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Water Quality Assessment and Health Implications: A Study of Kano Metropolis, Nigeria

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Abstract

This study presents a water quality analysis aiming to understand their relationship with prevalent health problems reported in Kano metropolis. The study collected ten water samples from each eight distinct areas within Kano State, Nigeria. pH levels ranged from 6.50 to 7.20, falling within the permissible range recommended by the WHO. The highest turbidity was 51.66NTU. Hardness ranged from 158.6 to 297.7 mg/L, falling within the limit. Alkalinity levels surpassed the standard in most areas, while TDS fell below the standard. Cadmium concentrations ranged from 0.04 mg/L to 0.162 mg/L, with both values exceeding the WHO limit. Nickel levels ranged from 0.369 mg/L to 1.288 mg/L, surpassing the WHO recommendation of 0.2 mg/L. Lead concentrations reached alarming levels, exceeding the recommended value of 1.00 mg/L, with Municipal and Fagge recording concentrations of 3.7882 mg/L and 3.5627 mg/L respectively.

Chromium concentrations varied from 0.82 mg/L to 4.4 mg/L, all surpassing the WHO limit. In Tarauni Arsenic concentration was 0.01 mg/L aligning with the standard, however, in other areas, it surpassed. Iron concentrations ranged from 0.2 mg/L to 1.31 mg/L. Zinc concentrations exceeded WHO limits in all areas, ranging from 3.08 mg/L in Ungogo to 4.4 mg/L in Fagge. We compare the reported devastating diseases with our findings and suggest that the emerging health hazards in Kano State, including gastrointestinal illnesses, chronic kidney disease, and cardiovascular diseases, are associated with poor water quality.

Keywords: Water Quality, Water Contamination, Heavy Metals, Kano.

1. Introduction

Water is a polar molecule (H_2O) made up of two hydrogen atoms and one oxygen atom, making it a necessary element for life on Earth. Its molecular structure results in several distinct properties that are important for a variety of biological, chemical, and environmental activities [1]. Water is essential for human survival as it makes up approximately two-thirds of the body and requires one to seven liters per day to function properly and prevent dehydration [2]. Humans demand water in three key categories: household, industrial, and agricultural [3]. Having reliable access to water enhances good health and well-being [4]. Water quality is determined by its physical, chemical, and biological properties, affecting its utility for various reasons. Potable water, often known as drinking water, should be safe for human consumption and pose no major health risks over time. Traditional drinking water sources include surface water (rivers, streams, lakes) and groundwater (boreholes and wells). Groundwater is becoming increasingly important due to contamination of surface water and the belief that it gets purified as it flows through bedrock [5].

Water is crucial for survival, but it also contributes to disease transmission and mortality in developing nations due to limited access and quality [6]. Drinking water can be contaminated with pathogenic bacteria (e.g., *Salmonella typhi, Shigella dysenteriae, Escherichia coli, Klebsiella pneumonia*), chemicals (e.g., fertilizer, pesticides, metals), and industrial waste, reducing its quality and making it unfit for use. Contaminated drinking water can spread diseases like diarrhea, cholera, dysentery, typhoid, and polio, as stated in WHO information sheets. Contaminated drinking water is predicted to cause 502,000 diarrheal deaths annually [7]. In an experiment conducted in Maiduguri

Metropolis's borehole water satisfies WHO requirements due to its appropriate pH, electrical conductivity, turbidity, and total dissolved solids levels [5]. Furthermore, assessments conducted in Anyigba Town, Kogi State, demonstrate general adherence to WHO guidelines, implying the safety of the drinking water. The aforementioned evaluations underscore the paramount significance of consistent observation and remediation to guarantee both environmental sustainability and public health [1]. Zinc levels were higher in well and pump water sources, although copper concentrations were highest in borehole water samples in Kano Metropolis. On the other hand, the pH, temperature, and electrical conductivity of the borehole water on the Federal University Dutse campus exceeded permissible limits, suggesting that it was unfit for human consumption [8]. An assessment conducted in Gassol, Taraba State, Nigeria, suggested that water quality of the case study meets some of the WHO criteria, but in order to reduce health hazards, improvements are necessary, especially in the areas of turbidity, iron content, pH, and chlorine levels [5]. Moreover, the physicochemical and microbiological quality of the borehole water from E-One Estate in Calabar, Cross River State, Nigeria, is insufficient, requiring treatment prior to consumption for human safety. [8] proposed that even if the water from boreholes in Anyigba, Kogi State, Nigeria, somewhat satisfies WHO criteria, precautions must be taken to avoid pollution and maintain water quality standards.

In research conducted by Elenwo, E et al authors investigated that elevated oil and grease content contributed to the contamination in borehole water quality in Obio-Akpor Local Government Area (LGA), Rivers State, Nigeria to not meet WHO and NESREA standards and suggested that to address the urgent problems with the area's water quality, immediate corrective action is required. Similarly, the presence of dissolved organic compounds and elevated amounts of ammonia (NH_3) in borehole water near a dump site in Port Harcourt, Nigeria, may be harmful to human health [9]. In Nsukka, Enugu State, Nigeria, the majority of physicochemical parameters are within permissible limits; nonetheless, certain deviations are noted, such as elevated lead (Pb) concentrations, hardness levels that surpass limitations, and slightly below-average pH values, even if no coliform bacteria are found [4].

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The majority of previous research used physicochemical measures to evaluate the water quality, while some studies examined the presence of heavy metals. Physicochemical and heavy metals mixed in Kano City were not provided by any of the research, though. This study stands out for carrying out an extensive analysis of the physicochemical characteristics and heavy metal concentration in water samples obtained from various parts of the metropolis. Additionally, it makes a major contribution to our understanding of the connection between the area's widespread health concerns and the quality of the water in question.

2. Materials and Methods

This section discusses the research area's location, as well as the survey methodology and materials.

The Kano Metropolis is located between latitudes 11°55'23.93"N and 12°3'53.10"N of the Equator, and longitudes 8°27'42.26"E to 8°36'41.62"E of the Greenwich Meridian (Figure 1). The metropolis consists of eight local government units, each serving as a council, encompassing a total land area of 499 km². The anticipated population in 2022 is 4,219,209, with a 2.8% growth rate [28].

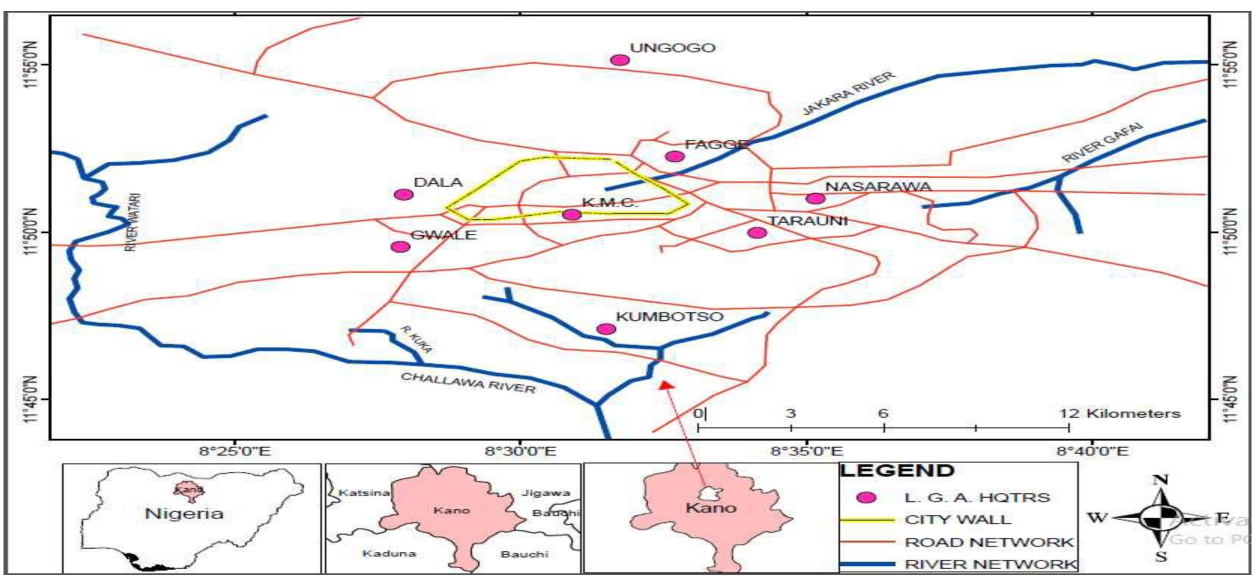

Figure 1: Kano Metropolis Cartography and GIS Unit at Kaduna Polytechnic (2019)

Water samples were taken from 10 boreholes from Nassarawa (NSR), Tarauni (TRN), Kumbotso (KUM), Municipal (MUN), Gwale (GWL), Fagge (FGE), Dala (DAL) and Ungogo (UGG). The samples were collected using sterilized sample collection method in triplicate in well-labeled clean bottles and rinsed with borehole water. The pH and temperature were monitored at the sampling site with a digital pH meter and thermometer. The samples were then appropriately maintained in the laboratory to prevent contamination and facilitate subsequent examination. Turbidity and Total Suspended Solids (TSS) were measured with a turbidity meter, while electrical conductivity and Total Dissolved Solids (TDS) were measured with a conductivity meter. Titration was used to quantify total hardness and alkalinity, whereas calorimetry was used to measure suspended particles. Chloride and nitrate levels were also assessed, and the water samples were digested to detect heavy metals using Atomic Absorption Spectroscopy (AAS). This thorough sampling and analysis technique was designed to correctly and reliably examine several physicochemical characteristics and heavy metals concentration in borehole water samples.

Table 1: Method and Techniques used for measuring the Parameters

S/n	**Parameters / Unit**	**Materials**
1.	Temperature (^{O}C)	Digital Thermometer
2.	PH	PH meter
3.	Turbidity (NTU)	Turbidity meter
4.	Conductivity (µS/cm)	Conductivity meter
5.	Hardness (mg/L)	Titration apparatus
6.	Alkalinity(mg/L)	Titration apparatus
7.	TSS (mg/L)	Turbidity meter
8.	TDS (mg/L)	Conductivity mete
9.	SS (mg/L)	Calorimeter
10.	Chloride (mg/L)	Spectrophotometer ANACHEH 220model
11.	Nitrate (mg/L)	Spectrophotometer ANACHEH 220model

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3. Result

The laboratory results for physicochemical parameters and heavy metals were compared With WHO permitted limits and discussed in Table 2 and 3

3.1 Result of the Physiochemical Analysis of the Water Samples

Table 2: Mean of physicochemical parameters for Kano metropolis water samples compared to recommended by World Health Organization in 2020 [10].

S/N	PARAMETERS	NSR	TAR	KUM	MUN	GWA	FAG	DAL	UGG	WHO (2020)
1	Temperature (^{O}C)	29.66	29.33	30.33	32.33	31.33	32.40	32.66	33.66	-
2	pH	6.96	7.20	6.56	6.90	6.766	6.78	6.70	7.0	6.5-8.3
3	Turbidity (NTU)	51.66	41.34	39.78	9.0	34	7.0	47.0	45.51	5
4	Conductivity(µS/cm)	577.4	432.3	412	579	801	751.6	751.6	768.6	1000
5	Hardness (mg/L)	209.4	158.6	188.5	194	197.95	297.7	297.7	255.8	500
6	Alkalinity (mg/L)	230.6	111.6	221.6	298.3	243.3	530	360	375	200
7	TSS (mg/L)	297	218	255	296	410	274.6	284.6	386	1700
8	TDS (mg/L)	289.3	408	500	298	407	286.6	276.6	386	1200
9	SS (mg/L)	7.666	1.00	0.000	0.000	256.6	8.000	8.000	65.14	-
10	Chloride (mg/L)	51.3	127.3	29.61	50.99	12.83	20.72	39.00	65.14	< 250

Keys: WHO: World Health Organization, TSS: Total Suspended Solid, TDS: Total Dissolve Solid, SS: Suspended Solid, Nassarawa: NAS, Tarauni: TAR, Kumbotso: KUM, Municipal: MUN, Gwale: GWA, Fagge: FAG, Dala: DAL, Ungogo: UNG

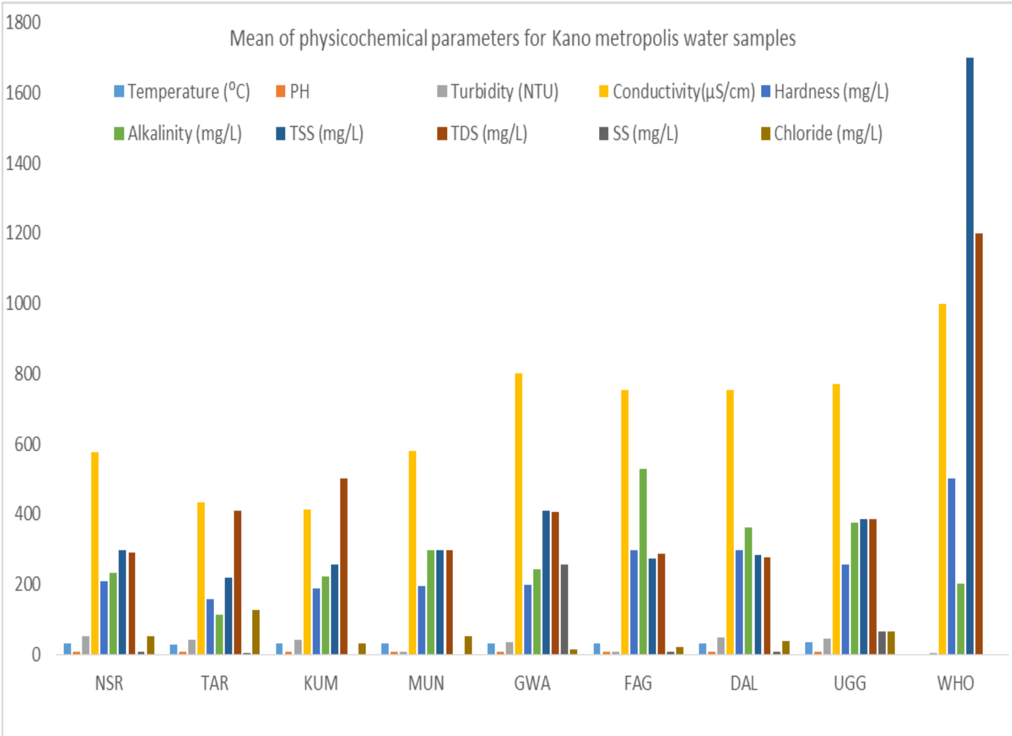

Figure 2: Mean of physicochemical parameters for Kano metropolis water samples compared to recommendation of WHO (2020) guidelines

3.2 Result of Heavy Metal Analysis of the Water Samples

Table 3: Borehole Mean Concentration of Heavy Metals in Water Samples Compared to WHO/FAO Permissible Limits

S/N	**Area**	**(Cd) (mg/L)**	**(Cu) (mg/L)**	**(Ni) (mg/L)**	**(Pb) (mg/L)**	**(Cr) (mg/L)**	**(Hg) (mg/L)**	**(As) (mg/L)**	**(Fe) (mg/L)**	**(Zn) (mg/L)**
1	NAS	0.072	0.167	1.155	3.4326	1.17	0.012	0.08	0.30	**3.75**
2	TRN	0.070	0.260	0.722	2.8464	0.82	0.003	0.01	0.30	**4.30**
3	KUM	0.040	0.199	0.369	1.9068	1.25	0.002	0.02	0.34	**3.65**
4	MUN	0.070	0.247	0.628	3.7882	0.95	0.001	0.12	1.25	**3.09**
5	GWL	0.057	0.220	1.288	3.1287	1.01	0.005	0.04	0.40	**3.45**
6	FAG	0.101	0.176	1.196	3.5627	4.40	0.011	0.03	0.20	**4.40**
7	DAL	0.076	0.235	1.047	3.2842	0.95	0.002	1.64	1.31	**3.20**
8	UGG	0.162	0.308	1.127	3.369	1.25	0.001	0.12	0.18	**3.08**
9	WHO	0.003	1.000	0.20	1.000	0.05	0.001	0.01	0.30	**3.00**

Keys: WHO: World Health Organization, Cd: Cadmium, Cu: Copper, Ni; Nickel, Pb: Lead. Chromium: Cr, Mercury: Hg, Arsenic: As, Iron: Fe, Zinc: Zn.

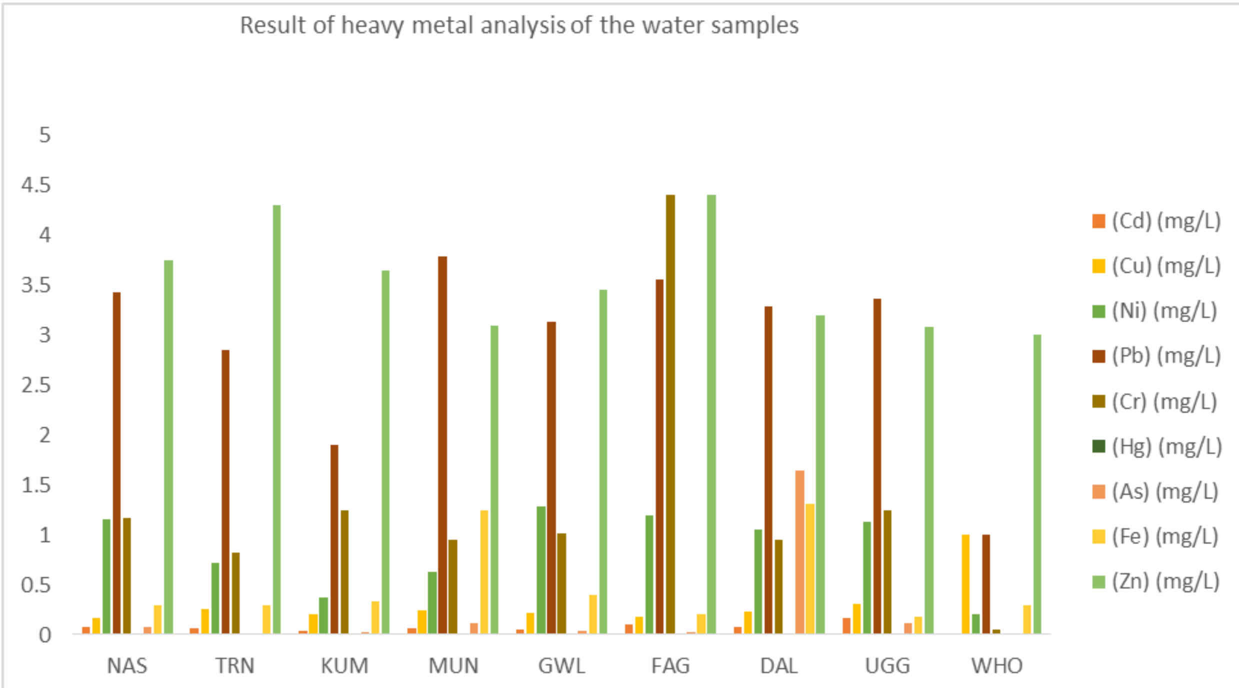

Figure 3: Borehole Mean Concentration of Heavy Metals in Water Samples Compared to WHO/FAO Permissible Limits

4. Discussion

4.1 Physicochemical Analysis

The physicochemical properties of water samples across the eight areas are outlined in Table 2. And Figure 2. Temperatures range from 29.33°C to 33.66°C, with NSR recording the lowest and UGG the highest temperature readings. The borehole water temperatures fall within a moderate range, although there isn't a recommended standard for water sample temperatures [11]. pH, representing the acidity or alkalinity of a substance, correlates with the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-) in water. While pH typically doesn't directly affect consumers, it stands as one of the pivotal operational parameters for water quality. The pH levels of the samples across these sites ranged from slightly acidic to alkaline, spanning from 6.50 to 7.20, all falling within the permissible range recommended by the World Health Organization (6.5 to 8.3) (WHO, 2020). Tarauni, Kumbotso, Dala, and Ungogo registered the lowest turbidity value of 41.34 NTU, 39.78 NTU, 47 NTU and 45.51 NTU respectively. While the remaining four local governments showed poorer values, with Nassarawa recording the highest NTU level as shown in Figure 2. This disparity may be attributed to the presence of suspended solids and particles like clay, silt, finely divided organic, and inorganic matter, which contribute to water cloudiness. Elevated turbidity levels in drinking water are linked to a higher incidence of acute gastrointestinal illness (AGI) among the residents of Kano metropolis, although this association could be context-specific [12]. There's a pressing need for treatment in these four areas, surpassing the recommended value of 5 NTU. In terms of conductivity, Gwale exhibits the highest value at 801 µS/mL, while Kumbotso shows the lowest at 412 µS/mL. The conductivity levels across all areas align perfectly with the WHO standard of 1000 µS/mL [13]. Hardness ranges from 158.6 to 297.7 mg/L, spanning from Tarauni to Dala, and the acceptable limit for total hardness of borehole water is 500 mg/L, as per the WHO guidelines from 2008. Since the water in all eight areas falls within this permissible limit, we can conclude that the borehole water in Kano metropolis is categorized as soft water. Alkalinity denotes water's ability to neutralize acids. Consuming alkalized water is believed to enhance hydration, improve acid-base balance, and boost anaerobic exercise performance in combat sport athletes [14]. However, the WHO recommends an alkalinity value ranging from 20 to 200 mg/L. With the exception of Tarauni, the alkalinity levels in the other areas surpass the WHO's recommended limit. Total Dissolved Solids (TDS) vary from 276.6 mg/L to 500 mg/L, all falling below the WHO permissible value of 1200 mg/L Suspended Solids (SS) reach their peak in Ungogo at 65.14 mg/L and hit the lowest point at 0.00 mg/L in Kumbotso and Municipal, with no recommended value provided by the WHO. Elevated chloride concentration in drinking water has been associated with increased risks of galvanic corrosion, dezincification of plumbing materials, and premature plumbing failures [15]. Fortunately, the chloride and nitrate content of all the water samples remain below the WHO recommended limits, which are < 250 mg/L for chlorides and < 50 mg/L for nitrates. It's worth noting that drinking-water nitrate concentrations exceeding regulatory limits have been linked to elevated risks of colon cancer and neural tube defects [16].

4.2 Atomic Absorption Spectroscopy

Atomic Absorption Spectroscopy (AA) was employed for the analysis of heavy metals. The results revealed that cadmium exhibited the highest concentration in Ungogo at 0.162 mg/L, while its lowest concentration was observed in Kumbotso at 0.04 mg/L as depicted in Figure 3. Notably both concentrations surpassed the permissible limit WHO. The elevated levels of cadmium in these regions suggest potential sources of contamination, emphasizing the necessity for additional investigation and remedial actions. Consumption of water containing cadmium above the permissible limit can elevate the body's cadmium burden, leading to tubular dysfunction and renal damage [17]. The concentration of copper ranged from 0.167 mg/L in

Nassarawa to 0.308 mg/L in Ungogo, all falling below the WHO recommended value of 1.00 mg/L. Although copper concentrations remain within acceptable limits, ongoing monitoring is crucial to maintain compliance with water quality standards and mitigate potential adverse diseases for good health and well-being of individuals.

Nickel levels were recorded at 1.288 mg/L in Gwale and 0.369 mg/L in Kumbotso, surpassing the WHO recommendation of 0.2 mg/L [15]. The elevated nickel concentration in Gwale suggests potential industrial influences in the area, underscoring the need to identify and address potential pollution sources. This is particularly critical given that nickel in drinking water can pose health risks, especially for vulnerable demographics such as toddlers, children, and individuals sensitive to nickel [18]. Lead concentration reached alarming levels in Municipal and Fagge, measuring 3.78 mg/L and 3.5627 mg/L respctively as depicted in Figure 3. In both areas, all water samples exceeded the recommended value of 1.00 mg/L. Such elevated lead levels present substantial health hazards, highlighting the immediate necessity for efficient water treatment and regulatory measures to protect public health. High lead content in drinking water is linked to heightened cardiovascular morbidity and reduced levels of magnesium and calcium in the water [12]

Chromium concentrations varied from 0.82 mg/L in Tarauni to 4.4 mg/L in Fagge, all surpassing the permissible value of 0.05 mg/L. The detection of elevated chromium levels emphasizes potential contamination concerns and highlights the critical importance of implementing comprehensive water quality management strategies. Elevated chromium concentrations in drinking water can jeopardize consumer health, as evidenced by a Hazard Index (HI) value of 1.02 for children and 2.02 for teens, indicating a significant risk for these demographics [19]. With the exception of Municipal and Ungogo, where mercury concentrations hover around the borderline, other listed areas exhibit slightly elevated levels. The increased mercury concentrations in these regions are linked to past mining activities and/or natural thermal and volcanic phenomena. Prolonged exposure to mercury can lead to symptoms such as erethism, tremors, gingivitis, and preclinical alterations in kidney function [20]. In Tarauni, the arsenic concentration measured 0.01 mg/L, aligning with the WHO permissible value of 0.01 mg/L. Conversely, other areas exhibited concentrations surpassing the normal range.

Elevated arsenic levels in drinking water can elevate mortality rates among young adults, induce skin lesions, and increase the risk of cardiovascular disease [19]. Therefore, these areas require diligent treatment and monitoring measures. Regarding iron concentration, Fagge recorded the lowest concentration at 0.2 mg/L, falling within the permissible value of 0.3 mg/L, whereas Dala reported the highest concentration at 1.31 mg/L. Zinc concentrations exceeded the permissible limit set by the WHO, with Fagge recording the highest at 4.4 mg/L and Ungogo the lowest at 3.08 mg/L. A high groundwater zinc concentration is correlated with a notable reduction in the risk of childhood-onset diabetes. Moreover, increased zinc intake is linked to memory deficits [21] and decreased fetal liver zinc concentrations, resulting in fetal zinc deprivation and impaired fetal growth [20].

4.3 Health Hazard

Ofili et al have reported that Kano State is a prominent hotspot for acute gastrointestinal illnesses, which may be related to higher turbidity levels as this study [22] Found. Furthermore, compared to earlier estimates, study by M. O. Odubanjo et al indicates that Kano has a noticeably greater frequency of chronic kidney disease (CDK) [23]. According to this study, Kano City has higher than average levels of cadmium, which is known to produce renal disease and may be a factor in a higher rate of CDK in the local population. Chromium and nickel contamination mostly affects vulnerable populations, including children, pregnant women, and toddlers, which might have negative health effects. The disturbing maternal morbidity rate of 34.8% in Kano State, Nigeria, as highlighted by H. Salihu et al highlights the urgent need for critical obstetric care for expectant mothers [24]. A moderate disease burden was found in the Kano Central Senatorial District, where 10 to 50% of youngsters showed signs of previous infection, according to research done by Farouk et al [25], Nickel and chromium-contaminated water can worsen malaria by impairing immunity, inducing inflammation, and hemolyzing patients. Children and pregnant women are among the vulnerable demographic groups who are most at risk from exposure to these toxins, which could worsen the disease.

According to Farouk et al cardiovascular diseases are rapidly becoming more common in Kano State and the surrounding northwest regions of Nigeria [25]. Their findings highlight the critical need for focused interventions and creative approaches to healthcare in order to deal with the region's growing health crisis. The study findings indicating higher than average amounts of nickel and arsenic in Kano City are consistent with the established health hazards linked to these heavy metals [12]. Because it promotes growth, strengthens immunity, and aids in wound healing, zinc is essential for human health. On the other hand, consuming too much zinc, especially from water sources, might be detrimental to memory [21]. On the other hand, a lower incidence of pediatric diabetes is associated with higher amounts of zinc in groundwater [26]. Insufficient zinc levels in the mother can hinder the growth of the fetus. Mitigating zinc accumulation in water is crucial, as the levels of zinc in Kano Metropolis are beyond the WHO's permitted limit [27].

5. Conclusion

Finally, the study sheds light on the physicochemical properties and heavy metal contamination of Kano metropolitan water source. The study's result emphasized the critical need to resolve Kano City's serious health problems, which may be related to the city's water quality. These problems include kidney, cancer, and cardiovascular disorders among others. Water samples from different parts of Kano State were analyzed for their physicochemical characteristics and heavy metal content. The results showed that the levels of cadmium, nickel, lead, and chromium in the samples were alarmingly high, exceeding WHO-permitted limits. Increased levels of turbidity and alkalinity highlight the urgent need for targeted treatments and cutting-edge medical techniques to lessen the region's escalating health crisis. Continued monitoring, combined with clean water and sanitation, is critical to ensuring Kano citizens have access to safe and clean drinking water. In the future, investigations into the socioeconomic determinants of access to clean water and healthcare services, the identification of particular sources of contamination, and longitudinal studies to monitor water quality measures and health consequences should be the main areas of focus.

6. Acknowledgments

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7. Authors Contribution

The tests were devised and planned by Ma'aruf Abdulmumin Muhammad, Mustapha Sulaiman, Habib Muhammad Usman, Saifullahi Lawan Panda, and Inuwa Musa Idris. The experiments were conducted by Ma'aruf Abdulmumin Muhammad and Mustapha

Sulaiman. The readings were organized and executed by Saifullahi Lawan Panda and Habib Muhammad Usman. The manuscript was written under the direction of Inuwa Musa Idris. Each author contributed constructive criticism and helped to shape the study.

8. Declaration of Interest

The authors state that none of the work described in this publication appears to have been influenced by any known competing financial interests or personal ties.

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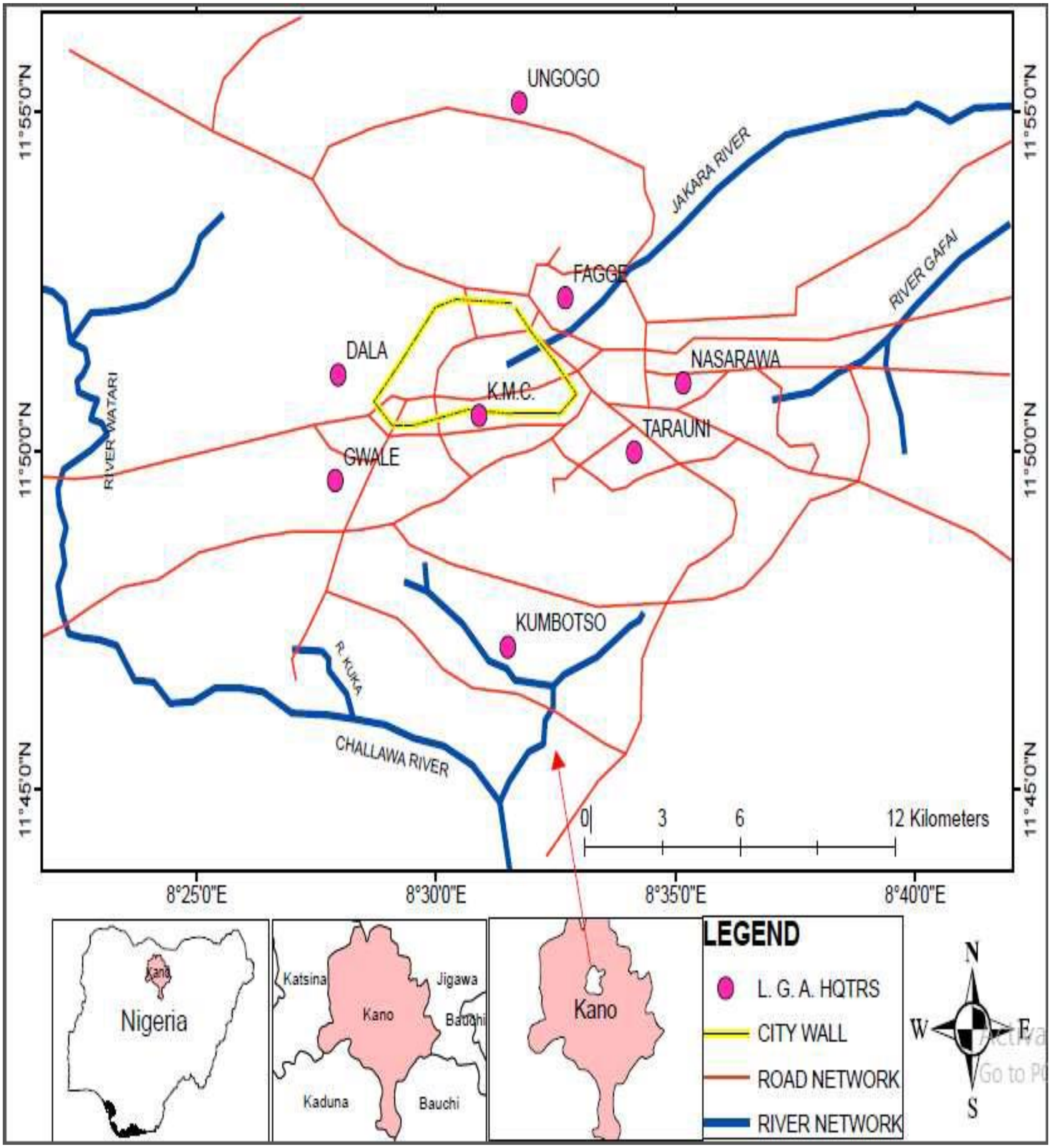

Figure 1: Kano Metropolis Cartography and GIS Unit at Kaduna Polytechnic (2019)

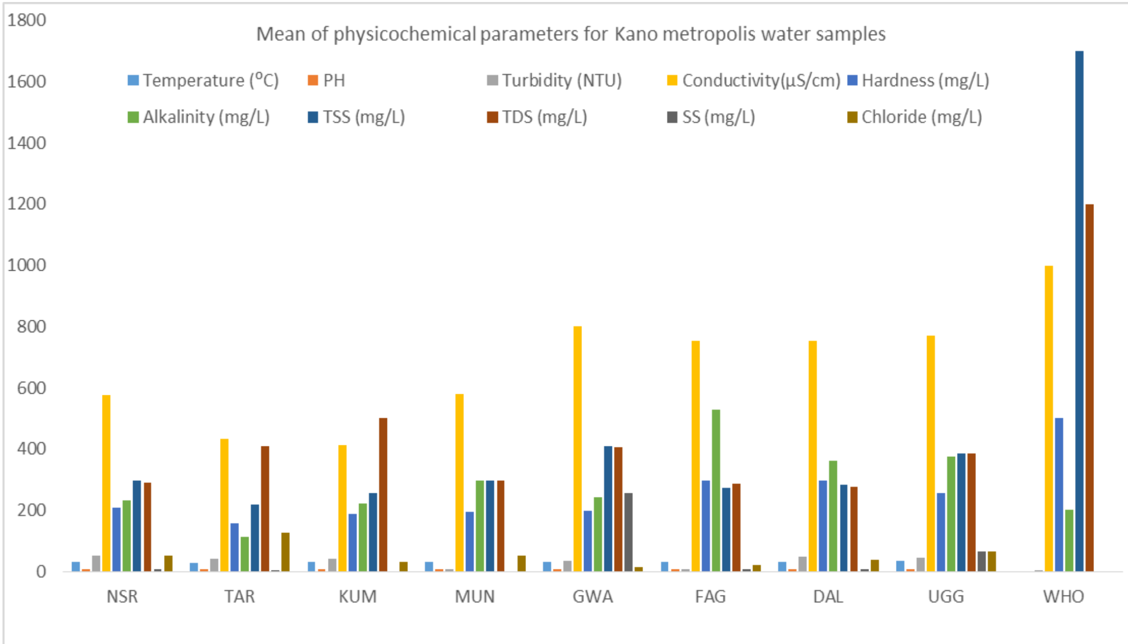

Figure 2: Mean of physicochemical parameters for Kano metropolis water samples compared to recommendation of WHO (2020) guidelines

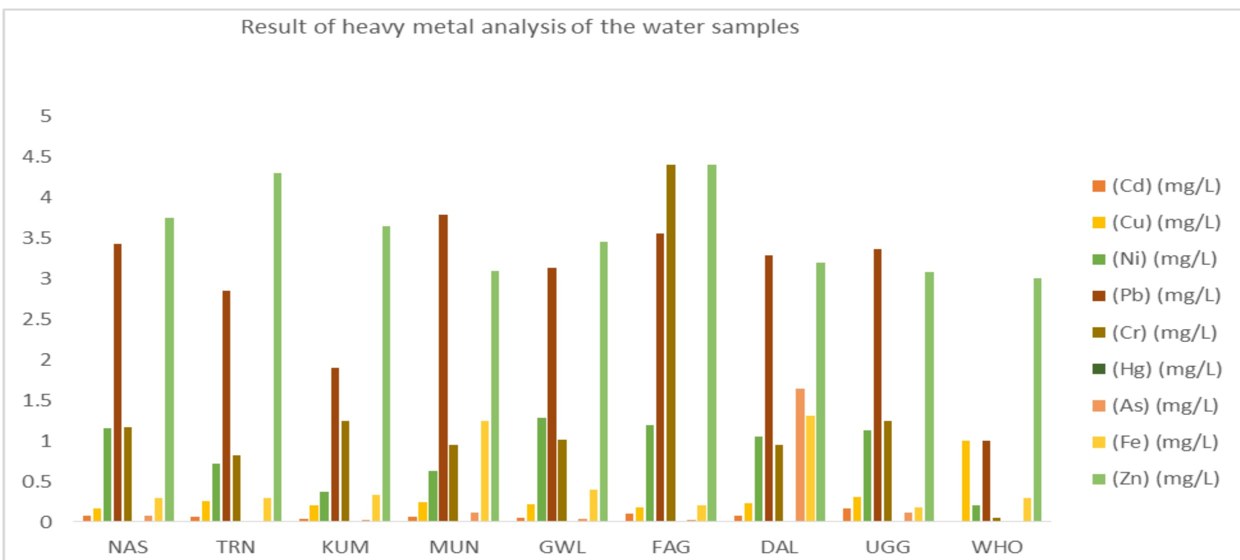

Figure 3: Borehole Mean Concentration of Heavy Metals in Water Samples Compared to WHO/FAO Permissible Limits

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Table 1: Method and Techniques used for measuring the Parameters

S/n	Parameters / Unit	Materials
1.	Temperature (^{O}C)	Digital Thermometer
2.	PH	PH meter
3.	Turbidity (NTU)	Turbidity meter
4.	Conductivity (µS/cm)	Conductivity meter
5.	Hardness (mg/L)	Titration apparatus
6.	Alkalinity(mg/L)	Titration apparatus
7.	TSS (mg/L)	Turbidity meter
8.	TDS (mg/L)	Conductivity mete
9.	SS (mg/L)	Calorimeter
10.	Chloride (mg/L)	Spectrophotometer ANACHEH 220model
11.	Nitrate (mg/L)	Spectrophotometer ANACHEH 220model

Table 2: Mean of physicochemical parameters for Kano metropolis water samples compared to recommended by World Health Organization in 2020 [10].

S/N	PARAMETERS	NSR	TAR	KUM	MUN	GWA	FAG	DAL	UGG	WHO (2020)
1	Temperature (^{O}C)	29.66	29.33	30.33	32.33	31.33	32.40	32.66	33.66	-
2	pH	6.96	7.20	6.56	6.90	6.766	6.78	6.70	7.0	6.5-8.3
3	Turbidity (NTU)	51.66	41.34	39.78	9.0	34	7.0	47.0	45.51	5
4	Conductivity(µS/cm)	577.4	432.3	412	579	801	751.6	751.6	768.6	1000
5	Hardness (mg/L)	209.4	158.6	188.5	194	197.95	297.7	297.7	255.8	500
6	Alkalinity (mg/L)	230.6	111.6	221.6	298.3	243.3	530	360	375	200
7	TSS (mg/L)	297	218	255	296	410	274.6	284.6	386	1700
8	TDS (mg/L)	289.3	408	500	298	407	286.6	276.6	386	1200
9	SS (mg/L)	7.666	1.00	0.000	0.000	256.6	8.000	8.000	65.14	-
10	Chloride (mg/L)	51.3	127.3	29.61	50.99	12.83	20.72	39.00	65.14	< 250

Keys: WHO: World Health Organization, TSS: Total Suspended Solid, TDS: Total Dissolve Solid, SS: Suspended Solid, Nassarawa: NAS, Tarauni: TAR, Kumbotso: KUM, Municipal: MUN, Gwale: GWA, Fagge: FAG, Dala: DAL, Ungogo: UNG

Table 3: Borehole Mean Concentration of Heavy Metals in Water Samples Compared to WHO/FAO Permissible Limits

S/N	**Area**	**(Cd) (mg/L)**	**(Cu) (mg/L)**	**(Ni) (mg/L)**	**(Pb) (mg/L)**	**(Cr) (mg/L)**	**(Hg) (mg/L)**	**(As) (mg/L)**	**(Fe) (mg/L)**	**(Zn) (mg/L)**
1	NAS	0.072	0.167	1.155	3.4326	1.17	0.012	0.08	0.30	**3.75**
2	TRN	0.070	0.260	0.722	2.8464	0.82	0.003	0.01	0.30	**4.30**
3	KUM	0.040	0.199	0.369	1.9068	1.25	0.002	0.02	0.34	**3.65**
4	MUN	0.070	0.247	0.628	3.7882	0.95	0.001	0.12	1.25	**3.09**
5	GWL	0.057	0.220	1.288	3.1287	1.01	0.005	0.04	0.40	**3.45**
6	FAG	0.101	0.176	1.196	3.5627	4.40	0.011	0.03	0.20	**4.40**
7	DAL	0.076	0.235	1.047	3.2842	0.95	0.002	1.64	1.31	**3.20**
8	UGG	0.162	0.308	1.127	3.369	1.25	0.001	0.12	0.18	**3.08**
9	WHO	0.003	1.000	0.20	1.000	0.05	0.001	0.01	0.30	**3.00**

Keys: WHO: World Health Organization, Cd: Cadmium, Cu: Copper, Ni; Nickel, Pb: Lead. Chromium: Cr, Mercury: Hg, Arsenic: As, Iron: Fe, Zinc: Zn.