Environmental Implications of Heavy Metal Concentration in Surface Waters and River Sediments of Onitsha and Environs, Southeastern Nigeria

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ABSTRACT

Concentrations of Zinc, Cadmium, Lead, Copper, Nickel, Manganese, Arsenic, Selenium and Mercury in the surface water, and river sediments of Onitsha area, Anambra state of Nigeria, were determined using Atomic Absorption Spectroscopy and Mercury Cold Vapor Analysis. Average concentrations of heavy metal in the surface water ranged between 0.001µg/l-5.013 mg/l, while that of river sediments ranged between 0.001-3.138mg/kg. This shows moderate to very heavy pollution of both surface waters and river sediments of Onitsha area. Results of the study showed that there is an interaction between the lithology, urban and industrial activities with the aquatic environment. It is recommended that industries should be mandated to treat their effluents before discharging then into the ecosystem, and caution should be exercised in the use of the water for domestic and agricultural activities.

Keywords: *Heavy metals, Concentrations, Pollution, Industrial Wastes.*

INTRODUCTION

Many nations, including Nigeria have witnessed tremendous growth in industrialization, as evident in establishment of both large and small scale processing and production factories across the nation.

Onitsha, a commercial city located in the southeastern part of Nigeria, is traversed by several of these manufacturing industries, such as several brewery industries, textile industries, small scale welding companies, and mechanic workshops. The wastes of these industries, and several dump sites, are usually discharged or sited close to the River Niger and other minor rivers in the city, or sometimes, they are washed into the river by surface runoff.

Heavy metals such as; Pb, Zn, Cu, Hg, As, Mn, Cd etc which are major components of most industrial effluents and emissions play key roles in contamination and pollution of the ecosystem (Thuy et al, 2000). According to Wild (1993), heavy metals are hazardous metals that are usually of high density (above $5g/cm^3$). Certain quantities of some heavy metals occur naturally in the environment (soil or water), but significant quantities that may cause contamination or pollution of the environment are discharged by industries. Pollution occurs when some part of the environment is made harmful or offensive to organisms especially humans by addition of hazardous chemicals, while contamination occurs when the quality of some parts of the environment has been impaired by addition of hazardous substances which may not have immediate adverse effects on the organism. (Howard and Ransom, 1978). According to Fordyce (2000), some heavy metals like Zn and Fe, are beneficial to humans in trace amounts, but toxic when tolerable level is exceeded. Others like As, Cd, Pb, and Hg are generally toxic to humans irrespective of their concentrations.

According to WHO (2002), in a bid to improve their living conditions, human beings try to exploit the nature, manufacturing new products, establishing more industries, and improving on old ones.

Thus the presence of heavy metals in the environment constitutes a major global source of concern to environmental scientists and engineers because heavy metals are not only harmful to humans and animals, but tend to bio-accumulate in the food chain (Yoon *et al*., 2006). Also Onder and Dursun, (2006), opined that apart from being aesthetically offensive, can act as health hazard to people as well as to plants and other biota. Fossil fuel combustion, agrochemical applications, metallurgical industrial activities and industrial wastes generation over the last century (Fitzgerald and Clarkson, 1991; Mason *et al*., 1994) have undoubtedly intensified the emission of various heavy metals and other pollutants into the environment thereby stressing the terrestrial, aquatic and atmospheric ecosystem beyond their natural recycling capability.

Table 1 is a summary of some heavy metals, and their toxicity effects while Table 2 is Heavy metal quality standards for domestic water.

Table 1: Heavy metals and their toxicity effects (Modified after Fordye, 2000)

Heavy Metals	Toxicity
Cd	Renal and heart diseases, weaken bones and tumors.
Pb	Neurological disorders, convulsions, kidney and brain damage.
Hg	Neurological disorders, Irritability and liver damage.
As	Cancer, skin diseases and poisoning.
Zn	Enzymes and skin disorders.
Cu	Gastrointestinal irritant, liver damage.
Se	Hairloss, nervous disorder.

Table 2: Heavy metals quality standards for sources of domestic water (WHO, 2007)

Parameter	Max Allowable Value for drinking water
Zn	5(mg/l)
Cd	0.01(mg/l)
Pb	0.05(mg/l)
Cu	0.05(mg/l)

Ni	20(μ g/l)
Mn	0.5(mg/l)
As	0.01(mg/l)
Se	0.01(μ g/l)
Hg	0.001(mg/l)

Contaminated waters and their sediments are a concern not only because they act as a continuing source of potential problems for water quality and the biota in the waterway, but because they may represent means to quantify the relationship between sources of waste/urban runoff and water quality degradation (Murray, 1996).

Heavy metals have been found useful as indices of pollution, because they are highly toxic to humans and animals, as well as have a persistent nature in the environment, therefore a knowledge of the changing concentration and distribution of heavy metals in various compartments of the environment is a priority for good environmental management programme all over the world (Don Pedro et al 2004).

The present study therefore, examines the heavy metal concentrations and their pollution potentials in the River sediments and surface water resources in Onitsha, in order to assess possible anomalous accumulations, its impacts on the environment, and thereby suggest monitoring for areas where significant anthropogenic inputs are expected.

GEOLOGICAL SETTING AND CLIMATE.

Onitsha Metropolitan Area is located at the confluence of rivers Niger and Anambra in Nigeria (Nwankwor and Eche, 1990).

Onitsha with an upland area of between 150 and240m in height is the commercial nerve center of Anambra state, and the largest market city in Nigeria (Ofomata, 2007). It is located in Southeastern Nigeria, between longitudes 6^0 45' -$7^0$00' E and latitude $6^0$00' -$6^0$15'N (Fig1). It occupies the eastern flank of River Niger. Its climate falls within the sub-equatorial and the tropical hinterland climatic belts of Nigeria. This climate is influenced by two major trade winds: the warm moist Southwest Trade Winds during the rainy season and the North East Trade Winds during the dry and dusty harmattan. Its temperatures are relatively constant throughout the year with maximum monthly temperatures varying from 780 and 810^0 F. Its annual rainfall is reasonably high with value of about 1,850mm (Nigerian Metereological Agency, 2011)

The vegetation is light forest interspersed in some areas with tall trees, which could be hard or soft. However, most of the natural vegetation has been destroyed due to the rapid development taking place in the city.

Its soils, particularly at the banks of the River Niger are characterized by a wide plain of Alluvium. Intercalations of sandy and muddy soils exist around the Nkpor and Ogidi areas.

The study area covers the Western flank of the Anambra Basin (Fig. 1), characterized by vast sedimentary basin which is underlain by Ogwashi- Asaba Formation, Ameki Formation, Nanka Sands and Imo Shale of the Anambra Basin. The basin delineates the southern border of the Benue Trough which was formed (along with the Afikpo Syncline and Abakaliki Ridge) during the Santonian tectonism (Offodile, 1975; Ofoegbu, 1985).

The Stratigraphic sequence of the study area is shown below in Table 3.

Table 3: Stratigraphic sequence of the study area (Ofoegbu,1985; Okeke and Igboanua, 2003)

AGE	FORMATION	THICKNESS (m)	LITHOLOGY
Miocene-Oligocene (25-35m.y.)	Ogwashi-Asaba Formation	500	Unconsolidated sandstones with Mudstones and Lignite seams
Eocene (35-55m.y.)	Ameki Formation/ Nanka Sands	130	Sandstones and Silstones with Clays as lenses. Nanka Sands Consist of fine-Coarse sandstone With lenses of Calcareous Shale
Paleocene (55-65m-t1)	Imo Shale/ Ebanebe Sandstone member	400/10-40	Fine textured dark grey shale with arenaceous sandstone member

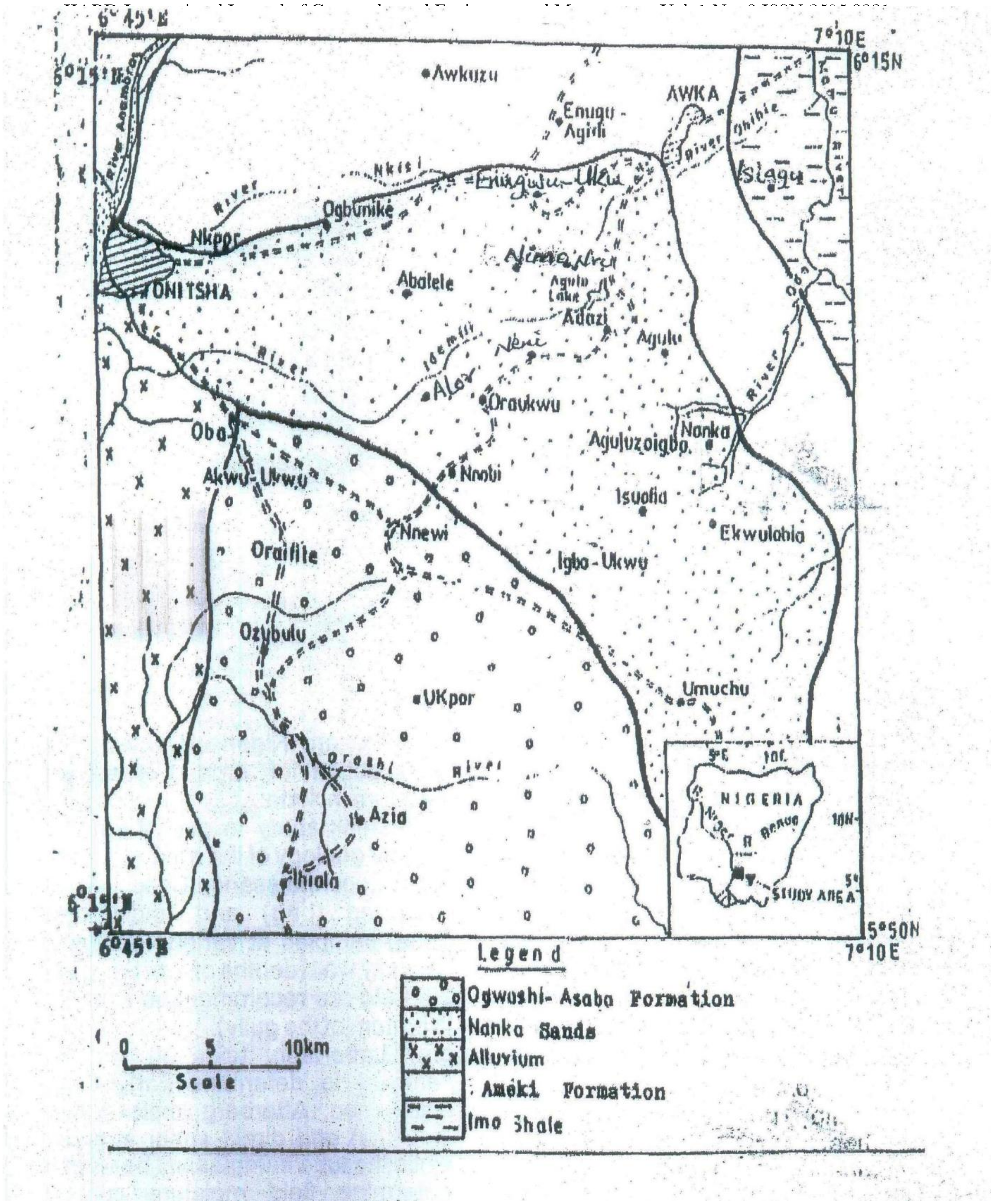

Fig. 1: Geological map of the study area (Adapted from Offodile, 1975.

MATERIALS AND METHODS

Sample Collection

Clean latic containers, rinsed with distilled water prior to sample collection for heavy metals analysis (Ogunfowokan and Fakankun, 1998; Ogunfowokan *et al*., 2008), to prevent metals adhering to the walls of the container. 12 surface water samples and 4 river sediment samples were collected from the locations described in Table 4.
For each river location visited, the downstream portion was identified, after which about three (3) samples were collected, at about 1.5metres apart (Edet et al, 2003).

Samples of fine grained river sediments were also collected from each river course using the hand held core sampler (Shelton and Capel, 1994).

Table 4: Shows sampling Locations

Sample Location	**Description**	
Sample No.	**Sample Location Description**	
	Surface water samples	**Coordinates**
L=	Nwangene river	$6^0 48'$- $6^0 51'$
M=	River Niger	$6^0 03'$- $6^0 07'$
N=	Nkissi river	$6^0 52'$-$6^0 55'$
O=	Idemili river	$6^0 51'$-$6^0 53'$
	River sediments samples	
LS=	Sediments from Nwangene River (L)	
MS=	Sediments from River Niger (M)	
NS=	Sediments from Nkisi River (N)	
OS=	Sediments from Idemili River (s)	

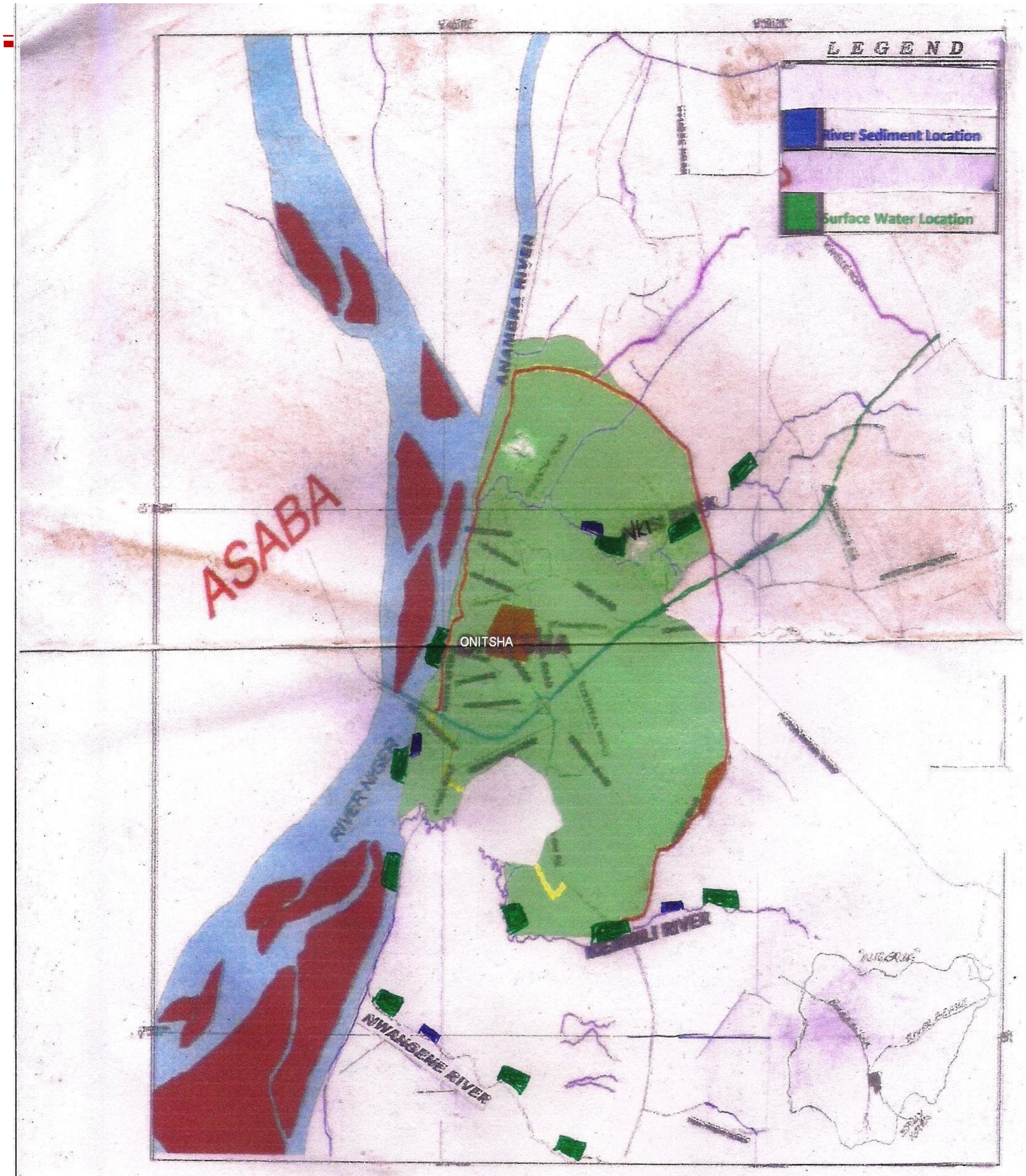

Fig 2 : Location map of study area (modified from UN- Habitat, 2002)

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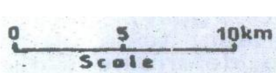

Laboratory Analysis

Water Samples

Preliminary treatment of the surface water samples involves digestion, in which the method of APHA et al, (1995); Ogunfowokan et al., (2008) was used to dissolve the particulate matter in the samples to prevent clogging of the burner, to ensure that all metals present is atomized and the samples made colourless. The digested sample was cooled down, quantitatively transferred into a volumetric flask. A blank solution was concurrently done.

Atomic Absorption Spectrophotometry (AAS) was used for the analysis of Cd, Pb, Mn, Cu, Zn, Se, As, & Ni. For mercury, cold vapor AAS analysis was done, since it cannot be aspirated due to its high toxicity (Csuros and Csuror, 2002).

Sediments (solids);

This refers to all matter that remains as residue after evaporation to dryness at 103^0C to105^0C.

A modification of an earlier described method (Ogunfowokan et al., 2008) was employed to secure the release of bound or free metals, then, a blank determination was also carried out to establish blank levels for the metal analysis.

RESULTS AND DISCUSSION

Results

The concentration of heavy metals in samples of surface water in Onitsha area from various locations are shown in tables 5 and 6, and illustrated in figures 4 and 5.

Discussion

The analytical result in this study revealed a large spread of the
contaminant metals in the surface waters and soils, which is traceable to waste arising from; dyeing of fabrics, electroplating processes, metallurgical activities, plastic manufacturing activities, etc going on in the area.

The concentration of Zinc in water samples and river sediments at all the locations were generally less than 5mg/l highest desirable level of zinc in drinking water (Ogunfunwokan et al, 2006) a mean value of 0.3mg/l, for the water samples, and 0.2mg/kg, for the river sediments (table 5 and 6). However, these values far exceeded the 20µg/l level for water meant for aquatic ecosystem (Fatoki et al, 2002; Ogunfowokan et al, 2006). Thus while the likelihood of water poisoning by Zinc is minimal since the limiting concentration level is not exceeded for now, the same cannot be said of aquatic biota.

Mean cadmium levels ranged from <0.004-0.7µg/l in the surface water samples, and 0.003-0.113mg/kg for the river sediments. The upper limits thus exceed the stipulated recommended guidelines of 0.01mg/l (WHO, 2007).

It goes without saying that the concentration of Cd, particularly in the surface water samples poses serious health problems for both the aquatic ecosystem, and the humans who use the water from time to time for both domestic and agricultural purposes.

Pb, a highly toxic, naturally occurring metal and that even a little of it in the human body can cause damage to the brain, kidneys, nervous system and red blood cells. Results from the study area revealed values as high as 5.013mg/l, and 2.810 µg/kg for both the surface water samples, and river sediments respectively (tables 5 and 6). These values were generally above the 0.05mg/l WHO recommended allowable value for sources of drinking water, (WHO, 2007), and the 0.019µg/kg Pb level for unpolluted sediments (GESAMP, 1982). High levels of Pb in the sediment could be ascribed more to anthropogenic effects than to lithogenic factors. Thus treatment should be done before water is being used for domestic and agricultural purposes.

Copper concentration in Onitsha area ranged from, <0.001mg/l in areas around Ozomagala, and around Housing Estate at Ugwuagba, to maximum values of 0.13mg/l in Nwangene area. These values were clearly higher than the Maximum contaminant level of 0.05mg/l in drinking water (WHO, 2007) implying that the water may be free from copper induced health problems for the humans relying on water from Onitsha area for agricultural and domestic purposes.

For the sediments, mean value ranged from 0.011-0.084µg/kg, thus anthropogenic input could not be said to be very serious considering the fact that the background Cu concentration range in an unpolluted soil is 5-30mg/kg (Pais and Jones,1997) while the value in an unpolluted sediment is 33mg/kg (GESAMP,1982).

The implication of this is that the levels of Cu in the sediments were more attributable to lithogenic effects rather than anthropogenic factors. However, future slow build up Cu in the sediments and along the food chain in the consumers of products from this area cannot be ignored.

Concentration of Nickel was completely unnoticed in areas like Nkissi, and Nwangene, while areas around Omagba areas recorded values <0.001mg/l, and areas around River Niger yielded maximum average values of 0.017mg/l. These values were below the 50µg/l maximum contaminant level of Ni in fresh water (EEC, 1980), and the 20µg/l Ni level of maximum allowable concentration in drinking water (WHO, 2007). In the sediments, concentration of Ni, ranged between 0-0.004µg/kg. The values fell below the normal background range of 30-40mg/l in unpolluted soils (Pais and Jones,1997), as well as the 0.064-0.067mg/l Ni levels measured in coal and sediments from River Ekulu in Enugu, Nigeria (Adaikpoh et al,2005). Nevertheless, because Ni can be extremely toxic to man even at low concentrations in domestic water supply when consumed (Stoepper, 1997), there is the need for its near total removal in water meant for domestic purposes.

Surface water values of Manganese recorded highest value of 0.137mg/l. This value did not exceed the 0.5mg/l WHO provisional guideline value for drinking water (WHO, 2007). For the river sediments, maximum value recorded 0.077mg/kg around Ndemiri River. These values were lower than 0.256 -0.389mg/kg levels recorded for Mn in coal and sediments from River Ekulu in Enugu (Adaikpoh, 2005), and also lower than the usual background levels (200-3000mg/kg) in unpolluted soils.

The sources of Mn in the sediment in this study might likely be more of geochemical than anthropogenic. The deficiency and accumulation of large concentration of Manganese can have repercussions on the central nervous system of humans, thus its environmental monitoring is as important as those of the other metals.

Average values of Arsenic ranged from 0.001µg/l in samples from Ozomagala, and Nwangene, and as high as 10µg/l in samples collected from River Niger. Thus it falls at the maximum contaminant level of 10µg/l for As (WHO, 2007). Sources could be the Ifejika dumpsite (about six hectares large), textile industries, and other metallurgical activities taking place few meters away from River Niger. These industries discharge their effluents, and release aerosol particles as by-products from incineration of the metallic materials, thus the future possible bioaccumulation of As in the tissues of those who use the river water for long term domestic purposes, may however be of concern because of bio-magnification. Values of As in River sediments were however lower, with minimum and maximum values of 0.915, and 3.138mg/kg respectively. With background values in unpolluted soil put at 5mg/kg (Pais and Jones, 1997), it could be stated that sources could be the result of the application of arsenic containing herbicides, whose fluxes settled with the sediments over time.

Concentration for water samples for Selenium was recorded as 0.001-0.312µg/l, while for river sediments was between 0.002- 0.141mg/kg. Both values fell below the 2.000 set by Environmental Protection Agency Detection Limits.

Average value of Mercury in surface water of the study area recorded 1.013µ g/l (table 6). Thus a value above the 0.01µg/l, WHO guideline for Mercury in drinking water was observed, particularly in samples collected from Idemiri River,

a site very close to the Obosi dump site, along Onitsha- Owerri Express road, therefore a high risk of Hg poisoning is imminent for users of the river for domestic and other activities.

Table 5: Concentration of Heavy Metals and Some Physical Parameters in River Sediments of Onitsha Area.

Sample Locations	Zn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	As (µg/kg)	Se (µg/kg)	Hg (µg/kg)	COLOUR	ODOUR
1	0.088	0.113	1.005	0.084	NR	0.012	NR	0.017	0.071	Milky	Characteristics
2	0.009	0.003	1.313	0.011	0.002	0.059	3.138	0.012	0.184	Light brown	Characteristics
3	0.017	0.091	0.751	0.017	0.004	0.016	0.915	0.002	0.063	Brown	Characteristics
4	0.719	0.081	2.810	0.035	0.001	0.077	2.317	0.141	0.910	Brown	Characteristics

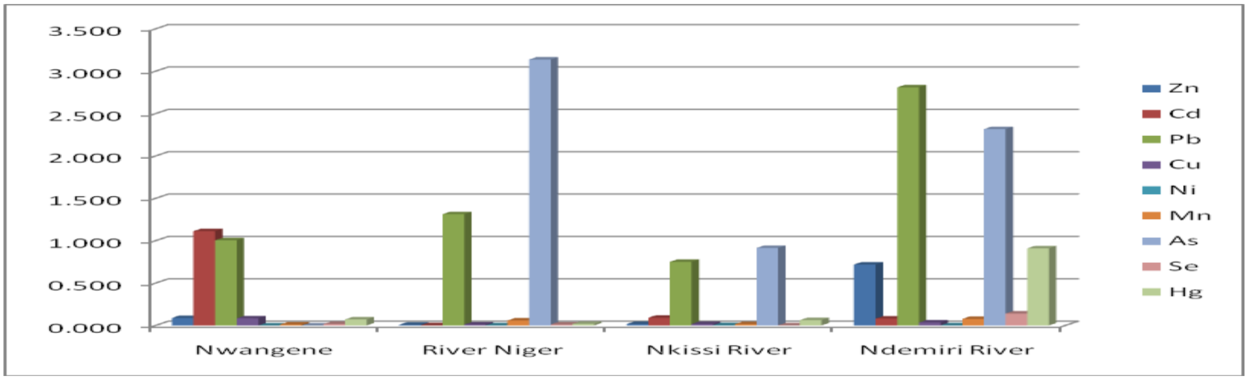

Fig. 4: - Plot of concentration of heavy metals (in mg/kg) of river sediments against sample locations.

Table 6: Concentration of Heavy Metals and Some Physical Parameters of Surface River Water of Onitsha Area.

Sample Locations	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)	Cu (mg/L)	Ni (mg/L)	Mn (mg/L)	As (µg/L)	Se (µg/L)	Hg (µg/L)	**COLOUR**	**PH**	**CONDUCTIVITY**
(1) Nwangene River	0.077	0.464	1.006	0.029	0.001	0.090	0.002	0.011	0.200			
	0.308	0.200	6.016	0.101	0.001	0.007	0.002	0.015	0.043			
	0.077	0.032	2.002	0.260	0.001	0.194	0.000	0.052	0.057			
Average	**0.154**	**0.232**	**3.008**	**0.130**	**0.001**	**0.097**	**0.001**	**0.026**	**0.100**	**Milky**	**5.7**	**160**
(2) River Niger	0.013	0.018	1.001	0.020	0.034	0.033	5.600	0.103	0.622			
	0.013	0.004	4.206	0.009	0.008	0.100	20.000	0.012	0.050			
	0.013	0.005	1.102	0.058	0.009	0.266	4.400	0.230	0.050			
Average	**0.013**	**0.009**	**2.103**	**0.029**	**0.017**	**0.133**	**10.000**	**0.115**	**0.311**	**Yellowish brown**	**5.8**	**1200**
(3) Nkisi River	0.037	0.038	1.000	0.001	0.016	0.050	2.100	0.036	0.100			
	0.037	0.100	3.760	0.040	0.004	0.150	0.019	0.009	0.097			
	0.148	0.276	0.880	0.082	0.004	0.075	4.238	0.009	0.394			
Average	**0.074**	**0.138**	**1.880**	**0.041**	**0.008**	**0.075**	**2.119**	**0.018**	**0.197**	**Brown**	**6.3**	**1310**
(4) Idemili	1.001	0.742	0.013	0.111	0.022	0.007	3.021	0.012	1.000			
	0.004	0.300	10.026	0.007	0.001	0.274	3.300	0.624	0.013			

River	2.010	0.071	5.000	0.236	0.010	0.130	12.642	0.300	2.026		
Average	**1.005**	**0.371**	**5.013**	**0.118**	**0.011**	**0.137**	**6.321**	**0.312**	**1.013**	**Reddish brown**	**5.8**	**1260**

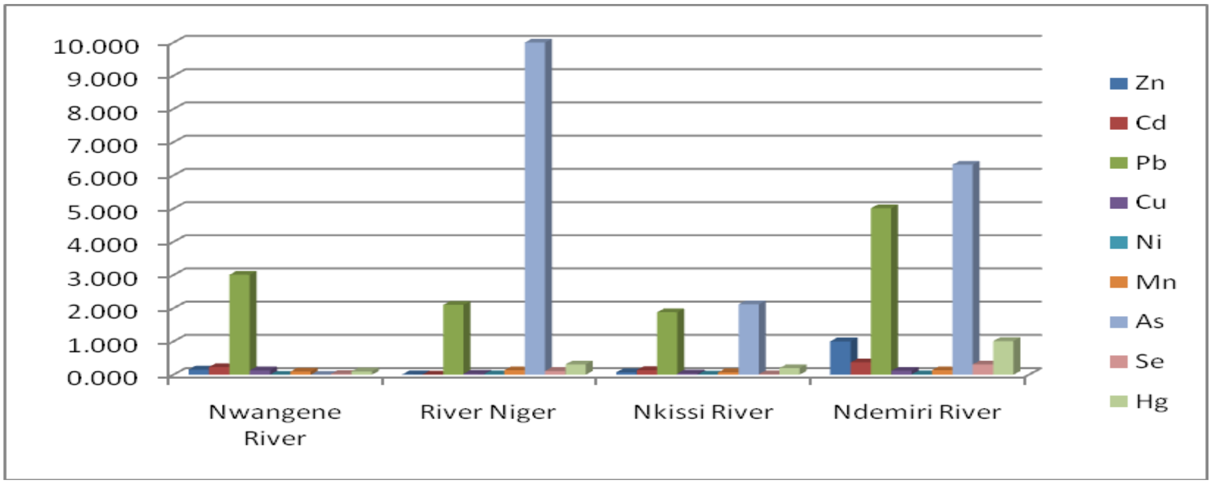

Fig. 5: - Plot of concentration of heavy metals (in mg/l) in surface water against sample locations.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This paper establishes that the surface waters in Onitsha are moderately polluted because the concentrations exceed the WHO quality standards. Heavy metal concentrations in the river sediments, particularly Pb, are also above the specified limit of natural waters. The highest concentration of the contaminant metals are found in the vicinity of the Onitsha Head Bridge (of the River Niger). The high concentration of metals is attributed to industrial / anthropogenic activities and wastes associated with them. It can therefore be stated opined that there is an interaction between the geology of the area, the waste from industries and the water resources of the area.

Recommendations

It is however recommended that industrial waste should be treated before it is discharged into the ecosystem. Furthermore, laws should be enacted and enforced, to check this menace Residents, particularly farmers and fishermen who live close by, they should be educated to exercise caution on the use of sediments or water from these rivers.
There is also a need to discourage residents from indiscriminate dumping of refuse, in order to avoid more significant dangers in the nearest future.
Serious caution must also be exercised in using the sediments or water from these rivers for agricultural practices as the levels of toxic heavy metals within the aquatic environment is on the high side.

REFERENCES

Adaikpoh, E.O, Nwangei, G.E, and Ogala, J.E (2005). Heavy metals concentration in Coal and Sediments from River Ekulu in Enugu, Coal city of Nigeria, J. Apppl. Sci. Environ. Mgt.9 (3),5-8

APHA, AWWA, WEF, (1995). Standard Methods for the Examination of Water and wastewater, America Public Health Association, America Water Works Association, Water Environment Federation, Chescen, L.S, and Eaton, A.D. 1st Edition.

Don Pedro, K.N, Oyewo, E.O, and Otitiloju, A.A, (2004). Trend of heavy metals Concentration in Lagos lagoon ecosystem Nig. W. Africa. Journal of applied ecology, 5:103-114.

Edet, A.E and Offiong, (2003). Evaluation of water quality pollution indices for heavy metal contamination monitoring. A case study of Akpabuyo-Odukpani area (southern Nigeria). Geojournal 1-10, kwuwer Acad Pub.

EEC, (1980). Council Directives 76/464/EEC, Official Journal of European Communities, vol.L.229; August 30th0, 11pp.

Fatoki, O.S., Luyizan, O. and Ogunfowokan, A.O. (2002). Trace Metal Pollution in Umuta River S.A.28 (2), 183-189.

Fordyce, F. (2000). Geochemistry and heath. Geoscience and development, No 6 pp. 6-8 8. GESAMP (IMO)/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP. 1982. Joint Group of Experts on the Scientific Aspects of Marine Pollution: The Health of the Oceans. Rep. Stud., GESAMP, (15): 108p and UNEP Reg. Seas Rep. Stud. 16,108pp.

Mason, R., Fitzgerald, W. and Morel, M. (1994). The Biogeochemical Cycling of Elemental Mercury: Anthropogenic Influences. *Geochimica et Cosmochica Acta* **58**, 3191-3198

Murray, K. S. (1996). Statistical comparison of heavy metal concentration in river Sediments. Environmental Geology. No.27 pp.54-58.

Nigerian Metereorological Agency (2007). Rainfall data in Nigeria, Federal Ministry of Aviation, Abuja, Nigeria.

Ntekim, E.E, and Bello, H., (2001). Evaluation of heavy metal content of soils and Well water around Jimeta Bridge, Yola, Northeastern Nigeria. Water Resources – Journal of the Nigerian Association of Hydrologists (NAH), Vol.14, pp.67-74.

Nwanjei, G.E, Iwugbue, C.M.A., and Okafor, M.I., (2007). Heavy metals in Surface soils under waste dumps from Onitsha. Journal of Biological sciences.7 (2), 405-408.

Nwankwo, G.I, and Eche, B.C., (1990). Hydrogeological Evaluation of the Greater-Onitsha Water Scheme, Anambra State, Nigeria. Journal of mining and Geology, vol.26, no. 2.

Ofoegbu, C.O. (1985). A review of geology of Benue Trough, Nigeria. Journal of African Earth Science, Vol. 3, pp.283-291.

Offodile, M. E. (1975). A review of the Cretaceous of the Benue Valley. In: Geology of Nigeria (kogbe, C.A.) pp.319-330.

Ofomata, A.U., (1975). Eastern Nig., A case study of Onitsha, Anambra State.

Ogunfowokan, A.O., Torto, N., Adenuga, A.A. and Okoh, E.K, (2006) .Survey of levels of Phthalate Ester Plasticizers in a sewage lagoon Effluent and a receiving stream environ. Monitor. Assess.118, 457-480

Okeke, O.C, and Igboanua, A.H., (2003). Characteristics and Quality Assessment of Surface Water and Groundwater Resources of Awka Town. Water Resources, Journal of Nigerian Association of Hydroeologists (NAH), Vol.16, pp. 11-19

Okeke, O.C, Essien, A. G., and Atueyi, C. C., (2005). Geochemical anomalies in Aba River sediments, associated with anthropogenic activities in Aba area, Southeastern Nig. Journal of Research in Physical Science .Vol.1, No. 1.pp. 22-33.

Ogunfowokan, A.O. and Fakankun, O.A. (1998). Physicochemical Characterization of Effluents from Beverage Processing Plants in Ibadan, Nigeria. *Intern. J. Environ. Studies* **54,** 145 - 152.

Ogunfowokan, A.O., Adenuga, A.A., Torto, N. and Okoh, E.K. (2008). Heavy metals Pollution in a sewage treatment oxidation pond and the receiving stream of the Obafemi Awolowo University, Ile-Ife, Nigeria. *Environ. Monit. Assess.* **143**, 25 – 41.

Ogunfowokan, A.O., Torto, N., Adenuga, A.A. and Okoh, E.K. (2006). Survey of Levels of Phthalate Ester Plasticizers in a Sewage Lagoon Effluent and a Receiving Stream *Environ. Monitor. Assess*.**118**, 457 – 480

Onder, S. and Dursun, S. (2006). Airborne heavy metal pollution of *Cedrus libani* (A. Rich.) in the city center of Konya (Turkey). *Atmospheric Environment* **40**, 1122–1133). Seasonal mean levels of heavy metals in water and associated sediments from Ajawere River in Oke-Osun farm settlement, Osogbo, Nig. Proceedings of the Environmental management conference, Federal university of agriculture, Abeokuta, Nig.

Pais, I. and Jones, J. B. jr. (1997). The Handbook of Trace Elements, CRC Press, 90pp.

Shelton, L.R, and Capel, P.D. (1994). Guidelines for collecting and processing Samples of stream bed sediment for analysis of trace elements and organic contaminants for the National Water Quality Assessment Program: U. S Geological Survey, Open file Report 94-458.

Thuy, H. H.T, Torschall, H. J., (2000). Trace element distribution in aquatic sediments of Danang-Hoian area. Veitnam. Vietnam Environmental Geology 39, pp.755-740.

UN: Habitat (2002): State of World Cities.

WHO. (2007). *Guidelines for Drinking water*. 1st Addendum to 3rd edition. Recommendations, Geneva.

WHO (2002), World Health Report: Reducing risks, promoting healthy life. World Health Organization, Geneva Yoon, J., Cao, X., Zhou, Q. and Ma, L. 2006, Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site, *Science of the Total Environment* **368** (2–3): 456–464.

Wild, A. (1993). Soils and the environment: An Introduction, Cambridge University Press, Britain.