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Assessment of Heavy Metals in Groundwater at New Panteka Area of Kaduna, Nigeria

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Abstract*—Assessing the concentration of heavy metal is paramount in determine the overall quality of water. In the study, 10 samples of groundwater from boreholes and hand dug wells were collected at New Panteka metal market and its immediate surroundings .The pH levels and concentration of seven heavy metals (Fe, Cu, As, Cd, Pb, Cr and Zn) was determined using a pH meter and Atomic Absorption Spectrophotometer (AAS) respectively. The result indicated that the groundwater was weakly acidic, having an average pH of 6.4. The analysis showed that Chromium (Cr) with an average concentration of. 0.043mg/L,was above the permissible limit in some of the samples while Lead (Pb) with a mean concentration of 0.143 mg/, was found to be above WHO and NIS threshold for drinking water in all the samples. Arsenic had a mean concentration of 0.004mg/L and exceeded the permissible limit in one sample. Copper (Cu), Zinc (Zn), Iron (Fe) and Cadmium (Cd) were all detected but at concentration levels that are deemed suitable for human consumption. The elevated levels of Lead and Chromium and the presence of Arsenic constitute a serious threat to the overall groundwater quality in the area, which has a direct health implication on its users.

Keywords*— *Heavy metals, Kaduna, Panteka, Groundwater, Water quality

1.0 INTRODUCTION

Water is an extremely important natural resource that is not only essential for the survival of mankind but also for the survival of the entire natural environment. Global water distribution indices put the amount of fresh water to be about 2.5%, while saline water constitutes the rest of 97.5%. Groundwater makes up for 30.1% of the available fresh water globally (Gleick, 1996). Potable water is any water that meets the acceptable standard for human consumption. Availability of water has played a key role in the growth and development of civilizations. Social welfare and economic development may be hampered in the absence of reliable and potable water supply (Tijjani, 1994). Groundwater is water found beneath the surface of the earth, it exist within pore spaces and in the fractures of rock formations. Groundwater is an important component of the hydrological circle and is the preferred source of water for a significant number of the world's population (Guppy et al, 2018), this is mostly due to its reliability, relative ease in accessibility and its potable nature (less likely to be polluted) (Margat *et al*, 2013).

Rapid increase in population and industrialization has placed immense pressure on groundwater and its quality. Water quality describes the physical, chemical and biological condition of water with respect to its suitability for a specific purpose, such as consumption, irrigation or leisure. Groundwater is generally considered to be more portable than surface water due to natural filtration as it flows through porous layers of soil (Bala & Byami, 2011). Groundwater pollution is any change in physical, chemical and biological characteristics of groundwater which is also harmful to living organisms. Groundwater Pollution can occur naturally, through weathering of rocks or by anthropogenic process. Groundwater pollutants are mostly products or byproducts of human actives such as agricultural chemicals like pesticides, fertilizer, insecticides; radioactive pollutants; biological agents; pollutants from automobiles, urban waste, lead paints and leakages of chemicals and oil, (Petruzzelli et al, 2010). Heavy metals are naturally occurring elements having a high atomic weight and high density which is five times greater than that of water (Banfalvi, 2011). Even though heavy metals can naturally be found in trace amounts in water, yet still some can be toxic even in minute concentrations (Ali *et al*, 2015). Lead, Chromium, Arsenic, Cadmium, Nickel, Zinc, Cobalt and Selenium are extremely toxic and can lead to serious health complications when ingested or even by regular skin contact (Adepoju-Bello & Alabi, 2005).

Atomic absorption spectrophotometry (AAS) is a commonly used technique for elemental analysis of water samples. AAS is a sensitive technique, which can detect elements in up to ng/mL levels especially when graphite furnace mode is used for atomization (Lee & Saunders, 2003). The goal of this study is to determine the presence and concentration of seven heavy metals (Fe, Zn, Cu, Pb Cr, As, and Cd) in the groundwater at New Panteka and the immediate surrounding. New Panteka is a metal market and scrap yard that is now part of the Kaduna metropolis; it houses mechanical, electrical and chemical workshops, metal scrap yards, automobile spare part shops, fabrication workshops and painting facilities. The workshops and facilities are known to use huge amounts of chemicals and solvents that contain significant amounts of heavy metals. The New Panteka metal market and scrap yard lacks any proper drainage and waste disposal system, this has led to indiscriminate dumping of chemicals, solvents and other waste products that are rich in

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heavy metals, this regular activities greatly increases the likelihood of groundwater contamination the area. The New Panteka was initially situated in an area that was sparsely populated with little or no residential dwellings, but with the rapid growth of population and Kaduna city, the surrounding area is now inhabited. The residents in the New Panteka environs depend 100% on groundwater (Borehole and hand dug wells) for drinking and domestic use.

World health organization (WHO) and Nigerian Industrial Standard for drinking water (NIS) are some of the international and local organization/institutions that have developed guideline, limits and requirements that can be used or compared with to determine the suitability of any water for drinking and domestic use.

2.0 MATERIAL AND METHODS

2.1 Study AreaTemplate

The study area is New Panteka metal market and scrap yard, it is located along the Nnamdi Azikwe Express (Western bypass) in Kaduna city, North-western Nigeria. The study area lies between latitudes 10^0 33′ 39’’ to 10^0 34’ 26¨ N and longitudes 7^0 24′ 23’’ to 7^0 25’ 17’’E with a total surface area of 3.21km^2 (Figure 2.0). Kaduna city is underlain by the Crystalline Basement rocks. The dominant rock types are the migmatite-gneiss complex and the Older Granites which intruded the host gneissic rocks (Obaje 2009). Prolonged in-situ weathering of the Crystalline Basement rocks under tropical conditions has produced a sequence of unconsolidated material (laterites) whose thickness and lateral extent vary extensively (Rahaman, 1988). There are three major types of aquifers in the study area namely weathered overburden aquifer, fractured bedrock aquifer and the stream alluvial deposits aquifer. The three aquifers are interconnected and form one hydraulic system with unconfined water table. (Adanu & Schneider, 1988).

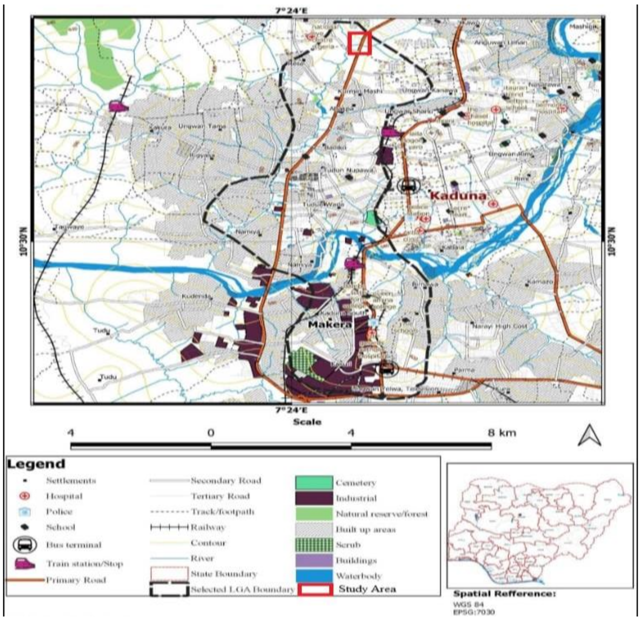

Figure 2 : Topographic Map of Kaduna showing the study area

2.2 Determination of pH

The pH of groundwater from 10 wells was measured in the field using Ohaus ST 300 portable pH meter. In field measurement was done for increased accuracy. Precautions where taking to avoid erroneous reading due to improper/complete placement of pH Meter electrode in the sample.

2.3 Sample Collection and preparation

10 Water Samples were collected in April 2021 at different wells/boreholes, the corresponding GPS coordinates were also recorded (Table 2.1). New tightly capped plastic bottles were used for collection of the water sample, and at each sampling point the bottle was rinsed with the water to be sampled before the water was collected. Few drops of concentrated nitric acid were added to the samples to prevent precipitation and biological growth. The samples were then placed in iceboxes at 4^0C and transported to the laboratory for analysis.

Table 2.1: location of samples collected at New Panteka and Environs

Sample	Latitude	Longitude	Source
A1	10°34'17"N	7°25'03"E	Well
A2	10°34'15"N	7°25'02"E	Borehole
A3	10°34'13"N	7°25'03"E	Well
A4	10°34'06"N	7°24'57"E	Well
A5	10°33'53"N	7°24'55"E	Well
A6	10°34'30"N	7°24'59"E	Borehole
A7	10°34'08"N	7°24'52"E	Well
A8	10°34'17"N	7°25'12"E	Well
A9	10°34'19"N	7°25'14"E	Borehole
A10	10°34'08"N	7°24'52"E	Well

2.4 Materials

Trace 1800 Atomic Absorption Spectrophotometer (AAS) coupled with a graphite furnace atomizer and an auto sampler was used for the heavy metal analysis. A high-density graphite tube was used for atomization. Normal single hollow cathode lamps were used for irradiation. Thousand milligrams per liter standard solutions of each of Fe, Cu, Zn, Cr, As, Cd and Pb, which were prepared from nitrate salts and used for calibration purpose. Mixed working standard solutions containing all metals were prepared by dilution in appropriate ways using double distilled deionized water. Measurement for each solution was done in triplicate and the average was taken.

3.0 PREPARE YOUR RESULTS AND DISCUSSION

Table 3.1 presents the summary of results; pH and the concentrations of heavy metals from boreholes and hand dug wells studied the study area.

The pH levels within the study area range from 6.25 to 6.77 with an average value of 6.42. The water is weakly acidic. Three samples (A4, A5 and A6) were within the world health organization (WHO) 2011 and Nigerian industrial standard (NIS) 2015 suitable limits for drinking water of 6.5-8.5 (Table 3.2). The pH in the rest of the samples were slightly below the threshold. pH is an important parameter with regards to heavy metal toxicity. As the level of hydrogen ions increases, heavy metals such as lead, copper and cadmium are released into the water instead of being absorbed into the sediment. As the concentrations of heavy metals increase in water, their toxicity also increases (Uba *et al*, 2003).

Table 3.1: Table 3.1 Summary of pH and the concentration of heavy metals from the study area

Sample	pH	Fe (mg/L)	Cu (mg/L)	Zn (mg/L)	Cr (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)
A1	6.34	0.180	0.099	0.173	0.039	0.003	ND	0.370
A2	6.25	0.325	0.082	0.219	0.038	0.003	ND	0.220
A3	6.30	0.282	0.066	0.188	0.058	0.016	0.001	0.282
A4	6.77	0.436	0.083	0.174	0.039	ND	ND	0.061
A5	6.74	0.328	0.019	0.164	0.041	ND	ND	0.067
A6	6.58	0.240	0.021	0.169	0.031	0.003	ND	0.083
A7	6.33	0.396	0.029	0.133	0.065	ND	ND	0.079
A8	6.28	0.275	0.028	0.106	0.044	0.007	ND	0.099
A9	6.30	0.300	0.028	0.163	0.036	0.009	ND	0.101
A10	6.33	0.233	0.031	0.125	0.038	0.005	ND	0.063

ND = Not Detected

Iron concentration in the samples ranges from 0.180 mg/L to 0.436 mg/L. The average concentration of Iron was determined to be 0.299 mg/L. Four samples (A2, A4,A5 and A7) had Iron concentration that were slightly above 0.3mg/L, which is the WHO 2011 and NIS 2015 permissible limit of iron for drinking water. Iron occurs naturally in groundwater but levels can be increased by dissolution of ferrous borehole and hand pump components (Ali et al, 2005). Research works on groundwater geochemistry done in other parts of Kaduna metropolis by Ogbozige *et al* (2017) and Mahre *et al* (2007) had similar range for Iron concentration.

The concentration of chromium in groundwater of the study area range from 0.31 mg/L to 0.065 mg/L with an average of 0.043 mg/l. Samples A3 and A7 had chromium concentrations of 0.058 mg/L and 0.065 mg/L respectively, they are slightly above the 0.05 mg/L permissible limit for chromium set by NIS and WHO (Table 3.2). The rest of the samples had values slightly below the permissible limit, but can still be regarded as high when compared to the work of Musa *et al* (2020) that found zero chromium in groundwater samples collected from an area less than 3km from New Panteka. The relatively high concentration of chromium could be attributed to the painting and fabrication activities at the New Panteka, chromium compounds are added to paints to provide corrosion protection and reflective properties (Zauro et al, 2013).

A normal adult requires approximately 2-3 mg of copper per day (Adepoju-Bello & Alabi, 2005). Consumption of high levels of copper can cause nausea, vomiting, diarrhea, gastric (stomach) complaints and headaches. Long term exposure over many months and years can cause liver damage and death (Mahipal & Rajeev 2019). Sample A1 had the highest concentration of copper with 0.099mg/L, while sample A5 had the lowest, with a concentration of 0.019mg/L. The mean concentration was calculated as 0.049mg/L. All samples had copper concentration well below the WHO 2011 permissible limits of 2mg/L and NIS 2015 limit of 1mg/L.

Zinc is the 25th most abundant element in nature, making up between 0.0005% and 0.02% of the Earth's crust (Irwinetal, 1997). The concentration of Zinc found in the study area range from 0.106 mg/L to 0.219mg/L, with a mean concentration of 0.1614 mg/L. All the samples were found to have concentrations below the set limits by WHO and NIS for drinking water (Table 3.2).

The concentrations of Arsenic range from 0.00mg/L to 0.016mg/kg and the mean concentration of 0.0043 mg/L. Samples A4 and A5 had no trace of arsenic in them. Sample A3 had the highest concentration of 0.016, which is slightly above the permissible limit (table 3.2). Seven other samples had concentrations well below the limit. Consumption of high levels of arsenic can course vomiting, skin rashes; nausea. Long-term exposure from drinking water can cause cancer and skin lesions (Yoshida et al 2004).

Cadmium was only detected in sample A3 with a concentration of 0.001mg/L, with all other samples having no trace of cadmium. The WHO and NIS permissible limit for cadmium is 0.003 mg/L. Exposure to cadmium has been known to cause kidney, liver and bone damage.(Mustapha et al, 2015)

Table 3.2: Comparison of Field Data (Author's Result) with NIS (2015) and WHO (2011) Recommended Values for pH and Selected Heavy Metals for Drinking and Domestic uses

Parameters	**Unit**	**WHO 2011**	**NIS 2015**	**Author's Result 2021 Range**	**Average**
pH	–	6.5 – 8.5	6.5 – 8.5	6.25 – 6.77	6.422
Fe	mg/l	0.3	0.3	0.180–0.436	0.299
Cu	mg/l	2	1	0.019 – 0.099	0.049
Zn	mg/l	3	3	0.106 – 0.219	0.1614
Cr	mg/l	0.05	0.05	0.031 – 0.065	0.043
As	mg/l	0.01	0.01	0.00 – 0.016	0.0043
Cd	mg/l	0.003	0.003	0.00 – 0.011	0.011
Pb	mg/l	0.01	0.01	0.061 – 0.37	0.143

Lead was found to be in concentration ranging from 0.061mg/L to 0.37mg/L, with the mean concentration of 0.143 mg/L. Lead is a hazardous; it can injurious even in minor quantities, due to its high toxicity, the permissible concentration for lead in drinking water for both WHO and NIS is 0.01mg/L. All 10 tested samples had concentrations above the permissible limit. Sample A1 had the highest lead concentration of 0.37mg/L, which is 37 times above the limit, while the mean concentration is over 1400% above the permissible limit. Extreme levels of lead absorption in the human body can cause death or perpetual harm to the brain, central nervous system and kidneys (Mahipal & Rajeev 2019). Lead is found in engine oils, paints and other hydrocarbon products that are used in large quantities every day at the New Panteka.

4.0 CONCLUSION AND RECOMENDATION

The concentration of heavy metals in groundwater at New Panteka was determined using Atomic Absorption Spectrophotometer (AAS), while the pH of the water was determined using a portable pH meter. The result showed that the water was weakly acidic with an average pH of 6.4. The concentration of lead in all samples was found to be well above the established threshold set by WHO and NIS. Two samples showed chromium concentrations in excess of the permissible limits, while one sample had Arsenic concentration that was above the standard for drinking water. However the concentration of Zinc, Iron, Cadmium and copper were all within the WHO and NIS threshold for drinking water. The result indicated the great risk improper disposal of chemical waste poses to groundwater; the continues indiscriminate and improper dumping of chemicals will eventually pollute the groundwater and make it unsuitable for human consumption. This study may serve as baseline information for future work to monitor changes in groundwater composition over time.

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