

## Trace Metals Correlation Trends between: Water and Fish; Sediment and Fish in Qua Iboe River, Oruk Anam, Nigeria

### Abstract:

Environment and its components is an aspect in environmental management that attracts greater attention of researches as it relates to human life. Components of environment refer to the biotic and the abiotic components including their kinds, levels, interactions among them leading to the state of the environment. In unpolluted environment, contaminants levels are within background levels but in a polluted environment, contaminants exist in elevated levels. In this research, trace metals (Cadmium, Cd; Chromium, Cr; Nickel, Ni; Copper, Cu; Vanadium, V; Lead, Pb; and Tin, Sn) in water, fish and sediment samples from Qua Iboe River, Oruk Anam, Nigeria were determined using atomic absorption spectrometer. The results revealed variable levels of the investigated parameters in the samples. There was significant positive correlation between the studied trace metals in water, fish and sediment in both seasons. Correlation of the trace metals between water and fish as well as sediment and fish also revealed positive correlation. Between water and fish, significant positive relationship exist between Cd in water and that in fish ( $r = .957, P < 0.01$ ), Cr in water and that in fish ( $r = .997, P < 0.01$ ) and between sediment and fish, positive correlation exist between Cd in sediment and that in fish ( $r = .971, P < 0.01$ ), Cr in sediment and that in fish ( $r = .988, P, 0.01$ ) and so on. It could be concluded therefore that all the trace metals studied showed positive correlation within and between samples analysed. From the results, routine monitoring of the trace metals in the studied river is strongly advocated for sustainability of the ecosystem for use by the present without compromising the standard for future generations.

**Keywords:** Metals, river, sediment, fish, analysis, correlation, ASS, statistical

### 1. Introduction

Water is a basic need in life. This includes plants and animals lives. The roles of water to living things cannot be overemphasized. Extinction of some species of aquatic organisms may result if pollution levels of the water body can no longer support lives of aquatic organisms. Water quality parameters are given prime consideration in the assessment of pollution status of ecosystem. "The quality of any water sample depends significantly on the levels of water quality parameters and contaminants it contains. Level of contaminants or pollutants in aquatic environment vary from one water body to another depending on certain factors such as natural and anthropogenic prevalent in them. Although pollution occurs naturally, it is the anthropogenic activities that create more problems" [5, 13, 17]. "Some humans do not actually understand that contamination or pollution status of their environment is significantly caused by them as a result of their pollution induced activities. Such activities include agriculture, fishing, boating, drilling of all types, transportation, roads construction, swam reclamation, establishment of numerous up-stream and down-stream industries and a host of other activities carried out by man aimed at solving his social and economic problems. This is a reflection of the correlation between anthropogenic activities and impacts on humans and the environment. Higher levels of the anthropogenic activities in the environment

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correlate greater the impacts on the environment, biotic and abiotic components. It should be noted that the state of environmental pollution correlates correspondingly to health conditions of living resources of the area” [3, 10, 13]. In heavily industrialised area, effects of all such activities within the area may be immediately apparent on humans, plants and even objects within the environment. Effects may include corrosion of building roof, car roofs, and corrosion of steel pipes, among others as a result of acid rain. Human health may be adversely affected to a level that may even result in abandonment of the environment depending on the level of pollution. This shows that there are interactions between biotic and the abiotic components of the environment” [8, 9, 19].

“In aquatic ecosystem, there are some kinds of relationships between levels of chemical elements in the river water and sediment lying under as well as aquatic biota such as fish that lives in the water. Correlation exist in levels of chemical elements between water and sediment; sediment and fish as well as water and fish including aquatic plants through accumulation” [8, 15, 16]. There is also correlation between levels of these chemicals in fish and humans who consume the fish. This may depend on factors such exposure frequency, exposure duration, body weight, age among other factors. It should be noted therefore that the levels of contamination or pollution in any environment is proportional to the levels of anthropogenic activities among other factors. “Sediment is considered as sink for many chemical elements including trace metals. In many cases, researches have revealed that the concentrations of elements in sediment can even be greater than the overlying water. Trace metals are metals in extremely small quantities that are present in plants and animal cells and tissues. Results of researches reveal that a greater percentage of trace metals load in aquatic environment is held up to particulate matter which some are embedded in sediment” [6, 10, 14]. Distribution of trace metals in sediment in a highly populated area can also provide historic records levels anthropogenic impacts on the aquatic environment. “Studies on the sediment cores over the years have been extensively used as pollution records in many countries of the world. Results of sediment core studies can be used to establish principally impacts of anthropogenic and on depositional environment. It is therefore understood that elevated levels of trace metals in sediments can be ascribed to land-based and aquatic activities among others” [7, 10, 11].

“Researches reveal that fish and marine products contain certain chemical elements which can be essential to human life at low concentration. These chemical elements can become toxic at elevated concentrations as a result of accumulation. The levels of these chemical elements in water and sediment beyond background levels reflect corresponding levels of anthropogenic activities within the ecosystem” [1, 2, 7]. “The similar trend holds for fish, in an unpolluted environment, fish normally carry natural burden of trace metals but in a heavily polluted areas the burden goes beyond background levels. It is worthy of note that impacts of land-activities on river water also have corresponding impacts on the sediment lying underneath and the fish that lives in the river” [3, 12, 18].

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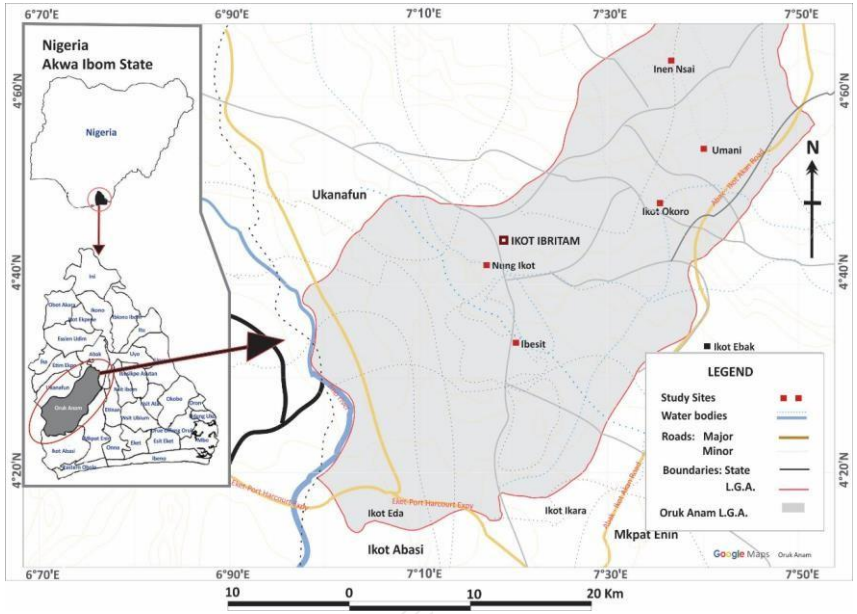
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## 2. Methodology

### Study Area

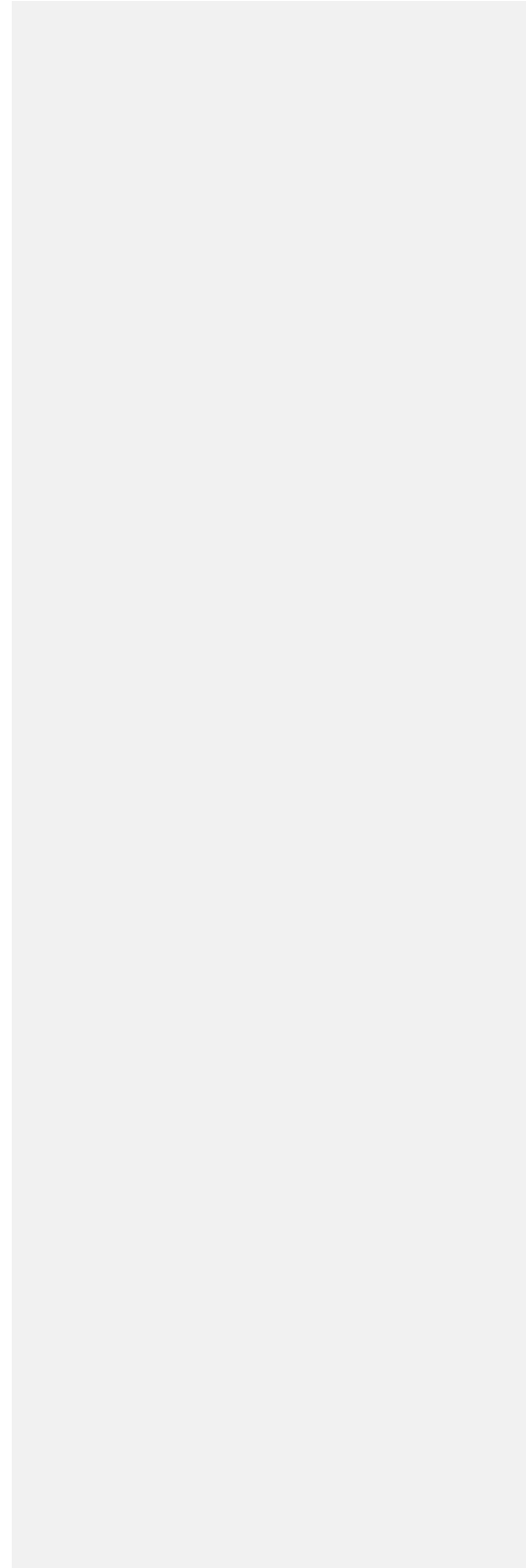
The study area is Qualboe River (QIR) flowing through Akwa Ibom State in Nigeria. As presented in Figure 1, it is located between latitude 04° 28'31.0"N and 07°10'12.4"N and longitude 06° 52'50.5"E of Greenwich Meridian. It flows through Inen Nsai, Umani, Ikot Okoro, Nung Ikot and Ibesit in Oruk Anam into Ibagwa in Abak.



UNDER PEE

**Figure 1: Map of study area**

UNDER PEER REVIEW



### Sampling, Preservation and Treatment:

Samples preservation is a vital step in any analysis. It is a measure taken to prevent reduction or loss of components of interest from the samples once the samples are removed from their natural sources. A good preservation method maintains the integrity of the samples and guarantees the validity of the result [4, 16].

#### Water Samples

The bottles for water samples collection were properly prepared prior to sampling. In the field, the bottles were pre-rinsed several times with the water from the different sampling points. Water samples were collected using pre-rinsed 1-litre (1L) polyethylene bottles by dipping each mouth of the container against the flow direction to avoid trapping air bubbles in the bottle [13, 19]. Water samples for dissolved oxygen determination were fixed on site with 2 mL of Winkler solutions. 1 and 1 using separated dropping pipettes for each respectively. These samples for trace metals analysis were collected with HNO<sub>3</sub> pre-rinsed (1L) polyethylene containers and 5 mL of concentrated nitric acid (HNO<sub>3</sub>) to a pH < 2 was added to maintain the oxidation state of the metals and to reduce microbial action. Samples collected were properly labeled noting the sampling locations, date and hour of sampling as well as samples temperature. The samples collected were immediately placed in an ice box and transported to the laboratory for analysis.

#### Sediment Samples

Sediment samples were collected along side with water samples using Eckman grab sediment sampler at five different points around each sampling location and thoroughly mixed together to form a composite bulk sediment sample. These sediment samples collected were stored in polyethylene bags and labeled properly to indicate sampling locations, date and time of collection'' [12, 16, 18] The samples were placed in an ice box and transported to the laboratory for analysis. ''Prior to analysis, sediment samples from each study site were first air-dried on reaching the laboratory and later placed in porcelain oven-dried crucibles and at a temperature of 105°C for 24 hours to remove moisture. The dried samples were then ground into a homogeneous mixture with the help of a porcelain mortar and pestle and sieved through 2 mm mesh screen to remove coarse materials. Each of the finely dried sediment (20 g) was kept in an air-tight plastic bottle prior to digestion.

#### Fish Samples

''Fish samples were collected from the five sampling locations with the help of local fishermen using local fishing traps (Ikpa) set adjacent to the sampling locations at dusk and inspected at dawn. Five medium sized fish samples were obtained and placed in a locally made aquarium and transported immediately to laboratory for analysis. Prior to analysis, the fish samples were washed with distilled water to remove loosely held particles before they were gutted and decapitated using stainless steel kitchen knife. The decapitated fish samples were filleted on both sides, placed in a porcelain crucible and dried in an oven'' [4, 5, 16, 18]. The dried muscles were homogenised using mortar and pestle. The resultant homogenised fish samples were stored in a well-labeled plastic bag prior to digestion.

### Digestion of Samples and Analysis

#### Sediment Samples

''Each of the finely homogenised sediment samples (2.0 g) were digested in a mixture of nitric acid (HNO<sub>3</sub>) and hydrochloric acid in the ratio of 3:2 in a silica beaker and refluxed in a hot sand bath for 1 hour. The resultant solutions were transferred to an evaporating dish after refluxing where they were heated gently on a hot plate and left to evaporate to near dryness. They were

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leached with 5 mL of 2% nitric acid and the undigested portion of the sediment filtered off using acid washed filterpaper” [16,17]. The filtrate was put in a volumetric flask and made up to 100 mL with distilled water. The digested samples were aspirated into atomic absorption spectrometer.

#### Fish Samples

In the analysis of fish, the finely homogenised fish samples (2.0 g) of each were put in a crucible and burned in a furnace until it turned to ash. The ash was leached with 5 mL of 6 M HCl in a volumetric flask and made up to 50 mL using distilled water. The digested samples were prepared in triplicate and analysed using atomic absorption spectrometer.

#### Preparation of Blank Samples

Blank sample was prepared along side with all the reagents used for sample digestion

#### Quality Control and Assurance

The implementation of laboratory quality assurance and quality laboratory methods, including the use of standard operating procedures, calibrations with standards, analysis of reagent blanks and analysis of replicates guaranteed the quality of the analytical data. Each sample was analysed in triplicates. All chemicals and reagents used in the study were of analytical grade. Standard solutions prepared were performed under clean laboratory environment. All samples were digested along side with blanks. Quantification of the metallic contents of digested samples and blanks was carried out with the Unicam 939/935 Atomic Absorption Spectrophotometer which was pre-calibrated using certified standard.

#### Statistical Analysis:

The generated data were processed using the statistical package for social sciences (SPSS). Relationship between the analysed trace metals, mean concentrations in water, sediment and fish from all sampling sites were investigated using Person's correlation coefficient,  $r$ , at  $P < 0.05$  and  $0.01$  significant levels.

### 3. Results and Discussion

Results of analysis of trace metals in water, fish and sediment samples from Qua Iboe River, Oruk Anam, Nigeria were presented in Tables 1, 2 and 3 respectively. Results in Table 4 presented correlation analysis of the trace metals within fish. Results in Tables 5 and 6 presented correlation analysis of the trace metals between water and fish while Tables 7 and 8 presented correlation analysis of the trace metals between sediment and fish samples for both seasons.

The levels of the trace metals studied in water samples from the five sampling locations in both seasons were as presented in Table 1.

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**Table 1: Levels (mg/L) of trace metals in surface water of Qua Iboe River for 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±0.01	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	0.04 ±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	0.07 ±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=IkotOkoro,NI=NungIkot,IB=Ibesit,STD=Standard deviation.

Statistical analysis of the results indicated that the levels of the trace metals in water samples in most cases increased from Inen Nsai sampling location (upstream) to Ibesit location (downstream). Moreover, in some cases, the levels of the trace metals were higher in dry season than wet season reflecting concentration and dilution effects in dry and wet season respectively.

Results of analysis of trace metals in sediment samples from the sampling locations are presented in Table 2.

**Table 2: Levels (mg/kg) of trace metals in sediment of Qua Iboe River 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	0.15±0.01	0.03±0.01	0.03±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=IkotOkoro, NI=NungIkot, IB=Ibesit, STD=Standard deviation.

Results of analysis of the trace metals in sediment samples from the five sampling locations showed the trend of increase from upstream to downstream. Higher levels of trace metals were recorded in dry season than wet season as applicable to the analysis of water samples.

Results of trace metals analysis in fish samples from the sampling locations are presented in Table 3.

**Table 3: Levels (mg/kg) of trace metals in fish for wet and dry seasons**

<u>Trace Metals</u>		<b>Cd</b>	<b>Cr</b>	<b>Ni</b>	<b>Cu</b>	<b>V</b>	<b>Pb</b>	<b>Sn</b>
IN	Wet	0.06±0.01	0.87±0.02	0.06±0.01	0.06±0.01	0.23±0.01	0.01±0.01	0.21±0.01
	Dry	0.09±0.01	0.74±0.01	0.48±0.01	0.33±0.01	0.33±0.01	0.02±0.01	0.26±0.01
UM	Wet	0.07±0.00	0.78±0.01	0.08±0.01	0.23±0.01	0.12±0.01	0.23±0.01	0.27±0.01
	Dry	0.30±0.00	0.5±0.01	0.07±0.01	0.50±0.01	0.32±0.01	0.23±0.00	0.29±0.01
IO	Wet	0.48±0.01	0.8±0.01	0.03±0.01	0.41±0.01	0.45±0.01	0.31±0.01	0.37±0.01
	Dry	0.30±0.01	0.53±0.01	0.04±0.01	0.51±0.01	0.04±0.01	0.41±0.00	0.38±0.01
NI	Wet	0.48±0.01	0.56±0.01	0.03±0.01	0.61±0.01	0.33±0.01	0.43±0.01	0.41±0.01
	Dry	0.51±0.01	0.67±0.01	0.03±0.01	0.51±0.01	0.4±0.01	0.45±0.01	0.51±0.01
IB	Wet	0.58±0.01	0.87±0.01	0.03±0.01	0.44±0.01	0.6±0.01	0.45±0.00	0.56±0.01
	Dry	0.53±0.01	0.71±0.01	0.03±0.01	0.50±0.01	0.4±0.01	0.45±0.01	0.40±0.01

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

The results of fish analysis in most cases indicated higher levels of the trace metals in downstream than wet season. The results also revealed higher levels in dry than wet season.

**Table4:Correlationbetweentracemetalsinfish**

	Cd	Cr	Ni	Cu	V	Pb	Sn
Cd	1						
Cr	.934**	1					
Ni	.929**	.864**	1				
Cu	.971**	.841**	.879**	1			
V	.791**	.820**	.543**	.776**	1		
Pb	.982**	.927**	.879**	.950**	.826**	1	
Sn	.983**	.939**	.881**	.941**	.827**	.987**	1

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

Results in wet season showed that Cd had significant positive relationship with Cr ( $r = .934$ ,  $p < 0.01$ ), Ni ( $r = .929$ ,  $p < 0.01$ ), Cu ( $r = .971$ ,  $p < 0.01$ ), V ( $r = .791$ ,  $p < 0.01$ ), Pb ( $r = .982$ ,  $p < 0.01$ ) and between Pb and Sn, a significant positive correlation was established at ( $r = .987$ ,  $p < 0.01$ ). Also Cu showed a significant positive correlation with V ( $r = .543$ ,  $p < 0.01$ ), Pb ( $r = .879$ ,  $p < 0.01$ ) and Sn ( $r = .881$ ,  $p < 0.01$ ) while Pb showed a positive relationship with Sn at ( $r = .987$ ,  $p < 0.01$ ) as reported in Table 4. The same trend of positive correlation was also recorded in dry season. The results indicated that as the concentration of Cd in fish increased, there were corresponding increases in concentrations of other trace metals in the fish. Similar positive correlation pattern of the investigated trace metals in water and sediment was observed for both wet and dry seasons.

**Table5:Correlationbetweentracemetalsinwaterandfishforwetseason**

		Fish						
		Cd	Cr	Ni	Cu	V	Pb	Sn
Water	Cd	.957**	.948**	.890**	.884**	.781**	.963**	.972**
	Cr	.922**	.997**	.839**	.824**	.836**	.923**	.939**
	Ni	.911**	.782**	.865**	.904**	.669**	.894**	.906**
	Cu	.978**	.854**	.900**	.995**	.761**	.961**	.955**
	V	.948**	.849**	.837**	.941**	.787**	.945**	.963**
	Pb	.949**	.929**	.869**	.906**	.835**	.927**	.941**
	Sn	.476*	.410*	.409*	.526**	.433*	.371	.390

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

**Table6:Correlationbetweentracemetalsinwaterandfishfordryseason**

		Fish						
		Cd	Cr	Ni	Cu	V	Pb	Sn
<b>Water</b>	Cd	.978**	.985**	.899**	.916**	.726**	.957**	.982**
	Cr	.910**	.987**	.764**	.835**	.758**	.947**	.930**
	Ni	.953**	.890**	.833**	.953**	.884**	.963**	.933**
	Cu	.972**	.883**	.868**	.984**	.868**	.964**	.940**
	V	.935**	.800**	.870**	.959**	.844**	.902**	.908**
	Pb	.945**	.872**	.902**	.927**	.741**	.931**	.959**
	Sn	.867**	.854**	.808**	.799**	.674**	.844**	.908**

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

Results in Table 5 show correlation of trace metals in water and fish during wet Season. The results revealed that there was a significant positive relationship between Cd in water and that in fish ( $r = .957, p < 0.01$ ), Cr in water and fish ( $r = .997, p < 0.01$ ), Ni in water and fish ( $r = .865, p < 0.01$ ), Cu in water and fish ( $r = .995, p < 0.01$ ), V in water and fish ( $r = .787, p < 0.01$ ). The relationship between Sn in water and fish was significant at ( $r = .390, p > 0.05$ ). Results in Table 6 shows the results of correlation of trace metals between water and fish during dry season and followed the same pattern as observed during wet season. The results indicated that for both seasons, there was a significant positive relationship between concentrations of trace metals in water and metals in fish. That implies that for both seasons, as the concentrations of trace metals in water increased significantly, there were corresponding significant increases in the concentrations of the metals in fish.

**Table7:Correlationbetweentracemetalsinsedimentandfishforwetseason**

		Fish						
		Cd	Cr	Ni	Cu	V	Pb	Sn
<b>Sediment</b>	Cd	.971**	.873**	.841**	.981**	.842**	.976**	.971**
	Cr	.932**	.988**	.810**	.856**	.892**	.940**	.949**
	Ni	.982**	.868**	.944**	.980**	.699**	.956**	.955**
	Cu	.983**	.978**	.927**	.925**	.794**	.965**	.970**
	V	.986**	.888**	.945**	.976**	.726**	.965**	.961**
	Pb	.943**	.797**	.889**	.959**	.681**	.928**	.929**
	Sn	.988**	.898**	.889**	.989**	.813**	.977**	.975**

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

**Table 8: Correlation between trace metals in sediment and fish for dry season**

	Fish							
	Cd	Cr	Ni	Cu	V	Pb	Sn	
Sediment	Cd	.956**	.961**	.815**	.922**	.842**	.979**	.949**
	Cr	.929**	.991**	.862**	.830**	.605*	.913**	.954**
	Ni	.960**	.806**	.981**	.970**	.674**	.868**	.921**
	Cu	.909**	.736**	.983**	.917**	.551*	.789**	.870**
	V	.976**	.841**	.937**	.993**	.794**	.923**	.943**
	Pb	.934**	.781**	.864**	.979**	.852**	.908**	.888**
	Sn	.979**	.858**	.932**	.986**	.783**	.933**	.948**

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

Results in Table 7 show correlation of trace metals in sediment and fish in both seasons and revealed that during wet season, there was a significant positive relationship between Cd in sediment and that in fish ( $r = .971, p < 0.01$ ), Cr in sediment and fish ( $r = .988, p < 0.01$ ), Ni in sediment and fish ( $r = .944, p < 0.01$ ), Cu in sediment and fish ( $r = .925, p < 0.01$ ), Pb in sediment and that of the fish ( $r = .928, p < 0.01$ ). Table 8 presented results of correlation analysis between trace metals in sediment with those in fish during dry season and revealed that there was a significant positive relationship between Cd in sediment and that in fish ( $r = .956, p < 0.01$ ), Cr in sediment and fish ( $r = .991, p < 0.01$ ), Ni in sediment and fish ( $r = .981, p < 0.01$ ), Cu in sediment and fish ( $r = .917, p < 0.01$ ), Pb in sediment and that of the fish ( $r = .908, p < 0.01$ ). The results also show that there were significant positive relationship between concentrations of metals in sediment and those in fish for both seasons. The results implied that in water and fish during wet season, there was a significant positive relationship between concentrations of metals in water and metals in sediment. This indicated that for both seasons, as the concentrations of trace metals in sediment increased significantly, there were corresponding significant increases in the concentrations of metals in fish.

### Conclusion

Correlation analysis revealed positive relationships between Cd with Cr, Ni, Cu, V and Pb in the water, sediment and fish in both the dry and wet seasons. There were also positive relationship between the trace metals in water and fish as well as sediment and fish in both seasons. Concentrations of the trace metals obtained in water during dry season were higher than levels reported in wet season reflecting concentration and dilution effects of the metals in dry and wet seasons respectively. The results revealed that as the concentrations of the metals increased in water, there was also corresponding increase in their concentrations of the metals in fish in both seasons. The results further revealed that correlation of the trace metals between sediment and fish in both seasons followed the same trend. It could be concluded therefore that significant positive correlations exist between levels of trace metals in the river and fish and also between sediment and fish. Hence, pollution control of fish and sediment by government can best be achieved by

Commented[U66]:was

Commented[U67]:a positive

Commented[U68]:the dry

Commented[U69]:the wet

Commented[U70]:the concentration

Commented[U71]:a corresponding

Commented[U72]:the concentrations

Commented[U73]:the correlation

Commented[U74]:the government

pollution control of the river through regulatory framework of anthropogenic activities within and around aquatic ecosystem.

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