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Quality of Groundwater around an Abandoned Lead-Acid Battery Company in Ibadan, Nigeria

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Authors' contributions

This work was carried out in collaboration amongst all the five authors. Author POO designed the study and wrote the protocol. Authors POO, AYS and UJO managed the literature searches. Authors POO, FJO and QOA wrote the first draft of the manuscript. All the five authors managed the analyses of the study, read and approved the final manuscript.

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ABSTRACT

The physicochemical parameters for groundwater within the vicinity of an abandoned automobile battery company were assessed to determine the water qualities. Water samples were collected from the nine hand-dug wells from the adjascent settlement for analysis of 12 parameters and heavy metals. The heavy metals were determined by Atomic Absorption Spectrophotometer (AAS) and other parameters by various scientifically accepted standard methods. The study showed the mean concentrations of Iron (Fe), Zinc (Zn), Copper (Cu), Chromium (Cr), Lead (Pb), and Cadmium (Cd) ranged from 2.80 to 16.00 mg/l, 0.98 to 1.46 mg/l, 0.23 to 1.38 mg/l, 0.1 to 0.89 mg/l, 5.05 to 13.15 mg/l and ND to 0.17 mg/l, respectively while pH, electrical conductivity, total dissolved solids, total suspended solids, total solids, total alkalinity, total hardness, sulphate, nitrate, phosphate, chloride and chemical oxygen demand mean values ranged between 6.18 and 11.35, 253.50 and 1007.67 µS/cm, 270.50 and 851.47 mg/l, 2.95 and 19.62 mg/l, 273.45 and 771.82 mg/l, 291.58 and 807.85 mg/l, 181.25 and 601.67 mg/l, 35.00 and 397.00 mg/l, 0.45 and 3.12 mg/l, 411.71 and 1005.92 mg/l, 0.49 and 4.40 mg/l, and, 2108.33 and 2393.33 mg/l, respectively. The study revealed that more than

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50% of the well waters parameters investigated were generally above the World Health Organization (WHO) recommendations. The water qualities were very poor as regards heavy metals levels, pH, solid particles, conductivity, phosphate and chemical oxygen demand. This poses health risk to the population that depends on the well waters. Thus, the well waters in the study area require purification as a matter of urgency to make it totally fit for human consumption or domestic uses as this would surely prevent the outbreak of water borne diseases.

Keywords: Hand-dug wells; automobile battery; vicinity; physicochemical parameters; WHO.

1. INTRODUCTION

Water is life but good and potable one. United Nations put people that lack access to clean water to more than 700 million which is why the target of Millennium Development Goals for a sustainable access to safe drinking water and basic sanitation seems to be a mirage. The growth of industrialization and urbanization processes with corresponding population together with agriculture activities in developing nations bring about risk of pollution to natural environments such as soils, waters and air.

Groundwater (hand-dug wells and boreholes) contamination or pollution occurs when contaminants or pollutants are released to the ground and infiltrate or get leached into the water body in the ground. This contamination can occur naturally from minor unwanted constituent or impurities in the groundwater which partly depend on the nature of the geological material through which the groundwater moves [1]. To prevent health hazards, there should be provision of potable water to the rural and urban populace as water is importance to human body physiology and man's continued existence [2,3].

Ground water is one of the major important drinking water sources throughout the world especially in most of the village areas. It is a common and major source of drinking water in Ibadan, Nigeria especially the people located in the vicinity of the study area. Heavy metals are most considerable contaminants in ground water and excess levels of heavy metals might cause several short term and long term health effects to the human beings. However contamination of all these groundwater with heavy metals, majorly hand-dug wells is inevitable due to rapid industrialization in recent years as sources of heavy metals include industrial activities such as oil explorations activities, mining, manufacturing and agricultural practices as well as commercial and domestic practices that generate wastes, and also natural factors [4]. Manufacturing and services industries have high demands for cooling water, processing water and water for general cleaning purposes. This used water caused groundwater pollution when returned to the hydrological cycle. This in turn reduces the groundwater quality. High levels of heavy metals especially lead (Pb) were found in groundwater located in the vicinity of a battery factory in Nigeria which called for purification before the water is suitable for consumption [5].

No concentration of metal elements or any metal has been reported as being safe, because long term exposure to low concentration is equally harmful due to bioconcentration and biomagnification. However some are essential in life processes at moderate concentrations. The monitoring of groundwater quality has been widely investigated and reported in other part of the world [5-7] and Ibadan [8]. However, there was still paucity of data or information on the quality of groundwater around industrial areas in Ibadan, southwestern Nigeria. The aim of this study is to determine some physicochemical parameters of groundwater in the vicinity of a battery manufacturing company, Ibadan, Nigeria.

2. METHODOLOGY

2.1 Description of Study Area

The study area is located in the vicinity of an abandoned automobile battery company which is situated in a vast land around Wofun area along Kute road, Ibadan, Nigeria (Fig. 1). The company is surrounded by developing sites and villages for residential settlements with portions of land used for agricultural purposes. Ibadan is located on latitude 7° 20N and longitude 3° 5E and annual rainfall of about 1250 mm.

2.2 Sampling

The nine hand dug wells water located in the small residential area (village) during the time of study were collected in February, 2005. Water samples were obtained with the aid of plastic bucket that has been previously washed with clean water and detergent and rinsed with distilled water, with a long rope attached. The water samples were taken and stored in well labeled clean polyethylene containers after thorough agitation of water in respective wells, to ensure proper mixing for homogeneous and true representative samples. The water samples for heavy metals analysis were adjusted with concentrated nitric acid to pH < 2 to reduce the microbial activities and prevent the adsorption of metal ions onto the surface of the sample containers. These were transported to laboratory for analysis.

Prior to sample collection, all the sample containers were thoroughly washed with detergent and sterilized with 50% HCl for 12 hours. They were then washed with water and rinsed with distilled water.

2.3 Methods of Analysis

Ion-exchange chromatography technique with some modifications was used for the concentration of the heavy metals (such as Zn, Cr, Cu, Fe, Pb and Cd) that were present in the water samples. This technique is based on exchange adsorption principle whereby ions of interest (analytes) adhere to an active site are later eluted with a solvent. Dowex 50 cation exchange resin was carefully packed into a burette up to a column length of 15 cm above glass wool at the bottom. The flow rate was adjusted between 2.5 – 3.0 ml per minutes. About 10 ml concentrated nitric acid was passed through the burette to charge the resin active site and pre-adjusted pH 5.2 of 500 ml water sample was then passed through resin inside the burette at the preset flow rate, and finally eluted with 25 ml concentrated nitric acid. The procedure was carried out in duplicate for all samples and the eluted water samples analysed using Atomic Absorption Spectrophotometer (AAS) Bulk scientific 200 model. The physicochemical parameters were determined according to standard methods [9,10]. The pH and electrical conductivity were measured by Jenway 3015 pH meter and conductivity meter, respectively. Total alkalinity and total hardness by titrimetric methods, chloride by Mohr's method (titrimetry).

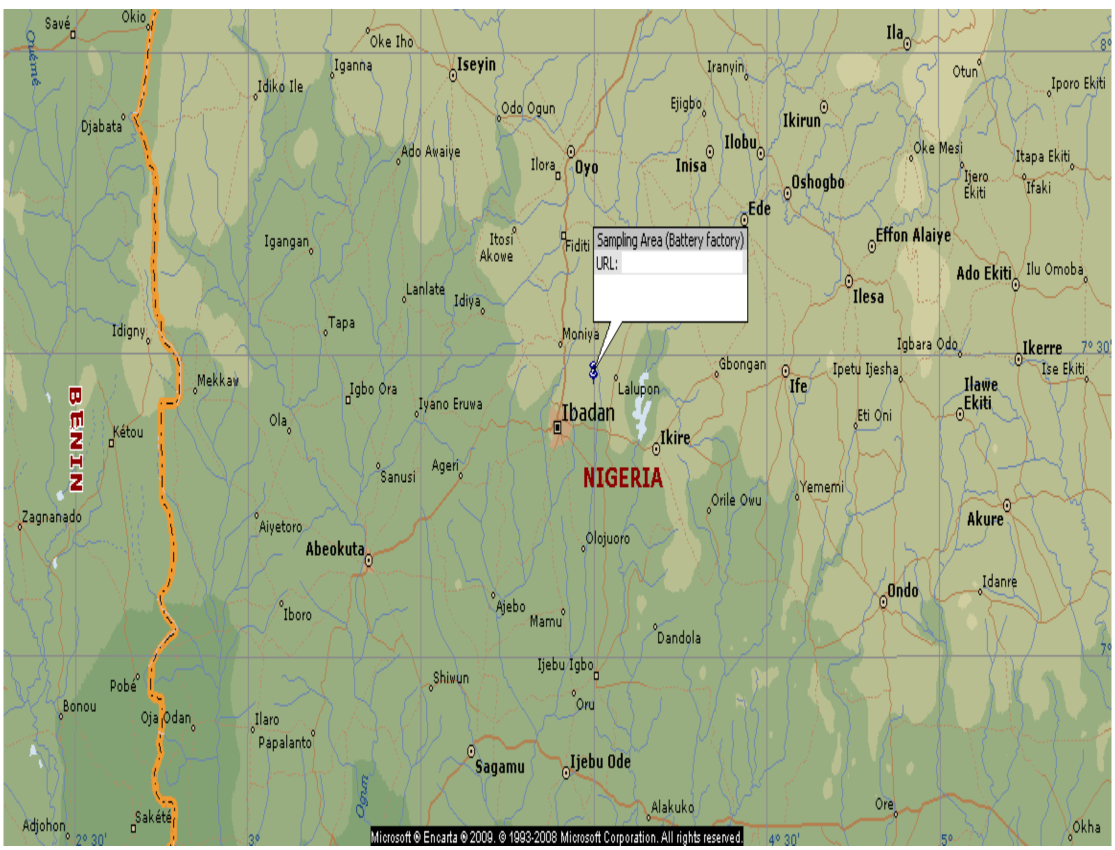

Fig. 1. Map of Ibadan showing the study area

Sulphate by turbidimetry, phosphate (vanadate-molybdate reagent colorimetric method) and nitrate by 2, 4-xylenol colorimetric method, all using UV-Visible spectrophotometer while chemical oxygen demand (COD) was determined by reflux oxidation titrimetric method. The total solids, total dissolves solids and total suspended solids were determined gravimetrically. All the parameters were also determined in duplicate.

All chemicals used were of analytical grade. All previously washed and cleaned glassware and plastics used were soaked in 10% nitric acid solution overnight and then rinsed with distilled water. Blanks were prepared and incorporated in the samples.

3. RESULTS AND DISCUSSION

The results of heavy metal concentrations and other physicochemical parameters collected from hand dug wells around the battery company are depicted in Table 1 and Table 2, respectively. The mean concentrations of Fe in the well water sampled (SW) range from 2.80 mg/l to 16.00 mg/l. These concentrations were far above the WHO recommended limit of 0.3 mg/l for potable water [11]. It has been widely reported that Nigeria soil contain high Fe content and also Fe is regarded as one of the most abundant metals in the earth's crust [12]. However, Fe is an essential element in human nutrition at acceptable amount. It is found in natural waters at concentrations between of 0.5 mg/l and 50 mg/l.

The Zn mean concentrations ranged from 0.98 mg/l to 1.46 mg/l. The values obtained were far below the recommended limit of 3.0 mg/l set for Zn content by WHO for drinking water [11,13]. Zn is an essential human and plant nutrient element at right proportion for normal body functions including growth and development, and causes less toxicity to human. However its excess in the body promote health problems such as dizziness, fatigue and neutropenia while its deficiency causes hair loss, depression, anorexia, diarrhea, dermatitis, decreases agility of respiratory muscles and retard wounds healing process [14,15].

The mean concentrations of Cu in wells around the battery company ranged between 0.23 mg/l and 1.38 mg/l. These concentrations were far below the allowable limit of 2.0 mg/l for Cu set by WHO for drinking water [11]. This may be due to the fact that Cu does not always present as impurity in Pb smelting which is major operation of the battery company. Cu is vital for normal body functions at require amount but its excess may leads to nervous system disorder and damage to brain [16], anemia, liver and kidney damage.

The mean concentrations of Cr content in this study ranged from 0.10 mg/l to 0.89 mg/l which were above the recommended level of 0.05 mg/l for Cr [11]. A small quantity is required for smooth body functions. Long-term Cr exposure may cause liver and kidney damage, circulatory and nerve disorder, and cancer to genome [17,18].

The mean concentrations of Pb ranged from 5.05 mg/l to 13.15 mg/l. These concentrations were very far above the WHO recommendation of 0.01 mg/l for Pb [11,13] Pb is one of the metals that do not play any vital role in living body. Pb is an extremely poisonous and carcinogenic and can also cause prolonged health risks such as anemia, vomiting, loss of appetite, convulsions, irritability, headache, blood pressure, lung and stomach ulcer, irreversible damage to brain, liver and kidney [19-21]. Lead and mercury may cause the development of autoimmunity in which a person's immune system attacks its own cells which leads to joint diseases, circulatory system and neurons [22].

The mean level of Cd in this study ranged between ND and 0.17 mg/l. The recommended limit for Cd by WHO in drinking water is 0.003 mg/l [11]. About 77.78% of well water contains high concentration of Cd above acceptable standard of WHO. Cd always present as impurity in Pb smelting environment. Cd contaminations in drinking water can be caused as impurities in zinc smelting and cadmium accumulates primarily in kidneys for long time where it causes kidney damage as well as acute health effects as a result of over exposure to high concentration [23]. Cd also has no biological function in living body and possesses carcinogenic properties [24] as well as long biological effects [23] that leads to chronic effects as a result of accumulation in the liver and renal cortex [25].

The mean pH values of well water samples around the battery company ranged from 6.18 to 7.23. This means some of the well waters were slightly acidic while some were within the WHO recommendation of pH for potable water of 6.5 to 8.5 [11]. The pH, 'power or potential of hydrogen' is a measure of hydrogen ion concentrations in water which indicate the degree of acidity or alkalinity of the water. The pH affects the solubility and availability of nutrients, and therefore serves as one of the important indicator of pollution of water body.

The mean electrical conductivity, EC, values ranged from 253.50 to 1007.67 µS/cm. EC values usually related to the amount of dissolved solids [26,27]. This implies that higher EC values indicate higher content of dissolve salts [28].

The mean value of total dissolved solids, TDS ranged between 270.50 and 851.47 mg/l. It describes all solids (usually inorganic or mineral salts) such as sodium, potassium, magnesium, calcium, carbonates, bicarbonates, chlorides and sulphates and small amount of organic matter that dissolves in water. TDS usually originate from natural sources, urban run-off, sewage and industrial waste water [29]. The mean values of total suspended solids, TSS and total solids, TS ranged from 2.95 to 31.43 mg/l and 273.45 to 771.82 mg/l, respectively.

Table 1. Mean heavy metal levels (mg/l) in water sample

Sample	Fe	Zn	Cu	Cr	Pb	Cd
WS1	3.05	0.98	1.23	0.38	11.53	0.17
WS2	8.33	1.15	0.55	0.56	10.47	0.12
WS3	9.45	1.37	0.35	0.48	13.15	0.14
WS4	9.20	1.24	0.57	0.10	9.35	0.04
WS5	16.00	1.26	0.31	0.46	10.30	ND
WS6	13.81	1.15	0.23	0.56	12.83	0.12
WS7	2.80	1.18	0.95	0.89	10.90	0.10
WS8	11.30	1.46	1.38	0.45	7.50	0.04
WS9	15.00	1.04	0.40	0.40	5.05	ND

Table 2. Mean physicochemical parameters levels of the water samples

Parameter	Sample								
	WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8	WS9
pH	7.21	7.23	6.82	6.24	7.17	7.58	6.18	6.24	6.58
Electrical Conductivity, EC (µS/cm)	814.33	318.67	1007.67	478.00	558.67	600.00	253.50	475.50	444.50
Total Dissolved Solid, TDS (mg/l)	740.20	277.37	851.47	430.00	561.50	305.00	375.00	585.00	270.50
Total Suspended Solid, TSS (mg/l)	8.30	12.02	31.43	7.83	19.62	9.20	3.45	17.88	2.95
Total Solid, TS (mg/l)	748.50	289.38	771.82	437.83	581.12	314.20	378.45	602.88	273.45
Total Alkalinity (mg/l)	524.30	333.48	385.20	296.93	554.62	807.85	291.58	240.75	484.18
Total Hardness (mg/l)	547.50	238.75	601.67	287.50	600.00	573.75	181.25	246.25	321.25
Sulphate (SO_4^{2-}) (mg/l)	397.00	169.33	314.33	327.50	243.33	122.50	48.50	197.00	35.00
Nitrates, NO_3^{2-} (mg/l)	2.43	2.62	2.36	0.45	1.56	0.62	3.12	0.71	0.60
Phosphates, PO_4^{3-} (mg/l)	884.52	1005.92	411.71	771.69	1020.97	939.43	1000.35	400.64	719.59
Chloride, Cl^- (mg/l)	2.30	0.65	4.40	1.20	0.68	0.49	0.64	1.43	0.60
Chemical Oxygen Demand, COD (mg/l)	2360.33	2108.33	2393.33	2365.00	2283.33	2295.00	2385.00	2322.50	2350.00

Total alkalinity mean concentrations in the well water ranged from 240.75 to 807.85 mg/l. Alkalinity is a measure of buffering capacity of water. It is caused by hydroxides, carbonates, bicarbonates, borates, silicates and phosphates [30]. Total hardness mean values ranged from 181.25 to 601.67 mg/l. It describes the effect of dissolved minerals, usually calcium and magnesium salts which determine the suitability of water for domestic, industrial and drinking purposes. Hardness may be attributed to the introduction of domestic sewage and industrial effluents into water [31].

The mean concentrations of sulphate in the wells ranged from 35.00 to 397.00 mg/l. Sulphate occurs naturally in minerals and mostly discharge into water body from industrial wastewater and through atmospheric deposition [29]. About 50% of the well water contains sulphate values above the permissible limit of 200 mg/l for sulphate [13].

The mean values of nitrate in well water ranged from 0.45 to 3.12 mg/l. These values obtained were far below the WHO recommended limit of 10 mg/l for nitrate level. Nitrate is the end product of oxidation or aerobic decomposition of organic nitrogenous matters. Nitrate concentration may depend on the nitrification and denitrification activities of micro-organisms. Atmospheric nitrogen can also be washed down by rain into water body and ground and eventually leach into groundwater. Nitrate is reduced to nitrite in the stomach of infants. Nitrate concentration in groundwater and other water bodies are normally low but can as well reach high level as a result of leaching, run-off from agricultural land and contamination from animal wastes [29]. High levels of nitrate and nitrite in drinking water could cause metthaemoglobinaemia, the 'blue-baby syndrome' in children and death in farm animals [32].

Phosphate mean values of the well water samples ranged between 400.64 and 1020.97 mg/l. Phosphates are essential nutrients for plant growth but high level can lead to algal growth called algal bloom.

The mean chloride concentrations in wells ranged from 0.60 to 4.40 mg/l. Chloride level in excess of 250 mg/l [13] above gives rise to detectable taste in water. Chloride maintains acid-base balance, and its excess may cause [33]. Chloride in water may come from natural sources, industrial effluents, sewage and urban run-off.

Chemical oxygen demand, COD has mean values ranging from 2109.33 to 2393.33 mg/l. It is a measure of oxidation of reduced chemicals in water or a measure of oxygen required to oxidize a sample by strong chemical oxidant. The COD obtained from the study area were very high which may be attributed to domestic and industrial wastes.

4. CONCLUSION

The study shows that more than 50% of the physicochemical parameters investigated in the hand-dug wells in the vicinity of the battery company were above the recommended limits set by regulatory agency such as WHO especially heavy metals concentrations. Heavy metals can cause serious health problems with varied symptoms depending on the nature and quantity of the metal ingested.

Since no concentrations of heavy metal have is safe, because long term exposure to low concentration is equally harmful. Therefore the well waters are unfit for domestic uses. The low groundwater quality especially due to elevation of heavy metals might be connected with the untreated industrial effluents discharged from the battery company. Purification or treatments of the well waters are necessary because of relatively high concentrations of heavy metals such as Pb in the water. Meanwhile government or organization concerned could assist the residents of that area by providing potable water to avert possible epidemics because the health of the people living in the area is at risk.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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