HEALTH RISK ASSESSMENT OF HEAVY METALS IN GROUND WATER SAMPLES FROM STUDENT RESIDENCES OF HIGHER INSTITUTION

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ABSTRACT

Anthropogenic and geogenic contamination have led to pollution of ground water with high levels of heavy metals. This study assessed the health risk of heavy metals in ground water samples from student residences of Olabisi Onabanjo University, Ago-Iwoye, Nigeria. Physicochemical properties were determined using standard analytical procedures while heavy metals [Zinc (Zn), Manganese (Mn), Iron (Fe), Nickel (Ni), Cadmium (Cd), Lead (Pb)] concentrations were determined using Atomic Absorption Spectrometer. The carcinogenic and non-carcinogenic health risks assessment via oral and dermal contact was estimated in terms of hazard quotient (HQ) and cancer risk (CR). The results of samples' physicochemical properties include; temperature (≤ 28.9 ^{o}C), pH (≤7.06), turbidity (≤2.65 NTU), Electrical Conductivity (≤474 **µS/cm**), Total Suspended Solid (≤4.00 mg/I), Total Dissolved Solid (≤207.00 mg/l), Total Acidity (≤300.00 mg/I), Total Hardness (≤172.00 mg/l), Chloride (≤25.00 mg/I), Dissolved Oxygen (≤5.66 mg/l), Nitrates (≤3.90 mg/I), phosphates (≤0.78 mg/l), and sulphates (≤46.50 mg/l) with only total hardness that is above the WHO permissible limit. The concentrations of Zn, Mn, Fe, Ni, Cd, Pb (mg/L) are ≤0.055, ≤1.138, ≤0.363, ≤0.052, ≤0.008, BDL respectively and all are below the WHO permissible limits except Mn. The HQ and HI for non-carcinogenic health risk through oral and dermal exposure to Ni and Cd considered in this study is below unity and with no risk except Mn in AR sample. The CR values in all sites were within the acceptable cancer health risk range of 1.00×10^{-4} to 1.00×10^{-6} except for Ni at site MR.

Keywords: Carcinogenic risk, ground water, health risk, heavy metals, physicochemical properties.

Introduction

Water is one of the most vital resources required by all living organisms for their survival and growth, making it a basic resource necessary for all human and industrial activities (Taruna & Alankrita, 2013; Simpi *et al*., 2011). Despite its importance, it is one of the most poorly managed resources, depriving over 1 billion people the access to portable water (Ayodele *et al*., 2024). Clean water supposed to be free and abundance but nowadays, this has become scarce commodity globally (Fitriyah *et al*., 2024); more than 95 % are saline, frozen in ice caps or glaciers in inaccessible forms (Hosseininia & Hassanzadeh 2023). Globally, 50 % of domestic water required for house shores is accessed from groundwater (Okoye *et al*., 2023; Ogunsanwo *et al*., 2024).

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Ground water is now becoming a major source of water for domestic purposes, as supply from surface water is not adequate to cater for human needs; about one-third of the world's population relies on it (Piyathilake *et al*.2022; Shaibur *et al*., 2024). Groundwater (hand-dug well and borehole water), is a major source of freshwater aside surface water, (freshwater, lakes, rivers, and streams) it is used domestically in both urban and rural areas of the world, constituting about two-third of the fresh water reserves across the world. It's ease of treatment and self-cleansing ability makes it an important reserve of quality and portable water (Kanmani & Gandhimathi, 2013; Adeyemi *et al*., 2017; Nta *et al*., 2020). Increase in human anthropogenic activities including; improper usage of chemicals (pesticides and persistent organic pollutant) and waste disposal, mining activities, industrial discharge have led to the release of many contaminants into water bodies, and these activities has significantly impacted the quality and usability of ground water (Liu *et al*. 2024; Ewim *et al*. 2023; Ukonu *et al*., 2022).

Contamination of groundwater with heavy metals is becoming a global issue due to their negative impact on human health (Jafarzadeh *et al*., 2022). The presence of high levels of heavy metals in groundwater has been associated with severe health effects, including kidney damage, degenerative neurological conditions, respiratory and cardiovascular diseases, and cancer (Badeenezhad *et al*., 2023; Chowdhary *et al*., 2020). Exposure to high levels of Fe can affect the kidney, liver and cause cardiovascular diseases, elevated levels of Cu are noxious and can cause vomiting, diarrhea, loss of strength, and liver cirrhosis (Shaibur *et al*., 2024;). Cd contamination even at trace level negatively impact food and water supplies globally especially, in Asia and Africa (Kubier *et al*., 2019).

Some heavy metals are micronutrients, these are required for essential metabolic processes in the body, and these include; copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) but, may become toxic when their permissible levels are exceeded. The pathway of heavy metals into human body includes, oral consumption, dermal contact, and inhalation (Rehman *et al*.,2018; Ogamba *et al*., 2021; Jafari *et al*., 2019). Improved water quality and sustainable management of water resources is one of the aims of SDG (Goal 6), it is directly related to sustenance of life on earth and this can only be achieved with proper monitoring of level of contaminants in groundwater. According to World Health Organization (WHO), physical, biological, and chemical parameters of portable water must be regularly monitored to ascertain its quality (Manjare *et al*., 2010). Need for the regular assessment of the physiochemical properties and heavy metals in ground water becomes pertinent as safety and pollution level in the environment is greatly depended on the quality of water. Consumption or use of contaminated portable or ground water is one of the major channels for transmission of many diseases (Adimalla & Qian 2021). In view of this, the main objective of this study is to assess the physicochemical properties and health risk of heavy metals content in ground water collected from the students' residential areas (within and off campus) at Olabisi Onabanjo University, Ago-Iwoye, Nigeria. This study will provide necessary information on the water quality, its suitability for domestic use and health risk.

Experimental

Study Area

The study areas are the students' residence at Olabisi Onabanjo University, Nigeria namely; Permanent-site residence (PR), mini campus residence (MR), Ago-Iwoye residence (AR) and Oru residence (OR) where a large number of students reside. The location of the residence is between longitude 6°56' N and 6°57' N and latitude of 3°52'E and 3°56' E.

Sampling

A total of 24 (6 from each site) ground water samples were randomly collected from hand-dug wells and boreholes located in the students' residence areas. The samples were collected into 2.5 L pre-cleaned polyethylene bottles, labeled and stored in ice bags before transporting to the laboratory for immediate analyses.

Laboratory analysis

The physicochemical properties and determination of concentrations of heavy metals in the collected water samples were carried out at the laboratory of Lagos State Environmental Protection Agency (LASEPA) laboratory.

Physicochemical analysis

Physicochemical properties of the collected samples were determined following standard procedures as reported by Gebresilasie *et al*., (2021). Temperature and DO were measured using dissolved oxygen meter (HANNA HI-2400), turbidity was measured using turbidity meter (HACH 2100N), pH was measured after calibration using pH meter (HANNA Edge), conductivity and TDS were measured using conductivity meter (HANNA Edge). Total alkalinity was determined using titrimetric method, total hardness was determined using EDTA titrimetric method, and chloride concentration was determined using argentometric titration method. TSS and metal anions (Sulfate, Phosphate, and Nitrate) were measured using UV-visible spectrophotometer (HACH DR6000).

Heavy metal analysis

100 mL of filtered water sample was digested using 5mL of Conc. HNO_3 and a few glass beads were added to prevent bumping, in a 250 mL conical flask. The mixture was digested on a hot plate for about six hours at 80 °C until the volume was reduced to one-fifth of its original volume. The solution was cooled, filtered using Whatman number 41filter paper, and then diluted to 50 mL in volumetric flask with distilled water (Gebresilasie *et al*., 2021). The concentrations of heavy metals [Zinc (Zn), Manganese (Mn), Iron (Fe), Nickel (Ni), Cadmium (Cd), Lead (Pb)] in the digest were determined using Atomic Absorption Spectrometer (Thermo Scientific ICE 3000).

Human health risk assessment

Health risk assessment of the toxic metals in the water samples was evaluated by calculating non-carcinogenic and carcinogenic health risks. Risk assessment is described as a method of assessing the risk of any potential adverse health effects during a specified period by assessing the level of risk and the chronic effects of carcinogen or non-carcinogen heavy metals on the human health (Wongsasuluk *et al*., 2014; Nkpaa *et al*., 2018).

Non-carcinogenic risk

The US Environmental Protection Agency (USEPA) method was applied to evaluate the non-carcinogenic risk for children and adult. This was done by calculating Hazard Quotient (HQ) and Hazard index (HI) via chronic

daily intake (CDI) by ingestion and dermal absorption routes as presented in Equations (1) and (2), respectively (Seleem *et al*., 2021).

$$CDIing = \frac{Cw \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

$$CDIderm = \frac{Cw \times SA \times Kp \times CF \times ET \times EF \times \times ED}{BW \times AT} \quad (2)$$

The input assumptions and values for the calculation of the chronic daily intake through oral ingestion and skin absorption are presented in Table 1.

TABLE 1

Parameters and input assumptions for exposure assessment of metals (Seleem et al., 2021).

Exposure parameters	Unit	Values	
		Ingestion	Dermal adsorption
Heavy metal concentrations (Cw)	mg/L	-	-
Ingestion rate of water (IR)	L/day	2.5	-
Skin-surface area (SA)	cm^2	-	19652
Permeability coefficient (Kp)	cm/hour	-	Pb 0.0001, Zn 0.0006, Ni 0.0002, Fe 0.001, Mn 0.001, Cd 0.001
Exposure time (ET)	hour/event	-	0.67077
Exposure frequency (EF)	day/years	350	350
Exposure duration (ED)	year	70	70
Body weight (BW)	Kg	70	70
Average time (AT)	days	25550	25550
Conversion factor (CF)	L/cm3	-	0.001

Hazard Quotient (HQ) is used to quantify the non-carcinogenic human health riskand it is the ratio of pollutant to the dose level (a reference dose or RfD). RfD It is defined as the maximum permissible level of a mineral that will not cause any harmful effects on human health (Table 2). The (HQ) of the individual metal was estimated using Equation 3:

$$HQ = \frac{CDI}{RfD} \quad (3)$$

$$HI = \sum HQing + \sum HQderm \quad (4)$$

Hazard index (HI) value is obtained by combining the individual values of HQs and it is used to access the overall potential for non-carcinogenic effects caused by multiple chemicals (Nkpaa *et al*., 2018; Seleem *et al*., 2021) as indicated in equation 4.Non-carcinogenic impacts may occur in the residents when HI is > 1, while the exposed person is

unexpected to experience evident harmful health impacts when HI is<1 (Mohammadi *et al*., 2019; Haque *et al*., 2018).

TABLE 2

Reference dose (RFD) and slope factor (SF) for different metals (Seleem et al., 2021)

Heavy Metals	RFD (mg/kg/day)	SF (mg/kg/day)$^{-1}$
Zinc	3.0×10^{-1}	-
Manganese	2.4×10^{-2}	-
Iron	7.0×10^{-1}	-
Nickel	2.0×10^{-2}	1.7
Cadmium	5.0×10^{-4}	3.8×10^{-1}
Lead	3.5×10^{-3}	8.5×10^{-4}

Carcinogenic risk

The carcinogenic risk of Ni and Cd via ingestion and dermal routes was evaluated by assessing the daily exposure of an individual to contaminant over a lifetime and the probability of developing cancer. The potential carcinogenic risks (CR) and target cancer risk (TCR) through ingestion and dermal exposure are evaluated using equations 5 and 6.

$$CR = CDI \times SF \quad (5)$$

$$TCR = \sum CRing + \sum CRderm \quad (6)$$

SF, slope factor (per mg/kg/day) for Ni, Cd and Pb is expressed in terms of the likelihood of cancer developing at a specific lifetime exposure level (Table 4). CRing is the sum of cancer risk for metals through ingestion exposure. CR derm is the sum of cancer risk for metals through dermal exposure. TCR is the target cancer risk (Seleem *et al*., 2021).

Results and Discussion

The results of physicochemical properties and heavy metals concentration of the collected water samples were presented in tables 3 and 4 respectively.

Physiochemical parameters

All the samples collected from the study areas were colourless, and odourless, which conforms with the World Health Organization (WHO) and Nigeria Standard Drinking Water Quality (NSDWQ) standards for drinking water. The mean temperature of the ground water samples is 28.75 ± 0.245°C and all were below the WHO (2022) permissible limit of 35.0 – 40.0 °C and this could be attributed to the environmental temperature. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour, and corrosion problems (Ayale *et al*., 2020).

TABLE 3

Physicochemical properties of the analyzed ground water samples

PARAMETERS	AR	MR	OR	PR	WHO 2022 (mg/L)	NSDWQ 2022(mg/L)
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Temperature ^{O}C	28.45 ±0.35	28.75 ±0.07	28.9 ±0.14	28.9 ±0.01	35.0 – 40.0	NS
pH	7.06 ±0.028	6.95 ±0.34	6.70 ±0.49	7.01 ±0.06	6.50 -8.50	6.50 -8.50
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Turbidity (NTU)	2.65 ±0.49	0.75 ±0.07	1.90 ±0.14	0.95 ±0.07	5.00	5.00
EC (µS/cm)	474.00 ±9.17	311.00 ±4.23	294.60 ±5.67	410.50 ±2.12	1000.00	1000.00
TSS (mg/l)	1.00 ±1.41	1.50 ±0.71	4.00 ±1.41	BDL	NS	10.00
TDS (mg/l)	204.00 ±1.41	149.90 ±2.97	148.90 ±0.56	207.00 ±0.01	500.00	500.00
TA (mg/l)	175.00 ±14.14	192.50 ±24.74	182.50 ±3.53	300.00 ±0.01	200.00	NS
TH (mg/l)	160.00 ±16.97	144.00 ±5.65	132.00 ±16.97	172.00 ±5.65	100.00	150.00
Chloride (mg/l)	25.00 ±1.41	6.00 ±5.65	2.00 ±0.01	4.00 ±2.82	250.00	250.00
DO (mg/l)	4.48 ±0.26	5.66 ±0.47	5.64 ±0.37	5.49 ±0.30	>5.00	>5.00
Nitrates (mg/l)	3.90 ±0.14	1.85 ±0.35	2.10 ± 0.01	1.20 ±0.14	10.00	50.00
Phosphates (mg/l)	0.78 ±0.11	0.40 ±0.06	0.54 ±0.13	0.45 ±0.01	5.00	NS
Sulphates (mg/l)	27.50 ±0.70	46.50 ±8.89	39.00 ±4.47	2.50 ±2.12	250.00	250.00

NS: Not specified; BDL: Below detection limit; SD: Standard deviation

The pH of the samples ranges from 6.5 ± 0.495 – 7.06± 0.028 and all were within the WHO (2022) and NSDWQ (2022) permissible limit of 6.5 – 8.5. pH value is largely depended on the amount of carbonates, bicarbonates and CO_2 and this may be a leading cause for the variation of the pH value among all sites (Ukonu *et al*., 2022). This phenomenon may arise from the difference in the topography of the boreholes and hand dug wells in the sampling sites.

Electrical Conductivity (EC) is the measure of the soluble salt concentration in the groundwater and it is also a pollution indicator which decreases the quality of the water bodies (Ogunsanwo *et al*., 2024). The EC of the samples ranges between 294.60 – 474.00 and all were within the WHO (2022) and NSDWQ (2022) limits of 1000 µS/cm. Total Dissolved Solids (TDS) is the measure of the organic and inorganic salts such as carbonate, bicarbonate, sodium, potassium, calcium and magnesium. At level above 500 mg/L, there may be tendency of production of scaling in water pipes, heaters, boilers and household appliances (Ayale *et al*., 2020). The TDS ranges between 148.90 – 207.00 mg/l of all samples were found to be within the WHO limit of 500 mg/L and NSDWQ limit of 1000 mg/L. The EC and TDS result of the samples were above the result obtained by Ogunsanwo *et al*., (2024) who assessed groundwater in Ogun state with EC and TDS being 12.50 - 206.0 µS/cm and 9.38 - 154.58 mg/L respectively and the results were within the results obtained by Okoye *et al*., (2023) who assessed groundwater in capital of Ogun state with EC and TDS being 76 – 1200 µS/cm and 35.68 – 777.42 mg/L.

Total hardness (TH) of water is the level of Mg ion and Ca ion present in the water samples. The TH of the samples ranges between 132 – 172 mg/L which is above the WHO (2022) and NSDWQ (2022) limit of 100 and 150 mg/L respectively. Hardness of water is not pollution parameter but an indicator of water quality in terms of Ca^{2+} and Mg^{2+} expressed as $CaCO_3$ (Ayale *et al*., 2020). According to Roxanne and Tom (2012) classification, the samples were moderately hard; though, the water may still be safe for drinking base on the fact that Mg and Ca are part of micronutrients required

in the body for physiological processes and metabolic activities, but necessary precautions needs to be taken because high levels of hardness may lead to heart disease and kidney problem (Ukonu *et al*., 2023; Ogunsanwo *et al*., 2024).The results of TH recorded in this study are similar to the report of Odukoya and Laniyan (2015) for groundwater within and around Ago Iwoye. High level of TH may be due to the presence of Ca or Mg containing rocks in the study sites such as dolomite, chalk, gypsumand limestone while magnesium is found in kieserite, carnallite, dolomite, epsom salt and talc (Ogunsanwo *et al*., 2024).

Total Alkalinity (TA) in water is the measure of natural salts and other ionic species which include bicarbonates, phosphates, and organic acids. It is the acid neutralizing capacity of the water samples (Ayodele *et al*., 2024; Ukonu *et al*., 2022). The TA level of the samples from site AR, OR and MR were within the WHO (2022) permissible limit but above the limit in site PR. However, it is worthy to know that low alkalinity can cause corrosion of pipes and increases the chance for the release of heavy metals (Ma *et al*., 2020). Turbidity is the measure of cloudiness/haziness of water probably caused by the presence of suspended particles which can degrade the quality of water. High turbidity increases the chances of contamination and may invariably amount to water-borne diseases (Ayodele *et al*., 2024). The turbidity of all samples was within the WHO (2022) and NSDWQ (2022) acceptable limit of 5 NTU. According to Ayegbo *et al*., (2020) sewage solids, silt and sand washings, clay particles, organic and biological sludge or industrial discharges are the major causes of increase in turbidity level.

Dissolved Oxygen (DO) is a measure of the purification capacity of the water body (Ma *et al*., 2020). The DO values of all samples were in the range of 4.48 – 5.66 mg/l which were within the permissible limit of WHO (2022) and NDSQW (2022) of 5 mg/L. These values were similar to the result obtained by Gebresilasie *et al*. (2021) with DO values of an average of 5.87 mg/L. Other physiochemical parameters such as TSS, nitrate, phosphate, chloride, and sulphate were all recorded to be within the WHO (2022) and NSDWQ (2022) permissible limit.

Result of concentration of heavy metals in the collected samples

The result of the concentrations of heavy metals (Zinc (Zn), Manganese (Mn), Iron (Fe), Nickel (Ni), Cadmium (Cd), and Lead (Pb) in the collected samples is presented in Table 4. Zn and Mn were detected in all the analyzed samples while Fe and Cd were only detected in OR and MR samples respectively. The concentration of Mn in the samples were in the range of 0.394 – 1.138 mg/L and are above the NSDWQ (2022) permissible limit of 0.10 mg/L but within the WHO (2022) permissible limit of 0.50 mg/L except for sites AR and OR which were above the permissible limit. Manganese in water is usually attributed to the contact of the water source with dissolved soils, rocks and minerals of manganese.

TABLE 4

Concentration of the heavy metals analyzed ground water samples

Metals	AR	MR	OR	PR	WHO, 2022	NSDWQ, 2022
Zn	0.001± 0.001	0.044 ± 0.025	0.051 ± 0.006	0.055 ± 0.039	1.5	3
Mn	1.138 ± 0.903	0.394 ± 0.111	0.524 ± 0.371	0.479 ± 0.116	0.5	0.1
Fe	BDL	BDL	0.363 ± 0.056	BDL	0.3	0.3
Ni	BDL	0.052 ± 0.037	0.009 ± 0.006	BDL	0.02	0.07
Cd	BDL	0.008 ± 0.006	BDL	BDL	0.002	0.003
Pb	BDL	BDL	BDL	BDL	0.015	0.01

NS: Not specified; BDL: Below detection limit

High concentration of Mn in water gives the water unpleasant taste, though there is no record of toxicological effect and health risk associated with excess manganese exposure (Ukonu *et al*., 2022; Ayegbo *et al*., 2021). Fe concentration in the samples was found to be in the range of BDL – 0.363 mg/L and were below detection limit in all the sites except OR which had value slightly above the WHO (2022) and NSDWQ (2022) limit of 0.30 mg/L. Fe is an essential element required for metabolic activities in human and deficiency of iron can cause cardiovascular collapse, vomiting, diarrhea and failure of blood clotting (Ma *et al*., 2020). High concentration of Fe in water could lead to colouration of the water body (Okoye *et al*., 2023).

Ni and Cd concentration in the samples ranged from BDL to 0.052 mg/L and BDL to 0.052 mg/L respectively and are below detection limit in all sites except in site MR where both metals were detected and at concentration slightly above the WHO (2022) permissible limit. Detection of these metals call for concern because of the adverse effect they cause at high concentrations. Cd is linked to renal failure, endocrine disruption and calcium homeostasis. Ni and Cd are also known to cause cancer in humans (Okoye *et al*., 2023; Jegede *et al*., 2022). Zn was detected in all the samples ranging from 0.001 to 0.055 mg/L at concentration lower than the WHO (2022) and NSDQW (2022) permissible limits. The concentration of Pb was below detection limit in all the samples analyzed. Overall, the abundance of heavy metal in groundwater within the study areas is in the order: Mn > Fe > Zn > Ni > Cd > Pb. The result obtained in this study agrees with the result of the water quality in Ogun state, Nigeria carried out by Ogunsanwo *et al*., (2024)

Risk assessment

The evaluation of the risk assessment of toxic metals in the analyzed water samples was carried out by calculating the non-carcinogenic and carcinogenic risks and the results are presented in tables 5, 6 and 7.

Non-carcinogenic health risk

Chronic daily intake (CDI), estimated hazard quotient (HQ) and hazard index (HI) of the analyzed Zn, Mn, Fe, Ni and Cd in groundwater from the study sites via ingestion and dermal contact pathway are presented in Tables 5 and 6 respectively. The CDI values of each metal in the samples ranged from 1.083 $\times 10^{-7}$- 1.263 $\times 10^{-3}$,7.115 $\times 10^{-5}$ - 2.614 $\times 10^{-}$

^{2}, 0.000 – 1.195 × 10^{-3}, 0.000 – 1.195 × 10^{-3}, 0.000 – 1.838 × 10^{-4} mg/kg/day for Zn, Mn, Fe, Ni, Cd respectively. From the calculated CDI values, the heavy metals human exposure was more prominent via ingestion compared to the dermal pathway. For both pathways, the heavy metal human exposure for the sampled areas is in the following order: AR >OR >PR > MR.

All heavy metals accounted for in this study have HQ and HI values < 1 except Mn in AR sample. HQ and HI value <1 is an indication that no non-carcinogenic impacts may occur on the residents (Seleem *et al*., 2021). HI value slightly above 1 via ingestion route as noticed for Mn at site AR, although it is negligible but if not monitored may pose long-term non-carcinogenic health risk to the residents (Seleem *et al*., 2021).

TABLE 5

The heavy metals of chronic daily intake (CDI) through different pathways

Heavy Metals		Zn	Mn	Fe	Ni	Cd	Pb
CDI_{ing}	AR	2.297× 10^{-5}	2.614× 10^{-2}		0.000	0.000	0.000
	MR	1.011× 10^{-3}	9.051× 10^{-3}	0	1.195× 10^{-3}	1.838× 10^{-4}	0
	OR	1.172× 10^{-3}	1.204× 10^{-2}	8.339× 10^{-3}	2.067× 10^{-4}	0	0
	PR	1.263× 10^{-3}	1.100× 10^{-2}				
CDI_{derm}	AR	1.083× 10^{-7}	2.055× 10^{-4}	0	0	0	0
	MR	4.767× 10^{-6}	7.115× 10^{-5}	0	1.878× 10^{-6}	1.445× 10^{-6}	0
	OR	5.526× 10^{-6}	9.462× 10^{-5}	6.555× 10^{-5}	3.250× 10^{-7}	0	0
	PR	5.959× 10^{-6}	8.650× 10^{-5}	0	0	0	0

TABLE 6

Hazard quotient (HQ) and hazard index (HI) of heavy metals in ground water through ingestion and dermal pathway

		Zn	Mn	Fe	Ni	Cd
HQ_{ing}	AR	7.657× 10^{-5}	1.089	-	-	-
	MR	3.369× 10^{-3}	3.771× 10^{-1}	-	5.973 × 10^{-2}	3.675 × 10^{-1}
	OR	3.905× 10^{-3}	5.015× 10^{-1}	1.191 × 10^{-2}	1.034 × 10^{-2}	-
	PR	4.211× 10^{-3}	4.585× 10^{-1}	-	-	-
HQ_{derm}	AR	3.611× 10^{-7}	8.562× 10^{-3}	-	-	-
	MR	1.589× 10^{-5}	2.964× 10^{-3}	-	9.390 × 10^{-5}	2.889 × 10^{-3}
	OR	1.842× 10^{-5}	3.943× 10^{-3}	9.364 × 10^{-5}	1.625 × 10^{-5}	-
	PR	1.986× 10^{-5}	3.604× 10^{-3}	-	-	-
HI	AR	7.693× 10^{-5}	1.098	-	-	-
	MR	3.385× 10^{-3}	3.801× 10^{-1}	-	5.982 × 10^{-2}	3.704 × 10^{-1}
	OR	3.924× 10^{-3}	5.055× 10^{-1}	1.201 × 10^{-2}	1.035 × 10^{-2}	-
	PR	4.231× 10^{-3}	4.621× 10^{-1}	-	-	-

HQ_{ing}- ingestion and HQ_{derm}- dermal

TABLE 7

Target cancer risk (TCR) of the human health risk through ingestion and skin absorption exposure pathways

		Ni	Cd
CR_{ing}	AR	-	-
	MR	2.031×10^{-3}	6.983×10^{-5}
	OR	3.515×10^{-4}	-
	PR	-	-
CR_{derm}	AR	-	-
	MR	3.193×10^{-6}	5.489×10^{-7}
	OR	5.526×10^{-7}	-
	PR	-	-
TCR	AR	-	-
	MR	2.034×10^{-3}	7.038×10^{-5}
	OR	3.520×10^{-4}	-
	PR	-	-

Carcinogenic health risk

The CR values calculated for samples in all sites were all within the acceptable cancer health risk range of 1.00×10^{-4} to 1.00×10^{-6}(Haque *et al*., 2018, Seleem *et al*., 2022; USEPA, 2020) except for Ni at site MR having a value of 2.031×10^{-3} which is above the limit and this is an indication of long-term cancer risk. However, according to Haque *et al*., (2018), this value is graded as medium risk indicating it can be overlooked but protective measures is needed because lifetime exposure may pose cancer risk to the residents. The highest CR was recorded for Ni (ingestion) in MR (2.031×10^{-3}) and lowest is Cd (dermal) in MR (5.489×10^{-7}). CR for ingestion is higher compared to dermal route. The Target Cancer Risk (TCR) of only Ni and Cd were considered in this study and the result is presented in Table 7. The TCR via ingestion and dermal routes ranges between 5.526×10^{-7} , – 2.031×10^{-3} and 5.489×10^{-7} , – 6.983×10^{-5} for Ni and Cd respectively.

Conclusion

This study assessed the quality of ground water samples in student residential areas in terms of their physicochemical properties and health risk of heavy metals content. The physicochemical properties of all the water samples and analyzed heavy metals were within the WHO permissible limit, with exception of water hardness and Mn and Fe in sites MR and AR. The studied heavy metals in the samples may pose less non-carcinogenic and carcinogenic health risk except Mn and Ni in ground water of few sites and ingestion route is the most dominant route of heavy metal exposure. Generally, the water quality of the ground water in the studied site is moderately safe but caution needs to be taken as hard water may waste soap and long-term consumption may have negative health implication.

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Conflict of interest

No conflict of interest to be disclosed. In this study

Ethical approvals

This study does not involve experiments on animals or human subjects.

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