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Physico-Chemical Properties of Borehole Water and Heavy Metal Contamination in Soil near an Open Dumpsite in Giwo District, Bauchi, Nigeria.

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Abstract
This study investigates the physico-chemical properties of borehole water and heavy metal contamination in soil near an open dumpsite in Giwo District, Bauchi. Environmental pollution from industrialization, urbanization, and inadequate waste management has contaminated soil and water with organic and inorganic matter, posing significant health risks. Water samples were analyzed using standardized APHA methods, including pH, temperature, colour, electrical conductivity, turbidity, total dissolved solids, dissolved oxygen, biochemical oxygen demand (BOD), and chemical oxygen demand (COD). Most parameters met World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) standards. However, BOD levels exceeded the WHO guideline of 5 mg/l, ranging from 12.20 ± 0.004 mg/l to 13.56 ± 0.005 mg/l, and COD levels surpassed the recommended limit of 200 mg/l, ranging from 251.60 ± 0.030 mg/l to 298.20 ± 0.003 mg/l, indicating significant organic pollution near the dumpsite. Soil samples were analyzed for eight heavy metals – Zinc (Zn), Iron (Fe), Copper (Cu), Cadmium (Cd), Chromium (Cr), Lead (Pb), Arsenic (As), and Manganese (Mn) – using Atomic Absorption Spectroscopy. The results showed low concentrations of heavy metals, with Index of Geo-accumulation (I_{geo}) values ranging from -1.6 to -17.0 and Contamination Factor (C_F) values from 0.00 to 0.01, indicating minimal contamination. The Pollution Load Index (PLI) values were 0.0028, 0.0031, 0.0026, and 0.0025 for Giwo 01, Giwo 02, Giwo 03, and Giwo 04, respectively. These findings highlight the need for improved waste management practices to prevent further water contamination and elevated heavy metal levels in the Giwo District.

Keywords: Physicochemical, Pollution, Heavy Metal Water, Soil, Giwo

INTRODUCTION
Rising environmental pollution has recently become a major global concern due to heightened industrialization, urbanization, and poor waste management practices (Parvez *et al.*, 2023). Pollution from various sources introduces an abundance of contaminants into the ecosystem, which disperse across environmental media such as soil and water. Among these contaminants, heavy metals are particularly noteworthy due to their persistence and toxicological effects on living organisms (Okechukwu *et al.,* 2024). These metals, which include cadmium, copper, chromium, lead, manganese, nickel, zinc among others, have

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densities greater than 5 g/cm^3, making them especially hazardous even at low concentrations (Okorie *et al.,* 2024).

Soil and water contamination can result from both natural processes like mineral weathering and human activities such as mining, farming, fossil fuel combustion, and industrial waste disposal (Orisadare *et al.,* 2020). Contaminated soil and water can lead to the accumulation of heavy metals in plants, which in turn poses a risk to animals and humans who consume these plants. Over time, this bioaccumulation can cause severe health problems, including organ damage and various chronic diseases (Yahaya *et al.,* 2010). Moreover, heavy metals in soil can adversely affect soil health, reducing agricultural productivity and altering soil microbiota (Garandi *et al.,* 2021).

Previous studies have extensively documented the sources and impacts of heavy metal contamination. For instance, global emissions of cadmium reached 743.77 tons in 2009, while around 30,000 tons of chromium and 800,000 tons of lead have been discharged into the environment over the past fifty years (Zhao *et al.,* 2022). Research has also shown that soil contaminated with heavy metals can significantly affect plant growth and food safety (Okorie *et al.,* 2024). Additionally, groundwater contamination, often stemming from industrial leachates, agricultural runoff, and landfill seepage, has been a significant focus of environmental studies (Okorie *et al.,* 2024).

The quality of water in both rural and urban areas has deteriorated consistently over recent decades due to chemical, biological, and physical contaminants (Nagpurkar *et al.,* 2023). The use of contaminated water is linked to the spread of waterborne diseases, which account for a significant proportion of global illnesses and deaths (Pakhtunkhwa *et al.,* 2019). Studies such as those by Rahmanian *et al.* (2015) have evaluated the physicochemical parameters of water to assess contamination levels and potential health risks. The interplay between soil and water contamination underscores the importance of comprehensive environmental monitoring and pollution mitigation strategies.

Despite the extensive research on heavy metal contamination, there remains a critical need to understand the localized impacts of these pollutants, particularly in regions with poor waste management practices. This study aims to fill this gap by analyzing the physicochemical properties of borehole water samples and evaluating heavy metal contamination in soil samples near an open dumpsite in the Giwo District of Bauchi.

MATERIALS AND METHODS

Description of Study Area

Giwo, situated near Ningi LGA in Bauchi State, located on the northern fringe of the Jos Plateau at an elevation of 616m above sea level, it lies between Latitude 10^{o} 22' 17' N and Longitude 9^{o} 50' 11'' E. The town's emergence was influenced by migration from Bauchi and Plateau states due to various factors such as search for arable land, security, basic amenities etc. With an annual growth rate of 2.8%, Giwo is experiencing rapid expansion, as indicated by a household survey conducted by Glawe (2014).

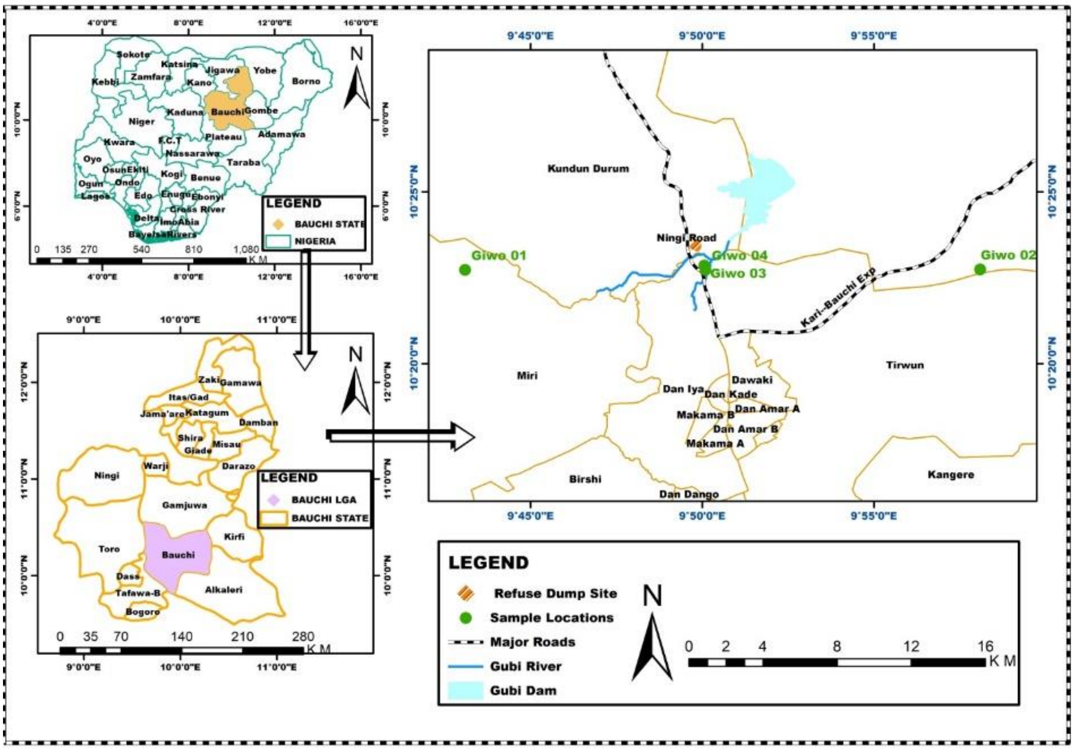

Figure 1: Giwo District, Bauchi LGA

Physiochemical Analysis

Water analysis was conducted in accordance with established procedures outlined by the American Public Health Association (APHA, 1998). Temperature and pH were measured on-site using a thermometer and pH meter, while all other parameters were analyzed in the laboratory using standardized APHA methods, ensuring consistent, reliable, and accurate data collection. The specific parameters assessed included; Color, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD).

Soil Sample Collection and Analysis

Four soil samples were collected from four random locations near a dump site in Giwo District, Bauchi at a depth of 30 cm. At each sampling site, two soil samples were taken and thoroughly mixed to create a composite sample. These composite samples were labeled as Giwo 01, Giwo 02, Giwo 03, and Giwo 04. The collected soil samples were air-dried in the laboratory at room temperature and then sieved through a 2 mm mesh for digestion and further laboratory analysis. The digestion procedure followed the method described by Parvez *et al*. (2023). The digested samples were analyzed using Angstrom Atomic Absorption Spectroscopy (Model AA-320N) for the presence of eight heavy metals: Zn, Fe, Cu, Cd, Cr, Pb, As, and Mn.

Index of Geo-Accumulation (I_{geo})

The index of geo-accumulation originally designed Muller (1969) was used to assess the level of heavy metal contamination in soil samples collected in Giwo given in equation 1:

$$I_{geo} = Log_2\left[\frac{C_n}{1.5 \times B_n}\right] \ldots\ldots\ldots.(1)$$

where C_n is the measured concentration of the metal in the sample, B_n is the background concentration of the metal, 1.5 is a constant factor that accounts for natural fluctuations in the background levels.

The background concentration (B_n) data of the heavy metals investigated in Giwo soil sample are given in Table 1 based on the average shale world geochemical background Concentration as reported by Turekian & Wedepohl (1961).

Table 1: Average Shale, World Geochemical Background Concentration (Turekian & Wedepohl 1961).

Heavy Metals	Background Concentration (mg/kg)
Zinc (Zn)	95
Iron (Fe)	47,200
Copper (Cu)	45
Cadmium (Cd)	0.3
Chromium (Cr)	90
Lead (Pb)	20
Arsenic (As)	13
Manganese (Mn)	850

The index of geo accumulation is classified into seven categories, ranging from uncontaminated to extremely contaminated as defined by Muller (1969) which is shown in Table 2

Table 2: Degree of soil contamination based on I_{geo} accumulation (Muller 1969).

Index Class	**I_{geo} Value**	**Level of Contamination**
0	$I_{geo} < 0$	Practically uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately to heavily contaminated
4	$3 < I_{geo} < 4$	Heavily contaminated
5	$4 < I_{geo} < 5$	Heavily to extremely contaminated
6	$I_{geo} > 5$	Extremely contaminated

Contamination Factor (C_F)

The contamination factor (C_F) is a measure used to assess the level of contamination of a specific heavy metal in soils or sediments by comparing its current concentration to a background concentration(Awoyemi et al., 2021). CF is typically categorized in four to indicate the level of concentration; Low Contamination ($C_F < 1$), Moderate Contamination ($1 \leq C_F < 3$), Considerable Contamination ($3 \leq C_F < 6$), Very High Contamination ($C_F \geq 6$). The C_F levels of soil sample collected in Giwo was assessed using equation 2 (Hakanson, 1980):

$$\boldsymbol{C_F = \frac{C_n}{B_n} \ldots\ldots\ldots\ldots\ldots (2)}$$

Where C_n is the concentration of the metal in the contaminated sample, B_n is the concentration of the metal in the background (usually representing natural levels).

Pollution Load Index (PLI)

Pollution Load Index originally proposed Tomlinson *et al.* (1980) was used to assess the overall level of heavy metal contamination in soils samples collected in Giwo. The C_{Fs} of the particular heavy metals at a sample site are used to construct the PLI, which is given by equation 3

$$PLI = (CF_1 \times CF_2 \times CF_3 \ldots\ldots\ldots CF_n)^{1/n} \ldots\ldots\ldots (3)$$

Where CF_1, CF_2,…..,CF_n are the Contamination Factors for different metals, n is the number of metals assessed.

The PLI provides a single value that indicates the overall level of heavy metal pollution, a PLI value ≤ 1 indicates baseline pollution or no pollution while PLI levels greater than one indicates pollution, with higher values indicating higher pollution levels

RESULTS AND DISCUSSION

Physico-Chemical Analysis of Water Samples

Table 3 presents the result of the physico-chemical analysis of water samples collected from Giwo along with the World Health Organization (WHO, 2017) and The Nigerian Standard for Drinking Water Quality (NIS, 2015) for comparison.

Table 3: Physico-chemical Properties of the Water samples Collected from Giwo

	Giwo 01	**Giwo 02**	**Giwo 03**	**Giwo 04**	**WHO/ NSDWQ**
pH	6.90 ± 0.020	7.51 ± 0.100	7.53 ± 0.005	7.47 ± 0.001	6.5-8.5 (WHO)
Temperature ^{0}C	26.9 ± 1.000	27.7 ± 0.050	28.1 ± 0.060	28.2 ± 0.100	25 (WHO)
DO mg/l	14.04 ± 0.000	10.46 ± 0.003	15.40 ± 0.001	12.65 ± 0.005	6.5 (WHO)
TDS mg/l	189.76 ± 0.001	154.81 ± 0.010	131.31 ± 0.004	127.70 ± 0.001	500 (NIS)
BOD mg/l	12.20 ± 0.004	13.56 ± 0.005	8.90 ± 0.001	7.50 ± 0.006	5 (WHO)
COD	251.60 ± 0.030	205.00 ± 0.005	236.10 ± 0.050	298.20 ± 0.003	200 (WHO)
Turbidity (NTUs)	1.36 ± 0.010	1.56 ± 0.001	1.58 ± 0.002	1.27 ± 0.000	5 (**NSDWQ**)
Color (TCU)	0	0	0	0	15 (**NSDWQ**)
EC µs/cm	235 ± 0.100	274 ± 1.00	254 ± 0.200	258 ± 2.00	1000 (**NSDWQ**)

pH

The pH values for the four water samples from Giwo ranged from 6.90 to 7.53 all falling within the WHO/ NSDWQ acceptable range of 6.5 to 8.5. This indicates that the all the water sample are neither highly acidic nor basic, making it safe for drinking and other domestic uses.

Temperature

The recorded temperatures ranged between 26.9 °C - 28.2 °C which are slightly above the WHO standard of 25°C for drinking water. While recorded temperature values are not within the ideal range, they may not pose significant health risks (NIS,2015). However, the elevated temperatures could affect chemical equilibrium and there by leading to decomposition of organic and inorganic matter.

Dissolved Oxygen

DO essential for the survival of all aquatic life forms, including species responsible for self-purification mechanisms in aquatic ecosystems (Bilewu *et al.,* 2022). DO levels of water samples collected at all sites in Giwo exceed the WHO minimum requirement of 6.5 mg/l, with values ranging from 10.46 to 15.40 mg/l. High DO levels are beneficial for aquatic life and indicate good water quality. Specifically, Giwo 01 and Giwo 03 have particularly high DO levels, suggesting excellent oxygen availability for aquatic organisms. Although Giwo 02 and Giwo 04 have slightly lower DO levels compared to Giwo 01 and Giwo 03, they still exceed the WHO standard, indicating that the water quality remains good but might hint at the presence of organic matter decomposition or localized oxygen depletion in the area.

Total Dissolved Solids
The TDS values for all Giwo water samples are significantly lower than the NSDWQ limit of 500 mg/l, ranging from 127.70 to 189.76 mg/l. This indicates that the water contains relatively low levels of dissolved inorganic and organic matter, making it suitable for consumption. The low TDS levels suggest that the water is not heavily laden with dissolved salts and solids, contributing to its overall quality.

Biochemical Oxygen Demand
BOD measures the amount of dissolved oxygen required by microorganism to decompose organic matter and some inorganic matter such as iron, sulfides among others (Patil *et al.*, 2012). From the analysis, BOD levels at all sites exceed the WHO guideline of 5 mg/l, with values ranging from 7.50 to 13.56 mg/l. This indicates significant organic pollution of across all four water samples, likely stemming from the refuse from the dumpsite. Giwo 04 has the lowest BOD at 7.50 mg/l, suggesting the presence of less readily decomposable organic matter compared to the WHO standard. Giwo 02 has a significantly higher BOD at 13.56 mg/l, indicating substantial levels of organic pollution that could deplete oxygen levels and harm aquatic life.

Chemical Oxygen Demand
COD measures the organic pollutants in water by determining the amount of oxygen required to oxidize these organic substances, this implies higher COD values indicate higher levels of organic pollution (Patil *et al.*, 2012). From the result in Table 3 it can be seen that all water samples analyzed exceed the WHO standard of 200 mg/l, with values ranging from 205 mg/l to 298.20 mg/l. This high COD indicates a significant presence of organic substances that can degrade water quality.

Turbidity
According to Rahmanian *et al.* (2015), turbidity is a measurement of how cloudy water becomes due to suspended particles like silt, clay, and organic matter. Although turbidity in and of itself has no direct effect on health, it can harbor microorganisms and protect them from disinfection processes. In addition, it can trap biocides and heavy metals, which could complicate water treatment processes and increase the risk of pathogens in treated water (NIS, 2015). The NIS criterion of 5 NTU was reached by the turbidity levels of the water samples collected from Giwo, suggesting very clean water with low amounts of suspended particles. The reported values fall well inside the allowed limit, ranging from 1.27 to 1.58 NTUs.

Colour
From the analysis presented in Table 3, it can be seen that all four water samples collected in Giwo recorded a colour value of 0 TCU, which were all below the standard limit of 15 TCU set by the NSDWQ. This absence of color suggests that the water is free of any pigmented substances.

Electrical Conductivity (EC)
Electrical conductivity measures water's ability to conduct electricity, which is directly proportional to its dissolved mineral content (Ma *et al.*, 2020). Form the result presented in Table 3, it can be seen that all four water samples collected from Giwo are within the acceptable limit of 1000 μS/cm set by NIS, indicating lower concentrations of dissolved ions and favorable drinking water quality.

Heavy Metal Analysis of Soil Sample Collected from Giwo.

Table 4: Concentration of Heavy metal of soil sample close to dumpsite in Giwo.

	Sampling point			
Heavy Metals (mg/kg)	**Giwo 01**	**Giwo 02**	**Giwo 03**	**Giwo 04**
Zinc (Zn)	1.131 ± 0.010	1.016 ± 0.005	0.967 ± 0.005	1.082 ± 0.009
Iron (Fe)	0.887 ± 0.005	0.957 ± 0.010	1.004 ± 0.020	0.546 ± 0.006
Copper (Cu)	0.476 ± 0.010	0.278 ± 0.010	0.584 ± 0.040	0.663 ± 0.003
Cadmium (Cd)	0.114 ± 0.007	0.103 ± 0.005	0.089 ± 0.002	0.147 ± 0.005
Chromium (Cr)	0.075 ± 0.001	0.057 ± 0.001	0.100 ± 0.004	0.097 ± 0.001
Lead (Pb)	0.109 ± 0.000	0.048 ± 0.001	0.050 ± 0.001	0.084 ± 0.002
Arsenic (As)	0.008 ± 0.001	0.093 ± 0.002	0.011 ± 0.001	0.005 ± 0.001
Manganese (Mn)	1.107 ± 0.050	1.318 ± 0.080	0.975 ± 0.010	0.754 ± 0.007

Table 4 present the analysis of heavy metal concentrations in the soil samples from Giwo. The result showed that most of the heavy metals analyzed are present in low concentrations ranging from 0.05 mg/kg for lead in Giwo 03 to 1.131 mg/kg for Zinc in Giwo 01. The results of this research are relatively low compared to those reported by Isah *et al.* (2023) in their study of a mechanic workshop in Azare Town, Bauchi State. Despite the low concentrations of these heavy metals in Giwo, their toxicity remains a significant concern. This is exemplified by the amount of lead detected in various parts of tomatoes in a study conducted by Sanusi *et al.* (2023) at Ajiwa Fadama Farms in Katsina State.

Table 5: Index of Geo-Accumulation, Contamination Factor and Pollution Load Index of Soil Samples from Giwo

	Giwo 01		Giwo 02		Giwo 03		Giwo 04	
Heavy Metals	I_{geo}	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	CF
Zinc	-7.0	0.01	-7.1	0.01	-7.2	0.01	-7.0	0.01
Iron	-16.3	0.00	-16.2	0.00	-16.1	0.00	-17.0	0.00
Copper	-7.1	0.01	-7.9	0.01	-6.9	0.01	-6.7	0.01
Cadmium	-2.0	0.38	-2.1	0.34	-2.3	0.30	-1.6	0.49
Chromium	-10.8	0.00	-11.2	0.00	-10.4	0.00	-10.4	0.00
Lead	-8.1	0.01	-9.3	0.00	-9.2	0.00	-8.5	0.00
Arseni	-11.3	0.00	-7.7	0.01	-10.8	0.00	-11.9	0.00
Manganese	-10.2	0.00	-9.9	0.00	-10.4	0.00	-10.7	0.00
PLI	0.0028		0.0031		0.0026		0.0025	

Index of geo-accumulation

The I_{geo} values for all eight heavy metals in soil samples collected from the four Giwo study locations, as presented in Table 3, are all negative. The negative I_{geo} accumulation values indicate index class 0 which means the soil in Giwo is practically uncontaminated with I_{geo} accumulation values ranging from -1.6 for Cadmium in Giwo 04 to -17.0 for Iron in Giwo 04. Although the I_{geo} values for Cadmium in all four sample locations range from -2.0 to -1.6, these values are closer to zero compared to other heavy metals. This suggests a slight contamination relative to background levels, though the overall risk remains very low.

Contamination Factor

From the result presented in Table 3 it can be observed that all the C_F values of heavy metals measured in Giwo are all less than 1 ranging from 0.00 to 0.01, indicating low contamination except for cadmium in all four sample location in Giwo which recorded a C_F value higher than other analysed heavy metals ranging from 0.03 to 0.49 suggesting a possible minimal contamination compared to other metals.

Pollution Load Index

The Table 3 also includes a PLI value for each sampling location. PLI considers the combined effect of multiple heavy metals. From the table it can be seen that the PLI values of all four location; Giwo 01, Giwo 02, Giwo 03 and Giwo 04 are 0.0028, 0.0031, 0.0026 and 0.0025 respectively. These low PLI values indicates minimal overall heavy metal pollution in the Giwo soil samples.

CONCLUSION

This study investigated some physico-chemical properties of water near an open dumpsite in Giwo District, and assessed the potential heavy metal contamination in nearby soil. From the findings of the research, water samples from Giwo met most physico-chemical standards for drinking water, with the exception of BOD and COD, which significantly exceeded WHO guidelines across all locations. This indicates significant organic pollution likely originating from the dumpsite. On the other hand, analysis of the eight heavy metals in soil samples from Giwo revealed generally low concentrations. I_{geo} and C_F values suggested minimal contamination for most metals, except for Cadmium which showed slightly elevated levels ranging from -2.0 to -1.6 compared to background concentrations. The PLI values were very low across all locations four Giwo location, indicating minimal overall heavy metal pollution in the soil samples. Implementing proper waste management practices in Giwo especially at open dumpsite is crucial to prevent further water and soil contamination.

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