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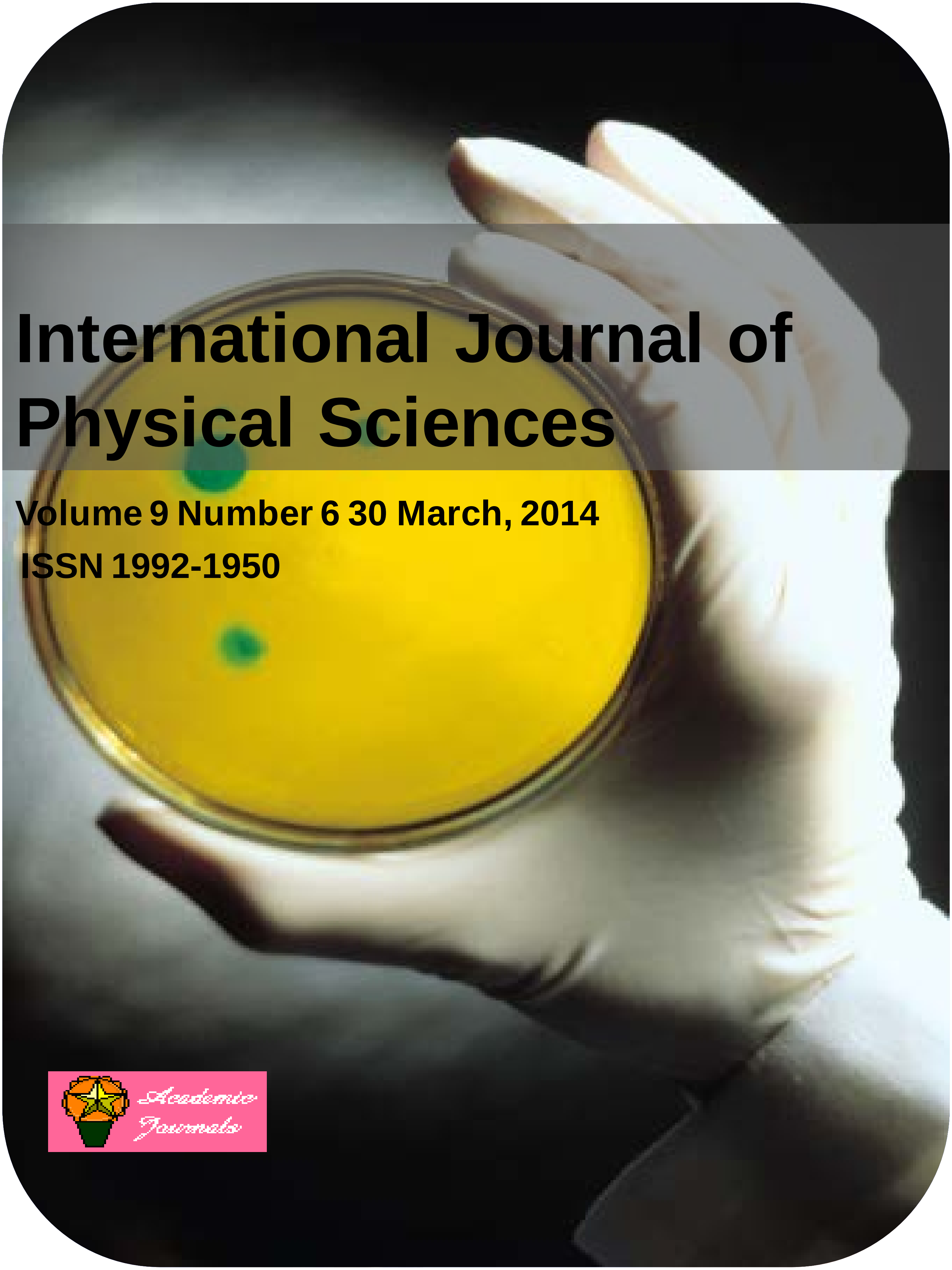

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Full Length Research Paper

Health risk assessment in relation to heavy metals in water sources in rural regions of South East Nigeria

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This report presents a study of seven heavy metals concentrations in rural water supplies of South East region of Nigeria. The concentration levels of As, Hg, Cd, Pd, Cr, Cu and Fe were evaluated in samples of water collected from the major water sources in the study area viz: streams, ponds/lakes and shallow hand dug wells. Flame Atomic Absorption Spectroscopy was used to assay the levels of Fe, Cu, Cr, Pb, Cd and As while cold vapour AAS was used for Hg determination. The human health risk assessment was performed by determining the water ingestion (IW), oral daily intake (DI), hazard quotient (HQ) and total hazard index (THI) of the metals from human oral consumption. The result of the analysis indicated the level ranges of the metals as follows Hg. (0.00-0.01 ppm), As (0.010- -2.01 ppm); Cd (0.00-0.25 ppm); Pd (0.38-3.04 ppm) Cr (0.01-0.65 ppm); Cu (0.21-2.65 ppm) and Fe (0.75-15.01 ppm). The risk assessment results indicated that HQ of As, Cd, Cr and Pb were mostly of moderate risk, (HQ > 1) while those of Hg, Fe and Cu indicated no risk. The THI of all the water bodies assessed were of high risk except one river.

Key words: Hazard quotient, risk assessment, heavy metals, rural settlements, toxicity, south east, water sources, ingestion, oral daily intake.

INTRODUCTION

Over a billion people lack access to safe potable water supply globally and out of this number, more than 300 million people living in rural areas of sub-Saharan Africa are being affected (Bresine, 2007). Rural settlements in Nigeria are characterized by lack of potable water supply. This situation makes the dwellers depend on streams, natural ponds/ lakes, shallow hand dug wells and harvesting of rainfalls for their whole water needs. However, it is known that water resources in rural areas of Nigeria are prone to pollution either by low level of hygiene manifested by the inhabitants or by agricultural and local industrial activities of the inhabitants (Ikem et al., 2002; Adeleye and Adebiyi, 2003; Adekunle et al., 2007).

These rural areas are most often neglected by government as they lack basic infrastructure like potable water, health facilities, access roads, sanitation facilities and even electricity. The near absence of these facilities exposes the dwellers to a variety of health related risks. Contamination of water sources unarguably stands prominent among the many ills plaguing the rural settlements in developing countries.

Heavy metals pollution of water resources have been on front burners lately due to the health risks associated

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with their presence. The major anthropogenic sources of heavy metals in rural aquatic environment are known to be agricultural activities, homes, local markets, abattoirs traditional industries such as blacksmithing, foundries, and smelling of metals and crude oil (Akujieze et al., 2003; Baccarelli and Bollati, 2009; Galadima et al., 2011; Kaitantzian et al., 2013). All these activities severe water sources quality by introducing harmful toxic metals into them. It is a common knowledge that majority of water sources in Nigeria available to local inhabitants are either unsafe or difficult to obtain and are stressed by poor management (Galadima et al., 2011). Hence about 60% of the South East Nigerians which live in rural areas continuously use water contaminated with all kinds of germs, heavy metals, and other pollutants enough to cause various diseases. The study of heavy metals contamination and their adverse effect on living organisms in aquatic environment and human beings have been widely studied all over the world (Singh et al., 2005; Nabi et al., 2007; Kimete et al., 2010; Nagehi, 2012). South Eastern Nigeria has a current population projection of 19,904,478 and cover an area of 28,821.56 km^2 belonging to the forest savanna mosaic zone of Nigeria (NPC, 2006). Of this population 11,942,687 are rural dwellers.

The objectives of this present study were to: determine the present levels of seven heavy metals in the water samples; compare the obtained values with the WHO acceptable limits for those metals in potable water and assess the health risks of ingestion of the waters by the determination of their daily oral intake, hazard quotient (HQ) and total hazard index (THI). Currently no epidemiological study has been reported in these rural areas with regards to toxic metal poisoning.

MATERIALS AND METHODS

Study area

The study area, Uzouwani, lies between longitude 6°30^1 and 7°00 East and 6°55^1 and 7°1^{1}North. Many rivers and streams abound in the area which belong to the Anambra river system and consist of 17 communities described as being 100% rural content (UPA, 2010). The dwellers draw almost all their water needs from streams, natural lakes/ponds and shallow hand-dug wells. These dwellers are 100% agriculturists and traditional industrialist and even civil workers practice one form of agricultural activity or the other. A sketch map of the study area showing the sampling stations is presented in Figure 1.

Water sample collection

The study area was divided into five agricultural cluster zones for the purposes of sample collection. Water samples were collected from three streams, twenty shallow hand dug wells (SHDW) and ten lakes/pond nearest to human settlements and most susceptible to anthropogenic influences. For each stream, six sampling status were created to capture the entry point of pollution sources and not in any way equidistant. Overall, 48 sampling points were created for the study and at each sampling time, 48 water samples were collected and analysed. The analysis was carried out once monthly over a period of four months between August and November, 2011. This gave a total of 192 determinations. The collection of water samples was done with 2 L polyethene bottles washed with detergents and copiously rinsed severally with deionized water. The water upon collection was acidified with few drops of concentrated nitric acid to keep the metals in solution. The samples were transported to the analytical laboratory in an ice-water mixture cooled boxes for analysis (Kimete et al., 2010).

Equipment and chemicals

Instrumental method was adopted using flame Atomic Absorption Spectrophotometer (Model UNICAM 929) with air /acetylene flame except for mercury where cold vapour was used. All chemicals used were analytical grade reagents. Standard solutions of the studied metals were prepared from their salts and used for calibration curve for Fe, Cu, Cr, Pb, Cd, As and Hg. Their standard solutions were prepared in aqueous solutions containing 2% of nitric acid. The determinations were carried out according to the standard methods for water quality (APHA, 1998).

The limit of detection for the metals were calculated as three times the standard deviation for the digested blanks (n = 5). Also the limit of quantiation LOQ was got as three times the LOD. The values of LOQ and LOD obtained are shown in Table 1.

Health risk assessment

The exposure of the rural dwellers to toxic metal contamination in the water samples were quantified using the equation developed by Bockting et al. (1996) to obtain the ingestion of water samples this ingestion of surface water (mg/kg/day):

$$[CW \times IRW \times EF \times AF] \div BW$$

Where
IW = Injestion rate of surface water (litre/exposure day),
EF = Exposure frequency,
AF = Absorption factor,
BW = Body weight.

Health Risk assessment of the toxicants was interpreted based on the values of HQ and THI. Values less than one (HQ or THI < 1) means no risk and the greater the values above one, the greater is the level of risk of the toxicants manifesting long term health hazard effects increasing (Lemy, 1996 ; Wang et al., 2012).

The Hazard Quotient HQ was also estimated from the equation:

$$HQ = \frac{D}{RfD}$$

where RfD in the oral reference dose or tolerable daily intake which was obtained from United States Environmental Protection Agency tables (USEPA – IRIS 2010) and refers to the maximum amount of toxicant which does not translate to adverse effect on the one ingesting the toxicants.

The parameters used in the calculation are shown in Table 2.

RESULTS

The results of the determinations are shown in Table 3 (Concentration of the trace heavy metals in the studied rivers), Table 4 (Concentration of the trace heavy metals in the studied ponds/lakes) and Table 5 (Concentration of

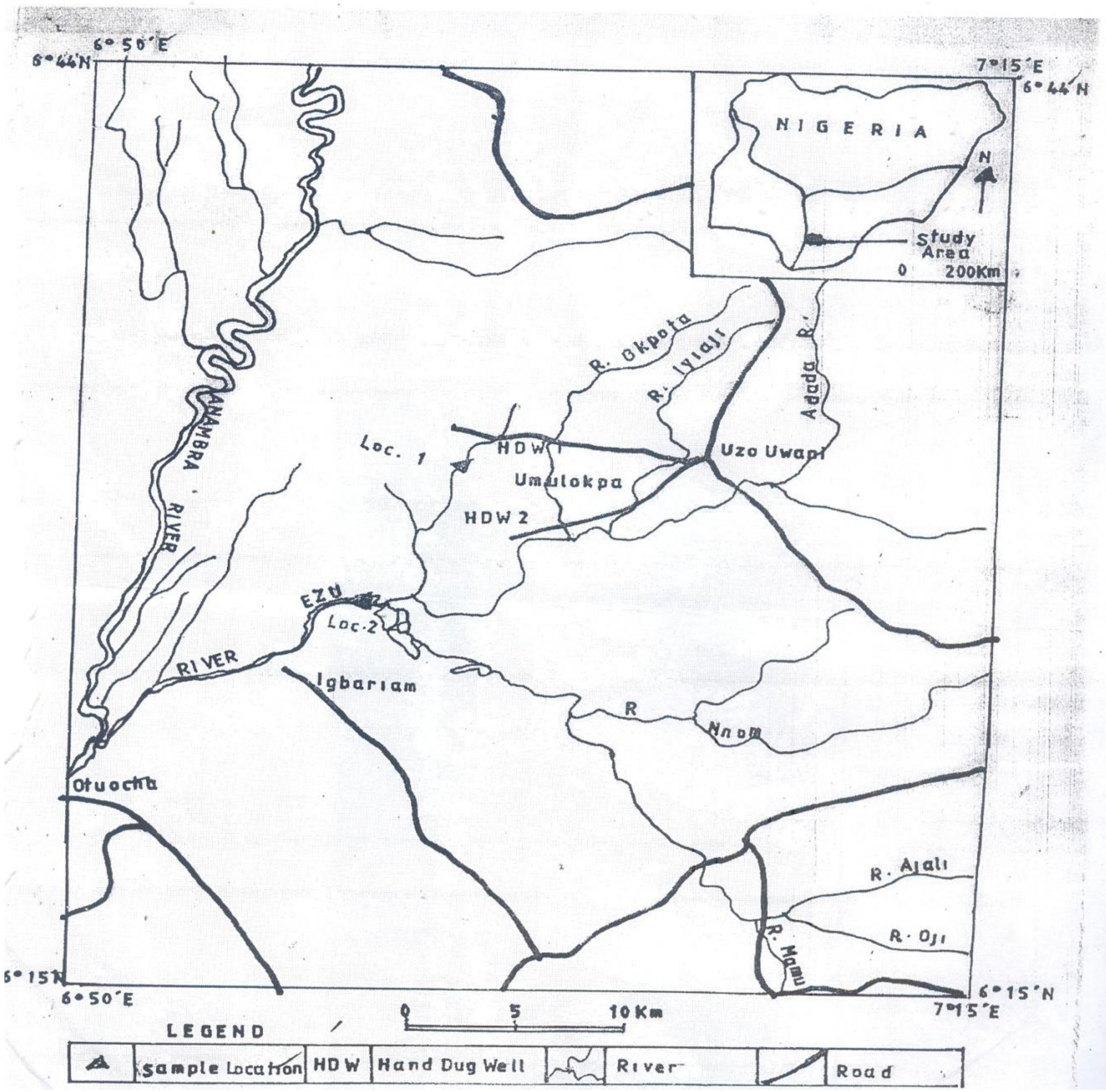

Figure 1. Sketch map of the study area showing sampling stations.

Table 1. Limit of Detection (LOD) and Limit of Quantitation (LOQ) of toxic metals and water samples using FAAS.

Metal	LOD (mg/L)	LOQ (mg/L)
As	0.002	0.006
Hg	0.003	0.009
Cd	0.001	0.004
Pb	0.002	0.006
Cr	0.003	0.009
Cu	0.002	0.006
Fe	0.005	0.010

the trace heavy metals in the studied shallow hand dug wells). The concentration levels of total Arsenic had a range of 0.01 to 2.01 mg/L. The metal was not detected in Iyiakoro River and had a maximum concentration in Obina River. Highest concentration of arsenic occurred at Adani cluster ponds/lakes and Adani cluster shallow hand dug well. Mercury was not detected in majority of the water samples except in water samples from Adani clusters of ponds and shallow hand dug well where it has a maximum concentration of 0.001 mg/L.

The cadmium levels in the water samples had ranges of 0.001 to 0.090 mg/L; not detected (n.d) -1.00 and 0.002-

Table 2. Parameters used in the exposure equation.

Parameter	Child	Adult	References
IRW (litres/exposure day)	50×10^{-3}	50×10^{-3}	Van Wijnen (1982)
EF (days/365 days)	30	30	Albering et al. (1999)
AF (unitless)	1	1	Albering et al. (1999)
BW (kg)	15	70	Veerkamp and en Berge (1990)

Table 3. Concentration of the trace heavy metals in studied rivers.

Metallic Ion (ppm)	Ezu	Obinna	Iyiakoro	WHO Max limit
As	0.02±0.03	0.08±0.011	ND	0.050
Hg	ND	ND	ND	0.001
Cd	0.090±0.011	0.015±0.011	0.001±0.02	0.003
Pb	0.90±0.02	0.40±0.11	0.07±0.01	0.050
Cr	0.44±0.02	0.32±0.02	0.01±0.11	0.002
Cu	0.20±0.11	0.45±0.02	0.22±0.02	1.000
Fe	1.80±0.12	1.52±0.11	1.40±0.11	0.300

ND = Not Detected.

Table 4. Concentrations of the trace heavy metals in studied ponds/lakes.

Metallic Ion (ppm)	Adani	Opanda	Pond/lake clusters Ukpabi Nimbo	Umulokpa	Nkpologwu	WHO Max. limit
As	2.00±0.02	1.00±0.03	0.070±0.03	0.01±0.003	0.060±0.03	0.050
Hg	0.001±0.03	ND	ND	ND	ND	0.001
Cd	0.110±0.02	0.050±0.003	0.080±0.003	ND	1.00±0.001	0.003
Pb	3.00±0.02	2.54±0.03	1.45±0.01	0.99±0.02	2.01±0.03	0.050
Cr	0.65±0.02	0.35±0.04	0.20±0.15	0.22±0.03	0.35±0.03	0.002
Cu	0.65±0.01	0.32±0.01	0.21±0.02	0.28±0.02	2.65±0.02	1.000
Fe	0.75±0.01	1.45±0.02	4.50±0.01	3.31±0.02	6.50±0.03	0.300

ND = Not Detected.

Table 5. Concentrations of the trace heavy metals in studied shallow hand dug wells (SHDW).

Metallic Ion (ppm)	Adani	Opanda	Ukpabi Nimbo	Umulokpa	Nkpologwu	WHO Max. limit
As	1.85±0.02	1.34±0.05	0.87±0.03	0.02±0.03	0.05±0.011	0.050
Hg	0.001±0.03	ND	ND	ND	ND	0.001
Cd	0.25±0.001	0.020±0.001	0.115±0.030	0.002±0.001	0.95±0.10	0.003
Pb	3.54±0.03	2.11±0.04	0.65±0.04	0.38±0.02	0.66±0.01	0.050
Cr	0.45±0.12	0.15±0.01	0.32±0.03	0.08±0.12	0.39±0.02	0.002
Cu	0.90±0.02	0.45±0.01	0.65±0.03	0.10±0.01	0.33±0.02	1.000
Fe	8.00±0.04	7.10±0.03	2.50±0.11	1.45±0.01	15.0±0.05	0.300

ND = Not Detected.

0.95 mg/L in rivers, ponds/lakes and hand dug wells respectively. The concentration levels of lead which ranged between 0.07 to 0.90 mg/L; 0.99 to 3.00 mg/L and 0.38 to 3.54 mg/L in rivers, ponds/lakes and hand dug wells respectively were higher in all the water samples than the set limit by WHO (2008). The levels of chromium were of the ranges 0.01 to 0.44 mg/L; 0.20 to 0.65 mg/L and 0.08 to 0.45 mg/L in rivers, ponds/lakes and hand dug wells respectively. The concentration levels of copper in the water bodies were 0.20 to 0.45 mg/L; 0.21 to 2.65 mg/L and 0.10 to 0.90 mg/L in rivers, ponds/lakes and hand dug wells respectively. In rivers, ponds/lakes and hand dug wells respectively. The concentration iron was found to be above the recommended level in domestic water use in all the water samples analyzed.

DISCUSSION

The arsenic concentrations were higher than the maximum set limit (0.050 mg/L) set by World Health Organization (WHO, 2008) for domestic water usage in all water samples except those from Ezu and Iyiakoro Rivers, Umulokpa clusters of ponds/lakes and shallow hand dug wells. Arsenic enters water bodies through natural and anthropogenic sources. It enters ground water through the desorption of arsenic bound to iron oxides Arsenic is also used in various agricultural insecticides, herbicides, animal diseases prevention and growth stimulants for chicken and swine.

Epidemiological studies have suggested a correlation between chronic consumption of drinking water contaminated with arsenic and the incidence of all leading causes of mortality (Huet et al., 1975; Antman, 2001; Jones, 2007). The toxicological effects of arsenic in drinking have been recently reviewed by Moonis and Yuh-Shan (2011). The epidemiological record of arsenic in study area is totally lacking due to poverty, poor medical care and consequently absence of medical statistics.

The detected mercury in water samples from Adani clusters of ponds and shallow hand dug well were within the set limit by WHO which is, Agricultural Chemicals such as fumigants and preservers and local industries are the major sources of mercury in such rural water supplies. However, the presence of mercury at all calls for regular monitoring of the water bodies in this area. Exposure to mercury via food, water or fish or dental amalgam may raise the blood mercury levels which may lead to neurological damage in adults.

Cadmium is present as a pollutant in phosphate fertilizers and is also found in PVC products, colour pigment alloys and in re-chargeable nickel- cadmium batteries. These cadmium containing products are not recycled but dumped together with household waste, thereby polluting the environment. It has been established that an association exist between cadmium exposure and chronic renal failure (Bernard et al., 1992; Jarup et al., 1995; Hellstrom et al., 2001). Skeletal damage, which was first reported in Japan (called Itai-itai or ouch –ouch) was as a result of using cadmium contaminated water for irrigation of local rice fields. Several other reports have suggested that a relatively low cadmium exposure may give risk to skeletal damage (Alfven et al., 2000; Nordberg et al., 2002).

The concentration levels of lead were higher in all the water samples than the set limit by WHO. This discovery portends serious danger to the inhabitants of the study area. Adults take up to 10 to 15% of lead in food and water whereas children may absorb up to 50% through the gastro intestinal tract. Lead is accumulated in the skeleton with a half life in the skeleton of 20 to 30 years (WHO, 1995). The symptoms of acute lead poisoning are headache, irritability, abdominal pain and numerous symptoms related to nervous system. Recent researches have shown long term lead exposure in children may results in diminished intellectual capacity, encephalopathy, acute psychosis, concentration and learning difficulties and reduced ability to understand (WHO, 1995). Though epidemiological data of lead poisoning is totally absent in the study area due to high level of poverty, neglect, near absence of medical facilities and superstitious beliefs, the possibility of presence of symptoms of lead poisoning in the studied area is strongly speculated (Ubachukwu, 2004).

The concentration iron was found to be above the recommended level in domestic water use in all the water samples analyzed. Excess iron in water and food constitute health hazard, to people. Chronic consumption of water with iron overload results in gene mutation leading to haemochromatosis whose symptoms include fatigue, weight loss, joint pains and ultimately heart disease, liver problems and diabetes (US-CDC, 2011). Furthermore, iron in water also causes severe allergic reaction (rash, lives, itching), difficulty in breathing, tightness in chest, swelling of the mouth, lips and face, black tarry stools and blood or streaks of blood in the stool and severe vomiting or stomach pain (US-CDC, 2011).

Except in Nkpologwu cluster of ponds/lakes, the concentration levels of copper in the water bodies were within the set limit. The main sources of copper in rural water bodies include local industries effluents, domestic wastewater, fumigation and agrochemicals and weathering of copper bearing rocks. All these activities take place in the studied area which may be the reasons for slight elevation of copper levels in the water samples. Like other toxic metals, long term exposure to copper can cause irritation of nose, mouth and eyes which can lead to headache, stomachache, dizziness, vomiting and diarrhea among other health hazards.

The levels of chromium in the water samples were all higher than the set limit except for Iyiakoro river. Water containing chromium ions in excess of the set limit may have an erythropoietin effect such as increased occurrence of goiter among humans and animals (Oyeku and Eludoyin, 2010).

Similar studies in some rural settlements showed elevated levels of toxic metals in rural ground and surface water sources (Adekunle et al., 2007; Ogunlaja and Ogunlaja, 2007; Nwagozie and Ogelle, 2007). This situation is a source of worry considering the fact that typical rural community in Nigeria is devoid of basic infrastructures that make life worth living.

Table 6. Ingestion of water (IW) (×10^{-2}), Oral Daily Intake (DI) (×10^{-2}), Hazard Quotient (HQ) and Total hazard index (THI) of Heavy metal of the water samples

Variable		Ag	Hg	Cd	Pb	Cr	Cu	Fe	THI
Ezu River	IW_{child}	0.020	ND	0.09	0.900	0.44	0.20	1.80	11.535
	IW_{adult}	0.004		0.019	0.193	0.094	0.043	0.385	
	DI	0.041		0.84	1.83	0.899	0.408	3.68	
	HQ	1.362		1.84	5.22	3.00	0.702	0.053	
Obinna River	IW_{child}	0.08	ND	0.015	0.4	0.32	0.45	1.52	6.027
	IW_{adult}	0.017		0.003	0.086	0.068	0.386	0.325	
	DI	0.163		0.137	0.817	0.653	0.096	3.104	
	HQ	0.543		0.613	2.33	2.18	0.317	0.044	
Iyiakoro River	IW_{child}	ND	ND	0.001	0.07	0.010	0.22	1.40	0.752
	IW_{adult}			0.0002	0.015	0.002	0.047	0.30	
	DI			0.002	0.143	0.020	0.449	2.86	
	HQ			0.041	0.409	0.068	0.112	0.041	
Adani Lakes/ ponds clusters	IW_{child}	1.000	ND	0.110	3.00	0.65	0.65	0.75	78.224
	IW_{adult}	0.214		0.023	0.642	0.139	0.139	0.161	
	DI	2.040		0.225	1.10	1.327	1.327	1.531	
	HQ	68.076		2.246	3.130	4.425	0.332	0.02	
Opanda Lakes/ponds Clusters	IW_{child}	0.5	ND	0.05	2.54	0.35	0.32	0.310	58.068
	IW_{adult}	0.107		0.011	0.543	0.075	0.068	2.96	
	DI	1.02		0.102	7.146	0.715	0.653	0.70	
	HQ	34.04		1.021	20.419	2.383	0.163	0.042	
Akpabi Nimbo Lakes/ponds Clusters	IW_{child}	0.07	ND	0.08	1.45	0.20	0.21	4.50	16.461
	IW_{adult}	0.015		0.017	0.310	0.043	0.044	0.903	
	DI	0.142		0.163	2.961	0.408	0.429	9.19	
	HQ	4.77		1.63	8.461	1.362	0.107	0.131	
Umulokpa Ponds/lakes Clusters	IW_{child}	0.01	ND	ND	0.99	0.22	0.28	3.51	10.359
	IW_{adult}	0.002			0.212	0.047	0.060	0.708	
	DI	0.02			2.78	0.449	0.572	6.76	
	HQ	400.68			7.96	1.498	0.143	0.09	
Nkpologwu (SHDW)	IW_{child}	0.06	ND	1.00	2.01	0.35	2.65	6.50	40.156
	IW_{adult}	0.013		0.214	0.430	0.075	0.567	1.39	
	DI	0.123		2.042	4.105	0.715	5.412	0.132	
	HQ	4.084		20.42	11.728	2.383	1.352	0.190	
Adani (SHDW)	IW_{child}	1.85	0.004	0.25	3.54	0.45	0.90	8.0	156.222
	IW_{adult}	0.40	0.0008	0.054	0.758	0.96	0.193	1.71	
	DI	3.78	0.008	0.511	7.22	0.919	1.83	16.3	
	HQ	125.94	0.766	5.105	20.655	3.063	0.460	0.233	
Opanda SHDW	IW_{child}	1.34	ND	0.02	2.11	0.15	0.45	7.10	105.400
	IW_{adult}	0.287		0.004	0.452	0.032	0.096	1.519	
	DI	2.74		0.041	4.30	0.306	0.919	14.70	
	HQ	91.22		0.408	12.312	1.02	0.230	0.210	

Table 6. Contd.

Ukpabi Nimbo SHDW Cluster	IW_{child}	0.87	ND	0.115	0.65	0.32	0.65	2.50	67.959
	IW_{adult}	0.186		0.025	0.139	0.068	0.139	0.535	
	DI	1.78		0.235	1.32	0.654	1.327	5.70	
	HQ	59.233		2.345	3.79	2.178	0.332	0.081	
Umulokpa SHDW Cluster	IW_{child}	0.02	ND	0.002	0.38	0.08	0.10	1.45	4.627
	IW_{adult}	0.004		0.004	0.081	0.0177	0.021	0.310	
	DI	0.04		0.039	0.776	0.163	0.281	2.96	
	HQ	1.36		0.393	2.217	0.545	0.070	0.042	
Nkpologwu SHDW Cluster	IW_{child}	0.05	ND	0.95	0.66	0.39	0.33	15.0	29.911
	IW_{adult}	0.011		1.203	0.141	0.083	0.071	0.321	
	DI	0.102		1.94	1.348	0.796	0.674	30.6	
	HQ	3.40		19.401	3.851	2.654	0.168	0.438	

ND = not detected, SHDW=shallow hand dug well.

Health risk assessment

The calculated ingestion of water (IW) for both child and adult, daily oral intake (DI), hazard quotient (HQ) and total hazard index (THI) are presented in Table 6. The result of the potential risk assessment calculations showed the Arsenic had hazard quotient (HQ) ranges of 0.543 to 125.94 while only three water bodies (Iyiakwo River, Obinna River and Umulokpa ponds/lake dusters) have values that pose no health risk to the rural dwellers who depend on them for drinking and cooking of their foods (HQ < 1). Total mercury was detected only in Adani shallows hand dug well cluster but its HQ is not yet a risk factor. The HQ for Cd in five out of the thirteen water body clusters studied indicated no risk while the rest pose potential risk for the users. The hazard index for Pb was high in all water samples except Iyiakoro river (HQ = 0.409). Cr had HQ values has than one in only two sample clusters while the rest pose moderate risk to the water users. Cu and Fe pose no hazard risk in all the water bodies except for Nkpologwu ponds where HQ value for Cu was 1.352, an indication of moderate risk.

The Total Hazard Index (THI) of the metals in all the water bodies studied show high risk except in Iyiakoro River (THI = 0.752) with the highest risk in Adani shallow hand dug well cluster (THI = 156.222). This result is a source of concern because of possible heavy metal bioaccumulation among the consumers of these water bodies. Similar risk assessments carried out by Muhammed et al. (2011) found HQ values less than unity for drinking waters of Kohistan region of Pakistan. Chromium (IV) was found by Kelepertzis (2014) to be of serious concern in drinking waters of Thiva area of Greece.

Conclusion

Seven toxic metals were assessed in water sources in the rural settlements. The results of the assay showed that except for mercury, all others showed presence in excess of set limit in most of the water samples. The hazard risk assessment of the water samples indicated moderate risk for some and high risk for others.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Adekunle M, Adetunji MT, Gbadebo AM, Banjoko B (2007). Assessment of groundwater quality in a typical rural settlement in South West, Nigeria. Int. J. Environ Res. J. Public Health. 4:307–318. http://dx.doi.org/10.3390/ijerph200704040007

Adeleye IA, Adebiyi A (2003). A physicochemical and microbial assessment of Oko-Oba-a Nigerian abattoir. J. Environ. Biol. 24:309–313.

Akujieze CN, Coker SJ, Oteze GE (2003). Ground Water in Nigeria millennium experience – Distribution, practice, problems and solutions. Hydrogeol. J. 1:59-274.

Albering HJ, Rila JP, Moonen EJC, Hoogewerff JA, Kleinjans JCS (1999). Human Health Risk Assessment in Relation to Environmental Pollution of Two Artificial Fresh water Lakes in the Netherlands. Environmental Health Perspective. 107:27–35. http://dx.doi.org/10.1289/ehp.9910727

Alfven T, Elinder CG, Carlsson MD, Grubb A, Hellstrom L, Persson B (2000). Low –level Cadmium exposure and Osteoporosis. J. Bone Miner. Res.15:1579–1586. http://dx.doi.org/10.1359/jbmr.2000.15.8.1579

Antman KH (2001). The History of Arsenic Trioxide in Cancer Therapy. The Oncologist. 6(suppl. 2):1–2. http://dx.doi.org/10.1634/theoncologist.6-suppl_2-1

American Public Health Association. (APHA) (1998). Standard Methods for the examination of water and waste water. 20th Edition. AWWA/NPCF. New York 5:24–26.

Baccarelli A, Bollati V (2009). Epigenetic and environmental Chemicals. Current Opinion in Pediatrics 21:243–251. http://dx.doi.org/10.1097/MOP.0b013e32832925cc

Bernard A, Roles H, Buchel JP, Cardenas A, Lauwery R (1992). Cadmium and Health: the Belgian experience. IARC Scientific publications. 118:15–23.

Bockting GJM, Koolenbander JGM, Swarjes FA (1996). SEDSOIL. Estimation of human exposure to sediments (in Dutch) Rpt no 715810011. Bilthoven. The Netherlands Institute of public Health and the environment.

Bresine E (2007). Sustainable water supply in developing countries. Geol. Soc. Amer. Paper No. 194-201

Galadima A, Garba ZN, Leke L, Almustapha M, Adams IK (2011). Domestic water Pollution among Local Communities in Nigeria – Causes and Consequences. Euro. J. Sci. Res. 52:592–563.

Hellstrom L, Elinder CG, Dahlberg B (2001). Cadmium Exposure and end–stage renal disease. Am. J. Kidney Dis. 3:1001–1008. http://dx.doi.org/10.1053/ajkd.2001.28589

Huet PM, Guillaum E, Cote J, Legare A, Lavoie P, Viallet A (1975). Noncirrhoitic Presinusoidal portal,hypertension associated with Chronic arsenical intoxication. Gastroenterology.68:1270–1277.

Ikem A, Osibanjo O, Sridhar MKC, Sobandea A (2002). Evaluation of groundwater quality Characteristics near two waste sites in Ibadan and Lagos, Nigeria. Water. Air Soil Pollutions.140:307–333. http://dx.doi.org/10.1023/A:1020165403531

Jarup L, Persson B, Elinder CG (1995). Decreased glomerular Filtration rate in cadmium exposed solderers. Occup. Environ. Med. 52:818–822. http://dx.doi.org/10.1136/oem.52.12.818

Jones FT (2007). A Broad View of Arsenic. Poultry Science.86:2–14. http://dx.doi.org/10.1093/ps/86.1.2

Kaitantzian A, Kelepertzis E, Kelepertsis E (2013). Evaluation of the sources of contamination in the suburban area of Koropi-Markopouulo, Athens,Greece. Bull. Environ. Contamin. Toxicol. 91:23-28.http://dx.doi.org/10.1007/s00128-013-1023-6

Keleperzis E (2014). Investigating the sources and potential health risks of environmental contaminants in the soils and drinking waters from the rural clusters in Thiva area (Greece). Ectotoxicol. Environ. Safety. 100:258-265. http://dx.doi.org/10.1016/j.ecoenv.2013.09.030

Kimete K, Islam K, Majlinda V, Majlinda V, Lirie S, Aferdita Z (2010). The level of heavy metals in several alternative water sources in the area Kastriot –Vushtrri-Drenas in Kosovo. BALWOIS.– Ohrid, Republic of Macedonia 25 -29 May. 1–11.

Lemy AD (1996). Evaluation of hazard quotient method for risk assessment of selenium. Ectotoxicology and Environmental safety. 35:156–162.

Moonis AK, Yuh –Sahn H (2011). Arsenic in Drinking water: A Review on Toxicological Effects, Mechanism of Accumulation and Remediation. Asian J Chem. 23:1889–1901.

Muhammed S, Shari MT, Khan S (2011). Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. Michrochem. J. 98:334-343. http://dx.doi.org/10.1016/j.microc.2011.03.003

Nabi Bidhendi GR, Karbassi AR, Nasrabadi T, Hoveidi H (2007). Influence of Copper mine on surface water Quality. Int. J. Environ. Sci. Tech. 4:85–91. http://dx.doi.org/10.1007/BF03325965

Nagehi F (2012). Heavy metals distributions in Water of the Aras River, Ardabil, Iran. J. Water Resource Protection. Available at http//www.readPeriodicals.com/201202/262332851htm.

National Population Commission of Nigeria (NPC) (2006). Population Census 2006. NPC Lagos, Nigeria.

Nordberg G, Jin T, Bernard A, Fierens S, Buchet JP (2002). Low bone density and renal dysfunction following environmental cadmium exposure in China. Ambio. 6:478–481.

Nwagozie IL, Ogelle E (2007). Water quality modeling of Rice – irrigated Obinna River Basin, Uzo uwani, Water, Air and Soil Pollution.100:197–212. http://dx.doi.org/10.1023/A:1018363205367

Ogunlaja A, Ogunlaja OO (2007). Physico –chemical Analysis of water sources in Ubeji community and their histological impact on organs of albino mice. J. Appl. Sci. Environ. Manage. 11:91–94.

Oyeku T, Eludoyin AO (2010). Heavy metal contamination of groundwater resources in a Nigerian Urban settlement. Afr. J. Envrion. Sci. Tech. 4: 207–214.

Singh KP, Malik AD, Sinha S (2005). Water Quality Assessment and Apportionment of pollution sources of Gomti River (India) using multivariate statistical Techniques: A case study. Chimica Acta. 538:355–374. http://dx.doi.org/10.1016/j.aca.2005.02.006

Ubachukwu PO (2004). Local Disease perception and treatment of enchocerciasis in uzo uwani Local Government Area of Enugu state, Nigeria. Animal Res. Int. 1:23–30.

United States Centre for Disease Control (US-CDC). (2011). Iron overload and Hemochromalosis. Centre for Disease control. March 28.

Uzo-uwani Professional Association (UPA) (2010). Our strategy paper. Available at www.uzouwaniprofessional.blogspot.com.

USEPA (2010), Integrated Risk Information System (IRIS). United States Environment Protection. Available online: http//www.Epa.Gov/irrris/index.infml (accessed October 2011).

Van Wijnen JH (1982). Health Risk Assessment in relation to soil pollution (Vogelmeer) (in Dutch) Tr. Soc. Geneesk. 60:555–559.

Veerkamp W, Ten Berge W (1990). Hazard Assessment of chemical contaminants in soil, ECETOC Technical Report 40 Brussels. European Chemical Industry Ecology and Toxicology Centre.

Wang X, Wang F, Chem B, Sun F, He W, Wen Di L, Si Wang Q (2012). Comparing the health risk of toxic metals through vegetable consumption between industrial polluted and non – polluted fields in Siaoguan; south China. J. Food, Agric. Environ. 10(2):943–948.

World Health Organization (WHO). (1995). Lead. Environmental Health Criteria.165. Geneva. World Health Organization.

World Health Organization (WHO) (2008). World Health Organization guidelines for Drinking water. Vol. 1. Geneva.

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Geophysical investigation of the effects of sewage in the soil at university of Nigeria, Nsukka, Enugu State, Nigeria

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Geophysical investigation was carried out to detect the spread of sewage effluent and to locate the sources and delineate migration paths and the extent of leachate plume. The study was to find out the geological formations that are the most conductive layers in the sewage site for the free flow of the contaminants. Soil tests showed that hydraulic conductivity, bulk density and water retention were variable in sewage soil, but consistent in soil unaffected by sewage. In sewage soil, maize crops performance, organic matter, total nitrogen exchangeability, cations exchange capacity and sodium were significantly enhanced than in non-sewage soil. In sewage soil, electrical conductivity (EC), zinc (Zn), lead (Pb), copper (Cu), Cadmium (Cd), salt concentration and other saline properties, total faecal coliform and microbial activities were high. Twelve vertical electrical soundings (VES) points with Omega Terrameter were used in the Schlumberger Array configuration which the geoelectrical section from the resistivity data revealed seven subsurface layers. Three low resistivity zones were detected as correspondent zones to the plumes. The comparative evaluation of the 3-D stack model of the resistivity of layers with respect to depth suggested that these three low resistivity layers were contaminated, especially as the depth to water table is more than 100m. The flow direction of the contaminant plume is northwest to southwest as indicated by stack model of the low resistivity layers. Generally, the contaminant plume is a threat to ecosystem and a great health problem to people living around the sewage site.

Key words: Delineate, contamination, leachate, sewage effluent, saline, ecosystem.

INTRODUCTION

The sewage site at University of Nigeria, Nsukka is accessible through numerous routes within the campus, e.g. from Nnamdi Azikiwe new Library through Eni-Njoku street, Murtala Mohammed Way and Louis Mbanefo street. The UNN campus is situated on the hills of Obukpa town and Agu-ihe of Nsukka Local

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Government Area in Enugu State, Nigeria.

Geophysical investigation was carried out with the aid of Omega Terrameter by the Department of Geology, UNN using Schlumberger Array configuration to detect the spread of sewage effluent; and also to locate and delineate the migration pathways and the extent of the leachate plume. The sewage site is envisaged as a potential source of groundwater contaminants in the campus and its environs. The soil tests were carried out at the Soil Science Unit and Department of Zoology, UNN.

The generation of the sewage effluent increased recently due to increase in the students population, and thus could be a possible source of contaminants to groundwater. The sewage effluent could be waste water generated mainly from toilets, bathrooms and laundry activities. The major sources of the waste water could be from students hostels, staff quarters, offices, medical centre, classrooms, banks, restaurants, primary and secondary schools in the campus.

Geologically, the sewage site is located on Ajali Sandstone which underlies Nsukka Formation. Ajali Sandstone within Nsukka and its environs is a sandstone unit with medium to coarse grained, moderately to poorly sorted, friable, whitish in colour with iron stains and clay lenses due to the overlying Nsukka Formation. The Nsukka Formation has sandstone, clayey shale and ironstone units (Oguamah, 1999). Ironstone is the prominent outcrop at the site.

The most outstanding threat to groundwater quality in the study area is the improper, unscientific, unacceptable and inadequate disposal, treatment and management of the sewage effluent generated. It is good to study the sewage disposal manipulations and handling from the oxidation ponds sewage systems. Due to the slow flow pattern of groundwater, the effluent plume spreads slowly as a contaminant (Montgomery, 2005), and thus the natural flow of groundwater disperses the sewage effluent as a plume of contamination. Thus, the study is to investigate the sewage effects in soil due to its indiscriminate wide spread on the soil surface for agricultural purposes.

GEOLOGY

The Benue Trough is a northeast-southwest trending sedimentary basin which consists of up to 5000 m of cretaceous sediments, contiguous with the rift basins of Niger, Chad and Sudan Republic (Akande, 2004) and extending to over 1000 kms from the Niger Delta to Lake Chad.

The sedimentary rocks of the Lower Benue Trough are the hosts of various igneous rocks (Obiora and Umeji, 2004). The main lithostratigraphic units that underlie the study area are the Ajali Sandstone and Nsukka Formation within the Lower Benue Trough. The Ajali Sandstone is of Maestrichtian Age and consists of white, medium to coarse grained sandstone and friable sands. It marks the height of regression that ended the Nkporo deposition cycle and the stratigraphic position of Ajali Sandstone between two paralic sequences of the underlying Mamu Formation and overlying Nsukka Formation indicates a continental origin. This could be due to the evidence of tidal origin showed with the development of herringborne cross stratification, bimodal-bipolar, paleocurrent pattern, suspension deposit on forest laminae and mixed bedding. Ajali Sandstone is the main aquiferous unit within the campus. Ajali Sandstone is most often stained red, and thus overlain by thick red soil due to weathering.

Nsukka Formation is of the Upper Maestrichtian to Danian Age, known as Upper Coal Measure. It consists of less sands and less coal seams than Mamu Formation which has up to five coal seams. It is deposited under paralic conditions in a strand- plain marsh within shallow marine environment and occasional fluvial incursion. Nsukka Formation is divided into sandstone unit, especially at its boundary with Ajali Sandstone; clay and ironstone units at its upper contact with Imo Shale. The outcrop of the sandstone unit of Nsukka Formation exists at the opposite Green House, about 1.5 kms from University gate to Owerre-Ezu Orba, near UBA and Oceanic Bank. It is an old quarry site and also weathered with elevation of about 450 m and about 4 m thick. There is another outcrop at Hilltop Odenigwe with elevation of about 480 m and about 5.5 m thick.

RESULTS AND DISCUSSION OF THE ANALYSIS OF THE PHYSICAL CHARACTERISTICS OF THE SOIL ENVIRONMENT

The physical characteristics of the soil environment within the sewage site are classified into two, namely soil at the sewage disposal area and the soil within the non-sewage disposal area. The two categories of soils are derived from the Nsukka Formation (that is, False Bedded Sandstone). It is deep and excessively drained. Soil within the sewage disposal area is very dark reddish brown to reddish brown, while non-sewage disposal area has dark reddish brown to red in colour.

The soil colour variations within the sewage disposal site could be attributed to the existence of sludge and sewage effluent. This is because of the presence of organic matter in the soil, especially for a very long time without oxygenated environment, but with contaminated water as moisture occupying the soil- pore spaces it always changes the clayey-shale soil-colour from light grey to dark grey or dark brown with pungent smell, unless the accumulation of either salts or iron oxide in the soil modify and alter the decomposition processes that affect the colour and odour.

Table 1 helps to classify the soil with respect to some physical properties, especially after the disposal of sludge and sewage effluent. The texture or physical size analysis indicated mainly sand and loamy-sand on the top soil, but the subsoil has sandy loam. However, the coarse texture in all soils could be due to the existence of Nsukka Formation (that is, False Bedded Sandstone) that is dominance in the area. Clay content ranged from about 6 to 18%, but increased with depth in sewage soil and has no known trend in non-sewage soil. Thus, clay content is low as well as silt content which ranged from about 1 to 10%. The low contents of clay and silt indicate the degree of weathering and leaching which the soil has undergone. The low contents of clay and silt could also

Table 1. Comparative evaluation of some physical characteristics of sewage and non-sewage soil-types.

Percentage					Percentage				
					(A) Sewage disposal area and soil-type				
Soil classification	**Depth (cm)**	**Sand**	**Clay**	**Silt**	**Bulk density (g/cm^3)**	**Micro porosity**	**Macro porosity**	**Ratio of micro/macro porosity**	**Percent of total porosity**
Sand	0-15	90	8	4	1.56	23	25	2:4	45
Loamy sand	15-36	87	7	7	0.82	39	8	5:1	47
Sandy loam	36-55	90	8	2	1.58	32	10	3:1	43
Sandy loam	55-105	80	18	2	1.55	35	12	5:4	40
Sandy loam	105-160	78	18	4	1.56	30	14	5:3	39
	Mean	85	12	4	1.41	32	14	-	43
					(B) Non-sewage Disposal area and soil-type				
Loamy soil	0-14	84	6	10	1.45	24	27	4:5	51
Sandy loam	14-37	82	14	4	1.48	24	26	4:5	50
Sandy loam	37-76	78	12	10	1.50	31	14	2:1	45
Sandy loam	76-90	76	18	6	1.53	24	16	3:2	40
Sandy loam	90-160	78	16	6	1.64	26	19	3:2	45
	Mean	80	13	7	1.52	26	20	-	46

be attributable to high detachability and transportability of these lighter materials (Obi and Ebo, 1995). Sand content was about 80% mean in non-sewage soil, and about 85% mean in sewage soil; but sewage soil may have sand content up to 90% due to easy dispersion of clay and silt fractions that were clearly washed away. The importance of clay dispersibility is a measure of soil structural integrity and implication of water infiltration and retention (Curtin et al., 1994).

For bulk density, the soil of sewage disposal area has a range from 0.82 to 1.58 g/cm^3, but for non- sewage disposal area, the soil has a range from 1.45 to 1.64 g/cm^3. The low bulk density in sewage soil could be due to the accumulation of humified sewage materials. Generally, organic matter has very low bulk density and hence the most likely cause of the low bulk density of the soil in the sewage disposal area. It was observed that there is an inconsistent pattern of bulk density with depth in sewage soil, but consistent pattern in non-sewage soil. This is because, sewage soil has discontinuity of soil profile due to the presence of humified sewage material layers. The density of the primary particles in sewage soil structures may be responsible for the low and high bulk density values variation. Generally, there was no positive improvement in bulk density and total porosity in both soil-types due to large application of sludge and sewage effluent over a long period of time, but short-time low application of sewage effluent to soil can yield positive improvement in the soil bulk density and porosity.

The high ratio of micro to macro porosity in sewage soil may make for aeration build-up and toxicity in plant roots and microorganisms. Pagliai and DeNobili (1993) observed that adequate proportion of micro and macro porosity was necessary for the existence of continuous air diffusion pathways in the soil.

In Table 2, the sludge and sewage effluent soil has a range of 0.39-0.49 volumetric water content at saturation. The highest volumetric water content at saturation of 0.49 could be due to the water adsorption capacity of organic matter. About 70% water retained in sewage soil at 60cm tension was more than 50% of water held in non-sewage soil. The actual amount of water retained in the sludge and sewage effluent soil was contributed by the amount of organic materials and the dominance of micro-pores. The non-homogeneous continuity of the sewage soil could be contributed to high water retention capacity.

At the same depth of soil profile of both sewage soil and non-sewage soil, the saturated hydraulic conductivity is variable and consistent in sewage and non-sewage soils respectively. It is as low as 4.21 cm/h in sewage soil against 7.10 cm/h in non-sewage soil. The permeability class ranged from moderate to rapid for sewage soil and rapid to very rapid for non-sewage soil. The long-term application of sludge and sewage effluent could reduce soil hydraulic conductivity due to the formation of biological materials within the crust. It could also be due to the accumulation of solids filtered from the effluent and/or the collapse of soil structure because of dissolution of organic matter. The same observation was made by Lieffering and McLay (1996) because they observed that long-term application of organic waste such as sludge and sewage effluent significantly reduce

Table 2. Volumetric water content retention characteristics at saturation and 60cm tension, hydraulic conductivity and dispersion ratio of the sludge and sewage effluent and non-sludge and sewage effluent soils.

S/No	Depth (cm)	Volumetric water content at saturation	Moisture (gg/L) at 60cm tension	Hydraulic conductivity (cm/h)	Dispersion ratio (percentage)	Permeability class
			(A) Sludge and sewage effluent soil			
(i)	0 –15	0.47	0.26	20.52	96	Rapid
	15 – 35	0.47	0.40	4.21	98	Moderate
	35 – 55	0.40	0.23	7.89	98	Moderately rapid
	55 –105	0.42	0.28	13.15	91	Rapid
	105 -160	0.39	0.29	19.47	80	Rapid
	Mean	0.42	0.35	13.05	93	Rapid
(ii)	0-18	0.48	0.22	20.52	97	Rapid
	18-43	0.49	0.40	4.21	98	Rapid
	43-65	0.42	2.30	7.89	98	Moderately rapid
	56-80	0.46	0.27	19.15	88	Rapid
	Mean	0.47	0.32	13.05	92	Rapid
			(B) Non sludge and sewage effluent soil			
(i)	0-14	0.51	0.25	24.72	63	Very rapid
	14-37	0.53	0.25	7.10	75	Rapid
	37-76	0.45	0.30	16.78	42	Rapid
	76-90	0.40	0.32	19.99	67	Rapid
	90-160	0.44	0.33	19.47	80	Rapid
	Mean	0.47	0.30	20.52	62	Rapid

soil permeability and the low permeability was attributable to the accumulation of solids filtered from effluent and the collapsed soil structure due to the dissolution of organic matter.

Dispersion ratio is a measure of soil's structural integrity which is used mainly to identify the soils susceptibility to slaking, crusting, infiltration and erosion capabilities during rainfall. Thus, dispersion ratio is about 98% in sewage soil and about 80% in non-sewage soil. The high dispersion ratio in sewage soil causes aggregate breakdown and subsequent clay dispersion leading to pore blockage and surface crushing. This leads to low water infiltration, high retention and very high surface soil erosion (Table 3).

The effects of exchangeable sodium on the soil are based on sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP). The saturated soil electrical conductivity (EC) is used to appraise the effect of soil salinity on plant growth. Salt concentration, total cations and osmotic pressure are used as indices of the wilting coefficient of soils. An index of the wilting coefficient of a soil is a measure of the quantity of water that the soil can supply to plants. A plant or flower wilts when it bends towards the ground because of either heat or lack of water.

The concentration values of SAR, ESP, EC, salt, total cation and osmotic pressure of sludge and sewage effluent soil are higher than that of non-sludge and sewage effluent soil. For example, the SAR values of the sewage effluent soil ranged from 0.06 to 0.13, with 0.13 been the highest value which indicates that a high percentage of exchangeable sodium has been built in the soil, but in non-sewage effluent soil SAR ranged from 0.06 to 0.10 indicating no significant exchangeable sodium (Onah, 2012). Therefore, if the non-sewage effluent disposal soil is to be considered as the baseline for comparative evaluation, it is evident that long-term application of sludge and sewage effluent greatly increase the exchangeable sodium concentration in the top soil and subsoil of the sewage soils. High SAR causes an increase in soil dispersion.

The soil salinity and the high SAR in soils causes the yields of salt sensitive crops to be restricted. Furthermore, the salts may interfere with the absorption of water by plant hair roots through reduction in the soil osmotic water potential, and thus decrease the amount of water that would be readily available for the plant roots uptake and increase in the wilting coefficient of soils. Therefore, high salt concentration in soils through heavy application of municipal effluent most often interfere with the absorption of water by soyabeans through the reduction in the soil osmotic water potential.

Table 3. Results of SAR, ESP, EC, salt concentration, total cation concentration, osmotic pressure and salinity hazards of sewage soil.

S/No	Depth (cm)	SAR	ESP	EC (μ/cm)	Salt conc. (mg/L)	Total cations conc. (mg/L)	Osmotic pressure (atm)	Salinity hazards
					(A)	Sludge and sewage effluent soil		
(i)	0-15	0.13	2.0	1.04	665.60	10.40	0.37	Yields of many crops, especially sensitive crops may be restricted.
	15-35	0.12	2.25	3.15	2016.00	31.40	1.13	,,
	35-55	0.09	2.00	0.38	243.00	3.80	0.14	,,
	55 -105	0.09	2.00	0.21	134.00	2.10	0.08	Salinity effects negligible
	105-160	0.07	1.50	0.18	115.20	1.18	0.07	Salinity effects negligible
	Mean	0.10	2.00	0.99	634.88	9.92	0.36	Salinity effects negligible
(ii)	0-18	0.10	2.00	1.16	742.40	11.60	0.42	Salinity effects negligible
	18-43	0.13	2.22	3.05	1925.00	30.60	1.10	Salinity effects negligible
	43-65	0.09	2.25	0.40	256.00	4.00	0.14	Salinity effects negligible
	65-80	0.10	2.00	0.21	134.00	2.10	0.08	Salinity effects negligible
	80-150	0.06	1.50	0.20	128.00	2.00	0.07	Salinity effects negligible
	Mean	0.01	2.00	1.00	642.56	10.06	0.36	Salinity effects negligible
					(B) Non – sludge and sewage effluent soil			
	0 – 14	0.08	1.50	0.09	57.60	0.90	0.03	Salinity effects negligible
	14 – 37	0.10	1.80	0.06	38.40	0.60	0.02	Salinity effects negligible
	37 – 76	0.08	1.76	0.03	19.20	0.30	0.01	Salinity effects negligible
	76 – 90	0.07	1.50	0.02	12.80	0.20	0.01	Salinity effects negligible
	90 – 160	0.06	1.50	0.02	12.80	0.20	0.01	Salinity effects negligible
	Mean	0.08	1.62	0.04	28.16	0.44	0.20	Salinity effects negligible
	Waste water	1.89	1209.60	18.90	0.68	Yields of very sensitive crops may be restricted	Yields of very sensitive crops may be restricted	Salinity effects negligible

CONCLUSION

The spread and migration pathways of sludge and sewage effluent in soil physical environment has variable and consistent hydraulic conductivity, bulk density and water retention in sewage soil zone and in soil unaffected by sewage respectively. From the geophysical study, the low resistivity zones are correspondent zones to the plumes. The 3-D stack model of the resistivity of layers with respect to depth suggest that the three low resistivity layers were contaminated. The study of flow direction of the sludge and sewage effluent is NW to SW as indicated by stack model of the low resistivity layers.

The permeability of the sludge and sewage effluent into the soil is moderate to rapid for sewage soil, but rapid to very rapid for non-sewage soil. Therefore, long application of sludge and sewage effluent reduce soil hydraulic conductivity. This is because of the dissolution and accumulation of solid particles filtered from the sewage effluent and organic matter.

Dispersion ratio which measures soil structural integrity helps to identify the susceptibility of the soil to slaking, infiltration and erosion. It is about 98 percent in sewage soil and about 80 percent in non-sewage soil. The high value of dispersion ratio in sewage soil causes clay dispersion that blocks the soil pores leading to surface crushing, low water infiltration and high surface erosion. Salt concentration, total cations and osmotic pressure in soil are the qualities applied as measures of the wilting coefficient that determines the quantity of water the soil can supply to plants. Both SAR and ESP are higher (0.06-0.13 and 1.50-2.25) in sludge and sewage effluent soil than (0.06-0.10 and 1.50-1.80) in non-sludge and sewage effluent soil. The implication is that there is no significant exchangeable sodium in non-sewage soil, but long-term application of sludge and sewage effluent can increase the exchangeable sodium concentration in topsoil and subsoil. Therefore, to improve and enhance the natural condition of the soil within the sewage disposal site, there must be scientific and sanitary approaches in handling the wastes to reduce the accumulation of both SAR and ESP.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Akande SO (2004). Cretaceous source and thermal maturation in the Nigeria sedimentary basins. Implication for offshore petroleum prospects. NAPE News. 3(5):20.

Curtin D, Campbell CA, Zentner RP, Lafond GP (1994). Long term management and clay dispersibility in the Haploborolls in Saskatchewan. Soil Sci. Amer. J. 58: 962-967. http://dx.doi.org/10.2136/sssaj1994.03615995005800030046x

Lieffering RE, McLay CDA (1996). The effect of high pH liquid wastes on soil properties: Aggregate stability and hydraulic conductivity. In first Int. Conf. on contaminant and the soil environment. Extended abstract, Adelsaide, pp. 253-254.

Montgomery CW (2005). Environmental Geology. McGraw-Hill Publ., USA. P. 970.

Obi ME, Ebo PO (1995). The effect of Organic and inorganic amendments on soil physical properties and maize production in severely degraded sandy soil in Southeastern Nigeria. Bioresource Tech. J. 51:117-123. http://dx.doi.org/10.1016/0960-8524(94)00103-8

Obiora SC, Umeji AC (2004). Petrographic evidence for regional burial metmamorphism of the sedimentary rocks in the Lower Benue Rift. J. Africa. Earth Sci. 38:269-277. http://dx.doi.org/10.1016/j.jafrearsci.2004.01.001

Oguamah VH (1999). The Geology of Nsukka and its environs in Nsukka L.G.A. of Enugu State. Unpublc B.Sc. Thesis, U.N.N. P. 83.

Onah DI (2012). Environmental and Geophysical Investigations of Sewage disposal and management at UNN. Unpubl. PGD Thesis, GLM Dept., ESUT. P. 134.

Pagliai M, DeNobili M (1993). Relationships between soil porosity, root development and soil enzyme activity in cultivated soils. Geoderma. 50:243-248. http://dx.doi.org/10.1016/0016-7061(93)90114-Z

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