contributing to the increased pollution of the river in the area be brought under control, to keep the environment safe for aquatic organisms and human lives that benefit from them along the food chain.

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