

**INTERRELATIONSHIP OF GEOLOGY AND WATER  
QUALITY: A CASE STUDY OF ISLAMABAD,  
PAKISTAN**



A thesis is submitted to Bahria University, Islamabad in partial fulfillment of  
the requirement for the degree in B.S Geology.

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## **ABSTRACT**

Water is the most important resource for life. A significant part of geology, which is the study of the Earth, is the study of water in terms of hydrogeology; how water and rock interact with each other. Rocks can not only facilitate water and provide it path but can also alter its chemistry. This study aims to highlight the relationship between the geology and water quality in the study area of Islamabad, the capital city of Pakistan. Forty-seven (47) samples were collected from all over the city at various locations from either bore water sources, filtration plants and surface streams and tested for their physical and chemical as well as heavy metal properties. Physical parameters including pH, EC, TDS, Salts, Temperature were analyzed. Chemical parameters including amount of Chlorides, Sodium, Carbonates, Calcium, Alkalinity and Total Hardness and heavy metals including Iron and Arsenic were analyzed. On the basis of the results we confirmed presence of Carbonates, Salts and other elements were due to geological formations present in the area (Margalla Hill Limestone, Murree Formation, Kamilal Formation, Lei conglomerates) which are concentrated with high Calcium, Salts and Carbonates. The Physical, Chemical and Heavy metal tests yielded results within normal limits set by EPA so there is no risk of hazardous contamination from natural causes except one sample which showed anomalously high EC, TDS and Salt values, for which any natural reasons have been identified.

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## ABBREVIATIONS

<b>pH</b>	Power of Hydrogen
<b>EC</b>	Electrical Conductivity
<b>TDS</b>	Total Dissolved Solids
<b>TW</b>	Tap Water
<b>FW</b>	Filter Water
<b>SW</b>	Surface Water
<b>PCRWR</b>	Pakistan Council of Research in Water Resources
<b>WHO</b>	World Health Organization
<b>EPA</b>	Environmental Protection Agency
<b>EDTA</b>	Ethylenediaminetetraacetic acid
<b>EBT</b>	Erichrome Black T
<b>L</b>	Litre
<b>N</b>	Normality
<b>M</b>	Molarity
<b>BDL</b>	Below detection limit
<b>mg/L</b>	Milligram per Litre
<b>ppm</b>	Parts per million
<b>µs/cm</b>	Micro Siemens per centimeter

## **CONTENTS**

<b>ABSTRACT</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>ABBREVIATIONS</b>	<b>iv</b>
<b>FIGURES</b>	<b>viii</b>
<b>TABLES</b>	<b>x</b>

### **CHAPTER 1**

#### **INTRODUCTION**

1.1 General Statement	1
1.2 Previous Work	3
1.3 Aims and Objectives	5
1.4 Methodology	5
1.4.1 Water Sampling	5
1.4.2 Geological Fieldwork	8
1.4.3 Laboratory Work	9

### **CHAPTER 2**

#### **STRUCTURAL AND HYDROGEOLOGICAL SETUP**

2.1 Introduction	10
2.2 Geologic Structure	10
2.3 Hydrogeological Setting	11

### **CHAPTER 3**

#### **STRATIGRAPHY OF STUDY AREA**

3.1 Introduction	13
3.2 Surghar Group (Jurassic and Lower Cretaceous)	13
3.2.1 Samana Suk Formation (Middle Jurassic)	13
3.2.2 Chichali Formation (Upper Jurassic and Lower Cretaceous)	13
3.2.3 Lumshival Formation (Lower Cretaceous)	14
3.3 Makarwal Group (Paleocene)	14
3.3.1 Hangu Formation	14
3.3.2 Lokhart Limestone	14
3.3.3 Patala Formation	15
3.4 Cherat Group (Lower Eocene)	15
3.4.1 Margala Hill Limestone	15

3.4.2 Chorgali Formation	15
3.4.3 Kuldana Formation	16
3.5 Rawalpindi Group (Miocene)	16
3.5.1 Muree Formation (Lower Miocene)	16
3.5.2 Kamli Formation (Lower Middle Miocene)	16
3.6 Siwalik Group (Neogene and Pleistocene)	17
3.7 Surficial Units (Pleistocene and Holocene)	17

## **CHAPTER 4**

### **METHODOLOGY**

4.1 Analysis of Physical Parameters	19
4.2 Analysis of Chemical Parameters	19
4.2.1 Chlorides	20
4.2.2 Carbonates	20
4.2.3 Total Hardness	21
4.2.4 Total Alkalinity	22
4.2.5 Total Calcium	23
4.3 Analysis of Heavy Metals	23
4.3.1 Arsenic	24
4.3.2 Iron	25

## **CHAPTER 5**

### **RESULTS AND DISCUSSION**

5.1 Physical Properties	28
5.1.1 pH	29
5.1.2 Electrical Conductivity (EC)	30
5.1.3 Total Dissolved Solids (TDS)	31
5.1.4 Salts	32
5.2 Chemical Parameters	33
5.2.1 Chlorides	35
5.2.2 Sodium	36
5.2.3 Carbonates	36
5.2.4 Total Hardness	39
5.2.5 Alkalinity	41
5.2.6 Calcium	43

5.3 Heavy Metals	45
5.3.1 Arsenic	45
5.3.2 Iron	45
5.4 General Discussion	47
<b>CONCLUSION</b>	<b>49</b>
<b>REFERENCES</b>	<b>51</b>

## FIGURES

Figure 1 Map showing study area and sampling points (Sheikh, 2007) and (ARCMAP)	3
Figure 2 Map showing sampling points and types of samples collected (ARCMAP)	6
Figure 3 Surface water sampling from natural spring at Shahdara, Islamabad	8
Figure 4 Outcrop for fieldwork near Shahdara, Islamabad. Eocene Chorgali formation and Miocene Murree formation observed.	9
Figure 5 Geologic Cross section of study area (Sheikh, 2007)	11
Figure 6 Stratigraphic Column of the region (Sheikh, 2007)	18
Figure 7 Digital meter (PCSTestr35) for analysis of physical parameters	19
Figure 8 Rapid Arsenic Test Kit used for Arsenic Analysis	24
Figure 9 Arsenic Test Kit Color Chart	25
Figure 10 UV4000 Spectrophotometer	27
Figure 11 Graphs showing pH values of samples 1-47	30
Figure 12 Graphs showing EC values ( $\mu\text{s}/\text{cm}$ ) of samples 1-47	31
Figure 13 Graphs showing TDS values (ppm) of samples 1-47	32
Figure 14 Graphs showing Salts (ppm) in samples 1-47	33
Figure 15 Graphs showing concentrations of Cl and NaCl (mg/l) for samples 1-47	35
Figure 16 Graphs showing concentration of Sodium (mg/l) of samples 1-47	36
Figure 17 Graphs showing concentrations of various carbonates (mg/l)	38
Figure 18 Graphs showing Total Hardness (mg/l) of samples	40



Figure 19 Graphs showing Alkalinity of samples (mg/L)	42
Figure 20 Graphs showing concentration of Calcium (mg/l)	44
Figure 22 Graphs showing concentrations of Iron (mg/l) in samples 1-47	46

## TABLES

Table 1: Sampling collection locations	6
Table 2 Results of Physical Parameters of water samples	28
Table 3 Table showing values for Cl, NaCl and Na (mg/l)	33
Table 4 Table showing concentrations of various carbonates present	36
Table 5 Table showing Total Hardness (mg/l) values of samples	39
Table 6 Table showing Alkalinity values of samples 1-47	41
Table 7 Table showing concentrations of Calcium (mg/l)	43
Table 8 Table showing concentration of Iron (mg/l) in samples	45

# CHAPTER 1

## INTRODUCTION

### 1.1 General Statement

Safe drinking water is not only a basic need and a requirement for living a healthy life, but it is also a fundamental human right. Water is the most important natural resource for life, second only to air. Water, like other living species on the planet, is the most crucial component for human life. Because the human body is 70% water, we must rely on fresh water to maintain this equilibrium and stay hydrated. (Rehman, et al., 2020) Today, everyone on the planet competes for less than 1% of the world's freshwater supply, whether it comes from groundwater or surface water. (Badmus, 2020)

Both surface and ground water are vulnerable to the detrimental impacts of water contamination, which can be caused by human (industry, mining, agriculture activities, and wastewater) or natural (ore deposits and rock denudation) sources. These consequences might range from poor human health and illness to land and financial losses in agriculture and business. Concerns about access to safe water have received a lot of attention in recent years, and several water purification methods have been developed to remove unwanted chemicals, elements, and objects from raw water (Khan, 2013). However, water that is relatively contaminant-free (and safe) one instant might become severely contaminated the next for a variety of causes, including accident, negligence, or natural events and/or processes (s).

The relevance of interaction between the rock/soil and water quality is shown by the chemistry of ground water and surface water sources. In many areas, the rock–soil–water relationship is a major source of groundwater pollution. (Umar, 2013)

Islamabad, the capital of Pakistan is a planned city built at the foot of the Margalla Hills just north of Rawalpindi dating around 1960. It is located between the coordinates: longitudes 72°45'-73°00' and latitudes. 33°30'-33°40' It has a monsoonal climate with hot, wet summers and chilly, dry winters; precipitation is typical of Pakistan's semiarid zone.

The primary streams that drain the region are the Soan and Kurang Rivers. The Soan River is fed by the northwestward flowing Ling River and the Kurang river is fed by the westward flowing Gumreh Kas, which flows from the region between the Kurang and the Soan. The Lei Nala flows southward into the Soan from the mountain front and urban areas, are their main tributaries. To supply water to the metropolitan area, the Kurang and Soan Rivers are dammed at Rawal and Sambli Lakes, respectively.

Ground water is produced principally from Quaternary alluvial gravels by a supplementary network of municipal and private wells reaching depths of up to 200 meters (m). The water table drops near the Soan River, from roughly 600 metres in the Margalla Hills to less than 450 meters, resulting in a zone of saturation 2–20 metres below the natural ground surface. The landscape of Islamabad's metropolitan region is made up of plains and mountains with a total relief of over 1,175 metres.

The Margalla Hills, which are part of the lower and outer Himalayas and include the Hazara and Kala Chitta Ranges, are located in the northern section of the metropolitan region. A piedmont bench with a south facing slope south of the Margalla Hills is lies beneath the Rawalpindi Group folded sandstones and shales (Miocene). The piedmont area has several peaks and alluvium covered valleys, despite the fact that the topography is typically not very dominant and broad plains of silt which is windblown are common. (Sheikh, 2007)

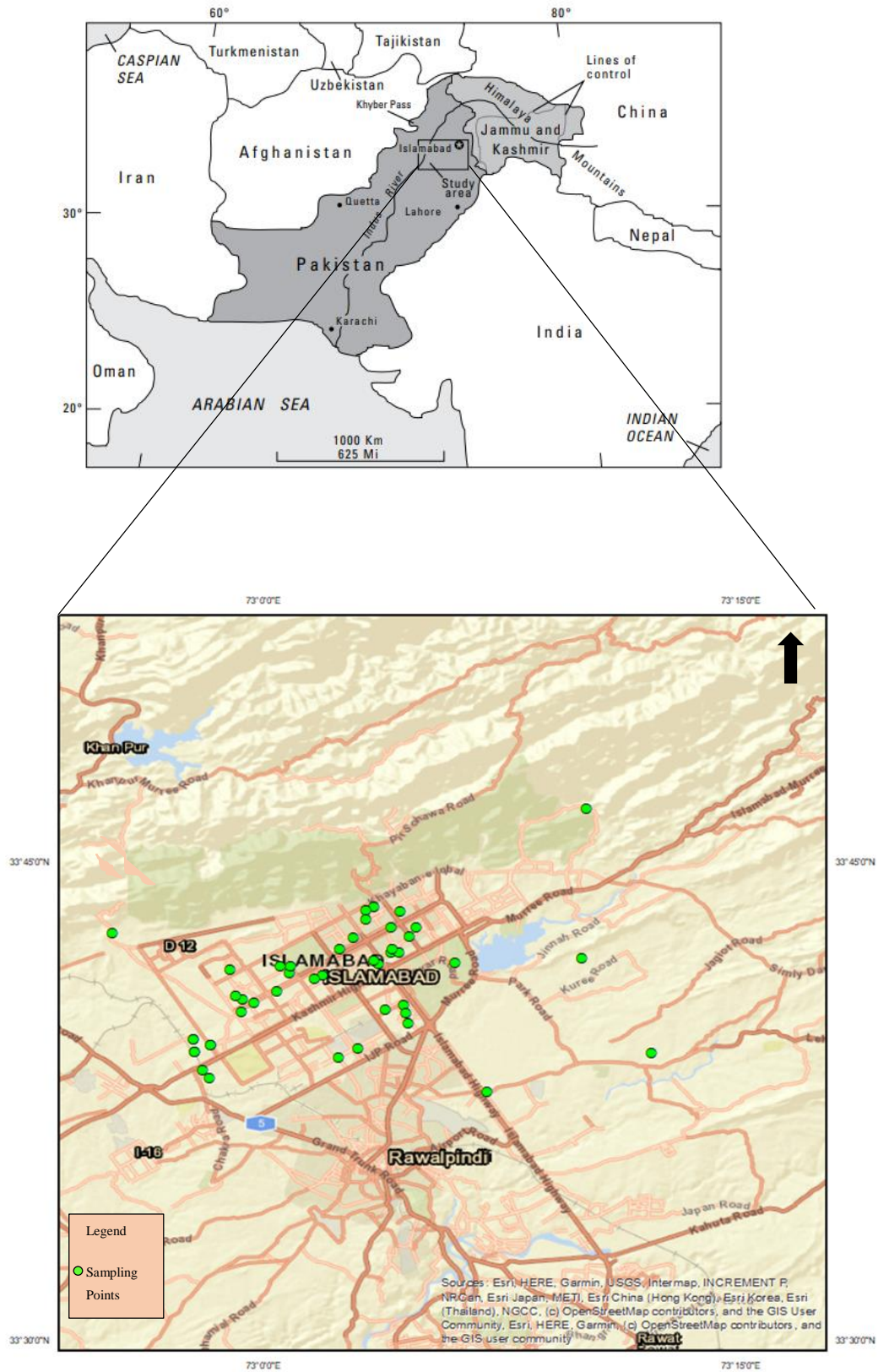


Figure 1 Map showing study area and sampling points (Sheikh, 2007) and (ARCMAP)

## 1.2 Previous Work

In a water quality report published by Pakistan Council of Research in Water Resources (PCRWR) in July 2010, A total of 32 filtration plants in Islamabad were monitored and analytical results of all the filtration plants were compared with WHO permissible limits for Drinking water. The samples were tested for metals and heavy metals like arsenic, lead, mercury, zinc, chromium, copper, Nitrate (N), Major Cations and anions. The water samples of all the filtration plants were found safe with respect to physiochemical water quality parameters. Level of Free Residual Chlorine was found below Detection limit (0.05 ppm). (RESOURCES, 2010)

In another Annual report (2015-2016) “Water Quality Status of Major Cities of Pakistan” published by PCRWR, in total, 25 marked locations were analyzed for the drinking water quality of Islamabad city. The analytical findings show that 17 (68%) sources were unfit for drinking purpose. The groundwater of Islamabad city was also termed as” CaHCO<sub>3</sub> type” water. The major finding of this study was bacterial contamination.

A study identifying the relationship between geology and water quality focusing on irrigational usage of water was conducted in the Zhob River Basin of Pakistan in 2013. Groundwater quality in Kilasiafullah sub-basin of Zhob River. The study mainly focused on EC, TDS, pH, major anions and cations, heavy metals, SAR, Na %, and KI. The area was divided into zones A and B. Sodium, chloride, SAR Na %, and KI concentrations were higher in zone A. The research represented that the quality of the groundwater is mainly controlled by water rock interaction in zones A and B. Limestone, dolomite, calcite, magnesite, mafic minerals, and dissolution of gypsum exposed in the area (in both zones) were the chief sources of calcium, magnesium, carbonate, bicarbonate, and sulfate, whereas potassium, sodium, and chloride were derived mainly from halite with subordinate feldspar dissolution in the groundwater. pH values in groundwater indicated its alkaline nature (pH > 7). On the basis of various criteria used such as EC, SAR, Na%, and KI most of the groundwater was found to be suitable for irrigation with some precaution and care especially in zone A with high sodium values. (Umar, 2013)

As seen from previous work, water testing has been previously carried out in the study area of Islamabad and studies relating geology and water have also been done in Pakistan, However, an obvious gap can be observed in the literature and research domain relating geology of Islamabad to its water quality. Thus, a research evaluating the impact of geology of the water quality of Islamabad area is essential to fill in this gap and bring forward new information and patterns in this grey area.

### **1.3 Aims and Objectives**

The aims and objectives of this study are as follows:

- (a) To test water quality of the study area through scientific method
- (b) To understand the geology of the area
- (c) To form a link between the geology and water quality of the area
- (d) To identify potential geological sources of contamination, if any

### **1.4 Methodology**

#### **1.4.1 Water sampling**

The adopted methodology for this study includes water sample collection, measurement of relevant parameters, and laboratory test of the collected samples and spatial analysis of data. Forty-seven (47) water samples were collected from various scattered ground and surface water sources including fresh springs, tube wells, tap water from bore and water filtration plants. The precise locations of sampling points were captured using a Global Positioning System in Mobile Phones (Google Maps). Samples were collected in 250 mL plastic bottles for multi-element analysis. Before sampling, the bottles were rinsed three times with the water to be sampled, and after sampling, the bottles were closed immediately to prevent exposure to air. Sampling was done with proper precaution wearing gloves and tightly closing bottle caps to prevent any leaking and exposure. The bottles were thereafter labeled for identification and transfer to the laboratory for analysis.

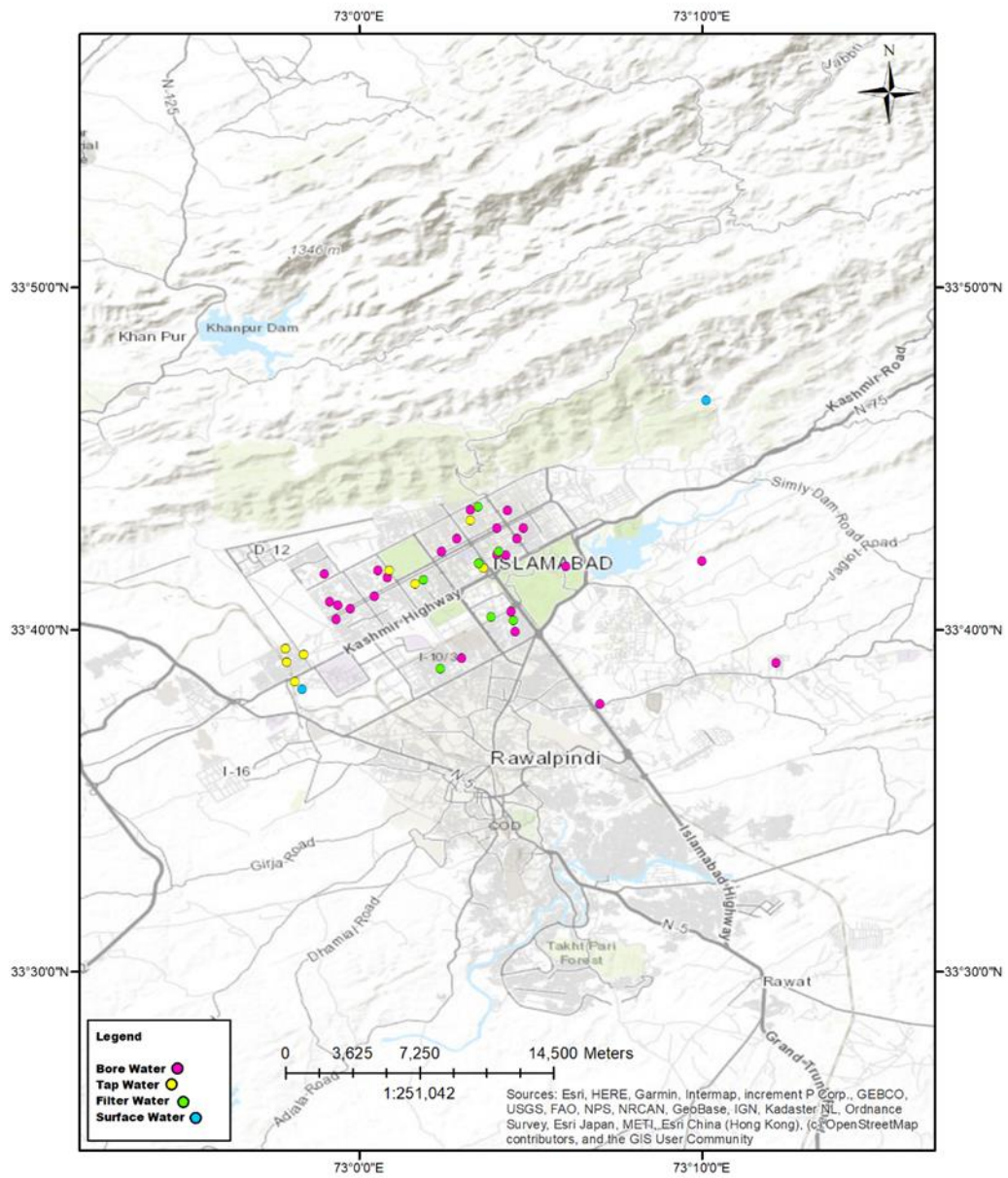


Figure 2 Map showing sampling points and types of samples collected (ARCMAP)

Table 1: Sampling collection locations

S.No	Latitude (Decimal degrees)	Longitude (Decimal degrees)
1	33.675	73.073
2	33.665	73.075
3	33.697	73.100



4	33.671	73.074
5	33.672	73.064
6	33.703	73.066
7	33.716	73.067
8	33.716	73.079
9	33.650	73.202
10	33.678	72.989
11	33.671	72.988
12	33.711	73.076
13	33.691	73.013
14	33.680	72.985
15	33.710	73.047
16	33.695	73.009
17	33.630	73.117
18	33.652	73.049
19	33.647	73.039
20	33.693	72.982
21	33.720	73.054
22	33.726	73.057
23	33.724	73.072
24	33.725	73.054
25	33.654	72.972
26	33.653	72.972
27	33.657	72.963
28	33.658	72.963
29	33.650	72.964
30	33.651	72.964
31	33.691	73.031
32	33.699	73.058
33	33.689	73.027
34	33.682	73.953
35	33.676	72.995
36	33.699	73.166
37	33.652	72.048
38	33.704	73.040

39	33.696	73.060
40	33.699	73.058
41	33.703	73.071
42	33.682	73.007
43	33.704	73.067
44	33.695	73.014
45	33.641	72.968
46	33.637	72.971
47	33.778	73.168



Figure 3 Surface water sampling from natural spring at Shahdara, Islamabad

#### 1.4.2 Geological fieldwork

A brief geological fieldwork was conducted in the vicinity of Margalla Hills, we visited Shahdara where we stopped at an outcrop located  $33^{\circ}46'42''$  N and  $73^{\circ}10'8''$  E, here we observed many beds of Murree formation and a few Chorgali formation beds of Eocene age. We saw fossiliferous sandstone of Chorgali formation making a contact with the Murree formation. A sample was collected from the site. It was observed most

of the lithology present were the red clays of Murree formation along with occasional limestone, which increased moving towards the Margalla hill tops.



Figure 4 Outcrop for fieldwork near Shahdara, Islamabad. Eocene Chorgali formation and Miocene Murree formation observed.

### **1.4.3 Laboratory Work**

The lab work part was divided into two phases. Phase 1 consisted of testing of physical parameters of the water samples which consisted of Colour, PH, Electrical Conductivity (EC), Total dissolved solids (TDS), salts and temperature. Phase 2 consisted of testing of chemical properties including percentage of Sodium, Chloride, NaCl, Calcium, Carbonates, Total Hardness and alkalinity as well as heavy metal tests like Arsenic and Iron. Various analytical techniques were used for this purpose; this is explained in the further chapters in detail. All the laboratory work was carefully carried out to ensure accuracy, methods like averaging and repetition were used to maximize result accuracy.

## CHAPTER 2

### STRUCTURAL AND HYDROGEOLOGICAL SETUP

#### 2.1 Introduction

The Pakistan-India and Eurasian tectonic plates started to converge and collide around 20 million years ago. This tectonic activity is the major force influencing the geology of Islamabad. In Islamabad, this process resulted in complex stratigraphy and structure. The sedimentary rocks of the region recorded a prolonged period of minor geologic fluctuations and slow deposition as the Pakistan-India tectonic plate drifted northward across the Indian Ocean. This was followed by a short period of far more severe tectonic activity and rapid deposition after the plates coalesced. As a result, just around 675 m of mainly marine sedimentary rocks represent the 150 million years from the Samana Suk Formation (Middle Jurassic) to the start of the Murree Formation (Lower Miocene), whereas the past 20 million years are marked by more than 7,572 m of continental sedimentary rock. Throughout the 1.5 million years of structural uplift and deformation prior to this, erosion has predominated deposition, leaving only thin, fragmented masses of alluvium and Aeolian silt behind. (Sheikh, 2007)

#### 2.2 Geologic Structure

Three structural zones are found in the Islamabad region, all of which are east-northeast trending. The zones indicate compression and are orientated as S. 20° E.:

1. The Margalla Hills in the north are made up of Jurassic to Eocene limestone and shale. These mountains have been folded and moved up along the Hazara fault zone.

2. The piedmont fold belt which is present in the south of the Himalayas. It lies underneath the truncated folds in the Rawalpindi Group sandstone and shale.

3. The Soan River, which runs primarily along the axis of the Soan syncline in the south most extent of the area. (Sheikh, 2007)

Islamabad is present at the southern margin and the front most part of the Hazara fault zone. This area is made up of a southward convex arc of folded and thrust rocks that stretch west and southwest away from the Himalayan syntaxis. The zone is reported to be around 25 km broad and 150 km long. The area has more than 20 distinct thrust sheets. Some of the thrust faults in Islamabad extend west-southwest underneath the piedmont fold belt because they are somewhat inclined towards the anterior part of Margalla Hills. The southern boundary of the Kala Chitta Range is an en echelon extension of the structural pattern of the Margalla Hills. It is generated by the extensions of these faults, which are particularly obvious north of Fetejhjang present about 25 km west of Rawalpindi.

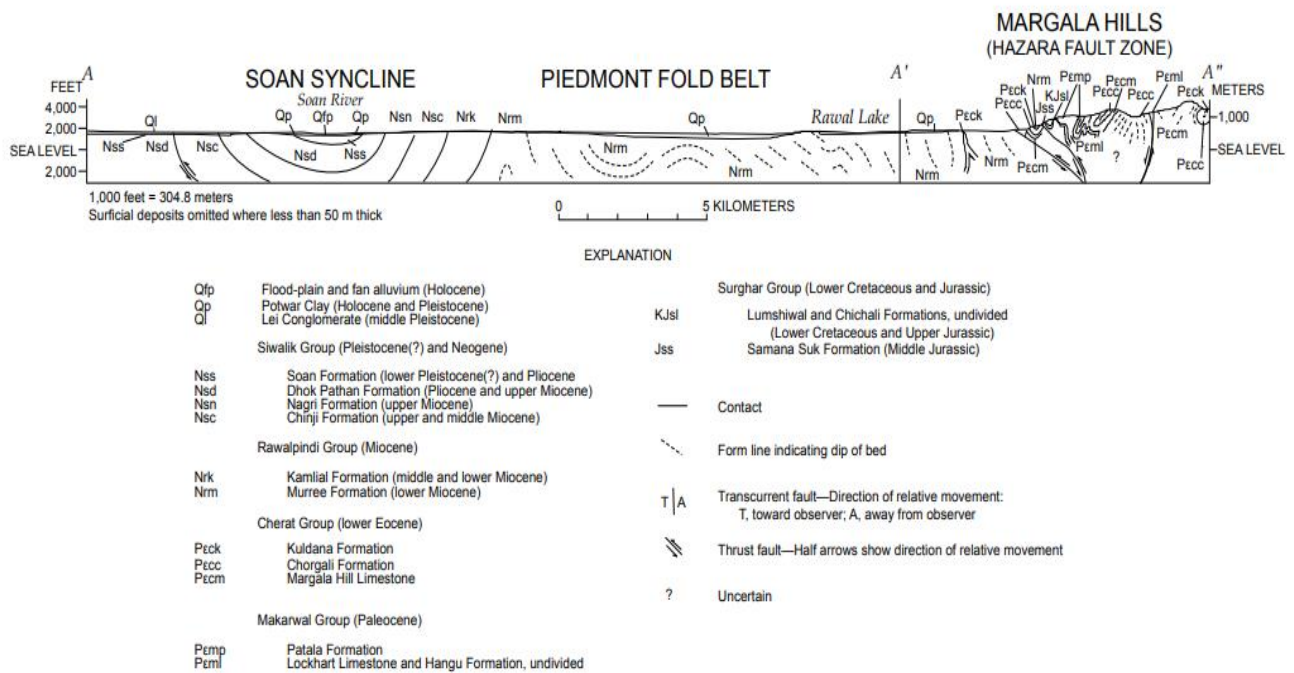


Figure 5 Geologic Cross section of study area (Sheikh, 2007)

### 2.3 Hydrogeological setting

The study area is located in the Soan River Catchment Basin. It developed as part of Tertiary and Pre-Tertiary sediments' indo-gangetic synclinorium. The sedimentary formations are classified into consolidated and unconsolidated sediments and range in age from Eocene to Recent. Limestone, sandstone, clay, shale, and

conglomerates are among the cemented strata, although they do not act as an aquifer. Terrace gravel and alluvial fill, on the other hand, are unconsolidated deposits that actively function as groundwater aquifers. (Munir, 2013)

Islamabad's hydrogeological conditions need to be improved. Typically, there is just one viable aquifer, which is marked by lithological heterogeneity and reaches a thickness of roughly 100 m locally. The non-cemented Lei Conglomerate represents the aquifer in the foothill area (Plain): gravel and sands imbedded in finer sediments produced from Rawalpindi Group sandstones and shales. Although there are relatively thick, about 14m, loam layers in the section, the deposit thickness is 106 m, allowing two aquifers to be interpreted. A layer of Potwar Clay exists on the surface, varying in thickness from 1 to 35 metres depending on the terrain relief. Because the mud and loam strata are prone to erosion, there are deep and wide canyons. Alluvial sediments, including differently grained and fine-grained sand, mud, loam, and gravelly loam, or sometimes 1–20 m thick gravel layers, make up the aquifer inside the river valleys. The aquifer's thickness varies from 2 to 20 metres. A layer of weakly permeable sediments has split it into two water-bearing layers in certain areas. Gravel, fine-grained sand, mud, and a loess layer cover the top terraces. (Krogulec, 2021)

The aquifers in the research region are generally unconfined, similar to other aquifers in Punjab, however they may be confined locally. Twenty-one hydrogeological wells have been sunk in Islamabad to estimate the level of the water table. The depth of the groundwater table varies greatly depending on the geological structure. The average depth to the groundwater table is over 8.5 metres, with a maximum depth of 19.5 metres. The depth of flood terraces is minimal, averaging 2 metres. (Krogulec, 2021) The groundwater basin identified in Islamabad has a depth to groundwater surface (m) of 5-20, high to medium capability of aquifer and high degree of groundwater development compared to other groundwater basins nearby. The assumed volume of groundwater is  $2 \times 10^9 \text{ m}^3$ .

## CHAPTER 3

### STRATIGRAPHY OF STUDY AREA

#### 3.1 Introduction

As the Indian and Eurasian plates collided, a significant sequence of strata deposited slowly at first and then rapidly when the collision occurred. The stratigraphy of Islamabad area in particular is affected by the tectonic processes that occurred. The sedimentary rocks deposited range from Jurassic formations like Samana Suk all the way to Recent alluvium deposits. The thickest and massive sequence is that of recent deposition of continental rock which is around 7,572 m thick. (Khan, 2013). Following is the stratigraphy generally described;

#### 3.2 Surghar Group (Jurassic and Lower Cretaceous)

##### 3.2.1 Samana Suk Formation (Middle Jurassic)

In the Samana Suk formation, subordinate marl and fossil bearing limestone is dominant. The limestone is dark, brown toned grey, and speckled yellow orange. The bedding found is medium to thick. The beds are micritic to oolitic, pelletal, and shelly in certain places. It contains dolomitic and sandy layers with marl that is splintery and pale olive grey to green-grey in hue. It is laminated, lightly bedded, and splintered. Escarpments and steep slopes are formed by the unit. The thickness of the exposed layer varies between 200 and 250 metres. (Shah, 2009) The contact with Chichali Formation, which lies above, is unconformable and the base isn't evident.

##### 3.2.2 Chichali Formation (Upper Jurassic and Lower Cretaceous)

Sandstone and shale are the major two types of rock found. The shale is splintery and sparsely bedded, it can be calcareous, with iron and phosphate rich nodules. The sandstone found is glauconitic and has a dull greenish hue. It is thin to medium bedded and has a fine grained texture. Dark grey limestone bands are found in the subordinate thin bands. Important fossils that can be found are belemnites and ammonoids. The Lumshival Formation is uniformly underlain by this unit. The range



of thickness is 34 to 50 m, according to the measurements. This formation represents Late Jurassic to Early Cretaceous epochs. (Shah, 2009)

### **3.2.3 Lumshiwai Formation (Lower Cretaceous)**

Subordinate limestone, shale and marine sandstone are present. The sandstone is dark brown and greenish grey in colour, with quartz and glauconite and is thin to thickly bedded with silty and glauconitic shale. Ammonoids and brachiopods may be found in the yellowish orange limestone, which is arenaceous, shelly, thinly bedded, and hard. In certain spots, the limestone has marl intercalated in it. The Lumshiwai Formation sits below the Hangu Formation in an unconformable layer as the Kawagarh Formation (Upper Cretaceous) in between the two was eroded. The erosion created escarpments and steep slopes. The thickness of the formation is between ten and fifty meters. (Shah, 2009)

## **3.3 Makarwal Group (Paleocene)**

### **3.3.1 Hangu Formation**

Sandstone, Claystone and intercalated shale are the main rocks found in this formation. The claystone and shale are red, brown, and greenish grey in color. The bedding pattern of shale is thin with laminations, it is also silty, sandy, iron bearing and bauxite bearing. The sandstone is red to brown or greyish black in color, its bedding pattern is thin to thick with brittle nature. The sandstone is oolitic, ferruginous, and quartzitic. The Hangu Formation is made up of heavily worn sediments that were produced in a humid, tropical, continental setting. The thickness of the layer varies between 2 and 8 meters. The marine Lockhart Limestone is conformably underlain by this unit. (Shah, 2009)

### **3.3.2 Lockhart Limestone**

This formation contains subordinate marl and shale, as well as marine limestone. The limestone is light grey to dark grey in color, the grains are medium size but are densely bedded. It is nodular in places as well as bituminous and fossil bearing. The marl is greyish dark and bears fossils. The shale is olive toned grey to



green grey in color, the cleavage is not well developed and the overall thickness is 70-280 meters. This unit lies beneath the Patala Formation. (Shah, 2009)

### **3.3.3 Patala Formation**

This formation contains limestone and subordinate marl, as well as shale. The splintery shale is green grey to brown grey in color, the laminations are thin, calcareous, with siltstone and sandstone as graded phases within the shale. The limestone is fossiliferous, grey to light grey, and sparsely bedded. The marl is a dark grey and rich with fossiliferous material. The Patala Formation is mostly composed of marine deposits with thickness between 70 and 80 meter and is conformable with the Margalla Hill Limestone underneath it.

## **3.4 Cherat Group (Lower Eocene)**

### **3.4.1 Margalla Hill Limestone**

Subordinate marl and shale, as well as marine limestone can be found in this formation. Dark grey to pale grey limestone with bedding being medium to thick. The limestone is reported to be nodular and fossil bearing. The marl is hard and varies in color from grey to brownish grey. Greenish grey to reddish brown shale with a splintery texture is found. The thickness is found to be between 60 and 90 meters. The contact with Chorgali Formation, which lies above the unit, is conformable. (Shah, 2009)

### **3.4.2 Chorgali Formation**

Marine shale, limestone, and marl are all present in this formation which is divided into two parts: lower and upper. The lower section is made up of splintery shale that is olive green to orange in tone and alternated with thin lenticular limestone strata and massive foraminifer-rich coquina beds. The higher half is made up of grey to light grey limestone that is thin to medium bedded, it is also flaggy, cherty, and fossil bearing. The marl is sparsely bedded and light grey to grey in color. The thickness measured varies from 30 to 120 metres and the overlying Kuldana Formation conforms to the unit. (Shah, 2009)

### **3.4.3 Kuldana Formation**

Marl, claystone of marine and continental origin, limestone, and sandstone are found in this formation. The claystone features gypsum intercalations and a varied hue. The marl is light grey to brownish grey in tone and contains fibrous gypsum. The bedding is thin to medium. The limestone ranges in color from white to light brown. The sandstone is calcareous, brown grey, and fine grained. 60–120 m is the thickness that has been recorded. The Murree Formation is underlain by this formation unconformably.

## **3.5 Rawalpindi Group (Miocene)**

### **3.5.1 Murree Formation (lower Miocene)**

In the Islamabad area, the Murree formation is the most notable formation. The most frequent lithologies are continental sandstone and claystone. The grain size of the sandstone is fine to medium, it is also thick and cross-bedded, jointed, micaceous and calcareous, and is reddish grey to purple grey in color. The pseudoconglomerate lenses are variegated and can be found in the claystone lithology which is purple to dark red. The sandstone found in the Murree Formation is rich in epidote. The measured thickness of this formation in the region spans from 2,000 to 2,895 meters. The overlying Kamliyal Formation has a conformable contact. (Shah, 2009)

### **3.5.2 Kamliyal Formation (lower and middle Miocene)**

Like the Murree formation, this formation also exhibits sandstone and claystone as the two major lithologies. Purple, Grey, and dark brick red calcareous and micaceous calcareous sandstones with medium to coarse grains, thick beds and joints can be found. We can find some beds of hard purple claystone are also found in the Kamliyal Formation with some beds of claystone showing weathering and yellow mottles. These weathered beds have a conglomerate appearance to them. The Kamliyal formation is separated from the Murree Formation by the spheroidal weathering seen in it. The thicknesses recorded spans from 1,200 to 1,600 meters. Underneath the Chinji Formation, the upper contact is conformable.

### **3.6 Siwalik Group (Neogene and Pleistocene)**

The Siwalik group is made up of the the Chinji, Nagri, Dhok Pathan and Soan formations from middle Miocene up to lower Pleistocene. These mostly contain sandstones that are grey to greenish grey or brown in color crossbedded and calcareous. Claystones that are reddish, brown, and orange in tone with some conglomerate beds as we move to the later formations. These are mostly medium-thickly bedded. Together, the group is around 2500-3000m thick.

### **3.7 Surficial Units (Pleistocene and Holocene)**

These units form the top most strata present, it is consisted of the most recent deposits from Pleistocene to Holocene. These contain the Lei conglomerates, Potwar Clay, Terrace alluvium, windblown silt, flood plain and fan alluvium and stream channel alluvium. These usually contain gravel, silt, clay and unconsolidated sediments. The most prominent of these is the Lei Conglomerate which also acts as an aquifer in the Islamabad area, it consists of carbonate cemented cobble conglomerate, angular limestone, quartzite, traces of old Siwalik rocks and even traces of igneous rocks.

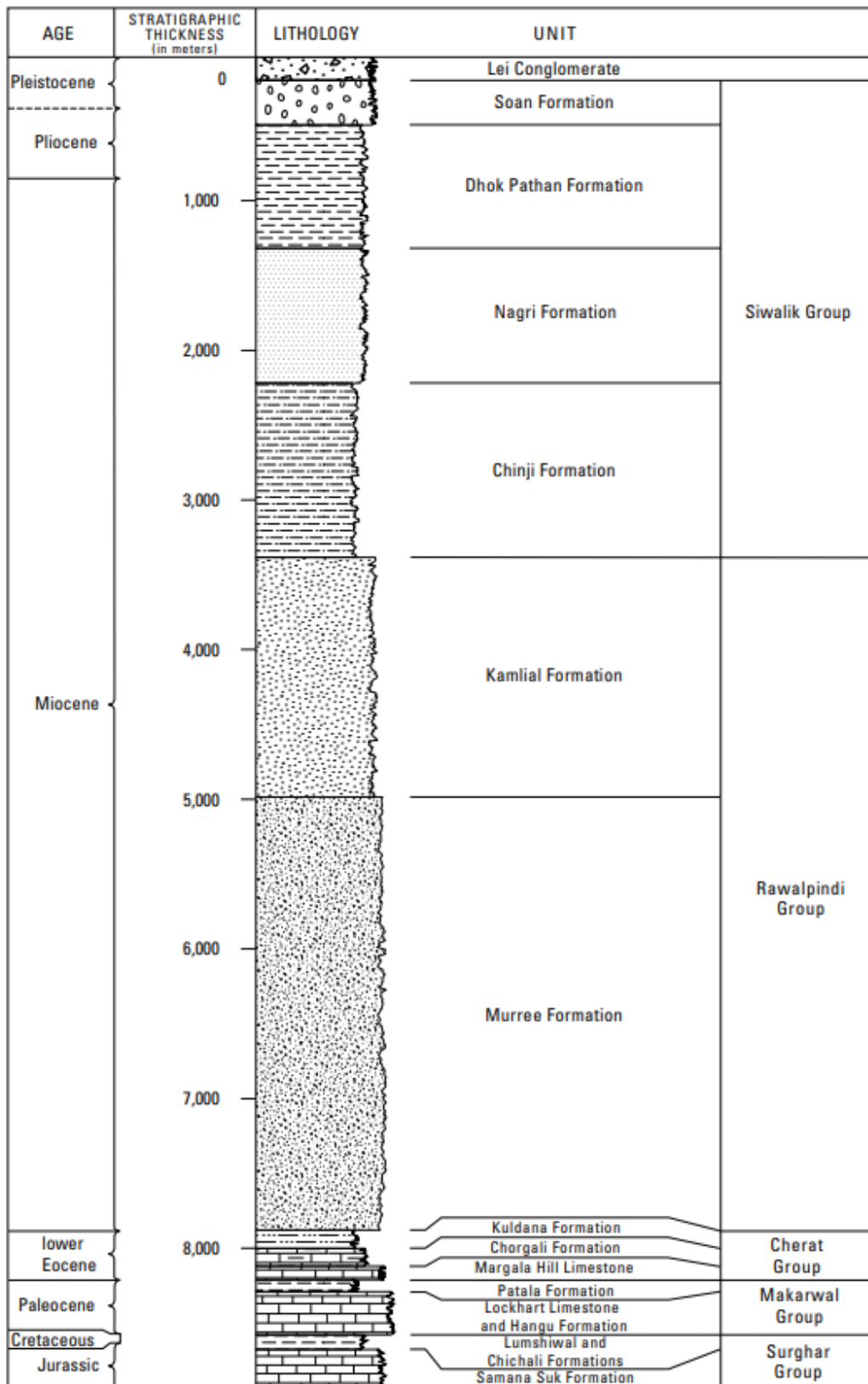


Figure 6 Stratigraphic Column of the region (Sheikh, 2007)

## CHAPTER 4

### METHODOLOGY

After sampling forty-seven (47) samples from the sampling locations, the samples were tested in the laboratory for estimation and analysis of their physical and chemical parameters.

#### 4.1 Analysis of Physical Parameters

The physical parameters were pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Salts and Temperature. All these parameters were tested using a digital meter called the PCSTestr 35. Before use, all the apparatus and tools were calibrated properly and readings were repeated thrice and averaged for accuracy.



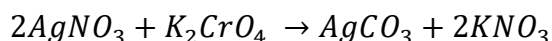
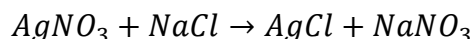
Figure 7 Digital meter (PCSTestr35) for analysis of physical parameters

#### 4.2 Analysis of Chemical Parameters

The chemical parameters were chlorides (Cl, Na, NaCl), Carbonates ( $\text{CO}_3$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{HCO}_3$  and  $\text{NaHCO}_3$ ), Total Hardness, Total Alkalinity and Calcium.

#### 4.2.1 Chlorides

Chlorides can be found as chloride ions in solutions, they can enter ground or surface water through various natural as well as anthropogenic processes. The estimation of chlorides is done through titration method with the following equation:



- **Indicator used:** Potassium Chromate  $K_2CrO_4$
- **Standard Solution:** 0.01N Silver Nitrate  $AgNO_3$
- **End point:** Brownish color
- **Procedure:** A burette was filled up to mark with silver nitrate and 50ml of sample water was taken in a flask. A few drops of potassium chromate were added to the sample water and titrated against the silver nitrate till color change was noticed from yellow to orange-brown. The burette readings were noted and used to find amount of chlorides, sodium and NaCl in the samples.
- **Calculations:**

$$\text{Mg Cl/L} = V \cdot N \cdot 35.45 \cdot 1000 / \text{Sample volume}$$

$$\text{Mg NaCl/L} = V \cdot N \cdot 58.45 \cdot 1000 / \text{Sample volume}$$

$$\text{Mg Na} = \text{mg Cl/L} - \text{mg NaCl/L}$$

$$N = \text{Normality of silver nitrate} = 0.01$$

$$V = \text{Volume of silver nitrate used}$$

$$\text{Sample volume} = 50\text{ml}$$

#### 4.2.2 Carbonates

Carbonates are salts of carbonic acid formed when metal ions with positive charge comes in contact with the oxygen atoms of carbonate ions. The estimation of  $CO_3$ ,  $Na_2CO_3$ ,  $HCO_3$  and  $NaHCO_3$  was done through titration.

- **Indicator used:** Methyl Orange
- **Standard solution:** 0.1M HCL
- **End point:** Red color

- **Procedure:** A burette was filled with HCL. 50ml of sample along with 2-3 drops of methyl orange were taken in a flask and titrated against the HCL till the end point was observed. The burette reading was noted.
- **Calculations:**

$$M_1V_1=M_2V_2$$

Where,

$M_1$ = Molarity of the whole sample

$V_1$ = Sample volume= 50ml

$M_2$ = Molarity of standard solution= 0.1M

$V_2$ = Burette reading after end point

After  $M_1$  is determined then amount of each carbonate can be found by:

$$\text{Amount/dm}^3 = M \times \text{molecular weight of carbonate}$$

#### 4.2.3 Total Hardness

The quantity of dissolved calcium and magnesium in water is the most basic definition of water hardness. Dissolved minerals, primarily calcium and magnesium, are abundant in hard water. Because water flows through soil and rock, it dissolves minute amounts of naturally existing minerals and transports them into the groundwater supply, water hardness is an issue for water systems that use groundwater as a source. Hard water can be provided to households if the minerals calcium and magnesium are present in the soil around a water-supply well (USGS, 2018). The total hardness was estimated using titration as follows:

- **Standard Solution:** 0.01M EDTA
- **Indicator:** Erichrome Black T (EBT)
- **End point:** Blue color

- **Procedure:** A burette was filled with EDTA standard solution. 50 ml of sample water with a few drops of EBT indicator and 20ml of ammonium chloride buffer was taken in a flask and then titrated against standard solution till red/purple to blue color change was observed.
- **Calculations:**

$$\text{Total hardness: } A * B * 1000 / \text{Sample volume}$$

Where,

A= Amount of EDTA used

B= 0.01M

Sample volume= 50ml

#### 4.2.4 Total Alkalinity

Any water's capacity to neutralize acids is measured as its alkalinity. The presence of bicarbonate, carbonate, and hydroxide ions is the fundamental reason for alkalinity. The alkalinity of a surface water body is mostly derived from the rocks and land that surround it. For example, the majority of the water entering a lake originates from runoff over the terrain, as precipitation falls in the watershed surrounding the lake. If the terrain includes limestone, runoff takes up compounds like calcium carbonate, it will raise the pH and alkalinity of the water. (Water Science School, 2018)

- **Standard Solution:** 0.02N Sulfuric acid  $H_2SO_4$
- **Indicator:** Methyl Orange
- **End point:** Pink color
- **Procedure:** A burette was filled with standard solution of sulfuric acid up to mark. 50ml of sample water was taken in a flask and a few drops of methyl orange were added and titrated against the standard solution till end point was reached.
- **Calculations**

$$\text{Total alkalinity} = \frac{\text{Volume of acid} * \text{Normality of acid} * 50000}{\text{Volume of sample}}$$

Where,

Normality of acid= 0.02N

Volume of sample= 50ml



#### 4.2.5 Total Calcium

In both saltwater and freshwater, calcium (Ca<sup>2+</sup>) is one of the most abundant inorganic cations, or positive ions. It is produced by the dissociation of salts in water, such as calcium chloride or calcium sulphate. Leaching of rocks is the primary source of calcium in the water. Streams running through limestone, dolomite, gypsum, and other calcium-containing rocks and minerals provide the majority of calcium in surface waters. (LEO, 2011)

- **Standard Solution:** 0.01M EDTA
- **Indicator:** Murexide Indicator
- **Other reagents:** 1M Sodium Hydroxide NaOH
- **End point:** Purple Color
- **Procedure:** Take 10 ml sample in 100ml beaker and add 10ml of distilled water and 0.5ml of NaOH to act as a buffer and then add a pinch of Murexide Indicator till pink color is seen. Transfer to a flask and titrate it against EDTA solution till purple color is seen and end point is reached. Note values of EDTA used.
- **Calculations:**

$$\text{Ca mg/L} = A * B * 400 / \text{ml Sample}$$

Where,

A= ml titration for sample

B= mg CaCO<sub>3</sub> equivalent to 1.00ml EDTA titrant

ml Sample= 10ml

#### 4.3 Analysis of Heavy Metals

Metals having large densities, atomic weights, or atomic numbers are referred to as heavy metals. (Wikipedia, 2022). While minor levels of metals occur naturally in our water resources, the majority of heavy metals enter the environment through industrial and commercial waste (mining, vehicle emissions, batteries, fertilizers, and paint and micro plastics). Heavy metals are also released into streams, lakes, rivers, and groundwater as a result of leaching or acidic rain breaking down soils and releasing heavy metals. (Sims, 2020). For heavy metals, we tested for Arsenic which is one of

the most toxic heavy metals even in the smallest amount and Iron which is a very common heavy metal which is considered a nutrient if present within range.

#### 4.3.1 Arsenic

Many rocks and sediments naturally contain arsenic as a trace component. The chemical form of arsenic, the geochemical conditions in the aquifer, and the biogeochemical processes that occur all affect whether or not arsenic is released into groundwater from various geologic sources. Human activities such as mining, as well as its diverse applications in industry, animal feed, wood preservatives, and pesticides, can leak arsenic into groundwater (Resources, 2019).

For our analysis of Arsenic, we used the Rapid Arsenic Test Kit for Water Analysis by Industrial Test Systems, Inc.



Figure 8 Rapid Arsenic Test Kit used for Arsenic Analysis

- **Procedure:** 50 ml of sample water was added to all five reaction bottles and 1 level of first reagent was added to each bottle and vigorously shaken upright for 15 seconds with caps on. Then, 1 level of second reagent was added to each bottle and again shaken for 15 seconds and the caps were replaced with turret

caps and set for 2 minutes. After 2 minutes 1 level of third reagent was added to all the bottles and shaken for 5 seconds upright and the testing strip was inserted in each bottle and set aside for 10 minutes. After 10 minutes, each strip was carefully removed and compared to the color chart given and results were recorded.

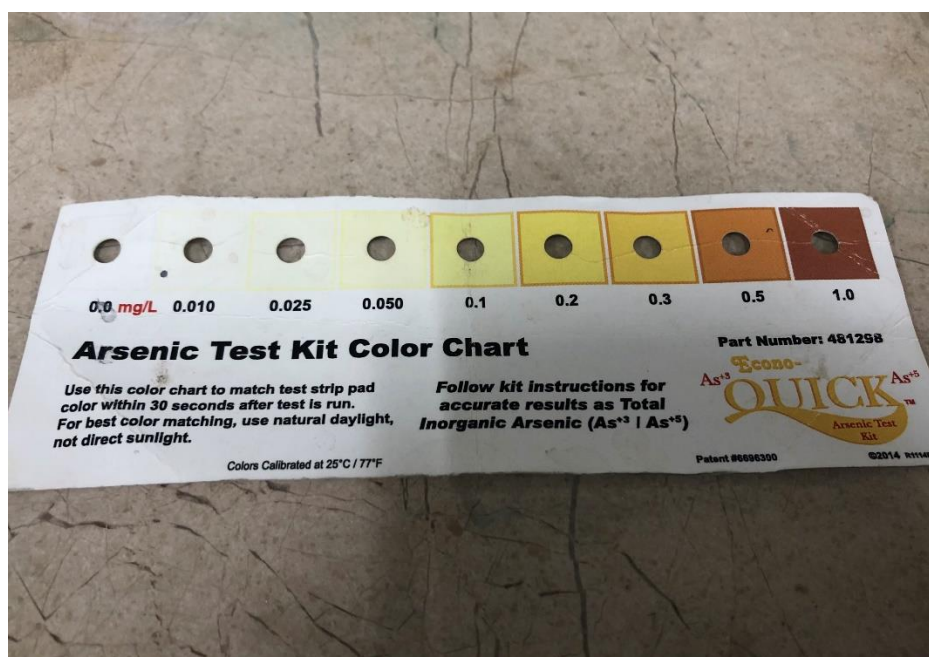


Figure 9 Arsenic Test Kit Color Chart

#### 4.3.2 Iron

Iron is found in soil, rocks, and plants in nature. Because iron is such an important metal for human health, little amounts are not dangerous. Magnetite, hematite, goethite, and siderite are the most common iron contributing minerals found in nature. The element is released into the water as a result of weathering processes. Seepage and corrosion are the two primary sources of iron in water.

Soil migration from higher to lower level surfaces, where the wells reside, is frequently induced by rain or molten snow. If there is iron in the soil, it will make its way into the well water. When soil iron dissolves in water, it becomes polluted and contaminates the water source. Secondly, wells are connected to pipelines and pumps so that water may be withdrawn and used. Corrosion occurs when pipes and pump casings are not properly maintained. Corrosion is a very real possibility if the well water

is hard. This corroded iron contaminates well water and makes its way to the consumer through water pipes. (Cannon, 2020)

For the determination of Iron content in our water samples the following method was used:

- **Principle:** 1,10-phenanthroline reacts with Ferrous ions present in the sample to form an orange colored complex in proportion to iron concentration.
- **Reagents:** Ammonium acetate buffer of 5.5 pH
  - 10% hydroxylamine
  - 0.25 % 1,10-phenanthroline
  - 0.01mg/ml Standard Iron solution
- **Device:** UV4000 spectrophotometer
- **Procedure:** 50ml of water sample was taken in a 100ml volumetric flask and 5ml dilute HCL and heated for about 10 minutes. Then, 1ml of hydroxylamine and 1ml of 1,10-phenanthroline was added along with 10ml of ammonium acetate buffer. The bottle was shaken thoroughly at each step. The bottle was diluted with distilled water up to mark and left for 5 minutes for color development. On the other side, a 5ml sample of 0.01mg/ml standard iron solution was taken in another flask and all steps were repeated with it. The absorbance of the spectrophotometer was set to 510nm and the absorbance of all the samples and iron standard solution were noted by recording the readings on the device.
- **Calculations:**

$$\text{Iron (mg/L)} = \left( \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \right) * (0.01 * 5 / \text{Sample Volume}) * 1000$$



Figure 10 UV4000 Spectrophotometer

## CHAPTER 5

### RESULTS AND DISCUSSION

#### 5.1 Physical Parameters

Table 2 Results of Physical Parameters of water samples

S.No	pH	EC ( $\mu\text{s}/\text{cm}$ )	TDS (ppm)	Salts (ppm)	Temperature ( $^{\circ}\text{c}$ )
1	6.81	462	326	228	20.6
2	6.54	564	399	279	20.7
3	7.14	333	235	163	20.8
4	7.02	456	321	224	20.7
5	6.97	556	394	276	20.7
6	7.08	562	397	278	20.8
7	7.07	454	322	224	20.8
8	7.19	500	354	247	20.6
9	7.41	505	366	248	20.7
10	7.32	555	392	274	20.6
11	7.09	507	359	251	20.6
12	7.3	507	359	251	20.5
13	6.95	680	482	339	20.5
14	6.92	580	410	287	20.4
15	7.46	335	237	164	20.1
16	7.21	483	342	239	20.2
17	7.25	460	327	227	20.3
18	6.9	582	412	289	20.5
19	7.34	462	327	228	20.4
20	7.22	546	387	270	20.4
21	7.4	454	322	225	21.2
22	6.93	540	384	269	20.9
23	7.21	430	305	212	20.9
24	7.12	517	366	256	20.9
25	7.34	416	295	206	21.0
26	7.55	342	242	168	21.0
27	6.99	527	373	261	21.1
28	7.26	600	425	298	20.9
29	7.1	630	446	313	21.0
30	7.52	422	299	208	21.1
31	7.06	580	409	287	21.2
32	7.17	521	369	258	20.9

33	7.47	546	387	271	21.1
34	7.74	279	198	137	21.0
35	7.43	577	408	286	20.9
36	7.63	540	382	268	21.0
37	6.98	633	448	315	21.0
38	7.06	606	429	301	21.1
39	7.44	558	394	276	21.2
40	7.56	385	271	189	21.2
41	7.85	398	282	197	21.1
42	7.15	343	243	169	21.2
43	7.67	318	225	156	21.1
44	7.27	520	367	257	20.9
45	8.11	1420	1010	735	20.9
46	7.36	439	311	217	21.0
47	6.92	528	374	261	21.1

### 5.1.1 pH

The pH of water is a measurement of how acidic or basic it is. The range is 0 to 14, with 7 being the neutral value. Acidity is indicated by a pH less than 7, while a pH greater than 7 denotes a base. ( Water Science School, 2019) The pH values of our samples lies between 6.54-8.11 with an average of 7.24.

Different factors, both natural and artificial, can change the pH of water. The majority of changes in nature are brought about by interactions with nearby rock, especially carbonate forms, and other substances. Acid rain in particular and wastewater discharges can cause pH to change. Limestone and carbonate materials both have the ability to stabilize pH variations in water. To neutralize pH, calcium carbonate (CaCO<sub>3</sub>) and other bicarbonates can mix with hydrogen or hydroxyl ions. The presence of carbonate minerals in the soil increases the water's capacity to buffer substances (alkalinity), which helps to keep the pH of the water near neutral even when acids or

bases are introduced. Additional carbonate minerals can turn neutral water mildly basic (Fondriest Environmental, Inc., 2013).

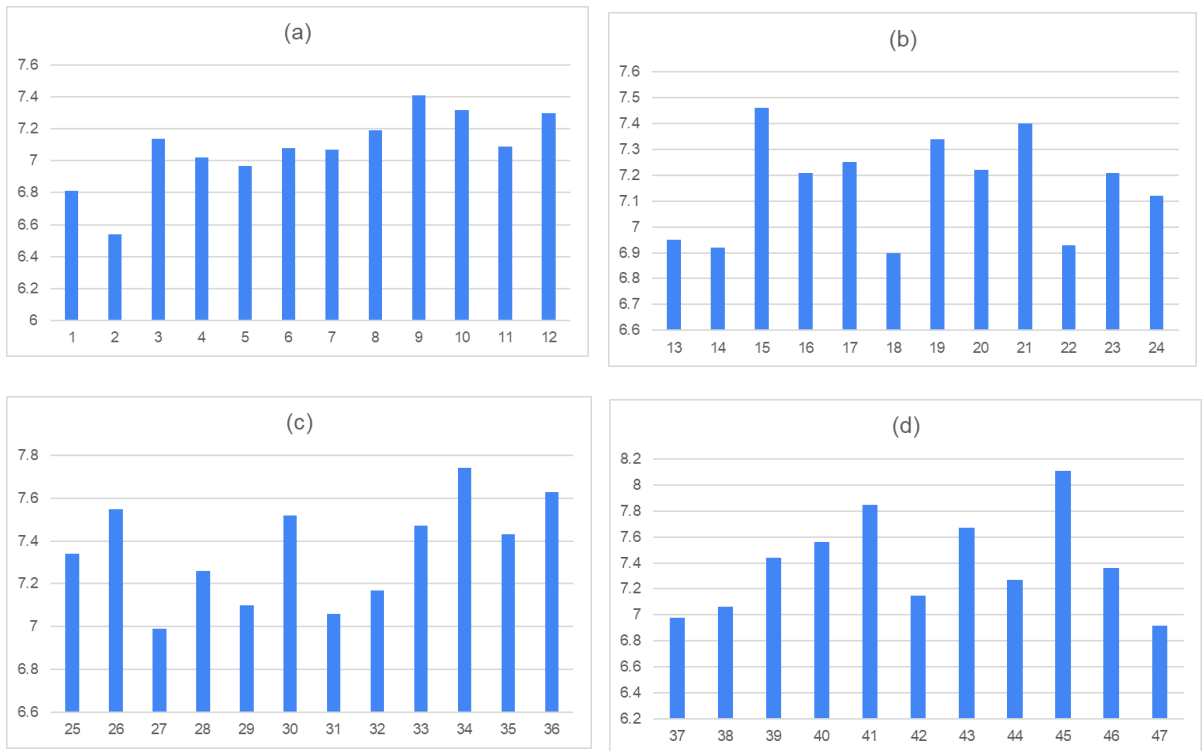


Figure 11 Graphs showing pH values of samples 1-47

### 5.1.2 Electrical Conductivity (EC)

Water's capacity to transmit an electric current is known as its electrical conductivity, or EC. Positively and negatively charged ions can form when salts or other compounds dissolve in water. The electrical conductivity of water is dependent on the ion concentration because these free ions in the water conduct electricity. Sodium, calcium, potassium, and magnesium are the main positively charged ions that influence the conductivity of water. Chloride, sulphate, carbonate, and bicarbonate are the main negatively charged ions. Rain, geology, and evaporation all have direct impacts on EC in water. (Aquaread, 2020)

The EC of our samples ranges from 279-1420  $\mu\text{s}/\text{cm}$  with an average of 514  $\mu\text{s}/\text{cm}$ .



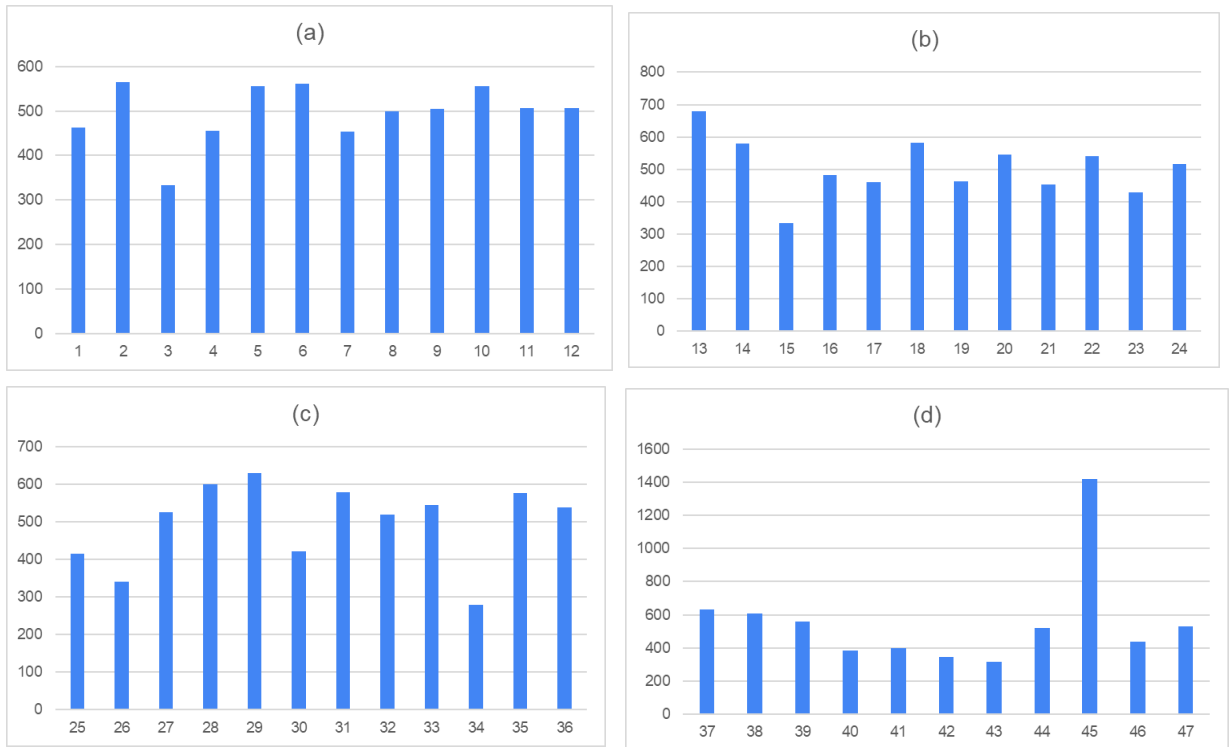


Figure 12 Graphs showing EC values ( $\mu\text{s}/\text{cm}$ ) of samples 1-47

### 5.1.3 Total Dissolved Solids (TDS)

Total Dissolved Solids which is referred to as TDS, calculates the total concentration of soluble salts and minerals in water. TDS may enter into water in through the water itself, through the air, and through the soil. Geological processes like leaching and dissolution can also facilitate TDS to enter water. While dissolved solids are present in all water, their concentrations differ depending on the source. For instance, surface water from rivers and lakes often has lower quantities of dissolved minerals than groundwater does and dissolved solid levels are normally relatively low in treated water, such as water from filter plants. (Winfield, 2022)

The TDS in our samples ranges from 198-1010 ppm with an average of 364 ppm.

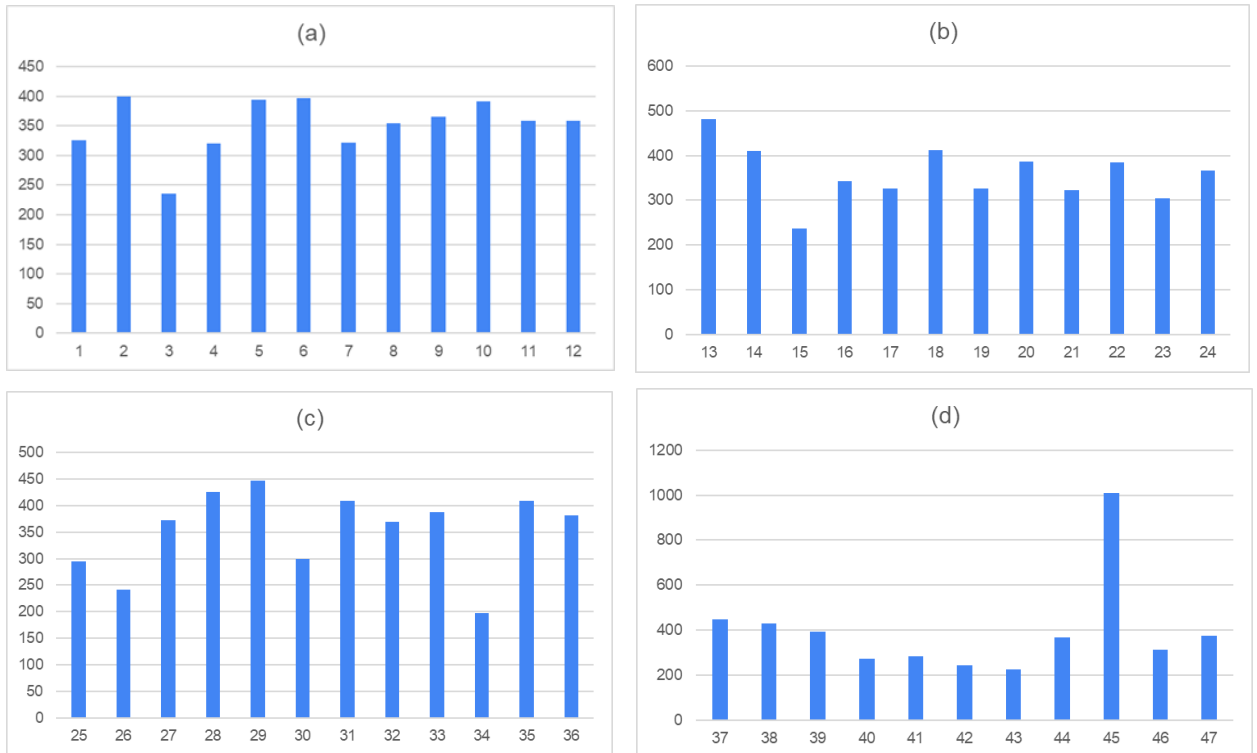


Figure 13 Graphs showing TDS values (ppm) of samples 1-47

#### 5.1.4 Salts

Sodium is the most common element present as sodium chloride salts in water which readily dissolves and is colorless, it gives water a salty taste if present in large amount. Salts can enter groundwater through anthropogenic sources or natural sources such as evaporite deposits. Rainfall may come into contact with rocks that contain highly soluble minerals when it seeps into the earth, making the water saline. (USGS, 2018)

With depth, the water in sedimentary layers becomes more and more saline. Sulfate-rich water is found close to the surface, followed by saline bicarbonate water at a lower level and more concentrated chloride water at further depths. Water trapped in sedimentary rocks can change into saline water through a number of processes. Sediment and rock solutions is one of them. (Craig, 1980)

The salts in our samples range from 137-735ppm with an average of 255ppm.

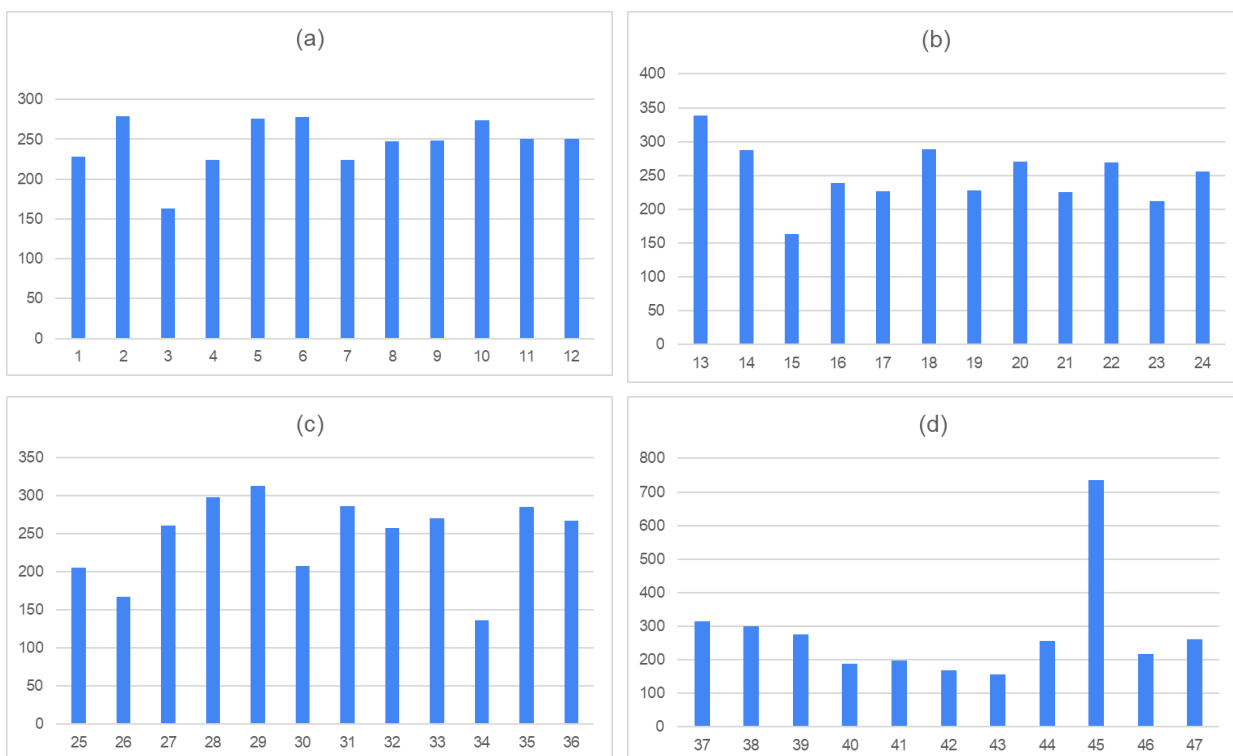


Figure 14 Graphs showing Salts (ppm) in samples 1-47

## 5.2 Chemical Parameters

Table 3 Table showing values for Cl, NaCl and Na (mg/L)

S.No	Cl (mg/L)	NaCl (mg/L)	Na (mg/L)
1	116.985	192.885	75.900
2	106.350	175.350	69.00
3	116.985	192.885	75.90
4	168.033	277.053	109.020
5	143.927	237.307	93.380
6	199.938	329.658	129.720
7	38.995	64.295	25.300
8	315.505	520.205	204.700
9	63.810	105.210	41.400
10	152.435	251.335	98.900
11	131.165	216.265	85.100
12	155.980	257.180	101.200
13	163.070	268.870	105.800
14	159.525	263.025	103.500
15	88.625	146.125	57.500
16	283.600	467.600	184.00

17	158.107	260.687	102.580
18	196.393	323.813	127.420
19	9.217	15.197	5.980
20	345.283	569.303	224.020
21	265.166	437.206	172.040
22	87.916	144.956	57.040
23	277.928	458.248	180.320
24	76.572	126.252	49.680
25	62.392	102.872	40.480
26	121.948	201.068	79.120
27	87.916	144.956	57.040
28	239.642	395.122	155.480
29	138.255	227.955	89.700
30	131.165	216.265	85.100
31	60.265	99.365	39.100
32	106.350	175.350	69.00
33	114.858	189.378	74.520
34	155.980	257.180	101.200
35	38.995	64.295	25.300
36	116.985	192.885	75.900
37	99.260	163.660	64.400
38	138.255	227.955	89.700
39	75.154	123.914	48.760
40	52.466	86.506	34.040
41	63.810	105.210	41.400
42	35.450	58.450	23.00
43	49.630	81.830	32.200
44	119.821	197.561	77.740
45	354.500	584.500	230.00
46	95.715	157.815	62.100
47	49.630	81.830	32.200

### 5.2.1 Chlorides

Chlorides in water can exist as chloride ions or salts such as sodium chloride (NaCl). They naturally occur in water. The concentration of chlorides found in our water samples range from 9.2-354.5 mg/L with an average of 135 mg/L. The concentration of sodium chloride in our samples ranges from 15.1-584.5 mg/L with an average of 222 mg/L.

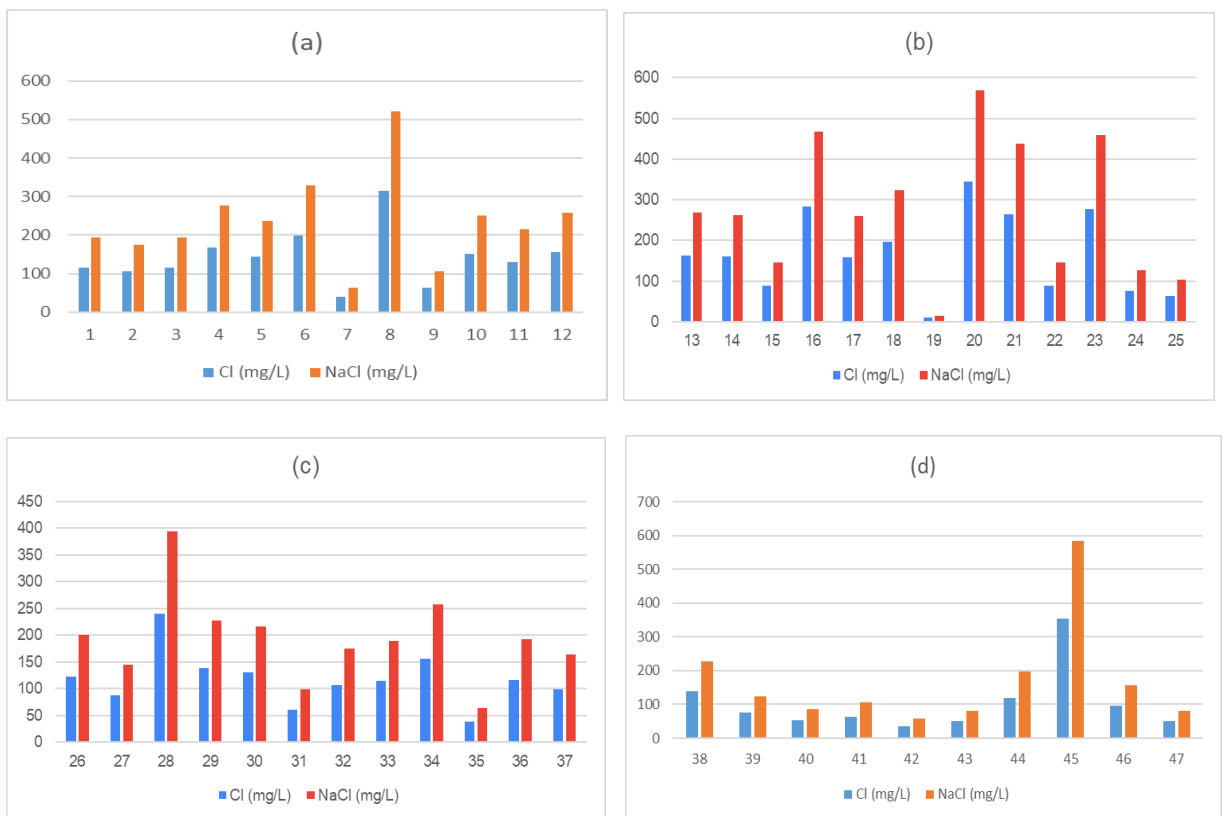


Figure 15 Graphs showing concentrations of Cl and NaCl (mg/L) for samples 1-47

## 5.2.2 Sodium

Sodium is a silvery white, soft and highly reactive metal. It is very common and is the sixth most abundant element present in the earth's crust. Sodium can be found in many minerals including rock salt, sodalite, feldspars etc. Most of the salts formed by sodium are very soluble in water. The range of sodium in our samples is 5.98-230 mg/L with an average of 87.3 mg/L.

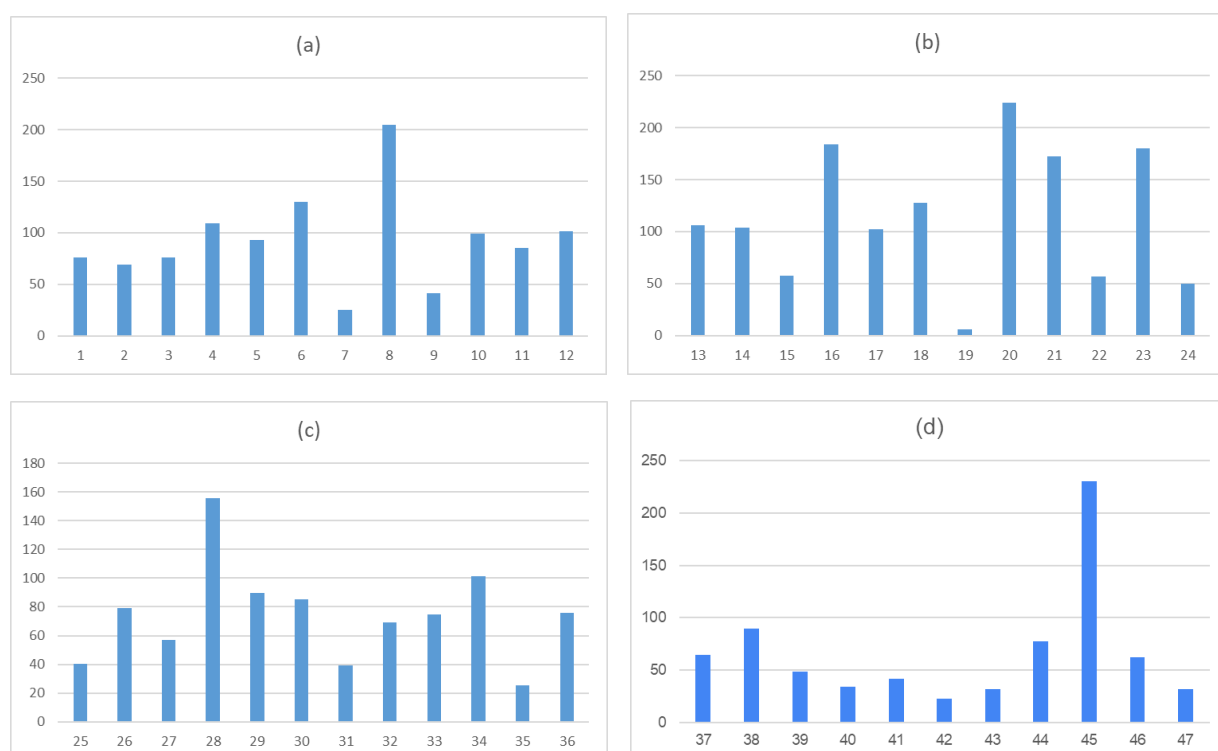


Figure 16 Graphs showing concentration of Sodium (mg/L) of samples 1-47

## 5.2.3 Carbonates

Table 4 Table showing concentrations of various carbonates present

S.No	Na <sub>2</sub> CO <sub>3</sub> (mg/l)	NaHCO <sub>3</sub> (mg/l)	HCO <sub>3</sub> (mg/l)	CO <sub>3</sub> (mg/l)
1	0.763	0.605	0.439	0.432
2	0.890	0.706	0.512	0.504
3	1.187	0.940	0.683	0.672
4	0.784	0.621	0.451	0.444
5	1.250	0.991	0.719	0.708
6	0.847	0.672	0.488	0.480
7	0.784	0.621	0.451	0.444

8	1.102	0.873	0.634	0.624
9	0.741	0.588	0.427	0.420
10	0.741	0.588	0.427	0.420
11	0.826	0.655	0.475	0.468
12	0.635	0.504	0.366	0.360
13	0.953	0.756	0.549	0.540
14	0.890	0.705	0.512	0.504
15	0.699	0.554	0.402	0.396
16	0.805	0.638	0.463	0.456
17	0.805	0.638	0.463	0.456
18	1.123	0.890	0.646	0.636
19	0.911	0.722	0.524	0.516
20	1.144	0.907	0.658	0.648
21	0.572	0.453	0.329	0.324
22	0.763	0.604	0.439	0.432
23	0.487	0.386	0.280	0.276
24	0.805	0.638	0.463	0.456
25	0.508	0.403	0.292	0.288
26	0.529	0.420	0.305	0.300
27	1.144	0.907	0.658	0.649
28	0.890	0.705	0.512	0.504
29	0.890	0.705	0.512	0.504
30	0.847	0.672	0.488	0.480
31	0.996	0.789	0.573	0.564
32	0.763	0.604	0.439	0.432
33	0.593	0.470	0.341	0.336
34	0.254	0.201	0.146	0.144
35	0.826	0.655	0.475	0.468
36	0.763	0.604	0.439	0.432
37	0.890	0.705	0.512	0.504
38	0.890	0.705	0.512	0.504
39	0.763	0.604	0.439	0.432
40	0.572	0.453	0.329	0.324
41	0.169	0.134	0.097	0.096
42	0.466	0.369	0.268	0.264
43	0.296	0.235	0.170	0.168
44	0.529	0.420	0.305	0.300
45	1.144	0.907	0.658	0.648
46	0.529	0.420	0.305	0.300
47	0.763	0.604	0.439	0.432

Carbonates are salts of carbonic acid and are usually insoluble in water. Their presence can be attributed to interaction of water with rock containing carbonates such as limestone. The concentration of  $\text{Na}_2\text{CO}_3$  ranges from 0.17-1.25 mg/L with an average value of 0.77 mg/L. The concentration of  $\text{NaHCO}_3$  ranges from 0.13-0.99 mg/L with an average of 0.62 mg/L. The concentration of  $\text{HCO}_3^-$  ranges from 0.09-0.72 mg/L with an average of 0.45 mg/L. The concentration of  $\text{CO}_3$  ranges from 0.096-0.71 mg/L with an average of 0.44 mg/L.

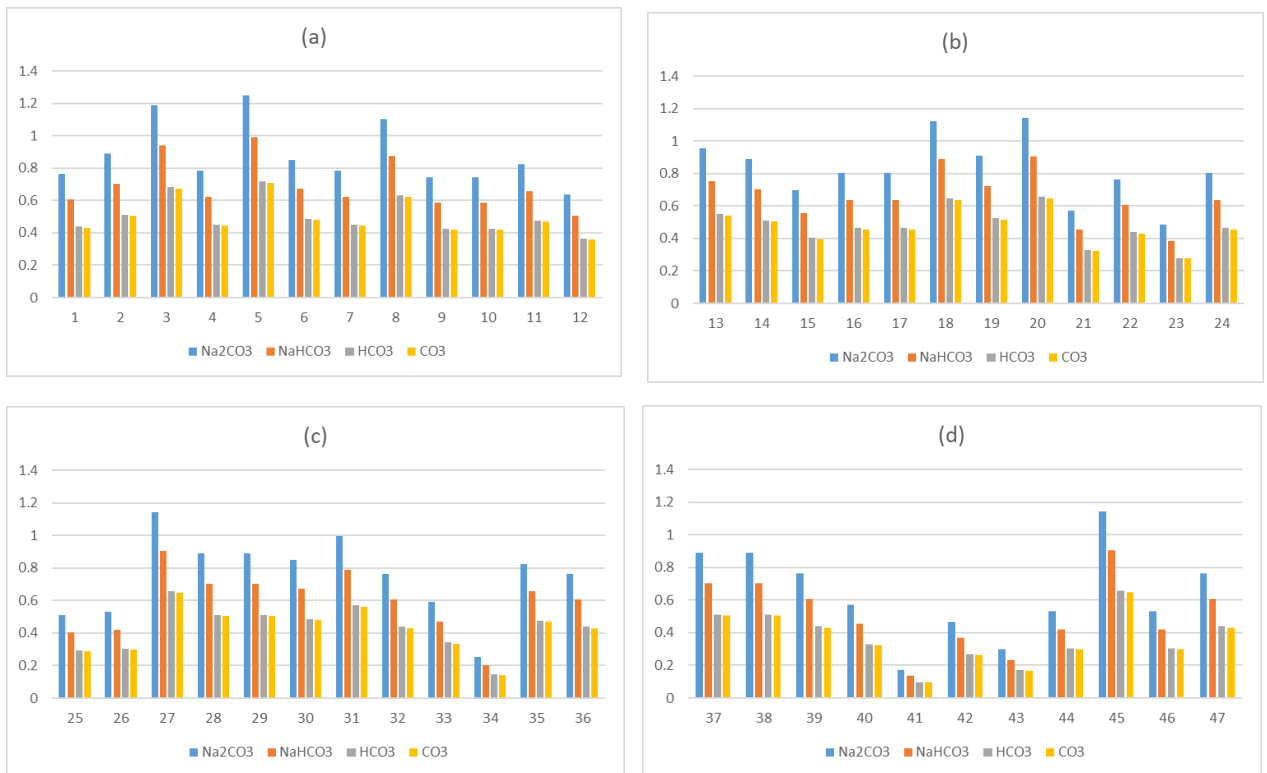


Figure 17 Graphs showing concentrations of various carbonates (mg/L)



## 5.2.4 Total Hardness

Table 5 Table showing Total Hardness (mg/l) values of samples

<b>S.No</b>	<b>Total Hardness (mg/l)</b>
1	276
2	358
3	122
4	228
5	316
6	188
7	302
8	196
9	160
10	256
11	302
12	242
13	324
14	176
15	150
16	140
17	230
18	316
19	270
20	270
21	214
22	320
23	98
24	234
25	150
26	132
27	228
28	230
29	276
30	172
31	324
32	192
33	220
34	160

35	332
36	328
37	340
38	312
39	278
40	194
41	70
42	166
43	140
44	250
45	BDL
46	244
47	284

The total hardness of water is accountable to the amount of Calcium and magnesium ions in water. The range for total hardness of our samples is BDL-358 mg/L with an average of 228 mg/L.

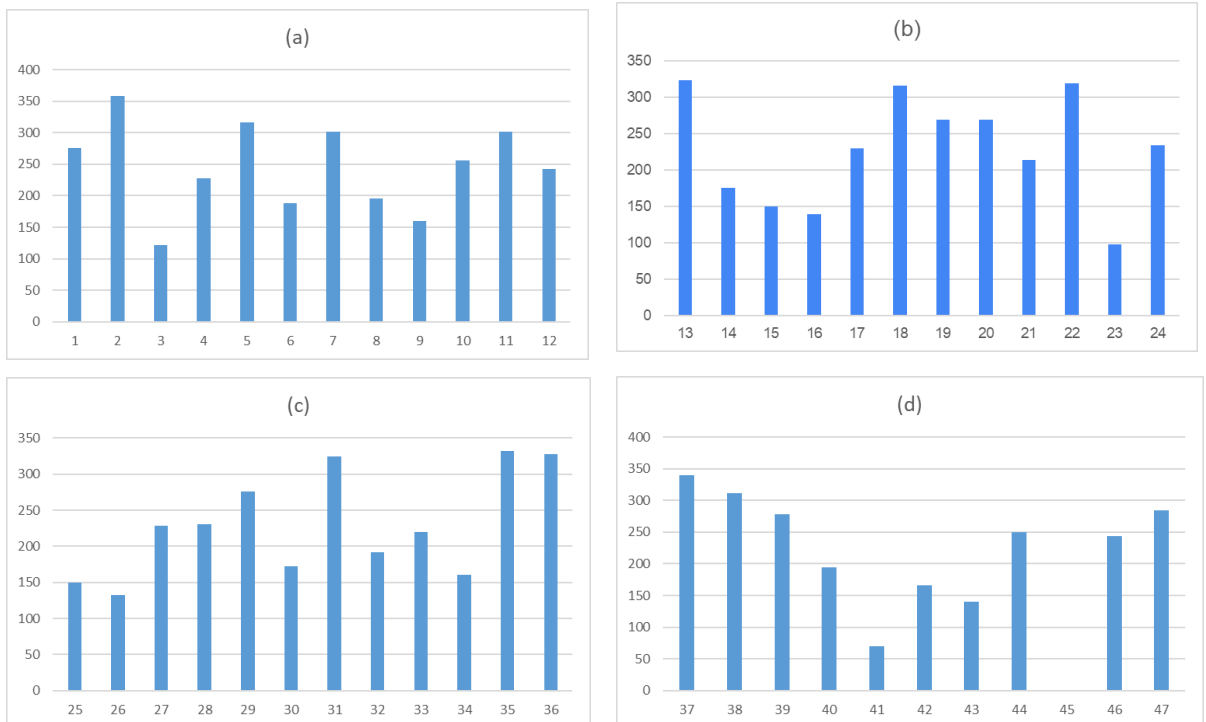


Figure 18 Graphs showing Total Hardness (mg/l) of samples

## 5.2.5 Alkalinity

Table 6 Table showing Alkalinity values of samples 1-47

S.No	Alkalinity (mg/L)
1	288
2	264
3	128
4	260
5	200
6	150
7	150
8	190
9	156
10	202
11	182
12	154
13	246
14	144
15	102
16	104
17	152
18	188
19	138
20	162
21	128
22	172
23	90
24	130
25	150
26	120
27	184
28	176
29	200
30	110
31	190
32	170
33	140
34	60
35	180
36	168
37	192

38	188
39	172
40	142
41	84
42	116
43	80
44	138
45	270
46	138
47	222

The values of alkalinity of our samples range from 60-288 mg/L with an average of 163.2 mg/L.

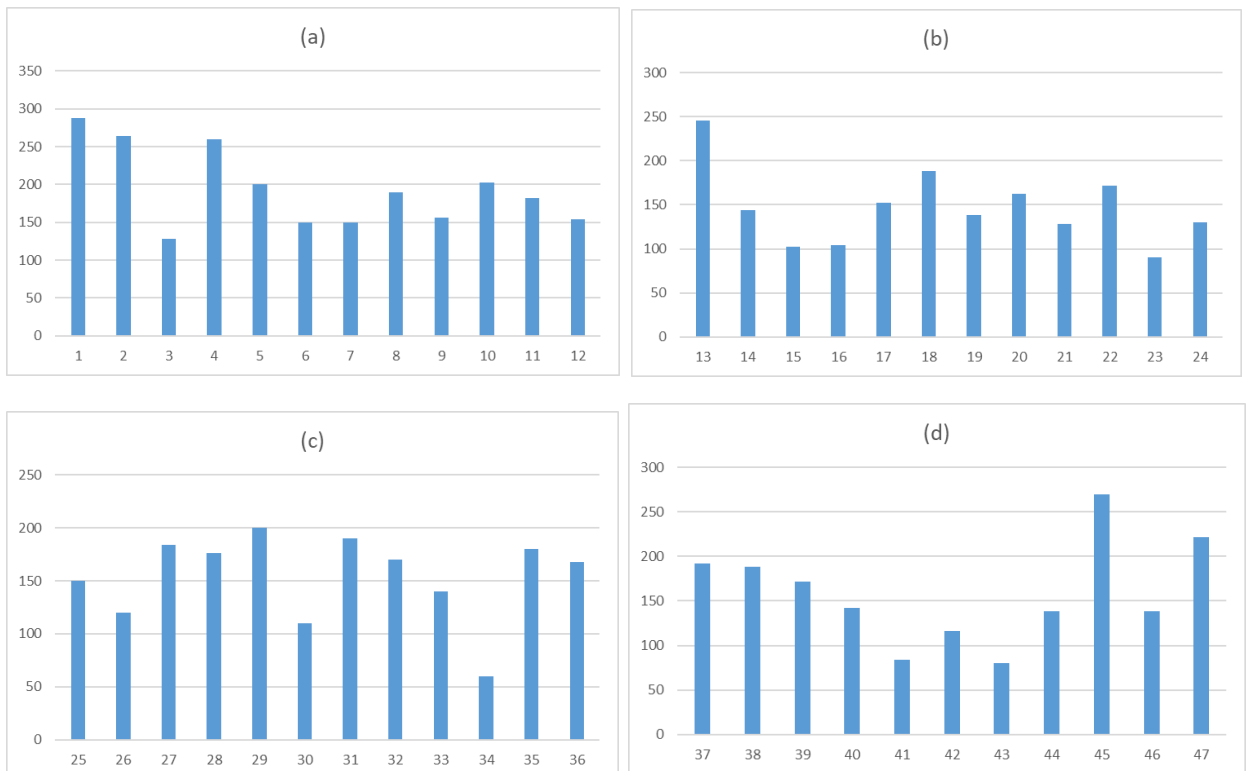


Figure 19 Graphs showing Alkalinity of samples (mg/L)

## 5.2.6 Calcium

Table 7 Table showing concentrations of Calcium (mg/l)

S.No	Calcium (mg/l)
1	16.64
2	11.52
3	3.52
4	6.72
5	7.68
6	6.72
7	8.00
8	5.12
9	4.16
10	7.36
11	10.24
12	8.32
13	9.60
14	4.16
15	4.16
16	3.84
17	6.72
18	8.32
19	7.36
20	8.32
21	5.44
22	8.64
23	4.80
24	5.76
25	3.84
26	2.56
27	7.04
28	5.12
29	6.40
30	7.36
31	11.20
32	6.08
33	5.76
34	4.48

35	7.68
36	9.60
37	8.32
38	9.60
39	9.92
40	6.40
41	3.84
42	3.20
43	6.08
44	7.36
45	1.92
46	6.40
47	8.32

The values for Calcium range from 1.92-16.64 mg/L with an average of 6.84 mg./L.

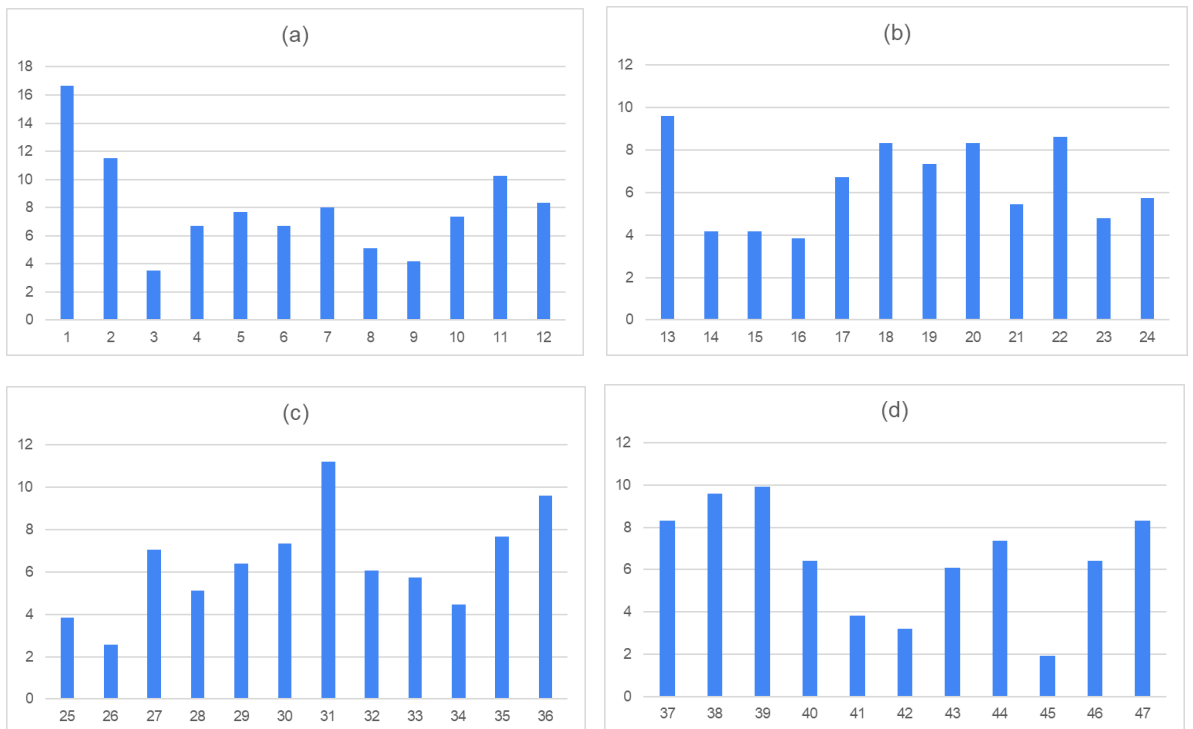


Figure 20 Graphs showing concentration of Calcium (mg/l)

### 5.3 Heavy Metals

#### 5.3.1 Arsenic

All the samples showed 0.0 mg/L concentration of Arsenic.

#### 5.3.2 Iron

Table 8 Table showing concentration of Iron (mg/l) in samples

S.No	Iron (mg/l)
1	0.789
2	0.289
3	0.421
4	0.394
5	0.184
6	0.368
7	1.394
8	0.526
9	0.578
10	0.342
11	0.315
12	0.342
13	0.342
14	0.368
15	0.447
16	0.315
17	0.342
18	0.210
19	0.289
20	0.263
21	0.263
22	0.315
23	0.157
24	0.184
25	0.210
26	0.211
27	BDL
28	BDL
29	BDL
30	BDL
31	0.079
32	BDL
33	BDL
34	0.289

35	0.184
36	0.500
37	0.184
38	0.210
39	BDL
40	BDL
41	BDL
42	BDL
43	BDL
44	BDL
45	BDL
46	BDL
47	BDL

The concentration of Iron range from being BDL (below detection limit) to 1.39 mg/L with an average concentration of 0.24 mg/L.

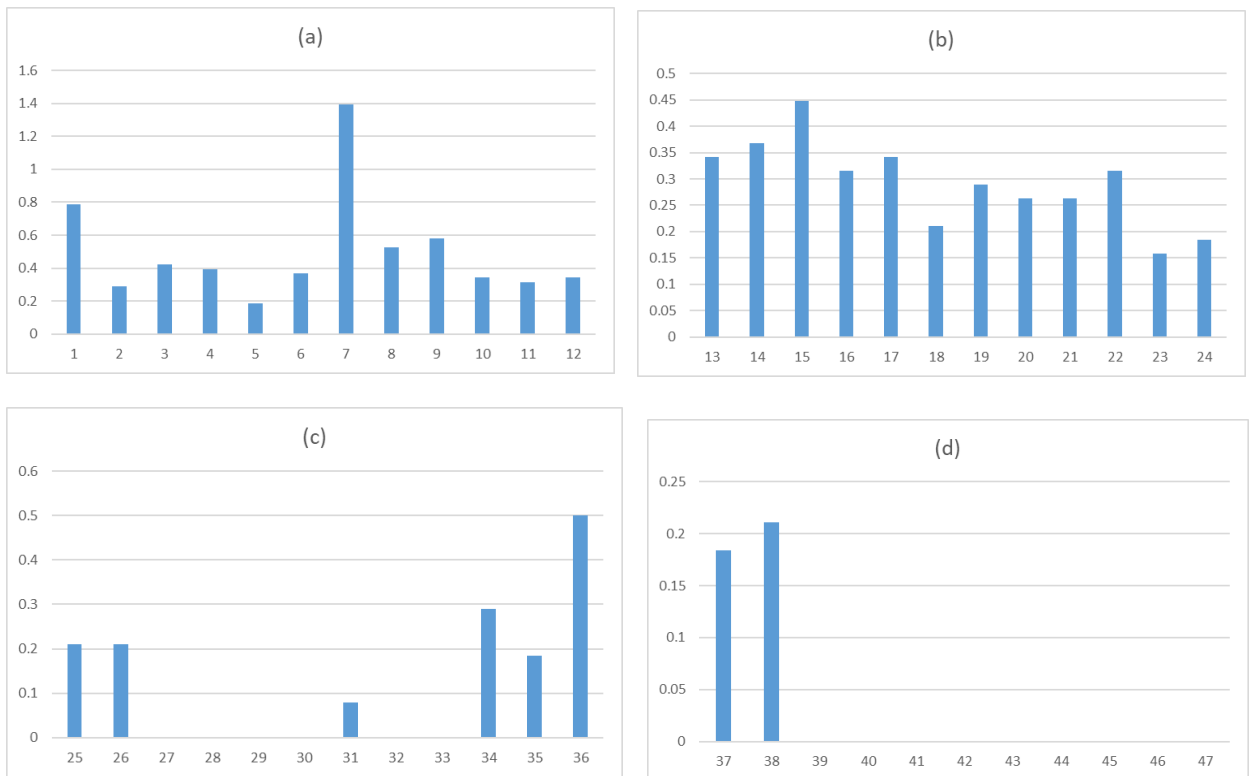


Figure 21 Graphs showing concentrations of Iron (mg/l) in samples 1-47



## 5.4 Discussion

From a stratigraphic perspective, what we understand about the geology of the study area is that the major lithologies present are sandstone, limestone, clays and conglomerates. From a geochemical perspective, we know these formations are rich with abundant Calcium, Sodium, Iron, Carbonates and other materials that may also be found in water. With processes like weathering, erosion, dissolution, precipitation and leaching rock and its contents can interact with water and its chemistry thereby, affecting the water quality. The amount of these substances in water depends on various factors including the rate of these processes, time, temperature, surface conditions etc. The minerals and gases that the water reacts with as it moves relatively slowly through the rocks and sediments of the Earth's crust have an impact on the chemical makeup of groundwater. Even locally, there is a great deal of fluctuation in the quality of groundwater due to several factors. As groundwater passes through pores and crack holes in rocks, its mineral content often rises. (NGWA, 1999)

Some of the minerals in the rocks and silt that make up an aquifer disintegrate when groundwater passes over them, a process known as "weathering." Long-term groundwater in an aquifer has had more time to interact with and weather aquifer components than freshly replenished groundwater therefore, one of the variables that might impact the concentration of dissolved solids is the age of the groundwater.

Through precipitation, evaporation, and groundwater recharge, the climate also impacts the amounts of different compounds in groundwater. There is less water to dilute the byproducts of rock weathering in dry areas because of low precipitation and high evaporation rates. Dissolved solids are concentrated in groundwater in dry locations due to the evaporation of shallow groundwater where the water table is close to the land surface. Wide-ranging regional patterns in dissolved-solids concentrations are the result of climatic variations that cut across many different geographical scales.

Because certain types of rocks weather more easily than others, geology influences concentrations of substances. Some sedimentary rocks, such shales, carbonate rocks, and evaporites, are more soluble and weathering prone than crystalline rocks like granites or sandstones that are rich in quartz. Geology can change on a local and regional level, as well as with aquifer depth (Water Resources, 2019).

With reference to our results and study area in particular, we can confirm presence of carbonates, Calcium, Magnesium, Sodium and Chlorides in the samples

which are consistent with the lithology which would contribute to these elements. For example, the limestone of Margalla Hill Limestone would contribute to the Calcium and Carbonates or the presence of Iron in Murree formation which is also present as the bedrock could contribute to the presence of iron in water or give the groundwater a reddish-brown tinge due to its red clays.

From a hazard perspective, all water quality parameters were under permissible limits as compared of PAK-EPA standards. One Sample, number 45 in particular showed high values of EC, TDS and salts which was due to high amount of chlorides and carbonates which could be a result of a deeper water table in that location. A speculation, yet something which could have influenced this particular sample could have been oil seepages reported in that area, sector H-13 of Islamabad (Web Desk, 2021) Since there was no amount of Arsenic detected in any of the samples it is safe to say, there is no risk posing to the residents of any Arsenic contamination.

## CONCLUSION

The study was performed to examine the water quality of Islamabad, Pakistan and relate it to geology. For this purpose, forty-seven (47) water samples were collected from various locations in the study area and tested in laboratory for certain physical and chemical parameters as well as heavy metals. The aim of water testing was to confirm presence of certain naturally occurring elements like Chlorides, Carbonates and Sodium etc. and observe how much they are present in our samples. The results we got established the presence of these elements and gave us an estimate of how concentrated they can be in water. Almost all the samples tested gave values within the normal range set by PAK EPA therefore, there were no major contamination or hazard related to these elements in water. One sample (sample 45) from sector H-13, Islamabad presented anomalous results, leading us to believe it is not fit for consumption, it is speculated to be as a result of deeper water well, and hence, a deeper water table and/or oil seepages reported in the area.

While making a link between the water quality and the geology of the study area, it is essential to understand the geology in depth from its structure to its strata. The major structure in the vicinity are the Margalla Hills which surround the area. The main rock types that can be found are sandstone, limestone, clays, conglomerates, silt and alluvium. These can be attributed to the major formations present including Margalla Hill Limestone, Murree formation, Lei conglomerate and recent alluvium deposits. The placement of Murree formation overlain by Lei conglomerate along with the tributaries of Soan and Kurang Rivers and Lei Nala contributes to the hydrogeology of the area.

The relationship of water quality and geology is established when we understand the geological processes operating that act as a source of introduction of certain elements from rock into the water it comes in contact with. Processes such as weathering, dissolution and leaching of rocks that contain many elements introduce those elements into water such as dissolution of limestone can be attributed to the increase in Calcium content in water which is further confirmed by water quality tests. Therefore, our knowledge of the rocks reported in the study area and the confirmation

of a significant amount of certain related elements forms the connection between water quality and geology.

To conclude this study, some final points of consideration would be:

- Residents of sector H-13 in Islamabad should properly treat the water (e.g. boil the water) or use filtered water for consumption as there could be health hazards due to high concentration of salts.
- More thorough research should be done on the topic as significant gap in literature exists. A major limitation in our study was the time constraint, lack of funding and limited laboratory facilities. Initiative should be taken for an in depth hydro-geochemical analysis of the geological formations present in the area and more water quality parameters must be tested to form a stronger link between water quality and geology.

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**INTERRELATIONSHIP OF GEOLOGY AND WATER  
QUALITY: A CASE STUDY OF ISLAMABAD,  
PAKISTAN**



**By**

**AMNA SHAFQAT  
MUHAMMAD ADIL**

**DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES  
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