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ASSESSMENT OF GROUNDWATER QUALITY USING PHYSIOCHEMICAL AND GEOCHEMICAL ANALYSIS IN THE VICINITY OF LEI NALA, ISLAMABAD, PAKISTAN

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Quality of groundwater samples in vicinity of Lei Nala in Islamabad was assessed using physio-chemical and geochemical parameters. Lei Nala was sampled at four different locations, ten shallow groundwater samples (upto 200 feet) and twelve deep groundwater samples (>200 feet) were collected for analysis. Absence of carbonate ions (CO_3^{-2}) in all groundwater samples indicates presence of limestone dissolution giving rise to bicarbonate and ultimately Ca-Mg type waters. Piper diagram reveals dominance with 53.86 % of Ca-Mg-type of water in the studied area. For anion concentration, HCO_3-type of water predominated with 96.15 % samples. There is no significant change in the hydro-chemical facies in the study area, indicating that most of the major ions are natural in origin which is due to the fact that groundwater is passing through sedimentary rocks and dissolves Margalla Hill Limestone thus dominating HCO_3 and Ca-Mg facies.

Keywords: Lie Nala, Groundwater, Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Piper diagram.

1. Introduction

Groundwater is globally important for human consumption, and any change in the quality can have serious consequences. Increasing population densities and agricultural activities have led to greater use of groundwater in the last 50 years [1]. This has caused adverse impact on groundwater quantity and quality. Groundwater use in Pakistan is increasing as surface water resources are becoming scarce. Greater use of groundwater systems has led to approaches for its management. In Pakistan, over exploitation and prevailing drought conditions are the possible causes of extinction of potable water reserves and inadequate replenishment of groundwater aquifers [2]. This has changed the flow dynamics of groundwater in the twin cities of Rawalpindi-Islamabad. It has stimulated seepage of untreated polluted water flowing through sewage drains. Islamabad, the capital of Pakistan, is a modern city and hosts a population of ~1 million. Due to rapid growth in population and construction work, the infiltration surface is sealed off to replenish the aquifer system. The Lei Nala which provides main drainage for industrial and domestic waste water has consequently become an extremely polluted stream and its water is not fit for drinking purposes even for the animals. The groundwater is chemically influenced by the limestone of the Margalla Hills [3]. The pumping wells installed adjacent to Lei Stream are, therefore, highly susceptible to infiltration of polluted Lei Nala water into the shallow groundwater reservoir under natural as well as artificially induced recharge conditions [4].

Water quality analysis is one of the most important aspects in groundwater studies. The hydro chemical study reveals quality of water that is suitable for drinking, agriculture and industrial purposes. Further, it is possible to understand the change in [5-10] water quality due to host rock, anthropogenic influence and determination of chemical budgets for terrestrial or aquatic systems [11-13]. Geochemical characteristics change from

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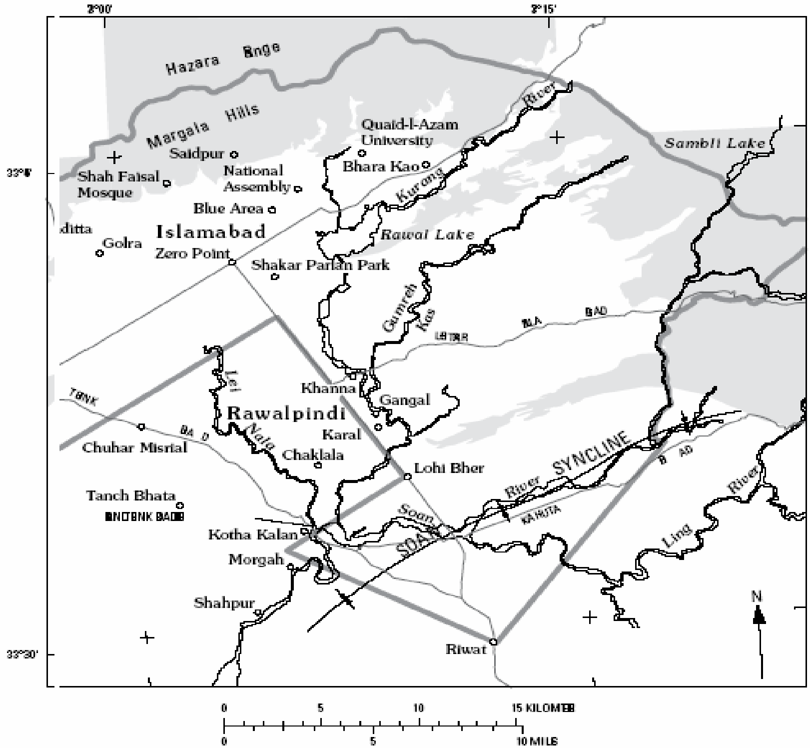

Figure 1. The drainage system of Islamabad city.

recharge, intermediate, to discharge zone according to the regional groundwater flow system [14]. These methods have been identified to provide insights into the nature of recharge that are difficult and expensive to obtain with physical based methods. The chemical parameters of groundwater play a significant role in classifying and assessing water quality [15, 16]. Chemical classification also throws light on the concentration of various predominant cations, anions and their interrelationships.

The objective of the present work is to discuss the major ion chemistry of groundwater of Islamabad. In this case the methods proposed by piper, Back and Hanshaw and Durov diagram have been used to study critically the hydrochemical characteristics of groundwater of Islamabad in the vicinity of Lei Nala.

2. Geology of the Area

Hydrogeologically, the study area lies in Soan river catchment basin in Potwar Plateau formed as part of Indo-Gangetic synclinorium of Tertiary and Pre-Tertiary sediments. Consolidated and unconsolidated deposits exposed in the area are of sedimentary origin and belong to Eocene to Recent in age. The consolidated deposits are mainly composed of limestone, sandstone, clay, shale and conglomerates. These deposits do not serve as aquifer and water travels through joints, cracks and fissures only. Unconsolidated deposits of recent age are found as terrace gravel and alluvial fill.

Groundwater in Islamabad area occurs in alluvial and hard rock deposits. The transmitting capacity of consolidated deposits is very low. Therefore, it can be considered only for small yields for requirement at the places of acute local shortage of water. Nevertheless alluvial aquifers are suitable for large scale groundwater development [17].

The Soan and Kurang rivers are the main draining streams of this area. Their primary tributaries are the Ling river, draining northwestward into the Soan; Gumreh Kas, draining westward into the Kurang from the area between the Kurang and Soan; and Lei Nala, draining southward into the Soan from the mountain front and urban areas (Figure 1). The Kurang and Soan rivers fall into Rawal and Sambli Lakes, respectively, to supply water for the urban area. Extensive forest reserves

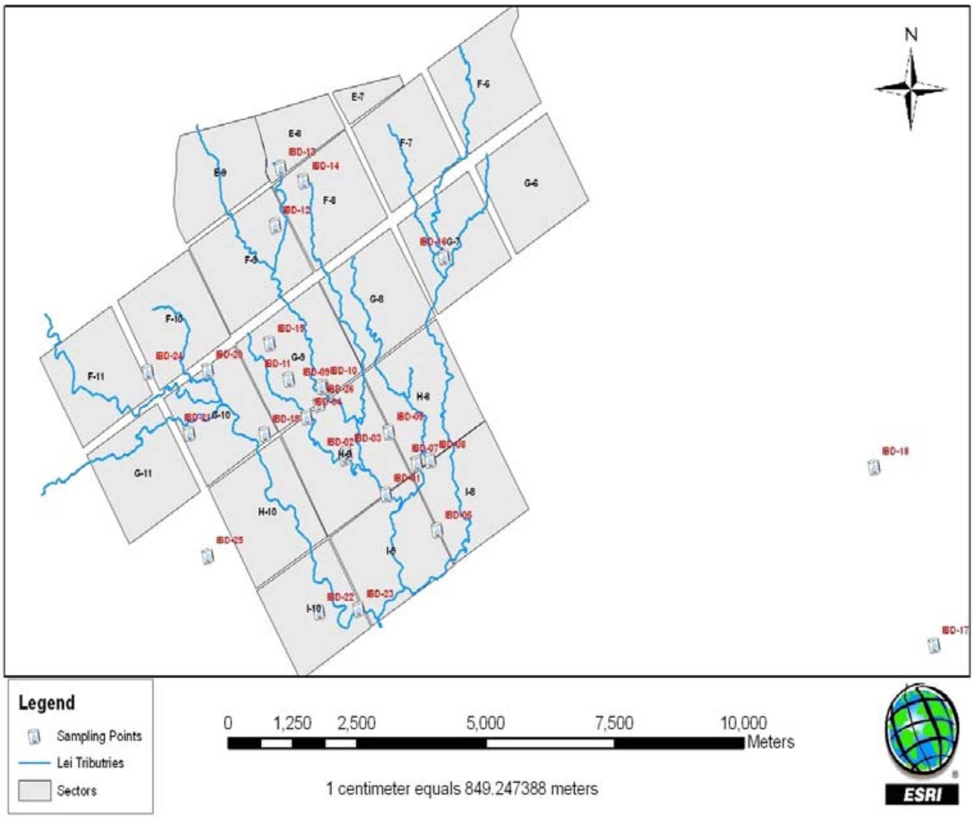

Figure 2. Location map of the study area, sampling points are shown with respect to Lei Nala

in the headwaters of the Kurang and Soan rivers benefit the quality and quantity of supply. A supplemental network of municipal and private wells as deep as 200 meters (m) produces ground water primarily from Quaternary alluvial gravels. The altitude of the water table decreases from about 600 m at the foot of the Margala Hills to less than 450 m near the Soan river, so that the saturated zone generally lies 2–20 m below the natural ground surface. Lei Nala carries most of the liquid waste from Islamabad and Rawalpindi and contributes greatly to the pollution of the Soan river. Solid-waste disposal practices also threaten the quality of ground-water reserves [18].

3. Materials and Methods

3.1. Field Sampling and In-situ Analysis

In the present investigation, stratified random sampling was carried out on the basis of water type in selected sites. Figure 2 shows sampling locations with respect to Lei Nala. Table 1 shows inventory of collected samples. Samples consisted of; surface water samples from Lei stream, shallow groundwater from the boring or hand pumps and deep groundwater samples from tube wells installed in vicinity of Lei Nala. Samples for chemical analysis were collected in plastic bottles and stored under cool conditions (<12° C) in ice box. In the field prior to sample collection all samples were first filtered using a Whatman-40 filter paper. The entire collected water samples were stored at ~ 5°C prior to analysis. Shallow groundwater samples were collected from hand-pumps and boreholes /mini pumping wells not greater than 150 feet. Deep groundwater samples were collected from tube-wells which are usually installed at depths greater than 400 feet. In total four (04) surface water samples from Lei Nala and twenty (20) groundwater samples from wells located in the vicinity of Lei Nala in Islamabad area were collected. Two groundwater samples were collected at some distance from Lei Nala. Standard field sample preservation methods were used for chemical analysis in the laboratory [19, 20]. Electrical conductivity (EC) and pH of collected samples were measured in situ with a portable digital conductivity meter (Model HI-8633, HANNA Instruments, U.K.) and digital pH meter (Model 3070, ELE International, U.K).

Table 1. Sample Inventory .

Sample Code	Location	Type	Coordinates	
			Latitude	Longitude
IBD-01	I-9	Nala	33°39'57.6" N	73°31'16.1" E
IBD-02	H-9/2	Nala	33°40'17.6" N	73°02'40.6" E
IBD-03	H-9/2	Tube well	33°40'19.9" N	73°02'41.7" E
IBD-04	G-9	Nala	33°40'39.7" N	73°02'08.7" E
IBD-05	H-8/1	Tube well	33°40'32.5" N	73°03'16.6" E
IBD-06	I-8	Tube well	33°39'38.6" N	73°03'57.5" E
IBD-07	I-8	Nala	33°40'15.4" N	73°03'39.9" E
IBD-08	I-8/2	Tube well	33°40'17.4" N	73°03'5.11" E
IBD-09	G-9/4, Al-Furqan Mosque	Boring	33°40'56.7" N	73°02'22" E
IBD-10	G-9/4 , I & T Centre,	Boring	33°40'57.3" N	73°02'20.7" E
IBD-11	G-9/1	Boring	33°41'00.7" N	73°01'53.2" E
IBD-12	F-9, Fatima Jinnah Park	Boring	33°42'58.0" N	73°01'44.1" E
IBD-13	E-8	Boring	33°42'58.0" N	73°01'44.1" E
IBD-14	F-8/2	Boring	33°42'50.9" N	73°02'03.3" E
IBD-15	G-9/2,	Tube well	33°41'20.2" N	73°01'37.1" E
IBD-16	G-7/2-4	Boring	33°42'10.5" N	73°03'59.8" E
IBD-17	Alipur	Boring	33°38'40.9" N	73°10'47.6" E
IBD-18	Chak Shahzad	Boring	33°40'19.09" N	73°09'56.34" E
IBD-19	G-10/4	Tube well	33°40'24.3" N	73°01'35.6" E
IBD-20	G-10/3	Tube well	33°41'4.727" N	73°0'46.465" E
IBD-21	G-10/2	Tube well	33°40'29.4" N	73°00'34.7" E
IBD-22	I-10/2	Tube well	33°38'51.434" N	73°02'21.12" E
IBD-23	I-10/4	Tube well	33°38'53.737" N	73°02'53.79" E
IBD-24	F-10/1	Tube well	33°41'03.1" N	72°59'57.4" E
IBD-25	H-10/1	Boring	33°39'21.4" N	73°00'49.2" E
IBD-26	G-9/4	Tube well	33°40'47" N	73°02'18.6" E

3.2. Laboratory Analysis

The samples were analyzed for major cations namely; (Ca^{+2}, Mg^{+2}, Na^{+1} and K^{+1}) were analyzed by ICP-OES [21]. Cl^{-1}, HCO_3^{-1}, CO_3^{-2} were measured by titration and sulfate concentration is determined by spectrophotmetric method [22]. Nitrate concentration is measured by High Performance Liquid Chromatograph (HPLC).

4. Results

The range of studied physiochemical parameters are given in Table 2. Electrical conductivity of Lei water samples varies from 684.4 - 841.5 μS/cm. While that of shallow and deep groundwaters lies between 581 - 2170 μS/cm and 397-911 μS/cm respectively. The total dissolved solid (TDS) content of Lei was found to be within range of 353-429 mg/L. The shallow groundwater has TDS values within the range of 284-1223 mg/L

Table 2. Range of Physiochemical Parameters of collected samples.

Parameters	Surface Water	Shallow Groundwater	Deep Groundwater
Electrical Conductivity (EC) (μS/cm)	684-842	581-2170	397-911
Total Dissolved Solids (TDS) (mg/L)	353-429	284-1223	226-484
pH	7.99-8.27	7.19-7.72	7.04-8.12
Temperature (ºC)	28.9-31.7	23.8-32.5	23.6-32.9

Figure 3. Anion concentrations in water samples.

while that in deep groundwater is from 226-484 mg/L. The pH value of Islamabad groundwater in study area ranges from 7.04-8.12 and 7.2-7.7 for deep and shallow groundwater respectively. The temperature of Lei samples varies from 28.9 - 31.7ºC. For shallow and deep groundwaters it ranges from 23.8-32.5ºC and 23.6-32.9ºC respectively.

Chloride concentration in Lei water samples ranges between 14.18-17.73 ppm, while the shallow groundwater has chloride concentration in the range of 9.75-85.97 ppm. Deep groundwater chloride range is 7.98-17.73 ppm. The concentration of sulfate in Lei water samples varies from 29.27-61.67 ppm. While it is within the range of 23.78-160.92 ppm in shallow and 3.02-80.03 ppm in deep groundwater. The concentration of bicarbonates in the Lei water, shallow and deep groundwater samples ranges from 250.1-353.8 ppm, 189.1-451.4 ppm and 170.8-427.07 ppm respectively. The anion concentration is more clearly presented in Figure 3.

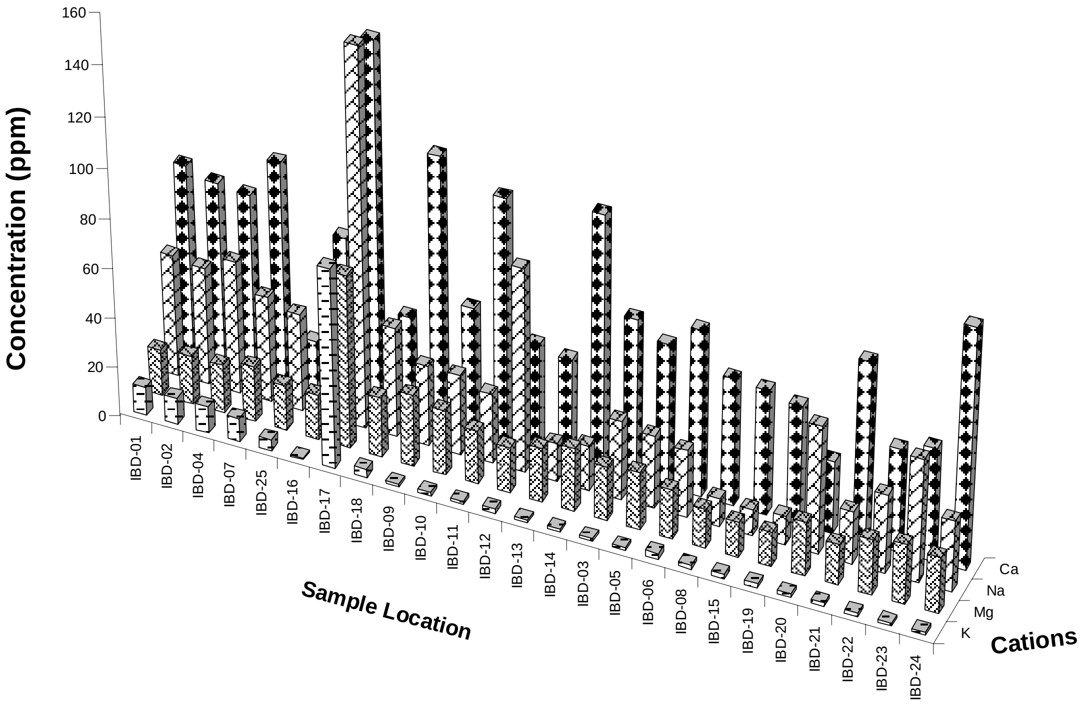

Figure 4. Major cation contents in water samples.

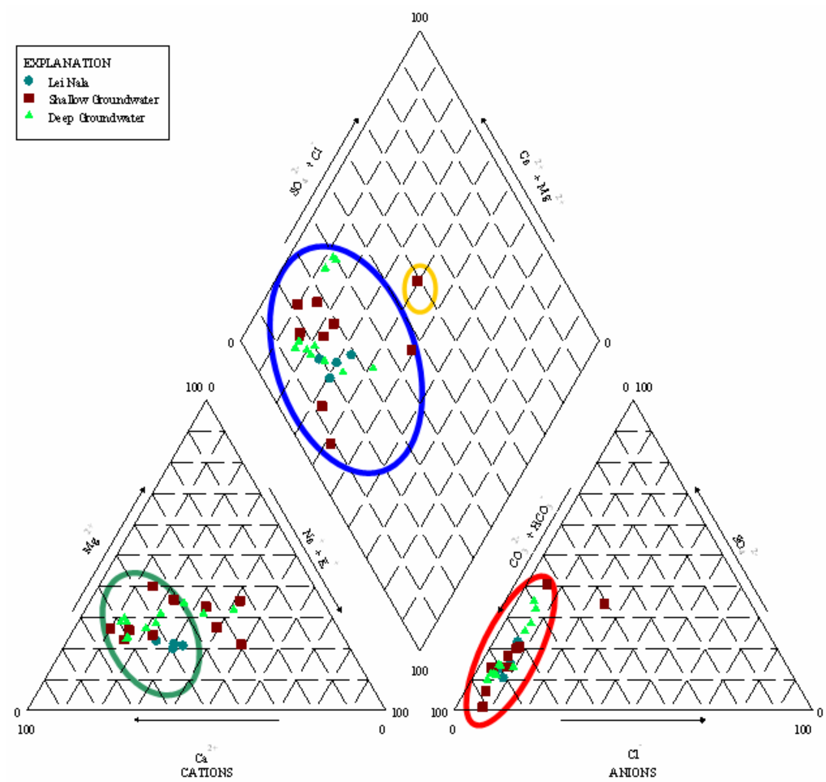

Figure 5. Piper diagram of collected water samples showing various water types present in the study area.

The sodium concentration in Lei water samples varies from 42.6 to 53.3 ppm while in shallow groundwater it ranges from 15.4 to 151.8 ppm and in deep groundwater its concentration is 10.7-52 ppm. The concentration of potassium in Lei Nala, Shallow and deep groundwater ranges from 9.5-11.4 ppm, 0.6- 0.8 ppm and 1.2-2.6 ppm respectively. The concentration of calcium in Lei water ranges from 72.2-88.6 ppm, while its concentration in shallow and deep groundwater lies within 29.2-102.3 ppm and 19.8-146.3 ppm respectively. The magnesium concentration of Lei water ranges within 18.6-22.6 ppm, while in deep groundwater it is 14-25.4 ppm and in shallow groundwater it is 18.2-70.1 ppm. Figure 4 has been incorporated to compare the major cation contents of the studied water system.

5. Discussion

Chemical data of representative samples from the study area presented by plotting them on a Piper-tri-linear diagram [23] is shown in Figure 5. These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are identified and listed in Table 3. The concept of hydrochemical facies was developed in order to understand and identify the water composition in different water bodies. The concentrations of major ions in the groundwater were notably higher than those in the river water. The general chemical composition of water supply was characterized as $Ca–HCO_3$ type, as the water type in Islamabad, though the concentrations of all ions in the groundwater were higher than in the river water. The solute concentrations of the tributaries and springs were higher than those of the main stream water, though the chemical patterns were almost the same. The solute constituents in the surface (main and tributaries) and deep groundwater were chemically unique and almost all the data fell into the category of HCO_3 type, whereas the chemical composition of the shallow groundwater changed from place to place. Shah [24] and Ahmad [25] have also described the significance of groundwater chemistry for Islamabad aquifers and Tahlab valley, Balochistan using Stiff Pattern and Trilinear Piper Diagrams respectively.

Table 3. Water types characterized using Piper diagram.

Sample Code	Location	Type	Water type
IBD-01	I-9	Nala	HCO_3
IBD-02	H-9/2	Nala	HCO_3
IBD-04	G-9	Nala	HCO_3
IBD-07	I-8	Nala	HCO_3
IBD-25	H-10/1	Boring	HCO_3
IBD-16	G-7/2-4	Boring	HCO_3
IBD-17	Alipur	Boring	$Mg-SO_4$
IBD-18	Chak Shehzad	Boring	HCO_3
IBD-09	G-9/4	Boring	$Ca-HCO_3$
IBD-10	G-9/4 , I & T Centre	Boring	HCO_3
IBD-11	G-9/1	Boring	$Ca-HCO_3$
IBD-12	F-9, Fatima Jinnah Park	Boring	Na
IBD-13	E-8	Boring	HCO_3
IBD-14	F-8/2	Boring	$Ca-HCO_3$
IBD-03	H-9/2	Tube well	HCO_3
IBD-05	H-8/1	Tube well	HCO_3
IBD-06	I-8	Tube well	Ca
IBD-08	I-8/2	Tube well	HCO_3
IBD-15	G-9/2	Tube well	HCO_3
IBD-19	G-10/4	Tube well	HCO_3
IBD-20	G-10/3	Tube well	HCO_3
IBD-21	G-10/2	Tube well	HCO_3
IBD-22	I-10/2	Tube well	HCO_3
IBD-23	I-10/4	Tube well	HCO_3
IBD-24	F-10/1	Tube well	HCO_3
IBD-26	G-9/4	Tube well	HCO_3

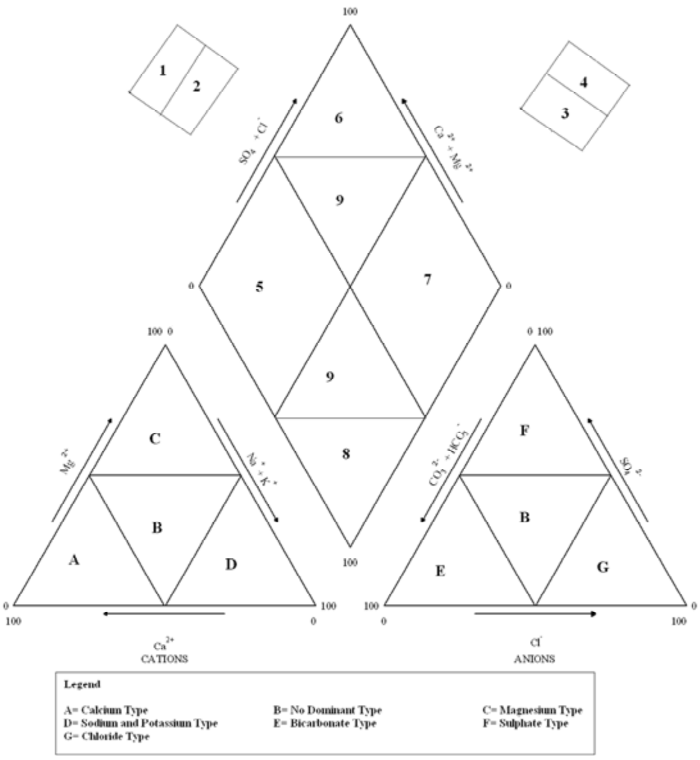

Figure 6. Classification diagram for anion and cation facies in the form of major-ion percentages. Water types are designed according to the domain in which they occur on the diagram segments.

Facies are recognizable parts of different characters belonging to any genetically related system. Hydrochemical facies are distinct zones that possess cation and anion concentration categories. To define composition class, Back and co-workers [26] suggested subdivisions of the tri-linear diagram (Figure 6). The interpretation of distinct facies from the 0 to 10% and 90 to 100% domains on the diamond shaped cation to anion graph is more helpful than using equal 25% increments. It clearly explains the variations or domination of cation and anion concentrations. Ca-Mg-type of water predominated in the studied area. The percentage of samples falling under Ca-Mg-type was 53.86 %. For anion concentration, HCO_3-type of water predominated with 96.15 % samples. There is no significant change in the hydro-chemical facies noticed in the study area, which indicates that most of the major ions are natural in origin. The reason is groundwater passing through sedimentary rocks dissolves Margalla Hill Limestone thus dominating HCO_3 and Ca-Mg facies (Table 4).

Table 4. Water types encountered in the study area.

Subdivision of diamond	Characteristics of Corresponding subdivisions of diamond-shaped fields	Percentage of samples in this category
1	Alkalies earth (Ca+Mg) exceed alkalies (Na+K)	53.86
2	Alkalies exceed alkaline earths	46.15
3	Weak acids ($C0_3$+HCO_3) exceed strong acids (SO_4+Cl)	96.15
4	Strong acids exceed weak acids	3.84
5	Magnesium bicarbonate type	0
6	Calcium-chloride type	0
7	Sodium-chloride type	0
8	Calcium-bicarbonate type	96.15
9	Mixed type (No cation-anion exceed 50%)	3.85

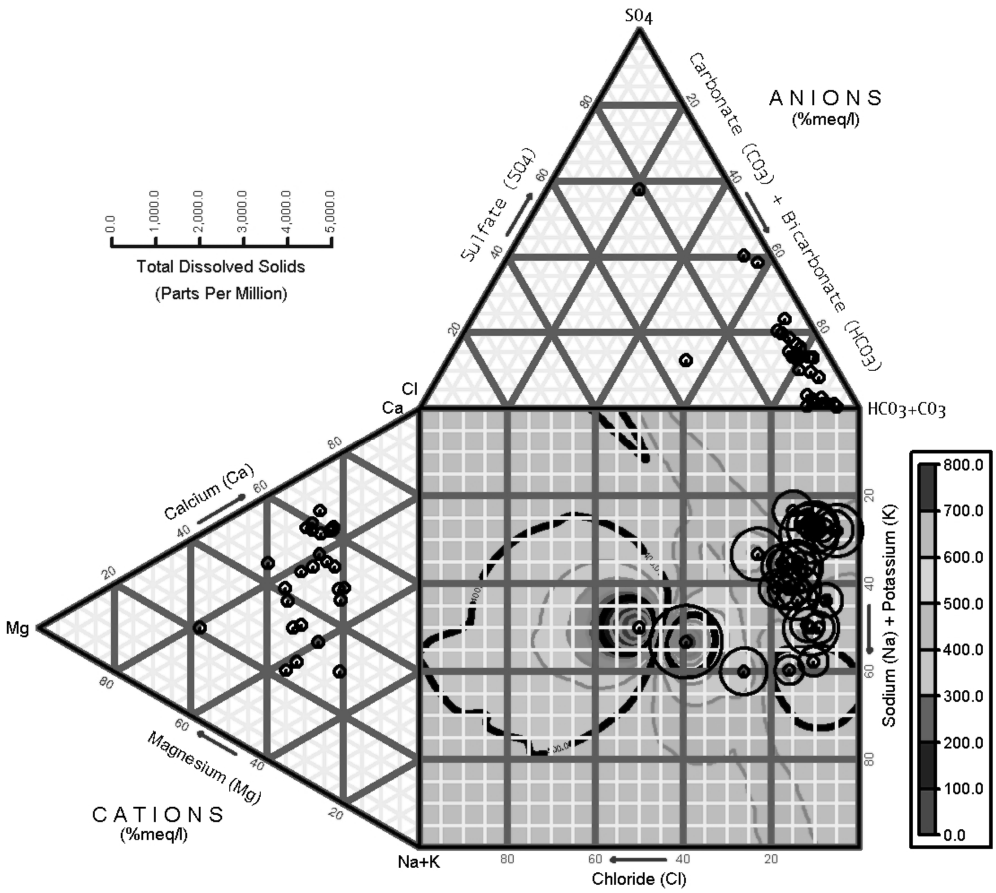

Figure 7. Durov diagram showing concentrations of anions, cations and TDS contour plot of the collected water samples from the study area.

The Piper diagram [23] is an alternative to the Durov [27]. The Durov diagram can be used to plot all samples in the open database or selected sample groups. Figure 7 shows the Durov Diagram, for water from various sources. It can be seen that the groundwater is calcium bicarbonate. High concentration of Ca and HCO_3 is due to dissolution of Margalla Hill Limestone along the pathways of Lei Nala. The chemical analyses show a low salt content (TDS).

6. Conclusions

Geochemical and physiochemical data has been used to characterize groundwater in vicinity of Lei Nala, Islamabad-Pakistan. The plots of the data have shown distinct groups for groundwater. Hydrochemical characters show that groundwater and surface water are off Ca-Mg-HCO_3 type. The hydrochemical data also reveals that the groundwater aquifers are generally of good quality and Lei Nala does not significantly contaminate groundwater bodies of this area.

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