Science World Journal Vol. 18(No 2) 2023 DOI: https://dx.doi.org/10.4314/swj.v18i2.7
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

ASSESSMENT OF HEAVY METAL CONTAMINATION IN GROUNDWATER FROM MOTORIZED BOREHOLES IN MAITUMBI, TIPA GARAGE AREA, MINNA, NIGER STATE

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ABSTRACT
Discharged industrial effluent poses a significant threat to groundwater due to potential heavy metal contamination. Elevated levels of heavy metals in drinking water pose serious public health risks. This study aimed to assess the quality of drinking water from motorized boreholes in Maitumbi, Tipa Garage Area, Minna, Niger State, by measuring heavy metal concentrations using Atomic Absorption Spectroscopy (AAS) as the analytical tool. Water samples were collected randomly from ten (10) boreholes, and the concentrations of some environmentally common heavy metals (Pb, Cd, Hg, Cu, Ni, and Cr) were determined using an Atomic Absorption Spectrophotometer of PG Instruments Ltd. (Model AA500). The results showed high concentration levels for most of the observed metals, which exceeded the permissible limits by the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO). Generally, the study suggests that the water samples are not safe for drinking directly and recommends some level of tertiary purification to reduce the heavy metal concentration levels to make them safe for drinking.

Keywords: Contaminant migration, portable water, trace metals, industrial effluent

INTRODUCTION

Access to safe drinking water is a fundamental human right and essential for the maintenance of public health and welfare. However, many communities worldwide, especially in developing countries, lack access to clean and safe drinking water (WHO, 2017). In Nigeria, most rural and urban settlers rely on hand-pumped or motorized boreholes as sources of drinking water. Motorized boreholes are drilled wells that use motorized pumps to extract water from the ground. Although motorized boreholes can provide a reliable source of water, they may also be a potential source of heavy metal contamination (Njar *et al*., 2012).

Heavy metals, such as lead (Pb), copper (Cu), mercury (Hg), cadmium (Cd), and chromium (Cr), are toxic to humans and can cause various health problems, such as kidney damage, cancer, and developmental disorders (Balali-mood *et al*., 2021). Therefore, it is essential to assess the quality of drinking water from motorized boreholes, particularly for heavy metal contamination.

In addition, treated industrial effluent from a company in the study area is discharged into the environment. Also, oil spillage from activities of heavy-duty vehicles in the heavy-duty vehicle park ("Tipa garage") in the vicinity of the study area could contribute to groundwater contamination. Contaminants ingress into groundwater due to natural means and human activities such as mining, industrial effluent, and indiscriminate dumping of waste, etc. as shown in multiple studies (Ajai*et al*., 2019; Idris *et al*., 2021; Okareh *et al*., 2023). Adeoye *et al*. (2015) showed that despite the treatment of the industrial effluent discharged into the environment in the study area, treated effluent from the company contains heavy metal concentrations that are higher than the standard permissible limits (Adeoye *et al*., 2015). There is a potential effect of increased heavy-metal levels in the groundwater of the surrounding area (Okareh *et al*., 2023). Moreover, literature references for research on the water quality of the study area with respect to heavy metal levels remain scarce.

Atomic absorption spectroscopy (AAS) is widely used analytical technique for determining heavy metals concentration in water (Adeoye *et al*., 2018; Zangina *et al*., 2019; Idris *et al*., 2021). It is a sensitive and reliable method for measuring trace amounts of heavy metals in water samples. AAS has been used in several studies to assess the quality of drinking water from various sources, including boreholes.

In this study, the research goal was to assess the quality of drinking water from selected motorized boreholes in the Tipa Garage Area of Maitumbi, Minna, Niger State by measuring heavy metal concentrations in the water using AAS as an analytical tool. Our findings will contribute to the understanding of the quality of drinking water from motorized boreholes in the chosen study area and will provide valuable information for the development of strategies to ensure the safety of drinking water for residents of the area and beyond.

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MATERIALS AND METHODS

Study Area

Maitumbi-Tipa Garage Area is a municipal area of Minna (the capital city of Niger State), located in the Bosso local government area (LGA) of Niger State, Nigeria. It is situated within longitude coordinates 6°35'36.06" & 6°34'34.36" and latitudes coordinates 9°38'26.88"& 9°37'43.03" 6°35.0'0.94" E and 9°38'9.38" N . Figure 1, Shows the map of the study area.

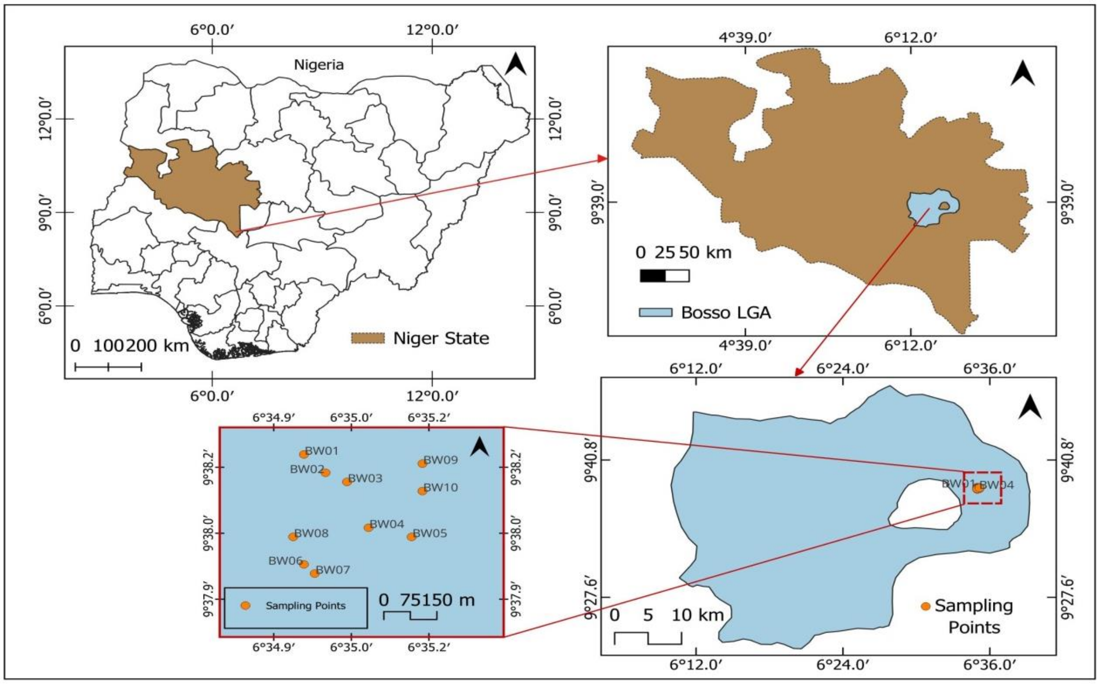

Figure 1. Maps showing the study area, showing the sampling points, developed using QGIS Open software (version 3.30.0)

1.2. Sample collection and preparation

Water samples were randomly collected from ten 10 motorized boreholes in the study area in June during the rainy season when contaminant migration is expected to be high (Varol & Tokatli, 2022). Water samples were collected directly from the tap head after allowing the tap to run for
approximately 15 min in the early hours of the morning. The samples were collected in acid-washed 330 ml plastic bottles container and the water samples were acidified to about 1% by adding nitric acid (HNO_3) and it was then transported to the laboratory at Badeggi, Niger State in an icebox for heavy metals measurement. The longitude and latitude coordinates of the sampling points were taken using a Germin GPS tool (etrex 10) available at the Department of Geology, Ibrahim Badamasi Babangida University. The samples were labeled with unique identifiers that included sampling points. The concentrations of heavy metals, including lead (Pb), copper(Cu), mercury (Hg), nickel (Ni), cadmium (Cd), and chromium (Cr), were determined using a PG Instruments Ltd.'s atomic absorption spectrophotometer (Model AA500) available at the Central Services Laboratory of National Cereals Research Institute, Badeggi, Niger State.

2.3 Heavy metals measurement using AAS

The instrument was switched on and allowed to warm for a few minutes. It was then calibrated using standard solutions of the desired heavy metals (Pb, Cu, Hg, Ni, Cd, and Cr), and the concentrations of the selected metals were determined from the absorbance of the sample that had been digested in preparation for the measurement, and calibration curve. The AAS operates by the excitation of isolated atoms from their ground states using radiation of a specific wavelength after passing through the sample solution.

RESULTS AND DISCUSSION

The results showed that the concentration of heavy metals in the water samples varies among the boreholes. Table I shows the measured concentration of heavy metals in the water samples considered.

Table I. Measured concentrations of the selected heavy metals in the ten borehole water samples

	Heavy Metal Concentration (mg/L)					
Samples	Pb	Cd	Hg	Cu	Ni	Cr
BW01	**0.534**	1.640	0.142	0.521	0.130	**0.039**
BW02	1.221	1.311	0.111	**0.823**	0.151	0.027
BW03	0.781	**1.692**	**0.163**	0.436	**0.098**	0.031
BW04	**1.403**	1.474	0.143	0.339	0.131	0.022

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BW05	1.313	1.331	0.131	0.664	**0.166**	0.019
BW06	0.893	1.437	0.132	0.453	0.144	0.021
BW07	1.245	1.481	0.067	0.371	0.136	0.022
BW08	1.326	1.367	0.121	0.286	0.122	**0.017**
BW09	1.336	1.421	**0.045**	0.349	0.134	0.018
BW10	0.962	**0.667**	0.056	**0.284**	0.151	0.021
WHO	**0.010**	**0.003**	**0.006**	**2.000**	**0.070**	**0.050**
NSDWQ	**0.010**	**0.003**	**0.001**	**1.000**	**0.020**	**0.050**

BW=Borehole Water 1 to 10

Across all water samples examined, the Pd concentration was lowest in water from BW01 with a concentration of about 0.534 mg/L, and highest in water from BW04 with a concentration level of about 1.403 mg/L as highlighted in Table I. The concentration of Cd was lowest in water from borehole 10 (BW10) with a value of 0.667 mg/L, whereas BW03 had the highest Cd content with a concentration level of 1.692 mg/L. Also, Hg had the highest concentration in BHW3 with a value of 0.163 mg/L and had the lowest concentration level in BW09 with a value of 0.045 mg/L. In addition, Cu was lowest in BW10 having a value of 0.284 mg/L, and highest in BW02 with a value of 0.823 mg/L. The water from borehole 3 (BW03), shows the lowest Ni content, with a value of 0.098 mg/L and BW05 had the highest Ni content of about 0.166. Finally, Cr concentration was the lowest in BW09 with a value of 0.017 mg/L and highest in BW01 with a value of 0.037 mg/L.

In addition, individual boreholes have Cr as the element with the lowest concentration and Cd as the element with the highest concentration in each of the respective water samples except for waters from BW10, where Pb is the highest.

The concentrations of heavy metals in the water samples were compared to the World Health Organization (WHO) (WHO, 2017) and the Nigerian local regulatory body; Nigerian Standard for Drinking Water Quality (NSDWQ) (NIS, 2015), limits for drinking water. Table II. Show standard limit permissible for the heavy metals in drinking water.

Table II. Local (NSDWQ) and international (WHO) standard permissible limits (NIS, 2015; WHO, 2017)

Heavy Metals	Concentrations Limits (mg/L)	
	NSDWQ	**WHO**
Pd	0.01	0.01
Cd	0.003	0.003
Hg	0.001	0.006
Cu	1.0	2.0
Ni	0.02	0.07
Cr	0.05	0.05

Compared with the standards, water from all boreholes had Pb, Cd, Hg, and Ni concentrations exceeding both the WHO and NSDWQ recommended limits. This finding is worrisome, as the presence of these metals at concentrations above standard permissible limits could constitute public health concerns.

Potential health threats due to the consumption of water from these boreholes include possible cardiovascular dysfunction, lung, and liver disease due to Pb content; cancer, degenerative born disease, kidney dysfunction, liver damage, and lung injuries due to high levels of Cd, renal dysfunction, ulceration due to high levels of Hg (Balali-mood *et al*., 2021); and cardiovascular disease, lung dysfunction, and cancer due to Ni exposure in concentrations beyond the allowed standard limit (Genchi *et al*., 2020).

However, the Cu and Cr concentrations in all borehole water samples were below the WHO and NSDWQ permissible limits. Therefore, it may not have a poor impact on water quality in the study area. Although Adeoye *et al*. (2015) found that Cd, Cu, and Ni concentrations in the industrial effluent of the company around the study area were beyond permissible limits, the Cu concentrations in the groundwater measured in the study were not above the permissible limits of standard organizations. However, a report by Adeoye *et al*. (2015) showed high Ni and Cd concentrations in the industrial effluent, and the Ni and Cd levels in the groundwater of the study area were higher than permissible limits, suggesting possible contamination from the effluent. Also, research by Adebayo*et al*.(2017) shows a high concentration of leached Pb and Cd in soil samples of auto-mechanic shops where oil spills are typical just like the “Tipa Garage” in the vicinity of the study area (Adebayo *et al*., 2017).

A study by Okare *et al*. (2023) has shown that the high heavy metal content in groundwater of industrial sectors in Shagamu and Otta, Ogun state, South-Western Nigeria may be due to the leaching of heavy metals from industrial effluent into groundwater especially areas close to the industry (Okareh *et al*., 2023). In addition, research on heavy metal levels in the groundwater of Universiti Teknologi MARA (UiTM), Kuala Pilah, Negeri Sembilan, Malaysia due to the presence of industrial wastewater effluent by Kassim *et al*. (2022) found high concentrations of Cr, Pb, and Ni above permissible limits in the lake water and discharged industrial effluent (Kassim *et al*., 2022). This suggests that the high concentration levels in the groundwater samples of the study area could be due to the migration of the effluent from the industrial effluent discharged in the vicinity of the study area.

The levels of heavy metals found in the water samples suggest that drinking water is unsafe without some level of remediation to reduce contamination levels. Several approaches can be used to reduce heavy metal contamination in water. Techniques, such as electrodialysis, can be employed. It involves the use of an ion-selective membrane to extract heavy metal ions from the water, or methods such as reverse osmosis, where the water is passed through a semipermeable membrane and the heavy metals are trapped and separated from the water in the membrane, or chemical precipitation using suitable precipitating reagents such as calcium hydroxide or sodium hydroxide and then sedimenting or filtering; and biological means through the use of specific microorganisms or plants that have the ability to accumulate or transform heavy metals in the water can be adopted, making the

DOI: https://dx.doi.org/10.4314/swj.v18i2.7

water safe for consumption; coagulation/flocculation and photocatalytic methods are among the techniques that can be adopted (Qasem *et al*., 2021; Saleh *et al*., 2022).
This research highlights the need for the development of a sustainable public water supply system with good water treatment plants that can supply portable water to residents of the study area and environs.

CONCLUSION
This study was designed to assess heavy metal levels in drinking water in the study area due to potential contamination from industrial effluent. The results of this study showed that Pb, Cd, Hg, and Ni concentrations found in drinking water from motorized boreholes in the study area are above permissible limits, making the water unsafe for human consumption. Pb concentration was found to vary in the range of 0.534 -1.403 mg/L, Cd in the range of 0.667 – 1.692 mg/L, Hg in the range of 0.045 -0.163 mg/L, and Ni in the range of 0.098 – 0.166 mg/L. However, Cu and Cr concentrations in the water samples vary in the range of 0.284 – 0.823 mg/L and 0.017 – 0.089 mg/L which are bellow standard permissible limits.
Water treatment techniques that will reduce the heavy metal levels in the water are recommended to ensure the continued safety of the residents of the study area against potential health hazards associated with exposure due to the consumption of water with high heavy metal content. This study highlights the importance of monitoring drinking water quality to assess contamination levels. The results from the current study could form baseline data for future research to determine the quality of water in the study area and its environs. In addition, water samples from the study area were collected during the rainy season when contaminant migration was high, and data from this study could be useful in studying the effects of seasonal variation, measurement techniques, sample collection points, and depth to the aquifer of water source on the concentration levels of heavy metals in groundwater and ensuring good human and environmental health.

Acknowledgment
The authors wish to thank the residents of the study area for their cooperation during the collection of samples.

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