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Water Quality Assessment of Some Selected Hand Dug Wells and a Borehole in North Eastern Parts of Bauchi Metropolis, Nigeria

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Abstract

Water samples were taken from six hand dug wells and a borehole for physico-chemical and microbial analysis to ascertain its quality, type and suitability for domestic, livestock and irrigation purposes. The ranges of results of the physico-chemical parameters are: temperature (28-31.5)oC, Conductivity (170-650)µs/cm, turbidity (1.0-90.8)NTU, and pH(7.0-8.5). Other chemical parameters include: cations - Ca2+(25.6 – 72.0)mg/l , Na+(23.1 – 75.87)mg/l, K+(0.14 – 78.3)mg/l, Mg2+(1.46 – 20.75)mg/l, Fe2+(0.0 – 1.1)mg/l, Cu2+(0.0 – 0.49)mg/l, Zn2+(0.00 – 1.74)mg/l, Pb2+(0.00 – 0.001)mg/l, Cr6+(0.00 – 0.02)mg/l and anions – HCO3-(54.0 – 140.0)mg/l, Cl-(32.5 – 114.96)mg/l, F-(0.23 – 0.77)mg/l, CO32-(32.4 – 84.0)mg/l, SO42-(10.31 – 121.0)mg/l, NO3-(1.08 – 75.7)mg/l, NO2-(0.013 – 0.69)mg/l. Data values analyzed from the results obtained indicate the water to be Ca-HCO3, K-HCO3, Mg-HCO3 and Na-Cl water type containing high concentrations of some major, minor and trace cations and anions which fall above the maximum permissible limits of the National Standard for Drinking Water Quality (NSDWQ) of Nigerian Industrial Standard (NIS), 2007. Physical and microbiological parameters indicate that the water is turbid and contain a high total coliform counts above the NIS set standards for maximum permissible limits. This may be attributed to proximities of soakaways and dumpsites to the wells which may need to be monitored from time to time. The water was also found to be suitable for irrigation.

Keywords: Water Quality, Water Type, Irrigation Water

1.0 Introduction

Groundwater in many semi-arid regions in the world is increasingly becoming the main source of water supply not only for domestic purposes but also for industrial and agricultural uses (Boutaleb et al., 2008). However, in some cases increased population and urbanization has exposed groundwater to threats of contamination, pollution and decrease in groundwater levels in most cities due to overdraft. This has constricted its flow to deeper weathered/fractured zones, thus, increased of the overburden thickness (Boutaleb et al., 2008; Adelana et al., 2008). Waters that are likely contaminated by disease causing agents, if consumed may pose and at the same time cause different health hazards and problems (Awopetu et al., 2013). Water availability and its quality need to be improved so as to reduce morbidity and mortality from infectious diseases in developing countries, resulting from personal and environmental hygiene and excreta disposal (WHO and UNICEF, 2010).

Analysis of water for quality and suitability is one of the most significant aspects in the study of groundwater. Water that is suitable by its quality for drinking is revealed through chemical study (Sadashivaiah et al., 2008). The chemical parameters of groundwater play a significant role in classifying and assessing water quality. Groundwater consists of major, minor and trace dissolved constituents. Constituents with concentration greater than 5mg/l, 0.01 – 10.0mg/l and less than 0.01mg/l are classified as major, minor and trace respectively (Davis and De Wiest. 1966). Alkali hazards are discovered in waters through some proposed indices during chemical analysis, when individual and ionic concentration are paired. One of such alkali hazards is the residual sodium carbonate (RSC) which is used as a criteria for to finding suitability of irrigation waters; although when one considers the combined chemistry of all the ions rather than looking at the individual or paired ionic characters may obtained a better results (Sadashivaiah et al., 2008).

2.0 Materials and Method

Water samples were collected from five different stations in Bauchi Metropolis. Sample HDW1, HDW2 and BHW3 were collected from Inkil Area. Sample HDW4, HDW5, HDW6 and HDW7 were collected from Gubi, Tirwun, Tafawa Balewa Housing Estate and Rafin Makaranta areas respectively. All the samples were collected from hand dug wells except for sample BHW3, which was collected from a borehole. The samples were collected in the month of May, 2012. Sample bottles were treated with dilute nitric acid followed by repeated washing with distilled water and with the sample water from source at the point of collection before sampling, after which the samples were transported to the laboratory for analysis. Coordinates at every sampling point were taken using Garmin Navigator Global Positioning System (GPS). Physical parameters (temperature, electrical conductivity, turbidity and pH) and microbial analysis were determined using Potalab WE10016 components and accessories, while chemical analysis for the determination of cations and anions in all the sample was done using DR 2000Hach Spectrophotometer (Egboh and Emeshili, 2006).

3.0 Results and Discussion

3.1 Results

Table 1: Combined results of physical, chemical and microbiological parameters of analyzed water sample in some selected hand dug wells and a borehole in north eastern parts of Bauchi Metropolis, Nigeria.

S/No	Parameters	Water Samples							NIS (2007) NSDWQ *MPL
		HDW1	HDW2	BHW3	HDW4	HDW5	HDW6	HDW7	
A	**Physical Parameters**								
1	Longitude (decimal degrees)	9.884833	9.8945	9.901694	9.854917	9.84600	9.839028	9.837972	
2	Latitude (decimal degrees)	10.301306	10.3075	10.304139	10.362111	10.349333	10.325278	10.358972	
3	Elevation (m)	601	591	585	600	605	642	595	
4	Source of Water Sample	Well	Well	Borehole	Well	Well	Well	Well	
5	Static Water Level (m)	5.40	4.50		8.40	6.90	10.55	11.05	
6	Temperature (^{0}C)	30.0	29.0	31.5	30	29	28	29	Variable
7	pH	7.0	7.4	7.5	8.2	8.5	7.3	7.6	6.5 – 8.5
8	Turbidity (NTU)	2	1	1	9.8	4.0	9.0	7.0	5
9	Electrical Conductivity (µs/cm)	520	280	550	650	170	300	300	1000
10	TDS(mg/l)	260	140	275	325	85	150	150	500
B	**Chemical Parameters**								
11	Total Hardness(as $CaCO_3$) mg/l	250	150	220	180	70	145	150	150
12	Bicarbonate, HCO_3^-(mg/l)	135	132	108	120	54	120	140	100
13	Calcium, Ca^{2+} (mg/l)	66	38	72	58.40	25.6	35.2	29.6	75

14	Magnesium, Mg^{2+} (mg/l)	20.75	13.42	9.74	8.32	1.47	13.92	18.55	0.20
15	Total Iron, Fe^{2+}(mg/l)	0.35	1.10	0.60	0.00	0.00	0.10	0.12	0.3
16	Copper, Cu^{2+}(mg/l)	0.00	0.00	0.05	0.21	0.14	0.49	0.30	1.0
17	Fluoride, F^-(mg/l)	0.23	0.77	0.45	0.33	0.27	0.68	0.63	1.0
18	Zinc, Zn^{2+}(mg/l)	0.45	0.32	0.76	0.76	1.20	0.00	1.74	3
19	Nitrate, NO_3^-(mg/l)	70.60	22.05	75.7	68.04	1.08	20.54	54.21	50
20	Nitrite, NO_2^-(mg/l)	0.24	0.02	0.7	0.5	0.01	0.22	0.13	0.2
21	Lead, Pb^{2+}(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001
22	Sulphate, SO_4^{-2}(mg/l)	121	60	115	56.2	10.31	31.45	50.42	100
23	Salinity as NaCl (mg/l)	98	37.31	76.82	121.86	34.44	45.04	34.44	-
24	Carbonate, CO_3^-(mg/l)	81	79.2	64.8	72.00	32.4	72	84	-
25	Chloride, Cl^-(mg/l)	92.45	40	72.45	114.96	32.5	42.45	35	250
26	Sodium, Na^+ (mg/l)	61.02	26.40	47.80	75.87	21.45	28.02	23.10	-
27	Chromium, Cr^{6+}(mg/l)	0.00	0.02	0.01	0.01	0.00	0.01	0.00	0.05
28	Potassium, K^+ (mg/l)	47.33	78.34	75.04	70.31	0.14	20.42	50.40	-
C	**Microbial Parameters**								
29	Total Coliform (cfu/100ml)	401	134	241	68	40	176	68	10
30	Faecal Coliform (cfu/100ml)	317	112	107	30	10	70	30	0

NSDWQ – National Standard for Drinking Water Quality, *MPL – Maximum Permisible Limits

3.2 Discussion

The results of physical, chemical and microbial analysis is shown in table 1. Water quality assessment criteria for this study are based on the maximum permissible limits of the Nigeria Standard for Drinking Water Quality (NSDWQ) of Nigerian Industrial Standard (NIS, 2007). All analyzed physical parameter values fall within the NIS values of maximum permissible limits. The high turbidity values of sample HDW4 and HDW6, exceeded the NIS set limits. This may have been attributed to the routine fetching of water in the wells by the inhabitants. Sample HDW5 is soft water, sample HDW2, HDW6 and HDW7 are moderately hard while sample HDW1, BHW3 and HDW4 are hard (Sawyer and Mc Carty, 1967).

All the major dissolved constituents cations and anions; Ca^{2+}, Na+, HCO_3^- and Cl^- parameter values fall below the NIS values of maximum permissible limits. High Mg^{2+} Values were observed to be above the maximum permissible limits of NIS in all the samples. SO_4^{2-} in sample HDW1 and BHW3 have exceeded the maximum permissible limits.. Excess SO_4^{2-} in combination with Mg^{2+} in drinking water causes laxative effect (WHO, 2008). Minor dissolved cations and anions as K^+, CO_3^- and F^- fall below NIS maximum permissible limits. Level of Fe^{2+} in sample HDW1, HDW2 and BHW3 and NO_3^- in HDW1, BHW3 and HDW4 exceeded the (NIS) maximum permissible limits. Excess nitrate in drinking water has the potential of causing cyanosis and asphyxia (blue baby syndrome) in infants less than 3 months (NIS, 2007). All the trace dissolved cations and anions (Cu^{2+}, Zn^{2+}, Pb^{2+} and Cr^{6+}) fall below the NIS maximum Permissible limits.

The result of microbial analysis (table 1) indicates that total coliforms were detected in all the samples with high values above maximum permissible limits set by NIS. This also reflects faecal contamination either due to proximities of the wells to either soak ways or refuse dumped sites which if these waters are consumed may cause urinary tract infections, bacteraemia, meningitis, diarrhea being the major cause of morbidity and mortality among children, acute renal failure and haemolytic anaemia (NIS, 2007).

4.0 Classification of Water Type

The results of the water type analysis are presented in figure 1-3 using Stiff (Stiff, 1951) and Piper (Piper, 1944). trilinear plots. Water in the study area are classified into four water types namely: Ca-HCO3, K-HCO3, Mg-HCO3 and Na-Cl. Ca-HCO3 water type dominates the area of study forming about 57.1% while the rest of the water types forms 14.3% each. (Table 2) The calcium could have been derived from the weathering of feldspars and clay minerals.

4.1 Suitability for Irrigation

The suitability of the water for irrigation are determined based on parameters, such as Salinity Hazard (SH), Sodium Absorption Ratio (SAR), Magnesium Harzard (MH), Exchangeable Sodium Ratio (ESR) and Residual Sodium Carbonate (RSC). The total soluble salt content of irrigation water generally is measured either by determining its electrical conductivity (EC), or by determining the actual salt content. The overall range of the conductivity values ranged from 170 to 650 µs/cm and therefore the water is considered to have low to medium salinity hazard (Wilcox, 1955). The water samples are within the good to excellent water class. In normal cases, irrigation water with an EC of less than 700 µs/ cm causes little or no threat to most crops, while EC of greater than 700 - 3000 µs/cm is doubtful and may limit their growth (Tijani, 1994). Sodium Hazard (SH) is estimated by Sodium Absorption Ratio (SAR) which relates to the proportion of Na+ to Ca2+ and Mg2+ in the waters (Richard, 1954).

Sodium Adsorption Ratio (SAR) = $\frac{\mathrm{Na}}{\sqrt{(\mathrm{Ca+Mg})/2}}$; ions in the equation are expressed in milliequivalent per liter. The calculated SAR in table 2 ranges from 0.82 – 2.46 which indicates excellent water class (Wilcox, 1955) and therefore good for irrigation. Magnesium hazard (MH) for irrigation water is proposed using the formula :

$$\text{Magnesium Hazard (MH)} = \frac{\mathrm{Mg}}{\mathrm{Mg+Ca}} \text{ X } 100$$

If the percentage hazard is less than 50, then the water is safe and suitable for irrigation (Szabolcs and Darab, 1964).. The magnesium hazard values range from 8.63-50.8% (Table 2), and can be classified as suitable for irrigation. Residual sodium carbonate (RSC) is defined as the difference in milliequivalents per litre between the bicarbonate ions and those of calcium and magnesium.

$$RSC = (CO_3^{2-} + HCO_3^{-}) – (Ca^{2+} + Mg^{2+})$$

Calcium and magnesium may react with bicarbonate and precipitate as carbonates. The relative sodium concentration in the exchangeable complex increases resulting in the dispersion of soil. When the RSC value is lower than 1.25 meq/litre, the water is considered good quality, while if the RSC value exceeds 2.5 meq/litre, the water is considered harmful (Eaton, 1950). The RSC Values of the water samples range from 0.00 - 0.512 meq/l and therefore good quality for irrigation.The exchangeable sodium ratio (ESR) is calculate as: Exchangeable Sodium Ratio (ESR) = Na+/ Ca2+ + Mg2+, With ionic concentration express in in meq/l. Exchangeable Sodium Ratio (ESR) values calculated range from 0.335 – 0.917 meq/l which is an indication that it can be used in all classes of soils (Wilcox, 1955).

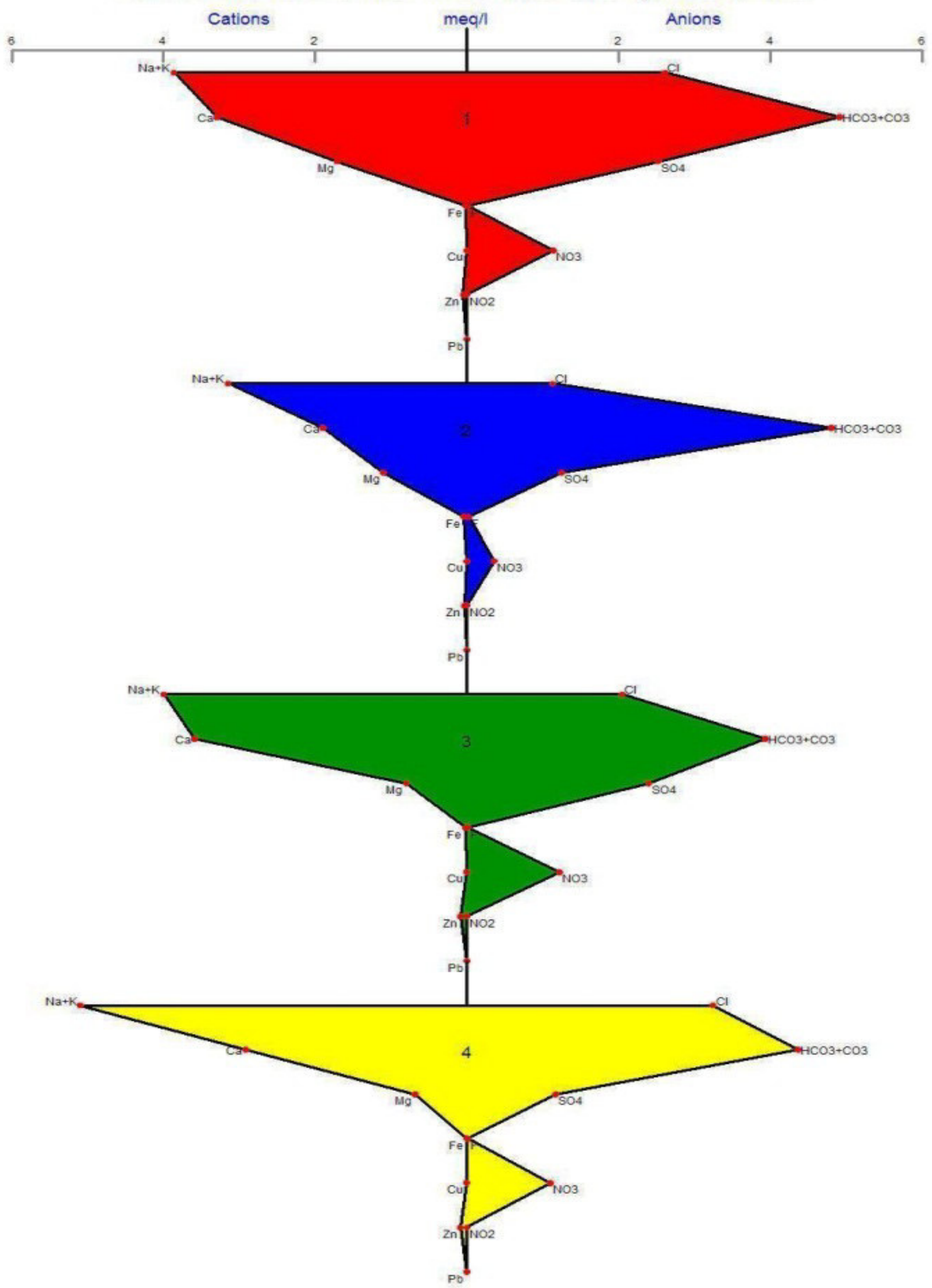

Figure 1: Cations/Anions distribution in water sample 1, 2, 3 & 4 of some selected hand dug wells in parts of Bauchi metropolis and environs.

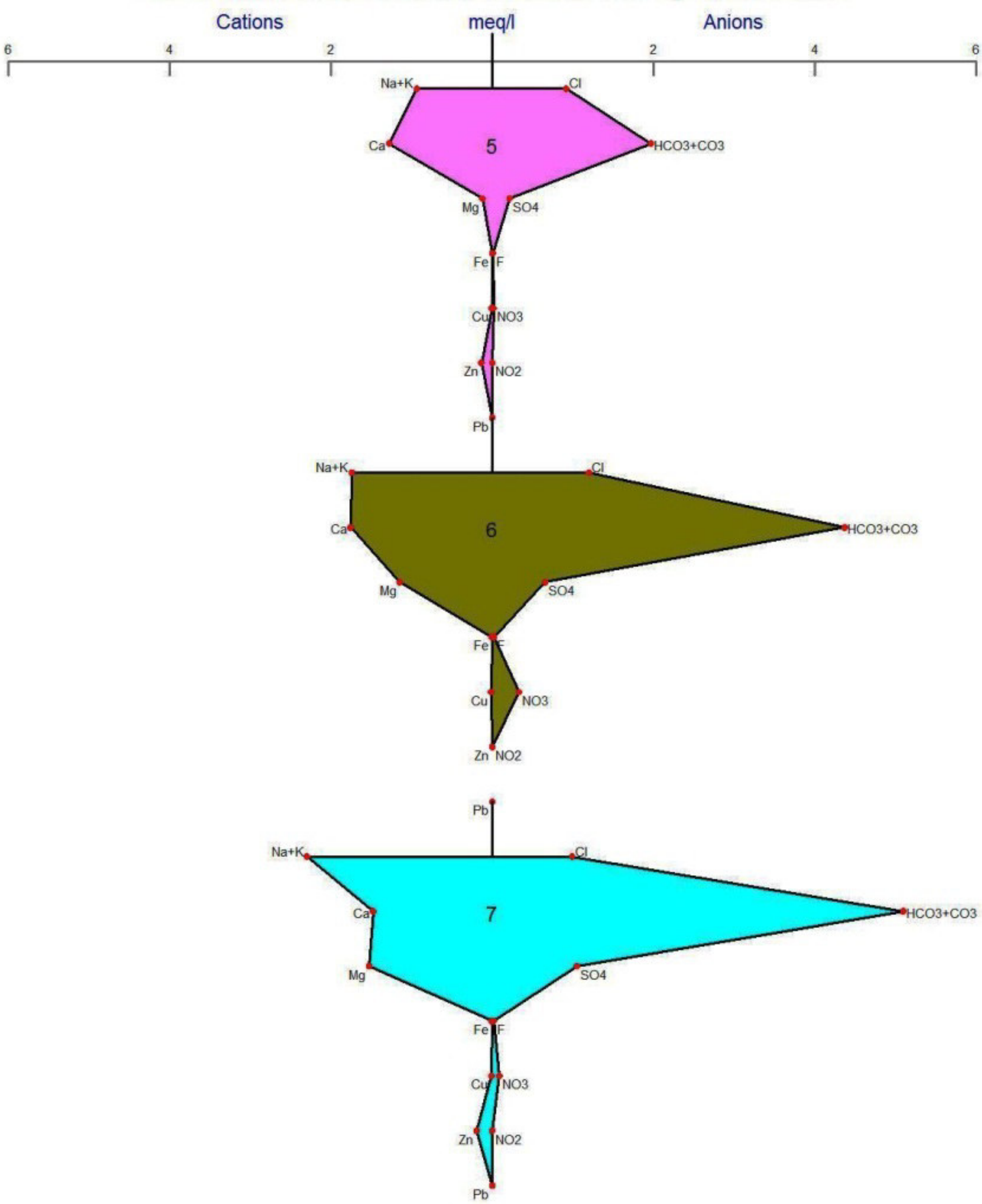

Figure 2: Cations/Anions distribution in water sample 5, 6 & 7 of some selected hand dug wells in parts of Bauchi Metropolis and environs.

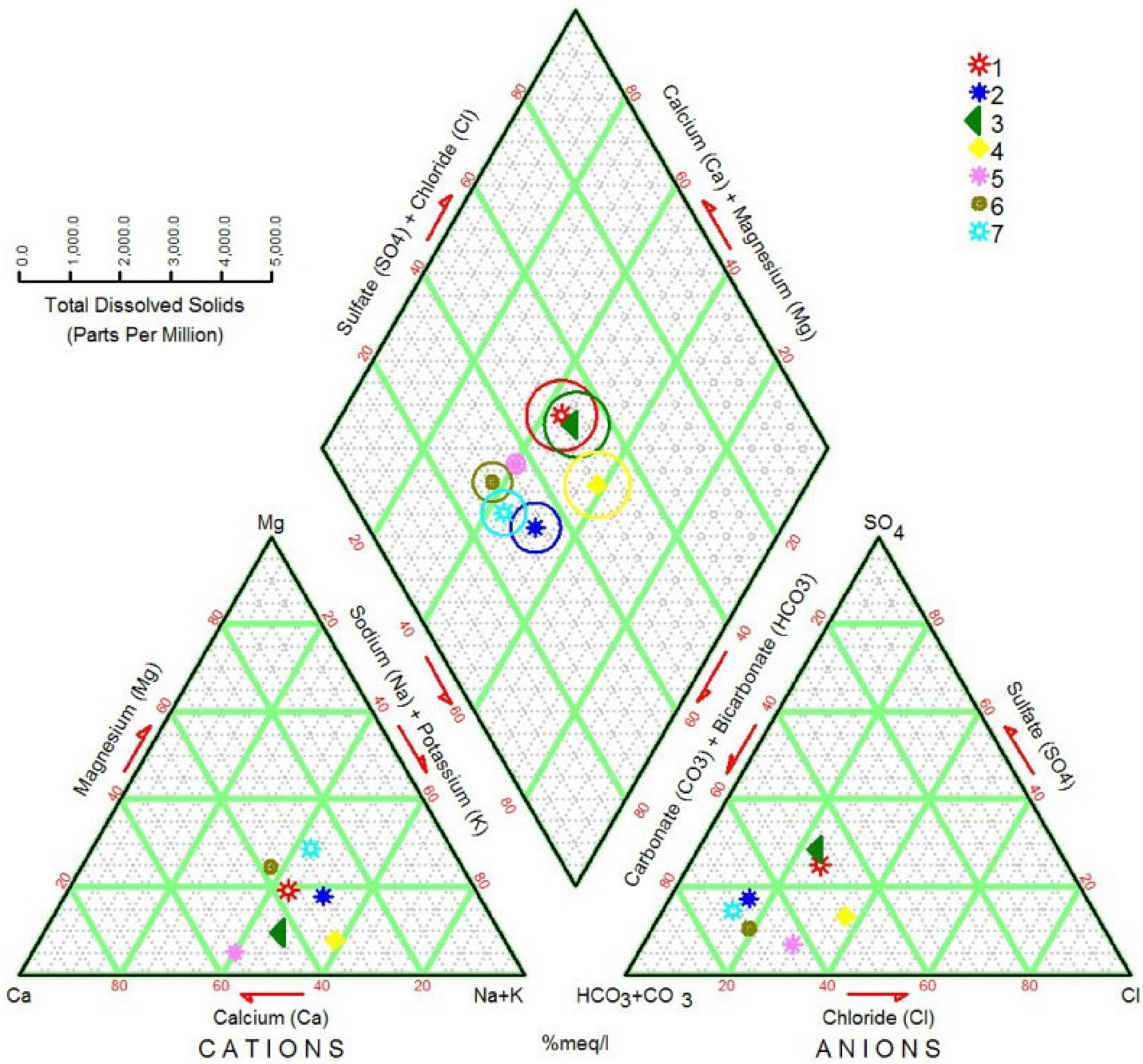

Figure 3: Piper trilinear diagram of water sample in of some selected hand dug wells in parts of Bauchi Metropolis and environs.

Table 2 Water types and irrigation water parameters - salinity and magnesium hazards, sodium absorption ratio (SAR), exchangeable sodium ratio (ESR) and residual sodium carbonate (RSC) in parts of Bauchi metropolis and environs

S/No	Parameters	Water Sample						
		HDW1	HDW2	BHW3	HDW4	HDW5	HDW6	HDW7
1	Longitude (decimal degrees)	9.884833	9.8945	9.901694	9.869028	9.868028	9.856556	9.841194
2	Latitude (decimal degrees)	10.301306	10.3075	10.304139	10.362111	10.349333	10.325278	10.358972
3	Elevation (m)	601	591	585	600	605	642	595
4	Source of Water Sample	Well	Well	Borehole	Well	Well	Well	Well
5	Depth of Well/Pond/Borehole	6.16	5.30		10.7	12.5	11.50	12.53
6	Static Water Level (m)	5.40	4.50		8.4	6.9	10.55	11.05
7	Water Type	$Ca\text{-}HCO_3$	$K\text{-}HCO_3$	$Ca\text{-}HCO_3$	Na-Cl	$Ca\text{-}HCO_3$	$Ca\text{-}HCO_3$	$Mg\text{-}HCO_3$
8	Sodium Absorption Ratio **(SAR)**	1.68	0.94	1.4	2.46	1.12	1.01	0.82
9	Salinity Hazard	Medium	Medium	Medium	Medium	Low	Medium	Medium
10	Magnesium Hazard	34.1	36.8	18.2	19.0	8.63	39.5	50.8
11	Exchangeable Sodium Ratio **(ESR)**	0.531	0.383	0.473	0.917	0.667	0.420	0.335
12	Residual Sodium Carbonate **(RSC)**	0.00	0.217	0.00	0.00	0.0418	0.00	0.512

5.0 Conclusion

The Results of the Physico-chemical and microbial parameters show that the waters are fresh ($85 \leq TDS \leq 325$mg/l), 57.1% of the water are soft to moderately hard ($70 \leq TH \leq 150$mg/l) while 42.9% of the water are hard ($150 \geq TH \geq 250$mg/l). 42.9% of the water are turbid while 57.1% not. Dissolved major, minor and trace constituents fall below maximum permissible limits of NIS, except for Mg^{2+}, Fe^{2+}, SO_4^{2-} and NO_3^- which fall above the maximum permissible limits. This may pose health threats to the inhabitants. Total coliform counts were abnormally high above the maximum permissible limits and therefore the inhabitants are likely to experience urinary tract infections, bacteremia, meningitis, diarrhea (one of the main cause of morbidity and mortality among children), cholera, typhoid fever, acute renal failure and haemolytic anaemia (NIS, 2007), among others. $Ca\text{-}HCO_3$ water type predominates the waters of the study area. Calculated values of SAR, SH, RSC, ESR and MH have presented the water to be satisfactorily suitable for irrigation.

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