Physical and Chemical Variations in Water Quality of Imo River Owing to Human Perturbations in the System

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Abstract: Studies on the physical and chemical changes in water quality of Imo River owing to human perturbations in the system were conducted for 12 months (between May 2016 and April 2017). Water samples were collected monthly in four stations along the river and analyzed using standard procedures. Mean values obtained for physico-chemical parameters of water samples showed that TDS, DO, BOD, nitrate, phosphate and ammonia values were higher in wet season while pH, temperature, electrical conductivity, chloride, sulphate, cadmium, copper, iron, lead, zinc and manganese values were higher during the dry season. The seasonality observed in the parameters during the study was attributed to influx of allochthonous materials and dilution as a result of surface run-off during the wet season and evapo-transpiration during the dry season. Spatial variation during the study was attributed to the nature and levels of human activities emanating within each of the stations. Physico-chemical parameters (ammonia, lead, iron, copper and cadmium) exceeded the permissible WHO Standard for portable water which calls for concern regarding its effects on human health. Correlation analysis revealed strong positive relationships amongst pairs of physico-chemical parameters of water suggesting that an increase in one parameters leads to a corresponding increase in another parameter. However, the series of activities going on in and within the study area, coupled with the findings of this study further vindicate the need for continuous monitoring and management of our indigenous water bodies. Based on the result of findings the water from Imo River is not portable for human consumption and other domestic activities.

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1. Introduction

In the beginning God created the universe, everything was beautiful. In the oceans the colourful fishes and marine lives illuminates the vast ocean bodies, the world was indeed impeccable. God decided that all these creation needs a leader, and then comes the creation of mankind the dawn of a new era. We are of the recognition that pollution is happening here and is happening now; it's not a nightmare or dream but real resulting from the nefarious activities of humans in the environment. It is in the light of this that we see pollution as a terrible monster which should be given top priority and proper management approach should be put in place to curb this menace. Let's not be more economical oriented but more environmentally oriented. All hands must be on deck to restore the environment to a friendly one albeit not to a pristine state.

In a developing country like Nigeria Water quality is a major economic and environmental issue. Alarming increase in human population, our interactions with the water resources on which we are completely dependent become more and more critical (George & Atakpa, 2015a). It is imperative to note that the major cause of environmental degradation is as a result of the nefarious activities by mankind which include industrial, mining, agriculture, house hold waste production, urbanization and other human related activities that is capable of increasing the concentration of heavy metal in the environment, thereby altering the physical and chemical status of the aquatic ecosystem which may in turn affect fish stocks and consequently extinction of many economic species (Ekpo, *et. al*., 2015).

The aquatic ecosystems are the final sink to every human activity on land. The impacts of anthropogenic activities on the aquatic ecosystem are devastating. All pollutants, atmospheric and land-based, invariably enter water bodies, by direct discharge, precipitations and run-offs. Water bodies, thus become sink as well as carriers of pollutants (George & Atakpa, 2015b). Water pollution has wide ecological impact, as it is an important raw material in photosynthesis and hydrological processes. The quality of water may be described according to their physical and chemical characteristics (George & Atakpa, 2015b). For effective maintenance of water quality through appropriate control measures, continuous monitoring of a large number of these parameters is essential.

Continuous monitoring and evaluation of the pollution state of our environment must be enforced to provide data which will serve as a guide in understanding the changes in the environment for proper planning, management and protection of the mangrove ecosystem which is the breeding ground for fry's and fingerlings from total annihilation by human induced activities. This paper therefore provides information to complement the existing data in the management of Imo River.

2. Material and Methods

2.1 Study Area

The study was carried out in Imo River (Fig 1) which is one of the essential rivers in Niger Delta region. It is situated on the South-East coast of Nigeria. The river originates from the Imo State (hill region) and flows through Imo, Abia and Rivers State before empting into the Atlantic Ocean. The river is located between Latitude 4°30'32"N and Longitude 7°32'3"E. It is a tidal River with extensive mangrove swamps, intertidal mud flats and influenced by semi-diurnal tidal regime. Industrial activities are also predominant (e.g. NNPC Power Station) add with illegal petroleum refineries and bunkering activities. The River is a source of drinking water and livelihood of the people of the area. The major occupation is fishing, lumbering and farming activities (Ogbuagu *et. al*., 2012).

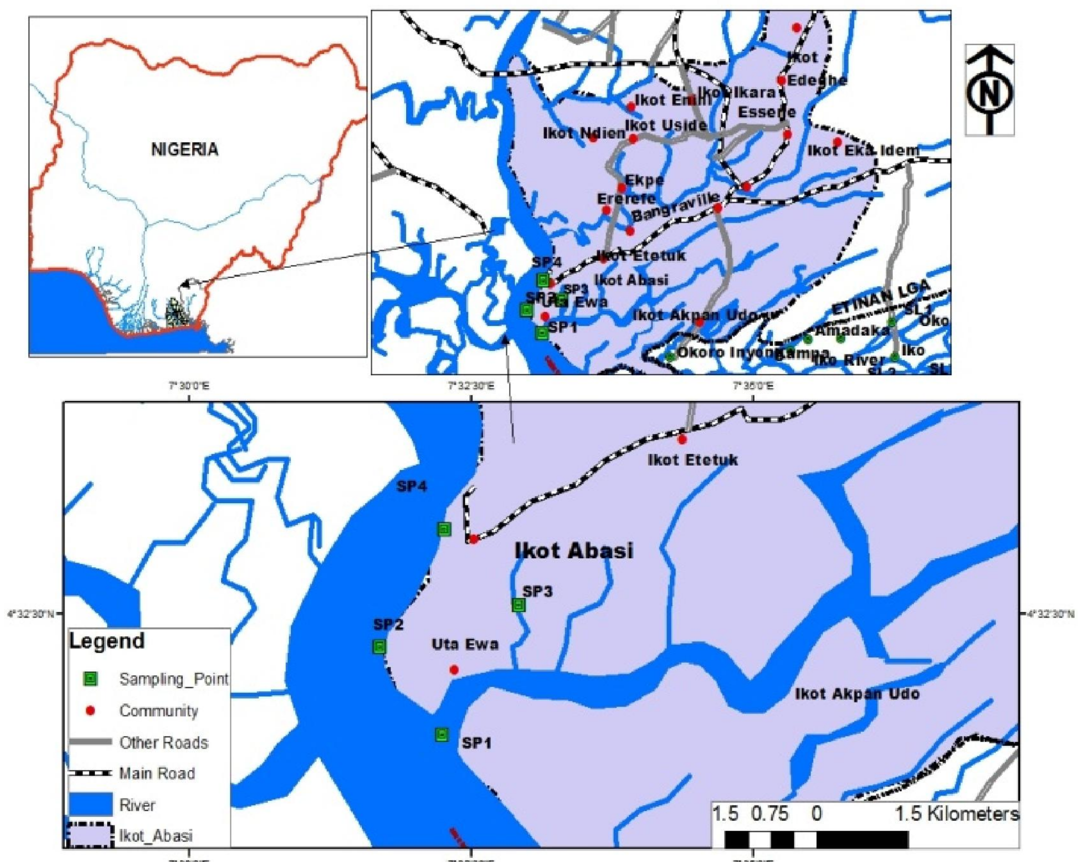

Fig 1: Map of the Study

2.2 Sample Collection / Analysis of Physical and Chemical Parameters

Water samples were collected from each sampling station using washed and sterilized plastic containers (1 litre). Water sample were collected by carefully lowering the sample bottle in the water to fill. Once the bottles were filled, they were pulled out of the water and firmly closed. Samples were collected once a month for twelve months (May, 2016 – April, 2017).

Physico-chemical parameters, such as temperature, pH, dissolved oxygen, electrical conductivity as well as total dissolved solids were measured *in situ* during sampling. The physico-chemical parameters were assessed using standard methods for examination of water and wastewater (APHA, 1998). A digital thermometer from

"EuroLab" was used in the determination of water temperature. A hand held pH meter from HANNAH Instruments was used for the determination of the H^+ ion index (acidity or alkalinity) of the water. Dissolved oxygen was measured with hand held (portable meter) from "Search Tech Instrument". A hand held instrument from HENNAH was used in determining the conductivity (in mS / cm) of the water. Total Dissolved Solid (TDS) was measured using a portable digital meter from "HENNAH" Instruments. Water samples for BOD_5, phosphate, chloride, Nitrate, sulphate and NH_3 was collected in 250ml glass specimen bottles. The bottles were filled with water and stoppered under water, ensuring that no air bubbles were trapped in it. 2ml each of Winkler's solutions A and B (Manganous sulphate and potassium iodide) were introduced into the sampling bottles. The contents of the bottles were then thoroughly agitated and transported to the laboratory. In the laboratory (Devine Concept Integrated Laboratory) Port Harcourt, the parameters were determined using standard laboratory methods according to Association of Official Analytical Chemist (AOAC, 2000). Trace metal such as Cd, Cu, Fe, Pb, Zn, Mn and Cr were determined using Atomic Absorption Spectrophotometer (model GBC scientific AASGF 3000) according to APHA, (1998).

2.3 Statistical Analysis

Statistical package for Social Sciences (SPSS) version 20 was employed to compute Mean, variance and standard error in the data. Also, one-way analysis of variance (ANOVA) and Least Significant Difference (LSD) test were employed to separate significant differences in mean values computed for stations while paired sample t-test was used to compare seasons. The probability level was set at p = 0.05.

3. Results

Table 1 shows the wet and dry season range and mean values of parameters observed during the study duration. Significant seasonal and spatial variations were observed in the studied parameters. However, it was observed that some parameters were higher during the wet season and these includes; TDS, DO, BOD, NO_3^-, PO_4^{3-} and NH_3 while others such as pH, EC, Cl^-, SO_4^{2-}, Cd, Cu, Fe, Pb, Zn and Mn were higher during the dry season (Table 1). Significant spatial and temporal variation were observed for pH, EC, TDS, BOD, NO_3^-, Cl^-, SO_4^{2-}, Cd, Cu, Fe, Pb, Mn and Cr while other parameters such as temperature, DO, NH3, and Zn varied in time and not in space.

The result of the correlation matrix among pairs of physico-chemical parameters in the wet and dry season is presented in Table 2 and Table 3. The results revealed significant positive relationship among pairs of physico-chemical parameters during the wet and dry season. However, the relationships were significant at (P = 0.001) and (P = 0.005). Significant positive relationships observed portends that an increase in one parameter may also lead to a corresponding increase in another parameter which was the case during the study. Seasonality also affected the relationships as is presented in Table 2 and Table 3. It was however, observed that the correlation matrix among pairs of physico-chemical parameters varies with respect to season as it is presented in the results.

Table 1: Seasonal range, mean variation, standard error of physico-chemical parameters measured in Imo River for wet and dry season (May, 2016 – April, 2017)

Parameters	Units	Range (Wet Season)	Range (Dry Season)	Mean ± S.E (Wet season)	Mean ± S.E (Dry season)	WHO Permissible limit
pH	-	5.50-6.70	6.10-7.40	6.25±0.07	7.27±0.01	6.5 – 9.0
Temperature	°C	25.30-27.60	26.20-30.10	26.45±0.18	27.68±0.21	25 °C – 30 °C
Electrical conductivity	µS/cm	32.00-77.00	28.00-78.00	47.47±2.42	49.21±3.11	70 µS / cm
Total Dissolve Solids	mg/l	17.00-41.00	16.00-39.50	26.79±1.21	25.94±1.48	500 mg / L
Dissolved Oxygen	mg/l	5.30-7.30	5.20-7.20	6.11±0.12	5.88±0.1	≥4 mg / L
Biological Oxygen Demand	mg/l	1.30-2.10	1.40-1.80	1.63±0.03	1.55±0.03	5.0 mg / L
Nitrate	mg/l	0.47-8.50	0.06-6.56	3.64±0.55	2.07±0.27	20 mg / L
Phosphate	mg/l	0.04-0.90	0.02-0.90	0.41±0.05	0.27±0.03	5 mg/ L
Chloride	mg/l	7.00-27.00	6.00-25.00	13.04±1.02	13.58±1.21	250 mg / L
Sulphate	mg/l	3.30-16.00	3.40-18.00	7.97±0.75	8.28±0.79	250 mg / L
Ammonia	mg/l	1.06-15.60	1.08-5.21	4.66±1.03	2.27±0.25	0.5 mg / L
Cadmium	mg/l	0.00-0.98	0.02-0.90	0.24±0.06	0.31±0.05	0.01 mg / L
Copper	mg/l	1.11-3.90	1.12-4.02	2.2±0.19	2.50±0.19	1.0 mg / L
Iron	mg/l	1.30-5.90	1.13-6.60	3.34±0.32	3.39±0.33	0.3 mg / L
Lead	mg/l	0.01-0.20	0.04-0.56	0.09±0.01	0.24±0.03	0.01 mg / L
Zinc	mg/l	0.00-0.90	0.02-4.52	0.39±0.07	1.40±0.27	3.0 mg / L
Manganese	mg/l	0.00-0.10	0.00-0.42	0.03±0.00	0.07±0.02	1.0 mg / L
Chromium	mg/l	0.00-0.12	0.00-0.14	0.01±0.00	0.01±0.01	0.05 mg / L

Table 2: Pearson's correlation matrix of physico-chemical parameters in water of Imo River for Wet Season (May – October, 2016)

	pH	Temp.	EC	TDS	DO	BOD	NO_3^-	PO_4^{3-}	Cl^-	SO_4^{2-}	NH_3	Cd	Cu	Fe	Pb	Zn	Mn	Cr
pH	1																	
Temp	-.040	1																
EC	.325	-.453*	1															
TD	.320	-.447*	.995**	1														
DO	-.047	-.517**	.217	.201	1													
BOD	-.063	.010	-.239	-.259	-.140	1												
NO_3^-	.126	-.616**	.727**	.725**	.414*	-.073	1											
PO_4^{3-}	.204	-.511**	.618**	.609**	.302	.116	.610**	1										
Cl^-	.204	-.489**	.950**	.940**	.207	-.187	.775**	.587**	1									
SO_4^{2-}	.270	-.022	.442*	.454*	-.026	.022	.247	.203	.317	1								
NH_3	.118	-.641**	.605**	.597**	.354	-.004	.943**	.601**	.661**	.208	1							
Cd	-.408*	-.416*	-.105	-.123	.257	.101	.083	.044	.025	-.082	.190	1						
Cu	-.028	-.179	.272	.268	.056	.167	.127	.374*	.242	.430*	.171	.485**	1					
Fe	-.516**	-.149	-.096	-.090	-.061	.008	.192	-.176	-.007	-.170	.186	.247	-.115	1				
Pb	-.393*	-.277	.240	.254	.104	.152	.305	.295	.277	.359	.307	.439*	.674**	.240	1			
Zn	.046	-.551**	.287	.281	.398*	.037	.399*	.108	.421*	.056	.320	.364*	.001	-.108	-.009	1		
Mn	.029	-.333	.251	.264	.438*	.069	.484**	.660**	.218	-.067	.472**	-.114	.042	-.095	.138	-.082	1	
Cr	.194	-.329	.109	.092	.372*	-.190	.185	.046	.119	-.003	.152	.008	-.071	.061	-.152	.272	-.101	1

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

Table 3: Pearson's correlation matrix of physico-chemical parameters in water of Imo River for Dry Season (November, 2016 – April, 2017)

	pH	Temp.	EC	TDS	DO	BOD	NO_3^-	PO_4^{3-}	Cl^-	SO_4^{2-}	NH_3	Cd	Cu	Fe	Pb	Zn	Mn	Cr
pH	1																	
Temp.	.126	1																
EC	-.553**	.173	1															
TDS	-.545**	.142	.989**	1														
DO	-.208	-.264	.009	.009	1													
BOD	-.329	.032	.100	.066	.462*	1												
NO_3^-	-.094	.080	.364*	.352	-.071	-.149	1											
PO_4^{3-}.	.040	.095	.208	.216	-.047	-.235	.264	1										
Cl^-	-.463**	.100	.916**	.929**	.148	.101	.402*	.350	1									
SO_4^{2-}	-.434*	.067	.872**	.879**	.111	.018	.434*	.323	.961**	1								
NH_3	-.210	.160	.529**	.530**	.111	-.068	.631**	.357	.602**	.577**	1							
Cd	-.136	.084	-.327	-.371*	.055	.297	-.157	-.054	-.306	-.325	-.011	1						
Cu	-.099	-.056	-.046	-.065	.138	.331	.373*	.151	.003	-.076	.246	.029	1					
Fe	-.528**	-.156	.077	.063	.268	.363*	-.079	-.231	.107	.114	-.031	.419*	.158	1				
Pb	-.366*	-.191	.094	.064	.141	.270	.390*	.015	.128	.136	.390*	.342	.496**	.211	1			
Zn	-.079	.175	.120	.099	-.199	-.127	.513**	.158	.135	.188	.026	.254	.151	.273	.030	1		
Mn	-.361*	-.258	.160	.181	.241	-.100	-.021	-.156	.222	.276	.071	-.112	-.123	.264	.027	.012	1	
Cr	.242	.341	-.157	-.147	-.161	-.136	-.216	.107	-.171	-.134	-.253	-.017	-.211	-.146	-.227	.051	.024	1

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

4.0 Discussion

The spatial and temporal variation in pH observed during the studies could probably be due to evapo-transpiration process, rainfall and the chemical and biological processes in the water (Mama and Ado, 2003). The mean pH values between both seasons showed significant difference both in space and time. Water pH which is an indicator of acidic or alkalinity condition of water status was within WHO permissible limit of 6.5-8.5 for aquatic lives. The mean pH value was slightly acidic to slightly alkaline throughout the period of study; this could be attributed to the dilution of fresh water inflow carrying along allochthonous materials into the river and photosynthetic activities within the water column. High pH recorded during the dry season could be due to the removal of CO2 by photosynthetic organism. The elevated pH values obtained during the dry season are similar to the results obtained by Adefemi *et al.* (2007) in water samples from Ureje, Egbe, Ero and Itapaj dams, all in Ekiti State; Dublin-Green (1990) in Bonny River; Ansa (2005) in Andoni flats of the Niger Delta area; Ekeh and Sikoki (2003) in the New Calabar River and George and Atakpa (2015b) in Cross River Estuary. However, studies by Nweke (2000), Ebere (2002) and Clarke (2005) inveterate elevated pH in dry season than in wet season which agrees with the result of the present findings.

The observed temperature demonstrated narrow amplitude of spatial variation but did not differ significantly which may be attributed to the time of sampling and the volume of riparian vegetation which may lead to a variation in water temperature between the stations as observed during the study. A similar observation was reported by Grover and Chrzanowski (2006). Seasonal variation was significant with higher temperature in the dry season which is consistent with tropical environments; in dry season, temperature is generally higher than in wet season. This might be ascribed to longer photoperiod and elevated intensity of sunlight. This observation was found to be consistent with the trends reported in previous studies within the Niger Delta (Chindah, *et. al*., 1999; Frankovich *et.al*. 2006, George and Atakpa, 2015b). The values of temperature obtained in the study were within permissible limit of WHO (2011) for portable water. This range is normal in the tropics (Akpan, 1999) and is attributed to the weather condition of the study area which is characterized by hot dry season and cold wet season (Moses, 1987; Akpan, 1999; Michael *et. al*., 2015). According to (WHO, 2011), temperature has significant impact on the growth and activities of ecological life and it greatly affects the solubility of oxygen in water. High water temperature enhances the growth of micro-organisms and may increase problems related to taste, odour, colour and corrosion. It is believed that the difference in temperature values of the water is not unrelated with solar radiation. Sunlight enforces a rise in water temperature in the dry season compared to the wet season values.

The significant increase in conductivity in the dry season is probably owed to high evapo-transpiration process which resulted in the concentration of the ions in the water (Allan, 2001). Significant difference was observed both spatially and temporally during the studies. This intra-seasonal variability indicates a strong influence of hydro-meteorological factors on conductivity levels in the river. Similar influence has been reported by Adebisi (1981) in Ogun River, Nigeria. This seasonality regime is consistent with those of other tropical rivers (Welcomme, 1985; Wright, 1982; King and Ekeh, 1990; Akpan and Ufodike, 2005). The levels of conductivity measured at Imo River were within WHO permissible limits but consistent with values obtained in most waters of the Niger Delta by Nwadiaro, (1989), Ogamba (2003), Agbozu and Emperor (2004), Agbozu and Izidor (2004) and George and Atakpa, (2015b).

The high wet season mean values in TDS was attributed to high precipitation which resulted in influx of allochthonous materials into the river through surface run-off. The result of this finding is consistent with the report of Akpan (2004) when working on water bodies in Uyo, Fatoki *et. al.,* (2001) in Umtata River (South Africa) and George & Atakpa, (2015b) in Cross River Estuary. Comparatively, higher values were considerably observed for all the stations in the wet than dry season. However, the mean difference between the dry and wet season's values of TDS was statistically significant both in space and time during the study.

DO concentrations varied between seasons with wet season concentration significantly higher than that of the dry season. The observed dissolved oxygen concentrations were within the tolerable range recommended by WHO (2011). Dissolved oxygen concentration beyond 4 mg / L is excellent while below 4 mg / L is injurious to aquatic life. Dissolved oxygen levels were higher in the wet season than in the dry season due to the increased current flow that enables the diffusion and mixing of atmospheric oxygen into the water. This finding is consistent with those reported for River Osun (Welcomme, 1979), Zambezi River (Hall *et al*., 1977), Qua Iboe River (Akpan, 1993) and Cross River Estuary (George and Atakpa, 2015b). These authors observed that tropical African aquatic systems generally have low DO in the dry season than the wet season.

BOD and NO_3^- varied significantly both spatially and temporally while PO_4^{3-} and NH_3 varied significantly only in space. Higher mean value was recorded for these parameters in the wet season than dry season. The wet season increase in these parameters was attributed to increased input from agricultural farmlands and decomposable organic matter brought in by surface runoff into the water body emanating as a result of human perturbations. The observed wet season high values in this studies is in accordance with those reported by Akpan and Offem (1993) for Cross River Estuary; Akpan (1993) for Qua Iboe River, Nigeria and Ebere (2002) in Okrika Creek, Nigeria. The values of these parameters did not exceed the WHO (2011) benchmark standards exception of NH_3 whose value exceeded the permissible limit for portable water.

Cl^- and SO_4^{2-} were considerably higher during the dry season and varied significantly both spatially and temporally. The elevated values of chloride and sulphate observed in this study during the dry season were attributed to dilution through municipal runoffs and precipitation during the wet season and evapocrystallization process increase chloride and sulphate ion concentration in the water during the dry season. This observation agrees with the findings of Chindah and Braide (2001) and Ebere (2002).

In this study, higher dry season mean values of trace metals than wet season values were observed. This trend may be due to dilution through municipal runoffs and precipitation during the wet season and adsorption to sediment particles because of reduced water volume usually associated with increase evaporation rate in the dry season (Obasahan, 2008). It was however, observed that all the trace metal studied showed significant variation in space and time exception of Zinc which varied significantly only in time suggesting similar anthropogenic activities within the stations. However, it was observed that some of the studied trace metals exceeded Federal Ministry of Environment (FMENV) and World Health Organization (WHO) permissible limit for portable water which calls for concern regards human health.

The use of correlation analysis in establishing relationships within and between variables, locations and organisms is well established in literature (Benson *et. al*. 2016). Positive correlations between physico-chemical parameters denote that an increase in one of these parameters leads to a corresponding increase in the other. These inter-relationship patterns may arise from high inflow of particulate matter from run-offs, coastal farmlands and release of untreated sewage into the water leading to an increase in organic materials in the water column. This belief stems from the fact of Mahananda *et. al.* (2010) that total suspended solids are composed of carbonates, chlorides, phosphates, bicarbonates and nitrates of calcium, magnesium, sodium, potassium, manganese, organic matter, salt and other particles. This synchronizes the correlation trend as observed during the study.

5.0 Conclusion

Results of studies conducted on the water quality of Imo River to assess its suitability for human consumption indicated variation in the quality of water emanating from human activities with respect to some physico-chemical parameters that were above threshold limit. The physico-chemical parameters such as Ammonia, lead, iron, copper and cadmium were above the permissible limit for portable water as recommended by FMENV and WHO. This suggests that human activities within the study area posed a serious threat on the quality of water of the river system. Most chemicals arising in drinking water are of health concern. A few chemical contaminants have been shown to cause adverse health effects in humans as a consequence of prolonged exposure through drinking water. It has been established that long term accumulation of lead in body tissues has neurotoxic, nephrotoxic, fetotoxic, and teratogenic effects on man just like most heavy metal contaminants. The seasonality observed in the parameters during the study was attributed to influx of allochthonous materials and dilution as a result of surface run-off during the wet season and evapo-transpiration during the dry season. Spatial variation during the study was attributed to the nature and levels of human activities emanating within each of the stations. Direct relationships between pairs of physico-chemical parameters as observed mandates that an increase in one parameter result in a corresponding increase in the other parameter. This study vindicate the essence of continuous monitoring of our water bodies as this will help to give vital information on the status of water bodies in Nigeria and to expedite remedial measures in the event of pollution.

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