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Groundwater Contamination Levels in Residential Areas having close Proximity with Fuel Filling Stations in two Local Government Areas of Ibadan

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Abstract

Levels of groundwater contamination with monocyclic aromatic hydrocarbons (Benzene, Toluene, Ethyl-benzene, and Xylene) and some heavy metals (Lead and Chromium) were assessed in residential areas having close proximity (1-20m radius) with fuel filling stations in two Local Government Areas (LGAs) of Ibadan. The fuelling stations in the study areas (Ibadan Southwest and Southeast LGAs) were grouped into five natural clusters and samples were collected from the neighbourhood of one fuelling station in each cluster based on its proximity to residential dwelling. Groundwater samples were collected in amber coloured bottles (500 ml) from two groundwater sources, most of which were well water (10 – 17m deep) located within and/or around the fuelling stations. Samples were transported to the laboratory and analysed (using spectrophotometric method) for possible contaminants which included Benzene, Toluene, Ethyl-benzene, Xylene, Lead, and Chromium. Results were analysed using descriptive statistics and were compared with the World Health Organisation (WHO) and the Standards Organization of Nigeria (SON) guideline limits. Mean concentrations of Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX) in groundwater were 4.5±1.7, 4.5±1.7, 4.4±1.7, and 4.7±1.9mg/l respectively. These were way beyond (about 400 times) the WHO permissible limits of 0.01, 0.7, 0.3, and 0.5mg/l respectively. Also, the mean concentration of Lead was high (1.31mg/l) compared with the WHO and SON permissible limits of 0.01mg/l.This study showed that the quality of groundwater sources in residential areas around fuel filling stations of the selected study areas was grossly contaminated with hydrocarbons (BTEX) and lead, making it seriously compromised and unsafe, especially for drinking by neighbouring residents.

Niveaux de contamination des eaux sous-terraines dans les zones résidentielles proches des stations de remplissage de carburant dans deux zones de gouvernement local d'Ibadan.

Abstrait

Les niveaux de contamination de l'eau souterraine avec des hydrocarbures aromatiques monocycliques (benzène, toluène, éthyl-benzène et le xylene) et des métaux lourds (plomb et chrome) ont été évalués dans les zones résidentielles ayant proximité (rayon 1-20m) et avec des stations de remplissage en carburant dans deux zones de gouvernement local (LGA) d'Ibadan. Les stations de ravitaillement en carburant dans les zones d'étude (Les gouvernements Sud-Ouest d'Ibadan et aussi de Sud-Est) ont été regroupées en cinq groupes de naturel et des échantillons qui ont été prélevés dans le quartier d'une station de ravitaillement en carburant dans chaque groupe en fonction de sa proximité de logement résidentiel. Les Échantillons d'eau souterraine ont été prélevés dans des bouteilles de couleur ambre (500 ml) de deux sources d'eau souterraine, dont la plupart étaient del'eau (10 - 17m de profondeur) situés à l'intérieur et / ou autour des stations de ravitaillement en carburant. Les échantillons ont été acheminés au laboratoire et analysé (en utilisant la méthode spectrophotométrique) pour les contaminants possibles MARQUÉE Benzène, Toluène, éthylbenzène, Xylène, le plomb et Chromium. Les résultats ont été analysées à l'aide des statistiques descriptives et ont été comparés avec l'OMS et l'Organisation des normes du Nigéria (SON) limites de directives. Les concentrations moyennes de benzène, toluène, éthyl-benzène et xylène (BTEX) dans les eaux souterraines étaient de 4,5 ± 1,7, 4,5 ± 1,7, 4,4 ± 1,7 et 4,7 ± 1,9 mg / L respectivement. Celles-ci étaient bien au-delà (environ 400 fois) des limites admissibles de l'OMS de 0,01, 0,7, 0,3 et 0,5 mg / l respectivement. En outre, la concentration moyenne de plomb était élevée (1.31mg / l) par rapport aux limites de 0,01 mg / l. Cette étude admissible de l'OMS et de SON a montré la qualité des sources d'eau souterraines dans les zones résidentielles autour des stations de remplissage en carburant de la zone d'étude sélectionnée était gravement contaminée par des hydrocarbures (BTEX) qui la rendre dangereuse, en particulier pour la consommation par les riverains.

Introduction

In Nigeria, groundwater forms a very vital source of water supply both for domestic and agricultural purposes (British Geological Survey, 2003). Although, the Nigerian Government has the responsibility to provide water supply and sanitation services to its citizenry, it has not been able to achieve these due to several challenges (Akpor and Muchie, 2011; Odafivwotu and Abel, 2014). In its 2008 Country Summary Sheet, the Water and Sanitation Monitoring Platform reported that Nigeria was not on track to reach the MDG target of 75% coverage for safe drinking water and 63% coverage for basic sanitation by the year 2015 (WSMP, 2008). The aftermath of this, is that most Nigerians are forced to seek out means of getting water supply for domestic use at all cost. This includes the primitive practice of digging wells and harvesting of rainwater (Ishaku *et. al.,* 2011). In the urban centres, well-meaning citizens and organizations provide water outlets for public utility and this also includes fuel stations. However, the groundwater body or aquifer is an endangered species in Nigeria due to pollution from multiple sources (Owa, 2013). Literature has shown that there is a negative proximity influence on residential properties close to a petroleum contamination site and that living close to a petrol station may have adverse effect on health, e.g. acute childhood leukemia (Robert, 1999; Brosselin *et. al*., 2009; Dauda and Odoh, 2012). Over the years, experience has shown that children are more susceptible to toxic exposure than adults. They are thus exposed because they have multiple exposure routes, rapid and active developmental process, and intake of food contaminants is proportionally higher than that of the adults (Monica *et. al*., 2014).

In developing countries, petroleum product leakage into groundwater sources is not a strange phenomenon. In most cases, petroleum product storage tanks are buried underground, the tanks not only but rust and leak, petroleum products flow downward, without adequate safety devices in place. At low concentrations, petroleum products make drinking water unpalatable (Adeleke, 2004). Apart from making drinking water unpleasant, petroleum products contain chemical compounds that are hazardous to health. Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX) are a group of volatile mono-aromatic hydrocarbons which have been classified as dangerous pollutants found together in crude petroleum and petroleum products. 18% (W/W) of standard gasoline is said to be made up of BTEX (Plaza *et al*., 2006). Benzene ranks as the most hazardous of the BTEX compounds and the risk of developing cancer increases with long term exposure to Benzene in drinking water (Pedersen *et al*., 2003).

In view of these worrisome scenarios, there is an impending danger in the indiscriminate siting of petrol filling stations in every nook and cranny of the ancient city of Ibadan. Hence, this study assessed groundwater contamination levels, especially in residential areas sited close to fuel filling stations by comparing results of analysis with known guideline limits.

Materials and Methods

Study Area

The study was carried out in Ibadan, Nigeria. Ibadan was created in 1829 as a war camp for warriors coming from Oyo, Ife, and Ijebu. Ibadan thus began as a military state and remained so until the last decade of the 19th Century (Laurent, 2003). At Independence, Ibadan was the largest and the most populous city in Nigeria and the third in Africa after Cairo and Johannesburg. It is located in South-western Nigeria, 78 miles inland from Lagos and it is a prominent transit point between the coastal region and the areas to the north. Its population is 5,580,894 according to 2006 census results, with eleven (11) local government areas (NPC, 2006). Ibadan Southeast and Southwest local government areas were chosen at random for this study from those in core Ibadan metropolis.

Study Design

The study involved a descriptive cross-sectional survey and a laboratory-based analysis of groundwater samples collected from the vicinity of five fuel filling stations in the two local government areas selected for the study.

Groundwater Sampling

The petrol stations were grouped into five natural clusters namely Olomi-Academy, Olorunsogo, Oke-Ado, New garage, and Apata. Groundwater samples were collected from the vicinity of one petrol station per cluster. Groundwater samples were collected in amber coloured bottles (500ml) from two groundwater sources (borehole or well [10-17m deep]) located inside and/or around (1-20m range) the fuel filling stations. It was observed that fuel stations provide public stand pipes from their ground water sources for use by neighbouring residents. It was therefore, needful to collect samples from some of the stations. All samples were properly labelled and transported to the laboratory for analysis. Samples were analysed for possible contaminants which include Benzene, Toluene, Ethyl-benzene, Xylene, Lead, and Chromium. The pH of the water was also examined.

Laboratory analysis

Determination of Aromatic Hydrocarbons using Spectrophotometric method

Aromatic hydrocarbons in groundwater samples were determined using the method by Osuji and Nwoye, (2007). Five (5) ml of water samples were measured into 250ml volumetric flask, and 50ml of xylene was added to it. This was vigorously shaken and left at room temperature to allow the xylene evaporate. The solution was then transferred into cuvette wells and its absorbance was determined using spectrophotometer at 410nm. Standards of 10ppm were prepared for each of the analytes from their various reagents.

1ml reagent (e.g. Toluene reagent) was measured into a 100ml volumetric flask. 70ml of Xylene was added to this and was made up to 100ml with distilled water. 10ml was taken from this into a 100ml volumetric flask and was made up with distilled water, thus, giving 10ppm. A calibration curve was obtained by measuring the absorbance of the dilute solution of standards at varying volumes of 2.5, 5.0, 10.0, 20.0, and 30.0mls. This procedure was done for all the analytes using their respective reagents and the concentrations were read on the calibrated spectrophotometer at 410nm.

Determination of heavy metal contaminants using Atomic Absorption

Spectrophotometer

Five(5)ml of groundwater samples were measured into a digestion tube. One tablet of selenium catalyst was placed inside the tube. Ten (10)ml of concentrated perchloric acid and 10mls of concentrated nitric acid (1:1) was measured into the digestion tube. The tube was placed inside a digestion block and slowly digested. The digest was washed into 100mls volumetric flask and made up with distilled water. This was centrifuged at 300rpm for 30 minutes to get the supernatant. Meter reading was done using the Atomic Absorption Spectrophotometer (AAS) at wavelength of 283.3nm for Lead (Pb) and 357.9nm for Chromium. The data obtained were summarised using descriptive statistics, the mean values were obtained and compared with guideline limits.

Results

The laboratory results for the analysis of BTEX, heavy metals and pH of groundwater samples are presented in Tables 1 and 2 below.

Table 1: Results of BTEX analysis in groundwater samples

Sample code	Benzene (mg/l) mean±std	Toluene (mg/l) mean±std	Ethyl-benzene (mg/l) mean±std	Xylene (mg/l) mean±std
A1	2.241±0.000	2.286±0.000	2.207±0.008	2.248±0.001
A2	2.115±0.001	2.159±0.001	2.113±0.049	2.292±0.003
B1	2.821±0.001	2.880±0.001	2.773±0.002	3.060±0.001
B2	3.030±0.001	3.091±0.001	2.973±0.004	3.284±0.000
C1	5.810±0.001	5.930±0.002	5.758±0.074	6.299±0.001
C2	6.263±0.004	6.392±0.002	6.152±0.002	6.792±0.002
D1	5.723±0.004	5.841±0.001	5.623±0.003	6.209±0.001
D2	5.601±0.000	5.718±0.004	5.501±0.001	6.072±0.002
E1	5.684±0.000	5.600±0.000	5.582±0.002	6.162±0.001
E2	5.723±0.004	5.341±0.001	5.622±0.003	6.208±0.000

Key in Sample code: A, B, C,D, and E are the five different locations (within petrol station vicinity) where groundwater samples were collected; 1 is the first groundwater source while 2 is the second groundwater source at each location. Groundwater sources at each location are approximately 10 to 15m apart.

Table 2: Results of Heavy metals and pH analysis in groundwater samples

Sample code	Lead (mg/l) mean±std	Chromium (mg/l) mean±std	pH mean±std
A1	1.680	0.034	6.700±0.000
A2	1.660	0.028	6.815±0.021
B1	1.570	0.017	7.050±0.071
B2	1.480	0.018	6.600±0.141
C1	1.340	0.024	7.250±0.071
C2	1.250	0.022	7.200±0.000
D1	1.074	0.014	7.000±0.141
D2	1.068	0.015	6.550±0.071
E1	1.012	0.016	6.725±0.035
E2	1.014	0.016	6.705±0.007

Key in Sample code: A, B, C,D, and E are the five different locations (within petrol station vicinity) where groundwater samples were collected; 1 is the first groundwater source while 2 is the second groundwater source at each location. Groundwater sources at each location are approximately 10 to 15m apart.

The mean concentrations of BTEX in groundwater samples as presented in Figure 1 are 4.50±1.7, 4.54±1.7, 4.43±1.7, and 4.86±1.9mg/l respectively. These were compared with the guideline limits from WHO. Although, the Standards Organization of Nigeria (SON) adheres to the WHO guideline for drinking water quality, it makes no provisions for the BTEX group of contaminants. The mean concentrations of all the monocyclic aromatic hydrocarbons (Benzene, Toluene, Ethyl-benzene, and Xylene) in groundwater samples were about 400 times higher than the WHO guideline limit. The mean concentration of Lead and Chromium (see figure 1) was compared with the SON and WHO limit and Lead was found to be more than 100 times above the set limits. The pH was weakly acidic or neutral with a mean of 6.68±0.1.

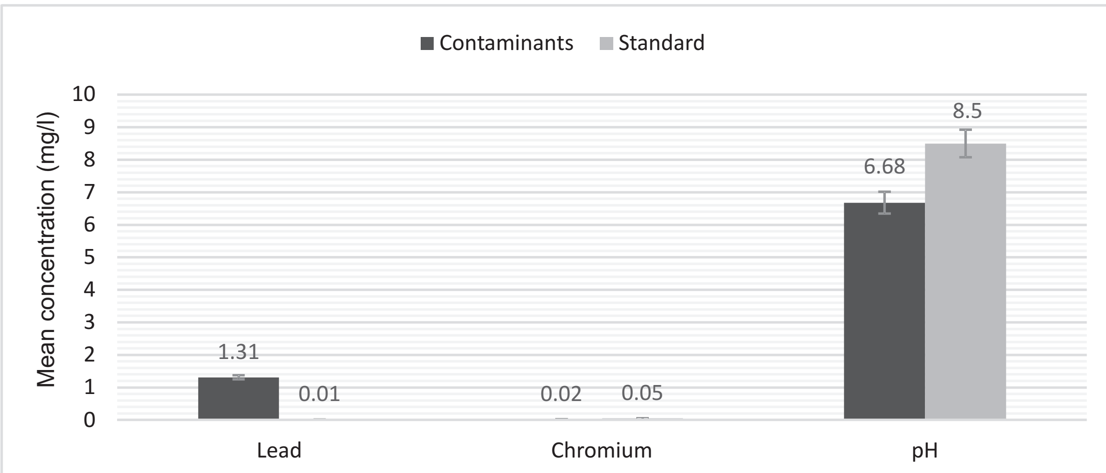

Figure 1: Mean concentrations of heavy metals and pH in groundwater samples compared with the WHO and SON Guidelines for drinking-water

Figure 2: Well water vividly polluted with oil at one of the fuel stations.

The result shows that the pH was weakly acidic or neutral having a mean value of 6.68±0.1. Although, pH usually has no direct impact on consumers, it is one of the most important water quality parameters and the optimum pH required often begin in the ranges of 6.5 to 8.5/9.5 (WHO, 2008).

With the mean concentrations of Benzene, Toluene, and Ethyl-benzene soaring so high (Figure 1), there is a grave indication of gross contamination and compromise in groundwater quality in the study area. This could have been a result of leaking underground storage tanks or even, direct spills into the environmental media from the service stations as observed in the course of the study. According to Pedersen *et al.,* (2003), benzene ranks as the most hazardous substance among the BTEX compounds and long term exposures to benzene in drinking water increases the risk of cancer.

Also, with the mean concentration of lead exceeding the limits set by WHO and SON (Figure 2), exposures in human can result in a wide range of biological effects depending on the level and duration of exposure. The reason for the high concentration level of lead observed is not clear since the ban on leaded fuel production, but similar study by Dauda and Odoh (2012), in Benue State in the year 2012 also revealed that lead levels of soil, and consequently, groundwater in the vicinity of fuel filling stations was the highest among the heavy metals studied. The United Kingdom Drinking Water Inspectorate however said that lead can occasionally occur naturally in groundwater sources (DWI, 2010). Whichever way, high levels of exposure to lead may result in toxic biochemical effects in humans, which in turn causes problem in the synthesis of haemoglobin (Lenntech, 2008). Exposure to lead causes various health effects and that becomes more probable due to long term exposures. High concentrations of lead in the body can cause death or permanent damage to vital organs in the body, e.g., the central nervous system, the brain, and kidneys. Damages resulting from lead poisoning include mental retardation, behaviour and learning problems, slowed growth, high blood pressure, reproductive problems in men and women, etc. Children are at the highest risk to lead poisoning and the effect can last a life time (Salem *et al.,* 2000).

Discussion

The exceedingly high concentration of most of the contaminants (Figures 1 and 2) was not unexpected because mere physical examination of what was obtainable on the field clearly points to this. There were direct spills onto the soil and drainage which could eventually impact on the environmental media of the surrounding neighbourhood. Also, close observation of one of the wells in one of the fuel stations revealed gross contamination due to the presence of oil on its surface. Sadly, this water is being used by neighbouring residents for domestic purposes.

Conclusion

This study has shown that the quality of groundwater sources in the study area have been grossly compromised, thereby jeopardizing the health of the neighbouring community, especially the younger ones. It is recommended that surveillance of environmental levels of these hydrocarbons and heavy metals should be engaged. This will help in knowing the trend of environmental contamination with these pollutants, thereby taking proper actions taken to ensure safety of the populace.

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