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Original Research Paper

Evaluation of Heavy Metals Content of Water Bodies at Two Industrial Communities of Eleme and Ewekoro, Southern Nigeria

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ABSTRACT

This study determined the concentration (ppm) of heavy metals, arsenic, zinc, chromium, nickel, iron, cadmium, lead, manganese, calcium and potassium in underground and surface water obtained from petrochemical refinery and cement producing site in some parts of southern Nigeria in order to assess the impact of petroleum processing and cement production on water quality. Water obtained from non-industrialized area (Umuariaga) served as control, alongside rain water and bottle water produced by Coca-Cola. Heavy metal concentration was determined using atomic absorption spectrophotometer. Results obtained for arsenic (0.01667±0.0086), lead (0.01778±0.0097) and cadmium (0.00300±0.0007) for surface water in petrochemical refinery site (Eleme) surpassed the WHO (0.01) guideline for arsenic and lead, and (0.003) for cadmium concentration in water. For cadmium in surface water (0.00367±0.0007) and underground water (0.00400±0.0007) found around cement producing region (Ewekoro), concentration obtained surpassed the WHO guideline for cadmium in water.

INTRODUCTION

Water is an essential natural resource used for industrial and domestic purposes. In rural areas, water bodies such as stream, rivers, rain water and lakes serve as water sources for the inhabitants of such area, considering that they lack access to potable water (Nevondo & Cloete 1991).

Water pollution involves the deposition of pollutants in water bodies and it majorly occurs through the action of industrialization. Industrial and agricultural wastes released into water bodies are often responsible for surface water contamination and this has been strongly associated with health risks.

Hilary (2014), in his study revealed that petroleum processing had a negative impact on river in the Niger Delta region of Nigeria, as his result indicated an increase in heavy metal concentration. Egborgen (1991) correlated the heavy metal pollution in Warri River to the industrialization of Warri town.

In cement factories, from limestone blasting activities through transportation to different process of cement refinery, harmful pollutants are emitted as by-products or as waste into the surrounding environment. Majorly, the region of cement producing sites constitutes many routes of soil and water pollution around the region (Ikyo et al. 2007, Akeem 2008, Abu-Allaban 2011, Anya 2012). Soil concentration of heavy metal pollutants can also give a guide to water pollution of heavy metals owing to the point that during rainfall, soil components are washed into water bodies. Fanan (2014) reported that soil around the vicinity of Dangote cement, Yandev is heavily polluted with heavy metals.

Heavy metals are elements with molecular weight ranging from 63.54 to 200.59 and specific gravity greater than 4 (Kennish 1992). CERLA (Comprehensive Environment Response Compensation and Liability Act) prepared a list of substances that most commonly pose the most significant potential danger to human health due to their toxicity and potential human exposure. Arsenic, lead and mercury tops the chart (Weinhold 2004, Bhatnagar 2006, CERCLA 2012). Heavy metals are highly soluble and their solubility is largely influenced by pH.

A critical review by Praveen & Purvi (2014) and Mark (2014), indicated the harmful effect of heavy metals in the cardiovascular system. Polluted ground and surface water sources have been well documented to act as a medium to spread of disease and with increasing industrialization, the depletion of ground water has been on the rampage (Khodapanah et al. 2009).

Crude oil analysis in Nigeria showed high concentrations of heavy metals like Fe, Zn, Cu, Pb and Hg (Kakulu 1985). Uncontrolled discharge of effluents by petroleum companies into the environment constitutes one of the main factors of degradation of the aquatic and terrestrial ecosystems also leading to the increase in the concentration of heavy metals. In the food chain, heavy metals in water accumulate in fishes, and by consumption of these fishes or contaminated water, the chain tends to increase the toxicological potential and risk in humans (Rainbow 1985, Mason 1991).

Heavy metals have been able to inhibit enzymes, and also biological pathways. Toxicity from heavy metal pollution can lead to respiratory illness, kidney disease, heart disease, neurological disease, and inhibition of electron transport chain (Ndubuisi 2007). The monitoring of heavy metals in the environment is fast becoming an essential aspect of pollution study.

MATERIALS AND METHODS

Sampling Location

Ewekoro: Ewekoro host the Lafarge cement industry and it is well known for its large limestone deposit. It has a population size of 55,093 (NPC 2010) and occupies an area of 594 km^2. Ewekoro is a local government in Ogun State, Western Nigeria. Ewekoro is bounded in the north by Abeokuta North and Abeokuta South Local Governments, in the south by Ifo Local Government, in the east by Yewa North and Yewa South Local Governments, and in the west by Obafemi Owode Local Government. Ewekoro local government lies between Latitude 6.2 and 7.8°N and Longitude 3.0 and 5.0°E (NIPOST 2009).

Eleme: Eleme is home to Eleme Petrochemical Company and is known for carrying out crude oil refining process. Eleme Petrochemical Company Limited (EPCL) is situated in Eleme, Rivers State in the oil rich Niger Delta area of Nigeria. It has a population size of 190,844 (NPC 2010) and occupies an area of 138 km^2. It is bound to the north by Obio Akpor and Oyigbo, in the South by Okrika and Ogu Bolo, in the east by Tai and the West by Okrika and Port Harcourt.

Umuariaga: Umuariaga in Ikwuano LGA of Abia State served as the control location for the purpose of study. Umuariaga is an area without industrial activities, except subsistence farming by its inhabitants.

Umuahia: Umuahia, a town is capital city of Abia state, Eastern Nigeria. Rain water used for this study was obtained from Umuahia. It has a population size of 359,230. It is a place with little industrial activity and also agricultural practices. It is mainly a place of residence inhabited by civil servants and petty traders.

Sampling techniques: Sampling was carried out from February 2015-April 2015. Sampling involved taking three (3) water samples from the various sampling locations. Surface water (stream) and underground water (borehole) was obtained thrice. Before obtaining the water samples, 2 litre polyethylene container was washed with detergent and dried to ensure that all water in the container evaporated. The containers were labelled accordingly with the alphabets as follows; A_1, A_2, A_3-H_1, H_2, H_3. In all, twenty four water samples were obtained and used for the study. Water samples from Umuariaga served as control water alongside, Eva bottle water produced by the Coca-Cola company. However, prior to water collection, 4 mL of 10% nitric acid was dropped into all the polyethylene containers for sample preservation as described by Michael (1982) and APHA (1992).

Heavy Metal Estimation

Heavy metals form complexes with organic compounds. It is however necessary to destroy the organic compounds and this is achieved by digestion with strong acids. Digestion destroys the organic matter, removes interfering ions and brings metallic compounds in suspension to solution. Water samples were handled by the method described by Gregg (1989). Specific metal standard solution was prepared. This was aimed at checking the accuracy of the atomic absorption spectrophotometer. The same procedure was carried out thrice for each water sample. Heavy metal estimation was carried out at PRODA Met. Laboratory, Emene, Enugu State.

Statistical Analysis

The data produced were analysed by one way ANOVA (Tukey) using SPSS Ver. 17 and reported as Mean±SD. Significant difference was accepted at 95 & % confidence level of probability.

RESULTS AND DISCUSSION

The mean and standard deviation of heavy metal concentration in this study is presented in Figs. 1-10. Due to human activities, heavy metals are rapidly increasing in the environment and their side effects have been well documented.

Results revealed the highest amount of arsenic (0.01667 ± 0.0086 ppm) occurred in surface water (stream) from Eleme region among studied water samples. Eleme is home to Eleme refinery, which is a site for processing crude oil, and its waste effluent is discharged into nearby water bodies in the region. Arsenic concentration was significantly higher ($P<0.05$) in Eleme surface water when compared to Eleme underground water (borehole) suggesting that the discharge from Eleme refinery has significantly ($P<0.05$) increased the concentration of arsenic in Eleme surface water. Arsenic concentration in Ewekoro region revealed no significant difference in surface and underground water samples. This suggested that arsenic may not be discharged or might be discharged as air effluent in minute quantities from cement industries. However, the presence of arsenic in Ewekoro surface and underground and Eleme underground water indicated that arsenic can occur in natural water bodies through natural and other anthropogenic sources (Merian 1984). Some natural sources include washing of top layer of soil, blasting of rocks and also soil and rock weathering. Arsenic is majorly transported in the environment by water (WHO 1981).

Arsenic was not detected in the control area Umuariaga in both surface and underground water and this can be attributed to the absence of industrialization as the major human activity on-going in that area is subsistence agricultural practice and cassava fermentation. Arsenic was also not detected in rain water obtained from Umuahia town. Arsenic might be present but in amount below the detection limit of the atomic absorption spectrophotometer machine. WHO (2011) indicated that the detection limit for arsenic determination using AAS is 0.001ppm. Eva bottle water showed no concentration of arsenic present. The Eva water is purified and treated water. Water purification and treatment is essential for production of quality water for human consumption. Purification and treatment process has been well documented to remove unwanted chemicals and compounds from water (Barakat 2011).

Results obtained from this study indicated that arsenic is

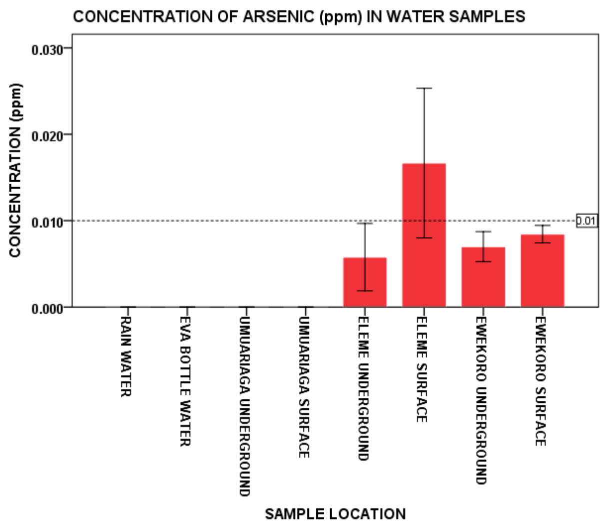

Fig. 1: The concentration of arsenic (ppm) in different water samples.

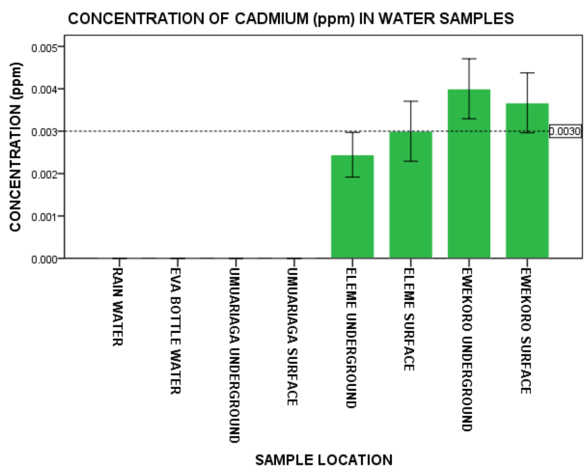

Fig. 2: The concentration of cadmium (ppm) in different water samples.

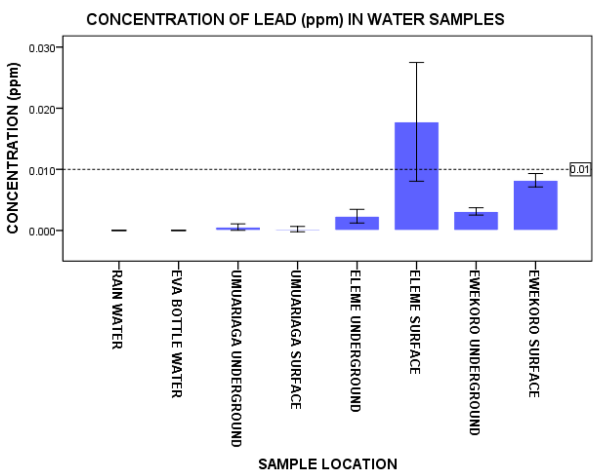

Fig. 3: The concentration of lead (ppm) in different water samples.

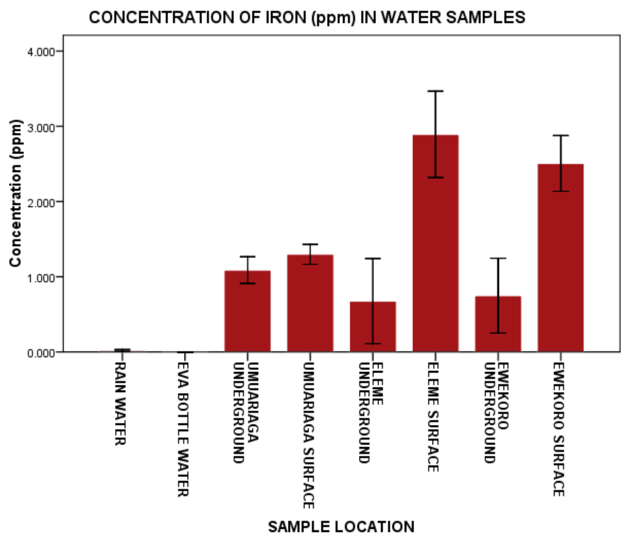

Fig. 4: The concentration of iron (ppm) in different water samples.

a prominent heavy metal present in water bodies around oil and gas exploration area and this corresponds with the findings of Uzoekwe & Oghosanine (2011), who studied the effect of refinery and petroleum effluent on water quality of Ubeji Creek, Warri, Southern Nigeria.

Further correlation analysis for arsenic specific for each sample location revealed that increase in arsenic concentration in Eleme surface water did not lead to an increase in the Eleme underground water arsenic concentration. This indicated that arsenic concentration from surface water did not find their way underground as water flows resulting from effluent discharge.

Arsenic is a naturally occurring element which can be deposited in water through the dissolution of minerals and ores or from industrial effluent discharge and atmospheric deposition. Natural sources can make a significant contribution to the arsenic concentration in drinking water (WHO 2008).

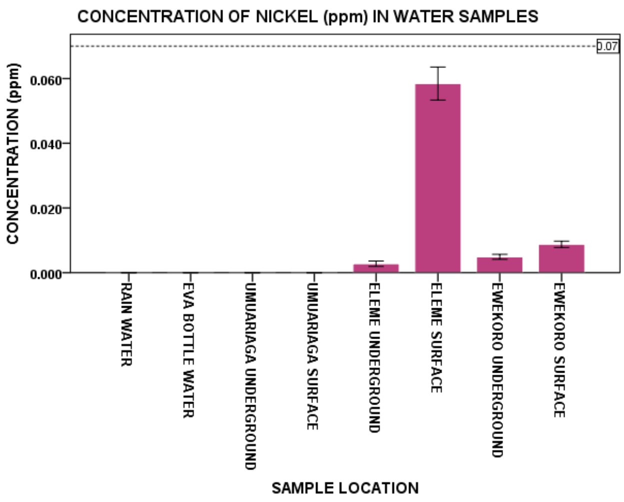

Fig. 5: The concentration of nickel (ppm) in different water samples.

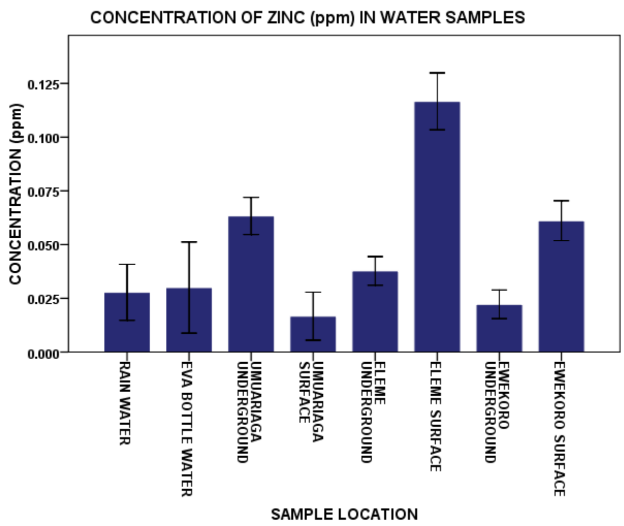

Fig. 6: The concentration of zinc (ppm) in different water samples.

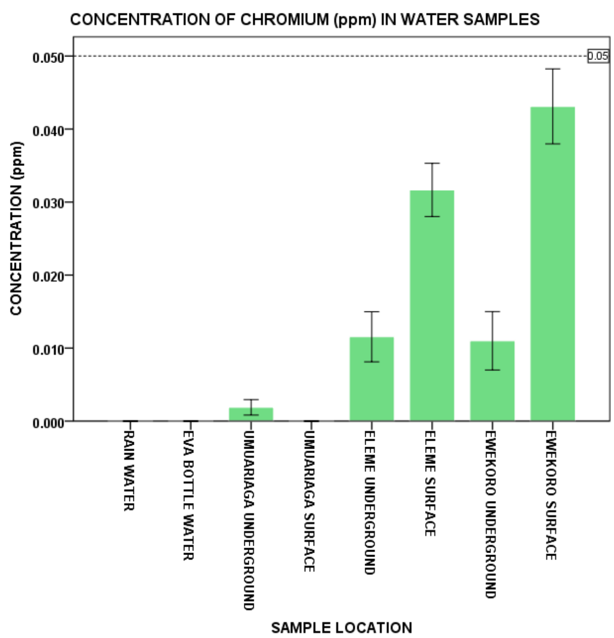

Fig. 7: The concentration of chromium (ppm) in different water samples.

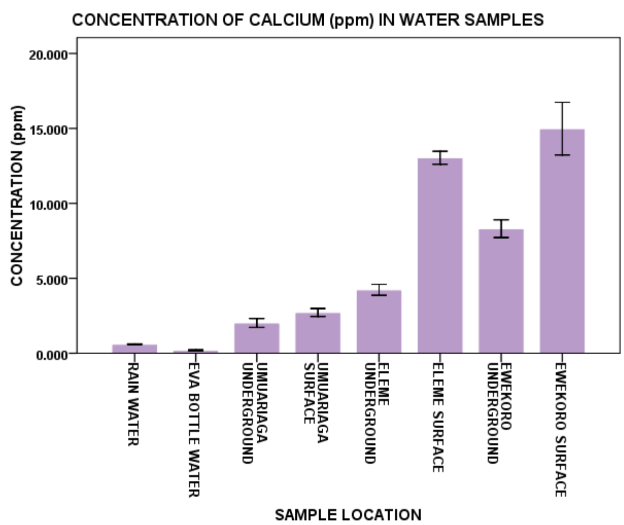

Fig. 8: The concentration of calcium (ppm) in different water samples.

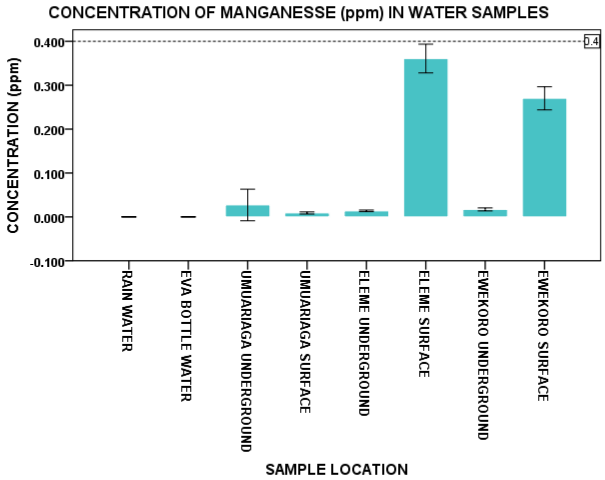

Fig. 9: The concentration of manganese (ppm) in different water samples.

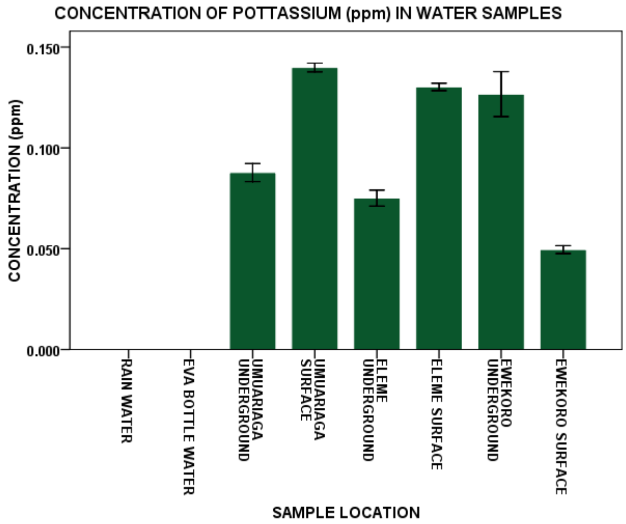

Fig. 10: The concentration of potassium (ppm) in water samples.

The Comprehensive Environment Response, Compensation and Liability Act prepared a list of substances that most commonly pose significant threat to human, and arsenic topped the list (CERLA 2012). Arsenic toxicity has been well documented to disrupt ATP production and it inhibits pyruvate dehydrogenase and uncouples oxidative phosphorylation. It inhibits energy-linked reduction of NAD^+ and increases hydrogen peroxide production leading to formation of ROS thus oxidative stress (Klassen 2003).

Arsenic can replace phosphate in many biochemical reactions and arguments are currently on-going to see if it can inhibit hexokinase, the first enzyme in the glycolytic pathway, thereby affecting glycolysis, since it can form glucose 6 phosphate. Arsenic metabolism has an important role in its toxicity. Its metabolism ensures the reduction of arsenic to a trivalent state and by oxidative methylation to a pentavalent state. Although the exact mechanism of action for its toxicity has not been fully understood (Hughes 2002). Hu et al. (1998) indicated that arsenic has a role to play in carcinogenesis, as it is capable of inhibiting DNA repair mechanisms.

Results obtained from this study clearly revealed that arsenic is a potential heavy metal released into the environment from oil and gas refining, and its concentration in this study was above the WHO (2008) permissible guideline.

Results for cadmium concentration indicated highest from Ewekoro underground water (0.004±0.0007 ppm), among the studied water samples and location. Ewekoro is home to Lafarge mega cement producing plant. Cement dusts are discharged into the environment through air and they can be deposited in soil and water bodies around the plant.

Results indicated that cadmium concentration in Ewekoro surface and underground water was not significantly different. This can be attributed to discharge of cement dusts from the cement plant into surface water bodies that flow underground, thereby carrying cadmium and depositing it into underground water bodies. Ewekoro is known for its limestone deposits (Oluwaseun et al. 2012), and studies by Claire et al. (2010) revealed that part of concentration of cadmium in the environment is of natural origin and can increase tremendously with the presence of limestone in such environment.

Concentration of cadmium in Ewekoro region was significantly higher than the Eleme counterpart, and cadmium concentration in Eleme surface, indicating that cadmium is a potential pollutant around cement industries, a finding strongly supported by Musa et al. (2013). In Eleme region, results did not reveal any significant difference in cadmium concentration in both surface and underground water, although presence in the water samples indicated that the discharge of effluent into water bodies is responsible. Study by Israel et al. (2008) indicated the presence of cadmium in effluent discharged from Eleme refinery.

Cadmium is also an environmental hazard and one major route of its discharge into the environment is through cement production (Denise 2012). John et al. (2013) reported that cement dust contains mixture of metals that are potential carcinogens and pose threat to human health. The WHO (2011) guideline for cadmium suggested a permissible level of 0.003 ppm for cadmium in water and limit of detection as 0.002 ppm.

Cadmium absorption is strongly dependent on its solubility and it can accumulate in the kidney. There is no indication of carcinogenicity by the oral route of exposure, and no clear proof for its genotoxicity. The kidney remains the main site for cadmium toxicity (WHO 2011).

Bhattacharyya (2009) detailed the exhaustive data that indicated low-level Cd-induced osteotoxicity accompanied by decreased bone mineral density and calciotropic hormone levels. Cadmium interferes with endocrine function, binding to cellular steroid receptors and can have oestrogen-like and androgen-like activity (Darbre 2006). Cadmium has role in oxidative stress as a result of its ability to react with essential elements required by many enzymes (Vesna 2011).

Correlation analysis of our data showed that the increase in cadmium concentration in surface water did not lead to an increase in underground cadmium concentration in both the studied locations, and in comparison with WHO (2011) guidelines for cadmium permissible concentration in water, cadmium concentration in Ewekoro surface and underground water and also Eleme surface water was higher than the permissible limit.

Lead concentration occurred highest in Eleme surface water (0.0031±0.0006 ppm) among all the studied water samples. Lead concentration was significantly higher in Eleme surface water when compared with Eleme underground water; this suggested that effluent discharge from Eleme refinery may be responsible for the large amount of lead deposited in the surface water around Eleme. Studies by Uzoekwe & Oghosanine (2011) revealed high amount of lead in effluent and water around a petrochemical refinery. Lead concentration in Ewekoro surface water was also significantly higher than the concentration of lead in surface and underground water in the control site. Ayedun et al. (2012) reported lead in underground water around a cement industry; also studies by Musa et al. (2013) reported lead in surface and underground water around the cement plant.

Lead was also detected in minute quantity in the control site (Umuariaga) surface and underground water, indicating lead is a natural occurring heavy metal, which can be present in water bodies even if industrial activities do not occur there or absence of lead dust. Yu (2005) reported lead can occur in natural surface water and underground water from the atmosphere or from the soil.

Correlation analysis revealed that increase in lead concentration in surface water did not lead to an increase in underground water lead concentration at the various sample locations. Eleme surface lead concentration exceeded the WHO (2011) permissible guideline for lead in water.

In the haem biosynthesis pathway, lead has been shown to replace zinc, inhibiting the enzyme ferrochelatase, porphobilinogen synthase and aminolevulinic acid synthetase, preventing porphobilinogen formation and the incorporation of iron into protoporphyrin IX (Piomelli 2002). The nervous system remains a major point of lead toxicity. Grant, (2008) reported that lead exposure also leads to renal dysfunction.

Exposure to lead has been well correlated with a wide range of effects, including various neuro developmental effects and mortality. Lead exposure also increases the risk of cardiovascular disease (Praveen & Purvi 2014).

Results showed that iron concentration was highest in Eleme surface water (2.89222±0.5739 ppm) when compared to other water sources and sample location. Iron was also detected in rain water at a very little concentration. Iron is the most abundant element in the earth crust and WHO (2011) has not yet established a guideline for iron concentration in water indicating it is not of health concern at levels found in drinking water and that iron can occur in natural water bodies at 0.5-50ppm. The increase in Umuariaga surface water iron concentration can be clearly linked to fermentation of cassava. Inhabitants of the community ferment cassava using the water, Abonna et al. (2005) reported that iron concentration is high in water used for fermentation of cassava.

Iron concentration in all studied water samples was low; although it was clearly shown from the results obtained that industrial activity could lead to an increase in iron concentration. Ujoh & Alhassan (2014) reported presence of iron in water around cement plant. Cement dust could contain irons that are emitted as waste and they can contribute largely to iron concentration if deposited in water. Uzoekwe & Oghosanine (2011) and Hilary (2014) reported high amount of iron in effluent discharge from petrochemical refinery and also iron in water bodies around the site when compared to water obtained from control region in their studies. These findings correspond with the result obtained from this study, indicating that effluent discharge from refineries could lead drastically to an increase in iron concentration in water bodies. Correlation analysis showed that an increase in iron concentration in surface water did not lead to an increase in iron concentration in underground water for the various sample locations.

Iron is an important cofactor in many enzymes catalysed reactions and takes part in many biological reactions and transport (Lippard & Berg 1994); it is an essential element required in human nutrition, mostly in iron (II) oxidation states. It is strongly required in the haem biosynthesis and a displacement of iron by other metals has shown to lead to serious clinical implications (Piomelli 2002). As a metal, excessive iron in blood especially in the free ferrous state can react with peroxides generating free radicals that can lead to oxidative stress and DNA damage. Iron toxicity is greatly influenced when iron occurs free in the cell, exceeding transferrin ability to bind to it (Cheney et al. 1995).

This study revealed that nickel concentration occurred highest in Eleme surface water (0.05844±0.0051 ppm) among studied water samples and locations. Nickel concentration in Eleme surface water was significantly ($P<0.005$) higher when compared with other water sources and location. The increase in nickel concentration in surrounding water can be ascribed to the discharge of effluent from the refinery. Israel et al. (2008) reported the presence of nickel in effluent discharge from Eleme refinery, (Nwineewii & Edem 2004, Hilary 2014) reported high amount of nickel in surface water around Niger Delta region of Nigeria, which is prone to oil pollution.

WHO (2011) reported water to be a minor stakeholder to total daily oral intake, indicating that where there is heavy pollution, nickel in groundwater can be mobilized. From the result of this study, nickel concentration was low in cement producing region. The WHO (2011) guideline for water quality indicated a value of 0.07ppm of nickel in water, and also a limit of detection of 0.0005ppm for nickel using AAS machine. Nickel not found or detected in the control region (Umuariaga) surface and underground water indicated that nickel is triggered with industrial activities, which made nickel below the detection limit using AAS. Nickel concentration did not exceed the WHO permissible limit in studied water samples and locations. Eshan et al. (2012) confirmed nickel as a known carcinogen, promoting the generation of reactive oxygen species, leading to oxidative stress and DNA damage. Correlation analysis showed that an increase in nickel concentration in surface water did not lead to an increase in nickel concentration in underground water at the various sample location.

Concentration of zinc occurred highest in Eleme surface water (0.11667±0.01322 ppm). Zinc was also detected in Eva bottle water. Zinc is an essential trace element found in almost all food and water in the form of salts or organic complexes. WHO (2011) reported that zinc concentration above 3ppm could be detrimental to human. WHO (2011) indicated that zinc concentration does not normally exceed 0.01ppm and 0.05ppm for surface and underground water respectively.

Zinc in rain water can be linked to the presence of contaminants and heavy metals in the atmosphere that are picked by rain water as it falls (Meera & Mansoor 2006). Activities like burning and cooking that send emissions into the atmosphere can also lead to the presence of heavy metals in rain water. Anna et al. (2010) also detected zinc in rain water obtained from Barcelona, Spain.

Zinc, as an essential element required for many biological processes to function properly, can be added in Eva bottle water as a means of supplementation for water consumers. The concentration of zinc derived for the various water sources and sample locations from our study is not of health concern and cannot pose any threat to life. Though zinc is required by many enzymes to function properly, in excess, zinc can potentiate toxicity and in excess zinc has been shown to affect copper and iron absorption. Zinc also can affect lipoprotein system, increasing LDL and decreasing functional HDL in blood (Fosmire 1990). When zinc is orally ingested and acted on stomach hydrochloric acid, it forms the corrosive zinc chloride (Bothwell et al. 2003). Excess zinc in the body leads to acute excitotoxic brain injury and correlates with the severity of dementia in chronic neurodegenerative diseases (Futao et al. 2011).

Chromium was highest in Ewekoro surface water (0.06111±0.0092 ppm) among the studied water samples and location. Chromium concentration in Ewekoro surface water was significantly higher ($p<0.05$) when compared to other water sources indicating cement dust contribute to the increase in chromium concentration. Ujoh & Alhassan (2014) reported high concentration of chromium in streams around a cement producing plant in central Nigeria. Chromium was significantly ($P<0.05$) higher in Eleme surface water when compared to Eleme and Ewekoro underground water. Uzoekwe & Oghosanine (2011) reported high amount of chromium in petroleum refinery effluent and also chromium present in surface water around the site. Correlation analysis indicated that an increase in surface water chromium concentration did not lead to an increase in underground water chromium concentration in all studied location. WHO (2011) reported that chromium is widely distributed in earth crust, indicating why chromium will be present in underground water in industrial areas, since chromium concentrations do not find their way underground from surface water. Hasti (2015) listed chromium as one of the hazardous pollutants present in industrial effluent.

WHO (2011) reported that the permissible guideline for chromium in water sample is 0.05ppm and the limit of detection by AAS is 0.0005-0.002ppm. However, all studied water samples did not exceed the WHO guideline for chromium.

Water soluble chromium (Chromium VI) has been well known to possess toxicity and carcinogenic effect (Barceloux & Barceloux 1992). It possesses specific transport mechanism that makes it enter the cell in large amount. Cellular studies have shown that high chromium concentration in the cell can lead to DNA damage and cell death (Eastmond et al. 2008). Chromium also leads to kidney damage, liver and blood cells through oxidation (Dayan & Paine 2001).

WHO (2011) did not propose a guideline for calcium, manganese and potassium in water, indicating level found in water are not of health concern and cannot cause health issues. However, result showed that their concentration increased significantly in the studied industrialized areas. Calcium was highest in Ewekoro surface water (14.9788 ± 1.7587 ppm) and was significant ($p<0.05$) higher when compared to other water samples and location. Adejuwon & Adelakan (2012) reported calcium concentration above 20ppm in rivers in Ewekoro. Cement dusts contain high amount of calcium as the primary raw material for cement production is $CaCO_3$. Calcium was also reported in Eva water. Calcium is a required nutrient in the living system and is usually added by organization producing water in little quantities.

Manganese is present in the earth crust. Manganese was highest in Eleme surface water (0.36078±0.032607 ppm). It was also high in Ewekoro surface water, indicating that industrial activity was responsible for the increase. Potassium also occurs in all natural water bodies. In this present study, it was present in all water sources and locations except rain water and Eva bottle water.

Except in very high concentration, calcium, manganese and potassium cannot impose adverse health effect. They are very useful in small amount for proper functioning of the body, and the level in which they were found in studied water samples cannot impose any threat to human health.

In this study, arsenic (0.01667±0.0086 ppm), lead (0.01778 ± 0.0097 ppm) and cadmium (0.00300±0.0007 ppm) in Eleme surface water were found to exceed the WHO guideline (0.01) for arsenic and lead and (0.003) for cadmium, in the water. Cadmium in Ewekoro surface (0.00367±0.0007 ppm) and underground water (0.00400±0.0007 ppm), was found to exceed the WHO (0.003 ppm) guideline. Risk estimation analysis, indicated that upon consumption of 1.667 litres of surface water in Eleme region, inhabitants, plants and animals are exposed to the risk of arsenic toxicity, consumption of 1.778 litres exposes inhabitants, plants and animals to lead toxicity and upon consumption of 0.3 litres of water, they are exposed to cadmium toxicity. For the Ewekoro region, consumption of 0.3 litre of water exposes inhabitants, animals and crop to cadmium toxicity.

Physical observation of water bodies in the industrialized area revealed the presence of household waste and dumps which are deposited in water by inhabitants of the community, and this can also lead to increased concentration of heavy metals in water bodies. Ayalagba & Ezenatein (2012) reported high amount of heavy metals in water bodies in waste disposal sites in Portharcout.

Apart from lead in Eleme surface water, arsenic in Eleme surface water and cadmium in Ewekoro surface water, all other studied metals were not above the WHO (2011) guideline. Also, the study showed ample evidence that the companies involved in the industrial activities have complied with standard treatment procedures before discharging their effluents of waste into the environment set by regulatory bodies, as concentration of determined metals were smaller compared to previous studies carried out by others, who studied heavy metals in both locations. Fermentation of cassava in heavy metal polluted water can also serve as a means by which the metal compound can get into human if consumed.

CONCLUSION

Generally, the concentration of heavy metals in sampled water obtained from industrialized region was significantly ($P<0.05$) higher than those of the control region, rain water and Eva bottle water. Human activities, cement producing and oil processing in the industrialised area land can lead to elevated concentration of heavy metals in water samples.

Results showed some level of heavy metal pollution in Eleme and Ewekoro region of Southern Nigeria. Humans and grazing animals may be exposed to serious danger through various pathways, especially the food chain. Therefore, there is a need of remediation strategies and management of contaminated soil as well as health impact assessment of the industrialised areas.

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