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Risk assessment of heavy metals in groundwater of Lagos State University, Epe, Lagos State, Nigeria

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Abstract

Risk assessment of groundwater is very important for the protection of the environment and human health. This work was carried out to assess the risk of heavy metals in groundwater of Lagos state University (LASU), Epe campus. 20 different locations for sampling were identified and coordinated using handheld Global Positioning System (GPS) for the purpose of universal identification and virtualization. Groundwater samples were collected from the 20 identified and coordinated locations with the aid of 1 litres plastics bottles which had been treated with 10 % nitric acid and rinsed with de-ionised water. The samples were labeled GW 1 – GW 20 and all the samples were characterized for heavy metals: Zinc (Zn), lead (Pb), copper (Cu), manganese (Mn), cadmium (Cd), nickel (Ni), chromium (Cr) and iron (Fe), using standard methods prescribed by American Public Health Association, American Water Works Association and Water Environment Federation (APHA/AWW/WEF). Heavy metal pollution index (HPI) and metal pollution index (MI) model were used to evaluate the overall quality and the severity of contamination of the groundwater respectively. The possibility of the groundwater to cause non – carcinogenic health problems when consumed was determined using non – carcinogenic health index (HI) model while the possibility to cause carcinogenic health issues was determined with the aid of carcinogenic risk (CR) model. The results revealed that HPI and MI values for LASU, Epe groundwater were 515 and 8.038 respectively. The oral non – carcinogenic health index for child and adult were 3.284 and 0.5166 respectively while the dermal non – carcinogenic values were 0.5159 and 0.0175 for child and adult respectively. The oral carcinogenic values for child and adult were 1051.8 x 10 -5 and 323.9 x 10 -5 respectively for the combined effects of heavy metals while the dermal carcinogenic values were 55.36 x 10 -5 and 0.0137 x 10 -5 for child and adult respectively for the combined effects of the heavy metals. It was concluded that LASU, Epe groundwater have the potential of causing carcinogenic health problems in both children and adults when consumed orally but when taken via dermal, it has the ability to cause carcinogenic health issues in children.

Keywords: Assessment; Carcinogenic; Groundwater; Heavy metals; Lagos State University; Non – carcinogenic; risk

1. Introduction

Groundwater is the water beneath the earth crust and it is the major source of drinking water that is water that is safe for cooking and drinking without any health risk, for almost one – third of the world population (Salami *et al.*, 2013; Sharma *et al.*, 2013 and Salami and Susu, 2015). It is also used for agricultural, domestic and industrial purposes (Zahid *et al.*,2022). The quality of the groundwater is affected by factors which include mineralization of watersheds, lithology water rock interaction like dissolution of minerals, recharge sources human impacts, redox and ion exchange (He *et al.*, 2021; Odunlami and Salami, 2017 and Mosood *et al.*, 2019). Availability of adequate, safe and clean water is very

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important for survival and sustainability communities and ecosystem (Akoteyon, 2013 and Susu and Salami, 2011) which is a global concern (Ibeh and Mbah, 2007) and a vital part of the sustainable development goals (SDGS) as the public health standard of a community is a function of purity and availability of drinking water also refer to potable water (Hossan *et al*., 2024; Fathi *et al*., 2018; Khan *et al*., 2011 and Ewaid, 2017).

Groundwater can be polluted by heavy metals which include cadmium, arsenic, chromium, zinc, lead, nickel, mercury and copper (Papazotos, 2021; Adeyemo and Salami, 2022; Alsubih *et al*., 2021 and Khalid *et al*., 2020). These heavy metals are released into groundwater as a result of natural and anthropogenic activities, which when use for drinking, adversely affects human health and leads to various diseases such as hypertension, melanosis, lung diseases, cancer, peripheral vascular diseases, cholera, hyperkeratosis among others (Ricolfi *et al*., 2020; Abbas and Cheema, 2015 and Abbas *et al*., 2021). Hence continuous monitoring of groundwater quality is essential for well-being of human life. In Nigeria especially in the university campuses, several reports have been issued by scholars on the quality of groundwater (Majolagbe *et al*., 2023; Ogundana and Talabi, 2014; olusegun *et al*., 2016; David *et al*., 2017; Bayowa *et al*., 2018; Habeb, 2020; Doris and Mildred, 2021 and Temitope *et al*., 2023).

Odukoya *et al*. (2013) worked on groundwater quality and identification of hydrogeochemical processes within University of Lagos, Nigeria. Physical analysis of the collected samples showed a slight alkalinity and acidity when compared to World Health Organisation (WHO) standards. The work also revealed that based on Gibbs classification, all the samples of groundwater examined were within the water – rock interaction which indicated that the weathering of rocks is the major controls of ion chemistry of groundwater in the region. David *et al*. (2017) studied the quality of groundwater in Covenant University, located at Ota, Ogun State, Nigeria. The study showed that the groundwater samples investigated were within the stipulated limits of Nigerian Standards for Drinking Water quality (NSDWQ) except for iron and cadmium which made the authors to declare the groundwater unfit for drinking.

Owamah *et al*. (2021) monitored groundwater quality in Niger Delta University, Balyesia State, Nigeria. The work provided a first time scientific data on groundwater quality status in the university. Some groundwater samples investigated were acidic while others have parameters like cadmium, total coliform and lead that were slightly above the WHO standards values. Anieka *et al*. (2023) investigated the geoelectrical, hydrogeological and hydrochemical properties of groundwater in University of Calabar, Southeastern Nigeria. The hazard quotients and hazard index values of trace elements investigated (Cd, Al, As, Cu, Mn, Ni, Zn, Cr, Pb and Fe) were less than 1 which indicated that the groundwater posed no health risk to people using the water.

From the available literature, risk assessment of groundwater in Lagos State University, Epe, Lagos State, Nigeria has not been carried out. Therefore the aim of this work is to carry out risk assessment of heavy metals in groundwater of Lagos State University, Epe, Lagos State, Nigeria. People in LASU, Epe campus depend solely on groundwater for drinking and domestic usage since the only mini water works on campus is not functioning. Hence, assessing the human exposure risk of the campus groundwater is not only imperative but also timely which justifies this work. The work will also provide fundamental data on LASU, Epe groundwater which can be used by the university authority for the management of LASU Epe campus groundwater, which further justifies this work.

2. Methodology

2.1. The Study Area

LASU, Epe campus was a military barrack before 1996 (Salami *et al*., 2021). It was changed to a full fledge academic campus in 1996. The campus is a large span of land which runs into thousand of acreage and on coordinates 3.9896°E and 6.588°N (Salami and Folami, 2021). It houses Faculty of Environmental Sciences, the School of Agricultural, Faculty of Engineering , School of Part Time Studies, and directrate for pre-degree programme. The Faculty of Engineering comprises departments of chemical, civil, mechanical, industrial, aerospace and electronic and computer engineering. The campus is beautifully along the coaster valley of Epe and surrounded by vast hectres of land use by the villagers for agricultural purpose (LASU Handbook, 2015). Some students and staff resident on campus using the available accommodation provided by the university management while the remaining staff and students are resident off the campus. The satellite image of the study area is shown in Figure 1.

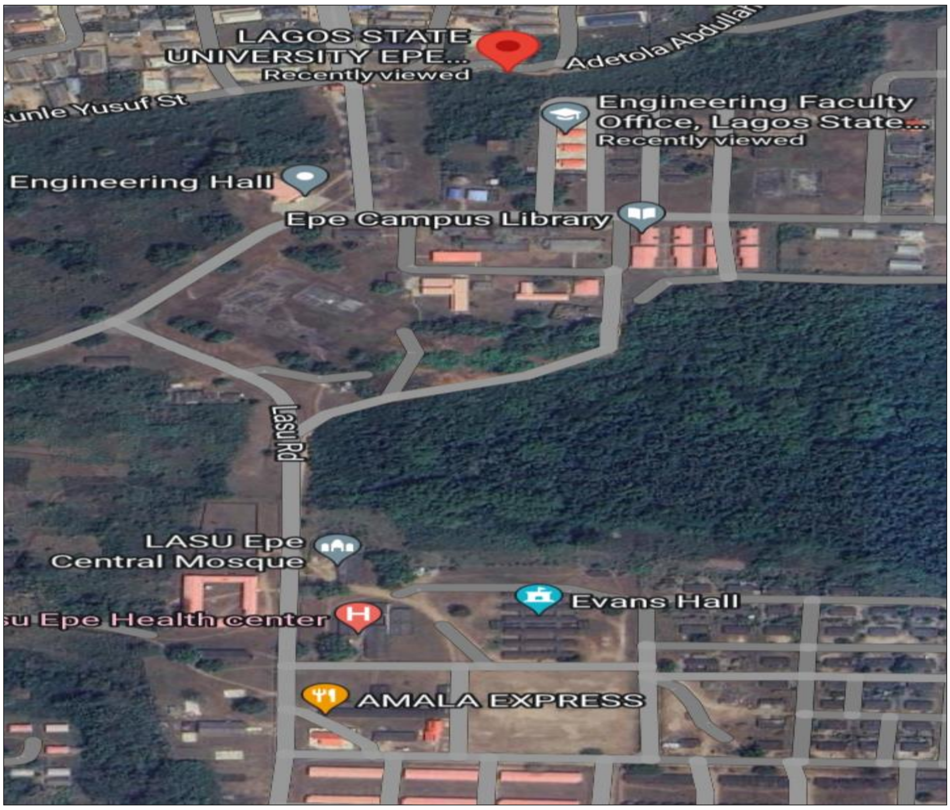

Figure 1 The satellite image LASU, Epe Campus

2.2. Coordination of Sampling Locations

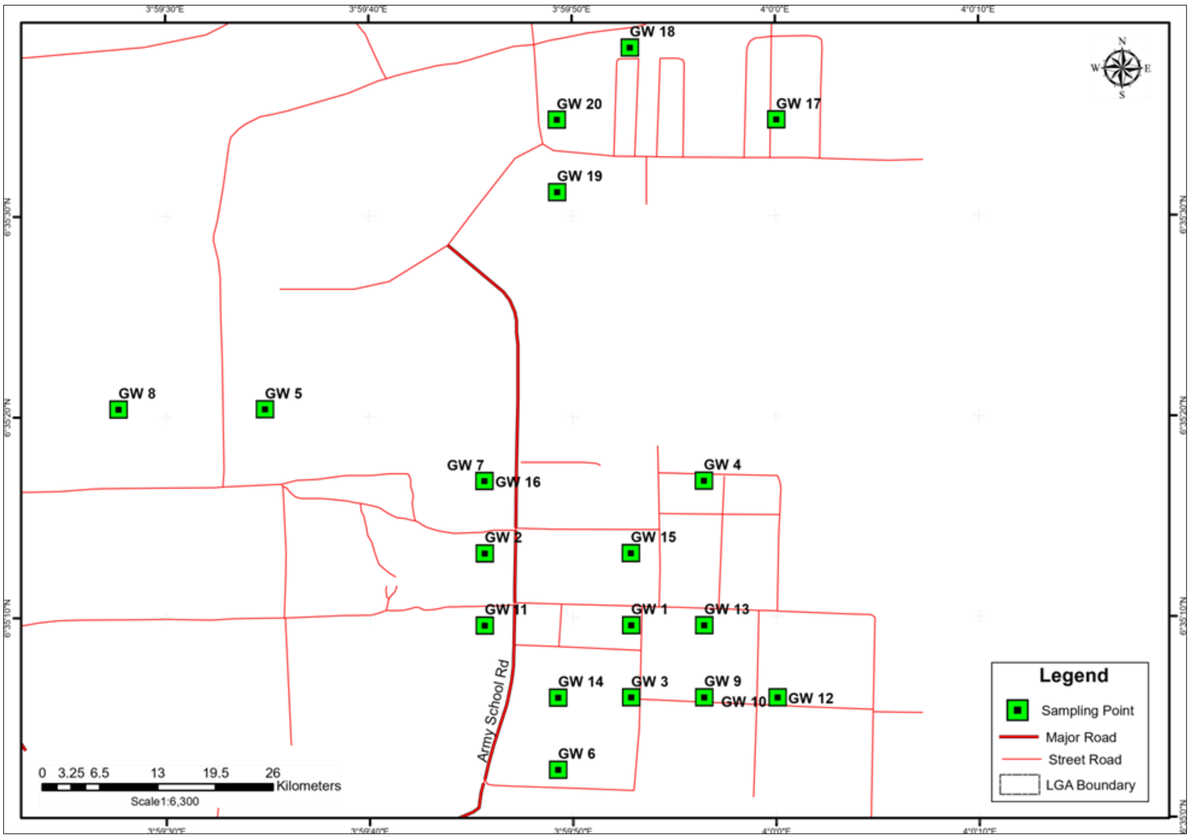

Figure 2 Locations of the sampling points

20 different sampling points were selected within LASU Epe campus for collection of groundwater samples which were labelled 1 – 20. The sampling locations were coordinated with the aid of handheld Global Positioning System (GPS) (Etrex 12 Garmin model) for the purpose of universal visulisation and identification of the sampling points. The locations of the chosen sampling points are depicted in Figure 2.

2.3. Sampling and Analysis

Samples of groundwater were taken from the boreholes in the identified and coordinated locations in the month of November, 2023 with the aid of 1 litre plastic bottles which had been treated by soaking in 10 % nitric acid and rinsed with de – ionised water in order to avoid contamination. During the sampling, the treated bottles were rinsed three times with groundwater to be sampled prior to filling and they were labelled GW 1 – GW 20. All the samples were were quickly taken to the laboratory without delay, for analysis of heavy metals using the standard methods for examination of water and wastewtaer as prescribed by American Public Health Association, American Water Works Association and Water Environment Federation (APHA/AWWH/WEF, 2017). All the analysis were performed in triplicate and the results were found reproducible within $\pm$ 2 % error.

2.4. Heavy Metal Pollution Index

The heavy metal pollution index (HPI) was evaluated using Equation (1):

$$HPI = \sum_{i}^{n} \frac{W_i Q_i}{W_i} \qquad \text{.........................(1)}$$

Where *n* is the number of heavy metals examined, *Wi* is the unit weight of *i*th heavy metal and *Qi* represents the sub – index of *i*th heavy metal.

The *Wi* was obtained by Equation (2):

$$W_i = \frac{K}{S_i} \qquad \text{...................} \qquad (2)$$

Where *K* is the constant of proportionality and *Si* is the permissible limit standard of ith heavy metal in water. The proportionality constant was calculated using Equation (3):

$$K = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}} \qquad \text{............................(3)}$$

Where

$$\sum_{i=1}^{n} \frac{1}{S_i} = \frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} + \frac{1}{S_4} + - - - \frac{1}{S_i} \text{.................(4)}$$

Where S_1, S_2, S_3, S_4, - - - are the standard values for various heavy metals investigated in groundwater. The sub – index value (Q_i) was calculated with the aid if Equation (5):

$$Q_i = \sum_{i=n}^{n} \frac{(M_i - I_i)}{(S_i - I_i)} \times \frac{100}{1} \text{.................} \qquad (5)$$

Where I_i represents the ideal value of *i*th heavy metals and M_i is the monitored value of *i*th heavy metal. In this study, the average value of ith metals examined was used as the monitored value of *i*th metals as done in the work of Lotfi *et al*. (2020). A modified scale of different categories is provided by Giri *et al*. (2014) and Mohamed *et al*. (2024) for understanding of HPI. The categories are excellent quality (HPI $\prec$ 25); good quality (25 $\prec$ HPI $\prec$ 50); poor quality (50 $\prec$ HPI $\prec$ 76); very poor quality (76 $\prec$ HPI $\leq$ 100) and high pollution risk that is suitable (HPI $\succ$ 100).

The metal index (MI) was evaluated with the model presented in Equation (6):

$$MI = \sum_{i=1}^{n} \frac{C_{ave(i)}}{UAL_i} \quad (6)$$

Where $C_{ave(i)}$ is the average concentration of each heavy metal examined and UAL_i signifies the upper allowable limit of ith heavy metal. According to Mohammed eta al. (2024) and Caeiro (2005), metal index is categorised into six classes: very clean (MI $\prec$ 0.3); clean (0.3 $\prec$ MI $\prec$ 1); partly affected (1 $\prec$ MI $\prec$ 2); moderately affected (2 $\leq$ MI $\prec$ 4); heavily affected (4 $\prec$ MI $\prec$ 6) and severally affected (MI $\succ$ 6).

2.5. Human Health Risk Assessment

Human health risk evaluation was carried out using the recommended model by the United State Environmental Protection Agency (USEPA, 2004) which examined the impact of environmental pollutants on health. The health risk evaluation is divided into two classes according to Habeb (2020) namely; non – carcinogenic risk (NCR) and carcinogenic risk (CR). The carcinogenic risk was used to examine the likelihood of having cancer due to long time exposure to LASU Epe groundwater while non – carcinogenic risk was done to assess the possibility of developing non – carcinogenic ailments like anemia, lung disease, advanced heart disease, dementia and motor neuron disease (MND) as a result of exposure to LASU Epe groundwater. Heavy metals in groundwater can enter our body by consumption (oral) and by skin contact (dermal).

The non – carcinogenic and carcinogenic risk were evaluated with the mathematical models depicted in Equations 7 – 12 (USEPA, 1989; Brindha et al., 2016; Planning Commission, 2011).

$$CDI_{oral} = \frac{C \times IR \times ED \times EF}{BW \times AT} \quad (7)$$

$$CDI_{dermal} = \frac{C \times ET \times EF \times K_P \times SA \times CF \times ED}{BW \times AT} \quad (8)$$

Where CDI_{oral} and CDI_{dermal} are the average chronic daily direct intake and average daily dose adsorbed by the skin respectively, C is the measured concentrations of heavy metals in water (mg/L); IR signifies ingestion rate of water (L/day); EF represents exposure frequency (days/years); ED stands for exposure duration (year); BW is the body weight (kg/person); AT depicts average time (days); Kp represents skin permeability coefficient; SA stands for the exposed skin area (cm^2); CF is the conversion factor and EF stands for exposure time.

The hazard quotient index (HQ) was calculated using Equation (9) and (10);

$$HQ = \frac{CDI_{oral}}{RFD_{oral}} \quad (9)$$

$$HQ = \frac{CDI_{dermal}}{RFD_{dermal}} \quad (10)$$

The non – carcinogenic risk was determined using non – carcinogenic health index (HI) in Equation (11);

$$HI = \sum HQ \quad (11)$$

However, the carcinogenic risk was evaluated with the aid of mathematical model shown in Equation (12);

$$CR = CDI \times CSF \quad (12)$$

Where *CSF* signifies cancer slope factor of heavy metals. The parameters used for evaluation of *HI* and *CR* are presented in Table 1.The exposure duration for adult was taken as 35 years because university is studied. In LASU, the duration of service is 35 years when people are employed. or child, the exposure duration was taken as 5 years because when a baby is born, between the age 5 and 6 years, he or she is expected to start schooling and, they school outside the campus.

Table 1 Parameters for evaluation of HI and HQ

S/N	**Parameters**	**Heavy metals (mg/L)**								**References**
		Zn	**Pb**	**Cu**	**Mn**	**Cd**	**Ni**	**Cr**	**Fe**	
1	RFD dermal	0.06	0.00042	0.012	0.00096	0.000025	0.0008	0.000075	0.14	Maryam *et al*. (2024); Adimalla (2020) and Saha (2017).
2	RFD oral	0.3	0.0014	0.04	0.024	0.0005	0.02	0.003	0.7	UNDESA, 2013
3	CSF oral (mg/kg/day	-	0.0085	-	-	15	0.91	0.42	-	COEHHA, 2019
4	CSF dermal mg/kg/day	-	1.5	-	-	0.38	-	20	-	Oni *et al*. (2022)
5	Kp	0.0006	0.0001	0.001	0.001	0.001	0.0002	0.002	0.0002	Saleem *et al*. (2019)
6	Si (mg/L)	1	0.01	3.0	0.05	0.001	0.07	0.05	0.3	WHO , 2009
7	SA Child (cm^2)	6,600								USEPA, 2002
8	SA Adult (cm^2)	18,000								USEPA, 2002
9	AT Child (day)	2190								Saha, 2017
10	AT Adult (day)	25,500								Saha, 2017
11	ET Child (hr/day)	1								Wu, 2009
12	ET Adult (hr/day)	0.58								Wu, 2009
13	CF (L/cm^3)	0.001								Wu, 2009
14	ED Child (year)	5								
15	ED Adult (year)	35								
16	EF (day/year)	350								Phillips and Moya (3013)
17	IR Child (L/day)	1.8								Adimalla, 2020
18	IR Adult (L/day)	2.2								Adimalla, 2020
19	BW Child (kg)	15								Giri and Singh, 2015
20	BW Adult (kg)	70								Giri and Singh, 2015

3. Results and Discussion

The numerical values of heavy metals investigated, drinking water quality standards, heavy metal pollution index and metal index of the groundwater in study area are presented in Table 2. The minimum and maximum values of lead were 0.003 and 0.015 mg/L respectively with an average value of 0.01 mg/L. The stipulated standard by NSDWQ and WHO is 0.01 mg/L. The average concentration of lead in the examined groundwater was slightly above the WHO and NSDWQ standards. The minimum and maximum concentrations of copper are 0 and 0.055mg/L respectively with a mean of 0.0277 mg/L which was below the threshold limit of 1.0 mg/L stipulated by WHO and NSDWQ. The minimum and maximum concentrations of nickel were 0.007 and 0.20 mg/L respectively with an average value of 0.053 mg/L. The mean value of nickel in the groundwater examined was above the stipulated limit of 0.02 mg/L recommended by NSDWQ and WHO for drinking water quality.

Table 2 Numerical values of heavy metals investigated in the groundwater

Heavy metals	Minimum	Maximum	Mean	*NSDWQ	**WHO
Zn	0.005	0.16	0.046	3.00	-
Pb	0.003	0.015	0.01	0.01	0.01
Cu	0	0.055	0.0277	1.00	1.00
Mn	0.004	0.171	0.028	0.20	0.05
Cd	0	0.006	0.001	0.003	0.003
Ni	0.007	0.20	0.053	0.02	0.02
Cr	0.005	0.027	0.0011	0.05	0.05
Fe	0.012	0.074	0.0289	0.3	0.3
HPI	515.30				
MI	8.038				

*NSDWQ (2015); **WHO (2008)

The mean values of manganese, cadmium, chromium and iron in the investigated groundwater were 0.028, 0.0011, 0.0011 and 0.0289 mg/L respectively. All these average values were below the threshold limits of 0.05, 0.003, 0.05 and 0.3 mg/L for manganese, cadmium, chromium and iron respectively by WHO. Fadipe *et al*. (2020) reported the mean concentration of chromium and iron to be 0.29 and 5.56 mg/L respectively in Osun State University groundwater. This revealed that the average concentration of iron in Osun state University groundwater was higher than the groundwater in LASU, Epe campus and also above the recommended value of 0.3 mg/L for iron in drinking water by NSDWQ and WHO. Auwal and Kwaya (2022) reported that the mean concentration of iron in groundwater from hand dugged wells and boreholes of Bayero University new campus were 1.38 and 0.83 mg/L. This showed the average iron content in groundwater of Bayero University new campus was above that of LASU, Epe campus and was also above the threshold limit value of 0.3 mg/l for drinking water as stipulated by WHO and NSDWQ.

The HPI of LASU, Epe campus groundwater investigated was 515.3. The mean values of all the heavy metals considered in this work were used in the calculation of the HPI. HPI is an important tool for evaluating the overall quality of groundwater concerning heavy metal contamination. It is very useful in assessing the impact of heavy metal on the water quality and act as an indicator for groundwater monitoring and management of health risk which are traceable to exposure of these heavy metals. According to Giri *et al*. (2024) and Mohamed *et al*. (2024), HPI value above 100 means the groundwater poses a high pollution risk and it is unsuitable for drinking. HPI value of 515.3 obtained for LASU, Epe campus groundwater indicated that the groundwater poses a high pollution risk and it is unfit for drinking. Aluko et al.(2023) assessed the groundwater quality by HPI in Ijare rural community and Alagbaka urban area in Ondo State. The authors reported HPI above 100 hence it can be said that the groundwater in the community studied by Aluko *et al*. (2023) and LASU, Epe campus groundwater were in the same category based on HPI.

Table 3 Numerical values of chronic daily intake and non – carcinogenic risk for groundwater in the study area

Parameters	Status	Heavy metals							
		Zn	**Pb**	**Cu**	**Mn**	**Cd**	**Ni**	**Cr**	**Fe**
CDI oral	Child	$4.4 x 10^{-3}$	$0.9 x 10^{-3}$	$2.66 x 10^{-3}$	$2.69 x 10^{-3}$	$1.06 x 10^{-3}$	$5.07 x 10^{-3}$	$0.1 x 10^{-3}$	$2.77 x 10^{-3}$
	Adult	$0.69 x 10^{-3}$	$0.15 x 10^{-3}$	$0.42 x 10^{-3}$	$0.42 x 10^{-3}$	$0.17 x 10^{-3}$	$0.8 x 10^{-3}$	$0.02 x 10^{-3}$	$0.44 x 10^{-3}$
CDI dermal	Child	$58.2 x 10^{-5}$	$0.211 x 10^{-5}$	$5.84 x 10^{-5}$	$5.91 x 10^{-5}$	$2.33 x 10^{-5}$	$22.37 x 10^{-5}$	$0.4 x 10^{-5}$	$6.10 x 10^{-5}$
	Adult	$19.78 x 10^{-6}$	$0.07 x 10^{-6}$	$1.98 x 10^{-6}$	$2 x 10^{-6}$	$0.79 x 10^{-6}$	$7.6 x 10^{-6}$	$0.16 x 10^{-6}$	$2.07 x 10^{-6}$
HQ oral	Child	0.015	0.686	0.066	0.112	2.112	0.254	0.035	0.004
	Adult	0.002	0.108	0.01	0.018	0.332	0.04	0.006	0.006
HQ dermal	Child	$9.7 x 10^{-3}$3	$5.02 x 10^{-3}$	$4.87 x 10^{-3}$	$61 x 10^{-3}$	$92.84 x 10^{-3}$	$28 x 10^{-3}$	$61.89 x 10^{-3}$	$0.4 x 10^{-3}$
	Adult	$3.3 x 10^{-4}$	$1.7 x 10^{-4}$	$1.65 x 10^{-4}$	$20.9 x 10^{-4}$	$31.53 x 10^{-4}$	$94.94 x 10^{-4}$	$21.01 x 10^{-4}$	$0.15 x 10^{-4}$
HI oral	Child	3.284							
	Adult	0.5166							
HI dermal	Child	0.5159							
	Adult	0.017							

A metal index measure (MI) directly how severe is the contamination by comparing concentration of metals to their maximum allowable concentrations. It evaluates the total pollution load from different metals. MI is used to determine if water is suitable for irrigation, drinking and other uses depending on the level and presence of potentially harm metals. It can also be used to pinpoint the source of contamination and to assess the effectiveness of water treatment processes. The MI of groundwater examined in the study area was 8.038. According to Mohamed *et al.* (2024) and Caeiro (2005), water with MI greater than 6 is severally affected. This implied that the groundwater of LASU, Epe campus has be severally affected by the heavy metals considered in this work hence it can be declared unsuitable for drinking. In the work of Anitha et al. (2021), the author reported that 73.3 percent of assessed groundwater from Peenya industrial area in India was severally affected by heavy metals. It can be deduced that 73.3 percent of examined groundwater from Peenya industrial area in India were in the category with investigated groundwater of LASU, Epe campus.

The numerical values of chronic daily intake, non – carcinogenic and carcinogenic human health risks of heavy metals examined in groundwater of the studied area are shown in Table 3. The mean values of heavy metals examined were used in the computation of non – carcinogenic and carcinogenic health index. Chronic daily intake (CDI) of groundwater refers to regular and long – term intake of groundwater and its potential health implications as a result of contamination. It is the calculation which estimates the mean daily intake of contaminants over a life time. The oral CDI obtained in this work varied between $5.07 x 10^{-3}$ and $0.1 x 10^{-3}$ for child and between $0.8 x 10^{-3}$ and $0.02 x 10^{-3}$. The dermal CDI ranged between 58.2 *x* 10-5 and $0.4 x 10^{-5}$ for child and between $19.75 x 10^{-6}$ and $0.16 x 10^{-6}$ for adult.

Hazard quotient is used to determine the potential for non – cancer health hazards from exposure to contaminants. Hazard quotient less than or equal to 1 means the level of exposure is below the level which can cause adverse health effects and a value greater than 1 implies the level of exposure may pose a potential health risk (PHAGM, 2025). The oral hazard quotient obtained in this work varied between 0.004 and 0.686 for child and between 0.006 and 0.332 for adult. The dermal hazard quotient ranged between $0.4 x 10^{-3}$ and $92.84 x 10^{-3}$ for child. For adult, it varied between $0.15 x 10^{-4}$ and $94.94 x 10^{-4}$. All the hazard quotient values for oral and dermal were below 1. This indicated that the LASU groundwater is not likely to cause non – carcinogenic health problem based on hazard quotient values.

Non – carcinogenic health index was obtained by summation of all individual hazard quotients for heavy metals considered in this work. The non – carcinogenic health index helps to take inform decisions about water quality management, public health and treatment. It also aid in assessing the combined risk exposure to multiple chemicals which affect the same health endpoint. The oral non – carcinogenic health indexes obtained in this work were 3.284 and 0.5166 for child and adult respectively while the dermal non – carcinogenic health indexes were 0.5159 and 0.0175 for child and adult respectively. Health index less than 1 implies the combined exposure is likely below the level of concern and adverse effects are not expected while a value above 1 indicates a potential for adverse effects (PHAGM, 2025). The non – carcinogenic health index values obtained for both oral and dermal, implied that LASU, Epe groundwater when taken by oral means, may cause non – carcinogenic adverse effects in children but unlikely to cause non – carcinogenic adverse effect in adults. However, when taken by dermal means, is not likely to cause non –carcinogenic health effects in both children and adult.

Carcinogenic risk means the chance that when contaminated groundwater is consumed, it could result to an increase risk of developing cancer over a life time. Heavy metals such as cadmium, lead, nickel and chromium have the potentials to enhance the risk of cancer in human (Cao *et a*l., 2014). For individual heavy metals, a carcinogenic risk value less than $1 x 10^{-6}$ is taken to be insignificant and the cancer risk value greater than $1 x 10^{-4}$ can be taken as harmful and worrisome. For combined heavy metals through all exposure routes, the acceptable carcinogenic level is $1 x 10^{-5}$ (Cao *et al*., 201; Wcislo *et al*., 2002 and Yang *et al*., 2014). The oral carcinogenic risk values for cadmium and nickel obtained were $58.37 x 10^{-4}$ and $46.29 x 10^{-4}$ respectively for child while oral carcinogenic risk value for cadmium and nickel were $24.92 x 10^{-4}$ and $7.28 ^x 10^{-4}$ respectively for adult. This implied that the carcinogenic risk of cadmium and nickel cannot be ignored when LASU, Epe groundwater is orally consumed.

Table 4 Numerical values of carcinogenic human health risk of heavy metals in groundwater of the study area

Parameter	Status	Pb	Cd	Ni	Cr	Sum
CR oral	Child	0.08 x 10-4	58.37 x 10-4	46.29 x 10-4	0.44 x 10-4	1051.8 x 10-8
	Adult	0.013 x 10-4	24.92 x 10-4	7.28 x 10-4	0.06 x 10-4	323.9 x 10-5
CR dermal	Child	0.0018 x 10-5	34.82 x 10-5	20.35 x 10-5	0.19 x 10-5	55.36 x 10-5
	Adult	0.006 x 10-7	0.012 x 10-7	0.69 x 10-7	0.66 x 10-7	0.0137 x 10-5

The dermal carcinogenic risk value of cadmium and nickel were $3.48 x 10^{-6}$ and $2.035 x 10^{-4}$ respectively for child. All the values for lead, cadmium, nickel and chromium were less than 1 x 10-6. Hence it can be said that cadmium and nickel in LASU, Epe groundwater can cause cancer health issues to children when taken via dermal. However, lead, cadmium, nickel and chromium in LASU, Epe groundwater are not likely to cause cancer health issues when taken via dermal. For the combined effects of lead, cadmium, nickel and chromium, the oral carcinogenic risk values of $1051.8 x 10^{-5}$ and $323.9 x 10^{-5}$ were obtained for child and adult respectively. The dermal carcinogenic risk values for the combined effects of heavy metals considered were $55.36 x 10^{-5}$ and $0.0137 x 10^{-5}$ for child and adult respectively. It can be deduced that when LASU Epe groundwater is consumed orally, it has the potential of causing carcinogenic health problems in both child and adult. However, when consumed via dermal, it has the potential of causing carcinogenic health problems in children.

4. Conclusion

The risk assessment of heavy metals in LASU, Epe groundwater has been carried out. The mean concentrations of all heavy metals consider in this work were within the threshold limits of guidelines for drinking water quality by NSDWQ and WHO, except nickel. The heavy metal pollution index obtained for LASU, Epe groundwater was 515.3 which indicated the groundwater poses a high pollution risk and it is unfit for drinking. The metal index value of the groundwater was 8.038 which implied that the groundwater have severely affected by the heavy metals considered in this work. The oral hazard quotient ranged between 0.004 and 0.686 for child and between 0.006 and 0.332 for adult. The dermal hazard quotient varied between 0.4 x 10-3 and 92.84 x 10-3 for child and between 0.15 x 10-4 and 94.94 x 10-4 for adult. The oral non – carcinogenic health index obtained were 3.284 and 0.5166 for child and adult respectively which means when LASU, Epe groundwater is orally consumed, it may cause non – carcinogenic adverse effects in children but not in adults. The dermal non – carcinogenic values of 0.5159 and 0.0175 were obtained for child and adult respectively which implied when LASU, Epe groundwater is consumed via dermal, it likely not to cause non – carcinogenic effects in both children and adults. The oral carcinogenic risk values of $1051.8 x 10^{-5}$ and $323 x 10^{-5}$ were obtained for child and adults respectively for the combined effects of heavy metals considered. The dermal carcinogenic risk values for child and adult were 55.36 x 10^{-5} and 0.0137 x 10^{-5} respectively for the combined effects of the heavy metals. It was concluded that LASU, Epe groundwater have the potential of causing carcinogenic health problems in both children and adults when consumed orally but when consumed via dermal, it has the potential of causing carcinogenic health problems in children

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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