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Ground Water Quality of some selected Wards in Maiduguri and Jere Local Government Areas of Borno State

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Abstract: *Maiduguri Metropolis and environ have experienced a dramatic increase in kidney related diseases in recent years, with their sources of water being prone to contaminations due to heavy metals. The study is aimed at checking qualities of borehole water samples from randomly selected areas in Maiduguri Metropolitan Council (MMC) and Jere Local Government Areas, while control was collected in Biu Local Government Area. Heavy metals were analyzed using AAS, UV Spectrophotometer, pH Meter and Turbidity Meter. The heavy metals analyzed includes; Arsenic, Chromium, Lead and Manganese. Physicochemical parameter such as; Colour, Turbidity pH, Total Dissolved Solid, Electrical Conductivity and Temperature were also determined. Mean values and Standard deviations of results were obtained. The concentration of heavy metals in water samples of MMC is in this decreasing order: Mn>Cr>Pb>As while that of Jere LGA is: Mn>Cr>Pb>As. Water samples in MMC showed that Arsenic concentration is highest in Hausari Zango 0.0157±1.0022 mg/l while Mairi Kuwait had the highest concentration for Jere LGA. Highest concentration of lead was found in Hausari Zango with a value of 0.078±0.0073 mg/l in MMC, while that of Jere LGA was found in Mairi Kuwait 0.0137±0.0002 mg/l. highest concentration of Nickel in MMC and Jere LGA was found in Hausari Zango 0.1020±0.0170 mg/l and Mairi Kuwait 0.0790±0.0020 mg/l respectively. The highest recorded values of turbidity MMC and Jere LGA were 14.0670±0.4970 NTU in Fezzan Main and 0.5906±0.0099 NTU in Mairi Maimusari Primary School. The pH values for the water samples of the study range from 6.61±0.0283 to 8.34±0.0636 ^{0}C in Hausari Zango and Bolori 1 Wards in MMC, while Jere LGA ranges between 7.04±0.0283 to 8.23±0.0778 ^{0}C in Mairi Kuwait and Dala Abuja Sheraton. The water samples have total dissolved solids ranging from 133±0.0000 to 1767±4.3647 mg/l in Shehuri North and Hausari Zango Wards of MMC, while Jere LGA recorded 80±4.9497 and 612±2.8284 mg/l in Dala Zannari and Mairi Maimusari Primary. Electrical conductivity value ranges from 265±4.2426 (Shehuri North) to 3540±1.4142 µs/cm (Hausari Zango) Wards of MMC, while Jere LGA ranges from 160±5.0711 to 1223±3.5355µs/cm in Dala Zannari and Mairi Kuwait.*

Keywords: *Turbidity, Aquifer, Physicochemical, AAS and UV, Spectrophotometer.*

Introduction

Groundwater will normally look clear and clean because the ground naturally filters out particulate matter. But, natural and human-induced chemicals can be found in groundwater. As groundwater flows through the ground, metals such as iron and manganese are dissolved and may later be found in high concentrations in the water. Industrial discharges, urban activities, agriculture, groundwater pumpage, and disposal of waste all affect groundwater quality (USGS, 2016). Direct exposure to heavy metals in drinking water beyond permissible limits has become a major public health concern, especially in the developing world. Anthropogenic activities causing the release of HMs from the naturally trapped sources into water sources have been identified (Bamuwuwamye *et al.,* 2017). The most common routes of human exposure to HMs

in industrial and residential areas are dermal, inhalation and oral ingestions (food, water) (Nastasescu *et al.,* 2020). These HMs can cause toxicity if their allowable levels are surpassed. The heavy metals are non-biodegradable and may amass in the ecosystem reaching unsafe proportion for human health (Abdel-Rahman *et al.,* 2019).

Greater parts of the sampling sites are situated on lowland, that makes it possible for runoff water to form waterlog areas. This can lead into the heavy metals that might have come along with the waste water to leach through the porous soil to the ground water, resulting into ground water contamination. Groundwater obtained through boreholes can be placed into three (3) categories; Shallow, Middle and Deep aquifers. Shallow boreholes are obtained at depths of between 100 – 150 m, Middle aquifers 200 m, while Deep aquifers are situated at 250 m and above. All these three categories of boreholes are obtained in the sampling sites of the research area.

Study Area

Borno state was created out of the former North Eastern state on the 3rd of February 1976, with Maiduguri as the state capital. The state is located within latitude 110 to 150 E and longitude 100 and 250 N and has an area of 69,436 sq km; it is the largest state in the Federation in terms of land mass (BSD, 2007). The state occupies the greatest part of the Chad Basin and shares borders with republic of Niger to the North, Chad to the North East and Cameroun to the East. Within the country its neighbors are Adamawa to the south, Yobe to the West and Gombe to South West. Based on 1991 provisional census figures, Borno state has a projected population of 2,596,589 and population density of 38 inhabitants per square kilometer (BSD, 2007). Borno state has a climate which is hot and dry for a greater part of the year although southern part is slightly milder. The period of wet season varies from place to place due to the influence of the various climatic factors such as the direction of the rain bearing winds and topography but the rainy season is normally from June to September and May to October in the south with relative humidity of about 49 % evaporation of 203 mm per year (BSD, 2007). The state has two major vegetation zones viz; Sahel and arid in the North with Sudan savannah in the South.

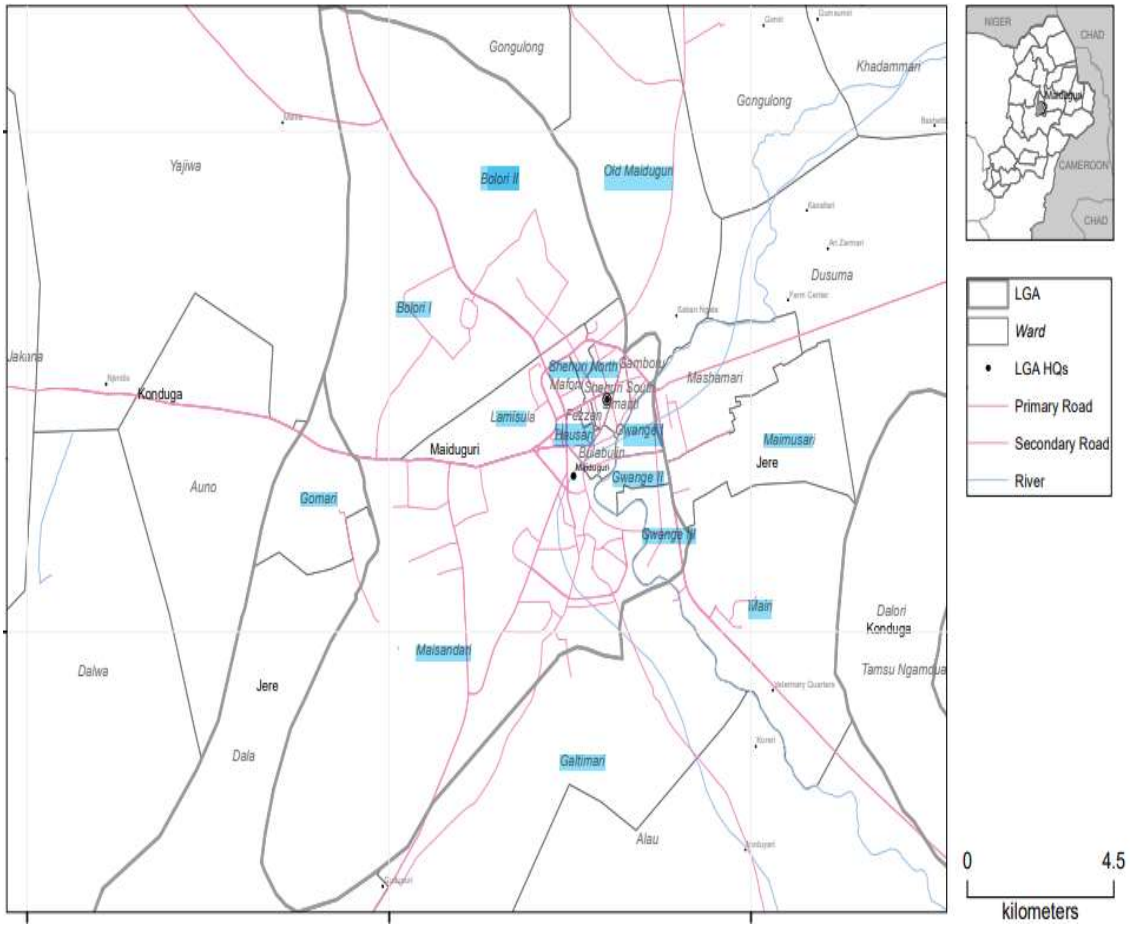

Figure 3.1 Map of Jere LGA, Borno State Showing Sampling Points (Update on: 05 February 2018 Sources: OSGOF, OpenStreetMap Feedback: ochanigeria@un.org More information: https://www.humanitarianresponse.info/en/operations/nigeriawww.unocha.org/nigeria www.reliefweb.int/country/nga)

Materials and Method

The instruments, glass wares and reagents used in this project work includes;

i. AAS Spectrophotometer (Buck scientific model 210VGP AAS, USA)
ii. UV Spectrophotometer (DR3900 HAC
iii. Distilled Water
iv. Turbidity Meter (TL2300)
v. pH Meter Hanna (HI9800)

Water sampling

Borehole water samples were randomly collected from the mapped-out areas in the month of May 2024. Thirty-one (31) samples were collected in all. Samples were collected in well-sealed polyethylene bottles. Those bottles had been previously washed thoroughly with clean water then rinsed with distilled water. Collected samples were immediately transported to the laboratory for analysis. (Jones *et al.,* 1999).

Laboratory Analysis

The equipment and instruments used in this study were all calibrated to check their status before and in the middle of the experiments. All Glass wares were cleaned with 10% concentrated Nitric acid (HNO_3) in order to clear out any heavy metal on their surfaces and then rinsed with distilled-deionised water. The digestion tubes were soaked with 1% (w/v) potassium dichromate in 98% (v/v) H_2SO_4 and the volumetric flasks in 10% (v/v) HNO_3 for 24 hours. After 24 hours, the tubes and flasks were rinsed with deionized water and then dried in oven. All apparatus and materials were kept in dust free place (drying cabinet) until analysis began. Prior to each use, the apparatuses were soaked and rinsed in deionized water. The calibration plot method described in the British Pharmacopoeia was adopted for the preparation of metal ion and AAS analysis. A stock standard solution, 1000 ppm, of the metal ion was prepared by dividing the molar mass of the compound containing the element by the molar mass of the element. The weight obtained was equivalent to 1.0 g of the metal ion. This weight (which is equivalent to 1.0 g of the metal) was dissolved in 1000 ml to give 1000 ppm. A working solution of 100 ppm was prepared from the stock solution and serial dilutions were made from the working solution. The absorbance of these solutions was obtained using AAS at 228.8, 283.3 and 253.7 nm for cadmium, lead and mercury respectively. The calibration graph was plotted and the regression equation was used to determine the heavy metal concentration. solution sample was fed into the AAS instrument, where the metals are vaporized and subjected to light at precise wavelengths. The degree of light absorption by the metals correlates directly with their concentration in the sample. By employing a calibration curve, the metal concentrations are precisely quantified. Rigorous quality control protocols are applied to guarantee result accuracy. In summary, AAS is a highly sensitive and accurate technique for assessing heavy metal levels across diverse sample types (Usman et al., 2023).

Various research studies have been carried out to investigate the levels of heavy metals and radon present in drinking water, as well as to evaluate the corresponding annual effective cancer risk, both in Nigeria and beyond. A study by (Ajiboye et al., 2022) has examined the levels of radon concentration in water in South western Nigeria. Nevertheless, it is important to note that water can contain many other possibly harmful elements, such as cadmium, lead, chromium, arsenic, and selenium, due to usual processes like tectonic activity and erosion, as well as human activities like fossil fuel combustion and industrial (Faweya et al., 2018). Even at low concentrations, these elements can generate free radicals that may cause oxidative stress and harm biological molecules and DNA (Jidele et al., 2021). Another research was conducted by (Dankawu et al. 2021) aiming at estimating the excess lifetime cancer risk and annual effective dose for borehole and well water samples. Their findings suggested that the water in the study area is not safe for domestic purposes and drinking.

Discussion

Physicochemical Properties

Physicochemical properties of water are characteristic of the climate, geochemical, geomorphological and pollution conditions, prevailing in the drainage basin and the underlining aquifer (Limgis, 2019). Groundwaters such as boreholes are prone to contamination due to heavy metals through leaching of surface water. Boreholes sited very close to solid waste dumpsites and sewages can greatly expose such water to contaminations. Some of the minerals and metals found in water are infant very essential for normal body growth and functioning, it

is when those metals exceed what is stipulated by the regulatory agencies such as; Nigerian Standards for Drinking and World Health Organization guideline values, that they pose a health threat or challenges.

Colour in drinking water is usually considered for aesthetic reasons. Contamination pattern due to colour in the studies showed that both MMC and Jere LGA has less issue of colour with few exceptions found with very high values. Most samples of MMC recorded 6 PtCo of colour and below, it is only Maisandari Polo and Fezzan wards that had 19±0.7071 PtCo each. Similar case was obtained in Jere LGA result, where only one location recorded 75±2.1213 PtCo (Mashamari Primary School) Jere LGA. The rest of the Wards had 5 PtCo and below.

Turbidity which is the optical clarity of the water is closely related to colour, because most times if the colour of water is high, turbidity likewise becomes high and vice versa. Values of turbidity in the studies is generally low since values for colour are low in most samples analyzed. MMC recorded highest turbidity value of 0.3251±0028 NTU in Ngomari Delori Ajilari Cross, while Jere Had the highest value of 14.067±6.4469 NTU in Fezzan Main.

pH which tells how acidic or alkaline a substance is, plays a role in the solubility of metals and ions in water. Almost all locations under study reveals pH value of slight acidity to slight alkaline nature. MMC had pH ranging from 6.61±0.0283 in Hausari Zango to 8.34±0636 in Bolori 1 Ward.

Total Dissolved Solid refers to the total soluble solutes found in waters with high TDS are generally not suitable for consumption. Results from the study revealed that very few areas had TDS above what is normal. MMC had three locations with over 1000mg/l TDS, these includes; 1082±2.8284 mg/l in Gwange 2, 1403±2.1213 mg/l in Bulabulin and 1767±4.3640 mg/l in Hausari Zango. Jere LGA recorded the highest value of TDS of 612±8284 mg/l in Mairi Kuwait Ward.

Electrical Conductivity is the numerical expression of the ability of water to conduct electric current, this is made possible due to the presence of ions in the water. It is total dependent on the concentration and mobility of ions of a solution. Electrical Conductivity is usually twice TDS. For MMC, the highest mean values of EC record are; 2163±4.9497µs/cm>2807±3.5355µs/cm>3540±1.4142 µs/cm that in Gwange 2, Bulabulin and Mairi Kuwait Ward respectively. Jere LGA had a high EC of 1132±2.8284 µs/cm and 1223±3.5355 µs/cm in Mairi Distinction Primary School and Mairi Kuwait Ward respectively.

Temperature values for the different samples were also recorded, mean temperature values for MMC ranged between; 27.9±0.1414 ^{0}C in Bulabulin Ward and 29.5±0.2121 ^{0}C in Gamboru Community Borehole. Jere recorded lowest temperature of 27.8±0.4243^{0}C with a high of 28.9±0.0707^{0}C in Alau Raw Water Pumping Station.

Heavy Metals

Table 1, above showed that the highest concentration of Arsenic in Maiduguri water sample is 0.0157±1.0022 mg/l in Hausari Zango, while the least concentration was found in Maisandari Polo with a value of 0.0005±0.0000 mg/l. The mean concentration of Arsenic in Maiduguri water samples is 0.0030 mg/l. Results of Jere Local Government Area in Table 2 revealed that, Mairi Kuwait had the highest concentration of Arsenic, while Dala Zannari recorded 0.0003±0.0000 mg/l as the lowest. The mean value for Arsenic in Jere is 0.0011mg/l. Results obtained in this study are found to be below that reported by (Jimme *et al.,* 2016) in close by

Yobe State, where they recorded 0.21mg/l in a wash borehole. Both the WHO and Nigerian Standard for Drinking Water Quality gave a permissible limit of 0.01 mg/l or 10 µg/l. The result of the studies therefore, indicate that Hausari Zango have amount of Arsenic that is above the allowable standard. Apart from Hausari Zango, all other sample locations in both Maiduguri and Jere Local Government Areas showed tolerable amount of Arsenic in their waters. Heavy metal correlation analysis revealed that, Arsenic had a strong positive correlation with the following; EC (As: r=0.999, Mn: r=0.999, Cr: r=0.916 and Hg: r=0.914 at α=0.05). There exists a moderate correlation of r=0.752 and r=0.757 that is copper and Nickel respectively.

In this study, Table 1 showed Maiduguri Metropolitan Council recorded highest concentration of lead in Hausari Zango with a value of 0.078±0.0073 mg/l and the lowest concentration of lead was observed in Maisandari Polo with a value of 0.0026±0.0000 mg/l. Mean concentration of lead for Maiduguri is 0.0151mg/l. The second area under the study that is Jere Local Government Area recorded the highest concentration of lead, with a value of 0.0137±0.0002 mg/l in Mairi Kuwait, while a lowest value of 0.0016±0.0000 mg/l was obtained in Dala Zannari (Table 2). Mean concentration of lead for Jere is 0.0057 mg/l. The maximum allowable limit of lead in drinking water is 0.01mg/l or 10µg/l, as issued by both the WHO and NSDWQ, while the American US EPA allowed up 15 µg/l. Based on the quality standards, as many as 9 locations in Maiduguri (Hausari Zango, Gwange 2 Bulabulin, Lamusula, Mafoni, Shehuri North, Biu Control) failed the criteria, 4 locations in Jere also had lead above the permissible limit. The places include Mairi Kuwait, Mairi Distinction Primary School, Biu Control and Mashamari Primary School. It is noteworthy that even the control recorded a high concentration of lead (Biu 0.0115±0.0002 mg/l). There is a strong and positive correlation between lead and Manganese in Jere Local Government Area, (r=1.000 α=0.05). there also exists a strong level of relationship between lead and the following heavy metals; As, Cr, and Hg (r=0.999, r=0.916 and r=0.916 respectively α=0.05).

A study carried out by (Mshelia *et al.,* 2023), showed that manganese in Polo and Old Maiduguri Wards are 0.12 mg/l and 0.18mg/l respectively. Concentration of Manganese in our current study reveal that, Hausari Zango have 1.952±0.092 mg/l as the highest, while Maisandari Polo recorded 0.0650±0.0010 as the lowest in Maiduguri Metropolis (Table 1). Mean value of manganese for Maiduguri is 0.3784 mg/l. Jere LGA results showed that, Mairi Kuwait have concentration of 0.3440±0.0030 mg/l, while the lowest concentration of 0.0410±0.0000 mg/l was found in Dala Zannari Ward (Table 2). The entire Jere, had mean concentration of 0.1435 mg/l. Guideline values given by WHO for manganese in drinking water is 0.2 mg/l, the value is recommended by NSDWQ, while the US EPA recommends that the general population should not ingest water with manganese concentrations greater than 1mg/l for more than 10 ten days per year. Results of the study on Maiduguri Metropolis and Jere LGAs, showed that, Hausari Zango had concentration far above the standards, and is also more than the values reported by (Mshelia *et al.,* 2022). Mairi Kuwait in Jere is also having concentration more than that stipulated by the guideline standards. Manganese result of Pearson Coefficient Correlation for Jere LGA, showed that Manganese had a very strong positive relationship with Lead at r=1.000 at α=0.05. As, and Cr also strongly correlated with Manganese at the following levels; (r=0.999, r=0.916 and r=0.911) respectively.

Hausari Zango of the Maiduguri Metropolis recorded a concentration of 0.3950±0.0190mg/l of chromium, that is closely followed by 0.1300±0.0010 mg/l in Gwange 2 Primary Health Care (Table 1). Maisandari Polo had the lowest concentration of chromium with a value of 0.0120±0.0000 mg/l. Mean concentration of 0.0759 mg/l was recorded for Maiduguri

Metropolis. Mairi Distinction Primary School of Jere Local Government Area, have chromium concentration of 0.1060±0.0010 mg/l, while Alau Raw Pumping Station record 0.0120±0.0000 mg/l as the lowest (Table 2). A mean concentration of 0.0371mg/l was also observed for Jere. The WHO and NSDWQ both gave a guideline value of 0.05mg/l or 50 µg/l. The US EPA gave permissible of 10 µg/l. The results from this study revealed that most locations recorded concentration of chromium above that given by all the regulatory standards Table1 and Table 2. Pearson correlation coefficient result for Chromium, revealed that, there is strong linear, positive correlation with Arsenic, Lead and Manganese as follows; Cr (r=0.996, r=0.995 and r=995, r=995) respectively.

Table 1: Mean Values of Physicochemical Parameters of Water Samples in MMC

Locations	Color (PtCo)	Turbidity (NTU)	pH	TDS (mg/l)	EC (us/cm)	Tempt. (0C)
Maf	6±0.7071	1.4100±0.0071	7.43±0.0402	700±1.4142	1402±1.4142	28.0±0.2121
Gwg 1	3±0.7071	0.3610±0.0078	7.47±0.0636	193±1.4142	387±2.8284	29.3±0.2828
She N	0±0.0000	0.2350±0.0042	7.27±0.0354	624±4.2426	1248±1.4142	28.3±0.1414
Bol 1	0±0.0000	0.1540±0.0057	8.34±0.0636	378±4.9497	756±2.1213	27.9±0.0707
Lim K	1±0.0000	0.4300±0.0141	6.75±0.1061	714±2.1213	1428±1.4142	28.5±0.1414
Bul PHC	2±0.0000	0.5200±0.0283	7.8±0.0707	1403±2.1213	2807±3.5355	27.9±0.1414
Mais P	19±1.4142	2.1000±0.0354	6.85±0.0566	116±1.4142	233±4.9497	26.8±0.1414
Mais A	9±0.7071	0.6540±0.0021	7.18±0.0354	137±3.5355	274±3.5355	28.1±0.2121
Gamb CBH	1±0.0000	0.2190±0.0014	7.74±0.0495	237±1.4142	474±1.4142	29.5±0.2121
Lami F	0±0.0000	0.2910±0.0042	7.02±0.0707	890±3.555	1779±5.6569	27.9±0.1414
Gwag 2 PHC	0±0.0000	0.4550±0.0014	7.43±0.0919	1082±2.8284	2163±4.9497	28.4±0.1414
Hau Z MS	0±0.0000	0.2010±0.0028	6.61±0.0283	1767±4.364	3540±1.4142	29.1±0.2121
Bol 2 APK	0±0.0000	0.2390±0.0014	7.39±0.0212	478±5.772	957±2.8284	28.5±0.2121
Gwg 3 PS	0±0.0000	0.6410±0.0064	7.94±0.1131	315±1.4142	756±3.5355	27.9±0.1414
Fez M	19±0.7071	14.067±0.0148	7.41±0.0283	209±3.5355	418±1.4142	28.5±0.2121
Sheh S IW	2±0.7071	0.6790±0.0049	7.65±0.0849	133±0.0000	265±4.2426	28.7±0.1414
Buu (CTL)	0±0.0000	0.0830±0.0007	8.11±0.1626	507±2.1213	1014±2.1213	28.1±0.2828

Maf = Mafoni, Gwg 1 = Gwange 1, She N = Shehuri North, Bol 1 = Bolori 1, Lim K = Limanti Kariari, Bul PHC = Bulunkutu Pri. Health Care, Mais P = Maisandari Polo, Mais A = Maisandari Alajeri, Gamb CBH = Gamboru Community Borehole, Lam F = Lamisula Filatari, Gwag 2 = Gwange 2 Pri. Health Care, Hau Z MS = Hausari Zango Mala Kachalla Sch., Bol 2 = Bolori 2 Ali Pindar Kwajjafa, Gwag 3 PS = Gwange 3 Pri. Sch., Fez M = Fezzan Main, She S IW = Shehuri South Ibrahim Waziri and Buu TZ (CONTR) = Biu Tizea Control

Table 2: Mean Values of Physicochemical Parameters of Water Samples in Jere LGA

Locations	Color (PtCo)	Turbidity (NTU)	pH	TDS (mg/l)	EC (us/cm)	Tempt. (0C)
Ngom DAC	0±0.0000	0.325±0.0028	8.12±0.0566	126±4.2426	251±3.5355	27.8±0.4243
Dal Zan	0±0.0000	0.109±0.0021	7.65±0.0919	80±4.9497	160±5.0711	28.5±0.2828
Ngom SAC	1±0.0000	0.199±0.0042	7.55±0.1131	105±2.8284	210±3.5355	28.4±0.3536
Old M	0±0.0000	0.252±0.0042	7.83±0.0990	342±0.0000	677±4.9497	28.2±0.2828
Mair DPS	0±0.0000	0.161±0.0028	7.64±0.0990	566±3.5355	1132±2.8284	28.2±0.1414
Dal AS	0±0.0000	0.096±0.0057	8.23±0.0778	105±2.1213	210±2.8284	28.4±0.1414
Ngom ACM	0±0.0000	0.194±0.0127	7.24±0.0566	142±3.5355	284±4.2426	28.5±0.2828
Masham PS	75±2.1213	0.191±0.0028	7.32±0.1273	471±6.3640	942±2.8284	28.5±0.3536
Farm C	0±0.0000	0.212±0.0028	7.81±0.0849	292±2.8284	586±4.9497	28.4±0.2121
Gal GY	2±0.7071	0.452±0.0064	7.07±0.0636	218±0.7071	436±4.2426	28.2±0.2121
Alau ARWP	3±0.7071	0.556±0.0035	7.87±0.0141	365±4.2426	730±5.6569	28.9±0.0707
Gal SB	0±0.0000	0.122±0.0021	7.24±0.0636	134±0.0000	269±1.4142	28.1±0.3536
Mari K PH	0±0.0000	0.165±0.0035	7.04±0.0283	612±2.8284	1223±3.5355	28.5±0.1414
Mair MPS	5±0.7071	0.596±0.0071	7.49±0.0495	87±2.8284	174±3.5355	28.2±0.3536
Buu TZ (CTL)	0±0.0000	0.083±0.0042	8.11±0.0707	507±3.5355	1014±4.9497	28.1±0.0707

Ngom DAC = Ngomari Delori Ajilari Cross, Dal Zan = Dala Zannari, Ngom SAC = Ngomari Sajeri Ajilari Cross, Old M = Old Maiduguri, Mair DPS = Mairi Distinction Pri. Sch., Dal AS = Dala Abuja Sheraton, Ngom ACM = Ngomari Ajilari Cross Main, Mash PS = Mashamari Pri. Sch., Farm C = Farm center, Gal GY = Galtimari Grave Yard, Alau ARWP = Alau Raw Water Pumping, Gal SB = Galtimari Solar Borehole, Mair KPH = Mairi Kuwait Prof House, Mair MPS = Mairi Maimusari Pri. Sch. and Buu TZ (CONTR) = Biu Tizea Control

Table 3: Mean Concentration of Heavy Metals in Water Samples MMC

Locations	As (mg/l)	Pb (mg/l)	Mn (m/l)	Cr mg/l)
Maf	0.0032±0.0001	0.0158±0.0003	0.3960±0.004	0.0800±0.0010
Gwg 1	0.0009±0.0000	0.0043±0.0001	0.1080±0.001	0.0220±0.0000
She N	0.0028±0.0001	0.0138±0.0002	0.3480±0.003	0.0700±0.0010
Bol 1	0.0016±0.0000	0.0082±0.0001	0.2070±0.002	0.0420±0.0000
Lim K	0.0032±0.0001	0.0159±0.0003	0.4000±0.004	0.0740±0.0010
Bul PHC	0.0048±0.0010	0.0241±0.0035	0.6100±0.045	0.1120±0.0080
Mais P	0.0005±0.0000	0.0026±0.0000	0.0650±0.001	0.0120±0.0000
Mais A	0.0006±0.0000	0.0029±0.0000	0.0730±0.001	0.0140±0.0000
Gamb CBH	0.0010±0.0000	0.0051±0.0001	0.1290±0.001	0.0240±0.0000
Lami F	0.0040±0.0001	0.0202±0.0003	0.5060±0.005	0.0930±0.0010
Gwag 2 PHC	0.0056±0.0001	0.0282±0.0004	0.7090±0.006	0.1300±0.0010
Hau Z MS	0.0157±0.0022	0.0781±0.0073	1.9520±0.092	0.3950±0.0190
Bol 2 APK	0.0021±0.0001	0.0107±0.0002	0.2680±0.003	0.0540±0.0010
Gwg 3 PS	0.0015±0.0000	0.0075±0.0001	0.1880±0.002	0.0630±0.0010
Fez M	0.0009±0.0000	0.0045±0.0001	0.1130±0.001	0.0380±0.0000
Sheh S IW	0.0006±0.0000	0.0029±0.0000	0.0720±0.001	0.0150±0.0000
Buu (CTL)	0.0023±0.0001	0.0115±0.0002	0.2880±0.003	0.0530±0.0010

Maf = Mafoni, Gwg 1 = Gwange 1, She N = Shehuri North, Bol 1 = Bolori 1, Lim K = Limanti Kariari, Bul PHC = Bulunkutu Pri. Health Care, Mais P = Maisandari Polo, Mais A = Maisandari Alajeri, Gamb CBH = Gamboru Community Borehole, Lam F = Lamisula Filatari, Gwag 2 = Gwange 2 Pri. Health Care, Hau Z MS = Hausari Zango Mala Kachalla Sch., Bol 2 = Bolori 2 Ali Pindar Kwajjafa, Gwag 3 PS = Gwange 3 Pri. Sch., Fez M = Fezzan Main, She S IW = Shehuri South Ibrahim Waziri and Buu TZ (CONTR) = Biu Tizea Control.

Table 4: Mean Concentration of Heavy Metals in Water Samples of Jere LGA

Locations	As (mg/l)	Pb (mg/l)	Mn (m/l)	Cr mg/l)
Ngom DAC	0.0005±0.0000	0.0026±0.0000	0.0660±0.0000	0.0220±0.0000
Dal Zan	0.0003±0.0000	0.0016±0.0000	0.0410±0.0000	0.0140±0.0000
Ngom SAC	0.0004±0.0000	0.0021±0.0000	0.0540±0.0000	0.0180±0.0000
Old M	0.0015±0.0000	0.0075±0.0001	0.1880±0.0020	0.0380±0.0000
Mair DPS	0.0025±0.0001	0.0125±0.0002	0.3150±0.0030	0.1060±0.0010
Dal AS	0.0005±0.0000	0.0023±0.0000	0.0570±0.0000	0.0190±0.0000
Ngom ACM	0.0006±0.0000	0.0029±0.0000	0.0730±0.0010	0.0250±0.0000
Masham PS	0.0022±0.0001	0.0111±0.0002	0.2790±0.0030	0.0570±0.0010
Farm C	0.0013±0.0000	0.0064±0.0001	0.1600±0.0020	0.0540±0.0010
Gal GY	0.0009±0.0000	0.0047±0.0001	0.1170±0.0010	0.0390±0.0000
Alau ARWP	0.0005±0.0000	0.0023±0.0000	0.0570±0.0000	0.0120±0.0000
Gal SB	0.0006±0.0000	0.0028±0.0000	0.0690±0.0010	0.0140±0.0000
Mari K PH	0.0027±0.0001	0.0137±0.0002	0.3440±0.0030	0.0700±0.0010
Mair MPS	0.0004±0.0000	0.0018±0.0000	0.0450±0.0000	0.0150±0.0000
Buu (CTL)	0.0023±0.0001	0.0115±0.0002	0.2880±0.0030	0.0530±0.0010

Ngom DAC = Ngomari Delori Ajilari Cross, Dal Zan = Dala Zannari, Ngom SAC = Ngomari Sajeri Ajilari Cross, Old M = Old Maiduguri, Mair DPS = Mairi Distinction Pri. Sch., Dal AS = Dala Abuja Sheraton, Ngom ACM = Ngomari Ajilari Cross Main, Mash PS = Mashamari Pri. Sch., Farm C = Farm center, Gal GY = Galtimari Grave Yard, Alau ARWP = Alau Raw Water Pumping, Gal SB = Galtimari Solar Borehole, Mair KPH = Mairi Kuwait Prof House, Mair MPS = Mairi Maimusari Pri. Sch. and Buu TZ (CONTR) = Biu Tizea Control

Figure 4.1 below shows the graphic presentation of physicochemical parameters of ground water samples in Maiduguri Metropolis. As observed, colour and turbidity in all sampled locations are so significant, while temperatures for all samples are within ambient, with mean value of 28.3 ^{0}C. The pH which had mean value of 7.4 is also not prominent in the chart. Electrical conductivity displayed the most prominent peak, with the highest value 3540 µs/cm (Hausari Zango). Total dissolved solid is next to EC, TDS is usually half the value of EC. TDS showed the highest peak of 1767 mg/l in the same Hausari Zango Ward. Biu being the control in the study showed 1014 µs/cm and 507 mg/l for EC and TDS respectively.

The graphical presentation of physicochemical results for Jere Local Government Area is quite different from that of Maiduguri Metropolis (Figure 4.2) below. Only one location displayed a peak in terms of colour, that is Mashamari Primary School, with a value of 75 PtCo. The whole samples showed very low turbidity, that is why there is no visible peak for turbidity.

Temperature values for Jere are similar to that obtained in MMC, with mean value of 28.3 ^{0}C. pH had mean value of 7.6 and is not visible in the chart.
Electrical conductivity, Total dissolved solids and Colour are the ones that displayed visible peaks. The highest peak in the chart, comes EC in Mairi Kuwait, with a value of 1223 µs/cm. the same Mairi Kuwait showed the highest peak for TDS with 612 mg/l.

Graphical presentation of heavy metals concentration in Maiduguri Metropolitan Council showed that, there is a very prominent peak for copper (Figure 4.3), in almost all the Wards, but the highest peak displayed in the chart is that of manganese in Hausari Ward. Biu the control, the as well as Limanti Kariari and Bulabulin Primary Health Care showed high peaks for copper and manganese respectively. In terms of Ward with highest concentration of heavy metals, Hausari Zango displayed the highest concentration of almost all the heavy metals. The order of concentration in terms of peak is in this order; Mn>Cr>Pb>As. Maisandari Ajelori showed least peaks, which invariably means location with least heavy metal contamination.

The graphical result of heavy metals in Jere Local Government Area as shown in Figure 4.4, revealed that copper peaks are more prominent. Almost all the study areas displayed varying concentrations of copper as can be seen in the figure. The next highly concentrated heavy metal is manganese and they occurred in this order; Mairi Kuwait>Mairi Distinction Primary School>Biu (Control)>Old Maiduguri>Mashamari Primary School>Old Maiduguri>Farm Centre>Galtimari Grave Yard>Ngomari Ajilari Cross Main>Galtimari Solar Borehole>Ngomari Dala Delori Ajilari Cross>Dala Abuja Sheraton>Alau Raw Water Pumping Station>Mairi Maimusari Primary School. Mairi Kuwait displayed highest peak for heavy metals, in the entire Jere Ward, while Dala Zannari indicated lowest peaks for heavy metals.

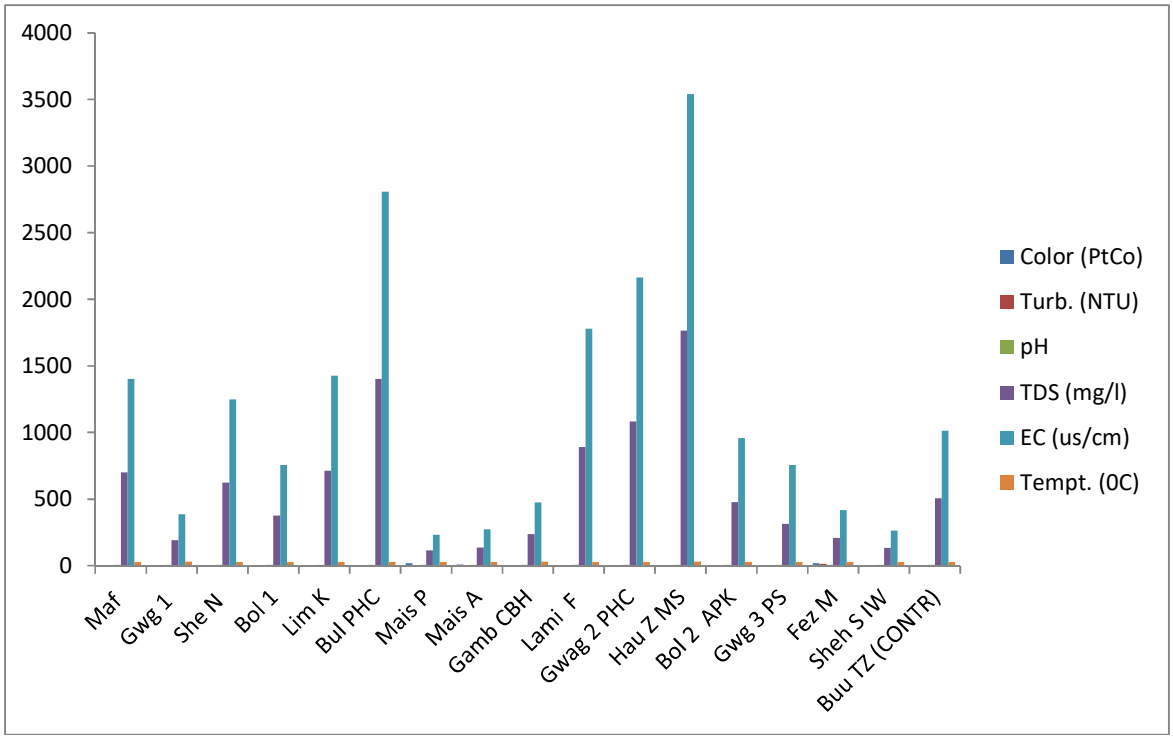

Figure 1: Variation of Physicochemical Parameters in Water Samples of MMC.

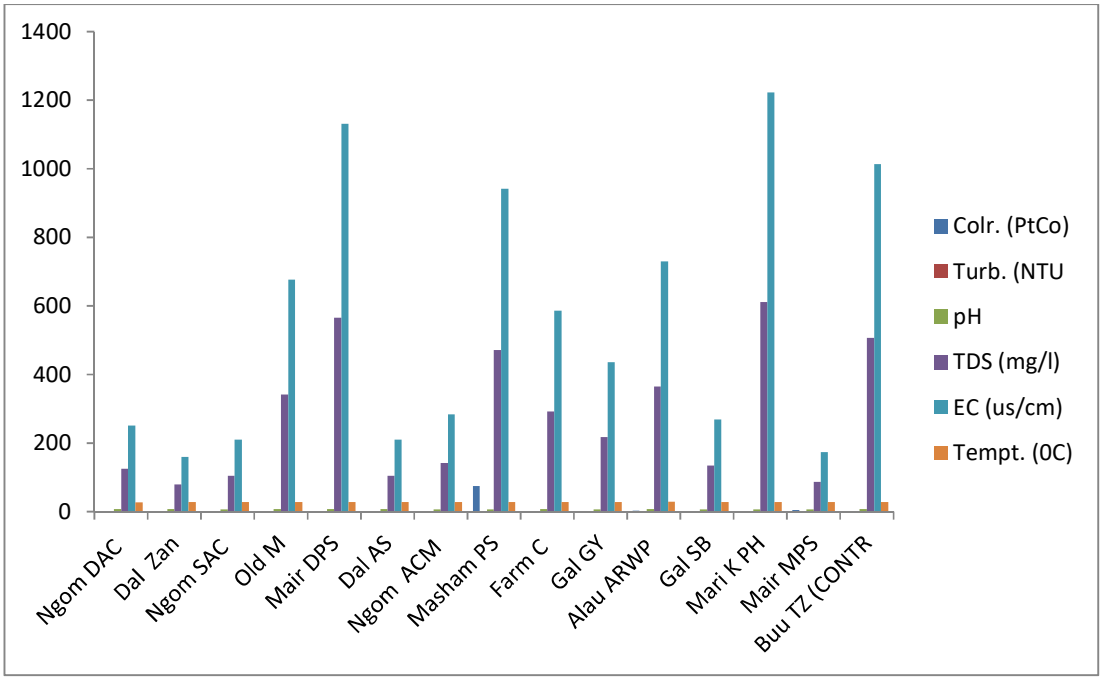

Figure .2: Variation of Physicochemical Parameters in Water Samples of Jere LGA

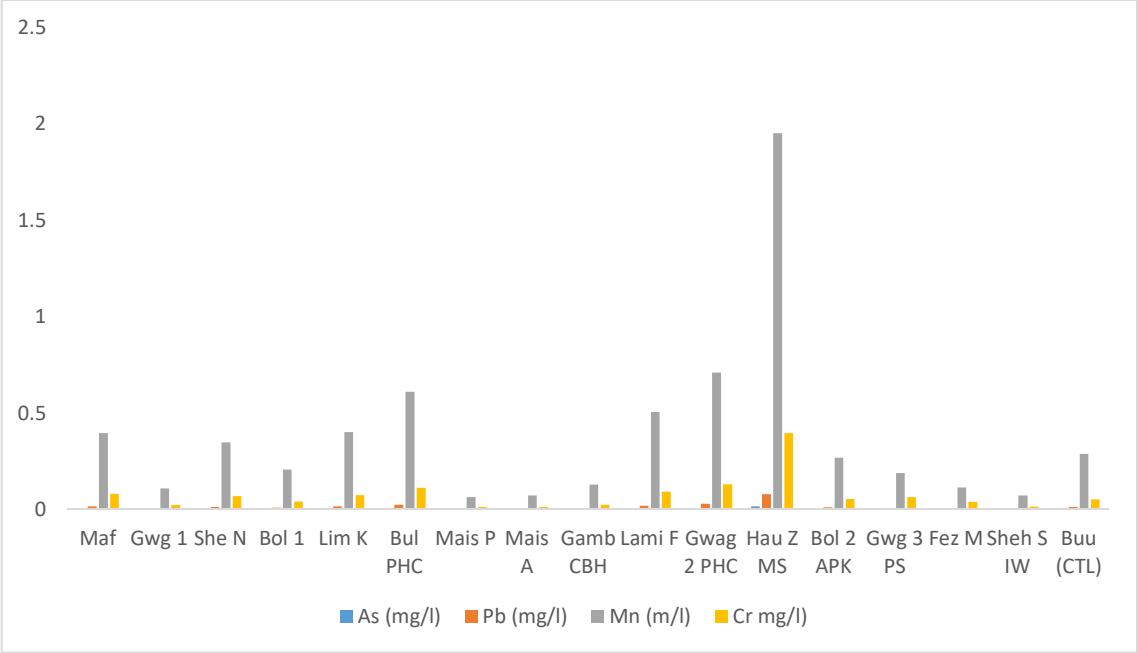

Figure 3: Variation of Heavy Metals in Water Samples of MMC

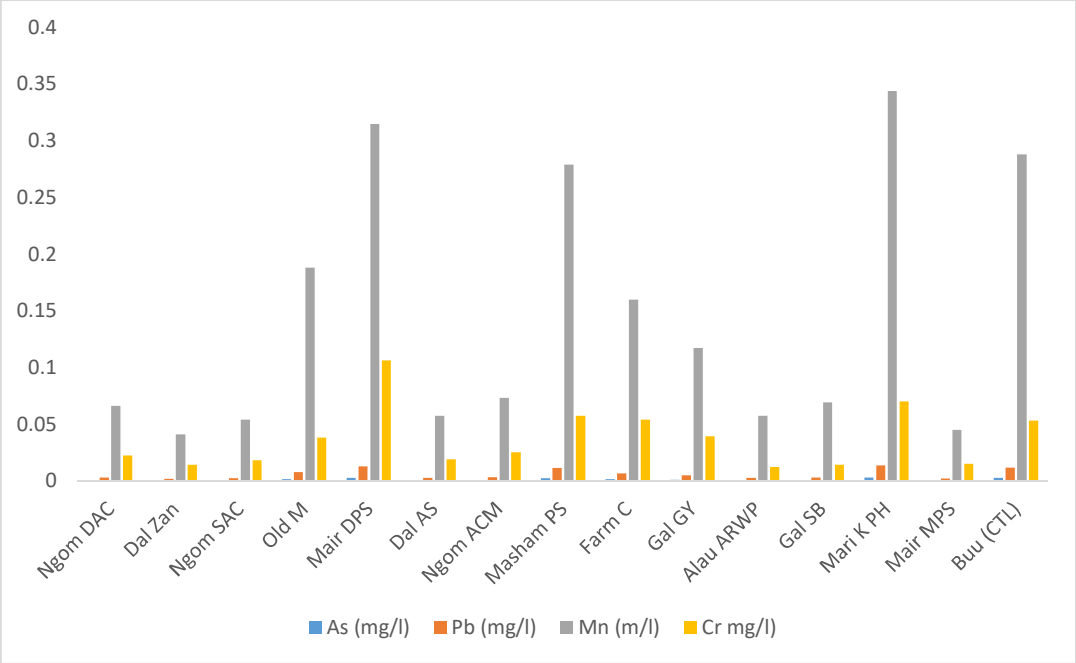

Figure 4: Variation of Heavy Metals in Water Samples of Jere LGA

Conclusion

The results from the investigation of water samples in Maiduguri Metropolis and Jere Local Government Areas of Borno state, reveals that there is significant health risk associated with few locations with regards to heavy metal contamination. Heavy metals like Manganese was found to be in very high concentration of up to 1.9520 ppm in Hausa Zango ward of the Metropolis, while Gwange 2 had 0.7090 ppm. Biu being the control recorded 0.6100 ppm. Jere Local Government Area recorded its high manganese value in Mairi K PH, this elevated concentration of manganese in those particular locations can make vulnerable groups such as children and infants to be affected, as manganese is known to have neurological effect on humans. The amount of Chromium in this study showed that chromium exceeded the WHO guideline. Chromium in Hausari Zango ward had the highest concentration of 0.3950 and that is followed by Gwange 2 with a concentration of 0.1300 ppm. The World Health Organization permissible level shows that, there is compromise in water quality of those areas (WHO, 2006).

References

1. Abdel-Rahman G.N., Ahmed M.B.M., Sabry B.A. and S.S.M. (2019). Heavy Metals Content in Some Non-alcoholic Beverages (Carbonated Drinks, Flavored Yogurt Drinks, and Juice Drinks) of the Egyptian Markets. *Toxicology Reports* 25; 6:210-214. doi: 10.1016/j.toxrep.2019.02.010
2. Ajiboye, Y., Isinkaye, M. O., Badmus, G. O., Faloye, O. T., & Atoiki, V. (2022). Pilot groundwater radon mapping and the assessment of health risk from heavy metals in drinking water of southwest, Nigeria. Heliyon, 8(2), e08840. https://doi.org/10.1016/j.heliyon.2022.e08840

3. Bamuwuwamye M, P. Ogwok, V. Tumuhairwe, R. Eragu, H. Nakisozi, P. E. Ogwang (2017). Human Health Risk Assessment of Heavy Metals in Kampala (Uganda) Drinking Water. *Journal of Food Research,* Vol. 6, No. 4; ISSN 1927-0887 E-ISSN 1927-0895.
4. Borno State Diary, (2007).
5. Dankawu, U. M., Shuaibu, H. Y., Maharaz, M. N., Zangina, T., Lariski, F. M., Ahmadu, M., Zarma, S. S., Benedict, J. N., Uzair, M., Adamu, G. D., & Yakubu, A. (2022). Estimation of excess life cancer risk and annual effective dose for boreholes and well water in Dutse, Jigawa State Nigeria. Dutse Journal of Pure and Applied Sciences, 7(4a), 209–218. https://doi.org/10.4314/dujopas.v7i4a.22
6. Faweya, E. B., Olowomofe, O. G., Akande, H. T., & Adewumi, T. A. (2018). Radon emanation and heavy-metals assessment of historical warm and cold springs in Nigeria using different matrices. Environmental Systems Research, 7(1). https://doi.org/10.1186/s40068-018-0125-x
7. Jimme M.A., Bukar W.M. and Monguno A.K. (2016). Contamination Levels of Domestic Water Sources in Maiduguri Metropolis, Borno State, Northeast, Nigeria. *Ethiopian Journal of Environmental Studies and Management,* 9(6): 760 – 768, ISSN:1998-0507. doi: http://dx.doi.org/10.4314/ejesm.v9i6.8.
8. Jones, I., D. N. Lerner and O. P. Baines. (1999). Multiple sock samplers: A Low - Cost Technology for Effective Multilevel Groundwater Sampling. *Ground Water Monitoring and Remediation*, 19 (1), 134 - 142. doi: 10.1111/j.1745-6592.1999.tb00197.x.
9. Limgri, 2019
10. Mshelia Y. M., Lawan M. D., Arhyel M. and Inuwa J. (2023). Physicochemical Analysis and Water Quality Assessment of Selected Location in Maiduguri Metropolis Using Weighted Arithmetic Water Quality Index. FUDMA Journal of Sciences, 7(4), 147-151.
11. Nastasescu V., M. Mititelu, M. Goumenou, A.O. Docea, E. Renieri, D.I. Udeanu, E. Oprea, A.L. Arsene, C.E. Dinu-Pîrvu, and Ghica M. (2020). Heavy Metal and Pesticide levels in Dairy Products: Evaluation of Human Health Risk. *Food and Chemical Toxicology*, 146, 111844
12. NSDWQ. (2007). Nigerian Standard for Drinking Water Quality. vol. NIS, 554, 15-22.
13. USGS, (2016), water.usgs.gov/edu/groundwater-contaminants.html.
14. Usman M., Farooq M., Wakeel A., Nawaz A., Cheema S. A., Rehman H., ur Ashraf I. and Sanaullah, M. (2020). Nanotechnology in Agriculture: Current Status, Challenges and Future Opportunities. *Science of the Total Environment*, 721, 137778. doi: 10.1016/j.scitotenv.2020.137778.
15. Usman, R., Mohammed, I. M., & Ubaidullah, A. (2023). Health Implication Of The Accumulation Of Heavy Metals Concentration In Ara And Laminga Water Sources Of Nasararawa Local Government Area In Nasarawa State https://www.researchgate.net/publication/356818726
16. WHO (2006), Guideline Standard for Drinking Water Quality.