Assessment and Impacts of Metal Recycling on Groundwater Quality in Ogijo, Ogun State, Nigeria

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ORIGINAL RESEARCH ARTICLE

Abstract- Groundwater is an essential source of water supply globally. Recently, however, the groundwater environment is being threatened due to heavy metal contamination resulting from the indiscriminate use, storage, and disposal of toxic metal elements. This study evaluates heavy metals concentrations in groundwater systems close to a metal recycling industry in Ogun State, Nigeria. In the study, thirty-six (36) water samples were collected from boreholes within the vicinity of a metal recycling industry and analysed using the atomic absorption spectrophotometer. Water samples collected had trace concentrations of iron (Fe), copper (Cu), lead (Pb), manganese (Mn), zinc (Zn), chromium (Cr), cadmium (Cd), and nickel (Ni); metal concentrations were highest in the borehole closest to the industry. Pb, Cr, and Mn concentrations were above the acceptable standards. The findings showed that the activities within metal recycling industries can potentially elevate toxic metal concentrations in groundwater water sources close to it if proper mitigation measures are not put in place.

Keywords- groundwater, heavy metals, metal concentrations, metal recycling.

1 INTRODUCTION

Groundwater largely remains a primary source of water supply globally and an essential component of the hydrological cycle (Li et al., 2021). However, this resource is fast deteriorating and severely threatened due to increased human activities and is thus a cause for concern in developed and developing countries, including Nigeria. Landfills leaks (Longe & Balogun, 2010), Industrial facilities and Agricultural activities (Li et al., 2021) are known potential point sources of groundwater pollution. Adu et al. (2015) and Aznar-Sánchez et al. (2018) identified improper use, indiscriminate disposal of metals and their derivative scrap as sources of toxic intrusion and groundwater contamination. Globally, there is increasing use of metals within the construction, aeronautics, automotive, railway, electrical appliance industry, and other economically beneficial uses (Aznar-Sánchez et al., 2018) due to its unique properties and strength (Wernick & Themelis, 1998).

Increased use of metals in production processes and various operations has led to high waste deposits (Tumova et al., 2020). The increase in elevated scrap metal waste in the environment is particularly of concern, considering that the demand for metal or iron for commercial use is anticipated to increase by five times its current demand or 2.5 billion tons annually by 2050 (Halada et al., 2008). These concerns have resulted in industries adopting cleaner production methods (Aznar-Sánchez et al., 2018), such as the reuse and recycling of metals (Fan & Wang, 2017; Capuzzi & Timelli, 2018).

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Despite the benefits recycling offers, the process produces waste slags, particulates, and untreated effluents (Olatunji et al., 2018, Capuzzi & Timelli, 2018). Raun et al. (2013) reported the potential risks associated with metal recycling facilities. In their work, Raun et al. (2013) observed metals such as iron, manganese, copper, chromium, nickel, lead, cobalt, cadmium and mercury in particulate matter emitted from metal recycling facilities in Houston, USA. Further studies shown the presence of metals in soils (Jenson et al., 2000; Ogunkunle et al., 2016; Fan & Wang, 2017; Olatunji et al., 2018) and groundwater (Adedeji et al., 2014; Ibe et al., 2020; Agrawal et al., 2021).

Nigeria is known to have about three billion tonnes of iron ore deposits, an essential resource needed for economic growth and development (Ohimain, 2013). The fallout from the collapse of the steel sector has shifted attention to steel scraps by manufacturing companies leading to increased use of secondary iron and steel smelting in production processes. These industries lack appropriate regulations in handling and disposal of waste metals, and necessary infrastructure to store, minimize, and dispose of the waste (Owoade et al., 2015). As a direct consequence of unregulated disposal processes, scrap metals account for 1.8% of municipal solid wastes (MSW) in South Western Nigeria (Ohimain, 2013).

Thus, potentially leading to incidences of heavy metals leaching into and contaminating groundwater sources in areas within the scrap iron industries, dumps and scrap yards (Adu et al., 2015). For a country that relies heavily on groundwater for its water needs, it is imperative to ensure that the quality of groundwater is not compromised, leading to dire economic and health consequences. Remediation of groundwater is not easy to achieve. It is time-consuming and cost-intensive. Hence it is necessary to protect its quality by evaluating groundwater quality characteristics and assessing potential pollution sources. This study seeks to evaluate heavy metal concentrations in groundwater systems close to a metal recycling industry.

2 Materials and Methods

2.1 Study Area

The metal recycling industry has been operational since its establishment in 2010. It is located along Ikorodu-Shagamu road and the industry lies within longitude 3˚31.39" and latitude 6˚ 44' 05" of Ogijo district, Ogun state, Nigeria. The major climatic seasons in the area are wet and dry. The wet season begins in May and ends in October, while the dry commences from November through April annually (Alabi et al., 2013), with temperatures ranging between 25.0°C and 28.8°C. The area is underlain by tertiary to recent coastal plain sands, which comprises a repetitive succession of clay and sandy horizons (Olatunji et al., 2018).

2.2 Water Sampling and Analysis

There are no shallow wells or streams around the vicinity of the study area. The only source of water supply in the area is through boreholes. There were few numbers of open residences around the study area and coupled with the inability to access the boreholes in the industry, samples were collected from six available boreholes, denoted as BH1 – BH6, located down-gradient the metal recycling industry (Fig. 1). A total of thirty-six samples were collected from August to October 2019 and 2020, respectively. The global positioning system (GPS) was used to determine the location of sampling points, and standard processes for sample collection was employed. The heavy metals concentrations measured were iron (Fe), copper (Cu), manganese (Mn), lead (Pb), zinc (Zn), chromium (Cr), cadmium (Cd) and nickel (Ni). Metals were measured using the atomic absorption spectrometer (AAS) VGP 210 Model.

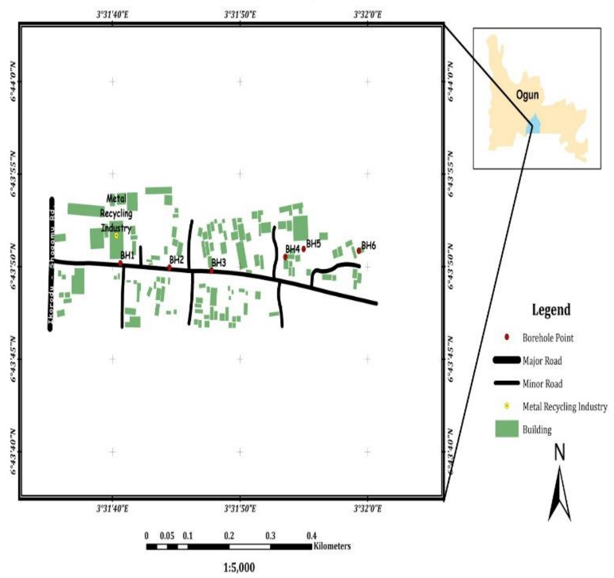

Fig. 1: Location of sampling points

3 Results and Discussion

The concentrations of eight heavy metals in the extracted groundwater samples from BH1- BH6 were compared with the guidelines set by the Nigerian Standards for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) to ascertain possible toxicity from metal intrusion in the groundwater samples. According to WHO (2006), Fe is readily found in freshwater at acceptable levels between 0.5 to 50 mg/L. Fe concentration values from samples collected in this study were below required NSDWQ and WHO standards, with concentrations ranging from 0.032±0.028 mg/L in BH1 to 0.018±0.004 mg/L in BH6.

Fe concentrations identified in water samples could be as a result of its natural occurrence in the geologic formation of the studied area, especially underlying BH2, which presented the highest Fe concentration of 0.30 mg/L (Fig 2). The result agrees with Angaye et al. (2016) study on boreholes located close to scrap metal dumpsites in Yenagoa metropolis, Bayelsa, Nigeria. It, however, does not preclude the presence of Fe in the water as coming from the scrap yard.

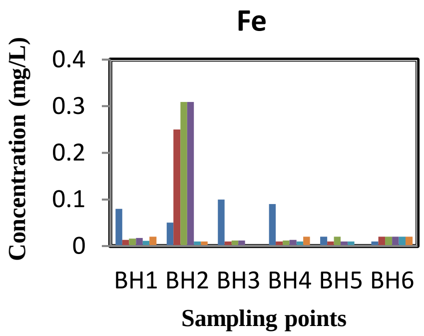

Fig. 2: Fe concentration in borehole samples

Cu concentration was highest in BH1 (0.1 mg/L) than other sampling points. The mean Cu values of the collected samples ranged between 0.033±0.033 mg/L to 0.020±0.004 mg/L (Fig. 3). Cu concentration values in the present study are reasonably low compared to results obtained by Ibe et al (2020) and Arinze et al. (2016) for borehole samples situated close to metal scrapyards in Imo and Anambra states, Nigeria, and are within the acceptable levels recommended by NSDWQ and WHO.

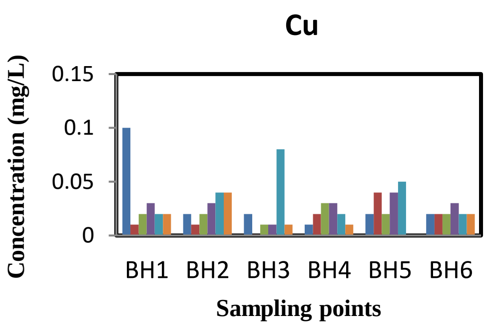

Fig. 3: Cu concentration in borehole samples

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High levels of Mn were seen in both BH1 and BH2, with the highest Mn concentration recorded in BH1 at 0.35mg/L. The mean concentration values of Mn were between 0.228±0.083 mg/L and 0.018±0.010 mg/L for all sample locations (Fig. 4). There was, however, a sharp drop in Mn concentration in samples drawn from locations further down the pollutant source. Generally, Mn levels were below the limits set by WHO and significantly lower than values obtained recorded by Wu et al. (2015). However, the values were slightly above the guidelines set by NSDWQ (2007). This slight increase is indicative of the intrusion from the pollutant source to the groundwater systems. Elevated Mn levels in water might result in neurological impairment (Verma et al., 2016) and taste problems in water (WHO 2006).

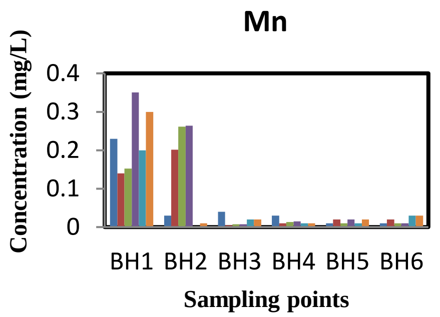

Fig. 4: Mn concentration in borehole samples

The Zn concentration values in the samples increased slightly from BH1-BH4 at mean values ranging from 0.420±0.078 mg/L to 0.177±0.064 mg/L. Elevated levels were recorded in BH1- BH4, with the highest value of 0.5 mg/L recorded at BH1 (Fig. 5).

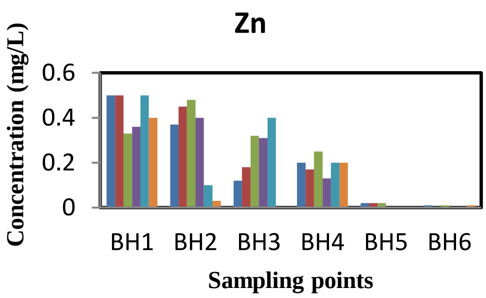

Fig. 5: Zn concentration in borehole samples

Though the observed concentration values are within the expected limits set by WHO and NSDWQ, close monitoring of the water samples should be done to avert possible future increases. This is because the results show the apparent intrusion of Zn into the groundwater body, with borehole BH1 recording the highest Zn concentration. High Zn levels in water are undesirable and could cause adverse health effects such as nausea, headache and diarrhoea (WHO, 2006).

Observed Pb concentration values in the collected samples exceeded acceptable levels, with mean values ranging from 0.028±0.014 mg/L to 0.008±0.004 mg/L. However, the highest Pb concentration of 0.23 mg/L was observed at BH1 located closest to the source company (Fig. 6).

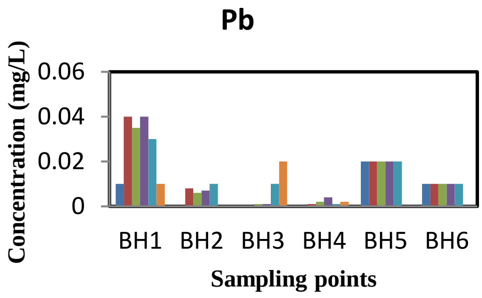

Fig. 6: Pb concentration in borehole samples

The occurrence of Pb in the water samples could be from lead-acid batteries, which constitute wastes deposited in metal scrapyards, as reported by Utang et al. (2013) and Ibe et al. (2020). Increased Pb concentration in groundwater have adverse health effects in infants, children and pregnant women. It is toxic and could affect the human nervous system (WHO, 2006). Tests for Cd showed mean concentration values ranging from 0.019±0.008 mg/L to 0.013±0.008 mg/L. Maximum concentration of 0.03 mg/L was detected at BH1, a value higher than acceptable regulatory levels (Fig 7).

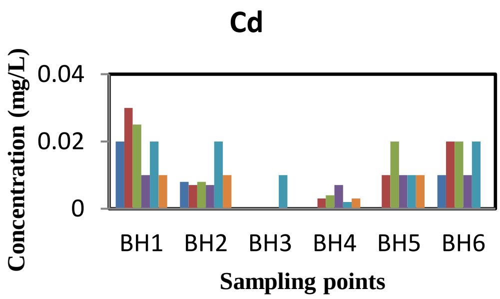

Fig. 7: Cd concentration in borehole samples

Cd is majorly used in the electrical and electronics industries (Wu et al., 2014) and has been found at elevated levels in groundwater close to e-waste recycling areas in China. Ndububa & Oyije (2019) recorded elevated Cd and Mn levels in water samples close to electronic dumpsites in Abuja, Nigeria. The concentration values of Cr and Ni were minimal and within acceptable limits.

The results from the water sample analysis showed trace concentrations of the investigated metals. Though metal concentration values in most of the analysed samples are within acceptable limits, Mn, Pb and Cd were slightly elevated and above acceptable levels. The concentrations reduced as the sample locations are further away from the polluting source. Heavy metals such as Pb, Cd, Cr, Cu, Ni, and Zn, are persistent contaminants that are generally mobile in soils thereby infiltrating into underground water. Soils play an important role in controlling the

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movement and possible groundwater contamination by heavy metals (Campillo-Cora et al., 2020). Clay soils, however, have a high affinity for adsorbing heavy metals in their interlayers. The sorption of these toxic metals reduces their concentration in the environment (Correia et al., 2020; Ugwu & Igbokwe, 2019). The underlying strata in the studied area consist of a high percentage of clayey soils (Adebayo & Oloruntoba, 2016) and could account for both the reduced metal concentrations observed in this area and the trace concentrations from BH1 to BH6. Generally, from this study, Pb, Cd, Cr, and Ni concentrations were significantly lower than the concentrations observed by Dahunsi et al. (2014) from three groundwater sources within a similar study area.

4 Conclusion

This study investigated heavy metals in boreholes located around a metal recycling factory in Ogijo, Ogun state. Results from this study show that concentrations of Fe, Cu, Zn, Cr and Ni were within the acceptable limits of WHO and NSDWQ. However, Mn concentrations were above the recommended NSDWQ standards, while Pb and Cd had concentration values higher than WHO and NSDWQ standards. In addition, the closest borehole (BH1) to the factory was majorly affected by the recycling activities in the industry. From this study, it is obvious that though the values of metals found in the water samples are not at levels that could be harmful, the results suggest that toxic metals are still present in slight excess in some locations. Reflecting that the clayey soil in the present study has rendered the heavy metals to precipitate, preventing them from reaching the groundwater timeously. Although the heavy metals loads have not reached risky limits, it could exceed limits in future if the situation is not controlled and the soil exceeds its capacity to entrain the metals. Thus, it is vital to immediately implement precautionary measures to avoid the harmful effects of high heavy metals concentrations in boreholes around the areas.

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