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Accumulation of Cadmium (Cd) and Lead (Pb) in the Niger River and Environs

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Authors' contributions

This work was carried out in collaboration between all authors. Author ACCE designed the study, wrote the protocol. Author OLA gave very useful advises and criticisms. Authors ACCE and BUO wrote the first draft of the manuscript and did the final formatting of the article. Authors ACC, EMO and BUO made literature searched for the present study. Author BUO analysed the study and made statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

The study investigates the levels, variability of cadmium (Cd) and lead (Pb) in surface waters of Niger River and adjoining areas. Investigation of lead and cadmium concentration in surface water within Onitsha metropolis range from 0.204 mg/L- 2.316mg/L (River Niger upstream surface and Nwanaene lake) to 0.004 – 1.431 mg/L (River Niger upstream surface/ Creek surface and Nwanaene lake). All samples collected and tested by AAS were above the WHO standard of 0.01mg/ L for Lead and 0.003mg/L for Cadmium. Mean concentration of lead (Pb) and cadmium (Cd) shows that a significant difference exists in some of the sampled water sources. The concentrations of Cadmium in sampled sources varied from slight to very high (Cv = 18.52-148.57%) while in Lead, the concentration was slight to moderate (Cv =15.54-64.85%). Pollution of surface water in sampled locations was anthropogenic/ site specific (mainly from waste deposition as noticed in Nwangene Lake), urban treatment of effluent from industries and prohibition of

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dumping of any kinds of refuse and sewage into the rivers and lakes within Onitsha and environs need to be fully enforced.

Keywords: Lead; cadmium; water; onitsha.

1. INTRODUCTION

Heavy metals are described as those metals which, in their standard state have a specific gravity (density) of more than about 5 g/cm^3 [1]. Heavy metals pollution is a result of increasing industrialization throughout the world. Industrial effluents and other wastes not properly recycled or treated are discharged into the environment due to inadequate environmental impact monitoring or enforcement in the state. Wastes generated from above named activities one way or the other impacts on the hydrological cycle thereby polluting or contaminating water resources. This is so because most of the water are not protected or monitored qualitatively, thereby exposing them to varying types of pollutants. This situation could be attributed to low level of awareness among the inhabitants, non enforcement of water laws and pollution control measures which apply to the water resources in the study area.

These wastes require special control, treatment and disposal methods. The practice of dumping of refuse and wastes is common in both the old urban areas and the new-urban areas adjoining them. Efficient waste management requires provision of well selected, designed and operated sanitary landfills. One consequence of open dumping is that large areas of land are required. Also nuisance from smell, contamination of surface and subsurface water and damage to arable land are experienced. Surface, ground water and land are polluted by flow of effluents into boreholes, wells, streams and rivers. Due to the importance of good water quality, monitoring of pollutants has become imperative. Nigeria's Decree 58 of 1988 established the Federal Environmental Protection Agency [2] and empowers it to protect the Nigerian environment from destruction. This law has not been effectively enforced and this has consequently allowed indiscriminate pollution of the environment.

2. DESCRIPTION OF THE STUDY AREAS

Onitsha is located in Anambra State in Eastern Nigeria and lies within latitudes 5°22^1 and 6°48^1 and longitudes 6°32^1 and 7°20^1. Onitsha in Anambra State is located on the east bank of River Niger and covers an area of about 49,000km^2. It is one of most important commercial centres in sub-Sahara African, as well as a transit city in Nigeria. It has an estimated population of about one million inhabitants. The socioeconomic characteristics of Onitsha consist of about 75 percent labour force that is engaged in tertiary sector, such as, trading and services. The remaining 25 percent of labour force is engaged in manufacturing and industrial activities. However, Onitsha is a centre for the production of local goods and services, as well as, a market for the sale of foreign goods. The Onitsha main market, which is reputed as the largest market in sub-Saharan Africa, has increased the tempo of commercial activities in the city in recent times. There are two main seasons the dry season, October – March and the rainy season (April – September) approximately corresponding to the dry and flood phase, respectively of the hydrological regime. The vegetation is derived guinea savannah [3].

3. METHODOLOGY

3.1 Sampling Strategy

Eleven sampling stations were chosen within the study area Fig. 1. The selections of these eleven sampling stations were based on observed possibility of contamination from activities/ industries in sampled locations. This research work was conducted between periods of 2004-2008. Before sampling, all the laboratory apparatuses and polyethylene bottles were sterilized by soaking overnight in 5% (v/v) nitric acid prior to rinsing with distilled water [4].

Research was performed in an enclosed and pollution free laboratory to minimize the potential risk of contamination. Five samples were collected and homogenized from each sampling station in order to obtain an average value for the analysis. Each bottle was properly labeled with its corresponding sampling station.

3.2 Heavy Metals Determination in Sampled Water

An experimental method of research was performed to assess the presence or absence of toxic heavy metals in selected samples and the concentration of each heavy metal when present. The selected heavy metals were Lead and Cadmium. Analysis of the heavy metal contents in the water samples was done with the use of UNICAM 969 model atomic absorption spectrophotometer (AAS). This method is based upon the absorption of radiant energy, usually in the ultra-violet and visible regions by neutral atoms in the gaseous state. Water sample were stored in 50ml of PVC bottles. Samples for heavy metal analysis were digested using nitric acid (65% purity) as described in the APHA methods [4].

3.3 Data Analysis

Analyses were conducted using the raw data obtained from the sample analysis. The obtained data were analyzed using SPSS v.18 and Minitab v.16 for descriptive statistic and also verify the relationship between various environmental matrices. This provides useful information about water quality for physical parameter analysis, such as the mean and average concentration of the water sample. Correlation coefficient, Covariance and one-way ANOVA were applied in order to test the sufficiency of one variable to predict another, to check variables variability in sampled sources and also to split the selected variables and sampling points into a finite number of groups with similar hydrogeochemical composition [5]. All obtained results were compared with the permissible limit of the World Health organization.

4. RESULTS AND DISCUSSION

The presence of heavy metals in the water is an alarming finding. The study aims to point out sources of contamination. Lead enters the human body in many ways; it can be inhaled from dust from lead paints, or waste gases from leaded gasoline. It is found in trace amounts in various foods, notably in fish, which are heavily subjected to industrial pollution. Some old homes may have lead water pipes, which can then contaminate drinking water. Heavy metals accumulate in water supply through human activity, such as industrial and consumer wastes. Commercial processes like mining, agriculture, manufacturing and the discarding of wastes in landfills are common source of heavy metal contamination. Rainwater, with its acidic pH, can cause these compounds to leach into surface and underground water supplies from the surrounding soil and rock [6].

Fig. 2 shows extent of industrialization of Onitsha. Category A involved food manufacturing industries including beer, starch and other miscellaneous food products, flavouring, soft drinks, floor and grain milling,

Fig. 1. Map of Onitsha metropolis showing some of study locations (Adapted from Google Earth Map)

meat, poultry and fish, tea, coffee and other beverage, dairy products, e.t.c. Category B, paints, vanishes, soap and detergents, agro-chemicals, pharmaceuticals, dry cell batteries, petroleum products, toiletries, cosmetics and industrial chemicals. Rubber products, plastics, foam are depicted in category C while category includes foundry, metal manufacturing & fabrications, aluminum producers, e.t.c. 'E' depicts electronics manufacturing/ coupling industries, refrigerators, bulbs, power control & distribution equipment; 'F' textile materials, leather products ropes, e.t.c. 'G' furniture. Category H shows glass, ceramic, asbestos, chalk, cement packaging and I depicts boat fabrication, automobile manufacturers, e.t.c. These industries are distributed within the Onitsha metropolitan city, and a large chunk from them impact negatively on the surface water of the said sampled areas.

The concentrations of Cadmium and Lead studied in the surrounding area are shown in Table 1. The mean values of Cadmium were in the following increasing order: River Niger/ Creek road surface (0.006±0.001) < River Niger upstream surface (0.019±0.013) < River Niger Downstream surface (0.045±0.015) < River Niger upstream riverbed (0.061±0.039) < River Niger/ Otumoye surface (0.063±0.013) < River Niger/ Creek road riverbed (0.082±0.007) < River Niger central drainage riverbed (0.148±0.018) < River Niger Central drainage surface (0.157±0.022) < River Niger Downstream riverbed (0.255±0.043) < River Niger/ Otumoye riverbed (0.300±0.028) < Nwangene Lake (1.124±0.093), whereas Lead was in the order River Niger/ Otumoye riverbed (0.201±0.058) < River Niger upstream surface (0.290±0.030) < River Niger Downstream surface (0.302±0.031) < River Niger Central drainage surface (0.335±0.023) < River Niger/ Otumoye surface (0.424±0.100) < River Niger Downstream riverbed (0.439±0.063) < River Niger/ Creek road riverbed (0.791±0.180) < River Niger central drainage riverbed (1.234±0.147) < River Niger/ Creek road surface (1.236±0.086) < River Niger upstream riverbed (1.445±0.282) < Nwangene Lake (1.935±0.191). The concentrations of Cadmium in sampled sources varied from slightly to very high (Cv = 18.52-148.57%) while in Lead, the concentration was slightly to moderately (Cv =15.54-64.85%).

Lead is highly toxic, very common [7] and harmful even in small amounts. Lead was found in all water samples tested and the values range from 0.081mg/L at Otumoye bed to 2.316mg/L at Nwangene Lake Table 2. In the areas under study, the main source of lead is petrol and other workshop additives. Petrol stations are sited all over the places with surface spills and leakages from buried tanks common.

A very useful and concise way of graphically displaying the distribution of a data set is the boxplot [8]. Boxplots summarizes the centre of the data (the median = the centre line of the box), the variation or spread (interquartile range=the box height), the skewness (quartile skew=the relative size of box halves) and presence or absence of unusual values ("outliers" and "extreme" values). The Boxplots in Fig. 3, gives a comparative analysis of cadmium content in the sampled sources; the boxplots show that the cadmium concentration from sampled sources of R. Niger U. Surf., R. Niger U. bed, Otumoye bed, Creek bed, R. Niger D. Surf., R. Niger D.bed, and N. Central bed, departed from a normal distribution not only in skewness, but also by the number of outliers and the extreme values. Cadmium concentration in water of Creek surface sampled source, departed from a normal distribution only in the skewness. It is noticed that the value in Nwangene Lake, Otumoye surf. N. Central surface is approaching normality. Significant outliers and extreme values abound for Otumoye bed. Generally, the extreme variation obtained in sampled sources are unexpected and maybe due to non-suitable measurements or handling of the water samples.

As part of the requirements for the application of ANOVA, normality of distribution and equality of variances, were tested using Kolmogorov-Smirnov and Shapiro-Wilk tests. Assumption about distribution normality was satisfied. Again we had two hypotheses: null hypothesis stated that there is no significant difference in the average values of cadmium and lead in sampled sources ($p < 0.05$), and the alternative hypothesis stated the opposite ($p > 0.05$). Test was performed for a significance level. From Table 3, the results indicated that the null hypothesis was accepted, which means that the premise of there being a difference in the average amount of cadmium in water source cannot be accepted. For example, in Fig. 3 cadmium mean values are shown; it can be noted that no big difference exists in water sources. The results showed that there are significant differences ($p < 0.05$) in the average amount of R. Niger U. Surf, R. Niger U. Bed, Otumoye Bed, R. Niger D. Bed and N. Central Bed, whereas, no significant difference existed ($p > 0.05$) between Nwangene Lake, Otumoye Surf., Creek Surf, Creek Bed, R. Niger D. Surf and N. Central Surf.

Furthermore, lead (Pb) concentration in sampled sources Table 4 shows that a significant difference exists. The results showed that there are significant differences ($p < 0.05$) in Pb concentration in sampled sources of Nwangene Lake, Otumoye Bed, Otumoye Surf. and N. Central Bed, whereas, no significant difference existed ($p > 0.05$) between R. Niger U. Surf., R. Niger U. Bed, Creek Surf, Creek Bed, R. Niger D. Surf, R. Niger D. Bed and N. Central Surf.

Results obtained from Fig. 4 depict various lead (Pb) concentrations in the sampled sources. Results shows that the lead concentration from sampled sources of R. Niger U. Surf., Nwangene Lake, Otumoye surf., Otumoye bed, Creek surface, R. Niger D. Surf., R. Niger D.bed, and N. Central bed, departed from a normal distribution not only in skewness, but also by the number of outliers and the extreme values. Lead concentration in water of R. Niger U. bed, Creek bed, and N. Central Surf. sampled sources, departed from a normal distribution only in the skewness. On the Table 4 shows tests of normality and homogeneity of variance for lead in sampled sources. There exists a significant difference ($p < 0.05$) in concentration of lead in Nwangene Lake, Otumoye Bed, Otumoye Surf., and N. Central Bed, whereas, no significant difference existed ($p > 0.05$) between R. Niger U. Surf, R. Niger U. Bed, Creek Surf, Creek Bed, R. Niger D. Surf., R. Niger D. Bed and N. Central Surf.

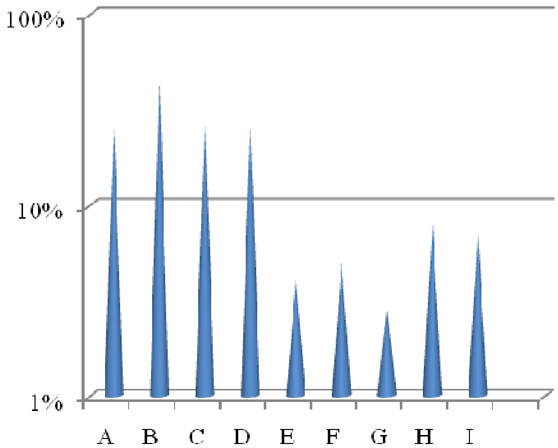
Spillages may emanate from vehicles and tanks including petrol tanks that convey fuel to about 200 petrol stations in the area on weekly basis, exhaust fumes from petrol combustion and fossil fuel combustion, which are also common sights in the area also contribute a lot to the pollution by lead as much lead is released into air and deposited onto land and surface water bodies. According to [9], Lead also goes into the environment via chemical industries and other avenues like small agricultural activities with fertilizer and pest control, sewage sludge, corrosion of metal, fossil fuel combination, metal scrap production and recycling of steel and iron mostly common in Onitsha. Electrical components, batteries cells, pigments and paints, printing and graphics, additives in fuel and lubricants are also present in the environment and are contributing to elevating the level of lead in the waters.

Cadmium occurs mostly in association with zinc and gets into water from corrosion of zinc coated ("galvanized") pipes and fittings [10]. At higher concentrations, it is known to have a toxic potential. The main sources of cadmium are industrial activities; the metal is widely used in electroplating, pigments, plastics, stabilizers and battery industries [11]. Cadmium is highly toxic and responsible for several cases of poisoning through food. Small quantities of cadmium cause adverse changes in the arteries of human kidney. It replaces zinc biochemically and causes high blood pressures, kidney damage etc [12]. Cadmium values were moderately high in subsurface water with range from 0.004mg/L at River Niger creek road surface and River Niger upstream surface to 1.431mg/L at Nwanaene lake Table 2. These high values especially at Nwangene lake, can be linked to the large quantities of cadmium laden wastes. Refuse dumps littering everywhere and the reckless disposal of sewage and wastewater. All concentration of Cadmium exceeded the World Health Organization standard of 0.003mg/L. Corrosion of metal objects like galvanized metal roof and wire fences are plenty in these cities and could have also helped to increase the quantity of cadmium over the years. More intensive investigations show that the manufacture and disposal of batteries of all kinds, paints and pigments, printing and graphics are contributors to cadmium elevation in Onitsha; this has been confirmed by other researchers [9, 12, 13]. These activities go on unrestricted in various corners of the cities.

Heavy metal toxicity is frequently the result of long term low level exposure to pollutants common in our environment: air, water, food and numerous consumer products. Exposure to toxic metals is associated with many chronic diseases. Various researches has points to same fact that low levels of Lead and Cadmium can cause a wide variety of health problems as previously enumerated; the toxicity of heavy metals is usually cumulative in nature [14].

Furthermore, correlation analysis conducted between two heavy metals shows a relationship ($r=0.543$); the possibility of impartation on each other exists.

This study is limited to the determination of the presence or absence of only two toxic heavy metals, namely, Lead and Cadmium in water, and to compare the level acquired if any, to the maximum allowable limits stated by World Health Organization [15].



Code	Tpe of Industries
A	Food industries
B	Petrol stations, agro-chemicals, pharmaceuticals
C	Chemical industries
D	Metal manufacturing
E	Electronics/ electronics
F	Textile materials
G	Furniture
H	Glass/ cement packaging.
I	automobile manufacturers, e.t.c *Source: MOI, 2008*

Fig. 2. Industrial densities in study locations (Onitsha and environs)

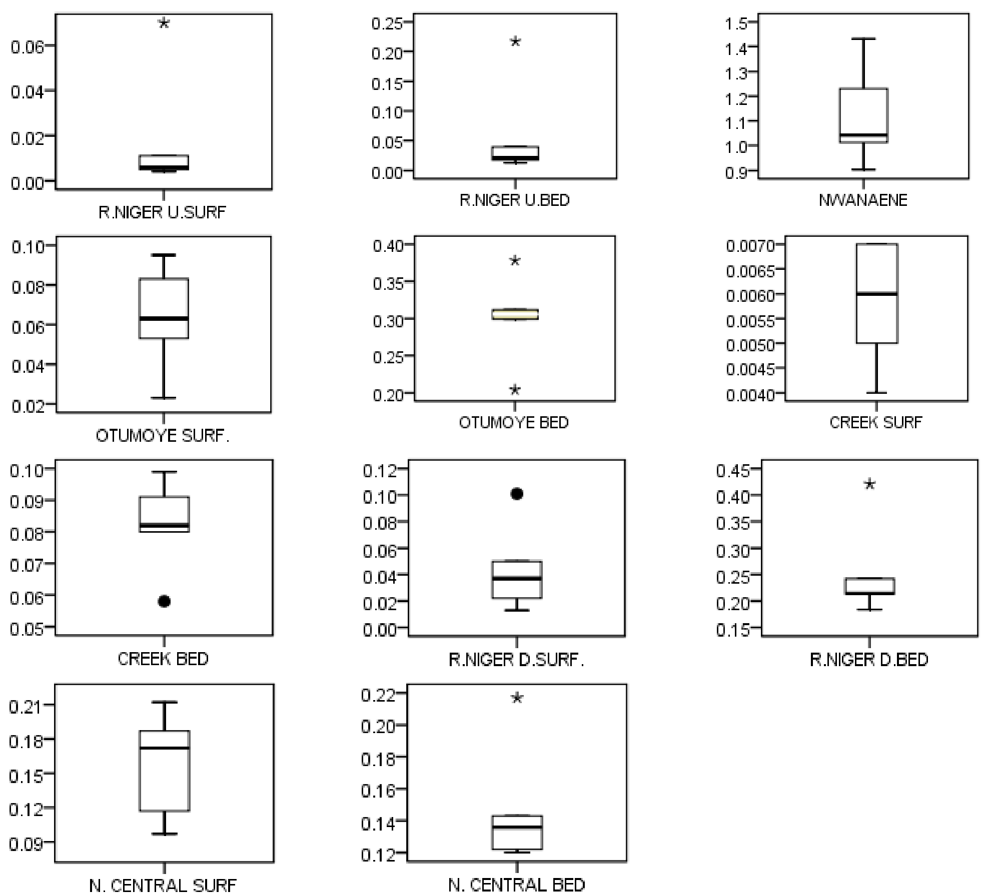


Fig. 3. Boxplots of measured values of cadmium at Niger River and environs

Table 1. Concentration of heavy metals (mg/L) in water samples from Onitsha, Anambra State, Nigeria

Sampling locations	Code	Cd (mg/L)					Pb (mg/L)				
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
River Niger upstream surface	A	0.070	0.004	0.005	0.011	0.006	0.204	0.392	0.273	0.282	0.300
River Niger upstream riverbed	B	0.012	0.039	0.217	0.017	0.020	2.273	1.198	0.869	0.938	1.947
Nwangene Lake	C	1.012	0.904	1.042	1.431	1.231	2.034	1.937	2.316	2.173	1.216
River Niger/ Otumoye surface	D	0.083	0.023	0.063	0.095	0.053	0.341	0.804	0.235	0.311	0.428
River Niger/ Otumoye riverbed	E	0.378	0.299	0.204	0.312	0.306	0.182	0.081	0.423	0.163	0.154
River Niger/ Creek road surface	F	0.007	0.004	0.005	0.007	0.006	1.288	1.204	0.929	1.315	1.444
River Niger/ Creek road riverbed	G	0.099	0.082	0.080	0.091	0.058	0.886	1.413	0.524	0.367	0.764
River Niger Downstream surface	H	0.050	0.013	0.022	0.101	0.037	0.288	0.199	0.394	0.310	0.317
River Niger Downstream riverbed	I	0.213	0.184	0.242	0.214	0.421	0.423	0.412	0.237	0.501	0.623
River Niger Central drainage surface	J	0.117	0.097	0.172	0.212	0.187	0.317	0.289	0.294	0.363	0.413
River Niger central drainage riverbed	K	0.143	0.122	0.217	0.120	0.136	1.188	1.078	0.993	1.809	1.104

Source: [16]

Table 2. Descriptive analysis of water samples from Onitsha, Anambra State, Nigeria

		Lead, Pb (mg/ L)						Cadmium Cd (mg/ L)					
SC	NOS	Range	Min	Max	Mean±S.E	Std dev.	Cv (%)	Range	Min	Max	Mean± S.E	Std dev.	Cv (%)
A	5	0.188	0.204	0.392	0.290±0.030	0.068	23.28	0.066	0.004	0.070	0.019±0.013	0.029	148.57
B	5	1.404	0.869	2.273	1.445±0.282	0.630	43.60	0.205	0.012	0.217	0.061±0.039	0.088	143.94
C	5	1.100	1.216	2.316	1.935±0.191	0.427	22.05	0.527	0.904	1.431	1.124±0.093	0.208	18.52
D	5	0.570	0.235	0.804	0.424±0.100	0.223	52.74	0.072	0.023	0.095	0.063±0.013	0.028	44.07
E	5	0.342	0.081	0.423	0.201±0.058	0.130	64.85	0.174	0.204	0.378	0.300±0.028	0.062	20.75
F	5	0.516	0.929	1.444	1.236±0.086	0.192	15.54	0.003	0.004	0.007	0.006±0.001	0.001	22.48
G	5	1.046	0.367	1.413	0.791±0.180	0.402	50.89	0.041	0.058	0.099	0.082±0.007	0.015	18.79
H	5	0.195	0.199	0.394	0.302±0.031	0.070	23.18	0.088	0.013	0.101	0.045±0.015	0.035	77.49
I	5	0.386	0.237	0.623	0.439±0.063	0.141	32.10	0.238	0.184	0.421	0.255±0.043	0.095	37.34
J	5	0.124	0.289	0.413	0.335±0.023	0.052	15.64	0.114	0.097	0.212	0.157±0.022	0.048	30.79
K	5	0.816	0.993	1.809	1.234±0.147	0.329	26.62	0.097	0.120	0.217	0.148±0.018	0.040	27.08

SC - Sample Code; NOS - Number of samples

Table 3. Tables showing test of normality and homogeneity of variance for cadmium in sampled water

Tests of normality							
	Sampled location	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Cd Concentrations	R. Niger U. surf	.413	5	.005	.631	5	.002
	R. Niger U. bed	.399	5	.009	.650	5	.003
	Nwangene	.253	5	.200*	.937	5	.647
	Otumoye surf.	.158	5	.200*	.972	5	.887
	Otumoye bed	.295	5	.179	.911	5	.476
	Creek surf	.221	5	.200*	.902	5	.421
	Creek bed	.248	5	.200*	.941	5	.676
	R. Niger D. surf.	.238	5	.200*	.891	5	.363
	R. Niger D. bed	.354	5	.040	.747	5	.028
	N. central surf.	.222	5	.200*	.932	5	.607
	N. central bed	.346	5	.051	.757	5	.034

Test of homogeneity of variance					
		Levene statistic	df1	df2	Sig.
Cd concentrations	Based on mean	2.970	10	44	.006
	Based on median	1.303	10	44	.259
	Based on median and with adjusted df	1.303	10	13.345	.320
	Based on trimmed mean	2.777	10	44	.009

Table 4. Tables showing test of normality and homogeneity of variance for lead in sampled water

Tests of normality							
	Sampled location	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pb Concentrations	R. Niger U. surf	.242	5	.200*	.947	5	.715
	R. Niger U. bed	.253	5	.200*	.872	5	.276
	Nwangene	.302	5	.155	.852	5	.202
	Otumoye surf.	.293	5	.187	.827	5	.131
	Otumoye bed	.357	5	.036	.809	5	.096
	Creek surf	.234	5	.200*	.924	5	.554
	Creek bed	.206	5	.200*	.946	5	.705
	R. Niger D. surf.	.223	5	.200*	.954	5	.767
	R. Niger D. bed	.223	5	.200*	.972	5	.891
	N. Central surf.	.236	5	.200*	.893	5	.373
	N. Central bed	.356	5	.037	.749	5	.029

Test of homogeneity of variance					
		Levene statistic	df1	df2	Sig.
Pb concentrations	Based on mean	1.227	10	44	.301
	Based on median	.891	10	44	.549
	Based on median and with adjusted df	.891	10	27.005	.554
	Based on trimmed mean	1.211	10	44	.310

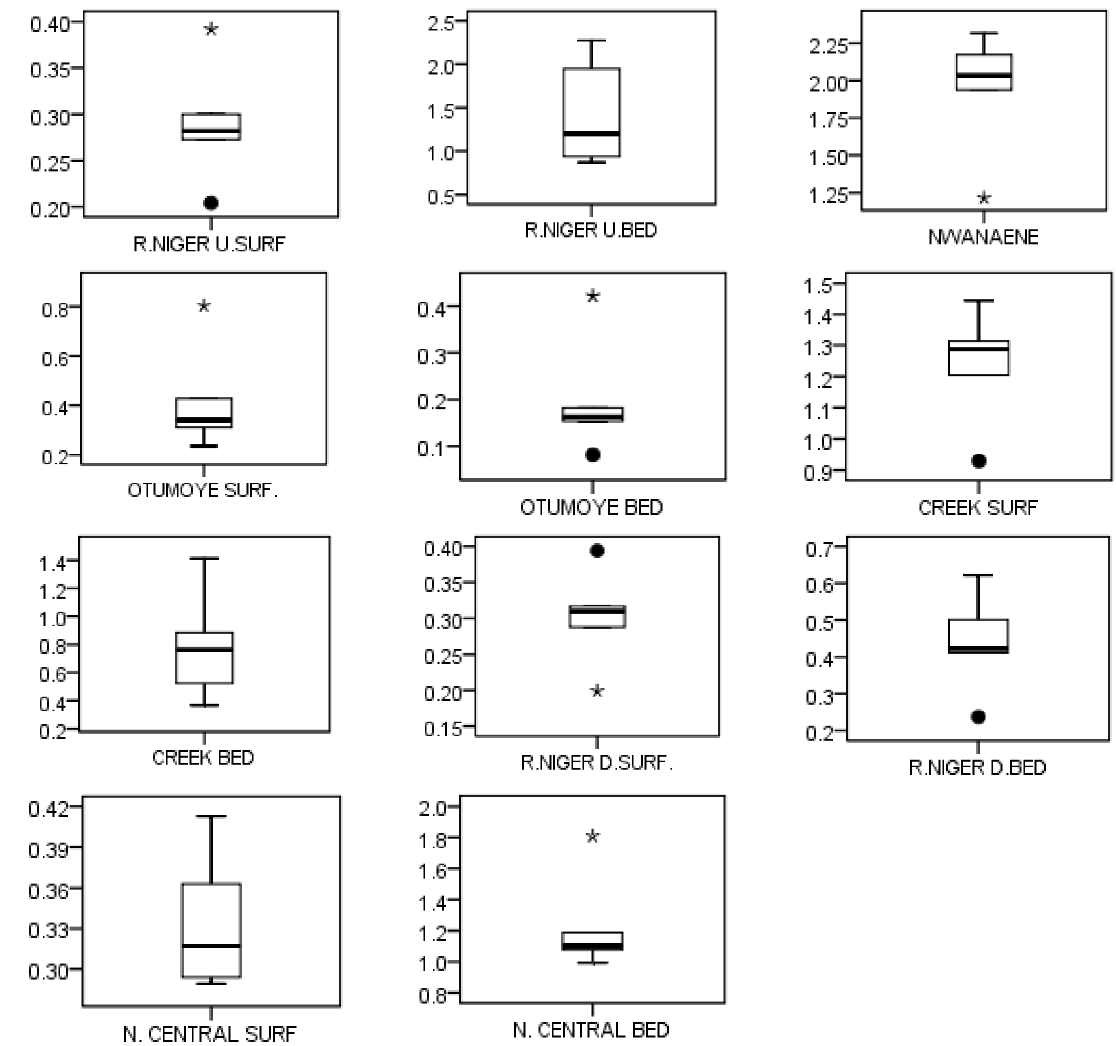


Fig. 4. Boxplots of measured values of lead at Niger River and environs

Most of the lead we take is removed from our bodies in urine; however, as exposure to lead is cumulative over time, there is still risk of buildup, particularly in children. Studies on lead are numerous because of its hazardous effects. Higher lead content was detected in milk of nursing mothers from Kamagayan (a highly industrialized area) compared to mothers from Talamban area (settlement without industries); [17]. High concentration of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys [18].

5. CONCLUSION AND RECOMMENDATIONS

The study aimed to test for the presence of heavy metals, specifically Cadmium and Lead in surface water of the Niger River and environs and to establish whether the concentrations of these heavy metals present are within standards set by the World Health Organisation and how they may affect human lives.

This research serve as an eye-opener to consumers, manufacturer, and the professionals in the health care system due to possible direct or cumulative effects it may cause. Since the study revealed significant concentrations of Cadmium and Lead in two of the water samples of heavily polluted areas, it is recommended that a more specific confirmatory test be performed and more replicates be tested by future researcher and to compare the various concentrations to other established limits for heavy metals.

Onitsha is generally littered with refuse dumps. Because of the large population density, the level of pollution is getting increasingly serious. The heavy metals in water come from these refuse dumps, industries, drug containers and hospital wastes, various forms of chemical dumps from the market and small scale industries.

Generally the values of these metals are highest between the end of dry seasons and commencement of rainy season. The inflow of effluent is directly related to capacity utilization of the industries which might also be seasonal. One does not therefore rule out that in the rainy or dry season high input of effluent could be responsible for different high values of results depending on the concentration of effluent being brought across the sections sampled from different places for the year under study.

In the light of the findings in this work, the author makes the following recommendations;

1. The introduction of modern, sensitive and reliable methods for testing drinking water for physical, chemical and biological parameters is very important and urgent. The development of adequate infrastructure for water testing laboratories is necessary. The presence of AAS equipment in every institute on is recommended. This would increase research work on all our water resources like obtains in most developed countries now.
2. The Anambra state government should take more seriously the waste management systems and make/enforce laws against pollution especially for dangerous chemical effluents from industries. The proper monitoring of industries through Environmental Impact Assessment (EIA) and Environmental Audit Report (EAR) should be enforced by the Ministry of Environment. It would be better if industrial effluents were treated before discharged.
3. The introduction of external quality assurance programme in the water testing laboratories is imperative. Problems of serious equipment error and half-baked personnel are casting doubts on the authenticity of some research data.
4. The Anambra State Government should ensure that the concerned officials of the health departments should report results as and when the water quality deviates from the national and international norms, to the government and the concerning public.
5. Epidemiological studies is highly recommended to

   i. Investigate the dose – response relationship between ingestion of heavy metals and cancer and non cancer end points of the circulatory system disease as they are common causes of morbidity and mortality.
   ii. Further investigate ingestion of heavy metals and adverse reproductive outcomes.
   iii. Research in other populations from other geographical areas of the state and country Nigeria. The information should include water-ingestion rates and intake of foods containing heavy metals.
   iv. Include consideration of interactions with host factors that might influence susceptibility to the adverse effects of heavy metal exposure, including age of exposure, dietary status, smoking and genetic polymorphisms that could affect metabolism.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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