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SEASONALITY OF SURFACE WATER CONTAMINATION BY HEAVY METALS IN THE LOWER ENYONG CREEK, S.E. NIGERIA)

O. M. UDOIDIONG, C. E. UDOSEN, M. U. OKOROJI, A. S. ETOK

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ABSTRACT:

Surface water samples from three locations in the Lower Enyong Creek, S.E. Nigeria were sampled over six months i.e June to October (wet season) and November in dry season for heavy metals such as Cd, Mn, Fe, Cu, Ni, Pb, Zn, Cr) using Atomic absorption spectroscopic method. Some specific physicochemical characteristics, such as temperature, hardness, alkalinity, salinity, TDS, TSS, pH and conductivity which are known to influence the interactions and dynamics of trace metal loads in water bodies were also determined. The result of the analysis indicated significant monthly variation of these parameters for the six months. Monthly summary statistics revealed a few seasonal patterns that echoed the hydrologic regime. During the short dry season in August–September period, all the sampled stream channels had lower levels of Cd, Ni, Zn, Cu Cr, Pb and Fe. Salinity, for instance, correlated strongly ($p<0.05$) with Cu (0.70); Cr (0.56); Ni (0.72); nitrate (0.61) and Na (0.49). However, the concentrations of most heavy metals were low, while Zn content was higher than the WHO standard for surface water which indicated significant contamination by Zn in the water body.

KEYWORDS: Surface water Heavy metals, Enyong Creek, Pollution and monthly variation

INTRODUCTION

According to Garbarino et al (1985) and Durube et al (,2007), heavy metals are chemical elements with specific gravity that is at least four to five times the specific gravity of water at the same temperature and pressure. These metals such as Pb, Cu, Cd, Cr , Zn, Fe, and Ni are among the most common environmental pollutants in the river systems. The hydrologic cycle clearly shows that contaminants in air, soil or on land ultimately end up in the river systems. However, the land-phase components of the hydrologic cycle viz; surface run-off, infiltration, sub-surface flow, percolation, and leaching of rocks and regolith may affect their concentration within any drainage basin. In addition, fertilizer application on farmlands, sewage, industrial wastes and petroleum exploration and exploitation are well known causes of surface water pollution. Hence, heavy metals belong to the group of elements whose hydro-geochemistry cycles have been greatly accelerated by man. Anthropogenic metals emission into the atmosphere such as Pb, Cu, Zn, Cd and Cr are 1:3 orders of magnitude higher than natural fluxes. As a consequence, these elements are expected to become increasingly accumulated in river systems.

The activity of trace metals in river systems and their impact on life vary depending upon the metal types. Of major importance in this regard is the ability of metals to associate with other dissolved and suspended components. Most significant among these associations is the interaction between metals and organic compounds in water and sediment. These organic species, which may originate naturally from process such as vegetative decay or result from pollution through organic discharge from municipal and industrial sources, have a remarkable affinity and capacity to bind metals (Signer, 1974). We do know that once these particles are incorporated into the fluvial ecosystem, they quickly become absorbed into the food web leading to mutations, change in tissue matter, biochemistry, behavior, reproduction and suppress growth in aquatic life, as well as cause disease which can be harmful to humans.

According to Salati and Moor, (2009), the persistence and non-bio-degradability of heavy metals may result in their bioaccumulation and bio-magnification in the fluvial environment and thus they are also known as 'chemical time bombs'. Often, natural and human disturbances release pollutants to the overlying water, where pelagic (water column) organisms can be exposed. In a recent

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study, Ogri et al, {2011), observed that the concentration of most metals in river system vary significantly between seasons, although differences in geology may influence the types and concentrations of the metals.

Arising from the foregoing, Enyong Creek, which may have resulted from the Imo River capturing its head waters at a point near Umuahia in SE. Nigeria (Udo, 1970) was chosen for detailed study of seasonal variation in metals loads. The river system is underlain by a wide variety of rocks including cretaceous shale and sandstone. The river is also subjected to organic pollution load arising from the effluent discharge from cassava processing mills near the river bank. This study becomes imperative because the basin is very rich in nutrients and as a result harbours numerous fishery resources. This work is aimed at assessing the seasonal variation in concentration of some heavy metals (Cd, Cr, Cu, Zn, Pb, Ni and Fe) in surface water in three locations within the lower Enyong Creek.

The Study Area

The investigated area is enclosed between latitudes 5°11′to 5°28′ N and longitudes 7°51′ and 7°59′E (Figure 1 It was delineated from toposheet No: Ikot Ekpene 322 NE on 1:50,000 scale.

Study locatios:

This study was conducted on three locations along the Enyong Creek viz; stream channels at Ito, Obio Usiere and Okopedi (Figure1). The geographic co-ordinates are listed in Table1.

Table 1: Sampling Villages and location.

Village	Location	
Ito	5°19.227’N	007°56.291’E
Obio Usiere	5° 15.693’N	007°56.970”E
Okopedi –Itu	5°12.144’N	007o58.913’E

Geologically, the area under study is underlain by a wide range of diverse geological formations ranging from Asu River Formations e.g the Abakiliki Anticlinorium to the recent alluvium in the south. The Asu River Group underlies most areas in the northern part of the study area e.g its intensely fractured outcrops at Uburu. The Asu River Group, which is Albian in age is sub-divided into three formations, comprising essentially of over 200m bluish grey to olive brown shales and sandy shales, fine-grained micacceous and calcareous sandstones and some limestones (Offordile, 2002). The area is well represented by structurally controlled ridges, denudational hills e.g the 150m high Obotme conical hill, steep-sided valleys, saddle and col at Obot Ito Ikpo, extensive wetlands and alluvial plains forming soil covers of silty clay, sandy and heavily weathered loamy and alluvium. The area enjoys tropical climate and the temperature ranges from 26 to 32º C. The fluctuations in temperature are fairly uniform in character, except during the dry months when the rise in temperature is higher than it is during the long wet period (eight months -March to October) and the level of humidity is high (84%) due to close proximity to the main Cross River Channel.

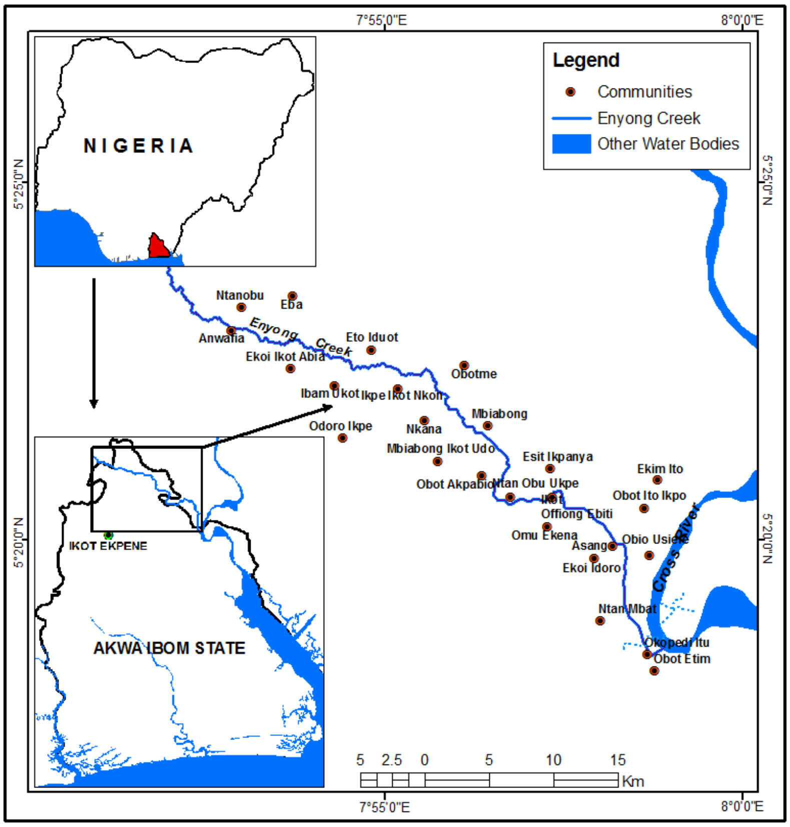


Figure1: Location of Lower Enyong Creek

The details of annual and monthly rainfall for Umudike (the closest station to the basin indicates that rainfall ranges from 1511mm in 1983 to 2572mm 1996 with a mean annual of 2156mm, c.v.=44.4% recorded between 1972 and 2012 (Table 2). The monthly distribution of rainfall is shown in Table 2 and Figure 2 clearly shows eight wet months -March to October, while the dry months are November to February. The rainfall pattern is uni-modal, but the little dry season in August may occur in some years. In the humid tropics rainfall is the main input into the river system and hence, Thornthwaite''s water balance was computed using rainfall and evaporation data (Udosen, 2000) to illustrate groundwater movement.

Table 2: Monthly Rainfall distribution at Umudike (1972-2012)

Month	Range in	Mean	Raindays/month
Jan	0-78	15	1
Feb	0-132	38	3
Mar	4-266	113	7
Apr	70-357	176	12
May	102-445	270	16
Jun	101-576	288	18
Jul	166-450	292	21
Aug	103-535	306	21
Sep	206-670	341	21
Oct	75-499	257	16
Nov	0-212	53	5
Dec	0-35	7	1

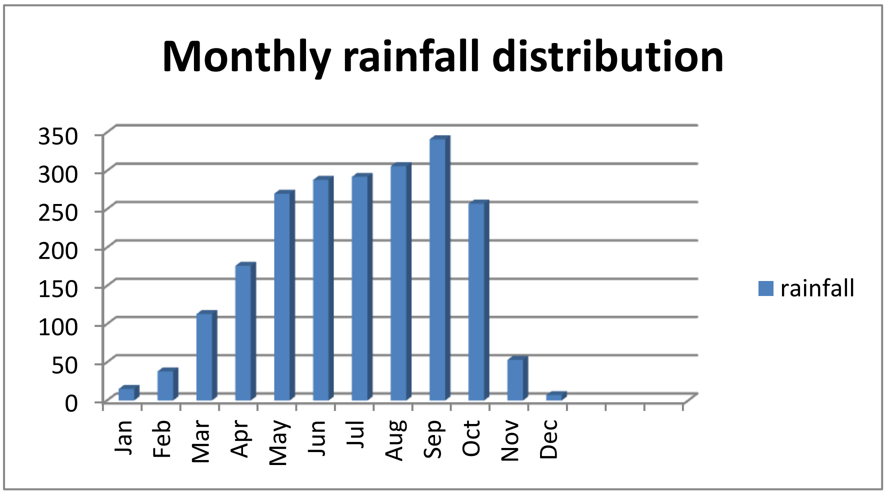


Fig 2: The mean monthly rainfall at Umudike, (1972-2012)

The results indicate a runoff coefficient of 0.68 for Uyo, located barely 18km south of the study area. The implication is that over 60 percent of rainfall is converted to surface runoff, depending on amount and type of vegetation, soil infiltration rates and slope characteristics. Furthermore, the computed water balance indicates that ground water contributes significantly to channel flow from June to September (Fig. 3). The demobilized rock minerals and metals may enter the river system from ground water between June and September

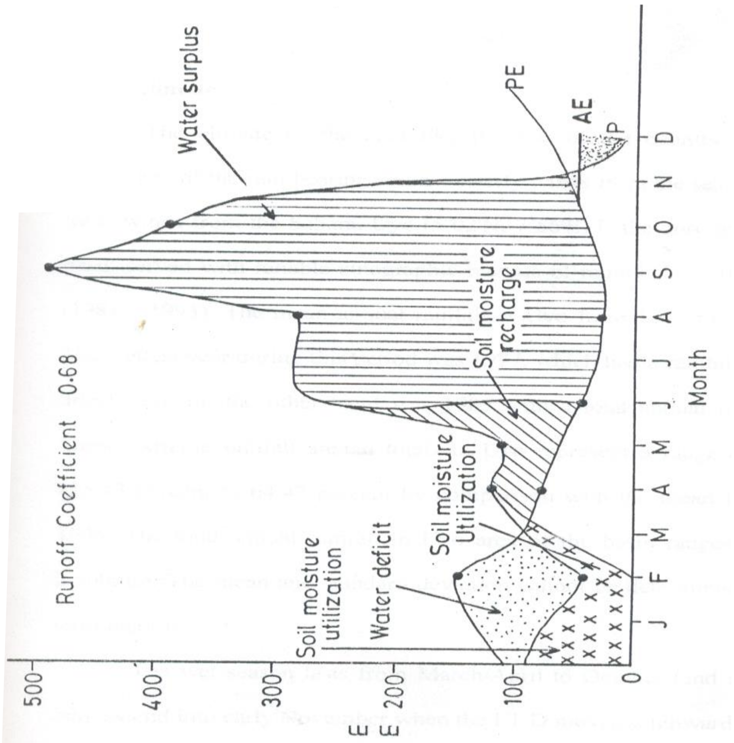


Fig. 3: Water Balance [Uyo]
Source: Udosen, (2000)

Materials and methods

Sampling was done from the three established sites between June and November, 2014 (heavy metals and physiochemical properties), Schlosser, 1982; Hanson, 1973; and Bartram and Balance, 1996). The water's chemical analysis was done using standard analytical methods of water analysis (Bartram and Ballance, 1996; APHA – AWWA – WPCF, 2005; USEPA, 1979). Sampling was done at specific time intervals (i.e 10am). At each sampling location, the surface water samples were collected at the middle of the river and stored in clean polythene bottles that have been pre-washed with nitric acid and thoroughly rinsed with deionized water (Bartram and Balance, 1996). Non-conservable parameters such as temperature, pH and electrical conductivity were determined, at the time of sampling, in the field (*in situ*). Water samples were collected approximately 15 – 20cm below the water surface with 125cm^3 using pre-cleaned and chemically neutral 1 litre plastic vessels for laboratory analysis of other physic-chemical parameters. AAS was employed for trace metals analysis

Statistical analysis: SPSS package was employed in both descriptive analysis and inferential statistics; pair-wise Pearsons Product Moment correlation (PPMC) to establish significant relationship between the physicochemical parameters, while factor analysis was employed to collapse the variables and sieve out redundant variables, as well as, isolate the sources of water pollution.

Results and Discussion

Descriptive statistics of physicochemical parameters (temperature, $_P$H, salinity, dissolve oxygen, total suspended solids (TSS) total dissolved solids (TDS), hardness, alkalinity, Na, NO_3,Ca,Mg, K, ammonium and conductivity in surface water studied at Ito, Obio Usiere and Okopedi during dry and wet season are presented in Table 3.The pH was slightly acidic in a range 5.55-6.46, 5.58- 6.34 and 5.62-7.08 and corresponding mean values of 6.09±0.4, 6.39±0.44 and 6.3±0.59 for Ito, Obio Usiere and Okopedi respectively. The range in $_P$H values is peculiar to Nigeria. The moderately acidic pH condition affects metal speciation and may enhance metals' solubility and possible leaching into the water column

Table 3: Changes in Physicochemical parameters at different locations/sub-catchments in lower Enyong Creek.

Physicochemical parameters	Min-max (Mean ±SD) ITO	Min-max (Mean ±SD) OBIO USIERE	Min-max (Mean ±SD) OKOPEDI
DO	2.85-3.88 (3.25±0.4)	2.88-3.71 (3.24±0.37)	0.90-8.4 (3.67±2.77)
Temperature	28.1-30.6 (28.3±0.1.24)	28.3-31.2 (29.38±1.02)	27-29.5 (28.38±0.99)
pH	5.55-6.49 (6.09±0.6)	5.58-6.83 (6.39±0.44)	5.62-7.08 (6.3±0.59)
Conductivity	4.14-61.3 (28.5±19.4)	5-42.5 (28.55±3.12)	16.9-89.2 (39.3±65.8)
Salinity	0.07-0.60 (0.33±0.4)	0.07-0.80 (0.26±0.17)	0.08-0.50 (0.22±0.15)
TSS	*0.00-0.007* (*0.013*±0.002)	0.0-0.004 (0.002±0.053)	0.0-0.04 (0.01±0.08)
TDS	7.00-16.72 (10.45±1.3)	2.0-19.72 (9.15±1.9)	2.0-11.0 (7.4±2.83)
Hardness	4.96-6.72 (5.27±0.6)	5.2-10.2 (46.62±70.03)	5.6-14.6 (7.9 ±3.4)
alkalinity	5.50-175 (102.8±5.9)	5.4-180 (90.68±59.15)	5.6-200 (99.4 ± 63.5)
Nitrate	1.32-3.01 (1.96±0.49)	1.37-3.26 (2.02±0.74)	1.37-3.46 (1.36 ± 1.2)
BOD	0.10-0.46 (0.3±0.16)	0.15-0.9 (1.40±0.98)	0.55-6.3 (1.98±2.17)

Source: Analyzed from Field Data, 2014

Water temperature, which is influenced by latitudinal location, season, air circulation, turbidity, amongst others ranged between 27°C and 31.2°C for all the stations. The temperature of natural inland waters in the tropics generally varies from 25°C to 35°C (Alabaster and Llyod, (1980). However, temperature range is critical, as it affects physical, chemical and biological processes in water bodies and consequently leading to alteration of concentration of dissolved oxygen. Hence, water temperature can strongly influence the feeding patterns, growth rates and breeding seasons of fish and shell fishes (Ezekiel et al, 2011). DO levels in the lower Enyong Creek ranged from 2.85 to 3.88 (3.25±0.4); 2.88-3.71, (3.24±0.37) and 0.90-8.4 (3.67±2.77) for Ito, Obio Usiere and Okopedi respectively

The concentration of DO in the lower Enyong Creek is affected by organic wastes and other nutrient inputs from sewage, agro-based cottage industries as well as agricultural and urban runoff, all of which can lead to a decrease in oxygen levels. Concentrations of DO in unpolluted waters are usually about 8-10 mg L^{-1} (Joseph and Jacob, 2010) and streams with a high DO concentration (greater than 8 mg L^{-1}) are considered healthy and are able to support a significant diversity of aquatic organisms. The dry months (November to February are usually the most critical time for DO levels because stream flows tend to lessen and water temperatures tend to increase. In general, DO levels of less than 3 mg L^{-1} are stressful to most aquatic organisms (WHO,2003). Table 3 shows that few of the water samples exhibited DO values less than 3 mg L^{-1}. As a result, the water at these sites will not maintain most aquatic organisms. The monthly DO (mg L^{-1}) values were as follows: June (3.00-3.88), July (3.11-3.91), August (3.25-3.28), September (3.68-8.4), October (2.04-2.76), November (0.9-2.88)- Table 4.

Table 4: Seasonal Variation of DO (in mg/l) in the lower Enyong Creek

Location	June	July	August	September	October	November
Ito	3.88	3.11	3.25	3.48	2.95	2.88
Obio Usiere	3.01	3.21	3.71	3.68	2.96	2.88
Okopedi	3.00	3.91	3.78	8.4	2.04	0.9

The mean values of salinity decrease downstream viz; 0.33±0.4, 0.26±0.17 and 0.22±0.015 recorded at Ito, Obio Usiere and Okopedi respectively (Table 3). Usually, salinity of surface water does not vary significantly along the coast due to the effects of tidal movements, waves and wind. Enyong Creek is neither influenced by tides nor waves and salinity values range from 0.07 to 0.80 mg/l for all the sample sites while the seasonal variation shows higher values in dry season (in this case November) as illustrated in table 5. This is contingent on low flow of water, decrease in water level, high rates of evaporation and salt water intrusion from the main Cross River channel

Table 5: Seasonal Variation of Salinity in the lower Enyong Creek

Lotion	June	July	August	September	October	November
Ito	0.30	0.09	0.07	0.40	0.50	0.60
Obio Usiere	0.20	0.08	0.07	0.20	0.20	0.80
Okopedi	0.20	0.10	0.08	0.20	0.22	0.50

In a related study, Dan et al (2014) established significant correlation between salinity and heavy metals in the dry season. They concluded that metals ions may have become immobile by the salt ions resulting in decrease in the levels of heavy metals in the surface water during dry season

Comparison of the overall distributions of water quality characteristics reveals differences between the three streams (Table 3 and Figs 4-7). Data for each stream shows that mean TSS was five to ten times higher between July and October at Okopedi-(downstream) than in Ito and Obio Usiere (Table 6) while TDS levels in all the stations were higher in June than any other month (Table 7 and Fiig.4). TDS also exhibited spatial variation and tended to increase in the upstream sample sites (Ito and Obio Usiere) as shown in Fig.4

Table 6: Seasonal variation of TSS in the lower Enyong Creek

Location	June	July	August	September	October	November
Ito	0.00	0.00	0.07	0.003	0.001	0.003
Obio usiere	0.00	0.00	0.002	0.004	0.002	0.002
Okopedi	0.00	0.00	0.04	0.002	0.023	0.002

Table 7: Seasonal Variation of TDS in the lower Enyong Creek

Location	June	July	August	September	October	November
Ito	16.72	9.00	7.00	9.00	10.00	11.00
Obio siere	19.72	2.00	7.00	7.00	9.20	10.00
Okopedi	11.00	2.00	6.00	7.00	8.20	10.00

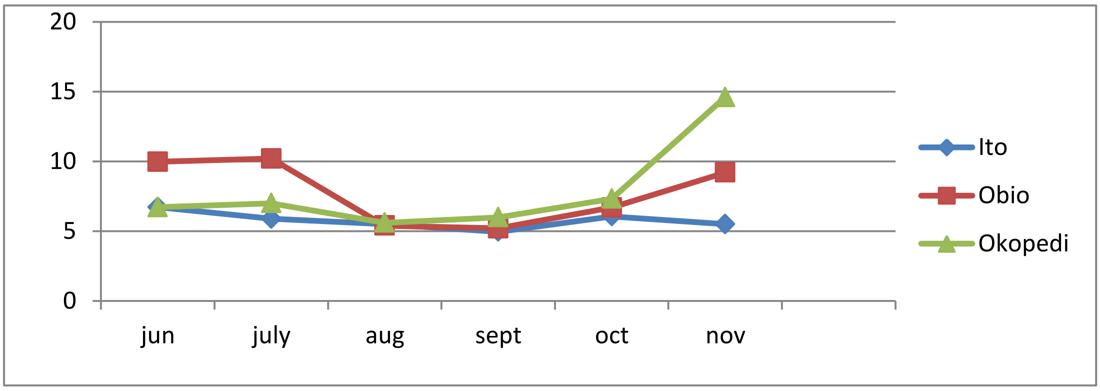


Fig.4 Seasonal Variations of TDS (mg L^{-1}) in surface water samples

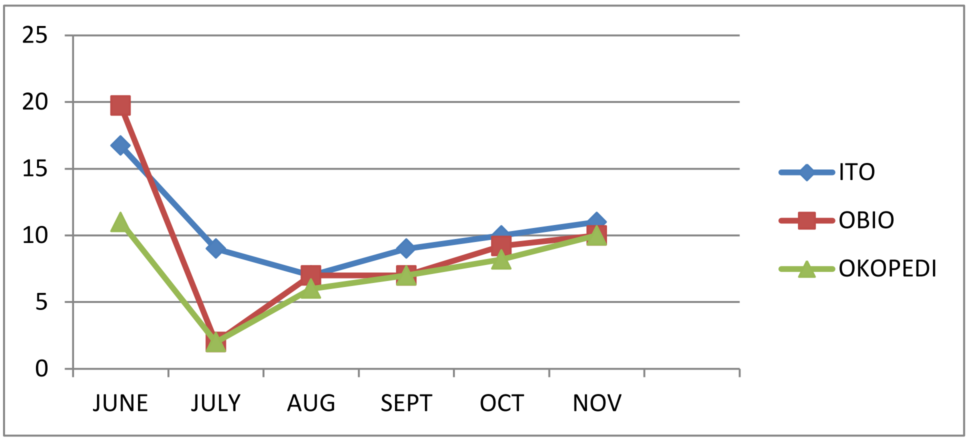
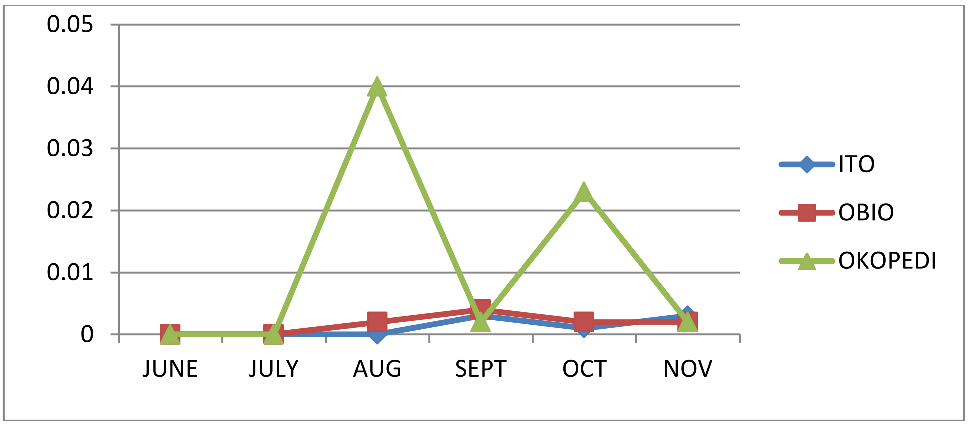
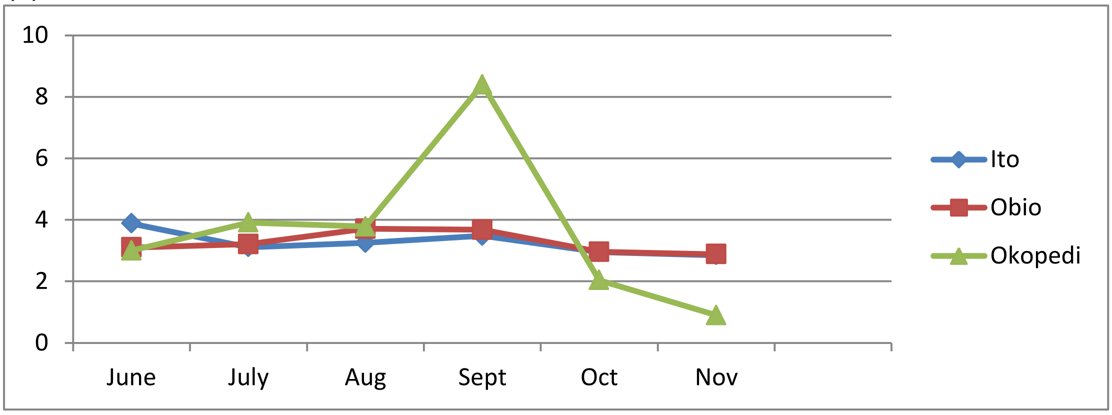


Fig. 5 Seasonal Variations of TSS (mg L^{-1}) in surface water samples



The three streams displayed similar distributions of nitrate, sulphate, potassium, magnesium, calcium and ammonium Table 3. Others studies have noted the linkages between flashy hydrology and elevated levels of nutrients in streams (Pionke et al, 2000;). Enyong Creek is not characterized by this hydrograph and the longitudinal differences in chemical water quality may reflect land use along the study reaches

(A)



(B)

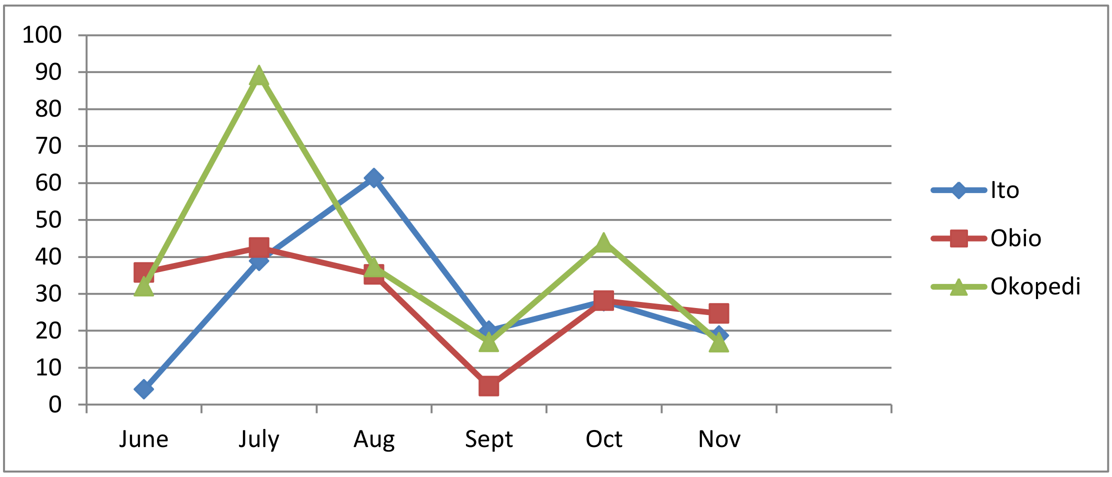


Fig 6: Monthly Variation in Total Hardness (A), dissolved oxygen (B), Conductivity (C) and $_P$H (D)

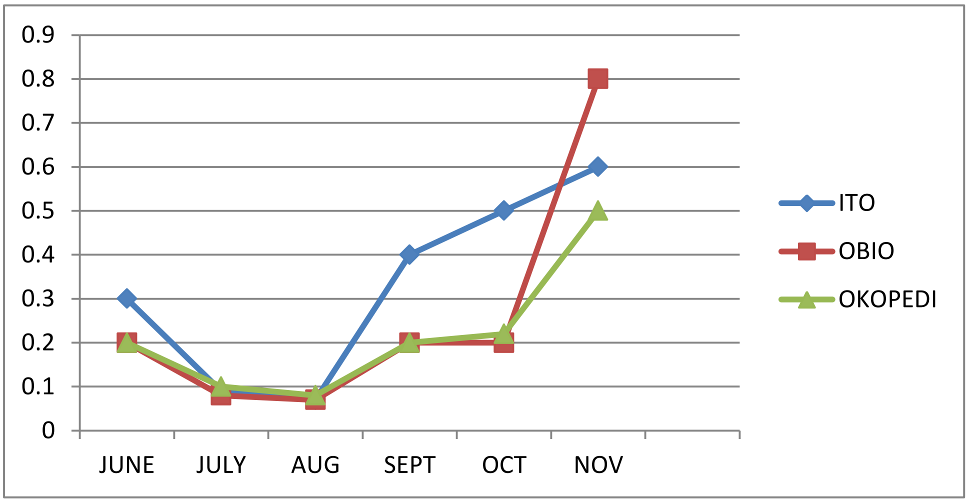


Fig. 7: Seasonal Variations of Salinity (mg L^{-1}) in surface water samples

It is observed from table 8 that the concentration of each metal in the surface water generally increases from station I to I1I. It is difficult to make an overall assessment of the degree of the contamination of surface water by heavy metals because of the variations in the concentration of heavy metals within locations. As can be seen from table 8, metal levels in the three stations exist in the order of Zn (0.14-1.9) > Fe (0.13 -1.5) > Cu (0.04 -0.9) > Ni (0.02-0.14) >Cr (0.01-0.42) > Pb (0.01-0.81) > Cd (0.01-0.2) measured in mg/l of which were generally lower than those reported for Lagos lagoon (Okoye, 1991) and Niger Delta coastal waters (Kakulu et al, 1988). However, similar trend in some heavy metals distribution was obtained in other similar studies. The high concentrations of Zn in the surface water have no identifiable point source discharge rather than non-point source discharge of wastes/effluents and lithological or crustal origin. There is no doubt that wastes generated due to human activities are discharged on land or stream in and around the study area were transported by surface run-off to the water body by rain. Thus, contribution from run-off in this regard may be significant as evident in Table 8. On the other hand, the relatively low metal level recorded in the study may be attributed to the preponderance of rural settlements in Enyong watershed.

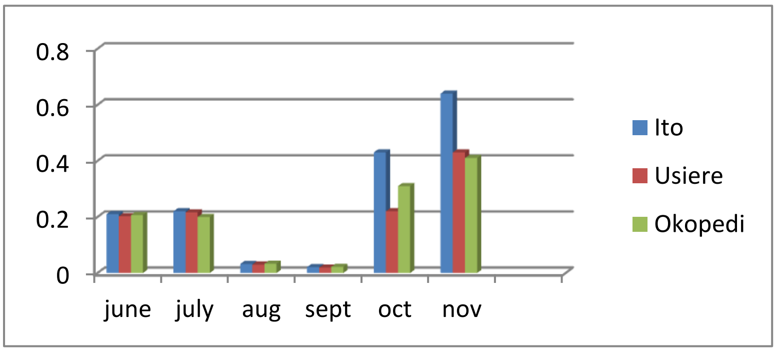
Table: 8 Changes in Trace metals loads of different locations/sub-catchments in lower Enyong Creek.

Trace metals	Min- max (mean ±SD) ITO	Min- max (mean ±SD) OBIO USIERE	Min- max (mean ±SD) OKOPEDI
Cu	0.026-0.889 (0.275±0.04)	0.006-0.9 (0.3058±0.04)	0.009-0.856 (0.298±0.117)
Fe	0.186-1.125 (0.697±0.06)	0.132-1.583 (0.638±0.142)	0.17-1.51 (0.638±0.242)
Zn	0.143-1.535 (0.962±0.684)	0.199-1.921 (1.143±0.728)	0.146-1.76 (1.092±0.734)
Pb	0.005-0.083 (0.0377±0.007)	0.002-0.1 (0.044±0.012)	0.001-0.081 (0.0037±0.0012)
Cr	0.021-0.415 (0.147±0.104)	0.011-0.348 (0.1093±0.014)	0.014-0.0352 (0.109±0.014)
Cd	0.005-0.112 (0.027±0.004)	0.002-0.202 (0.038±0.009)	0.001-0.13 (0.048±0.027)
Ni	0.021-0.643 (0.261±0.025)	0.019-0.437 (0.188±0.111)	0.022-0.411 (0.197±0.023)

Source: Analyzed from Field Data, 2014

Monthly summary statistics revealed a few seasonal patterns that echoed the hydrologic regime. During the short dry season in August–September period, all the sampled stream channels had lower levels of Cd, Ni, Zn, Cu Cr, Pb and Fe. Total hardness and conductivity levels exhibited patterns similar to heavy metals, but dissolved oxygen did not. DO levels rose during the drier August break in the downstream channel, while hardness values were much higher during beginning of the four dry months in November, possibly reflecting periods of lower groundwater inflows for each stream, particularly downstream. Salinity levels were elevated by about a factor of three during the drier months of November through April

(A)



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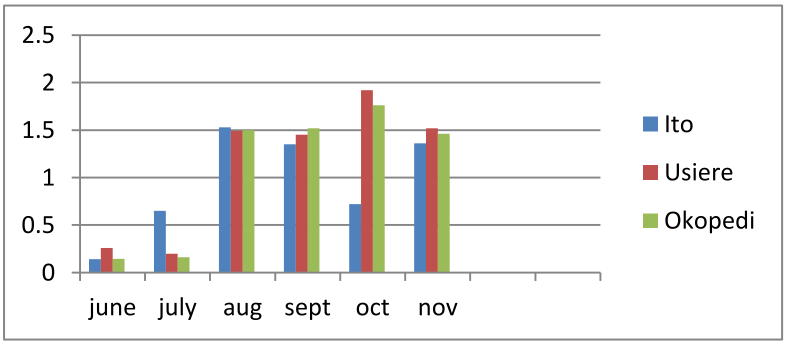

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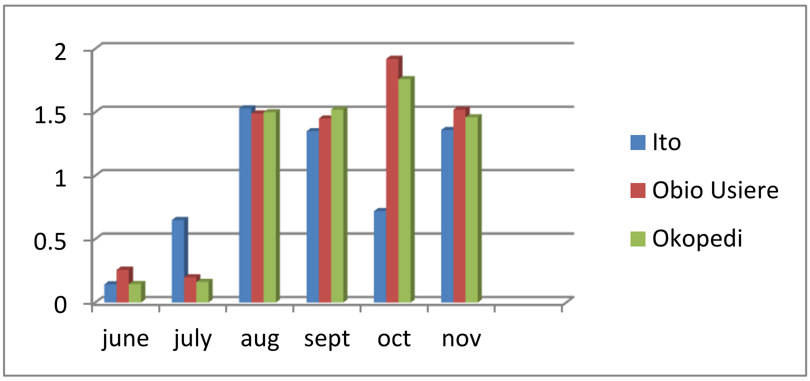
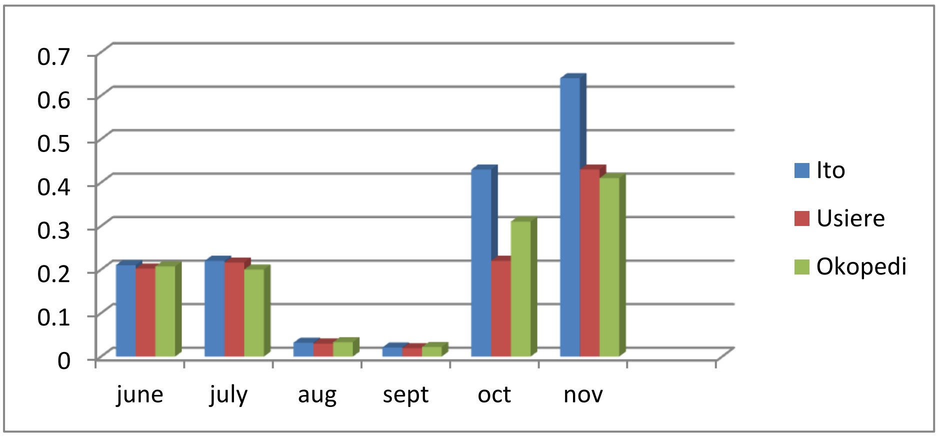


Fig. 8: Seasonal variation in Cd (A), Fe (B) and Cu(C) in the Lower Enyong Creek

(A)



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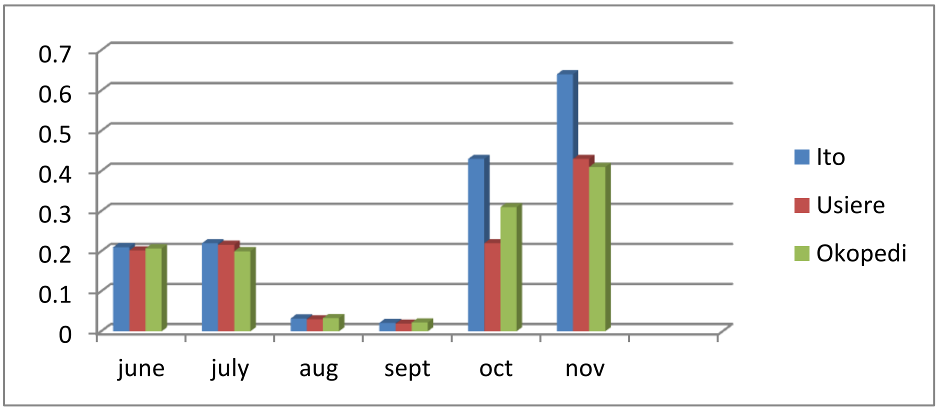

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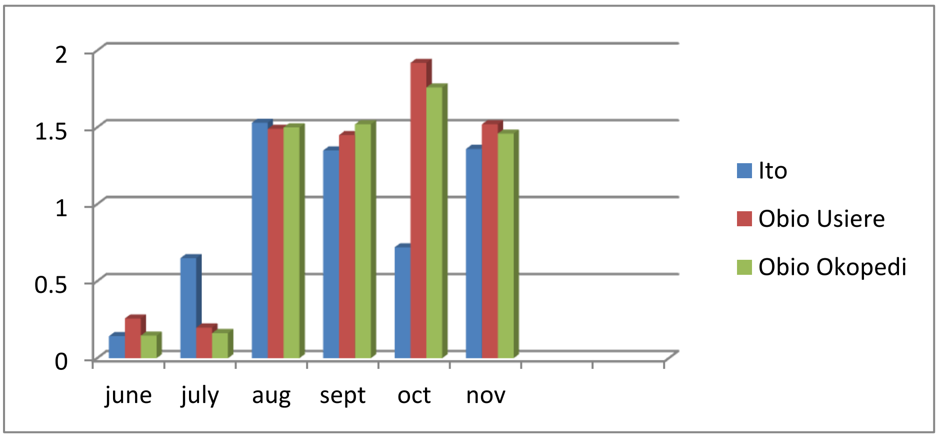

Fig. 9: Seasonal variation in Ni (A), Pb (B) and Zn (C) in the Lower Enyong Creek

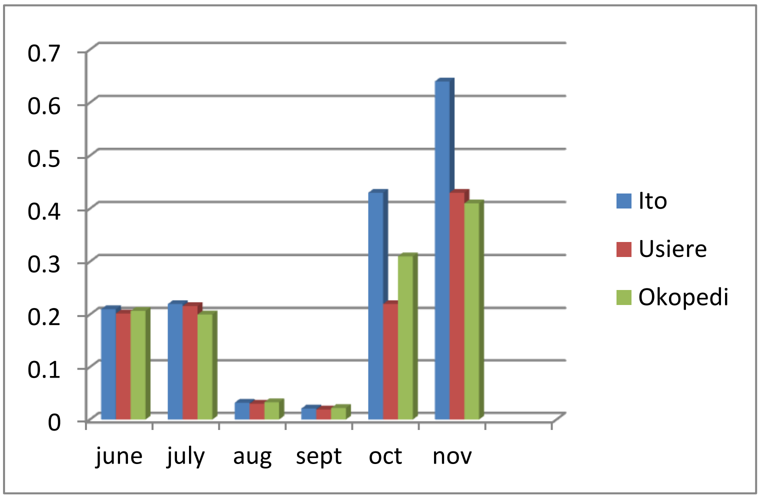

Fig. 10. Seasonal variation in Cr in the Lower Enyong Creek

Matrix of correlation coefficients between the physicochemical and metal levels in the surface water in the Lower Enyong Creek monitored for six (6) months (Table 9) indicates that only 25% of the 206 possible relationships were significant ($p<0.05$). The high correlation between metals such as Cu versus salinity (0.70); nitrate (-0.49) ammonium (-0.53) Fe versus temperature (-0.72); Zn versus ammonium (-0.76), potassium (0.51), and alkalinity (-0.52) indicates common lithological or crustal sources for the metals rather than the anthropogenic sources (Turekian, 1977). Their sources are essentially natural through geological modification –dissolution from cretaceous rocks. Also, Ni correlates strongly with salinity (0.72) while Cd shows negative relationship with alkalinity (-0.52) and Cr correlates negatively with ammonium (-0.55) and nitrate (-0.48) respectively. However, some identified anthropogenic sources of Ni, Cr and Cd include runoff from mechanized agricultural fields, domestic sewage and chemical wastes discharged into river channels. Another possible source of Ni is discharges from exhaust of boats. The relationships between Pb and electrical conductivity (0.72) as well as calcium (0.51) were equally significant at 0.01level.

Table 9: Correlation matrix of physicochemical/heavy metals parameters in the Lower Enyong Creek

Parameter	Cu	Iron	Zn	Lead	Cr	Cad	Nickel	Salinity	TDS	Total SS	Hardness	Alkalinity	Sulphate	Diss O	Nitrate	calcium
Fe	.24	-														
Zn	.45	.53*	-													
Pb	-.18	-.30	-.48*	-												
Cr	.93**	.08	.36	-.18	-											
Cd	.49*	-.18	.45	-.16	.64*	-										
Ni	.81**	.17	-.07	.01	.75*	.10	-									
Sal.	.70*	.41	.20	-.25	.56*	-.04	.72*	-								
TDS	.12	-.02	-.25	-.34	.12	-.06	.26	.34	-							
TSS	-.13	.22	.37	-.13	-.11	.18	-.32	-.31	-.21	-						
Hard	.34	.16	-.15	.04	.13	-.12	.39	.28	.16	-.24	-					
Alka	-.12	-.08	62*	.17	-.21	-.55*	.25	.31	.51*	.61*	.29	-				
Sulp	-.34	-.39	-.15	.04	-.35	-.26	-.07	-.13	.71*	-.16	.11	.62*	-			
DO	-.22	-.21	.17	-.1	-.21	-.14	-.29	-.01	-.12	-.09	-.14	.04	-.18	-		
Nitrate	-.49*	-.09	-.19	.46	-.48*	-.16	-.38	-.61*	-.64*	.37	-.11	-.45	-.26	-.16	-	
Cal	-.26	-.09	-.07	.51*	-.25	.02	-.20	-.38	-.54*	.32	-.19	-.48*	-.30	-.23	.80**	-
Magn.	.30	.24	.32	-.08	.29	.13	.23	.39	-.21	-.49	-.14	-.30	-.48*	.05	.10	.46
Potas.	.09	.44	.51*	-.28	-.03	-.25	.01	.32	-.35	.14	-.31	-.26	-.64*	.18	.07	.12
Amm	-.53*	-.43	-.76*	.18	-.52*	-.37	-.14	-.42	.23	-.04	.10	.35	.72*	-.23	.37	.25
Sodium	-.35	-.08	-.1	.30	-.37	-.06	-.37	-.49*	-.60*	.4	-.04	-.16	-.08	.08	.45	.27
P^H	-.04	-.08	-.04	.19	-.05	.21	-.06	.08	.11	-.17	-.25	-.03	.24	-.23	.10	.29
Temp	.12	-.72**	-.32	.18	.32	.39	.15	-.07	.29	-.36	.02	.06	.31	-.24	-.22	-.22
Cond.	-.18	-.24	-.24	.72*	-.14	.01	-.12	-.46	-.49	.36	-.05	-.31	-.14	-.18	.60*	.54*
BOD	-.16	.18	.30	-.18	-.20	.25	-.33	-.29	-.22	.26	-.04	-.54*	-.09	-.05	.45	.45

Cu	calcium	magnesium	Potassium	Ammonium	sodium	pH	Temperature	Conductivity	BOD. .
Cal	-								
Magn.	.46	-							
Potas.	.12	.43	-						
Amm	.25	-.26	-.49*	-					
Sodium	.27	-.35	-.12	.15	-				
P^H	.29	.23	-.14	.06	.15	-			
Temp	-.22	-.36	-.44	.08	-.14	.16	-		
Cond.	.54*	-.28	-.18	.17	.43	.10	.14	-	
BOD	.45	.19	-.03	.06	.28	-.40	-.08	.48*	-
Transp	-.14	-.09	.16	-.05	-.31	-.25	-.15	-.04	-.10

Significant at 0.05 level * significant at 0.01 level**

CONCLUSION

This study presented data on the baseline pollution of surface water in the lower Enyong Creek by heavy metals. It is shown that the concentrations of heavy metals like Zn, Pb, Cr, Mn, Ni, Cu, and Cd in the surface water are low, but require quarterly monitoring to prevent an increase. The concentration of Zn is higher when compared with the background value and target/ intervention values for micro pollutant of a standard soil which may constitute risk to the environment. The concentration of heavy metals in the sediment increased from station I to station II. Local conditions are more important than basin-scale land use in determining physical characteristics of streams

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