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Comparison of Groundwater Quality Between Paghman Regions and the Fourth Section of Kabul Sedimentary Basin, Kabul, Afghanistan

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Abstract
This study investigates groundwater quality in the Paghman area located in the fourth sector of Kabul, Afghanistan. The primary objective is to identify the natural causes of drinking water contamination, including toxic compounds and materials that leach from soluble rock formations, sediments, and soil into groundwater at infiltration points. We employed two distinct approaches: (a) area-based analysis and (b) laboratory analysis. The area-based analysis involved sampling water from various wells in Paghman and the fourth sector of Kabul. These samples revealed the presence of both soluble and insoluble sediments. Soluble materials interact with water through various chemical reactions, altering its quality, while insoluble materials were analyzed separately as solid components rather than in solutions. For this study, we assessed key water quality parameters, including electroconductivity, pH, temperature, and total hardness. Additionally, chemical analysis was conducted to measure concentrations of Ca, Na, K, Fe, SO_4, Cl_2, NH_3, Mg, F, HCO_3, and NO_3. Several years of conflict in this region contribute to the complexity of reasons responsible for these contaminants, ranging from lack of previous studies, uncontrolled discharge by a growing population, and possibly contaminants from exploded and unexploded ordnances. In addition, there is artisanal and small-scale mining by locals who discharge harmful chemicals to contaminate groundwater. By conducting a grid search of these contaminants, we hope to calculate water quality, attribute contaminants with health effects, and help municipalities with regulatory pathways to improve the quality of life for everyday citizens.

Keywords
Groundwater, water quality, total dissolved solid, water contamination, hydrochemistry

1. Introduction

Since 2004, groundwater levels in the Kabul Basin and the surrounding areas have significantly declined—from approximately 69 meters to around 148 meters. Sediments in the area originate primarily from the Quaternary period. The average drawdown during arid years varies depending on well depth: in wells 160 meters deep, the mean drawdown is 9.4 meters, while in 68-meters wells, it is 5.1 meters. In other areas, the drawdown ranges between 5.1 and 40 meters. It is influenced by factors such as regional morphology, proximity to river streams, and the aquifer type. From September 2005 to May 2006, groundwater levels declined by approximately 8 meters (Asaad et al., 2004). Seasonal fluctuations in groundwater levels occur due to Afghanistan's climate. Precipitation is more abundant in winter and spring, allowing groundwater levels to recover. However, in summer and fall, rainfall is minimal, leading to increased groundwater depletion. The Paghman District, located west of Kabul, covers an area of 600 km², with a population of 350,000. It consists of 180 villages and 12,290 acres of agricultural land (Avouac et al., 1996). The Kabul Basin is a plain enclosed by a mountain range. Its sedimentary formations originate from metamorphic rocks, as the surrounding mountains consist of metamorphic material. The sediment thickness at the center of the basin reaches approximately 2,000 meters (Banks et al., 2002). The basin spans 1,600 km² and is composed of Quaternary and Tertiary sediments, predominantly sands and gravels covering the bedrock. Sediment consolidation varies with depth–surface sediments remain unconsolidated, while deeper layers are more compacted due to higher concentrations of matrix or cementing materials (Belhassan et al., 2022). The Kabul Basin has a relatively uniform climate, with an average annual precipitation of 330 mm, a mean temperature between 10–13°C, and an annual evaporation rate of 1,600 mm. Three major rivers flow through the basin: the Paghman River, which enters from the west; the Logar River, which enters from the south and merges with the Kabul River at Shena village; and the Kabul River itself. The Logar River basin covers 30 km², with an aquifer thickness of 500 meters. The Kabul River basin spans approximately 12,888 km² (Biswas et al., 1994; Bohannon et al., 2005). Most precipitation occurs in winter, accumulating in mountainous regions. During the snowmelt season, this water replenishes both surface and groundwater supplies.

1.1. Geology of Kabul

From a geological perspective, the Kabul Basin was formed through complex tectonic activities during the lower Pleistocene (Tertiary period) (Bohannon et al., 2007). The basin's rock formations consist of metamorphic rocks, with multiple faults shaping the region. The Kabul Basin is bounded by the Bamiyan and Herat regions to the west and east and by Sarobi to the southeast, while the Chaman Moqur fault separates it from other formations (Fetter, 1988).

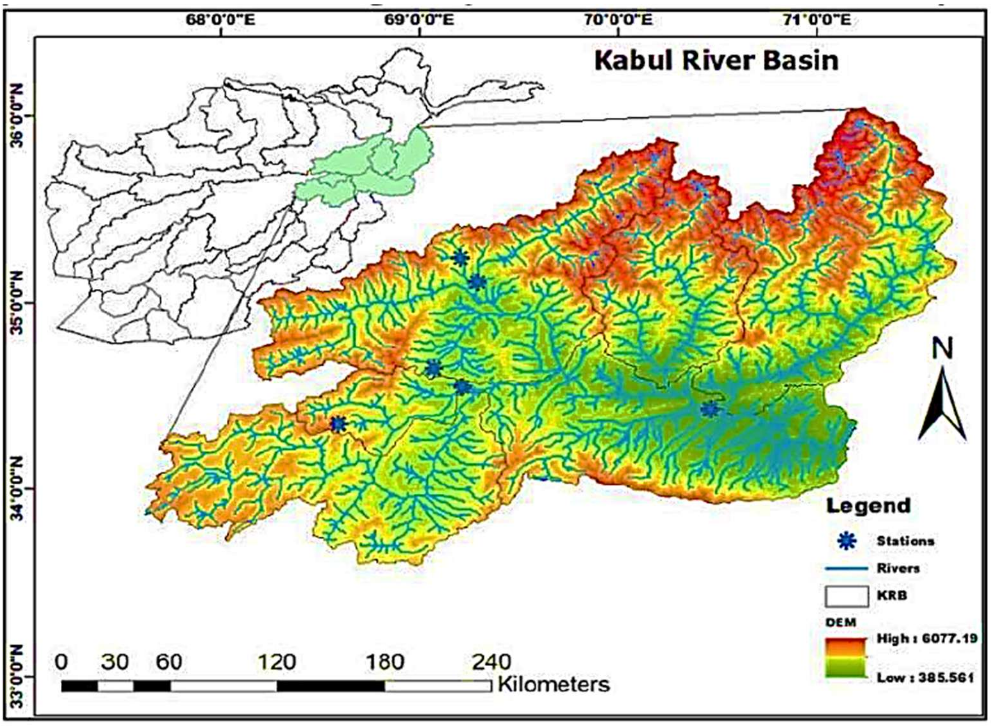

Fig. 1. The hydrological map of the Kabul Basins

The northern and western sections of the basin are composed of Precambrian Gneiss, Mica Schist, Quartzite, and marble, while the eastern and southern sections consist of flysch deposits. Major rivers in the region align with significant fault lines and are covered by Tertiary sediments (Grotzinger, 2007; Hamdard et al., 2022). These sediments, which date to the Neogene period, are primarily composed of gravel and have a thickness of approximately 600 meters.

The sediments in the Kabul Basin are categorized into four main groups (Koons, 1989; Misra, 2012; Manga, 2001; Molnar, 1990).

1. Mollusk Soil Series (Upper Miocene) – Composed of alternating layers of calcite, red-colored sandstone, conglomerates, and breccia, formed after regional uplift.
2. Pleistocene Series – Found in the central areas of the Kabul sedimentary basin, consisting of thin layers of silt, fine sand, and lacustrine sediments.
3. Sedimentary Terraces – Located in the Lataband area and dating to the Upper Pleistocene.

1.2. Hydrogeology of Kabul Basin

From a hydrogeological point of view, the Kabul Basin is characterized by fault and fracture zones filled with various types of sediments. The Neogene sediments in this basin form aquifers, and along fault lines and fracture zones, numerous artesian aquifers can be found. Along rivers, alluvial sediments are more prevalent, and aquifers are more abundant along these paths (Maurice, 2001; Niard, 2005). These sedimentary structures have developed according to river stream patterns. The sediments are highly porous, exhibiting significant permeability and porosity. They are composed of both angular and rounded gravel, shaped by different transportation processes. Gravels transported by streams tend to be rounded due to continuous abrasion, whereas those moved by gravity remain angular (Nakata, 1972; Putnis, 1992; Piper, 1944; Rasouli et al., 2023; Rasouli et al., 2024).

The basin contains various types of sediment deposits, including alluvial, deluvial, proluvial, and colluvial deposits, which accumulate along valley margins. These sediments are cemented or bonded by carbonate, clay, and iron oxide matrices, leading to varying degrees of consolidation. Many aquifers in the Kabul Basin extend along tectonic fractures, which are filled with fine materials. By analyzing these properties, it is possible to determine the stratigraphy and profile of different sediment layers. In these sedimentary series, younger sediments are located in the upper layers, while older sediments are found in the lower sections. The degree of consolidation is related to sediment thickness (Rasouli et al., 2023; Rasouli, 2021b). Aquifers in the Kabul Basin primarily consist of tectonic fractures filled with fine materials. In terms of stratigraphy, younger sediments generally form the upper layers, whereas older sediments are situated below. These sediments are cemented by carbonates, clay, iron oxides, and SiO_2 (Fig. 1).

Table 1. Physical properties of drinking water at Paghman villages

No	Parameter	Unite	Equipment	Type of Test
1	EC	µs/cm	Conductivity meter	Areal
2	TDS	Mg/Li	Potable groundwater, temperature	Areal
3	pH		pH- meter	Areal

Table 2. Chemical properties of drinking water at Paghman villages

No	Parameter	Formula	Unite	Measure equipment	Type of test
1	Calcium	Ca	Mg/Li	Spectra -Photo Model DR3900	Laboratory
2	Potassium	K	Mg/Li	Spectra -Photo Model DR3900	Laboratory
3	Sodium	Na	Mg/Li	Spectra -Photo Model DR3900	Laboratory
4	Sulfite	SO3	Mg/Li	Spectra -Photo Model DR3900	Laboratory
5	Nitrate	NO4	Mg/Li	Spectra -Photo Model DR3900	Laboratory
6	Chlorine	Cl	Mg/Li	Spectra -Photo Model DR3900	Laboratory
7	Iron	Fe	Mg/Li	Spectra -Photo Model DR3900	Laboratory
8	Nitrite	NO3	Mg/Li	Spectra -Photo Model DR3900	Laboratory

Table 3. General information about this research is at the Paghman

No	Code number	Area	Local name of well	Longitude	Latitude	Elevation	Date of sampling	Analysis date	Type of source	Water level (m)
1	019253	Arghandi Olia	Bazeed Khel	69.5449	34.2914	2290	21/Sep/2022	22/Sep/2022	Deep well	40
2	019254	Qargha	Kariz	69.3252	34.3243	1920	22/Sep/2022	23/Sep/2022	Deep well	35
3	019260	Company	Bagha Dawood	69.0304	34.3126	1910	23/Sep/2022	24/Sep/2022	Deep well	21
4	019261	Chandlababi	Saya Bagh	69.0231	34.58800	2283	24/Sep/2022	25/Sep/2022	Shallow well	5
5	019263	Khawage Masafar	Bazar Khage Masfur	68.5957	34.3241	2124	25/Sep/2022	26/Sep/2022	Deep well	13
6	019264	Dodamust	Sahia Malak	69.00798	34.3241	2080	26/Sep/2022	27/Sep/2022	Deep well	18
7	019265	Qali Haidarkhan	Musjida Safid	68.99079	34.56867	2010	27/Sep/2022	28/Sep/2022	Deep well	24
8	019266	Kariz	Dashta Kariz	68.98831	34.50350	2012	28/Sep/2022	29/Sep/2022	Deep well	23
9	019267	Qali Wazeer	Safakhna Muslim	69.0238	34.50987	1895	29/Sep/2022	30/Sep/2022	Deep well	23
10	019267	DahAraban	Lasa Arban	69.0337	34.3112	1910	30/Sep/2022	1/Oct/2022	Deep well	14
11	019268	Arghadisufla	Kariz Mudrasa	68.5654	34.3038	2190	1/Oct/2022	2/Oct/2022	Deep well	16
12	019269	ArghadiOlia	Qalia Sadik	68.5542	34.2749	2200	2/Oct/2022	3/Oct/2022	Deep well	12

1.3. Groundwater Investigation

1.3.1. Groundwater Characteristics

Groundwater originates from surface water that infiltrates into the subsurface through permeable formations like gravel, sediments, fractures, joints, faults, and karst zones. In some cases, groundwater remains underground for long periods, even centuries, and can become contaminated through various processes (Ruleman et al., 2007; Richard, 2000). Contaminants include substances that alter their turbidity, odor, taste, color, and hardness. Globally, groundwater constitutes approximately 30.1% of all freshwater resources. Groundwater contamination generally occurs in three ways: physical, chemical, and biological (Rasouli et al., 2023; Raymo et al., 1988; Sree Devi et al., 2001).

1.3.2. Physical Contaminations

Pure, natural water is colorless, odorless, and tasteless. It has a slight green tint due to its light absorption properties. At 4°C, its density is 1000 kg/m³, while its melting and boiling points are 0°C and 99.98°C, respectively. The chemical formula of water is H_2O, with a molecular weight of 18.015 g/mol. The primary physical characteristics of water include clarity, turbidity, odor, and sensitivity to contaminants. (Vaseashta et al., 2022).

1.3.3. Chemical Contaminations

Chemical contamination in groundwater results from interactions between dissolved substances and water. These contaminants include solids, acids, bases, fluorides, metals, organic compounds, and nutrients (Summerfield et al., 1994; Vaseashta et. al., 2021). When solid materials dissolve in water, physical and chemical reactions—such as hydration, hydrolysis, oxidation, and reduction—alter water quality.

Common chemical elements and compounds found in contaminated water include carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), hydroxide (OH^-), ammonia (NH_3), iron (Fe^{2+}), manganese (Mn^{2+}), strontium (Sr^{2+}), aluminum (Al^{3+}), fluoride (F^-), argon (Ar), hydrogen (H), cadmium (Cd), lead (Pb), mercury (Hg), and chromium (Cr) (Khudaverdyan et al., 2021). The presence of these substances can contribute to water hardness and toxicity, posing risks to both human health and the environment.

1.3.4. Biological Contaminations

Water is a fundamental resource that supports life on Earth (Torge et al., 2003). However, untreated water may contain various pathogens, viruses, and bacteria, leading to waterborne diseases. These diseases occur when people ingest contaminated water or come into contact with contaminated matter. Among the most common waterborne diseases, diarrhea is the primary symptom. Other significant waterborne diseases include cholera, norovirus, shigellosis, Legionnaires' disease, and typhoid fever. Pathogenic microorganisms found in contaminated water include:

- Hepatitis A (HAV): A viral infection affecting the liver.
- Protozoa: Single-celled eukaryotic organisms that can be free-living or parasitic.
- Cryptosporidium: A microscopic parasite causing cryptosporidiosis, a diarrheal disease.
- Giardia: A microscopic parasite that spreads through contaminated soil and feces (Thornthwaite, 1948).

While natural filtration mechanisms help remove contaminants before they reach aquifers, excessive and prolonged exposure to pollutants can lead to their infiltration into groundwater. Numerous other pathogens and bacterial colonies may exist in water, increasing the risk of waterborne disease outbreaks (WBDOs). One particularly concerning groups of bacteria is Vibrios. These small, curved, rod-shaped, facultative anaerobes belong to the Vibrionaceae family within the order Vibrionales. They are non-spore-forming, Gram-negative bacteria measuring approximately 1.5–3.0 µm × 0.5 µm. Notable species include:

- Vibrio cholerae: The causative agent of cholera.
- Vibrio parahaemolyticus: Associated with gastrointestinal infections.
- Vibrio vulnificus: Known for causing severe wound infections.

These bacteria possess pili (fimbriae) composed of TcpA protein, which plays a crucial role in cholera toxin expression and is essential for in vivo colonization. A detailed discussion of Vibrio species is beyond the scope of this article. However, the primary goal of water quality testing is to inform the public about potential contaminants and ensure safe water consumption (Tünnemeier, 2005).

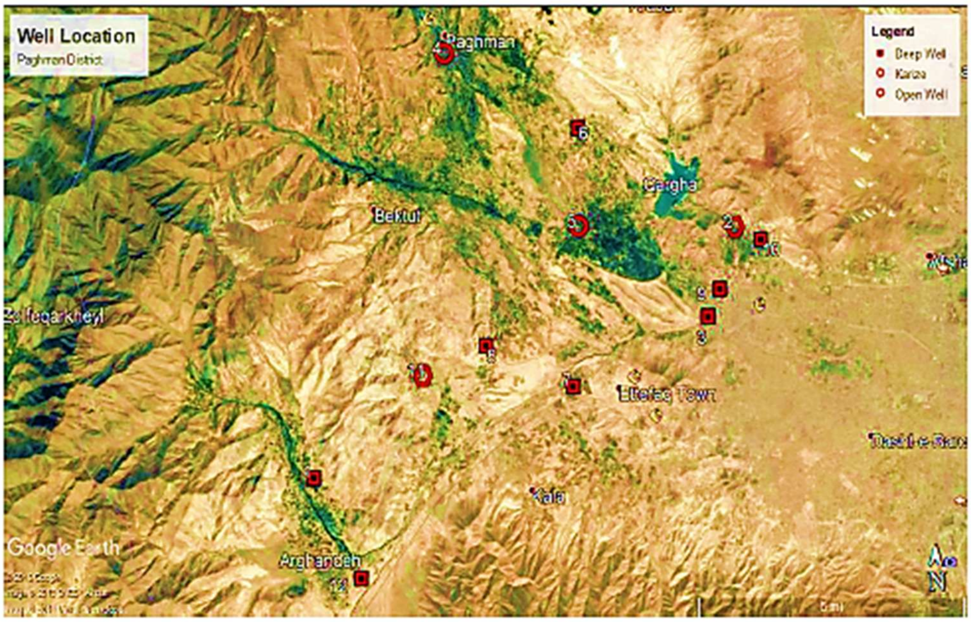

Fig. 2. Location map of 12 wells at Paghman region (Source – Authors)

2. Methods of Sampling and Analysis

The analysis of water samples in this study is divided into two categories: field analysis and laboratory analysis. A total of 12 wells in the Paghman villages were examined. The study included the assessment of some physicochemical parameters, including electrical conductivity (EC) (µS/cm), temperature (°C), dissolved oxygen (DO) (mg/L), total dissolved solids (TDS) (mg/L), and pH. Additionally, some key chemical elements such as calcium (Ca), potassium (K), sulfite (SO_3), ammonium (NO_4), chloride (Cl), iron (Fe), and nitrate (NO_3) were also analyzed (Tables 1 and 2).

2.1. Location Map of 12 Wells

Twelve water wells have been selected in the Paghman region (villages of Arghandi Olia, Qargha, Company, Chandlababi, Khawage Masafar, Dodamust, Qali Haidarkhan, Kariz, Qali Wazeer, DahAraban, Arghadisufla, and ArghadiOlia), as shown in Fig. 2.

3. Result and Discussion

3.1. Electrocoductivity of Water

Electrical conductivity (EC) refers to the ability of a salt solution to conduct electricity, which depends on the presence of dissolved ions. EC is commonly expressed in microSiemens per centimeter (µS/cm) and should be measured at thermal equilibrium, typically between 20 and 26°C. A portable, cost-effective, and user-friendly digital EC meter has been used for real-time water quality assessment (Urbano et al., 2006; Vaseashta, 2022). The measured EC values are presented in Fig. 3 and summarized in Table 4.

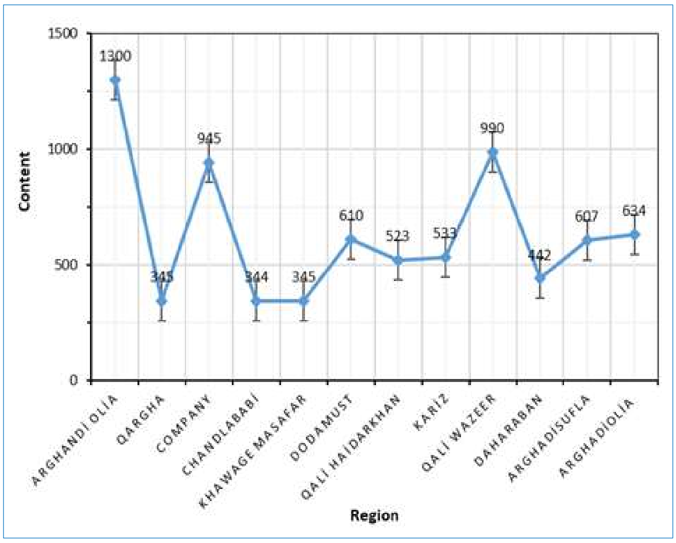

Fig. 3. The amount of EC in Paghman Region groundwater

Table 4. Shows the EC at the different villages of Paghman District

No	Code of well	Area	Local name	EC (µS/cm)
1	019253	Arghandi Olia	Bazeed Khel	1300
2	019254	Qargha	Kariz	345
3	019260	Company	Bagha Dawood	945
4	019261	Chandlababi	Saya Bagh	344
5	019263	Khawage Masafar	Bazar Khage Masfur	345
6	019264	Dodamust	Sahia Malak	610
7	019265	Qali Haidarkhan	Musjida Safid	523
8	019266	Kariz	Dashta Kariz	533
9	019267	Qali Wazeer	Safakhna Muslim	990
10	019267	Dah Araban	Lasa Arban	442
11	019268	Arghadisufla	Kariz Mudrasa	607
12	019269	Arghadi Olia	Qalia Sadik	634
Mean				582
The Asian Criteria				1500 µS/cm

However, it is important to note that EC meters cannot detect biological contaminants. Industrial conductivity probes often utilize an inductive (or toroidal) measurement method, which prevents direct contact between the liquid and the sensor's electrical components. In this approach, two inductively coupled coils are used: one serves as the primary (driving) coil, generating a magnetic field, while the other functions as the secondary coil of a transformer. As the liquid flows through a channel within the sensor, it forms a conductive loop in the transformer's secondary winding, generating an induced current that serves as the sensor's output.

3.2. Concentration of Hydrogen Ions (pH)

In this study, we compare the pH of the samples with the maximum and minimum pH WHO standards. The pH of groundwater samples in Arghandi Olia, Qargha, Company, Chandlababi, Khawage Masafar, Dodamust, Qali Haidarkhan, Kariz, Qali Wazeer, DahAraban, Arghadisufla, ArghadiOlia. On the other hand, if we compare it with WHO values, then it's between high pH = 8.5 and minimum pH = 6.5 (Vaseashta et. al., 2021; Vaseashta, et. a., 2022; Vaseashta et. al., 2023; WHO 2011; WHO, 2010; WHO, 2009). In such cases, it can be used for drinking for all purposes of life (Fig. 4 and Table 5).

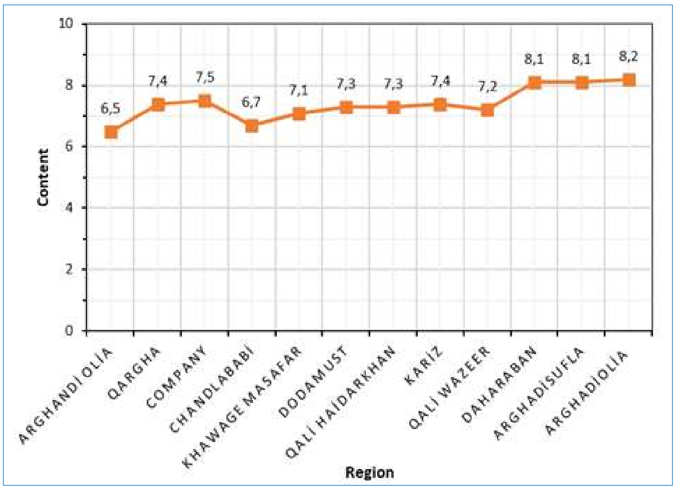

Fig. 4. The amount of pH in the Paghman Region groundwater

Table 5. Shows the pH at the different villages of Paghman District

No	Code of well	Area	Local name	pH
1	019253	Arghandi Olia	Bazeed Khel	6.5
2	019254	Qargha	Kariz	7.4
3	019260	Company	Bagha Dawood	7.5
4	019261	Chandlababi	Saya Bagh	6.7
5	019263	Khawage Masafar	Bazar Khage Masfur	7.1
6	019264	Dodamust	Sahia Malak	7.3
7	019265	Qali Haidarkhan	Musjida Safid	7.3
8	019266	Kariz	Dashta Kariz	7.4
9	019267	Qali Wazeer	Safakhna Muslim	7.2
10	019267	DahAraban	Lasa Arban	8.1
11	019268	Arghadisufla	Kariz Mudrasa	8.1
12	019269	ArghadiOlia	Qalia Sadik	8.2
Mean				7.4
The Afghanistan Criteria				6.5–8.5
The Asian Criteria				6.5–8.5

3.3. Hardness of Water

Water hardness is measured in mg/L and it is caused by various dissolved salts, which include cations such as Ca^{2+}, Mn^{2+}, Al^{3+}, Fe^{2+}, Sr^{2+}, K^{+}, Mg^{2+}, and anions such as HCO_3^{-}, SiO_3^{-2}, NO_3^{-}, Cl^{-}, and CO_3^{-2} . These ions are typically present in solution form. The primary sources of carbonates are parent rocks and other dissolved materials (WHO, 2011;

Worthington et al., 2009; Wheeler et al., 2005; Younger, 2009). Carbonate concentrations exceeding 60 mg/L are primarily due to calcium carbonate and can reach up to 150 mg/L. Water with a hardness exceeding 30–50 mg/L can contribute to the corrosion of metal instruments.

In this study, the hardness of various water samples, including surface water, toilet wastewater that may infiltrate groundwater, salt water, and industrial water, was measured using the 2340-C EDTA titrimetric method. This method was also applied to water samples from Paghman in the Kabul Region.

The procedure involved adding 10 mL of the water sample to 20 mL of fresh water, followed by 1–2 mL of a buffer solution (NH_4OH + NH_4Cl) to achieve a pH of approximately 10–10.1. Two drops of an indicator solution, typically weak acids or bases with conjugate forms exhibiting different colors, were then added to observe color changes due to pH variation. After five minutes, the ethylenediaminetetraacetic acid (EDTA) titration changed the color from red to blue, indicating the end of the titration process. The final color change was recorded to determine total hardness (Fig. 5 and Table 6).

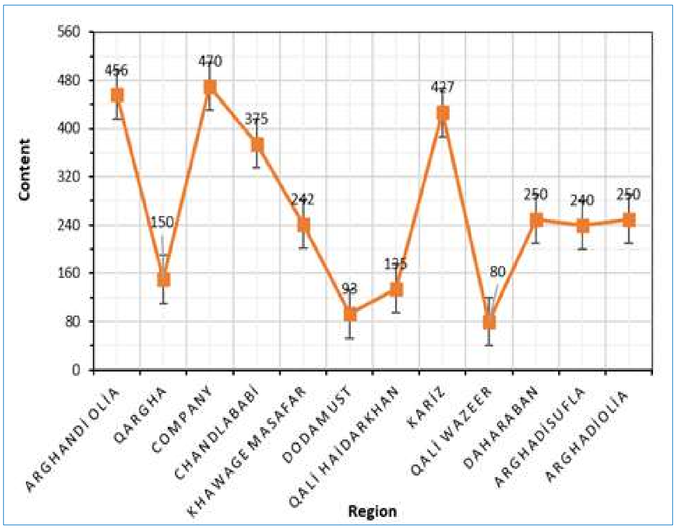

Fig. 5. The amount of hardness in Paghman Region groundwater

Table 6. Shows the hardness of the different villages of the Paghman District

No	Code of Well	Area	Local name	Hardness (μm/cm)
1	019253	Arghandi Olia	Bazeed Khel	456
2	019254	Qargha	Kariz	150
3	019260	Company	Bagha Dawood	470
4	019261	Chandlababi	Saya Bagh	375
5	019263	Khawage Masafar	Bazar Khage Masfur	242
6	019264	Dodamust	Sahia Malak	93
7	019265	Qali Haidarkhan	Musjida Safid	135
8	019266	Kariz	Dashta Kariz	427
9	019267	Qali Wazeer	Safakhna Muslim	80
10	019267	DahAraban	Lasa Arban	250
11	019268	Arghadisufla	Kariz Mudrasa	240
12	019269	ArghadiOlia	Qalia Sadik	250
Mean				264
The Afghanistan Criteria				500
The Asian Criteria				500

3.4. The Cations in Water Pollution

3.4.1. Calcium (Ca)

Calcium is commonly found in natural water sources, with its concentration dependent on the parent rock composition. It is primarily present as carbonates, bicarbonates, and sulfates. In saltwater, calcium is commonly found as calcium chloride and calcium nitrate, while in freshwater, calcium bicarbonates contribute to water hardness.

Although calcium is an essential dietary element, water is not a major dietary source of it. In this study, a 10 mL water sample was analyzed by adding 10 mL of fresh water. Then, 0.4 mL of sodium hydroxide was added to achieve a pH of 8–12. A small amount of Moroxid indicator ($C_8H_8N_6O_6$) was then introduced, and EDTA was used for titration (Fig. 6 and Table 7).

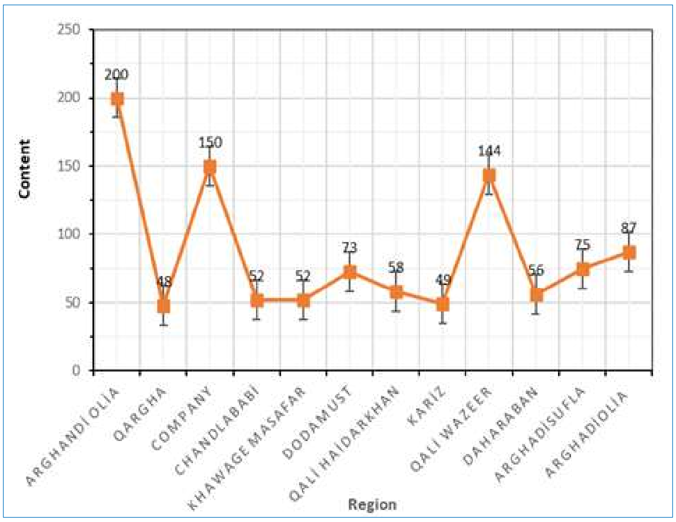

Fig. 6. The amount of Ca in Paghman Region groundwater

Table 7. Shows the calcium at the different villages of Paghman District

No	Code of Well	Area	Local name	Calcium
1	019253	Arghandi Olia	Bazeed Khel	200
2	019254	Qargha	Kariz	48
3	019260	Company	Bagha Dawood	150
4	019261	Chandlababi	Saya Bagh	52
5	019263	Khawage Masafar	Bazar Khage Masfur	52
6	019264	Dodamust	Sahia Malak	73
7	019265	Qali Haidarkhan	Musjida Safid	58
8	019266	Kariz	Dashta Kariz	49
9	019267	Qali Wazeer	Safakhna Muslim	144
10	019267	DahAraban	Lasa Arban	56
11	019268	Arghadisufla	Kariz Mudrasa	75
12	019269	ArghadiOlia	Qalia Sadik	87
Mean				87
The Afghanistan Criteria				200 mg/Li
The Asian Criteria				200 mg/Li

3.4.2. Determination of Sodium and Potassium by Flame Photometry

The concentrations of sodium and potassium were determined using flame photometry, which relies on the emission spectrum of these elements. Unlike other spectroscopic techniques, a flame photometer does not require an external light source as it measures the light emitted by excited atoms in the sample. The required energy for excitation is provided by the combustion of acetylene or natural gas in the presence of air or oxygen.

Key components of the instrument include the aspirator and burners, which play a critical role in sample aspiration and aerosol formation. In this process, the sample solution is introduced into the flame, forming fine droplets that decompose into neutral sodium and potassium atoms due to the flame's thermal energy. These atoms are then excited and subsequently return to their ground state, emitting light at characteristic wavelengths: 589 nm for sodium (Na) and 466 nm for potassium (K). The emitted light intensity is proportional to the concentration of the respective elements. In this study, the sodium concentration was found to be 3.5 ppm, while the potassium concentration was 2.8 ppm. Repeated measurements yielded varying results (Fig. 7 and Fig. 8).

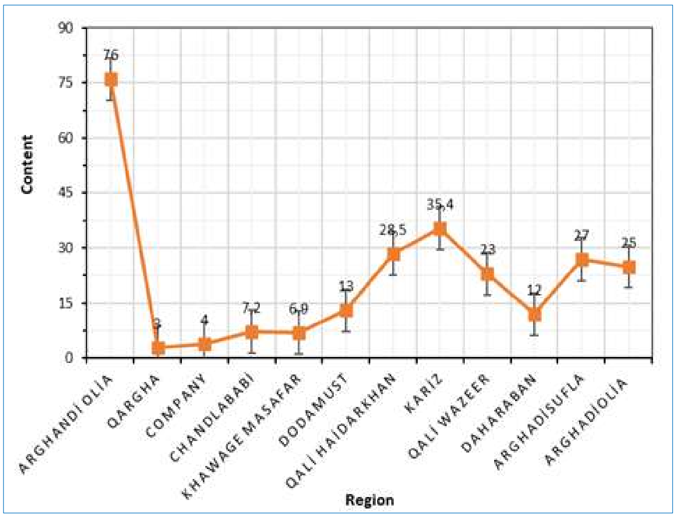

Fig. 7. The amount of Na in Paghman Region groundwater

Table 8. Shows the sodium at the different villages of Paghman District

No	Code of Well	Area	Local name	Sodium
1	019253	Arghandi Olia	Bazeed Khel	76
2	019254	Qargha	Kariz	3
3	019260	Company	Bagha Dawood	4
4	019261	Chandlababi	Saya Bagh	7.2
5	019263	Khawage Masafar	Bazar Khage Masfur	6.9
6	019264	Dodamust	Sahia Malak	13
7	019265	Qali Haidarkhan	Musjida Safid	28.5
8	019266	Kariz	Dashta Kariz	35.4
9	019267	Qali Wazeer	Safakhna Muslim	23
10	019267	DahAraban	Lasa Arban	12
11	019268	Arghadisufla	Kariz Mudrasa	27
12	019269	ArghadiOlia	Qalia Sadik	25
Mean				21.75
The Afghanistan Criteria				200 mg/Li
The Asian Criteria				200 mg/Li

3.4.2.2. Potassium (K)

Potassium is another essential element, though its concentration in water generally does not exceed 30 mg/L. The European Union has set a guideline limit of 10–12 mg/L for potassium in drinking water (Fig. 8 and Table 9).

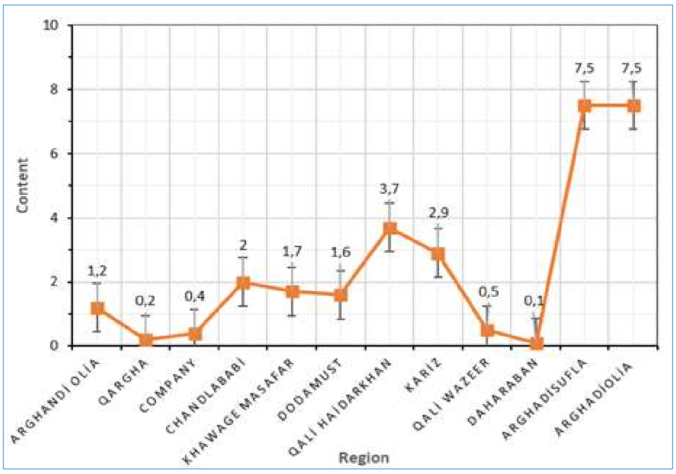

Fig. 8. The amount of K in Paghman Region groundwater

Table 9. Shows the potassium at the different villages of Paghman District

No	Code of well	Area	Local name	Potassium
1	019253	Arghandi Olia	Bazeed Khel	1.2
2	019254	Qargha	Kariz	0.2
3	019260	Company	Bagha Dawood	0.4
4	019261	Chandlababi	Saya Bagh	2
5	019263	Khawage Masafar	Bazar Khage Masfur	1.7
6	019264	Dodamust	Sahia Malak	1.6
7	019265	Qali Haidarkhan	Musjida Safid	3.7
8	019266	Kariz	Dashta Kariz	2.9
9	019267	Qali Wazeer	Safakhna Muslim	0.5
10	019267	DahAraban	Lasa Arban	0.1
11	019268	Arghadisufla	Kariz Mudrasa	7.5
12	019269	ArghadiOlia	Qalia Sadik	7.5
Mean				2.44 mg/Li

3.4.3. Determination Amount of Iron

To determine iron concentration, two test tubes (A and B) were prepared and rinsed with distilled water. Each tube was filled with 20 mL of potable water. Tube A was treated with Fe-1 reagent and allowed to react for three minutes, causing a color change. This color was then compared against a standard color chart. Tube B was used as a reference to determine the final concentration. The average iron concentration recorded was 0.02 mg/L, with the experiment repeated three times for accuracy (Fig. 9 and Table 10).

3.4.4. Anions

3.4.4.1. Sulfides

Sulfide concentrations in groundwater can fluctuate up to 1000 mg/L. These sulfides primarily originate from gypsum and other sulfide-bearing sediments. In river water, sulfides form due to oxidation, while in surface waters, industrial sources contribute significantly to their presence. Industrial processes, including paper production, release sulfur compounds, which later oxidize and dissolve in rainwater, leading to sulfide accumulation in water bodies. Sulfide-rich waters often have a characteristic rotten egg odor due to hydrogen sulfide (H_2S) gas emissions (Fig. 10 and Table 11).

3.4.4.2. Determination of Chlorides

Chloride concentration in surface water, groundwater, and wastewater was determined using potassium chromate as an indicator and silver nitrate ($AgNO_3$) as a titrant. The endpoint was identified by a color change from yellow to brick red. The chloride concentration was then calculated using the formula:

$$Mg\ Cl\text{-}/L = (A+B) \cdot F \cdot N \cdot 35450/ml\ of\ sample \quad (1)$$

where: A = titration solution for the sample, B = titration solution for potable water (0.1), F = factor (1.03), N = normality of silver nitrate.

Results are recorded in Fig. 11 and Table 12.

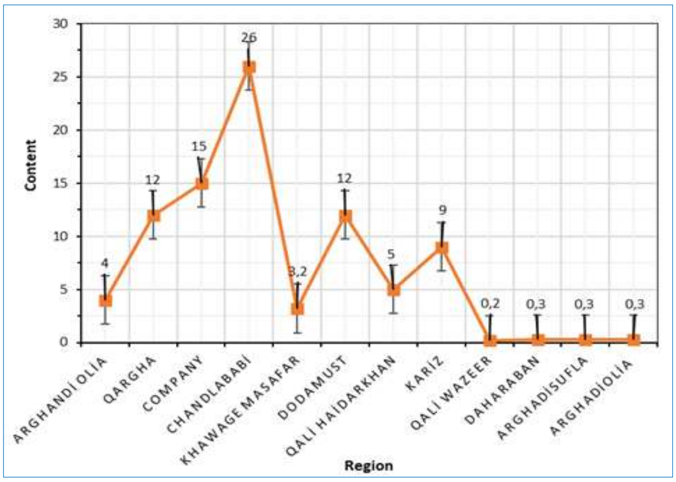

Fig. 9. The amount of Fe in Paghman Region groundwater

Table 10. Shows the iron at the different villages of Paghman District

No	Code of Well	Area	Local name	Iron
1	019253	Arghandi Olia	Bazeed Khel	4
2	019254	Qargha	Kariz	12
3	019260	Company	Bagha Dawood	15
4	019261	Chandlababi	Saya Bagh	26
5	019263	Khawage Masafar	Bazar Khage Masfur	3.2
6	019264	Dodamust	Sahia Malak	12
7	019265	Qali Haidarkhan	Musjida Safid	5
8	019266	Kariz	Dashta Kariz	9
9	019267	Qali Wazeer	Safakhna Muslim	0.2
10	019267	DahAraban	Lasa Arban	0.3
11	019268	Arghadisufla	Kariz Mudrasa	0.3
12	019269	ArghadiOlia	Qalia Sadik	0.3
Mean				0.3 mg/Li
The Afghanistan Criteria				0.3 mg/Li
The Asian Criteria				0.3 mg/Li

3.4.4.3. Nitrites (NO_3)

Nitrites (NO2-) and nitrates (NO3-) are measured in terms of nitrogen concentration (mg/L). The total nitrogen oxide content corresponds to the sum of nitrite and nitrate concentrations. Elevated levels of ammonia and nitrite often indicate industrial activity. The presence of iron in water suggests the reduction of nitrite. Nitrite is an intermediate product in the oxidation of ammonia, which originates from both inorganic ammonia and organic matter. This oxidation process in water and soil is facilitated by nitrifying bacteria, which promote oxygen acceptance. The excessive use of chemical nitrogen compounds contributes to increasing nitrogen levels in surface and groundwater. High nitrogen concentrations in water can have negative health effects, particularly for children. Nitrites formed through nitrogen reduction can react with secondary and tertiary amines, raising health concerns (Fig. 12 and Table 13).

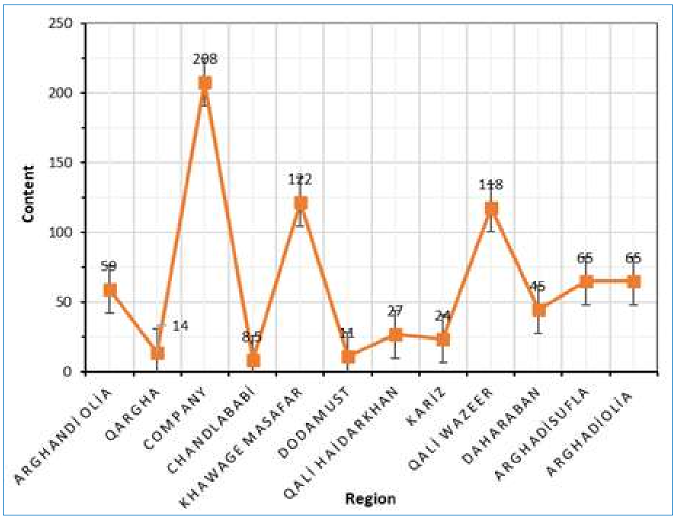

Fig. 10. The amount of SO_4 in Paghman Region groundwater

Table 11. Shows sulfite at the different villages of the Paghman District

No	Code of Well	Area	Local name	Sulfite
1	019253	Arghandi Olia	Bazeed Khel	59
2	019254	Qargha	Kariz	14
3	019260	Company	Bagha Dawood	208
4	019261	Chandlababi	Saya Bagh	8.5
5	019263	Khawage Masafar	Bazar Khage Masfur	122
6	019264	Dodamust	Sahia Malak	11
7	019265	Qali Haidarkhan	Musjida Safid	27
8	019266	Kariz	Dashta Kariz	24
9	019267	Qali Wazeer	Safakhna Muslim	118
10	019267	DahAraban	Lasa Arban	45
11	019268	Arghadisufla	Kariz Mudrasa	65
12	019269	ArghadiOlia	Qalia Sadik	65
Mean				63.87 mg/Li
The Afghanistan Criteria				250 mg/Li
The Asian Criteria				250 mg/Li

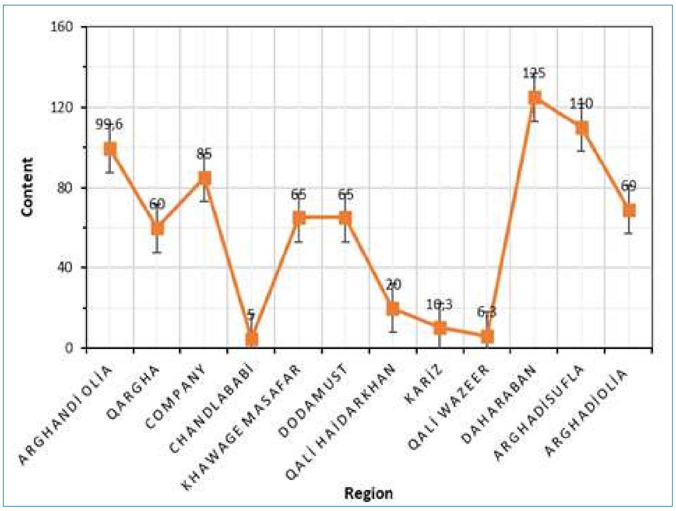

Fig. 11. The amount of chlorides in Paghman Region groundwater

Table 12. Shows the chlorides at the different villages of Paghman District

No	Code of Well	Area	Local name	Chlorides
1	019253	Arghandi Olia	Bazeed Khel	99.6
2	019254	Qargha	Kariz	60
3	019260	Company	Bagha Dawood	85
4	019261	Chandlababi	Saya Bagh	5
5	019263	Khawage Masafar	Bazar Khage Masfur	65
6	019264	Dodamust	Sahia Malak	65
7	019265	Qali Haidarkhan	Musjida Safid	20
8	019266	Kariz	Dashta Kariz	10.3
9	019267	Qali Wazeer	Safakhna Muslim	6.3
10	019267	DahAraban	Lasa Arban	125
11	019268	Arghadisufla	Kariz Mudrasa	110
12	019269	ArghadiOlia	Qalia Sadik	69
Mean				62.26 mg/Li
The Afghanistan Criteria				250 mg/Li
The Asian Criteria				250 mg/Li

3.4.5. The Means of Parameters

To enhance the accuracy and understanding of this study, we determined the mean values of key water quality parameters, including electrical conductivity (EC), pH, total hardness (TH), calcium (Ca), potassium (K), sodium (Na), sulfate (SO_4), nitrate (NO_3), chloride (Cl), and iron (Fe). These values were compared to global reference standards (Fig. 13 and Table 14).

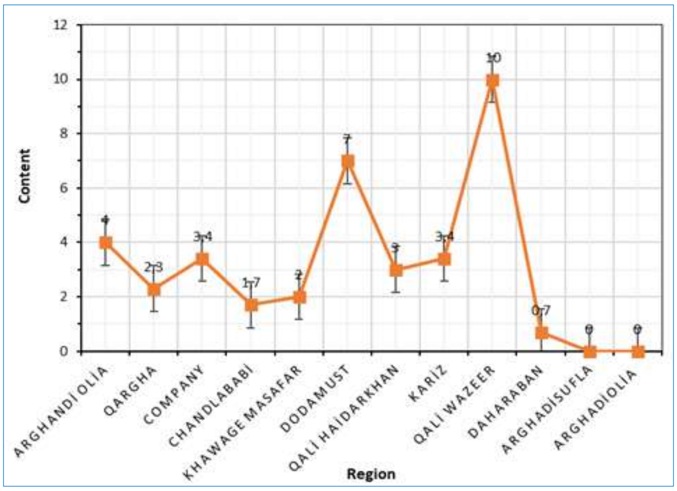

Fig. 12. The amount of NO_3 in Paghman Region groundwater

Table 13. Shows the nitrite at the different villages of Paghman District

No	Code of Well	Area	Local name	Nitrite
1	019253	Arghandi Olia	Bazeed Khel	4
2	019254	Qargha	Kariz	2.3
3	019260	Company	Bagha Dawood	3.4
4	019261	Chandlababi	Saya Bagh	1.7
5	019263	Khawage Masafar	Bazar Khage Masfur	2
6	019264	Dodamust	Sahia Malak	7
7	019265	Qali Haidarkhan	Musjida Safid	3
8	019266	Kariz	Dashta Kariz	3.4
9	019267	Qali Wazeer	Safakhna Muslim	10
10	019267	DahAraban	Lasa Arban	0.7
11	019268	Arghadisufla	Kariz Mudrasa	0
12	019269	ArghadiOlia	Qalia Sadik	0
Mean				3.125 mg/Li
The Afghanistan Criteria				50 mg/Li
The Asian Criteria				50 mg/Li

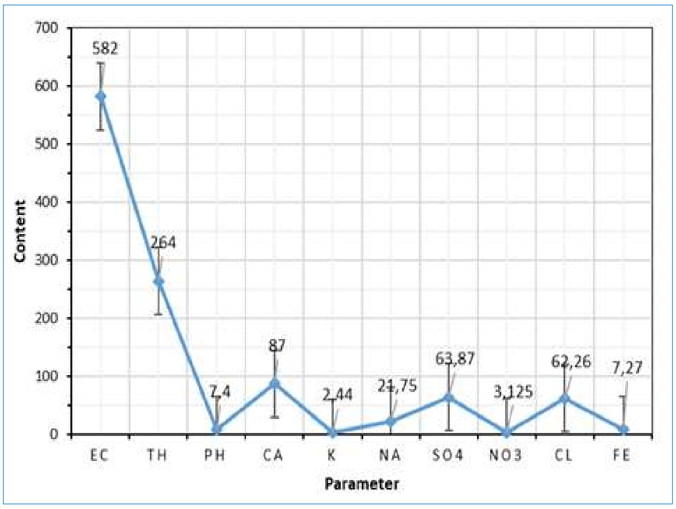

Fig. 13. Various parameters in Paghman Region groundwater

3.5.1. Fourth of Kabul

The fourth sector of the Kabul Basin is a geologically significant area containing various types of sediment, including gravel, sand, silt, and clay. Different types of aquifers exist in this region, such as aquifers, aquicludes, and aquifuges.

Generally, aquifers consist of gravel and sand, while aquicludes are composed of silt and clay. The aquifuges contain consolidated materials, with gravel cemented by fine clay and carbonate layers beneath the upper sedimentary deposits (Fig. 14). Aquifers are predominantly found along riverbanks and plains, where water-bearing materials are transported by river flow.

3.5.2. The Well Location Map in Forth Sector

This study assessed water quality from nine wells in the fourth sector of Kabul. These wells are located in different villages, including Dahkapak, Taymany, Wazirabad, Charahia Ansar, Makroyan, the Second Project of Taymany, Fruit Market, Parwan Seay and Mirza House (Fig. 15).

3.5.3. Groundwater Level

Groundwater levels in the fourth sector of Kabul vary depending on location and elevation. Over the past 30 years, prolonged drought conditions and low precipitation have significantly lowered groundwater levels in this area. The measured groundwater depths in different villages are as follows: Dahkapak (40 m), Taymany (25 m), Wazirabad (28 m), Charahia Ansar (30 m), Makroyan (34 m), Second Project of Taymany (27 m), Fruit Market (23 m), Parwan Seay (35 m), and Mirza House (24 m). The average groundwater level in the study area is approximately 30 m (Fig. 16).

3.5.4. The Methods of Sampling and Its Analysis

Water samples were analyzed using two approaches: regional (areal) analysis and laboratory analysis. Nine water samples were collected from the nine wells in the fourth sector of Kabul. Five key water quality parameters were examined: electrical conductivity (EC), temperature, dissolved oxygen (DO) and salinity.

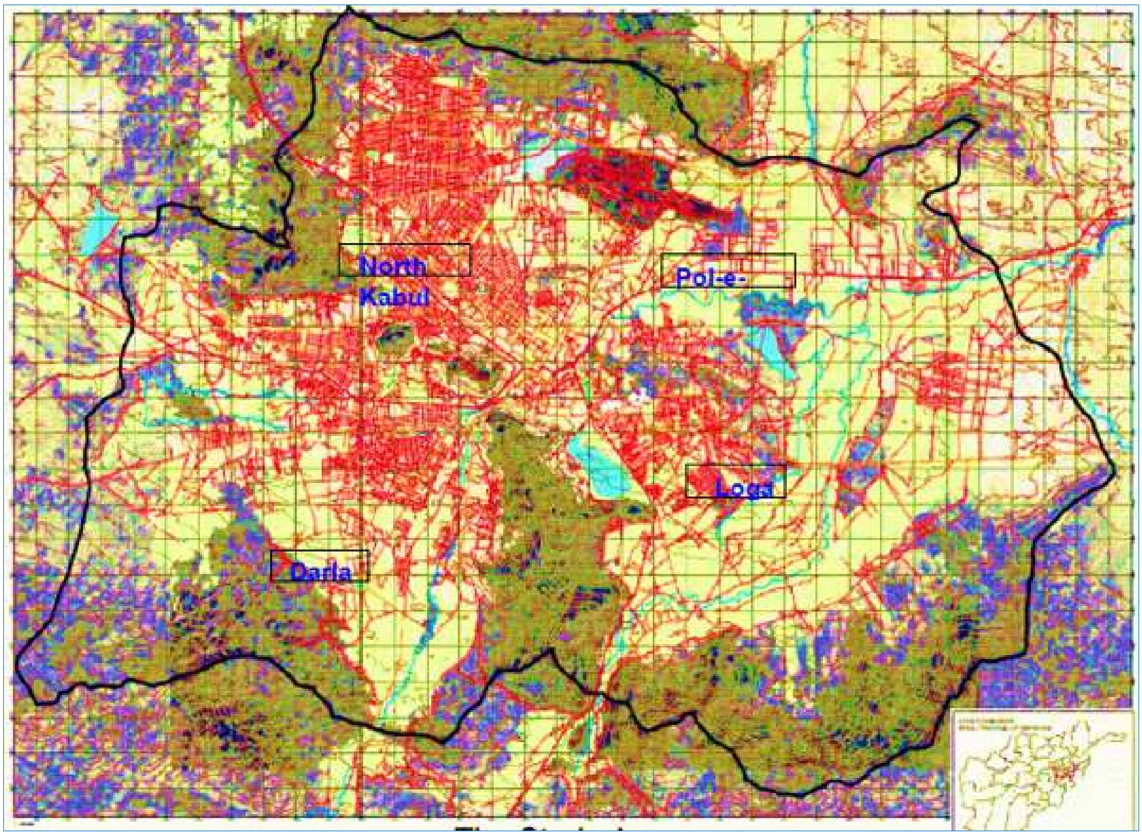

Fig. 14. Hydrogeological map of the fourth sector of Kabul (Source – Authors)

Fig. 15. Locations of 9 wells at DEM at the 4th sector of Kabul (Source – Authors)

3.5.4. Physical Properties of Groundwater

The taste and odor of groundwater are essential physical characteristics influencing its suitability for consumption and other uses. Groundwater can be classified based on five key physical properties: Color, Turbidity, Taste, and Chemical Parameters.

3.5.4.1. Color

Groundwater is generally greenish, in color. Variations in color result from the presence of dissolved organic and inorganic materials, typically measured in milligrams per liter (mg/L). Inorganic substances originate from minerals present in rocks, sediments, and soils within groundwater and surface water systems. In this study, groundwater exhibited a predominantly green color, indicating no significant contamination, making it suitable for both drinking and irrigation.

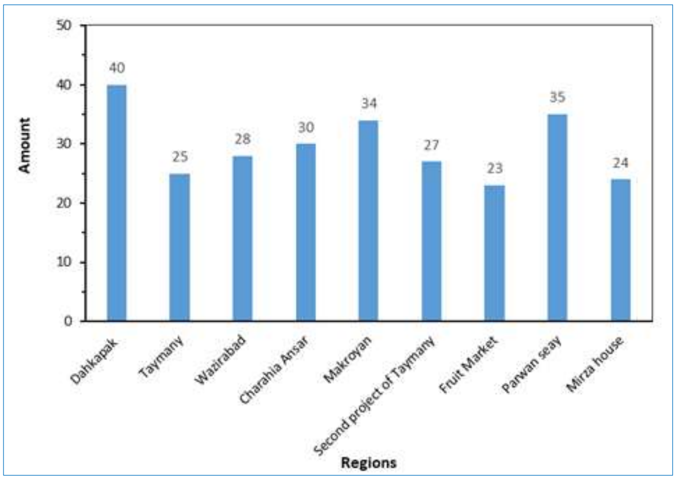

Fig. 16. The amount of water level in the fourth sector of Kabul Region groundwater

Table 15. Physical parameters at the different villages of the fourth sector of Kabul

No	Parameter	Unite	Equipment's	Type of test
1	EC	µs/cm	Conductivity meter	Areal
2	TDS	Mg/Li	Potable groundwater, temperature	Areal
3	pH		pH- meter	Areal

Table 16. Chemical parameters at the different villages of the fourth sector of Kabul

No	Parameter	Formula	Unite	Measure equipment	Type of test
1	Calcium	Ca	Mg/Li	Spectra -Photo Model DR3900	Laboratory
2	Potassium	K	Mg/Li	Spectra -Photo Model DR3900	Laboratory
3	Sodium	Na	Mg/Li	Spectra -Photo Model DR3900	Laboratory
4	Sulfite	SO_3	Mg/Li	Spectra -Photo Model DR3900	Laboratory
5	Nitrate	NO_4	Mg/Li	Spectra -Photo Model DR3900	Laboratory
6	chlorine	Cl	Mg/Li	Spectra -Photo Model DR3900	Laboratory
7	Iron	Fe	Mg/Li	Spectra -Photo Model DR3900	Laboratory
8	Nitrite	HCO_3	Mg/Li	Spectra -Photo Model DR3900	Laboratory

Table 17. Physical characteristics of drinking water

No	Parameter	Unit	Device of measurement	Type of test
1	EC	µm/cm	pH - meter	Areal
2	pH		pH - meter	Areal

3.5.4.2. Turbidity

Turbidity refers to the presence of suspended particles and dissolved solids that affect water clarity. In this study, turbidity was measured using a turbidity meter (mg/L), with additional evaluation through Total Dissolved Solids (TDS) analysis. The results indicated that groundwater turbidity levels were negligible, meeting international groundwater quality standards. All tested water samples were clear and deemed safe for drinking.

Table 18. Chemical characteristics of drinking water

No	Parameter	Formula	Unite	Device	Type of test
1	Calcium	Ca	Mg/Li	Spectra Photo Meter DR3900	Laboratory
2	Potassium	K	Mg/Li	Spectra Photo Meter DR3900	Laboratory
3	Sodium	Na	Mg/Li	Spectra Photo Meter DR3900	Laboratory
4	Sulfite	SO_3	Mg/Li	Spectra Photo Meter DR3900	Laboratory
5	Nitrate	NO_4	Mg/Li	Spectra Photo Meter DR3900	Laboratory
6	Chloride	Cl	Mg/Li	Spectra Photo Meter DR3900	Laboratory
7	Iron	Fe	Mg/Li	Spectra Photo Meter DR3900	Laboratory
8	Bicarbonates	HCO_3	Mg/Li	Spectra Photo Meter DR3900	Laboratory

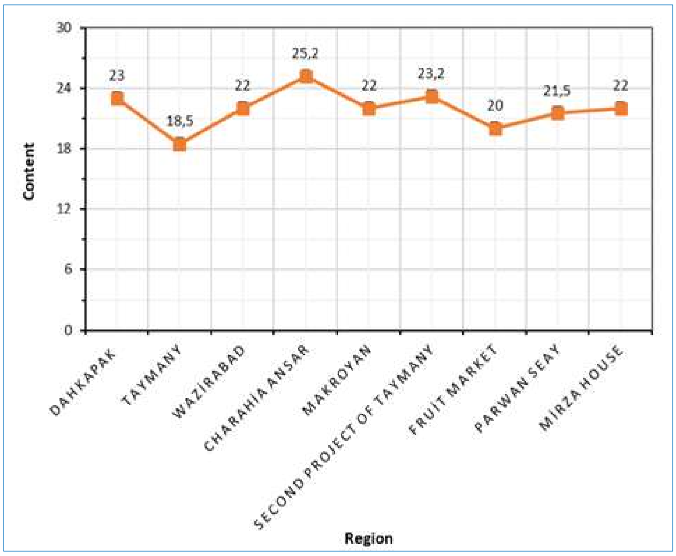

Fig. 17. The amount of temperature in the fourth sector of Kabul Region groundwater

Table 17. Shows the temperature at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Temperature (C°)
1	015118	Dahkapak	Faiz Mohammad House	23
2	015125	Taymany	Khana Sherakat	18.5
3	015126	Wazirabad	Zamarak House	22
4	016209	Charahia Ansar	Waheed Hamidi House	25.2
5	016228	Makroyan	Water Supply	22
6	017256	Second Project Of Taymany	Haji MirZa M. House	23.2
7	017257	Fruit Market	Abdul Zaher House	20
8	019294	Parwan Seay	Karim House	21.5
9	019295	Mirza House	Sheer Ali House	22
Mean				22
The Afghanistan Criteria				25–35
The Asian Criteria				25–35

3.5.4.3. Odor

The odor of groundwater is influenced by its interaction with surrounding materials, which can sometimes introduce toxic compounds. Odor may result from the infiltration of soluble substances present in the Earth's lithology or from chemical reactions within the water. In certain cases, excessive coloration can also contribute to undesirable odors (WHO, 2009). In this study, the odor of the collected groundwater samples remained within acceptable limits, confirming their suitability for drinking.

3.5.4.4. Taste

The taste of groundwater is influenced by the presence of dissolved minerals such as iron, salts, carbonates, and anhydrite, as well as organic compounds introduced during surface water percolation. In some cases, chemical contaminants and geological formations contribute to an undesirable taste (WHO, 2009). In this study, the groundwater taste was within acceptable limits, making it suitable for consumption.

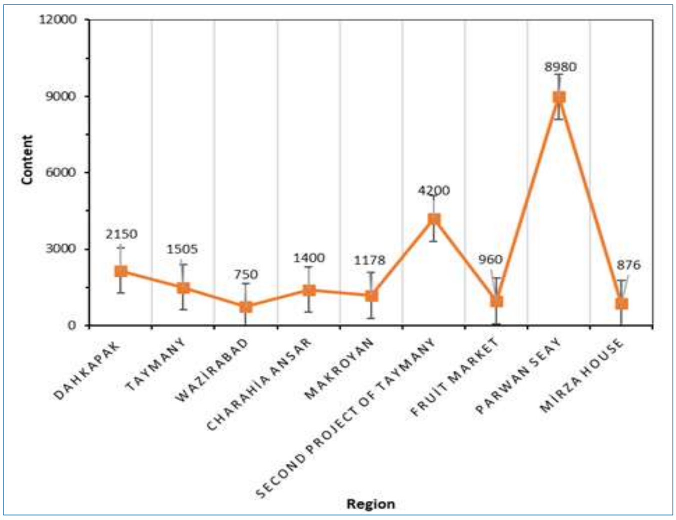

Fig. 18. The amount of EC in the fourth sector of Kabul Region groundwater

Table 18. Shows the EC at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	EC (µS/cm)
1	015118	Dahkapak	Faiz Mohammad House	2150
2	015125	Taymany	Khana Sherakat	1505
3	015126	Wazirabad	Zamarak House	750
4	016209	Charahia Ansar	Waheed Hamidi House	1400
5	016228	Makroyan	Water Supply	1178
6	017256	Second project of Taymany	Haji Mirza M. House	4200
7	017257	Fruit Market	Abdul Zaher House	960
8	019294	Parwan seay	Karim House	8980
9	019295	Mirza house	Sheer Ali House	876
Mean				2444.3
The Afghanistan Criteria				1500
The Asian Criteria				3000

3.5.5. Chemical Parameters

The chemical composition of groundwater is determined by the characteristics of dissolved substances, including solids, acids, bases, fluorides, metals, organic compounds, and nutrients. When solids dissolve in water, they undergo chemical processes such as hydration, hydrolysis, oxidation, and reduction, altering the water's overall quality. Various chemical components contribute to water hardness and potential toxicity, including CO_3^{2-}, HCO_3^-, OH^-, NH_3, Fe^{2+}, Mn^{2+}, Sr^{2+}, Al^{3+}, F^-, Ar, H, Cd, Pb, Hg, and Cr (Tünnemeier et al., 2005). This study specifically examined selected chemical and physical parameters of groundwater.

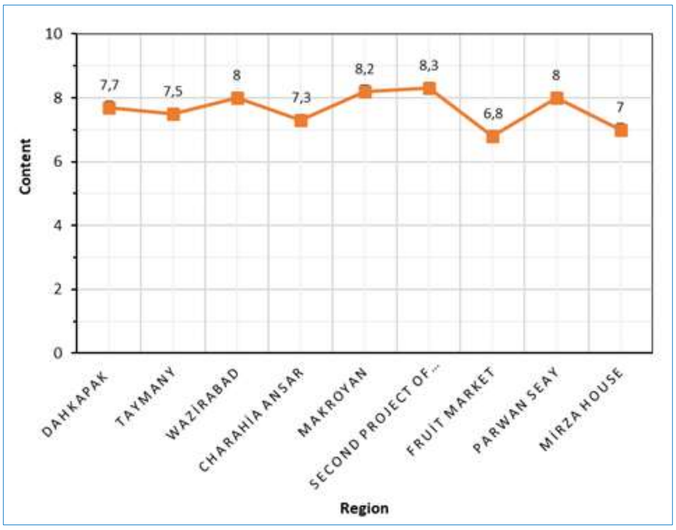

Fig. 19. The amount of pH in the fourth sector of Kabul Region groundwater

Table 19. Shows the pH at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	pH
1	015118	Dahkapak	Faiz Mohammad House	7.7
2	015125	Taymany	Khana Sherakat	7.5
3	015126	Wazirabad	Zamarak House	8
4	016209	Charahia Ansar	Waheed Hamidi House	7.3
5	016228	Makroyan	Water Supply	8.2
6	017256	Second Project of Taymany	Haji MirZa M. House	8.3
7	017257	Fruit Market	Abdul Zaher House	6.8
8	019294	Parwan Seay	Karim House	8
9	019295	Mirza House	Sheer Ali House	7
Mean				7.7
The Afghanistan Criteria				6.5–8.5
The Asian Criteria				6.5–8.5

3.5.6. Physical Parameter

3.5.6.1. Temperature

Groundwater temperature is influenced by depth, geothermal activity, and geographic location. Based on temperature ranges, groundwater can be classified into six categories:

- Very cold (5 °C)
- Cold (10 °C)
- Moderately warm (18 °C)
- Slightly warm (25 °C)
- Warm (37 °C)
- Very warm (>40 °C)

In this study, the groundwater temperature was approximately 22 °C, which falls within the optimal range for drinking and general use. For further details, refer to Fig. 17 and Table 17.

Electroconductivity is shown by the flow of electricity from the water solution, it depends on the ions in the water solution, as well as its belonging to the temperature during measurement (20–25 °C) (WHO. 2011). The EC test is done in areal, the result of a test comparing with WHO standards, as shown in (Fig. 18 and Table 18).

3.5.6.2 Concentration of Hydrogen Ions (pH)

In this study, we compare the pH of the samples with maximum and minimum pH WHO standards. The pH of groundwater samples in Dahkapak, Taymany, Wazirabad, Charahia Ansar, Makroyan, the Second project of Taymany, Fruit Market, Parwan seay, and Mirza house villages are neutral, and it is important for drinking use. On the other hand, if we compare it with WHO then it's between high pH = 8.5 and minimum pH = 6.5 (WHO, 2011). In such cases, it can be used for drinking and for all purposes of life (Fig. 19 and Table 19).

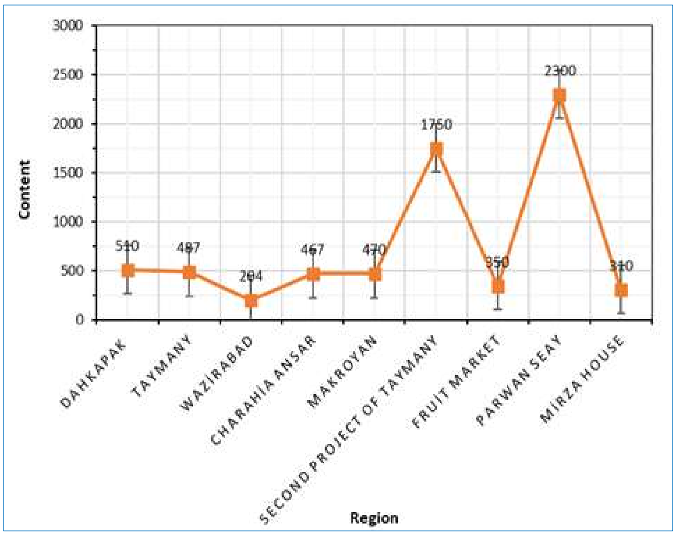

Fig. 20. The amount of TH in the fourth sector of the Kabul Region groundwater

Table 20. Shows the hardness of the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Hardness (mg/Li)
1	015118	Dahkapak	Faiz Mohammad House	510
2	015125	Taymany	Khana Sherakat	487
3	015126	Wazirabad	Zamarak House	204
4	016209	Charahia Ansar	Waheed Hamidi House	467
5	016228	Makroyan	Water Supply	470
6	017256	Second Project of Taymany	Haji MirZa M. House	1750
7	017257	Fruit Market	Abdul Zaher House	350
8	019294	Parwan Seay	Karim House	2300
9	019295	Mirza House	Sheer Ali House	310
Mean				6257
The Afghanistan Criteria				500
The Asian Criteria				500

3.5. 6.3. Hardness (H)

The hardness of groundwater belongs to some saline and there are some cations of Ca^{2+}, Mn^{2+}, Al^{3+}, Fe^{2+}, Sr^{2+}, K^{+}, Mg^{2+} that dissolved with inions HCO_3^-, SiO_3^{2-}, NO_3^-, SO_4^{2-}, Cl^- and CO_3^{2-}, it's measured by mg/L (Rasouli, 2020c). In these collected samples, the hardness of groundwater is shown in Fig. 20 and Table 20.

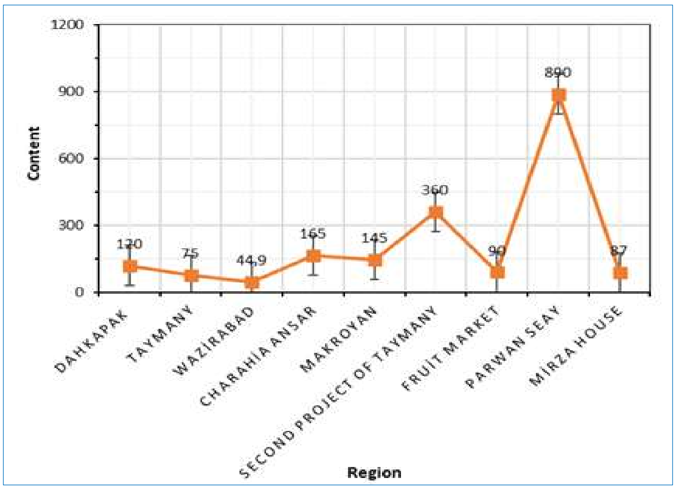

Fig. 21. The amount of Ca in the fourth sector of Kabul Region groundwater

Table 21. Shows the Ca at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Ca (mg/Li)
1	015118	Dahkapak	Faiz Mohammad House	120
2	015125	Taymany	Khana Sherakat	75
3	015126	Wazirabad	Zamarak House	44.9
4	016209	Charahia Ansar	Waheed Hamidi House	165
5	016228	Makroyan	Water Supply	145
6	017256	Second Project of Taymany	Haji MirZa M. House	360
7	017257	Fruit Market	Abdul Zaher House	90
8	019294	Parwan Seay	Karim House	890
9	019295	Mirza House	Sheer Ali House	87
Mean				1899
The Afghanistan Criteria				50
The Asian Criteria				50

3.5.7. Chemical Parameter

3.5.7.1. Calcium (Ca)

In this research, we found the quantity of Ca in groundwater by a Photometeric tool (test- Ray). Additional Ca we can discover in natural water, it's placed in mother rocks that are transitory from rock. Usually, calcium is found in Carbonates, bicarbonates, and sulfides. Similarly, in salty water, we can discover in the form of Calcium chlorides and Calcium bicarbonates, nevertheless for some time if we find that Calcium bicarbonates its related hardness of water and Calcium sulfites, Calcium nitrites and Calcium chlorides are the main reasons for the continuous hardness of waters. For Ca ions 10 mL was added in water, afterward 0.4 ml Sodium hydroxide for the basic environment, must be pH = 8–12, after one spoon of Monoxide indicator ($C_6 H_8 N_6 O_6$) adding and via solution E.D.T.A to changing the color. In normal conditions quality of Ca is according to the WHO and Asian countries is 200 mg/L (Rasouli and Vaseashta, 2023) as shown in (Fig. 21 and Table 21).

3.5.7.2. Potassium (K)

As we all know, K is one of the elements that is often found in nature but not exceeding 30 mg/L. Agreeing to the European Union, the concentration of salts in the water is between 10–12 mg.-L determined. The normal condition K is allowed 10 mg/l and the WHO and Asian Countries are 10 mg/l (Fig. 22 and Table 22).

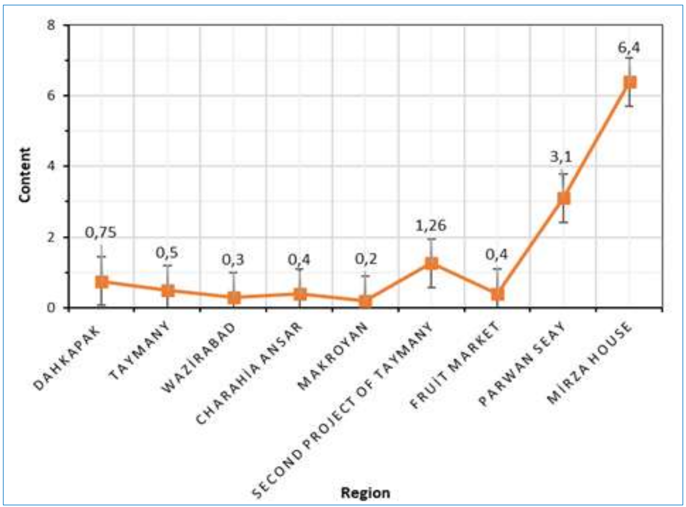

Fig. 22. The amount of K in the fourth sector of Kabul Region groundwater

Table 22. Shows the K at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Ka (mg/Li)
1	015118	Dahkapak	Faiz Mohammad House	0.75
2	015125	Taymany	Khana Sherakat	0.5
3	015126	Wazirabad	Zamarak House	0.3
4	016209	Charahia Ansar	Waheed Hamidi House	0.4
5	016228	Makroyan	Water Supply	0.2
6	017256	Second Project of Taymany	Haji MirZa M. House	1.26
7	017257	Fruit Market	Abdul Zaher House	0.4
8	019294	Parwan Seay	Karim House	3.1
9	019295	Mirza House	Sheer Ali House	6.4
Mean				4.5
The Afghanistan Criteria				
The Asian Criteria				

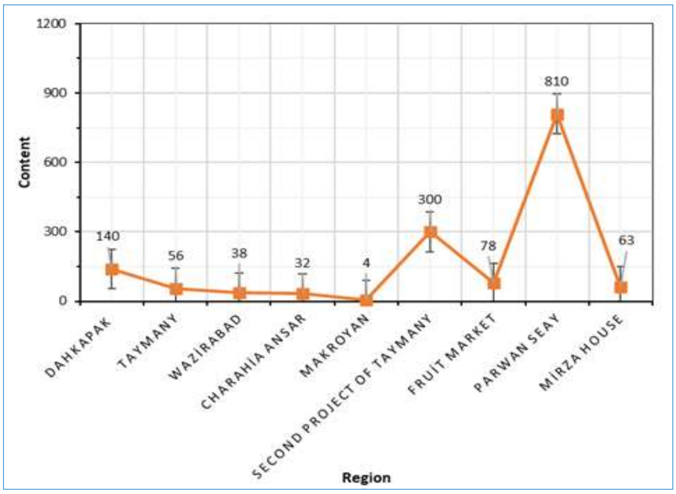

Fig. 23. The water level in the fourth sector of the Kabul Region groundwater

3.5.7.3. Sodium (Na)

This element is solvable and can be found in groundwater; in salty water, this element is more than 1-100 gm/L. When we want to modify water to soft water using $NaCO_3$ via exchange of Na basic element add to this solution. In the usual situations, water needs to consume a lesser amount of Na to protect water from toxic waste. In usual conditions, Na is 200 mg/L, and Na, according to the WHO and Asian Countries, is 200 mg/L (Fig. 23 and Table 23).

Table 23. Shows the Na at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Na (mg/Li)
1	015118	Dahkapak	Faiz Mohammad Hous	140
2	015125	Taymany	Khana Sherakat	56
3	015126	Wazirabad	Zamarak House	38
4	016209	Charahia Ansar	Waheed Hamidi House	32
5	016228	Makroyan	Water Supply	4
6	017256	Second Project of Taymany	Haji MirZa M. House	300
7	017257	Fruit Market	Abdul Zaher House	78
8	019294	Parwan Seay	Karim House	810
9	019295	Mirza House	Sheer Ali House	63
Mean				169
The Afghanistan Criteria				118
The Asian Criteria				118

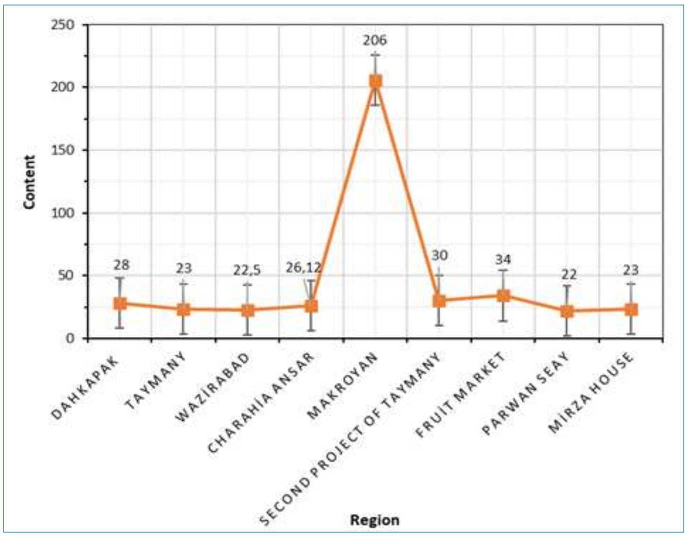

Fig. 24. The amount of Mg in the fourth sector of Kabul Region groundwater

Table 24. Shows the Mg at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Mg (mg/Li)
1	015118	Dahkapak	Faiz Mohammad Hous	28
2	015125	Taymany	Khana Sherakat	23
3	015126	Wazirabad	Zamarak House	22.5
4	016209	Charahia Ansar	Waheed Hamidi House	26.12
5	016228	Makroyan	Water Supply	206
6	017256	Second Project of Taymany	Haji MirZa M. House	30
7	017257	Fruit Market	Abdul Zaher House	34
8	019294	Parwan seay	Karim House	22
9	019295	Mirza house	Sheer Ali House	23
Mean				46
The Afghanistan Criteria				30
The Asian Criteria				30

3.5.7.4. Magnesium (Mg)

For Mg, we used software to find the quantity of Mg. In normal situations, Mg is in mg/L, the WHO and Asian Countries quantity of Mg is 30 mg/L (Fig. 24 and Table 24).

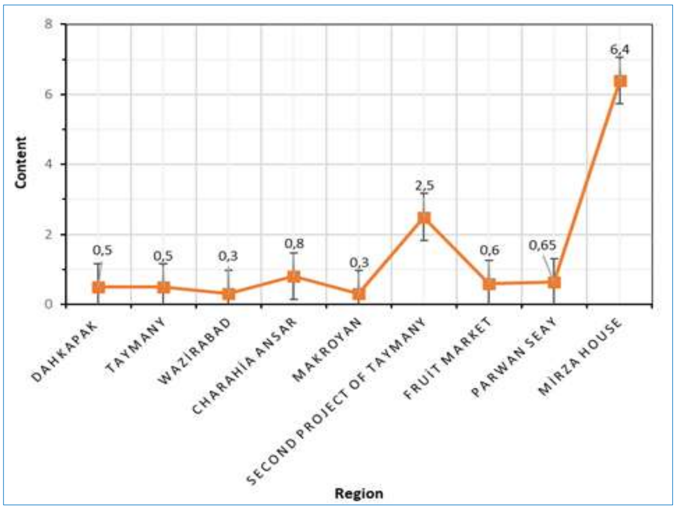

Fig. 25. The amount of fluoride in the fourth sector of Kabul Region groundwater

Table 25. Shows the fluoride in the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Fluoride (mg/Li)
1	015118	Dahkapak	Faiz Mohammad Hous	0.5
2	015125	Taymany	Khana Sherakat	0.5
3	015126	Wazirabad	Zamarak House	0.3
4	016209	Charahia Ansar	Waheed Hamidi House	0.8
5	016228	Makroyan	Water Supply	0.3
6	017256	The Second Project of Taymany	Haji Mirza M. House	2.5
7	017257	Fruit Market	Abdul Zaher House	0.6
8	019294	Parwan Seay	Karim House	0.65
9	019295	Mirza House	Sheer Ali House	6.4
Mean				0.3
The Afghanistan Criteria				0.3
The Asian Criteria				0.3

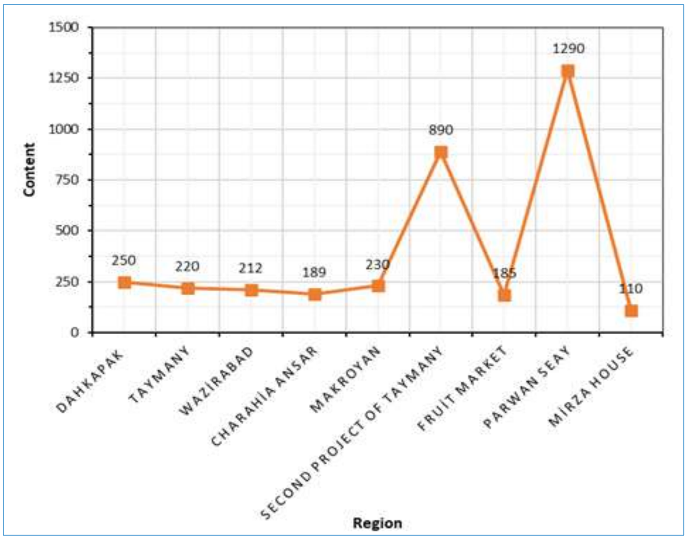

Fig. 26. The amount of SO_4 in the fourth sector of Kabul Region groundwater

3.5.7.5. Fluorides (F)

Fluorides are naturally and artificially added to the groundwater, it's measured by mg/L, and they are useful for teeth protection and health. If the amount of F exceeds in drinking water, it causes tooth cavities for children and bone problems in humans. According to WHO standards, the amount of F is between 0.6–1.7 mg/L (WHO, 2009). The collected samples' results are shown in (Fig. 25 and Table 25).

Table 26. Shows the SO_4 in the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	SO_4 (mg/Li)
1	015118	Dahkapak	Faiz Mohammad House	250
2	015125	Taymany	Khana Sherakat	220
3	015126	Wazirabad	Zamarak House	212
4	016209	Charahia Ansar	Waheed Hamidi House	189
5	016228	Makroyan	Water Supply	230
6	017256	The Second Project of Taymany	Haji Mirza M. House	890
7	017257	Fruit Market	Abdul Zaher House	185
8	019294	Parwan Seay	Karim House	1290
9	019295	Mirza House	Sheer Ali House	110
Mean				397.33
The Afghanistan Criteria				
The Asian Criteria				

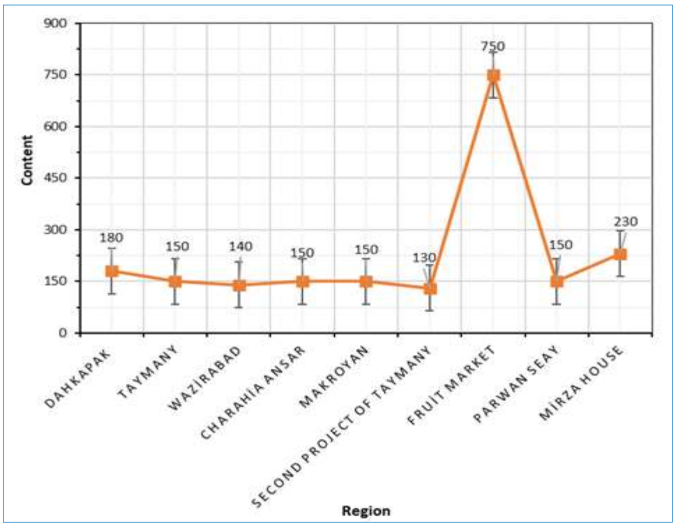

Fig. 27. The amount of HCO_3 in the fourth sector of Kabul Region groundwater

Table 27. Shows the HCO_3 in different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	HCO_3 (mg/Li)
1	015118	Dahkapak	Faiz Mohammad House	180
2	015125	Taymany	Khana Sherakat	150
3	015126	Wazirabad	Zamarak House	140
4	016209	Charahia Ansar	Waheed Hamidi House	150
5	016228	Makroyan	Water Supply	150
6	017256	The Second Project of Taymany	Haji MirZa M. House	130
7	017257	Fruit Market	Abdul Zaher House	750
8	019294	Parwan Seay	Karim House	150
9	019295	Mirza House	Sheer Ali House	230
Mean				297.7
The Afghanistan Criteria				
The Asian Criteria				

3.5.7.6. Sulfides (SO4)

The concentration of Sulfides in groundwater is 1–1000 mg/L (WHO, 2011), and it fluctuates somewhat. The main source of sulfides is gypsum and other mining in sediments.

In seawater the Sulfides achievement from the oxidation of Sulfides, Sulfites, and Neosulfites, and industrial factors usage. The Hydrogen sulfides spread from the chimney of factors and by acidic rains come down to the earth's surface and make sulfides. In this research, we found sulfides and their comparison with the WHO standard which is shown in (Fig. 26 and Table 26).

3.5.7.7. Bicarbonates (HCO_3)

Generally, the carbonates belong to those mother rocks that have lime and some elements such as Na, Ca, and Mg as well the carbonates that come from some indusial activities such as robber, coal, stoves, cooking places, and others, but in this research the amount of bicarbonates are normal, only in fruit market the amount is higher there will be the main reason of some activities (Fig.27 and Table 27).

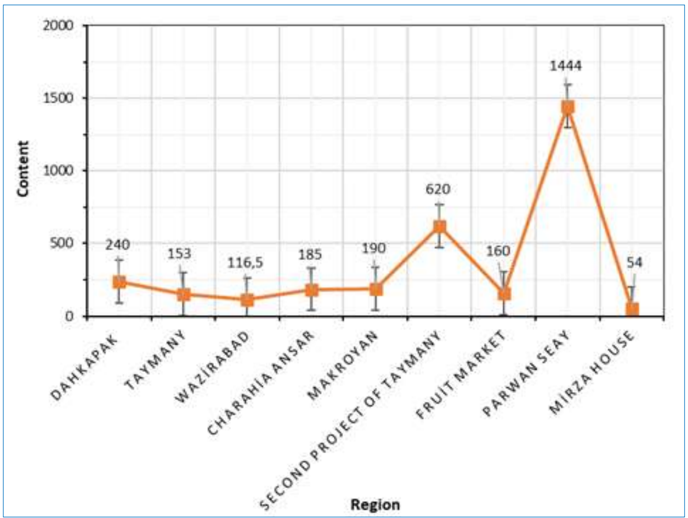

Fig. 28. The amount of Cl in the fourth sector of Kabul Region groundwater

Table 28. Shows the Cl in the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	Cl (mg/Li)
1	015118	Dahkapak	Faiz Mohammad House	240
2	015125	Taymany	Khana Sherakat	153
3	015126	Wazirabad	Zamarak House	116.5
4	016209	Charahia Ansar	Waheed Hamidi House	185
5	016228	Makroyan	Water Supply	190
6	017256	The Second Project of Taymany	Haji MirZa M. House	620
7	017257	Fruit Market	Abdul Zaher House	160
8	019294	Parwan Seay	Karim House	1444
9	019295	Mirza House	Sheer Ali House	54
Mean				348.3
The Afghanistan Criteria				250
The Asian Criteria				250

3.5.7.8. Chlorine (Cl_2)

The addition of chlorine is used to mitigate bacteria that live in water, and it always cleans water of different microbial and bacteria. After coloration changes the groundwater taste, it must not contain more than the normal state which causes different problems, if the quantity of Cl_2 exceeds standard conditions, it will harm the human body and living animals in the water. In the groundwater, the amount of Chlorine must not exceed 0.2 mg/L (WHO, 2009). Therefore, this study tries to compare groundwater samples with the ANSA standard, as shown in (Fig 28 and Table 28).

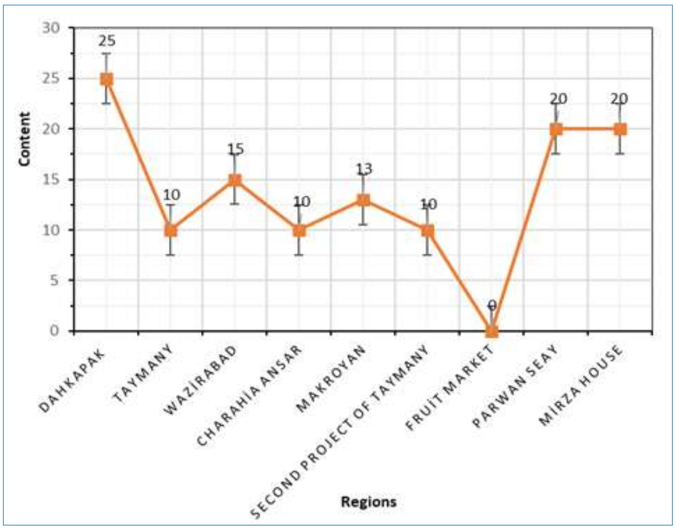

Fig. 29. The amount of NO_3 in the fourth sector of Kabul Region groundwater

Table 29. Shows the NO_3 at the different villages of the fourth sector of Kabul

No	Code of well	Village	Local name	NO_3 (mg/Li)
1	015118	Dahkapak	Faiz Mohammad House	25
2	015125	Taymany	Khana Sherakat	10
3	015126	Wazirabad	Zamarak House	15
4	016209	Charahia Ansar	Waheed Hamidi House	10
5	016228	Makroyan	Water Supply	13
6	017256	The Second Project of Taymany	Haji MirZa M. House	10
7	017257	Fruit Market	Abdul Zaher House	0
8	019294	Parwan Seay	Karim House	20
9	019295	Mirza House	Sheer Ali House	20
Mean				13
The Afghanistan Criteria				50
The Asian Criteria				50

3.5.7.9. Nitrites (NO_3^-)

It can be measured according to N amount (mg/L), the existence of Nitrites (NO_3^-), and NH_3 belonging to the non-standard bathrooms that are infiltrated into the groundwater. The existence of iron causes the reduction of Nitrites and as a result of the decomposition of organic material NH_3 and Nitrites (NO_3^-) produce, it belongs to nitrification which is done in the existence of oxygen. In this study, we compare the groundwater sample of NO_3^- with the ANSA standard, which is shown in (Fig 29 and Table 29).

4. Conclusion and Discussion

Groundwater quality was assessed in the Paghman district and the fourth sector of Kabul, Afghanistan, using 21 water samples collected from various villages. The physical and chemical parameters analyzed included electrical conductivity (EC), pH, total hardness (TH), calcium (Ca), sodium (Na), potassium (K), iron (Fe), sulfate (SO_4), chloride (Cl_2), ammonia (NH_3), temperature, magnesium (Mg), fluoride (F), bicarbonate (HCO_3), and nitrate (NO_3).

The measured values were compared with World Health Organization (WHO) standards, which set limits for key parameters, including EC (1500 µS/cm), pH (6.5–8.5), turbidity (<5 NTU), chloride (250 mg/L), hardness (500 mg/L), nitrate (11 mg/L), fluoride (1.5 mg/L), iron (0.3 mg/L), ammonia (<2 mg/L), sulfate (500 mg/L), and chlorine (0.5 mg/L). The analysis indicates that the groundwater samples generally comply with both national and international water quality standards, with only minor variations among the measured parameters. These findings suggest that groundwater in the Paghman district and the fourth sector of Kabul is suitable for use and could potentially serve as a viable water source for other districts in Kabul province and beyond.

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Author Contributions

Hafizullah Rasouli (H.R.), Abdul Rahman Osmani (A.R.O.), Kaltoum Belhassan (K.B.), Ashok Vaseashta (A.V.), Conceptualization: H.R., A.V., A.R.O, Methodology: H.R.; Software: H.R., A.V.; Validation, H.R., A.V., K.B., A.R.O., Formal analysis, H.R., A.V., K.B., A.R.O., Investigation, H.R.; Resources, H.R, A.V.; Data curation, H.R., A.V.; Writing-original and draft preparation, H.R., A.V., A.R.O., Visualization, H.R., A.V., A.R.O.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Data Availability Statement

Data is contained within the article.

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