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Assessment of Some Heavy Metals in Groundwater in the Vicinity of an Oil Depot in Nigeria

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Authors' contributions

This study was carried out in collaboration between both authors. Author POO designed the study, wrote the protocol and the first draft of the manuscript. Both authors POO and FJO managed the analysis and literature searches, read and approved the final manuscript.

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ABSTRACT

Assessment of heavy metals in groundwater located around refined petroleum products depot in Ibadan, Nigeria were carried out using Atomic Absorption Spectrophotometry (AAS) technique. Water samples were collected and analyzed for copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn). The mean concentrations (range) of 0.0064±0.005 mg/l (ND – 0.019 mg/l), 0.0014±0.002 mg/l (ND – 0.005 mg/l), 0.45±0.3 mg/l (0.06 – 0.96 mg/l) and 0.042±0.08 mg/l (0.018 – 0.389 mg/l) were obtained for Cu, Cr, Pb and Zn, respectively. Cd was not detected in all the water samples analyzed. All the heavy metals investigated in the water samples except Pb were generally below the recommended limits set by regulatory bodies such as World Health Organization (WHO) and Nigerian Industrial Standards/Standard Organization of Nigeria (NIS/SON) for drinking or potable water. There was elevation of Pb concentrations in all the water samples in the area which were significantly above the recommended limit. This suggests that source of Pb contamination could be from anthropogenic activities such as loading and offloading of petroleum products. This pollution of groundwater in the vicinity of the oil depot caused by Pb contamination is

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a potential threat to the people living in the area as groundwater is their major source of potable water. Therefore, government should provide good drinking water for people located in the area while remediation process of the heavy metal should be carried out on the site.

Keywords: WHO; lead; people; groundwater; recommended limit; oil depot; anthropogenic activities; contamination.

1. INTRODUCTION

Water pollution is the contamination of water bodies such as lakes, rivers, seas or oceans, aquifers and groundwater e.g hand-dug wells and boreholes. This occurs when pollutants are discharged directly or indirectly into the water bodies. Water pollution affects plants and organisms living in these bodies of water. In almost all cases the effect is damaging not only to individual and populations, but also to the natural biological communities. Groundwater is an important source of water in quest of searching for potable water in developing countries like Nigeria. The quality of this water is the concern of the world as there is tendency of pollution of groundwater as a result of leaching of heavy metals generated due to rapid industrialization and urbanization. These heavy metals such as copper, cadmium, lead, mercury, nickel, chromium, etc raises the normal concentration in water thereby causes pollution which is detriment to humans and animals healths. They tend to accumulate, bioaccumulate and biomagnify in body system. Studies have shown that industrial and agricultural activities are the major anthropogenic sources of pollutants in the environments through effluent discharge without prior treatment [1-4]. Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs [5]. Long-term exposure may result in slow and progressive physical, muscular, and neurological degenerative processes such as muscular dystrophy and multiple sclerosis [6]. It has been difficult to state what concentration of heavy metal that is safe, hence different agencies state different levels (limits) for a particular metal [7] such as World Health Organization, European Union Standard, Standard Organization of Nigeria recommended limits, etc.

Lead is a metal that has relatively low concentration in environment, not very soluble and hence nearly immobile in soil and very toxic to humans and organisms with long lasting effects [8]. Lead is used in automobile fuels, plumbing, paint, batteries, alloys, sewage wastes and fossil fuel combustion products. Surficial aquifers have been impacted by anthropogenic sources of lead which is persistent in the environment. No level of lead is considered safe in drinking water although an action level of 15 µg/L (parts per billion) can be used to identify highly impacted water. So it is imperative to sample for this metal in aquifers where they may occur at high concentrations like in the vicinity of industries such as oil depot that are likely to impact such contaminants, since their drinking standards are very low and there are a variety of anthropogenic sources.

The natures of the media through which the water find its way to the groundwater zone affect the quality of the groundwater (boreholes and dugout wells) sources as reported by [9]. Therefore, heavy metals discharge from vehicles, industries, wastes (hazardous or municipal), fertilizers (agricultural purposes) and accidentals oil spillage from tanker results in contamination of groundwater [10-12] as well as ruptured, damaged or leak oil pipes.

An oil depot has been defined as industrial facility for storing oil and/or petrochemical products where these products are transported to end users or for further storage [13-16]. Nigeria, one of the major crude oil producing countries in the world transported petroleum products through pipe lines to several oil depots located all over the country from where it is being carried by mobile tankers to end users [15,16]. The environments are contaminated with these products through accidental spills and leakages during loading and offloading of tankers in the depots as well as washing of oil storage tanks [17] and deliberate discharge of effluents by refineries. All these discharge arising from activities in depot significantly contaminate soils ultimately pollute both surface and groundwater through leaching or infiltration thereby constitute serious health and environmental hazards to humans and aquatic resources living in the area [14,18,19]. Crude oil especially when refined into various petroleum products contains diverse components such as hydrocarbons, heavy metals, antioxidants, dye additives, corrosive inhibitors, sulphur, naphthalene and show more toxicity compare to crude oil because speciation of metals are altered with addition of new metals to the products matrices during refining processes [14,16,19-21]. There are loads of heavy metals information which focuses on the exploration areas of oil by researchers in Nigeria and paucity of data or information on the surrounding pollution of especially groundwater around the depot or facilities where the refined oil products are being stored disseminated. Therefore the main objective of this study is to determine the level of heavy metals; Cadmium, Copper, Chromium, Zinc and Lead in groundwater located in the vicinity of an oil depot in Nigeria and compare with recommended standards.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study area, Nigerian National Petroleum Corporation (NNPC) oil depot is situated along Abeokuta road, Ibadan, Nigeria. It lies between latitude 07° 23 ′N and longitude 03° 49 ′E (Fig. 1). The sampling points designated as GW1 to GW2 were considered for sample collection.

2.2 Sampling and Analysis

Twenty groundwater samples were randomly collected from hand- dug wells around the NNPC depot with the aid of plastic bucket that has been previously washed and rinsed thoroughly with distilled water and suspended at one end of a rope. The sample containers were first washed three times with each water sample before collection and the containers were tightly covered immediately. 3 ml concentrated nitric acid was added to each sample to bring the water sample to pH < 2 and to reduce the microbial activities in order to maintain the integrity of the samples. They were the transported in an ice chest to the laboratory prior to analysis. Sampling was carried out during the month of May, 2015 (rainy season).

The acidified water samples were digested with concentrated nitric acid prior to heavy metals (Cu, Cd, Cr, Pb and Zn) analysis using Atomic Absorption Spectrophotometer (Bulk Scientific 210VGP).

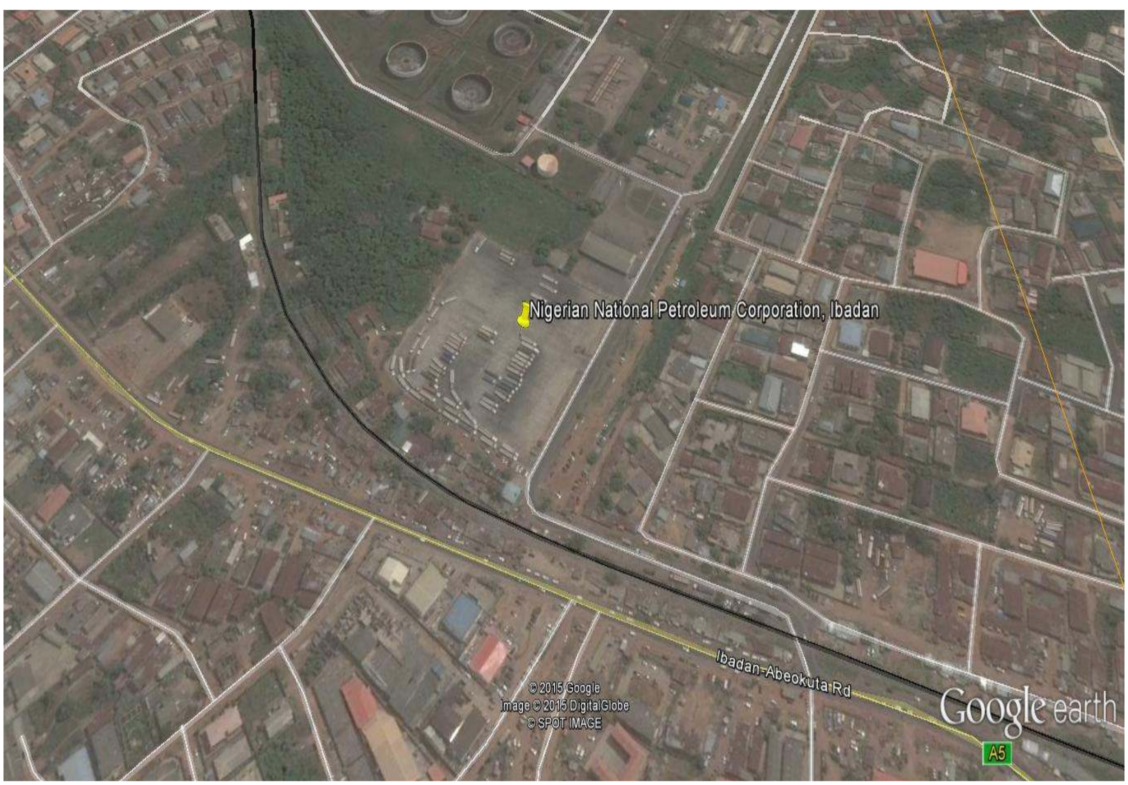

Fig. 1. Map of Ibadan showing sampling location

A blank sample was incorporated for every five water samples analyzed and duplicate analysis were carried out for all the samples. Reagents were analytical reagent (analaR) grade and commercial BDH stock standards were used for the instruments calibration according to manufacturer's instructions before analysis. All clean and prewashed plastic containers and glass wares used were soaked in 10% (v/v) nitric acid overnight and rinsed thoroughly with distilled water. A recovery study of the analytical procedure was carried out by spiking portions of previously analyzed samples with mixed standards of copper, lead, cadmium and chromium. These were then taken through the same analytical steps and the percentage recoveries determined. The minimum percentage recovery obtained for these metals was 91% for cadmium which validate the efficiency of extraction procedure and instrument used.

3. RESULTS AND DISCUSSION

The result of heavy metals analyzed in groundwater in the vicinity of the oil depot was presented in Table 1. Mean Cu contents in the water samples ranged between ND and 0.019 mg/l with an overall mean of 0.00635 mg/l. The highest Cu concentration was observed in GW12 while GW4, GW9 and GW16 were below the detection level. Mean Cr contents ranged from ND to 0.005 mg/l (GW13) with an overall mean of 0.0014 mg/l; the mean Pb concentrations in the water sample has minimum concentration of 0.06 mg/l (GW1) and maximum concentration of 0.96 mg/l in groundwater GW8 with an overall mean of 0.45 mg/l while the mean Zn contents in the water sample ranged between 0.018 mg/l and 0.389 mg/l with overall mean of 0.042 mg/l. Cd were not detected in the groundwater sampled which is similar to earlier reports in some groundwater in Ibadan [22]. The concentrations of Cu, Cd, Cr and Zn were below the WHO and NIS maximum acceptable limits of 2.0 mg/l, 0.003 mg/l, 0.05 mg/l and 3.0 mg/l, respectively [23,24] for drinking water in all water samples (Table 2). This observation suggests no anthropogenic input of these metals from the activities in the depot.

The overall mean values obtained for Cu, Cd, Cr and Zn contents in this study are far below the overall mean of 3.11 mg/l, 0.025 mg/l, 0.052 mg/l and 1.969 mg/l values obtained, respectively in groundwater samples by [14] in similar study in Nigeria; 1.22 mg/l and 0.003 mg/l for Cu and Cd, respectively in groundwater around battery factory in Ibadan, Nigeria [25]; 0.02 mg/l Cu content in water sample around dumpsite [26]. However the Cu content falls within 0.002 - 0.019 mg/l Cu contents reported by [27] from groundwater around some dumpsites in Lagos, Nigeria and also the heavy metals (As, Cd, Pb, Cu, Cr, Hg, Mn, Ni, Zn, Fe, and Se) contents of Jazan groundwater from South Saudi which were also below detection levels [28] thereby fall within WHO standards for drinking water.

Table 1. Mean concentrations of heavy metals (mg/l) in the water samples

Sample code	Cu	Cd	Cr	Pb	Zn
GW1	0.004	ND	0.001	0.060	0.021
GW2	0.003	ND	0.003	0.240	0.033
GW3	0.010	ND	ND	0.320	0.031
GW4	ND	ND	ND	0.320	0.023
GW5	0.005	ND	0.001	0.420	0.026
GW6	0.002	ND	ND	0.620	0.020
GW7	0.007	ND	0.001	0.800	0.024
GW8	0.004	ND	0.002	0.960	0.022
GW9	ND	ND	0.004	0.120	0.021
GW10	0.009	ND	ND	0.240	0.028
GW11	0.012	ND	ND	0.360	0.018
GW12	0.019	ND	0.004	0.620	0.389
GW13	0.006	ND	0.005	0.640	0.025
GW14	0.002	ND	0.003	0.840	0.023
GW15	0.003	ND	ND	0.260	0.024
GW16	ND	ND	ND	0.060	0.019
GW17	0.009	ND	0.002	0.160	0.030
GW18	0.005	ND	ND	0.340	0.027
GW19	0.009	ND	ND	0.740	0.021
GW20	0.018	ND	0.002	0.880	0.024

Table 2. Overall mean heavy metal concentrations compare with acceptable limit

	Cu	Cd	Cr	Pb	Zn
Mean	0.00635	ND	0.0014	0.45	0.042
Min	ND	ND	ND	0.06	0.018
Max	0.019	ND	0.005	0.96	0.389
SD	0.005	ND	0.002	0.3	0.08
WHO	2.0	0.003	0.05	0.01	3.0
NIS	2.0	0.003	0.05	0.01	3.0

ND = Not detected; NIS = Nigerian Industrial Standard; SD = Standard deviation; WHO = World Health Organization

Copper and Zinc are essential elements to humans and plants life as they are considered non-toxic at macro amounts [16,29]. They are important for body to function normally. However, excessive amount intake of these metals causes health problems: Cu can cause anemia, liver and kidney damages, stomach and intestinal irritation [29,30]; Zn causes fatigue, dizziness and neutropenia, vomiting, diarrhea, icterus (yellow mucus membrane), bloody urine, anemia, liver and kidney failure, impairment of growth and reproduction [7,31,32]); Cr can also cause liver and kidney damage, skin irritation and ulceration as well as circulatory and nerve tissue [29]; Cd bioaccumulation in body causes serious health problem such as skeletal and testicular tissue damage, kidney dysfunction (hinder filtering mechanism) as well as damage to red blood cells [32]. Cu and Zn recorded in this study were in the right amounts since their levels are within the recommended limits of regulatory agencies.

The levels of Pb were far above the WHO and NIS maximum permissible limits of 0.01 mg/l for potable water (Table 2). This elevation of lead content in surrounding groundwater might not be unconnected with the aged long adoption of lead compound such as lead tetra ethyl [$Pb(C_2H_5)_4$] as anti-knock agent in petrol to ensure smooth burning in internal combustion engines and the presence of heavy metals in crude oil as natural constituents of the earth crust. The high Pb level may be attributed to spillage of petroleum products arising from day-to-day activities taking place in the vicinity of petroleum depot [13,14].

This study result with high Pb are of great concern as Pb is one of the heavy metals that has no known biological importance in living body and described toxic even in trace amount [33].

Pb reduces intelligence quotient in children and lead poisoning in adults can affect the peripheral and central nervous systems, the kidneys and liver failure, brain damage, headache, vomiting, loss of memory, gastrointestinal tract, anemia, nausea, insomnia, loss of appetite, irritability, convulsions, blood pressure, anorexia, both male and female reproduction, animal carcinogen, hypertension along with renal failure, lung and stomach cancer [34-39].

4. CONCLUSION

These results show elevated concentration of Pb in all (i.e. 100%) groundwater sampled which were above the WHO and NIS maximum allowable limits for drinking water while other heavy metals investigated (Cu, Cd, Cr and Zn) were far below the allowable limits of the regulatory bodies. This suggest that groundwater such as hand dug wells which are only sources of water supplies are definitely not safe for agricultural purposes, irrigation and domestic purposes or human consumption especially for the people living in the vicinity of the oil depot. Prompt clean-up and remediation such as phyto-remediation should be carried out by appropriate environmental managements to proper uptake of Pb metal which has grossly polluted the groundwater. However, the anthropogenic activities around the oil depot should be controlled by relevant authorities to minimize the risks associated with the release of hazardous elements through oil spilling and leakages as well as washing of oil storage tanks in the surrounding. Meanwhile the government through the agent concerned should provide potable water for the people living around the oil depot.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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