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# Concentration and Comparison of Groundwater Quality in Kano Metropolis, Nigeria

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**ABSTRACT:** *The paper examined the concentrations of heavy metals and microbial parameters in groundwater and were compared to World Health Organisation (WHO)guidelines and National Standard for Drinking Water Quality standard. A total of 800 boreholes and wells water samples were purposefully and systematically collected in the metropolis and subjected to laboratory analysis where mean concentration values of Cadmium, Chromium, Zinc, Iron, Lead, Mercury, Arsenic, Copper, Manganese, Total Coliform count and Escherichia coli were determined in line with APHA 1998 standard procedures. The T- test statistical analysis, $p<0.05$ results showed that there were high and low significant variations between the concentrations values of heavy metals with WHO and NSDWQ permissible limits especially during wet season while microbial parameters only showed high significant variations except Zinc, Mercury, and Arsenic recorded no significant differences. The study therefore drew inference that wastewater and geomorphic processes contribute significantly to groundwater contaminations in the metropolis and recommends public education and enlightenment, strong legislation, provision of standard water treatment plants, adoption sustainable environmental concepts, attitudinal change, good drainage system should strictly be adhered to in order to harness good drinkable water potentials.*

**KEYWORDS**: Wastewater, heavy metals, groundwater, infiltration and concentration

## INTRODUCTION

Water is one of the necessities of life and needed for various processes in the ecosystem as well as the environment at large. It counts among the most widely distributed vital substances over the globe which is very imperative in the maintenance of human health, general well-being, proper functioning and development of communities (United Nations International Children Emergency Fund (UNICEF, 2017). The saying ‘‘water is life’’ is not a vague statement but germane, for lives regulate around it as no living thing can exist without it (Benjamin and Eziashi, 2017). Despite the numerous uses of water, it is pertinent to note that its distribution across the world is uneven and varies in quantity and quality. Some places have it in abundance while others do not. However, it is sad to note that many of the places that have it in abundance did not give necessary accord to secure it from being polluted, mostly by human actions (Lekan, 2019; UN Waters, 2015).

Groundwater is the second largest available reservoir of fresh water on the earth which is about 20% and form about 0.59% of the total world's oceans, seas and permanent ice. It is widely the main sources of drinking water in the world especially in the less developed nations and contribute significantly to industrial, agricultural and domestic services, sustenance of biodiversity as well as human life (Corcoran, *et al*. 2010). Despite its significance to lives Mshelia *et al*. (2020), posits that man through multifarious activities despite the feasible significant health effects has continued to pose threats to quality of water and largely to the environment.

United Nations Water (UN Waters 2015) reported that about 2.2 billion human beings all over the globe do not have clean drinkable water and of the figure, 785 million people do not have access to a basic water service. Similarly, in Africa, about 44% of the estimate populations do not have access to clean and reliable water supplies (WHO, 2015; United Nations, 2015; Corcoran *et al*. 2010) as well as in developing countries. In Nigeria, the situation is not different as about 64% out of the projected population of about 212 million in 2021 do not have access to good and portable drinkable water (UNESCO, 2016). This is as result of the fact that very many of the sources of water meant for drinking and other domestic uses have been polluted by anthropogenic activities or geological formations processes; a situation which has made the water resources to be inadequate even in places where it is considered to be abundance in nature over the globe (Global Water Security, 2012; Mshelia and Mbaya, 2022; Kankara, 2019).

The activities of man over the globe along with natural factors cause water pollution. Contamination of groundwater with industrial effluents, domestic wastewater, heavy metals such as arsenic, fluoride, chromium, mercury and nitrate among others pose serious health risks, depletion and devalue of water recourse and hit back at human. Hence, the study on the concentrations and comparisons of contaminants in groundwater quality being used by many for drinking to ascertain the water quality (Crossland *et.al.* 2005; Global Water Security, 2012; WHO, 2010).

## MATERIAL AND METHODS

This section deals with the location of the study area, methods and materials employed during the survey.

### Location of the Study Area

Kano Metropolis exist on latitudes $11^0$ 55′ 23.93″N and $12^0$ 3′ 53.10″N of the Equator and longitude $8^0$ 27′ 42.26″E to $8^0$ 36′ 41.62″E of the Greenwich Meridian (Figure 1:1). The metropolis is made up of eight local government areas each acting as a council habiting a total of $499Km^2$ as land mass with 2022 projected population is 4,219,209 at growth rate of 2.8% (UN-World Population Review, 2022). It arguably the largest centre of commerce and industry in Norther Nigeria.

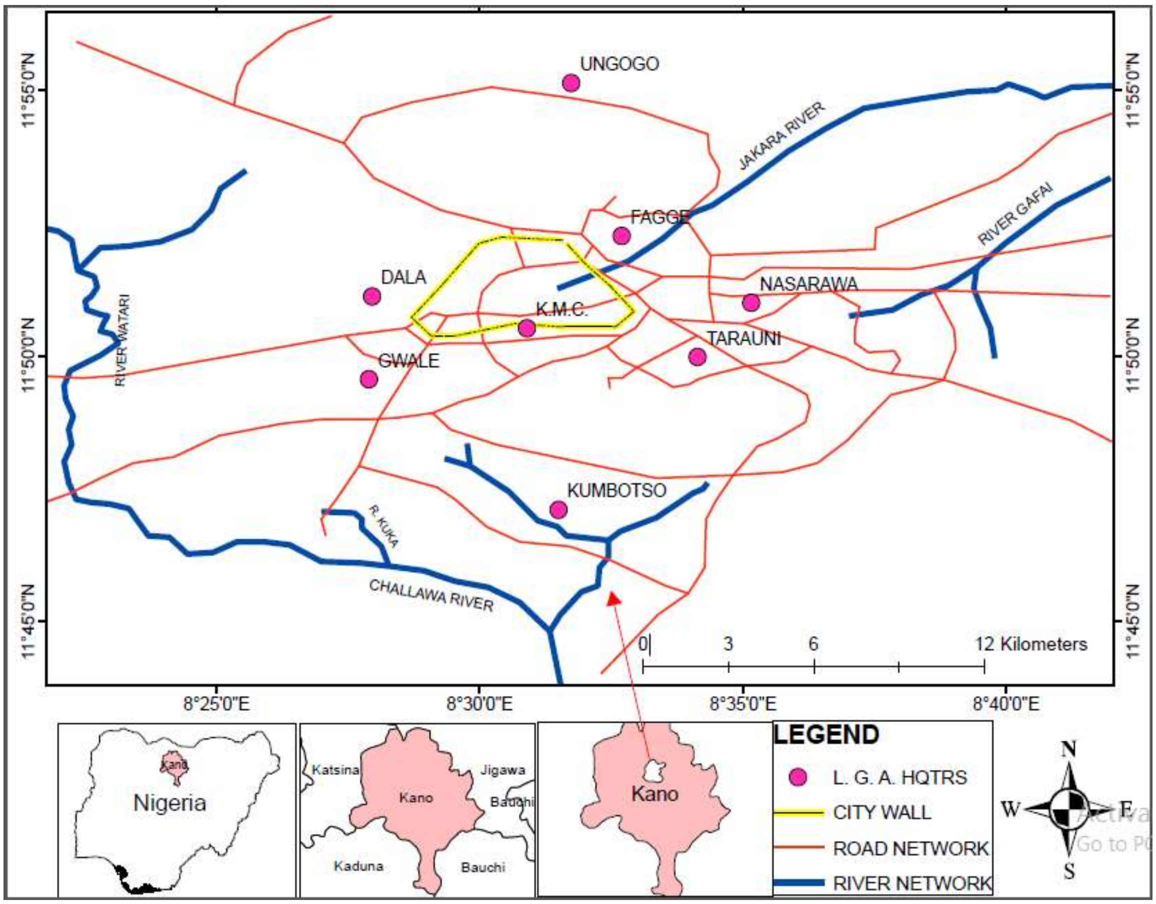


Figure 1.1: Kano Metropolis
Source: Cartography and GIS Unit Kaduna Polytechnic (2019)

**Weather and Climate**

Kano metropolis experienced tropical climate with different in nature with differing seasonal mechanisms that changes from hot to cool as well as from humid to wet. It has an average mean temperature range of 26 – $42^0$C (Ahmed, 2012). The wet period is from May to September having an average annual rainfall of 7000mm while dry season is usually from October – April.

**Sample Collection**

Eight hundred borehole and well water samples in the eight Local Government Areas (LGA) of the metropolis (Kano Municipal Council, Fagge, Dala, Gwale, Tarauni, Nasarawa, Ungogo and Kumbotso) were systematically collected during wet and dry seasons in the metropolis and taken to laboratory for determination of the concentrations of heavy metals in drinking water permissible limits stipulated by WHO guidelines and NSDWQ standard in accordance to American Public Health Association (APHA, 1998) standards and procedures at Chemistry Laboratory, Bayero University Kano. The mean concentration of heavy metals: Chromium, Arsenic, Mercury, Zinc, Lead and Iron at each point was recorded.

Using descriptive and inferential statistics of T-Test statistics analysis the concentrations values were pared with the WHO and NSDWQ standards to find out if there were significant or non-significant variations between each parameter with the WHO and NSDWQ permissible limits. This was achieved by arranging the values of the parameters analysed in the laboratory tabular form (at 0.05% confidence level).

Formula

$$T = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1{}^2}{n_1} + \frac{s_1{}^2}{n_2}}}$$

$S_1$ = standard deviation of first sets of values

$S_2$ = standards deviation of second sets of values

$n_1$ = standard deviation of first sets of values

$n_2$ = standard deviation of second sets of values

**RESULT AND DISCUSSION**

Results obtained from the laboratory analyses of the heavy metals and microbial parameters were compared with WHO and NSDWQ permissible limits and discussed as presented on Table 3.1, 3.2 and 3.3.

**Concentrations and Comparisons of Heavy Metals in Groundwater in Kano Metropolis.**

The concentrations of heavy metals were determined through laboratory analyses and compared to WHO and NSDWQ drinking water permissible limits for substantial and statistical variations in boreholes and well water during wet and dry seasons (Table 3.1). The mean concentration of Cadmium (Cd), Chromium (Cr) and Mercury (Hg) in borehole water at urban centre (UC) ranged from 0.04 – 0.25mg/L, 0.82 – 4.40mg/L and 0.001 – 0.012mg/L respectively in wet season while the dry season recorded Cd mean concentrations within ranges of 0.01 – 0.23mg/L, Cr of 0.65 – 1.01mg/L and 0.001 – 0.002mg/L of Hg. All Cd, Cr and Hg in boreholes during wet season measured above WHO and NSDWQ permissible limits as shown on Table 3.2 attributable to high seepages of industrial and domestic wastewater as also reported by Mshelia et al. (2021).

However, during the dry season Cd in BH8 in Ungogo, Hg in BH1, 2, 5 and 8 recorded 0.001mg/L fall within the permissible levels. Amoo *et al.* (2018) reported similar Cd results of 0.04 - 0.26mg/L and 0.002 - 0.31mg/L in three wells randomly selected at Sharada Industrial Area in Kano. Oyeku and Eludoyin (2010) also reported Cr concentration of 0.45 – 0.78mg/L in Marc Report No. 21. In the same vein, the results of Hg in this study is in line with the work of Sankhla *et al.* (2016) who investigated heavy metals contamination in water and their hazardous effect on human health in Bompai area of Kano metropolis.

Similar trends were observed in well water. Mean concentrations ranged of 0.009 – 0.015mg/L of Cd, 0.56 – 5.11mg/L of Cr and 0.001 – 0.052mg/L of Hg during wet season while Cd of 0.005 – 0.015mg/L, Cr of 0.54 – 3.38mg/L and 0.001 – 0.005mg/L of Hg during dry season. All concentrations of the three parameters were determined above the permissible limits except Hg of 0.001 in W2 at Fagge while during the dry season Hg in W2, 3 and 5 were found to be within the thresholds of 0.001mg/L as shown on Table 3.2. Furthermore, the T-test between the mean Cd value during wet and dry seasons and the NSDWQ (2015) standard $(t\ (39) = 2.67,\ p < 0.05)$ and $(t\ (39) = 0.82,\ p < 0.05)$ respectively which shows significant differences to NSDWQ (2015). Cr recorded $(t(39)= -1.32,\ p < 0.05)$ and $(t(39)= 0.93,\ p < 0.05)$ which statistically shows significant differences to NSDWQ (2015) standard while Hg measured $(t(39)= -1.99,\ p < 0.05)$ and $(t(39)= 1.91,\ p < 0.05)$ respectively which statistically shows significant difference during wet season but no significant difference in dry season to the NSDWQ (2015) standard ascribed to low seepages.

Similarly, the mean concentration of Arsenic (As), Lead (Pb) and Iron (Fe) in borehole water at urban centre (UC) during wet season ranged 0.01 – 1.64mg/L, 0.027 – 0.45mg/L and 0.2 – 1.31mg/L respectively while 0.01 - 0.03mg/L of As, 0.017 – 0.35mg/L of Pb and 0.38 – 3.75mg/L of Fe in dry season. Mean As in BH at Fagge, Kombotso and Tarauni fall within the limit, only Pb concentrations in Fagge and Fe in Dala and KMC measured above the threshold level of 0.03mg/L stated by WHO and NSDWQ (Table 3.1). Additionally, Table 5.10 shows As, Pb and Fe mean concentrations ranged from 0.01 – 0.08mg/L, 0.15 – 0.32mg/L and 0.21 – 2.62mg/L respectively in wet season in well water while the dry season recorded As mean concentration ranged of 0.01 – 0.07mg/L, Pb of 0.01 – 0.40mg/L and 2.01 – 3.10mg/L of Fe. As concentrations except in W7 fall above the limits of 0.01m/L while all well values of Pb and Fe measured within the thresholds of 0.3mg/L by WHO and NSDWQ except W6, 7 and 8 of Fe during wet season. During dry season, W4 and W8 of 0.02mg/L and W1 and W2 of 0.015mg/L fall above and slightly above the expected limit of 0.01mg/L while Pb and Fe concentrations fall within the permissible limit except Pb in W3 and W4.

The findings agreed with the values of 0.029mg/L to 0.45mg/L and 0.03 – 0.38mg/L reported by Begum *et al.* (2009) who studied heavy metals pollution of Cauvery River Water in India and attributed to wastewater infiltrations. Furthermore, the paired T-test between the mean As value

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during wet and dry seasons and the NSDWQ (2015) standard *(t(39)= 1.99, p < 0.05)* and *(t(39)= 1.83, p < 0.05)* respectively which statistically shows significant differences to the NSDWQ (2015) standard. Pb NSDWQ (2015) standard *(t(39)= 2.79, p < 0.05)* and *(t(39)= 0.94, p < 0.05)* respectively which statistically shows significant differences to the NSDWQ (2015) standard while Fe reported *(t(39)= 3.06 p < 0.05)* and *(t(39)= 1.88, p < 0.05)* which statistically shows significant difference during the wet period but shows no significant difference to NSDWQ (2015) standard. Similar trends were also observed in Zinc (Zn), Copper (Cu) and Manganese (Mn) in borehole and wells. The mean concentrations ranged 0.54 – 4.40mg/L of Zn, 1.00 – 5.63mg/L of Cu, 0.11 – 3.03mg/L of Mn and 0.54 – 2.81mg/L of Zn, 0.15 – 2.30mg/L of Cu, 0.21 – 2.45mg/L during wet and dry seasons respectively while well water ranged Zn of 2.34 – 5.62mg/L, Cu of 1.00 – 5.12mg/L, 0.77 – 4.10mg/L of Mn and Zn of 1.12 – 2.52mg/L, 0.03 – 2.03mg/L of Cu, 0.042 - 5.07mg/L of Mn in wet season and dry periods respectively (Table 3.1).

Table 3.1: Borehole Mean Concentration of Heavy Metals at Urban Centres in Kano Metropolis during Wet and Dry Seasons.

| | Dala | Fagge | Gwale | KMC | Kumbotso | Nasarawa | Tarauni | Ungogo | WHO (2010) | NSDWQ (2015) |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | BH1 | BH2 | BH3 | BH4 | BH5 | BH6 | BH7 | BH8 | | |
| **BH Urban WS** | | | | | | | | | | |
| Cadmium (mg/L) | 0.05 | 0.05 | 0.08 | 0.04 | 0.082 | 0.015 | 0.08 | 0.25 | 0.003 | 0.003 |
| Chromium(mg/L) | 0.95 | 4.4 | 1.01 | 0.95 | 1.25 | 1.17 | 0.82 | 1.25 | 0.05 | 0.05 |
| Mercury (mg/L) | 0.002 | .011 | 0.005 | 0.002 | 0.001 | 0.012 | 0.003 | 0.001 | 0.001 | 0.001 |
| Arsenic (mg/L) | 1,64 | 0.03 | 0.04 | 0.12 | 0.02 | 0.08 | 0.01 | 0.12 | 0.01 | 0.01 |
| Lead (mg/L) | 0.15 | 0.45 | 0.26 | 0.12 | 0.31 | 0.027 | 0.05 | 0.06 | 0.3 | 0.3 |
| Iron (mg/L) | 1.31 | 0.2 | 0.4 | 1.25 | 0.34 | 0.30 | 0.3 | 0.18 | 0.3 | 0.3 |
| Zinc (mg/L) | 3.2 | 4.4 | 2.45 | 3.0 | 1.65 | 3.75 | 4.3 | 0.54 | 3.0 | 3.0 |
| Copper (mg/L) | 4.72 | 5.63 | 2.45 | 3.55 | 2.32 | 1.83 | 2.92 | 1.0 | 2.0 | 1.0 |
| Manganese(mg/L) | 0.56 | 0.40 | 0.11 | 0.54 | 0.54 | 0.75 | 3.03 | 0.35 | 0.5 | 0.2 |
| **BH Urban DS** | | | | | | | | | | |
| Cadmium (mg/L) | 0.05 | 0.04 | 0.09 | 0.01 | 0.015 | 0.23 | 0.05 | 0.003 | 0.003 | 0.003 |
| Chromium(mg/L) | 0.81 | 1.01 | 0.65 | 0.81 | 0.88 | 0.68 | 0.81 | 0.96 | 0.5 | 0.5 |
| Mercury (mg/L) | 0.001 | .001 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 |
| Arsenic (mg/L) | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 |
| Lead (mg/L) | 0.11 | 0.02 | 0.02 | 0.017 | 0.35 | 0.02 | 0.02 | 0.16 | 0.3 | 0.3 |
| Iron (mg/L) | 3.01 | 2.13 | 1.35 | 3.75 | 1.34 | 2.69 | 2.78 | 0.38 | 0.3 | 0.3 |
| Zinc (mg/L) | 2.81 | 2.53 | 1.68 | 2.13 | 0.74 | 1.62 | 2.54 | 0.54 | 3.0 | 3.0 |
| Copper (mg/L) | 1.12 | 2.30 | 0.15 | 1.52 | 1.14 | 0.57 | 0.81 | 1.01 | 2.0 | 1.0 |
| Manganese(mg/L) | 0.45 | 0.51 | 0.21 | 0.21 | 0.47 | 0.22 | 2.45 | 0.49 | 0.5 | 0.2 |

BH= Borehole, WS= Wet Season, DS= Dry Season
Source: Field Survey, (2021).

Greater concentrations were recorded in BH2, 6 and 7 at Fagge, Nasarawa and Tarauni respectively. All Cu concentrations except BH8 Ungogo and all values in Mn of 1.0mg/L fall above the stipulated limits by NSDWQ (2015) during wet period ascribed to high seepages and runoff of wastewater. Reversed is the case during dry season where values fall within the limits (Table 5.9). However, few boreholes were found to be within the WHO level of 2.0mmg/L.

In well water, most of the determined concentrations measured above the permissible limits (Table 3.2), ascribed to high infiltrations, low buffers, and locations of the most of the well along water canals and soakaway. These results are in agreement to the studies carried out by Casimir *et al.* (2015) in Kaltungo, Gombe on heavy metals concentration and recorded Zn within the range of 0.73 - 3.670mg/L in wet season and 2.31 – 4.10mg/L in dry season.

Table 3.2: Well Mean Concentration of Heavy Metals at Urban Centre in Kano Metropolis in Wet Season

| | Dala | Fagge | Gwale | KMC | Kumbo tso | Nasar awa | Tarau ni | Ungo go | WHO (2010) | NSDW Q (2015) |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | | |
| **W Urban WS** | | | | | | | | | | |
| Cadmium (mg/L) | 0.009 | 0.009 | 0.012 | 0.015 | 0.012 | 0.009 | 0.009 | 0.010 | 0.003 | 0.003 |
| Chromium(mg/L) | 1.72 | 5.11 | 2.62 | 1.61 | 0.75 | 3.42 | 2.51 | 0.56 | 0.05 | 0.05 |
| Mercury (mg/L) | 0.004 | 0.001 | 0.002 | 0.0113 | 0.004 | 0.004 | 0.012 | 0.052 | 0.001 | 0.001 |
| Arsenic (mg/L) | 0.04 | 0.015 | 0.05 | 0.08 | 0.04 | 0.06 | 0.01 | 0.02 | 0.01 | 0.01 |
| Lead (mg/L) | 0.32 | 0.3 | 0.21 | 0.23 | 0.25 | 0.22 | 0.15 | 0.28 | 0.3 | 0.3 |
| Iron (mg/L) | 2.62 | 1.50 | 0.55 | 1.85 | 0.5 | 0.4 | 0.4 | 0.21 | 0.3 | 0.3 |
| Zinc (mg/L) | 4.18 | 3.11 | 3.00 | 3.74 | 3.25 | 5.62 | 5.12 | 2.34 | 3.0 | 3.0 |
| Copper (mg/L) | 5.12 | 2.54 | 4.11 | 4.23 | 2.98 | 1.30 | 2.10 | 1.0 | 2.0 | 1.0 |
| Manganese(mg/L) | 1.38 | 0.97 | 1.00 | 0.77 | 0.98 | 0.86 | 4.10 | 1.0 | 0.5 | 0.2 |
| **W Urban DS** | | | | | | | | | | |
| Cadmium (mg/L) | 0.005 | 0.01 | 0.015 | 0.009 | 0.012 | 0.008 | 0.006 | 0.01 | 0.003 | 0.003 |
| Chromium(mg/L) | 0.54 | 3.38 | 0.78 | 0.65 | 0.55 | 0.90 | 0.73 | 0.66 | 0.05 | 0.05 |
| Mercury (mg/L) | 0.003 | 0.001 | 0.001 | 0.002 | 0.001 | 0.005 | 0.003 | 0.002 | 0.001 | 0.001 |
| Arsenic (mg/L) | 0.015 | 0.003 | 0.07 | 0.02 | 0.015 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 |
| Lead (mg/L) | 0.03 | 0.01 | 0.4 | 0.03 | 0.04 | 0.02 | 0.015 | 0.2 | 0.3 | 0.3 |
| Iron (mg/L) | 2.40 | 3.1 | 2.15 | 2.15 | 2.34 | 2.32 | 2.05 | 2.01 | 0.3 | 0.3 |
| Zinc (mg/L) | 2.48 | 1.53 | 1.25 | 1.50 | 1.44 | 2.52 | 2.54 | 1.12 | 3.0 | 3.0 |
| Copper (mg/L) | 2.03 | 0.56 | 2.15 | 1.25 | 1.00 | 0.30 | 1.20 | 0.45 | 2.0 | 1.0 |
| Manganese(mg/L) | 0.75 | 0.11 | 0.01 | 0.12 | 0.22 | 0.042 | 5.07 | 0.31 | 0.5 | 0.2 |

W= Well, WS= Wet Season, DS= Dry Season
Source: Field Survey, (2021).

Furthermore, the paired samples T-test between the mean Zn value during wet and dry seasons and the NSDWQ (2015) standard as *($t(39)= 1.50$, $p < 0.05$)* and *($t(39)= 0.88$, $p < 0.05$)* respectively which statistically shows no significant difference during wet season but significant difference in dry season to the NSDWQ (2015) standard. Cu values recorded *($t(39)= -1.50$, $p < 0.05$)* and *($t(39)= 0.92$, $p < 0.05$)* respectively which statistically shows significant difference to the NSDWQ standard while the Mn concentrations recorded *($t(39)= -.78$, $p < 0.05$)* and *($t(39)= -.20$, $p < 0.05$)* respectively and statistically shows no significant differences to the NSDWQ (2015) standard.

**Concentration and Comparison of Microbiological Parameter in Groundwater**

Total coliform count (TCC) group and Escherichia coliform (E. coli) group were determined. The result of each parameter shows the concentration values as on Tables 3.3. The TCC and E.Coli mean ranged concentrations of borehole from 54 - 122cfu/100ml, 21 – 97cfu/100ml and 43 – 198cfu/ml, 27 – 132cfu/100ml respectively during wet and dry seasons as shown on Table 3.3 while the well water recorded TCC of 72 - 176cfu/100ml, E.coli 52 – 203 cfu/100ml in wet season and 34 - 132cfu/100ml of TCC, 34 - 170 cfu/100ml of E.coli during dry season. All values determined in borehole and well water fall very high above the permissible limit of 10cfu/100ml of TCC and 0.00cfu/100ml of E.coli given by WHO (2010) and NSDWQ (2015) respectively. Findings also showed that most boreholes and well located close to soakaways, pit latrines, wastewater canals and places common to open defecation (Plate 1 and 2) as in BH3, 4 and 8 in Gwale, KMC and Ungogo in wet season as well as BH 2, 3, and 6 during dry period. W3, 4, 6 and 8 in wet season and W3, 4 and 5 during dry season recorded high concentrations of TCC and E.coli as shown on Table 3.3.

Choudhury *et al*. (2016) who studied physicochemical and microbiological analyses of Bahini River Water of Guwahati, India (2017) also reported E.coli values of 64 – 211cfu/100ml and 43 – 169cfu/100ml during wet and dry seasons respectively. Furthermore, paired samples T-test between the mean TC value during wet and dry seasons and the NSDWQ (2015) standard *($t (39) = -8.267$, $p < 0.05$)* and *($t (39) = 1.45$, $p < 0.05$)* respectively which statistically shows significant differences to the NSDWQ (2015) standard while E.coli reported *($t(39)= -943$, $p < 0.05$)* and *($t(39)= -8.77$, $p < 0.05$)* statistically shows significant differences to the NSDWQ (2015) standard.

Table 3.3: Borehole and Well Mean Concentration of Microbial Parameters in Urban Centres of Kano Metropolis during Wet abd Dry Seasons

| | Dala | Fagge | Gwale | KMC | Kumb otso | Nasar awa | Tarau ni | Ungo go | WHO (2010) | NSDWQ (2015) |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | BH1 | BH2 | BH3 | BH4 | BH5 | BH6 | BH7 | BH8 | | |
| **BH Urban WS** | | | | | | | | | | |
| TC (cfu/100ml) | 68 | 56 | 122 | 96 | 75 | 55 | 54 | 78 | 10 | 10 |
| E-coli (cfu/100ml) | 43 | 65 | 198 | 120 | 54 | 94 | 55 | 122 | 0 | 0 |
| **BH Urban DS** | | | | | | | | | | |
| TC (cfu/100ml) | 32 | 66 | 97 | 52 | 25 | 75 | 21 | 22 | 10 | 10 |
| E-coli (cfu/100ml) | 27 | 132 | 129 | 70 | 83 | 118 | 55 | 21 | 0 | 0 |
| **W Urban WS** | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | | |
| TC (cfu/100ml) | 76 | 76 | 142 | 176 | 94 | 104 | 72 | 110 | 10 | 10 |
| E-coli (cfu/100ml) | 52 | 70 | 145 | 203 | 64 | 82 | 186 | 65 | 0 | 0 |
| **W Urban DS** | | | | | | | | | | |
| TC (cfu/100ml) | 46 | 45 | 96 | 132 | 127 | 89 | 62 | 34 | 10 | 10 |
| E-coli (cfu/100ml) | 34 | 46 | 105 | 170 | 34 | 54 | 73 | 61 | 0 | 0 |

BH= Borehole; WS= Wet Season; DS= Dry Season; W= Well
Source: Field Survey, (2021).

Plate 1: Well located close to toilet at Danagundi place
Source: Field Survey, (2020).

Plate 2: Well located at filthy (Defecated) at Konan Freedom, Sharada
Source: Field Survey, (2020).

Based on the various laboratory determinations of heavy metals and microbiological parameters, it can be deduced that most of the wells and boreholes at the effluent location are polluted and unfit for drinking. Findings also showed that the elevated levels of the parameters measured higher than the WHO and NSDWQ acceptable levels are attributed to seepages, leachates, inflow of wastewater into the soil profile, rivers, groundwater and ponds especially during wet season which often experience greater inflow during rainy season and low seepage during dry season due to reduced and absence of rain water. The indiscriminate disposal of wastewater and wastes of all sorts and non-adherence to environmental laws (NESREA and PPP) lead to environment pollution and consequently contaminates the fresh water due to the fact that most of the wells are shallow, hand-dug and located close to latrines, septic tanks or soakaways in the urban centres. Other contributing factors of significance are geological and geogenic processes as well geological formation of Kano metropolis.

## CONCLUSION AND RECOMMENDATION

The laboratory results and statistical analyses showed significant variations in considerable numbers of heavy metals and non-significant in few while microbial parameters reported significant variations in concentration values far above the permissive limits postulated by WHO (2010) and NSDWQ (2007). The values above the threshold levels can be attributed to high seepages, infiltrations of wastewater and runoff especially during the wet season. Geological locations and geomorphic processes such as weathering can be attributing factors to groundwater pollutions in Kano metropolis. Therefore, the study recommends the following:

a. Comprehensive wastewater management should be given the required attention by all Government agencies individuals and stakeholders.

b. Community base or grassroots enlightenment awareness involving ward or community leaders, ward and area heads (*Mai Unguwa, Bulamas, Dakachi, Obas, Egwes*).

c. There should be good synergy in terms of collaboration, participation and partnership of local environment and the government in waste management.

d. Effective environmental monitoring should also be encouraged and sustained.

e. There should be comprehensive environmental legislation that relates to environmental sanitation offences. The cases should be tried in environmental courts.

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