HEAVY METAL CONCENTRATIONS IN DOMESTIC WATER SOURCES IN SOME COMMUNITIES OF EDO STATE, NIGERIA

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Abstract: Water is an important resource to life. However, it is usually contaminated by human activities sometimes to an extent of posing serious health problem to man. Seventy-five (75) samples from different water sources (borehole, rainwater and bottled water) in some communities in Edo State were collected and analyzed in the laboratory to assess the presence and concentration of heavy metals in the water. The presence and concentrations of heavy metals (Fe, Mn, Zn, Cd, Pb, and Cu) were determined with the aid of Atomic Absorption Spectrophotometer and the following values for the heavy metals were obtained Fe ranged from 0.0218 to 0.457 mg/l for borehole water; 0.0216 to 0.546 mg/l for rainwater and 0.0038 to 0.086 mg/l for bottled water; Mn ranged from 0.0014 to 0.0904 mg/l for borehole water; 0.0046 to 0.0436 mg/l for rainwater and 0.003 to 0.0426 mg/l for bottled water; Zn ranged from 0.0014 to 0.2829 mg/l for borehole water; 0.0138 to 0.2189 mg/l for rainwater and 0.003 to 0.0411 mg/l for bottled water; Pb ranged from 0 to 0.0115 mg/l for borehole water; 0 to 0.0108 mg/l for rainwater and 0.013 g/l for bottled water and Cu ranged from 0.0117 to 0.0931 mg/l for borehole water; 0.0074 to 0.0916 mg/l for rainwater and 0.0027 to 0.066 mg/l for bottled water. Cd was however below detectable limit. The results showed that the concentrations of Fe, Zn and Pb were higher in rainwater than borehole and bottled water, while water collected from borehole was found to be contaminated more with Mn and Cu. Bottled water was the least contaminated. It was also revealed that with the exception of Fe and Pb, the concentrations of Mn, Zn and Cu in all the water samples examined in the study area were found to be within permissible limits of WHO, NSDWQ and NESREA. However, simple hygiene and public awareness should be encouraged.

Keywords: Edo State, heavy metal, permissible limit, water sources, WHO

Introduction

Water is an essential resource to man and for the sustenance of life. It is used for many purposes such as drinking, bathing, showering, agriculture and industrial activities. Domestic water supply is water used for all useful domestic purposes including consumptions, bathing and food preparation (Onuoha *et al.*, 2012). Domestic water sources in developing countries like Nigeria are under increasing threat from contaminations by heavy metals like copper, lead, cadmium, zinc, arsenic and manganese. Known sources (both naturally occurring and anthropogenic) of chemical contamination of water supplies include organic and inorganic substances from industrial effluents, municipal wastes, petroleum-derived hydrocarbons, detergents, mining, agricultural pesticides and fertilizers (Ergul *et al.*, 2013; Ndamitso *et al.*, 2013).

Groundwater, a source of drinking water, is any water found beneath the earth surface, including underground streams and water that fills the tiny spaces between soil and rocks grains (Irenosen *et al.*, 2014). Although, the importance and use of groundwater has increased significantly during the last decades in urban and rural areas of the country (Adekunle *et al*., 2007), contamination from natural and human activities is affecting this vital resource (Adetunde *et al*., 2011; Ishaku *et al*., 2011). Although groundwater is less contaminated than surface waters, pollution of this major water supply has been on the rise due to contamination by various toxic substances (Ezeigbo, 1989; Asaolu, 2004). In many developing and underdeveloped economies, public water supply to communities evidently provides a shortfall in demand. As most rural and semi-urban communities of Nigeria lack potable water for domestic use, rainwater harvest presents a natural alternative that has extensively solved water supply problems of inhabitants (Oni *et al.*, 2008). In many areas of the world today, rainwater can either be the only source of water for the household or more commonly a supplementary supply to ease the burden of water collection from other sources (Peter, 2007; Vikaskumar *et al*., 2007) as cited in Olaoye and Olaniyan (2012).

Another water source people particularly the elites and urban dwellers depend on is bottled water. Bottled water is defined as water that is intended for human consumption and is sealed in bottles or other container with no added ingredients except that it may contain safe and suitable fluorides (Oluyege *et al.*, 2014). Water quality and quantity are inextricably linked, but quality deserves special attention because of its implication on health and life. The most anthropogenic sources of metals in water are industrial, petroleum contamination and sewage disposal (Santos *et al*., 2005). These metals affect the quality of water.

Water pollution by heavy metals has become a question of considerable public and scientific concern in the light of the evidence of their toxicity to human health and biological systems (Anazawa *et al.*, 2004). Heavy metals receive particular concern considering their strong toxicity even at low concentrations (Marcovecchio *et al.,* 2007). They exist in water in colloidal, particulate and dissolved phases (Adepoju-Bello *et al.*, 2009) with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of anthropogenic origin (i.e. solid waste disposal, industrial or domestic effluents) (Marcovecchio *et al.,* 2007). Although, some of the metals are essential to sustain life such as calcium, magnesium, potassium and sodium which must be present for normal body functions, (Adepoju-Bello *et al.*, 2009). However, heavy metals at higher concentrations can cause adverse health effects or illness to man. For instance, zinc toxicity leads to diarrhea (Osibanjo and Majolagbe, 2012); manganese in drinking water is associated with neurological damage (Chennaiah *et al.,* 2014) and may hamper the intellectual development of children (Buschmann *et al.,* 2008). Iron has been associated with genetic and metabolic diseases (Fraga and Oteiza, 2002) and increases the risk of several cancers, including breast cancer (Gurzau *et al*., 2003). Copper toxicity is related to several health concerns, including stomach cramps, nausea, vomiting, diarrhea, cancer, liver damage and kidney disease (EPA, 2013) cited in Anake *et al.* (2014).

Water sources in the study area are not free from contamination due to various kinds of human activities which could affect the health and general well-being of the people. Therefore, the purpose of this study is to evaluate the concentration of heavy metals in borehole, bottled water and rainwater in the study area. This will help in determining the quality of these sources of water commonly used by people in Edo State Nigeria.

Materials and Methods

Description of the study area

Edo state is located in the heart of the tropical rain forest. The state lies within the geographical coordinates of longitude 5°04' East and 6°43' East and latitude 5°44' North and 7°34' North. To the north, it is bounded by Kogi State; to the east, it is bounded by Anambra State; to the south, by Delta State and to the west, by Ondo state (Fig. 1). Sources of water for domestic purposes include boreholes, rainwater, bottled water, river, well, dam and pond. Most people however depend on groundwater source.

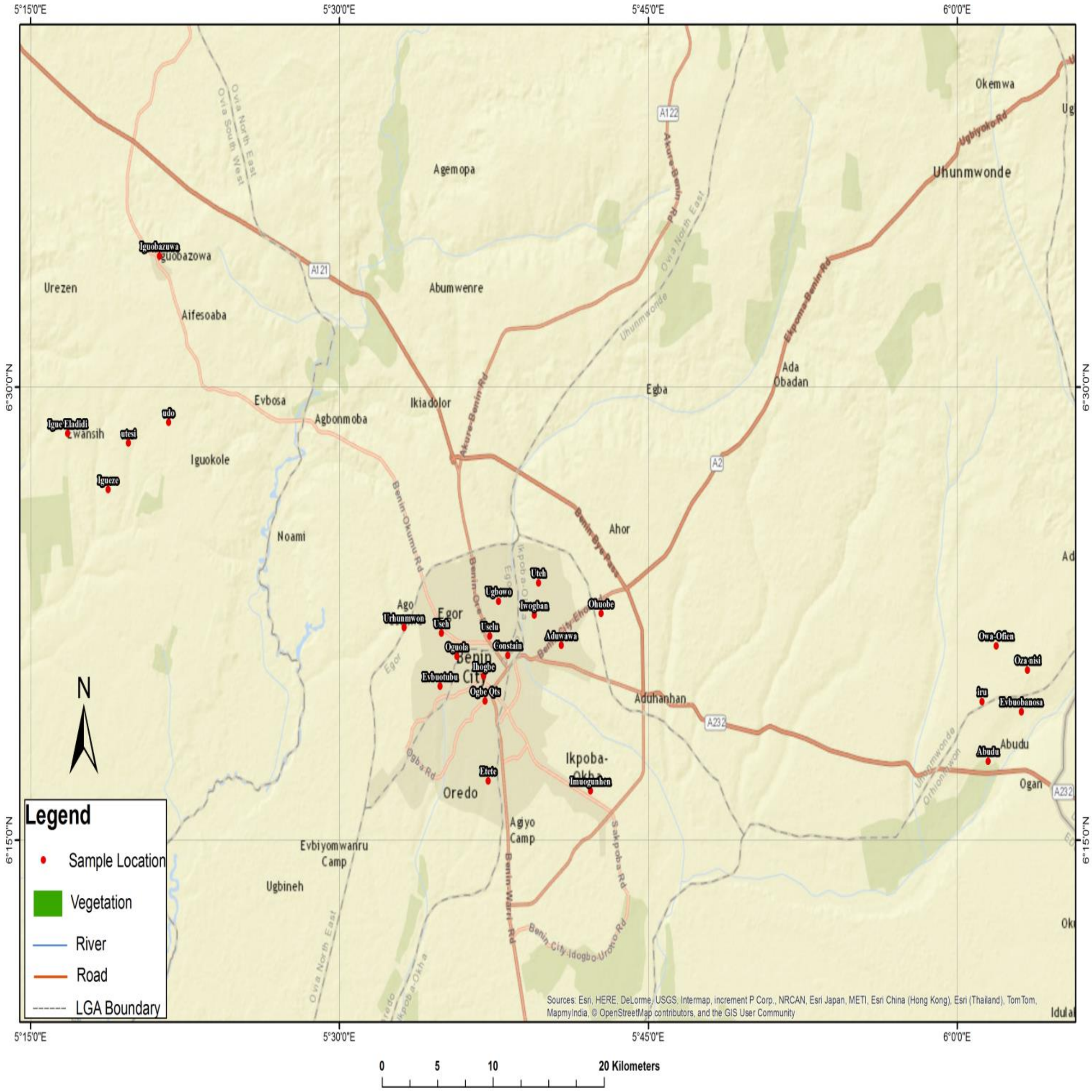

Fig. 1: Map of the study area

Sample collection and analysis

Seventy five (75) water samples (borehole, rainwater and bottled water) were collected with sterile and well labeled bottles from twenty five communities in Edo State namely: Uselu, Ugbowo, Evbuotubu, Useh, Urunmwom, Iwogban, Uteh, Aduwawa, Imuogunhen, Ohuovbe Oredo Costain, Ogbe, Oguola, Etete, Ihogbe, Abudu, Iru, Oza-nisi, Evbuobanosa, Owa-Ofien, Udo, Utesi, Igueze, Igue-Eladidi and Iguobazua.

Each of the communities mentioned above accounted for three water samples; one each from harvested rainwater, bottled water consumed in the area and stored borehole water. Water Samples collected were transported immediately to the laboratory for examination and analysis.The water samples and reagent blank were digested using concentrated nitric acid (HNO_3) for the determination of metal ions (Fe, Zn, Cd, Pb, Mn and Cu) concentration and was further analysed using Varian AA240FS Atomic Absorption Spectrophotometer

(Casimir *et al.*, 2015). This was critical in order to destroy the organic matrix capable of trapping the trace metals, and thus making them unavailable for the instrumental analysis. The statistical tool used was cluster analysis (dendrogram).

Results and Discussion

The results were presented based on the different values of heavy metals obtained in mg/l, sample locations, different water sources and permissible limits as shown in Tables 1 – 3. The result showed that Fe ranged from 0.0218 to 0.457 mg/l for borehole water; 0.0216 to 0.546 mg/l for rainwater and 0.0038 to 0.086 mg/l for bottled water; Mn ranged from 0.0014 to 0.0904 mg/l for borehole water; 0.0046 to 0.0436 mg/l for rainwater and 0.003 to 0.0426 mg/l for bottled water; Zn ranged from 0.0014 to 0.2829 mg/l for borehole water; 0.0138 to 0.2189 mg/l for rainwater and 0.003 to 0.0411 mg/l for bottled water; Pb ranged from 0 to 0.0115 mg/l for borehole water; 0 to 0.0108 mg/l for rainwater and 0.013 mg/l for bottled water and Cu ranged from 0.0117 to 0.0931 mg/l for borehole water; 0.0074 to 0.0916 mg/l for rainwater and 0.0027 to 0.066 mg/l for bottled water. Cd was however below detectable limit.

The attainment of protection of human health in water consumption involve guidelines for the presence of heavy metals which have been set by different local and International Organisations such as Nigerian Standard for Drinking Water Quality (NSDWQ), National Environmental Standards and Regulation Enforcement Agency (NESREA) and World Health Organization (WHO). Thus, heavy metals have permissible limits in water as specified by these organisations.

Table 1: Concentrations (mg/l) of heavy metals in borehole water in some communities in Edo State

Locations	Fe	Mn	Pb	Cd	Zn	Cu
Uselu	0.152	0.0147	0.0008	BDL	0.0495	0.0424
Useh	0.355	0.0158	0.0014	BDL	0.0098	0.0235
Urunmwon	0.348	0.0105	0.0104	BDL	0.0033	0.0397
Evbuotubu	0.282	0.0111	0.0000	BDL	0.0212	0.0639
Ugbowo	0.299	0.0301	0.0115	BDL	0.2829	0.0451
Iwogban	0.411	0.0054	0.0000	BDL	0.0004	0.0931
Uteh	0.325	0.0232	0.0092	BDL	0.0099	0.0399
Ohuovbe	0.457	0.0014	0.0077	BDL	0.0123	0.0493
Aduwawa	0.362	0.0129	0.0027	BDL	0.0014	0.0181
Umogunhen	0.305	0.0047	0.0019	BDL	0.0201	0.0416
Costain	0.218	0.0046	0.0000	BDL	0.0102	0.0241
Ogbe	0.367	0.0053	0.0011	BDL	0.0114	0.0146
Ihogbe	0.246	0.0063	0.0000	BDL	0.0011	0.0346
Oguola	0.224	0.0052	0.0001	BDL	0.0121	0.0136
Etete	0.336	0.0049	0.0018	BDL	0.0216	0.0325
Abudu	0.411	0.0024	0.0006	BDL	0.0201	0.0166
Owa-Ofien	0.446	0.0904	0.0000	BDL	0.0339	0.0888
Evbuobanosa	0.456	0.0093	0.0085	BDL	0.0232	0.0789
Iru	0.303	0.0042	0.0000	BDL	0.0142	0.0211
Oza-Nisi	0.198	0.0032	0.0000	BDL	0.0114	0.0217
Udo	0.184	0.0261	0.0014	BDL	0.0249	0.0154
Utesi	0.368	0.0072	0.0013	BDL	0.0216	0.0216
Igueze	0.131	0.0011	0.0000	BDL	0.0143	0.0122
Igue-Eladidi	0.215	0.0055	0.0019	BDL	0.0177	0.0119
Iguobazua	0.162	0.0113	0.0000	BDL	0.0123	0.0179
WHO (2011) mg/l	0.3	0.4	0.01	0.003	5.0	2.0
NSDWQ (2007) mg/l	0.3	0.2	0.01	0.003	3.0	1.0
NESREA (2007) mg/l	1.0	0.2	0.01	0.003	1.0	1.0

Table 2: Concentrations of heavy metals in rainwater in some communities in Edo State

Locations	Fe	Mn	Pb	Cd	Zn	Cu
Uselu	0.435	0.0376	0.0094	BDL	0.0252	0.0203
Useh	0.401	0.0089	0.0087	BDL	0.0726	0.0074
Urunmwon	0.310	0.0142	0.0023	BDL	0.0249	0.0617
Evbuotubu	0.470	0.0055	0.0095	BDL	0.0666	0.0738
Ugbowo	0.384	0.0124	0.0044	BDL	0.2082	0.0306
Iwogban	0.314	0.0035	0.0008	BDL	0.2189	0.0512
Uteh	0.423	0.0055	0.0048	BDL	0.0851	0.0916
Ohuovbe	0.373	0.0066	0.0083	BDL	0.0049	0.0154
Aduwawa	0.314	0.0137	0.0091	BDL	0.0394	0.0553
Umogunhen	0.032	0.0053	0.0108	BDL	0.0274	0.0452
Costain	0.362	0.0087	0.0034	BDL	0.0546	0.0533
Ogbe	0.395	0.0126	0.0077	BDL	0.0743	0.0422
Ihogbe	0.311	0.0103	0.0026	BDL	0.0618	0.0596
Oguola	0.412	0.0093	0.0021	BDL	0.0368	0.0426
Etete	0.285	0.0085	0.0000	BDL	0.0224	0.0498
Abudu	0.476	0.0065	0.0005	BDL	0.0376	0.0307
Owa-Ofien	0.463	0.0074	0.0075	BDL	0.0559	0.0703
Evbuobanosa	0.461	0.0074	0.0064	BDL	0.0231	0.0737
Iru	0.273	0.0113	0.0072	BDL	0.0336	0.0362
Oza-Nisi	0.411	0.0046	0.0018	BDL	0.0264	0.0186
Udo	0.546	0.0436	0.0018	BDL	0.0231	0.0192
Utesi	0.268	0.0138	0.0018	BDL	0.0275	0.0314
Igueze	0.216	0.0122	0.0000	BDL	0.0138	0.0276
Igue-Eladidi	0.426	0.0122	0.0023	BDL	0.0363	0.0249
Iguobazua	0.339	0.0148	0.0013	BDL	0.0162	0.0266
WHO (2011) mg/l	0.3	0.4	0.01	0.03	5.0	2.0
NSDWQ (2007) mg/l	0.3	0.2	0.01	0.03	3.0	1
NESREA (2007) mg/l	1.0	0.2	0.01	0.03	1.0	1.0

Table 3: Concentrations of heavy metals in bottled water in some communities in Edo State

Locations	Fe	Mn	Pb	Cd	Zn	Cu
Uselu	0.0390	0.0229	BDL	BDL	0.0268	0.0193
Useh	0.0380	0.0173	BDL	BDL	0.0122	0.0374
Urunmwon	0.0730	0.0426	0.013	BDL	0.0411	0.0544
Evbuotubu	0.0830	0.0327	BDL	BDL	0.0210	0.0407
Ugbowo	0.0038	0.0026	BDL	BDL	0.0031	0.0027
Iwogban	0.0375	0.0218	BDL	BDL	0.0375	0.0533
Uteh	0.0087	0.0054	BDL	BDL	0.0140	0.0077
Ohuovbe	0.0560	0.0117	BDL	BDL	0.0168	0.0266
Aduwawa	0.0660	0.0128	BDL	BDL	0.0135	0.0205
Umogunhen	0.0136	0.0033	BDL	BDL	0.0112	0.0058
Costain	0.0341	0.0062	BDL	BDL	0.0148	0.0077
Ogbe	0.0215	0.0321	BDL	BDL	0.0146	0.0316
Ihogbe	0.0880	0.0232	BDL	BDL	0.0175	0.0412
Oguola	0.1460	0.0317	BDL	BDL	0.0221	0.0364
Etete	0.0074	0.0054	BDL	BDL	0.0241	0.0143
Abudu	0.0063	0.0054	BDL	BDL	0.0051	0.0043
Owa-Ofien	0.0142	0.0057	BDL	BDL	0.0101	0.0078
Evbuobanosa	0.0760	0.0168	BDL	BDL	0.0345	0.0214
Iru	0.0470	0.0254	BDL	BDL	0.0176	0.0662
Oza-Nisi	0.0750	0.0234	BDL	BDL	0.0206	0.0226
Udo	0.0112	0.0065	BDL	BDL	0.0176	0.0184
Utesi	0.0650	0.0216	BDL	BDL	0.0126	0.0436
Igueze	0.0860	0.0322	BDL	BDL	0.0212	0.0217
Igue-Eladidi	0.0268	0.0229	BDL	BDL	0.0268	0.0193
Iguobazua	0.0128	0.0072	BDL	BDL	0.0138	0.0122
WHO (2011) mg/l	0.3	0.4	0.01	0.03	5.0	2.0
NSDWQ (2007) mg/l	0.3	0.2	0.01	0.03	3	1
NESREA (2007) mg/l	1.0	0.2	0.01	0.003	1.0	1.0

Iron

Higher concentrations of iron in borehole water in the study area were 0.457, 0.411 and 0.456 mg/l obtained in Ohuovbe, Abudu and Evbuobanosa, respectively. The high concentrations obtained in these locations were consistent with the work of Anake *et al.* (2015) which recorded values as high as of 0.73 and 1.4 mg/l in groundwater in Ota, Nigeria. Akoto and Adiyiah (2007) also reported 0.65 and 0.95 mg/l in their work. High concentrations recorded in rainwater were those collected from Udo with 0.546 mg/l and Evbuotobu with 0.47 mg/l. This is consistence with the study done by Ojo and Adekunle (2016) in Akure. In this study, all the bottled water had low concentrations which are in line with low values of 0.01-0.03 mg/l reported by Taiwo *et al.* (2010) in bottled water in Abeokuta and 0.01-0.05 mg/l recorded by Ibrahim *et al.* (2015) in Bauchi, Nigeria. The permissible limit of iron in water is 0.3 mg/l set by WHO (2011) and NSDWQ (2007) and 1.0 mg/l set by NESREA (2007). It was observed that borehole water obtained from Uselu, Urunmwon, Iwogban, Uteh, Ohuovbe, Aduwawa, Umogunhen, Ogbe, Etete, Abudu, Owa-Ofien, Evbuobanosa, Iru and Utesi representing 41% of the borehole water examined exceeded WHO (2011) and NSDWQ (2007) permissiblelimits. Also, rainwater in Uselu, Useh, Evbuotubu, Urunmwon, Ugbowo, Iwogban, Uteh, Ohuovbe, Aduwawa, Costain, Ogbe, Ihogbe, Oguola Abudu, Owa-Ofien, Evbuobanosa, Oza-Nisi, Udo, Igue-Eladidi and Iguobazua representing 59% of the rainwater samples examined exceeded WHO (2011) and NSDWQ (2007) permissible limits. This is in line with Anake *et al.* (2015) which observed that about 92% of iron in all the water samples they studied were all excessively greater than NSDWQ (2007) standard. However, NESREA (2007) permissible limit for iron was not exceeded in this study. The results implied that concentration of Fe was higher in rainwater but lower in bottled water. At levels above 0.3 mg/l, iron stains laundry and plumbing fixtures. Iron may also be present in drinking water because of the use of iron coagulants or the corrosion of steel and cast-iron pipes during water distribution (WHO 2011). Acute toxicity resulting from the accidental ingestion of large doses of Fe has been reported (Goldhaber, 2003).

Manganese

The concentrations of manganese (Mn) in the water samples studied ranged from 0.0014 to 0.0904 mg/l for borehole; 0.0046 to 0.0436 mg/l for rainwater and 0.003 to 0.0426 mg/l for bottled water. The Highest concentration of manganese in borehole water in the study area was obtained in Owa-Ofien with 0.0904 mg/l. In rainwater and bottled water, lower concentrations were recorded. Concentrations of Mn in all the water samples examined were generally low and were below permissible limit of 0.4 mg/l (WHO, 2011) and 0.2 mg/l (NSDWQ, 2007) and NESREA (2007). In comparing with similar study, investigating the chemical characteristics of Mn in Osun state, it was also seen that the concentrations of Mn in all the water samples were below the regulatory desirable level for the metal in the various water sources (Oluyemi *et al.*, 2010). However, In a previous study done by Casmir *et al.* (2015) in Kaltungo, Gombe State Nigeria, Mn value of 1.850 mg/l was reported. Based on the result from the various water types examined in this study, it can be implied that this metal do not pose possible health threat to consumers. It also implied that concentration of Mn was higher in borehole water than rainwater and bottled water examined. The presence of manganese in drinking-water, like that of iron, may lead to the accumulation of deposits in the distribution system. Concentrations below 0.1 mg/l are usually acceptable to consumers. Even at a concentration of 0.2 mg/l, manganese will often form a coating on pipes, which may slough off as a black precipitate (WHO, 2011).

Lead

The concentrations of lead (Pb) in the water samples studied ranged from 0 to 0.0115 mg/l for borehole water; 0 to 0.0108 mg/l for rainwater and 0.013 mg/l for bottled water. Lead concentrations for borehole water obtained were low except in Ugbowo with 0.0115 mg/l. The low values of Pb obtained in this study is consistent with the work of Kolawole and Obueh (2015) which also got low values. Chennaiah *et al.* (2014) however, reported that 33% of the water samples they studied exceeded permissible limits. The highest concentration in rain water was obtained in Umogunhen with 0.0108 mg/l which meant that concentration of Pb in rainwater were relatively low. This agrees with the studies of Chukwuna *et al.* (2012) in Oko Anambra State, Nigeria; Kolawole and Obueh (2015). In bottled water, the result showed that all tested samples were below detectable limit with an exception of the sample from Urunmwon which had 0.013 mg/l. The permissible limit of Pb in water is specified as 0.01 mg/l according to WHO (2011), NESREA (2007) and NSDWQ (2007). Slightly above these limits were found in Ugbowo, Umogunhen and Urunmwom for borehole, rainwater and bottled water respectively. Therefore, Pb content in 96% of the water samples examined was below permissible limits. The results implied that concentration of Pb was higher in rainwater than borehole and bottled water examined. The presence of lead is primarily from corrosive water effects on household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature and water hardness (WHO, 2011). Exposure to lead is associated with a wide range of effects, including various neurodevelopmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes (WHO, 2011).

Zinc

The concentrations of zinc (Zn) in the water samples studied ranged from 0.0014 to 0.2829 mg/l for borehole; 0.0138 to 0.2189 mg/l for rainwater and 0.003 to 0.0411 mg/l for bottled water. The concentration of Zn in all the borehole water examined was relatively low. This is consistent with the values (0.06-0.15 mg/l) obtained by Akoto and Adijiah (2007) and 0.01-0.028 mg/l reported by Oyem *et al.* (2015). Low values were also obtained in all the rainwater and bottled water examined which agrees with values obtained in similar studies done by David *et al.* (2013); Ibrahim *et al.* (2015); Ojo and Adekunle (2016). The results showed that the concentration of Zn in all the water samples was below the permissible limit of 5.0 mg/l set by WHO (2004), 1.0 mg/l set by NESREA (2007) and 3 mg/l set by NSDWQ (2007). Based on the result from the various water sources, it can be implied that Zn does not pose possible health threat to consumers in the study area except when build-up occur in the future. In a similar study on drinking water done by Khan *et al.* (2011), they found out that Zn content of the water they studied was below the permissible limit of 3.0 mg/l reported by WHO (2003). However, Chennaiah *et al.* (2014) reported that 11% of the water samples they studied exceeded the permissible limits of WHO (2004). The results implied that concentration of Zn was higher in rainwater but lower in bottled water. Zinc imparts an undesirable stringent taste to water at a taste threshold concentration of about 4 mg/l (as zinc sulfate) (Casmir *et al.*, 2015).

Copper

The concentrations of copper (Cu) in the water samples studied ranged from 0.0117 to 0.0931 mg/l for borehole; 0.0074 to 0.0916 mg/l for rainwater and 0.0027 to 0.066 mg/l for bottled water. The highest concentration of Cu in borehole water was obtained in Iwogban with 0.0931 mg/l which is contrast with 1.493 mg/l reported by Gutti *et al.* (2014) in Mubi, Adamawa state, Nigeria. 0.0916 mg/l in Uteh was the highest concentration obtained in all the rainwater examined which was below 2.342 mg/l reported by Ojo and Adekunle (2016) in a similar work in Akure. The concentration of Cu in rainwater samples examined was relatively low which is in line with the results obtained by Kolawole and Obueh (2015). In the work of Chukwuma *et al.,* (2012) in Anambra State, Cu was not detected in all the rainwater samples. Among The bottled water examined, only those obtained from Iru, Urunmwon and Iwogban had high concentrations of 0.066, 0.054 and 0.053 mg/l, respectively. Concentration of Cu in bottled water was also low which is comparable to low values of 0.01-0.07 mg/l reported by Ibrahim *et al.* (2015). All the water sample examined were below permissible limits of 2.0 mg/l set by WHO (2011), 1mg/l set by NESREA (2007) and NSDWQ (2007). This correspond with the work of Chennaiah *et al.* (2014) which reported that all the water samples they studied were within the permissible limits of WHO (2004). Casmir *et al.* (2015) also reported copper concentration of between 0.031 and 0.596 mg/l which were below permissible limit of WHO (2011). The results implied that concentration of Cu was higher in borehole water than other water types examined. Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/l. At levels above 2.5 mg/l, copper imparts an undesirable bitter taste to water; at higher levels, the colour of water is also impacted. It also results to gastrointestinal effects (WHO, 2011).

Cadmium Cd

Cadmium was below detectable limit in all the water samples examined in the study area. This corresponds with the studies of Chukwuma *et al.* (2012), David *et al.* (2013) and Oyem *et al.* (2015). Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10–35 years. The permissible limit of Cd as specified by WHO (2011), NSDWQ (2007) and NESREA (2007) is 0.003 mg/l.

The cluster analysis of the borehole water revealed that the concentrations of the heavy metals were similar in Oguola, Igue-Eladidi, Constain, Oza-Nisi and Ihogbe. Similarities were also observed in Udo, Iguobazua, Igueze and Uselu. However, Ugbowo had a different concentrations compare to other communities. In rainwater, cluster analysis showed that Oza-Nisi, Igue-Eladidi and Uselu had similar concentrations while Urunmwon, Aduwawa and Ihogbe; Iru, Utesi and Etete were also similar. However, concentrations of heavy metals in Ugbowo and Iwogban were far apart from others. In bottled water, Umogunhen, Owa-Ofien, Uteh and Iguobazua had similar concentrations while Uteh and Udo were far apart from what was obtained in other communities.

Conclusion

The study revealed that copper, zinc and manganese were within the acceptable limits of WHO (2011), NESREA (2007) and NSDWQ (2007). However, lead and iron were found to exceed these permissible limits in some locations while cadmium was below detectable limit. Dissolution of rock minerals with the groundwater and seepage of contaminants are possible reasons for the contamination. Therefore, water for domestic purposes should be regularly monitored for heavy metals to prevent excessive buildup of these metals in the human food chain. Effective enforcement of legislations related to water pollution control should also be done.

Conflict of Interest

Authors declare that there is no conflict of interest related to this study.

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