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Research Article

Cations-Anions Appraisal and Durov Fickleness of Groundwater Attribute in Abuja North-Central Nigeria

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Keywords

Hierarchical Clusters, Microbial, Alkalinity, Correlation, Hydrochemistry.

Abstract

This research centers on microbial, anions and chemical scrutinizes of 25 Abuja water samples, Nigeria. The cations, anions, soluble ions, trace elements, and heavy metal were obtained and compared with WHO standards. The mean highest anions, cations and bacteria counts were recorded as 1796.879 (Electrical conductivity), and least mean of F- 1.28mg/l, whereas standard deviation highest values were 857.13 µS/cm (EC), and lowest value of 0.45 mg/s (F-). Usually, the matrix values ranges between -1 and +1. Cl- and Alkalinity displays high positive connection (0.85), with K Plus Electrical conductivity (0.77). There is a negative correlation between HNO3 & Alkalinity, and F- & CO32- (-0.01). Four hydrochemical clusters were recognized from Hierarchical cluster scrutiny (HCS) with clearly partitioned water attribute. Series and time series plot reveals TDS concentration value between 1200 and 2100 mg/L, has the highest with the mean and SD are 1433.76 and 459.38 respectively. Results also confirm that, groundwater within the investigation zone is mostly hard to exceptionally hard, and faintly alkaline-fresh to briny in nature. From hydrochemistry illustration, the key groundwater categories are Ca, Na-Cl, Na-HCO3 and Mg-HCO3, which indicates that the groundwater within the investigated region are tolerably polluted with cations-anions, due to anthropogenic, ion exchange and mineral weathering.

1. Introduction

Human welfare is directly linked to the quality of water, but, constant access to safe water is a source of concern (Igibah et al. 2021; Amu et al. 2021). Primarily, ground and surface water are the main prominent water sources for many purposes (i.e. drinking, washing, irrigation etc). Although these water sources are precious, they are frequently contaminated with waste materials from human habitations (Okoye and Orakwe 2018; Enyoh et al. 2018). Beyond half of the world's inhabitants rely heavily on surface and groundwater as her main drinking water sources. In rustic districts in Nigeria, 95 percent of the total water used is derived from these two sources (Rajaveni et al. 2015; Tiwari et al. 2016a). Globally, it is expected that land and water resources will continue to develop, since majority of the surface water bodies like streams, rivers etc. interact with groundwater (Ali et al. 2018; Ngene et al. 2018). Some interactions include: discharge of groundwater (containing solutes) into surface water features and groundwater recharge by surface water bodies causes variations in groundwater quality. Surface water contamination can deteriorate groundwater quality just as groundwater contamination can deteriorate surface water quality Tiwari et al. 2015; WHO 2004). Consequently, it is indispensable to apprehend the relationship between surface and groundwater in the hydrological cycle for effectual management of water and land resources (Igibah et al. 2020; Isiuku and Enyoh 2020; Ibe et al. 2020). Seasonal changes in groundwater flow, precipitation (rainfall) and run-off affect the river discharge as well as the levels of river water contaminants (Igibah and Tanko 2019; Enuneku and Ineh 2020). Very often, most people rely on municipal water supply and private wells (boreholes) for their daily water requirements. The condition of water that is intended for use is a vital factor which is often assessed by its physicochemical and its microbial composition, which determines if the available water is fit for use. The permissible concentrations for several ions present in water are given by Tiwari et al. 2016b and WHO 2004. Consumed water containing chemical ions present in excess i.e. above permissible limits might affect health. A lot of researches conducted have testified health implications attributable to undesirable water quality (Basavarajappa and Manjunatha 2015; Karikari and Ansah-Asare 2006; Kumar et al. 2015).

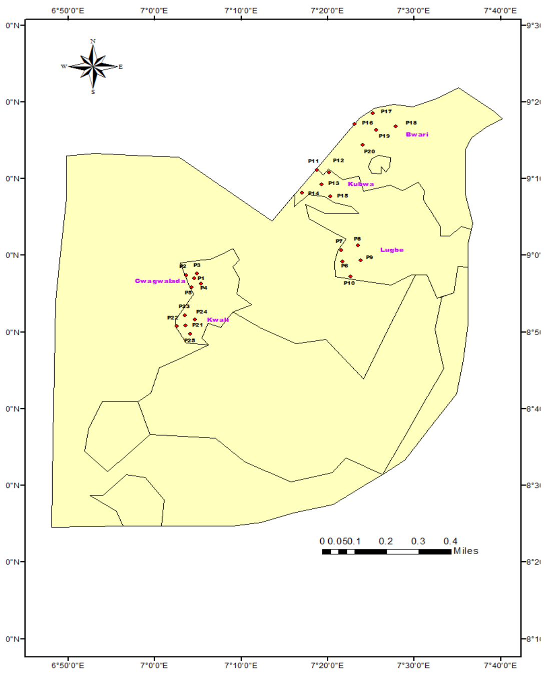

Figure 1. Illustration of research zone displaying samples localities

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2. Materials and techniques

2.1. Study region

In the data, Borehole water quality scrutiny was carried out in Abuja North in Federal Capital Territory, Nigeria within the localities in the map publicized in Fig. 1. The investigated region lies from latitude 9.4°N to 9.12°N and longitudes 7.39°E to 7.45°E, with projected population of 6,235,880 inhabitants, growing at a rate of 35% annually, make it retains its place as the fastest-growing metropolis on the African continent and in the world. The data displayed in this article supplied information on categorization of ground water samplings and analysis of human health threat connected with the consumption of excess anions and cations concentration in water.

2.2. Sampling collection

A total of 25 water samplings were collected from five water sources, that represented five Areas within Federal Capital Territory Abuja (Kwali, Gwagwalada, Kubwa, Lugbe and Bwari), Sampling was collected from 2018 to 2019. The collection spans from arid to rainy periods. All samplings were aseptically collected and well-labeled using 500-ml sterilized bottles, then transported at 4 °C (in a cool box-ice) to the University of Lagos Water Research Laboratory for investigation. All water samplings were analyzed within twenty-four (24) hours after collection.

2.3. Statistical analysis

Data obtained were subjected to statistical scrutiny via SPSS statistical package version 20 for descriptive scrutiny, and AquaChem software for the major cations and anions investigation. By using arithmetical tools, it is easy to ascertain the origins of likely groundwater contagion, allocation of the spatial domains of toxin sources, and tracking of transience of certain noxious waste and their potential origins.

3. Results and discussion

3.1. Outcome of Geospatial dissimilarity of water attribute scrutiny

Figure 2 indications the Hierarchical cluster scrutiny that was applied to the hydrochemical parameters obtained from all the samples points. The scrutiny created four hydrochemical clusters of the research area with physiognomies, then compared with WHO standard for drinking water (Table 1). Clusters 3 and 4 showed the worst violations of water quality standards with percent violation of 50 and 40% respectively. These clusters had average Total dissolve solid (TDS) concentration value more than 1000 mg/l, which makes them useful for irrigation purpose only in accordance with the Davis and De Wiest classification (1966). Cluster 1 was found to have the best hydrochemical quality followed by cluster 2 with percentage violations of 0.00 and 10.0%, respectively. The increasing order of water quality was cluster 1 > cluster 2 > cluster 4 > cluster 3. With this in mind, the inconsistency of water quality in the study area was mostly related with the individual idiosyncratic and cooperate activities done by the residents.

3.2. Outcome of Water Table Fluctuations Trends

Table 1 and Figures 3 & 4 shows the kurtosis, standard deviation, minimum, mean and maximum values of Abuja groundwater. The mean highest anions, cations and bacteria counts were recorded as 1796.879 (Electrical conductivity), followed by the Total Dissolved Solid (TDS) with value 1068.34mg/l, and least mean of F^- 1.28mg/l, whereas standard deviation highest values were 857.13 µS/cm (EC), next TDS (577.44 mg/l) and lowest value of 0.45 mg/s (F^-). Sodium is an exceptionally reactive variable that does not exist in its free state in nature. The principal source of the sodium in surface or ground water is the plagioclase feldspars as well as clinopyroxenes weathering, which serves as vital constituents for the charnockite. Health produced guideline through WHO 2006 has recommended the sodium ion in water to be 200 mg/l. In the investigated area, the sodium ion ranges from 56.01 to 515.45 mg/l, while the mean and standard deviation values were 260.19 and 195.77 mg/l respectively (Table 1). The spatial dispersal plot for sodium ion is displayed in Fig. 2. Relating to the WHO (2006) standard the investigated area, Lugbe, Gwagwalada and Kwali neighbourhoods fall beneath the tolerable limits, whereas the remain of the municipality possess excess quantity of sodium ion concentration. The surplus amount of sodium ion in groundwater within investigated zone can lead to the high blood pressure as well as toxemia pain for pregnant women (Enyoh et al. 2018). The surfeit amount of sodium ion concentration in the investigated zone is owing to charnockite rock weathering. Similarly, the WHO (2006) recommended the permissible limit of hardness in drinking water to be 300 mg/l. In the investigated zone, the hardness value ranges from 208.3 mg/l (station 1) to 1739.89 mg/l (station 1), with the mean as well as standard deviation values of 592.12 and 526.88 mg/l respectively (Table 1). The spatial dispersal map of the hardness content in the investigated area is displayed in Fig. 3. Kubwa study region contains moderately hard water, while Bwari, Kwali study zones contain hard water, and the rest of the localities contain very hard water. For the drinking purposes, Kubwa groundwater have desirable limit of Hardness in drinking water and some part of the Gwagwalada and Lugbe villages have permissible limit of hardness in drinking water.

pH is the illustration of acidity or solution basic nature, being ascertained through the hydrogen ion concentrations. WHO (2006) as well as BIS (2012), recommended 6.5–8.5 and 7.0–8.5 respectively; as the limit of pH in drinking or/ domestic water. In investigated zone, the pH varied between 5.6 and 7.44, with the mean value of 7.02 (Table 1). Relating to the BIS (2012) and WHO (2006) criterion, the investigated area localities Kubwa, Gwagwalada and Kwali have a desirable limit of p, but Lugbe and Bwari towns have below 6.5 pH. Excessive amount of pH in the drinking water will disturb the mucous membrane and water supply system (Isiuku and Enyoh 2020).

Table 1. Hydro-chemical features of cluster grouping

Parameter	Cluster 1	Cluster 2	Cluster 3	Cluster 4	WHO Limit
pH	**7.35**	6.40	6.93	6.42	6.5 – 8.5
Temp	**27.34**	23.12	26.22	24.70	NA
AlK	11.01	**55.01**	29.27	45.67	NA
TDS	987.32	**2112.32**	807.74	1531.35	1000
EC	497.34	**3310.11**	1343.29	2603.24	1500
Cl^-	32.59	**564.12**	136.26	414.46	250
$SO4^{2-}$	**567.89**	567.34	468.40	409.59	250
CO_3^{2-}	**24.98**	15.79	20.29	18.08	NA
NO^{3-}	**6.05**	0.00	4.94	2.89	50
HCO^{3-}	**656.43**	326.78	549.09	358.79	500
F^-	**1.81**	0.47	1.40	1.07	1.5
K^+	2.07	**8.70**	5.30	7.66	12
Na^+	**515.45**	55.98	358.51	85.38	50
Fe^{2+}	**2.34**	0.07	1.32	0.49	0.3
Ca^{2+}	67.56	23.87	**75.31**	51.08	300
Mg^{2+}	56.43	21.36	65.73	**115.03**	50
Mn	**0.04**	0.01	0.03	0.02	0.4
TH	231.67	213.56	**641.16**	505.01	500
SiO_2	**8.02**	0.67	4.56	2.99	NA

Bold – Highest value and cluster group.

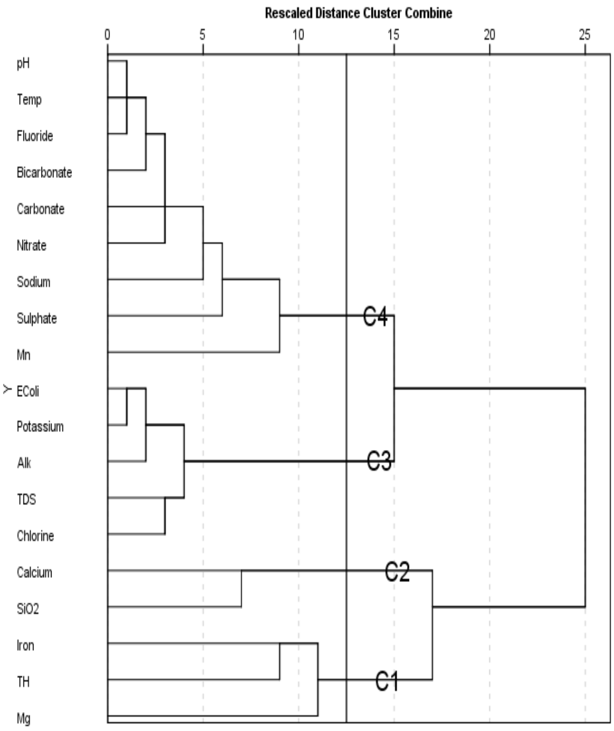
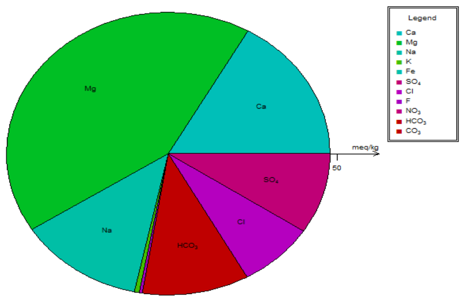
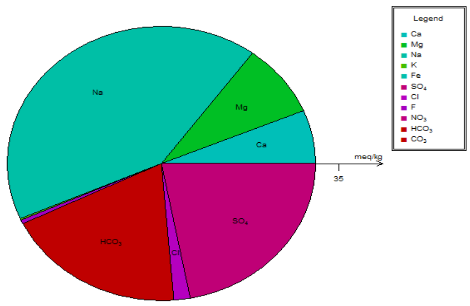


Figure 2. Cluster grading outcome from ground water parameters



(a)



(b)

Figure 3. Variability chart of the anions, cations and bacteria ions

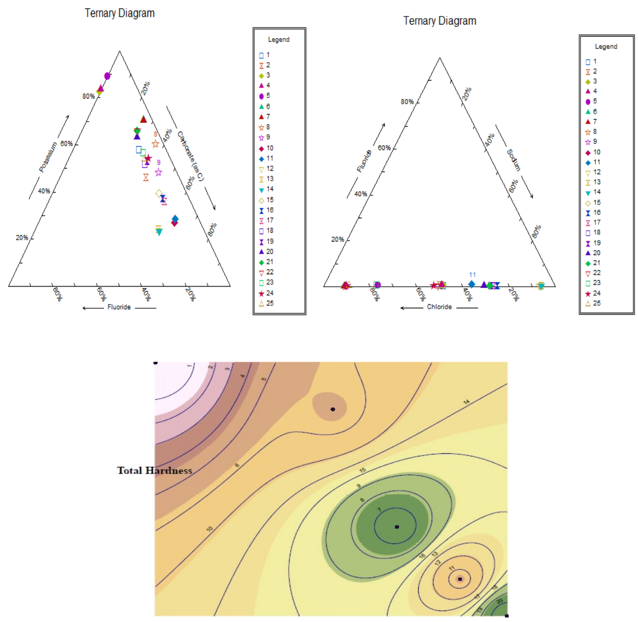


Figure 4. Changeability drawing displaying ions concentration

Majority of the carbonate ions in groundwater are gotten from the carbondioxide in the atmosphere and soil. The investigated area displayed the zero (0 mg/l) carbonate concentration at station 2 and 3, and highest value at station 5, with Gwagwalada community having neutral carbonate content in water. Calcium ranges from 32.56 to 564.12 mg/l (Table 1). The BIS (2012) and WHO (2006) have recommended that the desirable limit of calcium concentration ion in the drinking or/ domestic water is 75 mg/l. Relating to BIS (2012), the investigated area villages except some part of Gwagwalada, Lugbe and Kubwa fall beneath the safe region. Most part of the investigated area covered by low as well as very low calcium concentrations. Plagioclase feldspar and clinopyroxene that are characteristically found in Charnockite rock, are the key source of the calcium content in the investigated area.

Besides, the Charnockite rock is generally high in the investigated area. The surface material like rock as well as soil, disparities in topography, and land cover which manipulate the rate of weathering are the causes for the dissimilarity in the concentration of calcium in the waters of the investigated region (Igibah et al. 2020). Fluoride ions can happen either naturally or synthetically in drinking or/ domestic water, and are fascinated to some level in the bone structure of the body as well as tooth enamel. The BIS (2012) recommended that the highest desirable limit of fluoride content in drinking or/ domestic water is 1 mg/l and the WHO permissible limit is 1.5 mg/l. Excessive quantities of fluoride compounds instigate oxidization of piping and other water treatment tools. In the investigated region, fluoride concentration varies from 0.47 to 1.84 mg/l, whereas; the mean and standard deviation values are 1.28 and 0.45 mg/l respectively (Table 1). The variability dispersal of fluoride concentration of the investigated area is demonstrated in Fig. 5. Relating the test outcome to the BIS (2012) and WHO (2006) criterions, the investigated area Bwari and Lugbe communities have desirable levels of fluoride content in the drinking water and Gwagwalada, Kubwa and some areas in Kwali localities have the highest fluoride levels, which can cause fluorosis sicknesses (Ngene et al 2018; Tiwari et al. 2016a). The excessive quantities of fluoride concentration in the investigated region is as a result of weathering and leaching of the high availability of fluoride minerals, for instances amphiboles, lepidolite, apatite, and biotite. Similarly, the excess amount of nitrate as well as nitrite concentration can create the “brown blood sickness”. Mixture of these extreme quantities of nitrate together with nitrite concentration with water might transpire via industrial waste waters, fertilizer runoff, leaking soakaway/septic tanks, animal manures, sanitary landfills, and discharge from car exhausts (Rajaveni et al. 2015). The lowest amount of nitrite together with nitrate concentration in the study localities means low use of fertilizer, though the locations are agrarian regions.

The magnesium ranges from 21.36 to 346.56 mg/l, at station 2 and 1 respectively, while the mean and standard deviation values are 83.46 and 100.93 mg/l respectively (Table 2). The recommended drinking or/ household water guideline by WHO (2006) for the allowable limit of the magnesium in water is 30 mg/l, while the BIS (2012) tolerable limit in the absence of an substitute source is 100 mg/l. Enyoh et al. 2018, revealed that universal drinking water as well as beverages possess moderate-to-high quantities of magnesium (10–100 ppm), might potentially avert 4.5 million heart disease and stroke deaths per annual, worldwide, and this potential is estimated with 2010 global mortality figures joined with a recent quantification of water-magnesium inverse association with heart disease and stroke mortality. The variability dispersal map of the magnesium ion concentration is exhibited in Fig. 5. According to the above said criteria, all the magnesium ion concentration of five areas within Kubwa study area, nearly all areas within Lugbe and Gwagwalada scrutinized was above the desirable limit, but all Bwari groundwater analyzed and some localities within Kwali are within the tolerable limit in the absence of stand-in sources. The above said except localities fall beneath the above allowable level. The origin of excessive magnesium level in the groundwater is attributable to magnesite deposits as well as ultramafic rock occurrence of the investigated region. Natural water contains magnesium plus calcium, which initiated hardness of groundwater based on dissolved polyvalent metallic ions (Enyoh et at. 2018; Basavarajappa and Manjunatha 2015).

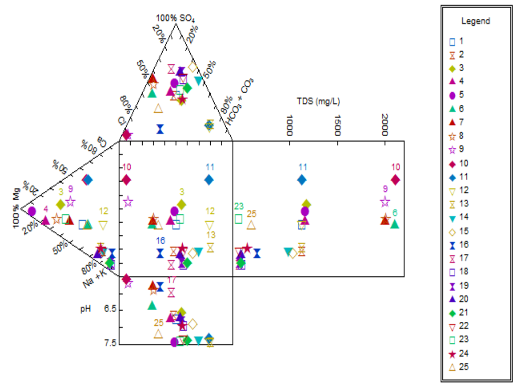


Figure 5. Durov plot for Abuja ground water samplings with various facies

Table 2. Descriptive statistics of water samplings obtained from the investigated site

	F- (mg/l)	Mg^{2+} (mg/l)	TDS (mg/l)	EC (µS/cm)	Cl^- (mg/l)	$SO4^{2-}$ (mg/l)	Na^+ (mg/l)	NO_3^- (mg/l)	HCO3- (mg/l)
Mean	1.28	83.48	10668.24	1796.87	236.41	447.23	260.19	4.20	480.58
Min	0.47	21.34	468.40	497.34	32.56	34.56	55.98	0.00	278.28
Max	1.84	346.56	2122.32	3310.11	564.12	890.65	515.45	6.16	666.25
SD	0.45	100.93	577.44	857.13	178.23	307.84	195.77	2.33	159.94
V	0.21	10185.79	333431.44	734672.28	31764.28	94764.32	38324.82	5.40	25582.18
Kurtosis	-0.96	3.77	0.74	-0.10	0.88	0.03	-1.78	-0.97	0.70
Skewness	-0.32	2.23	-0.62	-0.82	-0.48	-1.35	0.27	-0.61	-1.89
Q1	1.02	23.18	493.78	1162.40	169.01	172.40	57.40	3.11	324.17
Q3	1.77	77.73	1178.77	2352.98	323.73	765.71	483.39	6.08	655.38
WHO	1.5	30	2000	1500	250	200-400	200	50	200

3.3. Outcome of Durov and Piper Plot Scrutiny

Durov (1948) initiated another plot which offers more information on the hydro-chemical facies which help in identification of the water categories and it can exhibit some doable geochemical techniques that might aid in understanding attribute of groundwater and its appraisal (Igibah et al. 2021; Amu et al. 2021).

While, Piper plot is a means of visualizing graphical demonstration of chemistry in water samplings in hydro-geological investigations (Igibah and Tanko 2019; Amu et al. 2021).

Durov diagram is a multipart plot consisting of two ternary plots where the concerned cations are plotted against the anions of interest, besides their sides form a binary sum plot of cation against total anion concentrations with expansion form. For expanded version it comprises of electrical conductivity (EC) µS/cm and pH data added to the sides of the binary map to tolerate advance comparisons. Whereas, the piper plot enclosed three pieces, which are lower left triangle diagram symbolizing cations, while minor right triangle diagram denoting the anions, and a diamond draw in the interior epitomizing dual combination. There are six ion categories considered in the piper draw, vividly; magnesium, sodium plus potassium cations, carbonate together with hydro-gen carbonate anions, calcium, sulphate, and chloride. The investigated region water scrutiny result is displayed in piper diagram. The Durov plot (Figure 5) for Abuja groundwater samplings specifies that most of the samplings are in the stage of mixing, suspension with only some in reverse ion exchange. The pH portion of the plot discloses that groundwater in investigated area is alkaline which is preferred for drinking.

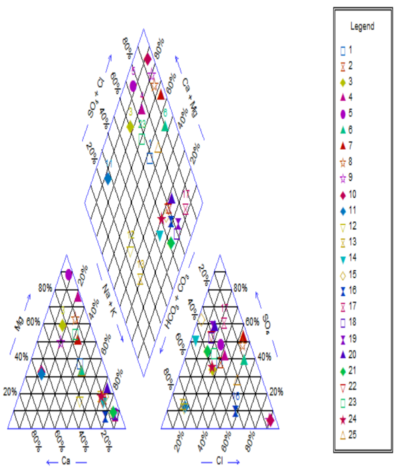


Figure 6. Piper plot for Abuja ground water samplings with various facies

The EC (µS/cm) of most of groundwater samplings not lies in the range of drinking water criterions adapted in Nigeria. According to the piper illustration (Figure 6), the localities Gwagwalada and Bwari are dominant in Sulphate-chloride- kind of water. Lugbe towns are dominant in sodium–chloride and Sodium-potassium, while Kubwa also dominant in both Sodium-potassium and Bicarbonate-carbonate type of water. The Kwali localities are dominant in the Chloride-carbonate and calcium–chloride class of water. The calcium–chloride plus sodium–chloride are rich in these zones because of Fissile Hornblende Biotite gneiss as well as Charnockite are the parent rock, which composed of sodium together with calcium rich minerals. All the five samples scrutinized within Kubwa town that are dominant in the magnesium bicarbonate category of water, is because the zones are influenced through magnesite deposits as well as ultramafic rocks. The localities: Kubwa, Lugbe and Kwali are dominant in mixed class of water, which means no cations and anions surpass 50%, while Gwagwalada and Bwari dominant with above 50% anions or cations. What's more, knowledge innovation regarding anions, cations and bacteria release in groundwater is especially cherished for Federal Capital Municipal Administration Bureau to heighten groundwater management and obviate groundwater contagion.

4. Conclusion

This paper illustrates the practicality of multivariate statistical techniques and water attribute tools for scrutiny of multifaceted water attribute data-sets and their interpretation. In general, the impact of agrarian runoff, anthropogenic deeds, ion exchange, as well as weathering is the sources of the groundwater contagion in the investigation region. Piper plot diagram displays that the localities in Gwagwalada and Bwari are dominant in Sulphate-chloride- kind of water. Lugbe towns are dominant in sodium–chloride and Sodium-potassium, while Kubwa also dominant in both Sodium-potassium and Bicarbonate-carbonate type of water. The Kwali localities are dominant in the Chloride-carbonate and calcium–chloride type of water. The villages Kubwa, Lugbe and Kwali are dominant in mixed type of water, which means no cations and anions exceeds 50%, while Gwagwalada and Bwari dominant with above 50% anions or cations. The Durov's diagram demonstrates that there are collaboration processes of two or more various facies that happened in surface water system. The water from the center of the plain, is positioned in triangle 1 and 2, rich in Ca-Cl plus $Mg\text{-}SO_4$ which triggering ion exchange as well as dissolution of vaporize minerals. In this scenario, the following propositions are indispensable to manage the water quality of the investigation region. The farmers should make effort to mitigate the influences of agrarian runoff. Government must kick off awareness about the susceptibility of high fertilizers usage. Anthropogenic deeds should be prohibited by government at all levels, besides; management and maintenance of the water resources should be incessant so as to halt the contamination.

Declaration of Conflict of Interests

The authors declare no conflict of interest. For the final piece, clearance from an ethics board is unnecessary.

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