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Assessment of Heavy Metals in Petroleum Hydrocarbon Contaminated Groundwater (A Case Study of Baruwa Community, Lagos State, Nigeria)

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Abstract:
This research investigated the extent of heavy metals present in the groundwater due to its contamination by petroleum hydrocarbon. Ten hand-dug wells were sampled within the test area and tested for 23 selected heavy metals. A carefully selected well at the upstream with no history of contamination was selected for the control samples. Concentrations of heavy metals were found to be lower in the Control Well compared to the petroleum hydrocarbon-contaminated wells. The Contaminated wells are dominated by B, Zn, Fe, Mn, and Ni in order of B>Zn>Fe>Mn>Ni respectively. Other metals were found in very low concentrations and largely below maximum acceptable concentrations by World Health Organization and United States Environmental Protection Agency. A comparison between the low concentration of heavy metals observed in the Control Well and the relatively high concentrations in contaminated wells showed strong indications of petroleum-hydrocarbon pollution.

Keywords: Contaminated Well, Groundwater, Heavy Metals, Petroleum Hydrocarbon

1. Introduction

Water is without doubt one of the most essential natural resources and groundwater is a major source of water supply [1]. According to [2] and [3] the wide use of groundwater can be attributed to the ease of access, higher water quality as compared to surface water, lower capital cost of production, less subject to seasonal and perennial changes, uniformly spreading over large areas and also better protection from pollution sources. These benefits have necessitated the use of groundwater as a primary water source in meeting societal demands. However, despite the various benefits of groundwater, its quality is largely dependent on its chemical composition and this can be altered by natural and anthropogenic sources [4].

One of the major sources of pollution to surface and groundwater is oil spillage. Oil spillage refers to the accidental leakage of crude oil or refined products on land or water during the process of transportation or distribution resulting in environmental pollution. Crude oil occurs naturally as a complex mixture of hydrocarbon, non-hydrocarbon compounds, and heavy metals which contains a measurable toxicity towards living organisms. The general increase of heavy metal content in the soil and groundwater has been largely linked to crude oil spillage [5-6]. Other sources of pollution in groundwater include liquid waste from industries, leachate from municipal refuse dumpsites, saltwater intrusion, domestic waste, pipeline vandalization, application of agricultural chemicals, etc [7].

The term "Heavy metal" refers to a group of metals and metalloids with an atomic density greater than 4000 kg/m^3, or 5 times more than water [8. Heavy metals occur naturally in the earth's crust and have varying contents in the environment resulting in spatial variations in concentration corresponding to the varying level of industrialization across regions. According to [9], the levels of heavy metals in the environment are increasing and have become a major global concern. These metals enter living organisms through food or proximity to emission sources and have tendencies to bio-accumulate i.e. stored faster than they are excreted [10]. To assess water quality and measure the concentration of these contaminants in groundwater, some scientific tools and procedures have been developed [11]. The parameters considered by these procedures include Total Dissolved Solids (TDS), pH, Conductivity, Turbidity, Total Suspended Solids (TSS), Heavy metals, and Total Organic Carbon (TOC). These parameters are assessed to see if their respective values or concentrations are higher than or within the safe limits set by the World Health Organization (WHO) or other regulatory bodies [12]. Heavy metals may cause severe harm to the health of humans and other animals (cancers, organ and neurological damage, and death). Therefore, this research is focused on the assessment of groundwater in the Baruwa Community concerning 23 heavy metals namely; Arsenic, Cadmium, Lead, Mercury, Zinc, Silver, Iron, Copper, Cobalt, Chromium III, Manganese, Molybdenum, Selenium, Aluminum, Antimony, Boron, Silicon, Vanadium, Barium, Beryllium, Strontium, Thallium and Nickel. Although, there are other communities in Nigeria with history of hydrocarbon petroleum contaminations. The study area is a built-up area with population over 100,000 people with about 10% of the populace complaining of health issues similar to what can be caused by heavy metals from water pollution.

2. Study Area

The Study area is the Baruwa community in Lagos State, it is situated in Alimosho Local Government Area of Lagos State, Nigeria (Figures 1 and 2). It lies between Latitudes 06˚ 35' 12" N, Longitude 03˚ 16' 21" E, and is bounded by Abesan and Gowon estate. It is drained by Lagos Lagoon, Badagry Creek, and Lekki Lagoon which runs into the lagoon. The Local Council is comprised of an arable landmass of about 57.621 km^2, predominantly residential with a population of about 100,000. There are about 350 hand dug wells in the area for domestic water supply however more than 200 of these wells are presently contaminated due to oil seepage from leaking underground NNPC (Nigerian National Petroleum Corporation) pipeline. A schematic field site map showing the study area with essential details on the available wells was obtained. Generally, some of these wells are monitored, some are not accessible, and filled partially/completely (Figure 3). The direction of groundwater flow, suspected point of leakage, and Nigerian National Petroleum Corporation (NNPC) pipeline Right of Way. The choice of the sampling wells considered location, accessibility, direction of groundwater flow, and the topography of the study area.

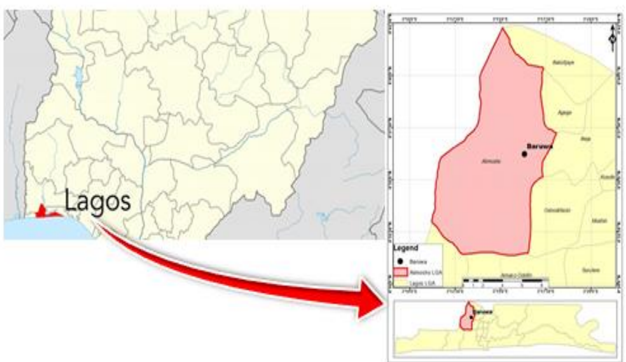

Figure 1. Map of Nigeria showing Lagos State indicating Baruwa the case study site.

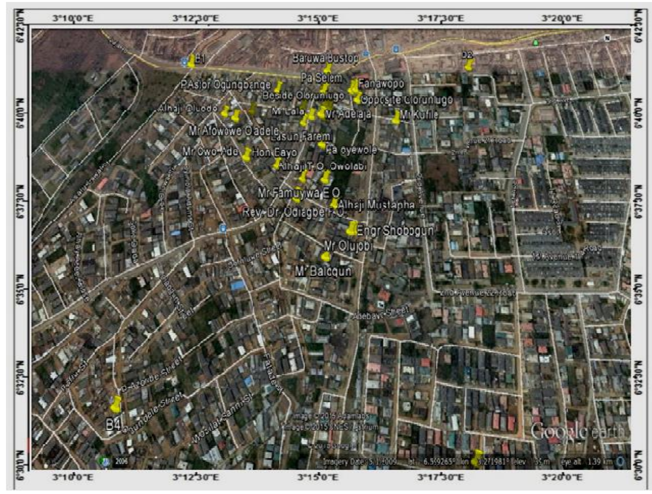

Figure 2: Google Earth Map of the area, indicating GPS locations of the located wells from the Garmin II GPS Device

Figure 3: Field site map showing well locations. [13]

3. Materials and Method

3.1. Water Sampling and Testing Methods

Water samples were collected from each sampling well in pre-cleaned polyethylene bottles. These bottles were rinsed with clean water and then soaked in 10% HNO_3 water overnight and washed with deionized water. The bottles were thoroughly rinsed with water at the sampling location before the water samples were collected. Bottled samples were filled and refrigerated. The samples were kept in a sample storage box at 4^0 C and transported to the laboratory in an insulated cooler where the digestion procedure commenced immediately.

3.2. Water Sampling and Analytical Methods

The samples were taken to the Institute of Agricultural Research and Training (IAR&T), Ibadan, and stored at 4^0 C for digestion and quantification of heavy metals. 50 ml of water samples were digested with 10 ml of concentrated HNO_3 and HCL in a ratio of 3:1 at 180^0 C for 15 minutes until the solution became transparent [14]. The solution was filtered using

Whatman No. 42 filter paper and the total volume of digest was maintained to 50 ml with distilled water and stored for further analysis.

3.3. Quantification of Heavy Metals

Heavy metals in digested water samples were determined as described by [15]. Digested water samples were quantified for the following heavy metals namely; As, Mn. Fe, Ba, Hg, Cd, Pb, Cr, Ni, Cu, Al, Zn, Se, V, Co, Si, Mo, Tl, Sr, Ag, Be, Sb, and B in Buck 211VGP Atomic Absorption Spectrophotometer (AAS) through the suction tube. Each of the trace mineral elements was read at their respective wavelengths with their respective hollow cathode lamps with appropriate fuel and oxidant combinations. To correct for background absorption, Procedural blanks were prepared and aspirated along with the analytical samples. The instrument was fitted using a specific lamp of a particular metal.

4. Results and Discussions.

4.1. Groundwater level

Groundwater levels measured in both control and contaminated sampled wells with the aid of an interface meter are within 21.00 – 26.00 meters below the ground surface. The diameters of sampled wells give a range of 0.82 – 1.93 meters (Table 1) which is consistent with similar wells in previous studies [16]. Also in similar wells, measured water table levels (21.00 – 26.00 meters) from this study, show a slight change in levels when compared with levels in separate studies (20.28 – 25.25 meters) [17] and (23.351 – 24.521 meters)[16].

Table 1: Sampled well parameters

Sampled Well	**Water Table (Current Study) (meter)**	**Water Table (Adekunte, 2008) (meter)**	**Water Table (Ola *et al*, 2016) (meter)**	**Well Diameter (meter)**
Control Well	23.450	Na	Na	1.200
Well 01	25.010	24.600	24.450	1.930
Well 02	24.800	Na	24.521	0.820
Well 03	24.700	24.400	24.334	1.750
Well 04	25.001	Na	23.351	1.120
Well 05	24.900	Na	24.437	1.650
Well 06	25.200	Na	Na	1.200

Na: Not Available for Investigation

4.2. Heavy Metal Concentrations

A wide range of heavy metal concentration values were observed for water samples in the study area with concentration varying from one sampling point to another.

Generally, the results show that heavy metal concentrations in the control well are lower than the concentrations of contaminated wells (Figure 4). Also, six out of the 23 selected heavy metals (Mercury, Beryllium, Strontium, Thallium, and Antimony) were not found in uncontaminated wells though their concentrations were low in contaminated wells. This further shows that the presence of the 6 metals is a result of pollution by petroleum-hydrocarbon in the study area.

Concentrations of each metal in contaminated wells vary from one well location to another and these concentrations ranged from 0.001-0.078 mg/l. Except for Lead, Cadmium, Mercury, Beryllium, Vanadium, and Strontium, all other heavy metals from the selected 23 are present in each sampled contaminated well.

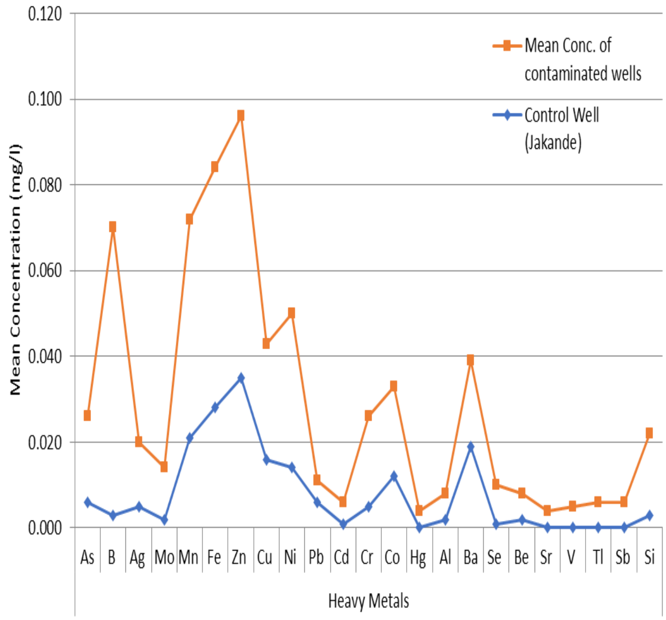

Figure 4: Mean concentration of metals in contaminated wells versus concentration of Control Well

Generally, in sampled contaminated wells, Boron, Manganese, Iron, and Zinc have the highest concentrations which range 0.037 ± 0.009 – 0.064 ± 0.009 mg/l, 0.042 ± 0.009 – 0.067 ± 0.009 mg/l, 0.038 ± 0.007 – 0.078 ± 0.007 mg/l, 0.049 ± 0.014 – 0.078 ± 0.014 mg/l with mean values 0.067 m/l, 0.051 mg/l, 0.056 mg/l and 0.061 mg/l respectively

The average concentration of the 23 selected metals ranged from 0.001- 0.067 mg/l and largely, the average concentration of each heavy metal is below the maximum acceptable concentration by WHO and US EPA except As, Ag, Hg, V, and Tl which are above the acceptable limits

The contaminated sampled wells within the pilot test area (Well01, Well02, Well03, Well04, Well05, and Well06) have average concentrations of 0.022 mg/l, 0.018 mg/l, 0.022 mg/l, 0.021 mg/l, 0.022 mg/l, and 0.021 mg/l respectively, which show a fairly even distribution of heavy metals in wells in the center of the study area.

Boron was found to have the highest average concentration of 0.067 mg/l, followed by Zinc with 0.061 mg/l in the contaminated wells. Other metals with high concentrations are Iron and Manganese with 0.056 mg/l and 0.051 mg/l respectively. This implies that contaminated wells are dominated by Boron, Zinc, Iron, Manganese, and Nickel in order of Boron>Zinc>Iron> Manganese>Nickel (Figure 5)
Generally, 78.26 percent of the selected heavy metals detected in the contaminated wells have mean concentrations lower than the acceptable limits set by WHO and USEPA. Only Hg, Be, Sr, V, Tl, and Sb have concentrations higher than the acceptable limits. There are significant differences in the concentration of heavy metals in the groundwater of the contaminated wells within the study area and the control sample, this report is similar to the output of the research carried out by [18- 19]. The results show that there is an indication of heavy metal concentration in groundwater polluted with petroleum hydrocarbon. [18];[20];[19]. The values of concentration of heavy metals in the groundwater are high causing public concerns about the health implications [21].

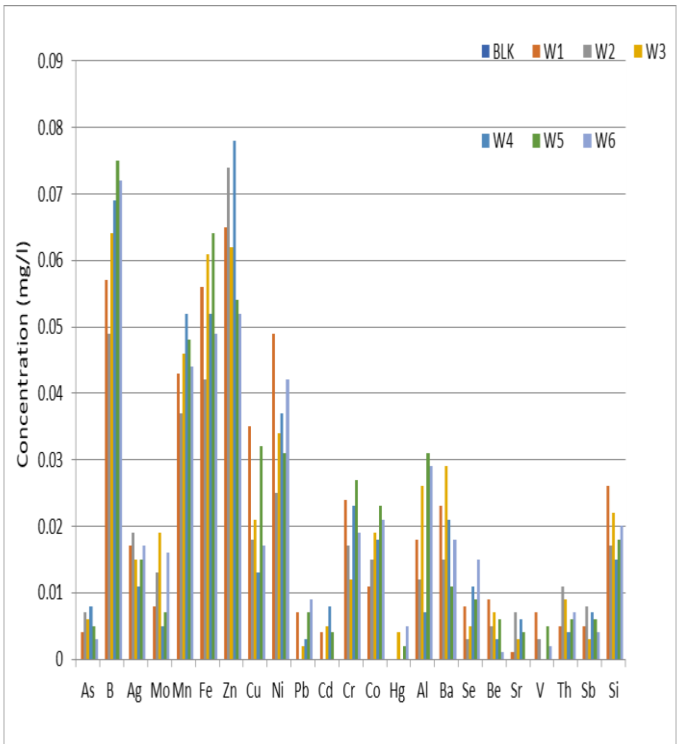

Figure 5: Concentration of heavy metals in contaminated wells

5. Conclusions

The results of the investigation confirmed the presence of the 23 selected heavy metals in the contaminated groundwater of the study area with varying degrees of concentration. A comparison between the low concentration of heavy metals observed in the Control Well and the relatively high concentrations in contaminated wells showed strong indications of petroleum-hydrocarbon pollution.
Also, Hg, Sr, V, Tl, and Sb were below the detectable limit in the Control Well but were found at low concentrations in contaminated wells. Higher concentrations of Boron in contaminated wells further support the increase of heavy metals concentration as a result of petroleum-hydrocarbon pollution.
High concentration of iron and manganese does not pose any health hazard but aesthetic, cosmetic, and technical effects should be expected in the study area. These are undesirable tastes, colors, odors, skin discoloration, corrosion, stains and damage to water supply equipment, and reduction in the effectiveness of treatments for other contaminants. The economic implications of these effects should be expected.

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References

[1]. Achyara, G., "The role of economic analysis in groundwater management in semi-arid regions the case of Nigeria". Hydrogeology Journal, vol. 12, pp. 33-39, 2004.
[2]. United Nations Education and Cultural Organisation (UNESCO), (2004). 'Groundwater resources of the world and their use.' Edited by Zekster, S, Everett, G.
[3]. Sharma, S. K., Petruseveki B., and Schippers J. C., (2001). Advanced groundwater Treatment Iron, Manganese, Fluoride, and Boron Removal.
[4]. Lou, S., Liu, S., Dai, C., Tao, A., Tan, B., Ma, G., Chalov, R. S.,& Chalov, S. R. "Heavy Metal Distribution and Groundwater Quality Assessment for a Coastal Area on a Chinese Island" *Pol. J. Environ. Stud.*, vol. *26* no. 2, pp. 733–745. 2017. https://doi.org/10.15244/pjoes/67064
[5]. Adesina, G. O., and Adelasoye, "K. A. Effect of crudeoil pollution on heavy metal contents, microbial population in soil and maize and cowpea growth". *Agricultural Sciences*, vol. *5* no. 1, pp. 43–50 2014.
[6]. Khlifi, R., and Hamza-Chaffai, A. "Head and neck cancer due to heavy metal exposure via tobacco smoking and professional exposure A review". Toxicology & Applied Pharmacology, vol. 248, pp. 71–88. 2010.
[7]. Adegbola, R. B., Oseni S. O., Anyanwu V. C., Majolagbe, A. O. and Sovi, S. T., "Application of electrical resistivity and hydrochemical methods to investigate agricultural pollution in some parts of Ojo, Lagos, Southwest, Nigeria" International Journal of Innovative Research & Development, vol. 1 no. 4 pp. 398 – 413, 2012.
[8]. Hashim, M. A., "Mukhopadhyay, S., Narayan, J., and Sengupta, B. Remediation Technologies for Heavy Metal Contaminated Groundwater Remediation technologies for heavy metal contaminated Groundwater" *Journal of Environmental Management*, vol. *92* no. 10, pp. 2355–2388, 2011. https://doi.org/10.1016/j.jenvman.2011.06.009
[9]. Khodabakhshi, A., Amin, M. M., Mozaffari, M. "Synthesis of magnetic nanoparticles and evaluation efficiency for arsenic removal from simulated industrial wastewater". Iran J Environ Health Sci Eng, vol. 8: pp. 189–200, 2011.
[10]. Daka, E. R., and Ekweozor, I. K., "Effect of Size on the Acute Toxicity of Crude Oil to the Mangrove Oyster". Journal of Applied Sciences & Environmental Management, vol. 8 no.2 pp. 19-22, 2004.

[11]. Dissmeyer, G. E. (2000) 'Drinking Water from Forests and Grasslands'. South Research Station, USDA Forest Service, Ashville, NC, USA.

[12]. World Health Organisation (WHO), (2011), 'International standards for drinking water, Geneva, WHO, 2011.

[13]. Fadugba, O.G. (2016). In Situ Pilot Scale Remediation of Hydrocarbon Contaminated Groundwater (A Case Study of Baruwa Community Lagos, Nigeria). A Ph.D. Progress Seminar presented at the School of Engineering And Engineering Technology Department of Civil And Environmental Engineering. The Federal University of Technology, Akure, Nigeria.

[14]. American Public Health Association, (APHA), (2005). 'Standard methods for the examination of water and wastewater', Washington, DC.

[15]. American Public Health Association, (APHA), (1998). 'Standard methods for the examination of water and wastewater, 20th ed., (Eds); American Public Health Association: Washington, DC.

[16]. Ola S. A., Fadugba O. G., and M. A. Uduebor "Slug Tests for Determination of Hydraulic Conductivity of Contaminated Wells" Environment and Natural Resources Research; Vol. 6, No. 2; 2016 ISSN 1927-0488 E-ISSN 1927-0496. (2016).

[17]. Adekunte, O.A. (2008) "Hydro-chemical Analysis of Shallow Wells for Hydrocarbon Contamination in Baruwa, Lagos, Nigeria", M.Eng Thesis, Civil Engineering Department, Federal University of Technology, Akure, Nigeria.

[18]. Adeniyi A. A. and Afolabi, J. A. (2002) Determination of total petroleum hydrocarbons and heavy metals in the soil within the vicinity of facilities handling refined products in Lagos Metropolis. Environmental international 28, 79-82

[19]. Adewuyi G. O., Etchie, O.T., and Ademoyegun, A. T. (2011). Determination of total petroleum hydrocarbons and heavy metals in the surface water and sediment of Ubeji River, Warri, Nigeria. Bioremediation, Biodiversity and Bioavailability 5(1), 46-51

[20]. Akporido, S. O. (2008) Assessment of water, sediment and soil pollution arising from crude oil spillage in the vicinity of Esi River Western Niger Delta. PhD Thesis, Chemistry Department, University of Ibadan, 198 pp

[21]. Asia, I. O. Jegede D. A., Ize-Iyamu O. K, and Akpasubi, E. B. (2007) The effects of petroleum exploration and production operations on the heavy metals contents of soil and groundwater in the Niger Delta. International Journal of Physical Sciences 2(10), 271-275