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Physico-chemical and heavy metal analysis of ground and surface water obtained from some selected areas in Kaduna metropolis

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Abstract

Water samples from 10 selected boreholes and 3 hand-dug wells within the three areas of Kaduna Metropolis were collected; Physico-Chemical parameters and heavy metals were determined. The results of the Physico-Chemical analysis were obtained in the following range, temperature (17.3-20.9), conductivity (44-60 mV), alkalinity (184-688 mg/l) BOD (6.5-15.4 mg/l) all within the set limit of WHO standard, TDS value (1197-2340 mg/l) fell above the set limit of WHO standard , the chemical constituents were obtained in the following range pH (7.25-7.67), Magnesium (1.28-6.08 mg/l), Calcium (0.12-0.90 mg/l), Nitrate (0.03-0.32 mg/l) with Chloride value (2.33-495.6) above the set limit of WHO standard, the highest value of 0.1241mg/l was found in Chromium. the concentrations of heavy metals (mg/l) Chromium, Iron, Lead, and Copper in the Groundwater were found in the following range, lead (0.0001- 0.120 mg/l), Chromium (0.0001- 0.124 mg/l), iron (0.0191- 0.3547 mg/l) and Copper (0.0006- 0.0070 mg/l). The results obtained fell within the limit set by World Health Organisation with the exception of Chromium which was 0.124 mg/l in sample SH3 and Lead which was in sample MF2. Which these two had concentrations above the limits set by World Health Organisation.

Keyword: Physico-chemical; Heavy metal analysis; Ground and surface water; Water samples

1 Introduction

Life on the earth is supported by water. Water is the colourless liquid that falls as rain, runs in lakes, rivers, oceans, ponds, and underground. Healthy drinking water is the basic need of the human health. Contaminated drinking water is a significant risk to human health (WHO, 2011). It is a very important component of every living organism. Most of all organisms on earth are made up of water. A tree weighs about 60 percent of water, while human weight is made up of about 50-60 percent water. Sources of water include ground water, surface water and rain. Surface water include; oceans, Rivers, streams, lakes and ponds. Ground water includes springs, deep wells and shallow wells. Different water bodies have different components depending on their location, how they were formed and activities surrounding their vicinity.

The quality of drinking water is essential for life. There are a number of reported cases of typhoid, diarrhoea and other water borne diseases arising from the consumption of contaminated water. Different works have been reported by many researchers on water quality assessment; today, contaminated water kills more people than cancer, AIDS, wars, terrorism or accidents, (Uduma AU 2014).

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2 Materials and method

2.1 Materials

pH meter (SUNTEX TS-2),Turbidity meter (DR2010),Conductivity meter (SUNTEX TS-2),Conical flask, Tissue paper, Water bath, Burette, Beaker, Whatman's filter paper, Filter funnel.

2.1.1 Reagents used

Distilled water, De-ionised water, pH indicators (Eriochrome black T, methyl orange and Phenolphthalein), HCl, EDTA (ethylenediaminetetracetic acid)

2.2 Method

2.2.1 Sample Collection

Before the commencement of sampling, a preliminary survey of the entire area where sampling was done was carried out. Groundwater from (13) thirteen different locations in all the Three areas of Kaduna Metropolis were collected. The samples were coded to avoid bias in analysis. All samples were from boreholes and a hand dug well. Sample codes and locations including the longitude and latitudes from the areas which they were obtained are illustrated in Table 1.0.

Table 1 Sample Codes and Origin

SAMPLE CODE	Campus	Location	LATITUDE "N"	LONGITUDE "E"
SH1	U/SHANU	Shifa Hospital	10° 32.441	7° 25.330
SH2		Karko Road	10^0 29.385	7^0 25.695
SH3		Kadgis Service Centre	10^0 29.385	7^0 25.608
SH4		Gida Godu Hijara	10^0 29.385	7^0 25.610
MF1	MARAFA	Prison Barracks	10^0 51.965	7^0 44.234
MF2		Muslim Quarters Our	10^0 31.183	7^0 24.535
MF3		Ladies of Apostle Catholic Church	10^0 31.178	7^0 24.415
MF4		KadPoly Boys Hostel	10^0 31.193	7^0 24.455
MF5		Marafa Mosque	10^0 31.361	7^0 24.412
GR1	U/MAIGERO	COCIN Church	10^0 48.265	7^0 45.801
GR2		Learners Junction	10^0 31.179	7^0 26.403
GR3		Einstern International School	10^0 48.061	7^0 26.514
GR4 GR5		Karji Junction Freedom Water Intake	10^0 48.221 10^0 48.265	7^0 45.801 7^0 45.801

2.3 Sampling Procedure

Thirteen (13) samples were collected from different locations of the Kaduna metropolis. Sampling sites were selected as per a sampling technique, (Chhatwal *et al.,* 2010) which represents the entire ground water. The high density polyethylene bottles (2 litres) were used. The containers were first washed with detergent solution, washed with tap water, then with distilled water and lastly, it was rinsed with the sample to avoid contamination, (Chhatwal *et al.,* 2010). The sampling bottles were kept air tight and labelled properly for identification. Aeration during sampling was avoided as far as possible and taken to the laboratory for the analysis immediately.

Figure 1 Tap water from Marafa area of kaduna state

Figure 2 Well water sample from karji junction (gr4)

3 Results

Table 2 Sample location, depth and elevation of well water samples

S/No	Sample Location	Depth	Elevation	Latitude ("E")	Longitude ("N")
1	Kadpoly Boys Hostel	1.8 m	184m	10^0 31.061	7^0 26.514
2	Karji Junction	2.0	200m	10^0 51.420	7^0 43.250

Table 3 Physico-Chemical Parameters of the sample of ground water in Kaduna Metropolis

Sample code	Area	Location	Temp (^oC)	EC mV	DO mg/l	TDS mg/l	TSS mg/l	Turbidity NTU	Alkalinity mg/l	BOD mg/l
SH1	U/Shanu	Shifa Hospital	20.4	56	42.9	1800	-2	1	312	15.4
SH2		Karko Road	20.0	62	31.0	760	2	-1	320	12.3
SH3		Kadgis Service Centre	20.2	55	29.3	740	-2	1	184	7.7
SH4		Gida Godu Hijara	20.2	62	40.4	2340	-3	3	384	13.2
MF1	Marafa	Prison Barracks	20.5	61	26.6	1080	12	0	536	8.1
MF2		Muslim Quarters	20.3	59	24.8	1080	2	0	392	

MF3		Kadpoly Boys Hostel	20.3	44	19.3	1800	-2	2	264	7.3
MF4		Our Ladies Of Apostle	20.3	44	38.9	2130	1	0	440	9.51
GR1		COCIN Church	20.1	61	42.3	740	0	5	336	12.4
GR2	U/Maigero	Learners Junction	20.3	59	22.2	1200	0	3	688	7.7
GR3		Einstern International School	20.9	59	22.2	1200	-2	-1	360	6.5
GR4		Karji Junction	20.5	55	23.3	1260	4	-1	450	8.0
GR5		Freedom Water Intake	17.3	60	49.5	520	0	-1	280	14.3
RANGE			17.3-20.9	44-60	22.2-49.5	520-2340	0-12	0-5	184-688	6.5-15.4
AVERAGE			20.1	56.7	31.7	1197.7	0.7	0.8	376.6	8.8
WHO LIMITS			**	**	**	1000	**	10	600	**

** mean no guidelines set because it is not of health concern according to World Health Organisation (WHO, 2008).

Table 4 Chemical constituent of the ground water samples of Kaduna polytechnic campuses

Sample Code	**Campus**	**Location**	**pH**	**Ca (mg/l)**	**Mg (mg/l)**	**Cl (mg/l)**	**NO_3 (mg/l)**
SH1	U/Shanu	Shifa Hospital	7.53	0.90	3.60	79.94	0.07
SH2		Kargako Road	7.67	0.36	1.44	136.8	0.10
SH3		Kadgis Service Centre	7.48	0.64	2.56	190.1	0.19
SH4		Gida Godu Hijara	7.60	1.52	6.08	268.2	0.08
MF1	Marafa	Prison Barracks	7.62	0.48	1.92	23.1	0.17
MF2		Muslim quarters	7.28	0.16	0.65	2.33	0.03
MF3		Kadpoly Boys Hostel	7.63	0.41	0.64	495.6	0.21
MF4		Our Ladies of Apostle	7.25	0.54	2.16	257.6	0.28
GR1	U/Maigero	COCIN Church	7.60	0.36	0.44	142.1	0.17
GR2		Learners Junction	7.58	0.38	1.52	39.25	0.32
GR3		Einstern International School	7.60	0.32	1.28	103.03	0.28
GR4		Karji Junction	7.50	0.12	0.48	195.40	0.24
GR5		Freedom Water Intake	7.63	0.84	3.40	39.26	0.16
RANGE			7.25-7.67	0.12-0.90	1.28-6.08	2.33-495.6	0.03-0.32
AVERAGE			7.53	0.54	2.01	151.7	0.17
WHO LIMITS			6.5-8.5	75	50	200	50

3.1 Heavy metal analysis

Table 5 Mean Concentrations of Heavy Metals in Ground Water Samples

Sample code	Campus	Location	Pb	Cu	Fe	Cr
SH1	U/Shanu	Shifa Hospital	0.0058 ± 0.004	0.0020 ± 0.000	0.0497± 0.002	-
SH2		Kargako Road	0.0001 ± 0.000	0.0009 ± 0.000	0.3013 ± 0.352	0.0011 ± 0.001
SH3		Kadgis Service Centre	0.0010 ± 0.001	-	0.0719 ± 0.021	0.1241± 0.124
SH4		Gida Godu Hijara	0.0020 ± 0.002	0.0037 ± 0.001	0.1262 ± 0.003	0.0170 ± 0.050
MF1	Marafa	Prison Barracks	0.0051 ± 0.006	0.0007 ± 0.001	0.1262 ± 0.003	0.0018 ± 0.002
MF2		Muslim Quarters	0.0043 ± 0.003	0.0010 ± 0.000	0.1093 ± 0.002	0.0016 ± 0.002
MF3		Kadpoly Boys Hostel	0.0120 ± 0.010	0.0025 ± 0.003	0.0927 ± 0.009	-
MF4		Our Ladies of Apostle	-	0.0006 ± 0.001	0.0326 ± 0.001	0.0016 ± 0.001
GR1		COCIN Church	± 0.0030.0019	0.0070 ± 0.000	0.2570 ± 0.023	0.0028 ± 0.002
GR2	U/ Maigero	Learners Junction	-	-	0.0687 ± 0.005	-
GR3		Einstern International School	-	-	0.0991 ± 0.007	0.0011 ± 0.001
GR4		Karji Junction	-	-	0.3547 ± 0.009	0.0007 ± 0.001
GR5		Freedom Water Intake	-	-	0.0191 ± 0.017	0.0001 ± 0.000
RANGE (mg/l)			0.0001-0.0120	0.0006-0.0070	0.0191-0.3547	0.0001-0.1241
WHO LIMITS			0.01-0.015	1.3	**	0.05

mean below detection limit

** mean no guidelines set because it is not of health concern at concentrations normally observed in drinking water, but may affect the acceptability of water at concentrations above 3000ug/l (0.5mg/

The levels of four heavy metals in all 13 ground water samples were analyzed using Atomic Absorption Spectrophotometer (AAS). The results are given as estimated standard deviation based on samples and the results are means of three replicates

4 Discussion

4.1 Physico-Chemical Parameters

The results of the Physico-Chemical analysis obtained indicates that the Turbidity of samples collected within the sampling period were all within the WHO permissible limit of 5NTU, the occurrence of turbidity in surface water may be permanent or seasonal (Ma J Et al, 2020). Ungwan Maigero (COCIN Church Street) bore hole with sample code GR1 has the highest turbidity of 5 NTU while (Einsetin School) GR4 has the lowest value of -1 NTU. The Total Dissolved Solids (TDS) comprises of inorganic salts and small amount of organic matter that are dissolved in water (Akubuenyi, 2013).

The maximum permissible limit standard for drinking water is 1000 mg/l, the average value obtained for this work is 1197.7, the highest 2340 mg/l while the lowest is 0.12 mg/l. All samples fell within the permissible limit set by WHO except samples MF2. MF3, MF5 (all within the main campus) and SHI (SHI) which were slightly higher.

4.2 Chemical Constituents

The chloride content is the samples is lowest in sample code MF2 from Marafa Mosque (Marafa) indicating that the Groundwater available in the area is fit for ablution before prayers and general domestic purpose since the values is 2.33mg/l been low the while the Boys Hostel in the College of Business and Management Studies (CBMS) with sample code MF4 in Marafa with value of 495.6 mg/l been hand-dug well which is above the permissible limit set by WHO of 250 mg/l. Excessive Chloride concentration in water increases rate of corrosion of metals in the distribution system depending on the alkalinity of water. This can lead to increased concentration of metals in water(Zhang H *et al.*, 2024). Calcium (Ca) as the most abundant mineral in the body is very useful in the development of infant bones also in the building and maintenance of teeth, the Ca of the sample collected within the sampling period were in the range of 0.12-0.90 mg/l. 0.12mg/l was obtained in the hand-dug well water from Einstein School in Ungwan Maigero with sample code GR4 while the highest value of 0.90mg/l is obtained in sample code SH1 in Shifa Hospital in Ungwan Shanu.

pH of all the sample collected within the sampling period were within the WHO standard for drinking water maximum permissible limit of 6.5-8.5 (WHO, 2008), the range of 7.25-7.67) was obtained. The lowest value obtained was in Our Lady of Apostle Catholic Church in Marafa Kaduna (MF4) while the highest value was recorded in Kargaka Road in Ungwan Shanu with sample code SH2.

Nitrate content in the sample ranged from 0.03 – 0.32mgl/l with an average of 0.17mg/l which is within World Health Organization (WHO) limit 50mg/l (WHO 2008). Excessive nitrate in the body is converted to nitrite which react with haemoglobin in the blood causing methemoglobin that results in coma and death especially in infants (John *et al*., 2008). Lowest value of 0.03 mg/l was obtained in the Musilm Quarters (Marafa) with sample code MF2 while the highest value was obtained in the ground water from Ungwan Maigero with sample code GR2 from Learner Junction.

The value obtained for Magnesium (Mg)was below the WHO limit of 75 mg /l (WHO, 2008).The highest value obtained was 6.08 mg/l in Gida Godu Hijara with sample code SH4 and Einstein School with sample code GR3 recorded the lowest value of 1.28 mg/l in Ungwan Maigero with an average value of 0.54 mg/l. Low chemical content found in Ungwan Maigero may be as a result of lesser population of people in the area and also less waste litter compared to the other areas.

4.3 Heavy Metal Analysis

The concentrations of heavy metal, Pb, Cr, Cu and Fe in the ground water samples analyzed are presented in Table 1.3.

- **Pb:** Lead is the most significant of all the heavy metals because it is toxic, very common (Balali-Mood M *et al.,* 2021) and harmful even in small amounts. Lead enters the human body in many ways. It can be inhaled in dust from lead paints, or waste gases from leaded gasoline. It is found in trace amounts in various foods, notably in fish, which are heavily subjected to industrial pollution. Some old homes may have lead water pipes, which can then contaminate drinking water. Most of the lead we take is removed from our bodies in urine; however, as exposure to lead is cumulative over time, there is still risk of buildup, particularly in children. Studies on lead are numerous because of its hazardous effects. High concentration of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys (Wani AL, *et al.,* 2015). In this study, Pb was observed in 9 samples out of the 13 locations sampled. The maximum level of Pb (0.0120mg/L) was found in ground water sampled from MF3 and a minimum of 0.0001 mg/l from SH2. All samples except MF3 conformed to the WHO permissible limits for Pb in drinking water which is 0.01 mg/l (WHO, 2008).
- **Cr:** Chromium is an essential micronutrient for animals and plants, and is considered as a biological and pollution significant element. Generally the natural content of chromium in drinking water is very low ranging from 10 to 50 μg/L except for the regions with substantial chromium deposits, (Mukherjee *et al.,* 2012). Chromium in excess amounts can be toxic especially in the hexavalent form. Sub chronic and chronic exposure to chromic acid can cause dermatitis and ulceration of the skin. Long-term exposure can cause kidney, liver, circulatory and nerve tissue damages. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high level of chromium (Saha, B *et al.,* 2022). In this study, chromium was not detected in only three of the samples SH1,MF3 and GR2 (Shifa Hospital,, well water from Kaduna polytechnic boys hostel in (CBMS) Marafa Location and borehole water from Learners junction in Ugwuan Maigero). In the other areas, Chromium level varied from 0.0001mg/L (GR5) to 0.1241mg/L (SH3). All other

samples fell within the WHO (2008) maximum admissible limit of Cr in drinking water (0.05g/L) except for SH3 located in the Ungwan Maigero.

- **Cu:** Contamination of drinking water with high level of copper may lead to chronic anemia (Acharya *et al.,* 2008). In this study, copper was not detected in five out of the 13 samples analyzed. Copper concentrations ranged between 0.0006 mg/l and 0.0070mg/l. There was no health related risk due to the presence of copper in drinking water of the study areas as they are all below the WHO (2008) maximum admissible limit of copper in drinking water which is 20mg/l.
- **Iron:** Iron is the fourth most abundant element by mass in the earth's crust. In water, it occurs mainly in ferrous or ferric state. Iron in surface water generally present is ferric state. It is an essential and non-conservative trace element found in significant concentration in drinking water because of its abundance in the earth's crust. Usually, iron occurring in ground water is in the form of ferric hydroxide, in concentration less than 500 µg/L (Agada, Felix & Udoji, Itodo. (2023).

The shortage of iron causes disease called "anemia" and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haermosiderosis (Kowdley KV., 2016). In the areas studied, iron content varies from 0.0191mg/l (GR5) taken from borehole water in the Freedom Water Intake in Ungwan Maigero to 0. 3547mg/l (GR4) taken from well water in Karji. All samples except that taken from Karji junction (GR4) conforms with the desirable concentration of iron in drinking water (300ug/L) set by WHO (2008). No guideline is set by WHO (2008) for iron content in drinking water because it is not of health concern at concentrations normally observed in drinking water.

5 Conclusion

Thirteen ground water samples were obtained from the three location of Kaduna Metropolis in order to investigate their quality in terms of their physicochemical properties, trace and heavy elements levels.

The results revealed that all the samples were within the Permissible limit set by the World Health Organization with the exception of Total Dissolved Solids (TDS) value of 2340 mg/l in water sample from the Boys Hostel (WS4) on the main campus and the high Chloride content found in the Boys Hostel in the College of Business and Management Studies (CBMS) with sample code WB4 with value of 495.6 mg/l been hand-dug well which is above the permissible limit set by World Health Organisation (WHO 2008) 250 mg/l.

The amounts of heavy metals in the water samples were within the recommended maximum allowable levels with the exception of Chromium having high value of 0.124 mg/l in the College of Engineering in (COE) on the main campus with sample code WS5 from Chemical Engineering Department above the permissible limit of 0.05 mg/l(WHO 2008) standard. Pb also was observed to be higher than (WHO, 2008) limit in MF3 from the Kaduna Polytechnic Boys Hostel of CBMS campus found in Marafa area.

The results reveal that water available in the Boys Hostel in CBMS of the kaduna polytechnic campus is not suitable for drinking; this may be as a result of toxic leach of chemicals from refuse dump around the hostel and also student domestic activities accumulated over the years during with the rest proven to be suitable for drinking and recreational purposes since there all fell within and below the permissible limit set by WHO.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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