Assessment of Seasonal Variations ofSome Heavy Metals between Water and Sediment in Qua Iboe River, OrukAnam, Nigeria

Abstract:
Environment which man lives requires sustainability for life continuity. This is because human activities release enormous amounts of diverse contaminantsinto aquatic ecosystem are continually increasing.It is worthy of note of some relationship between concentrations of contaminants in water bodies and sediment lying beneath through desorption of some contaminants from the water. In this study, heavy metals (Cd, Cr, Ni, Cu, V, Pband Sn) in water and sediment were determined using atomic absorption spectrophotometer. The results were subjected to statistical analysis using statistical package for social sciences. A significant positive relationship was established between the heavy metals in water and sediment in the studied river. A significant positive relationship between Cd in water and that in sediment was established at ($r = .973$, $p < 0.01$), between Cu in water and that in sediment ($r = .844$, $p<0.01$) in dry season. In wet season, results revealed that there was a significant positive relationship between Cd in water and that in sediment ($r = .925$, $p<0.01$), Cr in water and sediment ($r = .991$, $p<0.01$), Cu in water and sediment ($r = .937$, $p<0.01$).The results also revealed that the levels of the metals in both water and sediment were higher in dry season than wet season due to concentration and dilution effects respectively. The distribution revealed that as the concentration of the metals in water increased, there was a corresponding increase in concentration of the metals in sediment. This condition is capable of causing bioaccumulation of the metals in commercial fish especially bottom feeders with potential consequences on man through food chain.
Keywords: Analysis, ASS, heavy metals, sediment, statistical, and water.

Introduction

"The environment and its compartments have been severely polluted by heavy metals and other chemicals through anthropogenic activities. Although pollution occurs naturally, it is the anthropogenic activities that create more problems" (Akpan, *et al.*, 2024). ''Researchers have revealed that levels of pollution in different environmental media dependsignificantly on unregulated levels of anthropogenic activitiesamong other factors within these media''. ''Variation in levels of pollution across geographicalregions is a function of variation in levels of anthropogenic activities across such regions. In an environment, pollution affects both the biotic and the abiotic components of the environment. In aquatic environment, there is a correlation between the levels of pollution in water and sediment lying underneath and fish that live in the water as well as human that depend on the water and fish for consumption''(Ido*et al.*, 2023).Heavy metals are known to be naturally occurring contaminants which exist within background levels, but anthropogenic activities introduce them in large quantities into environment. This resulted in a reduced ability of the environment to support life thereby threateninglife of humans, animals and plants. This occurs due to bioaccumulation in the food chain as a result of the non-degradable nature of the trace metals. ''Environmental pollution will continue to be a worldwide concern and one of the great challenges faced by the global society. Among all the pollutants, heavy metals have received significant attention to environmental chemist due to their non- biodegradability'' (El-Zeing*et al.*, 2018). "Some heavy metals are toxic even at low concentrations. Metals such as arsenic, lead, cadmium, nickel, mercury, chromium,

cobalt, zinc and selenium are highly toxic even in minor quantity" (Ogri*et al.,* 2011). ''Increasing levels of heavy metals in our resources is currently an area of greater concern, especially since a large number of industries are discharging their metal containing effluents into fresh water without adequate treatment'' (Udosen*et al.,* 2016).

''Heavy metals become toxic when they are not metabolised by the body and accumulate in the soft tissues. They may enter the human body through food, water, air or absorption through the skin when they come in contact with humans in agriculture, manufacturing, pharmaceutical, industrial or residential settings'' (Alinnor, I. and Alagoa, A. 2014). Industrial exposure accounts for a common route of exposure for adults. Ingestion is the most common route of exposure in children. Natural and human activities are contaminating the environment and its resources, they are discharging more than what the environment can handle.''Some important anthropogenic sources which significantly contribute to the heavy metals contamination in the environment include automobile exhaust which releases lead, smelting which releases arsenic, copper and zinc; insecticides which release arsenic and burning of fossil fuels which releases nickel, vanadium, mercury, selenium and tin''(Amirah *et al.,* 2013; Emara*et al*., 2015; Edem*et al.* 2020)."Researchers have found out that human activities contribute significantly to environmental pollution due to the everyday manufacturing of goods to meet the demands of the increasing population in our nation.Over the years, OrukAnam has witnessed tremendous anthropogenic activities culminating in the overall development of the area. These activities include roads construction, industrilisation and all kinds of agricultural practices. The end products of these activities are usually washed into the aquatic environment when it rains thereby polluting the ecosystem with all kinds of heavy metals" (Amirah et al., 2013). There is recent data of the levels of these metals in the study area hence, the needs for assessment of the levels of the metals and seasonal variations in water and sediment in both wet and dry seasons.

2. Material and Methods

2.1 Study Area

The study area Qua Iboe River as shown in Figure 1 is located between latitude $04^{o}28'31$. and $07^{o}10'12.4''0''$North of the equator and between $06^{o}65'41.2''$ East of Greenwich Meridian. "It is the main river that drains across Akwa Ibom State. It flows in a southern direction through EtimEkpo, Ikot Okoro in OrukAnam via Ibagwa in Abak to EkpeneObom and EkpeneUkpa in Etinan Local Government Area, then through Ndiya in NsitUbium local government area before flowing into Alantic Ocean via Beight of Bonny" (Akpan *et al.,* 2024).

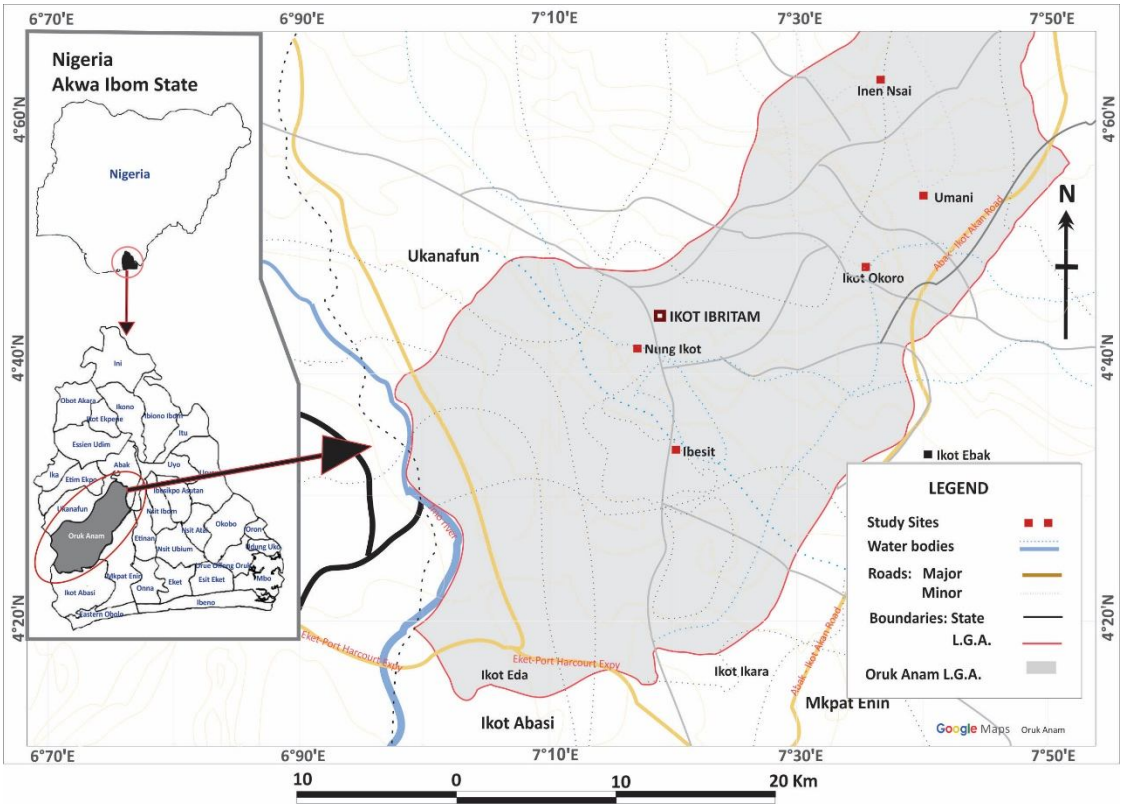

Figure 1: Map of the study area.
Predominant human activities in the study area include agriculture, roads construction, fishing and boating.

2.2 Samples Collection and Analysis

Samples were collected between November and October covering wet and dry seasons from five sampling locations namely: InenNsai (upstream), Umani, Ikot Okoro (downstream), Nung Ikot and Ibesit (downstream).

Determination of Heavy Metals in Water: "The concentrations of heavy metals were determined using UNICAM solar 969 Atomic Absorption Spectrophotometer (AAS). The water samples (100 mL each) were filtered using filter paper No.1. The filtrate was acidified with HNO_3 (10 mL) and 50% HCl solution (10 mL). It was evaporated to near dryness on an electric hot plate. The solution was transferred to a 100 mL volumetric flask and made up to mark with deionised water" (Edem*et al.* 2020). A blank was also prepared the same way with the omission of the sample using deionised water. The samples were aspirated into the air/acetylene flame.

Determination of Heavy Metals in Sediment

Sediment samples (1.0 g) were weighed into 250 mL Pyrex conical flasks. Mixed perchloric acid, nitric acid and sulphuric acid in the ratio of 1:2:2 (15 mL) were added and the samples were digested on a hot plate in a fume chamber at until dense white fumes appeared, signaling the end of digestion. The contents were cooled and filtered using filter paper (Whatman No.42) into 50 mL volumetric flasks and made up to mark with distilled water. A blank was also prepared similarly with the omission of the sample. The digested samples were aspirated into the AAS.

Quality Control

Quality control of the analytical data was guaranteed through the implementation of laboratory quality assurance and laboratory methods as well as the use of standard operating procedures, calibration with standards and analysis with reagent blanks.

Statistical Analyses

The generated data were subjected to descriptive statistics analysis using statistical package for social sciences (SPSS).

3. Results and Discussion

3.1 Levels of Heavy Metals in Water and Sediment Samples

The results of the levels of investigated heavy metals in water and sediment samples analysed in this study were presented in Tables 1 and 2.

Table 1: Levels (mg/L) of heavy metals in water samples in wet and dry seasons

Trace Metals		Cd	Cr	Ni	Cu	V	Pb	Sn
IN	Wet	0.02±0.01	0.01±0.01	0.01±0.01	0.02±0.01	0.01±0.01	0.00±0.00	0.02±0.01
	Dry	0.03±0.01	0.01 ±0.01	0.02±0.01	0.03±a0.01	0.02±0.01	0.00±0.00	0.00±0.01
UM	Wet	0.02±0.01	0.01 ±0.01	0.02±0.01	0.05±0.01	0.02±0.01	0.00±0.00	0.01±0.01
	Dry	0.04±0.01	0.0 ±0.01	0.03±0.01	0.07±0.01	0.03±0.01	0.00±0.00	0.02±0.01
IO	Wet	0.0±0.00	0.03 0.01	0.0±0.00	0.07±0.01	0.0 ±0.00	0.00±0.00	0.02±0.00
	Dry	0.06±0.01	0.04 ±0.01	0.01±0.01	0.08±0.01	0.04±0.01	0.01±0.00	0.02±0.01
NI	Wet	0.05±0.01	0.0±0.01	0.02±0.01	0.08±0.01	0.03±0.01	0.00±0.01	0.02±0.01
	Dry	0.07±0.00	0.08±0.00	0.04±0.01	0.10±0.00	0.04±0.01	0.01±0.00	0.03±0.00
IB	Wet	0.05±0.01	0.06±0.01	0.03±0.01	0.08±0.01	0.03±0.01	0.01±0.01	0.02±0.01
	Dry	0.08±0.00	0.09±0.00	0.04±0.00	0.10 ±0.01	0.04±0.01	0.01±0.00	0.03±0.01

IN = InenNsai, UM = Umani, IO = Ikot Okoro, NI = Nung Ikot, IB = Ibesit, STD = Standard deviation.

Table 2: Levels (mg/kg) of heavy metals in sediment for wet and dry seasons

Trace Metals		Cd	Cr	Ni	Cu	V	Pb	Sn
IN	Wet	0.02±0.01	0.02±0.01	0.02±0.01	0.05±0.01	0.03±0.01	0.01±0.01	0.02±0.01
	Dry	0.03±0.01	0.03±0.01	0.03±0.01	0.06±0.01	0.03±0.01	0.01±0.01	0.02±0.01
UM	Wet	0.06±0.01	0.04±0.00	0.04±0.01	0.07±0.01	0.04±0.01	0.01±0.01	0.04±0.01
	Dry	0.10±0.08	0.15±0.01	0.05±0.01	0.08±0.00	0.05±0.00	0.02±0.01	0.05±0.01
IO	Wet	0.08±0.01	0.05±0.01	0.07±0.01	0.11±0.01	0.06±0.01	0.03±0.01	0.05±0.00
	Dry	0.13±0.01	0.11±0.00	0.10±0.00	0.21±0.01	0.07±0.01	0.03±0.00	0.08±0.00
NI	Wet	0.10±0.01	0.11±0.01	0.08±0.01	0.15±0.01	0.06±0.01	0.03±0.01	0.07±0.01
	Dry	0.21±0.01	0.20±0.00	0.10±0.00	0.17±0.00	0.08±0.00	0.03±0.00	0.08±0.00
IB	Wet	0.10±0.01	0.11±0.01	0.08±0.01	0.10±0.01	0.03±0.01	0.01±0.01	0.07±0.01
	Dry	0.21±0.01	0.21±0.00	0.17±0.00	0.18±0.01	0.08±0.01	0.03±0.00	0.08±0.01

IN = InenNsai, UM = Umani, IO = Ikot Okoro, NI = Nung Ikot, IB = Ibesit, STD = Standard deviation.

Levels of Heavy Metals in Water: Table 1 shows the levels of heavy metals in water in both wet and dry seasons. The distribution pattern of the levels of heavy metals in the water indicated Cu > Cd > Cr > V > Ni > Sn > Pb.

Levels of Cadmium in Surface Water: The levels of cadmuim in water samples across sampling locations during wet season ranged between 0.02±0.01 and 0.05±0.01 mg/L and between 0.03±0.01 and 0.080±0.01 mg/L. The results obtained in this study were consistent with

levels obtained by Udosen*et al.* (2014) and were higher thanmaximum permissible limits of 0.003 and 0.005mg/L recommended for aquatic medium by Nigeria Industrial Standard and World Health Organisation respectively.Higher levels of cadmium are usually obtained in liver and kidney and lowest concentration in pancreas and spleen (Akpan *et al.* 2024). Effects of higher levels in man include kidney damage, diarrhea, stomach pains, and bone fracture among others.

Levels of Chromium in Surface Water: The levels of Cr in surface water ranged between 0.01±0.01 and 0.068±0.01 mg/L in wet season and during dry season, the levels ranged between 0.02±0.09 and 0.087±0.004 mg/L. Chromium is essential nutrient for humans and shortage may cause heart disease, disruption of metabolisms and diabetes. Excessive intake may cause real danger to human health such as skin rashes, stomach upset and ulcer, respiratory problems etc.

Levels of Nickel in Surface Water: The levels of Ni recorded across sampling locations ranged between 0.01±0.01 and 0.03±0.01 mg/L in wet season and between 0.02±0.01 and 0.04± 0.00 mg/L during dry season nickel. Levels recorded in study were consistent with maximum permissible limits of 0.02 and 0.07 mg/L for aquatic ecosystem recommended by NIS and WHO respectively. Nickel is relatively toxic and widespread in the environment. The effects of nickel exposures range from skin irritation, lungs and nervous system damage etc. Sources of Ni to the environment include weathering of minerals and rocks and geochemical emission and anthropogenic activities.

Levels of Copper in Surface Water: The mean levels of Cu obtained in surface water across sampling locations during wet season ranged between 0.02±0.01 and 0.08±0.01 mg/L in wet season and between 0.03±0.01 and 0.10±0.01 mg/L during dry season. In both seasons, levels obtained were with result reported by Ido*et al.* (2023) and below maximum permissible limit of 2.0 mg/L for aquatic environment recommended by NIS. Cu is essential to metabolism. Higher levels are toxic and cause liver damage. Long term exposure can result in nose, mouth and eyes irritation. Other effects include headache, dizziness, vomiting etc. (Udosen*et al.* 2016).

Levels of Vanadium in Surface Water: The mean levels of V in surface water across all sampling locations during wet season ranged from 0.01±0.01 to 0.03± 0.01 mg/L and from 0.02±0.01 to 0.04±0.01 mg/L. In both seasons, the levels recorded in some locations were abovepermissible limits of 0.02 mg/L for aquatic ecosystems recommended by NIS and USEPA. Higher levels in man can result lung disease and stomach problems.

Levels of Lead in Surface Water: From Table 3, the levels of Pb in water across the sampling locations ranged between 0.00±0.00 and 0.01± 0.00 mg/L in wet season and between 0.00±0.00 and 0.01±0.00 mg/L during dry season. The results obtained were below limits of 0.01 mg/L and 0.05 mg/L for surface water according to USEPA and NIS standards respectively. Higher concentration in man can result in brain and kidney damage, reproduction failure. Other effects include hearing loss, anemia, hypertension, kidney impairment, immune system dysfunction etc.

Levels of Tin in Surface Water: The mean levels of Sn in water across sampling locations ranged between 0.00±0.01 and 0.02±0.01 mg/L in wet season and during dry season levels obtained range between 0.02±0.00 to 0.03±0.01 mg/L. The levels of tin obtained in this study in both seasons were consistent with 1.0 and 2.0 mg/L standards given by NIS and WHO respectively.

On the whole, the levels of all the heavy metals determined in this study were higher in downstream than upstream due to increase in levels of anthropogenic activities downstream and downstream movement of contaminants in the studied river.‘‘Comparatively, levels of

heavymetals recorded in dry season were higher than levels obtained in wet season due to concentration and dilution effects in dry and wet seasons respectively"(Uwah*et al*.2021).

Levels of Heavy Metals in Sediment: Table 2 shows the results of mean levels of heavy metals in sediment across the sampling locations. The distribution pattern is shown below: Cu > Cd > Cr > Ni > V > Sn > Pb.

Levels of Cadmium in Sediment: The levels of Cd in sediment samples across sampling locations ranged between 0.02± 0.01 and 0.10±0.01 mg/kg in wet season and between 0.03±0.01 and 0.21±0.01 mg/kg in the dry season. The results were similar to levels reported by Gu *et.* (2018). Levels recorded in all locations in both seasons were consistent with permissible limits of 0.03 – 3.0 mg/kg in sediment recommended by department of petroleum resources.

Levels of Chromium in Sediment: The levels of Cr in sediment across all the sampling locations ranged between 0.02±0.01 and 0.11±0.01 mg/kg in wet season while it ranged between 0.03±0.01 and 0.21±0.00 mg/kg during dry season. These levels were consistent with levels recorded by Uwah*et al*. (2021) and below 0.5 mg/L permissible limit in sediment recommended by Department of petroleum Resources (DPR).

Levels of Nickel in Sediment: The levels of Ni in this study ranged between 0.02±0.01 and 0.08±0.01 mg/kg in wet season while during dry season the levels ranged between 0.03±0.01 and 0.17±0.00 mg/kg. Levels werehigher in dry season than wet season across the sampling locations reflecting concentration and dilution effects in dry and wet season respectively (Edem*et al.* 2020).

Levels of Copper in Sediment: The level of Cu in this study across the sampling locations ranged between 0.05±0.01 and 0.15 0.01 mg/kg in wet season and between 0.06±0.01 and 0.18±0.01 mg/kg in dry season. The levels of Cu recorded in sediment samples in this study were higher than levels reported by Uwah*et al.* (2013) and lower than permissible limit of 1.0 mg/kg recommended by NIS.

Levels of Vanadium in Sediment: The levels of vanadium in sediment obtained in this study across all the locations ranged between 0.03±0.01 and 0.06±0.01 mg/kg in wet season and between 0.03±0.01 and 0.08±0.01 mg/kg during dry season.Levels recorded were higher in dry season than wet season due to concentration and dilution effects in dry and wet season respectively, Etuk*et al.* (2020). Levels recorded in some sampling locations were higher than permissible limit of 0.002 mg/kg in sediment given by NIS. The study area requires routine monitoring of the metals through research to prevent escalation.

Levels of Lead in Sediment: The level of Pb in sediment samples across the sampling locations ranged between 0.01±0.01 and 0.03±0.01 mg/kg in wet season and between 0.01±0.01 and 0.03± 0.00 mg/kg during dry season. These levels were consistent with levels reported by Akpan *et al.*,2024; Ido*et al*. 2023and below permissible limit of 2,2 mg/kg in sediment given by DPR.

Levels of Tin in Sediment: The levels of Sn across the sampling locations during wet season ranged between 0.02±0.01 and 0.07 mg/kg and between 0.02±0.00 and 0.08±0.01 mg/kg in the dry season. As indicated in Table 2, the results showed that there were significant differences in levels obtained between Umani and InenNsai locations ($p<0.05$) in wet season. Levels obtained in all sampling locations in both seasons were below permissible of 0.5 mg/kg in sediment in aquatic ecosystems given by WHO and DPR.

Table 3: Correlation between heavymetals in water for wet season

	Cd	Cr	Ni	Cu	V	Pb	Sn
Cd	1						
Cr	.954**	1					
Ni	.891**	.780**	1				
Cu	.910**	.840**	.925**	1			
V	.938**	.854**	.937**	.955**	1		
Pb	.929**	.922**	.875**	.912**	.919**	1	
Sn	.390	.392	.431*	.497*	.476*	.488*	1

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

Table 4: Correlation between heavy metals in water for dry season

	Cd	**Cr**	**Ni**	**Cu**	**V**	**Pb**	**Sn**
Cd	1						
Cr	.966**	1					
Ni	.934**	.906**	1				
Cu	.936**	.893**	.986**	1			
V	.880**	.805**	.967**	.967**	1		
Pb	.917**	.864**	.908**	.931**	.915**	1	
Sn	.881**	.842**	.874**	.844**	.880**	.862**	1

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

Results in Tables 3 and 4 present correlationsbetween heavy metals in water across all the sampling locations for wet and dry season respectively. Results presented in Table 3 showed that Cd had significant positive relationship with Cr ($r = .954$, $p<0.01$), Ni ($r = .891$, $p<0.01$), Cu ($r = .910$, $p<0.01$), V ($r = .938$, $p<0.01$), Pb ($r = .929$, $p<0.01$). Cu showed significant positive relationship with V ($r = .937$, $p<0.01$), Pb ($r = .875$, $p<0.01$) while Pb showed correlation with Sn ($r = .488$, $p<0.05$).

In dry season, results in Table 4 showedcorrelation between heavy metals in water. It shows that Cd had significant positive correlation with Cr (r = .966, p<0.01), Ni (r = .934, p<0.01), Cu (r = .936, p<0.01), V (r = .880, p<0.01), Pb (r = .917, p<0.01) and Sn (r = .881, p<0.01). Cu showed significant positive correlation with V (r = .967, p<0.01), Pb (r = .908, p<0.01), Sn (r = .874, p<0.01) while between Pb and Sn, a significant positive correlation was established at (r =.862, p<0.01). The results indicated that as the concentration of Cd in water increased, there was a corresponding increase in the concentrations of other trace metals studied in the water. Similar pattern was observed during wet season. That means as the concentration of one metal in water increased, there was also a corresponding increase in the concentrations of other metals in the water. By extension, it implies that all the metals determined, had similar source of contamination of the river. Hence for sustainability of the river under study for use by present and future generations, routine monitoring of the metals is strongly advocated.

Table 5: Correlation between heavy metals in sediment during wet season

	Cd	Cr	Ni	Cu	V	Pb	Sn
Cd	1						
Cr	.901**	1					
Ni	.963**	.859**	1				
Cu	.933**	.967**	.948**	1			
V	.965**	.880**	.992**	.960**	1		
Pb	.953**	.801**	.973**	.893**	.971**	1	
Sn	.991**	.912**	.982**	.960**	.983**	.962**	1

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

Table 6: Correlation between heavy metals in sediment during dry season

	Cd	Cr	Ni	Cu	V	Pb	Sn
Cd	1						
Cr	.928**	1					
Ni	.844**	.823**	1				
Cu	.752**	.773**	.985**	1			
V	.912**	.833**	.978**	.928**	1		
Pb	.891**	.756**	.933**	.870**	.976**	1	
Sn	.923**	.852**	.969**	.918**	.994**	.970**	1

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

Results in Tables 5 and 6 present correlation of heavymetals between heavy metals in sediment for wet and dry seasons respectively. For wet season (Table 5), results show that Cd had significant positive correlation with Cr ($r = .901$, $p<0.01$), Ni ($r = .963$, $p<0.01$), Cu ($r = .933$, $p<0.01$), V ($r = .965$, $p<0.01$), Sn ($r =.991$, $p<0.01$). Ni had a significant positive correlation with Cu ($r = .967$, $p<0.01$), V ($r = .880$, $p<0.01$), Pb ($r = .801$, $p<0.01$) and between Pb and Sn a positive correlation was established at ($r = .962$, $p<0.01$) Table 4. During dry season (Table 6), Cd showed a significant positive relationship with Cr ($r = .928$, $p<0.01$), Ni ($r = .844$, $p<0.01$), Cu ($r = .752$, $p<0.01$), V ($r = .912$, $p<0.01$), Pb ($r = .891$, $p<0.01$) and Sn ($r = .923$, $p<0.01$). Cu also showed significant positive correlation with V ($r = .978$, $p<0.01$), Pb ($r = .933$, $p<0.01$) and Sn ($r = .969$, $p<0.01$) while between Pb and Sn, a significant positive relationship was established at ($r = .970$, $p<0.01$). The results revealed that as the concentration of Cd in sediment increased, there was corresponding increase in concentrations of other trace metals in sediment in both seasons.It implies that an increase in the concentration of one trace metal in sediment resulted in a corresponding increase in the concentrations of other metals insediment as reported by Iwegbue (*et al.* 2012). By extension, it implies that all the trace metals studied had similar source of contamination to the studied river and hence the need for routine monitoring to prevent escalation.

Table 7: Spatial distribution between heavy metals in water and sediment in wet season

		Sediment						
		Cd	Cr	Ni	Cu	V	Pb	Sb
Water	Cd	.925**	.941**	.922**	.963**	.939**	.907**	.936**
	Cr	.869**	.991**	.850**	.968**	.875**	.790**	.887**
	Ni	.908**	.780**	.926**	.859**	.935**	.940**	.912**
	Cu	.983**	.864**	.989**	.937**	.987**	.974**	.992**
	V	.970**	.869**	.947**	.907**	.950**	.964**	.963**
	Pb	.922**	.929**	.911**	.944**	.926**	.870**	.934**
	Sn	.477*	.408*	.473*	.455*	.464*	.458*	.494*

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

Table 8: Spatial distribution between heavy metals in water and sediment in dry season

		Sediment						
		Cd	Cr	Ni	Cu	V	Pb	Sn
Water	Cd	.973**	.980**	.891**	.828**	.918**	.861**	.929**
	Cr	.975**	.959**	.762**	.670**	.825**	.787**	.838**
	Ni	.967**	.856**	.885**	.797**	.953**	.953**	.958**
	Cu	.966**	.853**	.922**	.844**	.977**	.975**	.977**
	V	.897**	.778**	.925**	.855**	.977**	.973**	.973**
	Pb	.904**	.866**	.912**	.862**	.939**	.917**	.934**
	Sn	.854**	.848**	.792**	.730**	.843**	.787**	.860**

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

Correlation analysis between heavy metals in water and sediment showed significant positive correlations both at $p< 0.05$ and $p < 0.01$. In wet season, results in Table 7 revealed that there was a significant positive relationship between Cd in water and that in sediment ($r = .925$, $p<0.01$), Cr in water and sediment ($r =.991$, $p<0.01$), Ni in water and sediment ($r = .926$, $p< 0.01$), Cu in water and sediment ($r = .937$ $p<0.01$) and Sn in water and sediment ($r = .494$, $p<0.05$). Results in Table 8 shows that during dry season, there was a significant positive relationship between Cd in water and that in sediment ($r = .973$, $p<0.01$), Cr in water and in sediment ($r =.959$, $p< 0.01$), Ni in water and sediment ($r =.885$, $p<0.01$), Cu in water and sediment ($r = .844$, $p<0.01$), V in water and sediment ($r = .977$, $p<0.01$), Pb in water and that of the sediment ($r = .917$, $p<0.01$), Sn in water and sediment ($r = .860$, $p<0.01$). These results of spatial distribution of trace metals between water and sediment for both seasons implies that there was a significant positive relationship between concentration of trace metals in water and the metals in sediment (Mohiuddin *et al.* 1012). This indicated that as the concentrations of trace metals in water increased significantly, there was a corresponding significant increase in the concentrations of themetals in sediment in both seasons.This positive relationshipin levels of trace metals between water and sediment could be ascribed to desorption (deposition) of these chemicals on the sediment from overlyingwater. The rate of desorption of these chemicals from

the overlying water onto the sediment depends on the flow rate of the river, time frame, gravitational force, time, among other factors.Summarily, the heavierthe load of these chemicals in the river, the greater they were enriched in sediment lying underneath reported by Iwegbue (*et al.* 2012). There were also some correlations ($r > 0.01$), which suggested some levels of relationship even though not significant (Tables 7 and 8).

4. CONCLUTION

The following conclusions were drawn based on the objective and statistical analyses of the results.

The results of the analysis indicated variations in levels of Cd, Cr, Ni, Cu, V, Pb and Sn analysedin water and sediment samples across the sampling locations of Qua Iboe River.Higher levels of the metals determined were recorded in dry season than wet season due to concentration and dilution effects of the metals in water and sediment in dry and wet seasons respectively. There wasa significant positive relationship in the distribution between concentrations of heavy metals in water and sediment in the two seasons. It implied that as the concentrations of the metals in river water were increased, there were also corresponding increases in concentrations of the metals in the sediment. By extension, it implies that there is a positive correlation between the level water pollution andlevel of sediment pollution in aquatic ecosystem. It therefore means that the control of water pollution is directlya control of sediment pollution as well as aquatic organisms which live in the water. The levels of trace metals in aquatic ecosystem are attributed significantly to levels of anthropogenic activities other than natural sources since these activities introduce them in large amounts into the environment. Thereforeto maintain safe limits of the metals determined in water and sediment in this research as recommended by WHO, NIS, USEPA in aquatic ecosystem, human activities in our environment must be carried out in compliance to regulatory frame work by government.

COMPETTING INTERESTS

Authors have declared that no competing interests exist.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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