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Assessment of Groundwater Quality Using Selected Physicochemical Parameters in the Chehelsoton Area, Kabul

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ABSTRACT

Despite the importance of groundwater as a source of drinking and domestic water, limited information is available on groundwater quality in the Chehelsoton area. The lack of localized data on key physicochemical parameters limits assessment of potential health risks and sustainable groundwater use. Therefore, systematic evaluation of groundwater quality is needed. This study aimed to evaluate groundwater quality in the Chehelsoton area by analyzing selected physicochemical parameters and comparing the results with international drinking water standards. We collected five groundwater samples from the study area and analyzed six key chemical parameters for water quality assessment. Standard laboratory methods were used to determine the concentration and characteristics of the selected parameters. The results showed that the average values of the analyzed parameters in all three samples were within the permissible limits recommended by international standards for drinking water quality. The findings indicate that the groundwater of the Chehelsoton area is generally suitable for drinking and other domestic uses. The study also demonstrated that dissolved substances and chemical constituents in the groundwater did not exceed the acceptable limits that could negatively affect human health or industrial applications. Groundwater quality largely depends on the concentration of dissolved substances and chemical elements present in water. Therefore, monitoring these parameters is essential to protect public health and ensure sustainable water use. Overall, the analyzed groundwater samples showed no significant contamination, and no serious health risks associated with the studied parameters were identified.

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INTRODUCTION

Water is one of the most essential natural resources for human survival, environmental sustainability, agricultural productivity, and industrial development. Throughout history, the emergence and development of human civilizations have been closely linked to access to

reliable water resources. Rivers, lakes, springs, and groundwater systems have supported transportation, food production, economic activities, and urban expansion. In modern societies, access to safe and clean drinking water remains a fundamental requirement for public health and sustainable development. However, rapid population growth, urbanization, industrialization, and climate variability have increasingly threatened both the quantity and quality of water resources worldwide (Dupont, 2014).

Groundwater is considered one of the most important sources of freshwater, particularly in arid and semi-arid regions where surface water resources are limited or seasonally unavailable. Compared with surface water, groundwater is generally less vulnerable to microbial contamination; nevertheless, it may contain dissolved chemical substances that affect its suitability for drinking, domestic, agricultural, and industrial uses (Al Bomola, 2011). Groundwater quality largely depends on the concentration of dissolved minerals, heavy metals, and other physicochemical constituents. Elevated concentrations of certain compounds such as iron, sulfate, nitrate, and hardness-producing minerals may reduce water quality and create adverse health, aesthetic, and industrial effects (Brauch, 2005).

In many developing countries, including Afghanistan, groundwater has become the primary source of drinking water due to inadequate municipal water supply systems and the increasing scarcity of clean surface water. Kabul city, in particular, has experienced rapid urban growth over the past two decades, resulting in excessive groundwater extraction and increasing pressure on existing aquifers (Younger, 2009). Previous studies in Kabul have reported declining groundwater levels, uncontrolled well drilling, insufficient wastewater management, and rising risks of groundwater contamination linked to urban expansion, septic systems, solid waste disposal, and industrial activities. These environmental challenges have raised serious concerns regarding the sustainability and safety of groundwater resources in different parts of the city (Habib, 2014).

Several studies on groundwater quality in urban environments have emphasized the importance of monitoring physicochemical parameters to assess water suitability for drinking and identify potential environmental and health risks. Parameters such as pH, sulfate, iron concentration, total dissolved solids, hardness, and electrical conductivity are commonly used as groundwater quality indicators. Elevated levels of these parameters may contribute to unpleasant taste, odor, discoloration, pipe corrosion, staining, and, in some cases, adverse health impacts. Although groundwater quality assessment has received growing global scientific attention, few studies have examined the physicochemical characteristics of groundwater in specific residential areas of Kabul, particularly in the Chehelsoton area. Most previous studies have focused on either broader regional assessments or surface water contamination, while localized groundwater investigations remain insufficient (García-Tejero, 2011).

The Chehelsoton area of Kabul relies heavily on groundwater extracted through private and public wells for domestic consumption. Despite residents' dependence on these water sources, limited scientific information is available on the chemical quality of groundwater in

this area. In addition, increasing population density, unplanned urbanization, inadequate sewage systems, and uncontrolled waste disposal may negatively influence groundwater quality over time. Therefore, evaluating the physicochemical characteristics of groundwater in the Chehelsoton area is important not only to determine its current suitability for drinking and domestic use but also to support future groundwater management and environmental protection strategies (Shelton, 1994).

This study aims to assess selected physicochemical parameters of groundwater collected from wells in the Chehelsoton area of Kabul and compare the results with international drinking water standards. Specifically, the study investigates the concentrations and conditions of selected chemical indicators, including sulfate and iron compounds, through laboratory analysis of groundwater samples collected from different locations within the study area. The study further seeks to determine whether the analyzed groundwater meets acceptable standards for human consumption and domestic use.

The research is based on the following hypotheses:

1. Sulfate concentrations in groundwater in the study area may vary from low to elevated levels depending on local environmental conditions.
2. Given the relatively clear appearance of the groundwater samples, the iron concentration is expected to remain within the permissible range of international drinking water standards (Younger, 2009).

To address these objectives, groundwater samples were collected from selected wells in the Chehelsoton area and analyzed using standard laboratory titration procedures and physicochemical testing methods. The results were compared with internationally recognized drinking water standards to evaluate the suitability of groundwater for drinking and other domestic purposes.

This study contributes to the limited scientific literature on groundwater quality in Kabul city. The findings may provide useful information for environmental authorities, public health institutions, urban planners, and water resource managers regarding the current condition of groundwater in the study area. Furthermore, the research may support future groundwater monitoring programs and help raise public awareness of the importance of protecting groundwater resources from contamination and unsustainable exploitation.

METHODS AND MATERIALS

Study Area

The present study was conducted in the Chehelsoton area, located approximately 8.5 km south of Kabul city, Afghanistan. Geographically, the area lies between the Kabul River and the surrounding mountain ranges at 69°09′42″ E longitude and 34°27′50″ N latitude. Administratively, Chehelsoton belongs to District 7 of Kabul city. The area is bordered by Sarpol Qala-e-Ghaibi in the north, Qala-e-Fotuh in the south, Chehelsoton Mountain in the east, and the Kabul River in the west. According to regional demographic information, the

area has an estimated population of 374,685 inhabitants, with Dari and Pashto being the dominant spoken languages.

Groundwater extracted from wells is a primary source of domestic water supply in the study area. Rapid urbanization, increasing population density, and inadequate wastewater management systems have increased concerns about groundwater quality and sustainability in recent years.



***Figure 1**: Spatial map of Chehelsoton, source: Google Earth site* (https://earth.google.com/web).

Research Design

This study employed an experimental and analytical research design to evaluate selected physicochemical parameters of groundwater in the Chehelsoton area. The investigation consisted of both field sampling and laboratory analysis. The study aimed to determine the suitability of groundwater for drinking and domestic purposes by comparing it with guideline values established by the World Health Organization (WHO) and Afghanistan National Standards.

Sampling Strategy and Sample Collection

Groundwater samples were collected from wells located at two selected sites within the study area:

1. Ansarullah Mosque well
2. Rishkhor Qayoom Qudrat Mosque well

The sampling locations were selected based on groundwater accessibility, population dependence on well water, and geographical representation of the study area. We collected five groundwater samples from different points within these locations to ensure a representative analysis of groundwater quality conditions.

Before sampling, all polyethylene sampling bottles were thoroughly cleaned and rinsed three times with distilled water, then rinsed with groundwater from the respective sampling point to minimize contamination. Samples were collected directly from operational wells and stored under appropriate laboratory conditions until analysis.

For each sample, the following information was recorded:

- Sample identification number
- Sampling location
- Date and time of collection
- Physical observations of water quality
- Geographic and environmental characteristics of the site

We conducted preliminary site selection and sampling point identification using aerial imagery and satellite observations from Google Earth. Additional field surveys were subsequently performed to verify site accessibility and hydrogeological conditions.

Laboratory Analysis

The collected groundwater samples were analyzed at the Hydrology Directorate Laboratory of the Ministry of Energy and Water, Kabul, Afghanistan. Selected physicochemical parameters were determined using standard analytical procedures commonly applied in water quality assessment studies.

The analytical methods employed in this study included:

- Argentometric method (silver nitrate method)
- Complexometric titration method
- Volumetric analysis
- Gravimetric analysis
- Conductometric method
- Potentiometric method
- Flame photometer method
- Water hardness determination method
- Automatic instrumental methods
- Photo-complex analytical method

These methods were used to determine selected groundwater quality indicators, including sulfate concentration, iron content, hardness, and other chemical constituents relevant to drinking water assessment.

All analyses followed internationally recognized laboratory procedures recommended by the World Health Organization and standard water quality assessment protocols, including relevant APHA (American Public Health Association) analytical guidelines where applicable.

Quality Assurance and Quality Control

To ensure accurate and reliable analytical results, we implemented several quality control procedures during sampling and laboratory analysis. We sterilized and properly labeled sampling bottles before use. We calibrated laboratory instruments before analysis according to standard operating procedures. We conducted replicate measurements for selected parameters to minimize analytical errors and improve data reliability.

All measurements were recorded using the International System of Units (SI). The obtained experimental values were compared with WHO drinking water guideline values and

Afghanistan national water quality standards to evaluate groundwater suitability for drinking and domestic use.

Research Procedure

The research followed a systematic, sequential approach. First, the study collected and reviewed existing hydrogeological and environmental information for the study area. Researchers then identified sampling locations using satellite imagery and topographic observations, followed by field surveys and groundwater sample collection. The collected samples were analyzed in the laboratory using standard physicochemical methods. The analytical results were then compared with relevant national and international drinking-water standards, and groundwater quality was interpreted to assess suitability for domestic consumption.

FINDINGS

Table 1 presents the general characteristics and geographical information of the groundwater wells selected for this study in the Chehelsoton area of Kabul city. The table includes each well's local name, identification code, geographic coordinates (X and Y), and elevation (Z) above sea level. We selected two groundwater wells for sampling and analysis: the Ansarullah Mosque well and the Rishkhor Mosque (Qeyum Ghodrat) well.

The Ansarullah Mosque well is located at coordinates X = 514030 and Y = 3815144 with an elevation of 1812.41 m above sea level. In comparison, the Rishkhor Mosque well is located at X = 512147 and Y = 3810644 with an elevation of 1860 m above sea level. Differences in elevation and location between the two wells may influence groundwater characteristics and the concentrations of dissolved chemical constituents due to differences in hydrogeological conditions and local environmental factors.

The spatial distribution of the selected wells provides representative coverage of the study area and supports the evaluation of groundwater quality conditions in different parts of Chehelsoton.

Table 1. *Well characteristics and water properties*

Number	Local Well Name	Well Code	X	Y	Z
1	Ansarullah Mosque	11	514030	3815144	1812.41
2	Rishkhor Mosque, Qeyyum Ghodrat	77	512147	3810644	1860

Table 2 shows the sampling dates and corresponding laboratory analysis dates for the groundwater samples collected during the study period. Groundwater samples were collected over five consecutive days, from 1405/1/4 to 1405/1/8, and laboratory analyses were conducted one day after each sampling event.

The short interval between sampling and laboratory analysis was intended to minimize physical and chemical changes in the water samples before testing. Timely analysis is

important in groundwater quality assessment because prolonged storage may affect the concentration and stability of certain physicochemical parameters.

The sampling schedule also ensured consistency in data collection and allowed the researchers to monitor groundwater quality under similar environmental conditions during the study period.

Table 2. *Sampling Date and Its Analysis*

Number	Sampling Date	Analysis Date
1	1405/1/4	1405/1/5
2	1405/1/5	1405/1/6
3	1405/1/6	1405/1/7
4	1405/1/7	1405/1/8
5	1405/1/8	1405/1/9

Experimental Parameters

In this study, we analyzed several physicochemical parameters in the laboratory to evaluate groundwater quality in the study area. The analyzed parameters included physical and chemical indicators, and the results were compared with Afghanistan national standards and World Health Organization (WHO) guidelines for drinking water quality. The investigated parameters were as follows:

1. Fluoride
2. Sulfate
3. Nitrite
4. Iron
5. pH
6. Electrical Conductivity (EC)

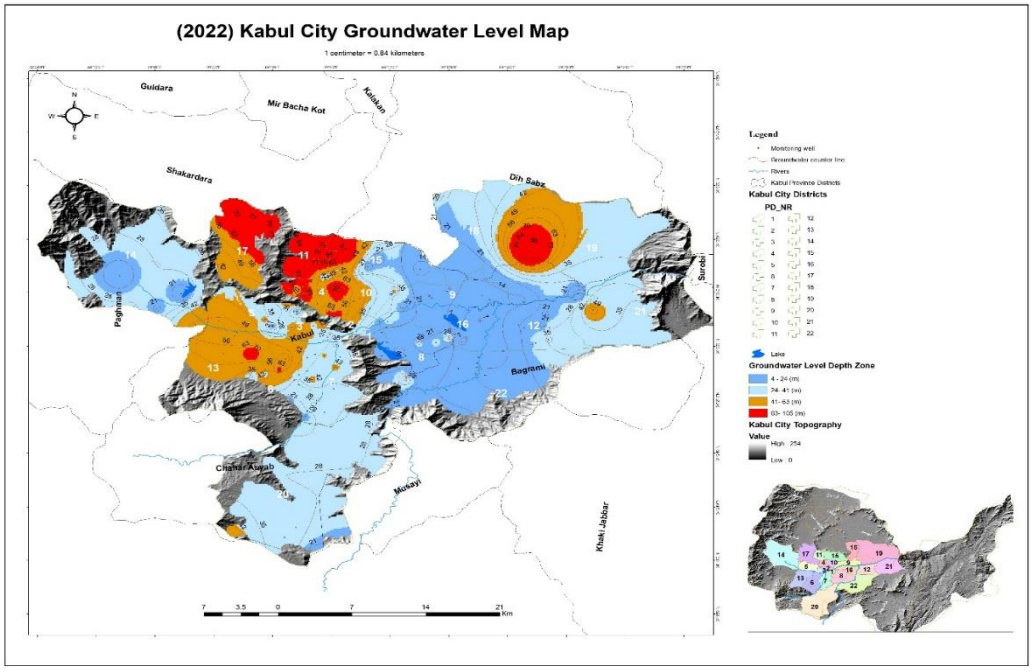


Figure 2. *Kabul City Groundwater Level Map (MEW, 2022)*

The 2022 Kabul City Groundwater Level Map (Figure 2) illustrates the spatial distribution of groundwater depth across Kabul City and its surrounding districts, based on monitoring-well observations and groundwater contour lines. The groundwater depth is classified into four zones: 4–24 m (light blue), 24–41 m (blue), 41–63 m (orange), and 63–105 m (red) below the ground surface. The map indicates that shallow groundwater (4–24 m) predominates across central and eastern Kabul, particularly around Bagrami, while moderate depths (24–41 m) occur in transitional areas. In contrast, deep groundwater levels (41–63 m and 63–105 m) are concentrated mainly in the western, northwestern, and northern parts of the city, including areas around Paghman, Shakardara, and Dih Sabz. The contour lines further demonstrate spatial variations in groundwater depth and help identify local groundwater gradients, while the topographic shading highlights the influence of surrounding mountainous terrain. Overall, the map reveals considerable spatial heterogeneity in groundwater depth across Kabul City, with deeper groundwater generally associated with elevated and peripheral areas and relatively shallow groundwater occurring in the central basin and lower-lying zones.

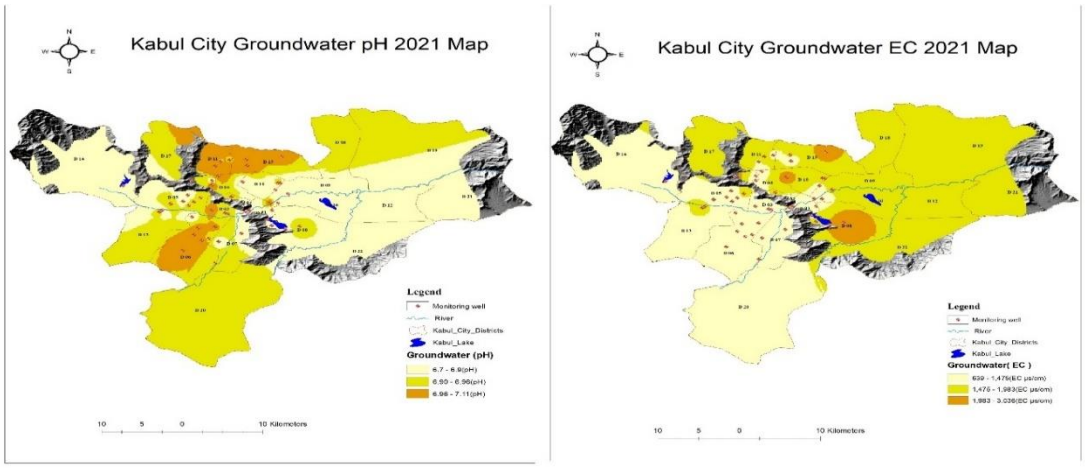


Figure 3. *PH and EC map of Kabul City Groundwater (MEW, 2021)*

Figure 3 shows the spatial distribution of groundwater pH and electrical conductivity (EC) in Kabul City in 2021, based on monitoring-well measurements. The pH map shows that groundwater is predominantly near-neutral to slightly alkaline, ranging from 6.70 to 7.11, with most areas falling within the 6.90–6.96 class, while relatively higher pH values (6.96–7.11) are concentrated mainly in localized areas of the central and northern districts. The EC map indicates greater spatial variability in groundwater salinity, with EC values ranging from 639 to 3,036 µS/cm; relatively low EC (639–1,475 µS/cm) occurs across substantial parts of the southern and western areas, whereas moderate values (1,475–1,983 µS/cm) are more widely distributed and higher EC values (1,983–3,036 µS/cm) are concentrated particularly around the central and northeastern parts of the city. Overall, the maps indicate that Kabul's groundwater is generally neutral to slightly alkaline. At the same time, elevated EC in localized areas suggests greater dissolved-ion concentrations and potential deterioration of groundwater quality, warranting further investigation of natural hydrogeochemical processes and anthropogenic influences.

A. Determination of Selected Chemical Parameters of the Ansarullah Mosque Well

Table 3 presents results for selected chemical parameters analyzed from groundwater samples collected from the Ansarullah Mosque well. The values were obtained through laboratory experiments and physicochemical analysis conducted during the research study.

Table 3. *Determination of Some Chemical Indicators of Groundwater from the Ansarullah Mosque Well*

pH	Iron (mg/L)	Nitrite (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Region well name
6.65	0.02	0.005	0	0.43	Ansarullah Mosque

The table presents results for selected physicochemical parameters analyzed from groundwater samples collected from the Ansarullah Mosque well. The measured parameters include pH, iron concentration, nitrite concentration, Sulfate concentration, and fluoride concentration. These parameters were evaluated to determine the groundwater's suitability for drinking and domestic use.

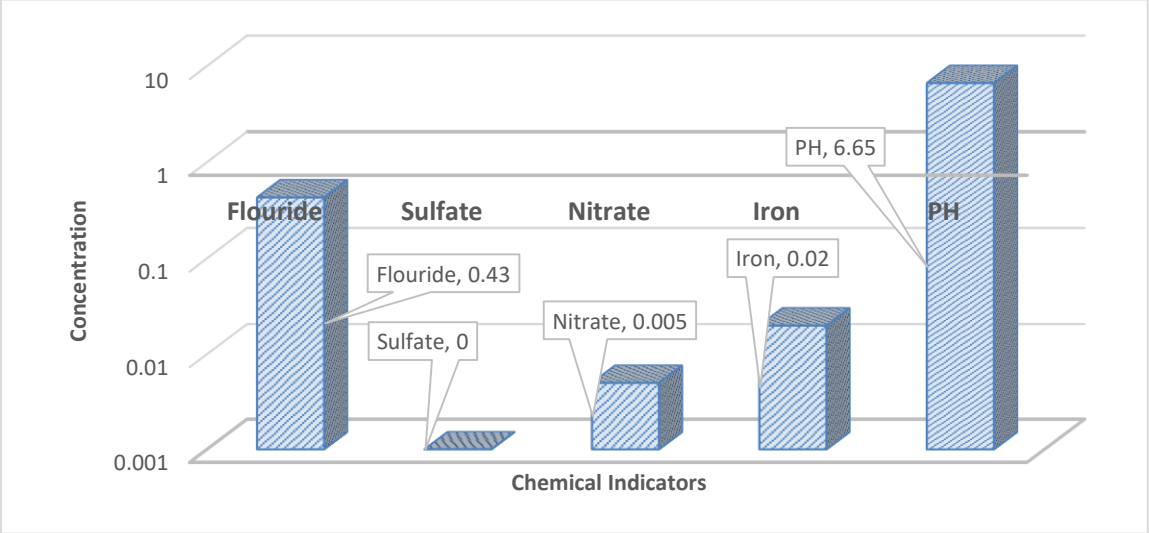


Figure 4. *Graph of Selected Chemical Indicators of Groundwater from the Ansarullah Mosque Well*

The pH of the water sample was 6.65, indicating slightly acidic groundwater that remains within the acceptable range recommended by the World Health Organization (WHO) for drinking water quality. The iron concentration was measured at 0.02 mg/L, which is well below the permissible limit and indicates no excessive iron contamination that could affect taste, color, or cause staining.

The nitrite concentration was 0.005 mg/L, which is within safe drinking water standards and suggests the groundwater is not significantly affected by nitrogen-related pollution. Sulfate concentration was recorded as 0 mg/L, indicating the absence of detectable Sulfate compounds in the analyzed sample. In addition, the fluoride concentration was measured at 0.43 mg/L, which falls within the acceptable range for drinking water and does not pose health risks associated with excessive fluoride intake.

Overall, the analyzed parameters indicate that the groundwater from the Ansarullah Mosque well is generally suitable for drinking and domestic purposes according to international water quality standards.

B. Determination of Some Chemical Parameters of Groundwater from the Rishkhor Well (Qayyum Qudrat Mosque)

Table 4 presents selected chemical parameters of groundwater collected from the Rishkhor well at Qayyum Qudrat Mosque. The values were obtained through laboratory experiments and physicochemical analysis conducted during the study.

Table 4. *Determination of Selected Chemical Indicator Values of Groundwater from the Rishkhor Well (Qayyum Qudrat Mosque)*

pH	Iron (mg/L)	Nitrite (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Region well name
7.3	0.01	0.008	1	0.39	Qayyum Qudrat Mosque

The table presents results for selected physicochemical parameters analyzed from groundwater samples collected from the Qayyum Qudrat Mosque well in the Rishkhor area. The analyzed parameters include pH, iron concentration, nitrite concentration, Sulfate concentration, and fluoride concentration. These parameters were evaluated to determine the groundwater's suitability for drinking and domestic use.

The pH value of the groundwater sample was measured at 7.3, indicating that the water is neutral to slightly alkaline and falls within the acceptable range recommended by the World Health Organization (WHO) for drinking water quality. The iron concentration was 0.01 mg/L, well below the permissible limit, suggesting the groundwater does not contain excessive iron that could affect taste, color, or cause staining.

The nitrite concentration was 0.008 mg/L, within the safe range for drinking water and indicating low nitrogen-related contamination. The Sulfate concentration was recorded as 1 mg/L, which also remains within acceptable international standards and does not pose significant health concerns. In addition, the fluoride concentration was 0.39 mg/L, which is considered safe for drinking water and below the maximum allowable concentration recommended by international guidelines.

Overall, the analyzed groundwater sample from the Qayyum Qudrat Mosque well shows acceptable physicochemical quality and is generally suitable for drinking and domestic use according to WHO and national drinking water standards.

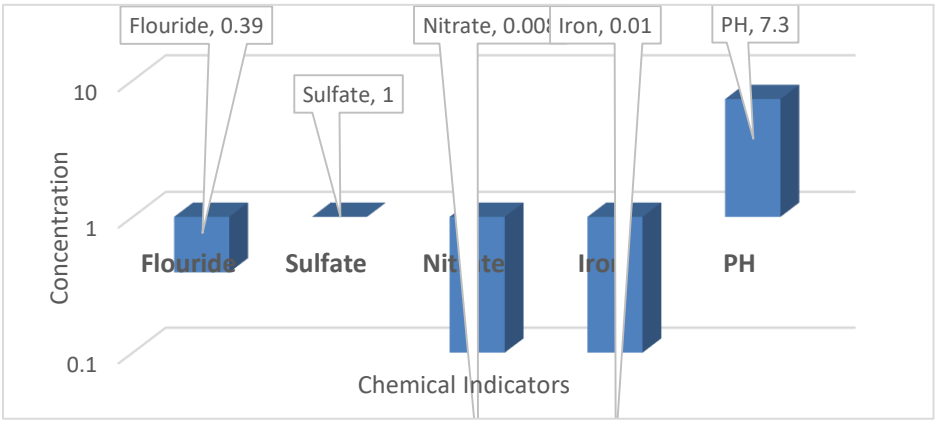


Figure 5. *Graph of Selected Chemical Indicator Values of Groundwater from the*

Figure 3 indicates that the average fluoride concentration in the groundwater of the Rishkhor area near Qayyum Qudrat Mosque in Kabul is 0.39 mg/L. Sulfate concentration was measured at 1 mg/L, while the nitrite concentration in the analyzed sample was 0.008 mg/L. The average iron concentration in the investigated groundwater was 0.01 ppm. In addition, the average pH of the groundwater sample was 7.3, which falls within the acceptable international standard range of 6.5–8.5 for drinking water quality.

The table shows that the pH of the investigated groundwater falls within the internationally accepted standard range. Low pH values below 6.5 are common in areas where runoff from mineral-rich regions enters water sources, creating acidic conditions that can significantly lower pH. Extremely high or low pH levels can noticeably affect water quality. High pH values may give water a soapy taste, while low pH values may give it a sour taste. Elevated pH effects are often more noticeable in infants and people with sensitive skin.

Water pH can affect human health both directly and indirectly. Direct effects may include irritation or damage to mucous membranes, particularly when the pH level is excessively high. Indirect effects mainly involve corrosion or damage to water supply systems, pipes, and household appliances, which commonly occur when water has a low pH value.

C. Electrical Conductivity of Groundwater in the Chehelsoton Area of Kabul City Based on the Conductometric Method

Table 5 presents the electrical conductivity (EC) values of groundwater samples collected from two wells located in the Chehelsoton area of Kabul city. The measurements were determined using the conductometric method, which is commonly used to evaluate water's ability to conduct electrical current based on the concentration of dissolved ions and salts.

Table 5. *Analysis of electrical conductivity of the Chehelsoton area of Kabul city*

Number	Local Well Name	EC (µS/cm)
1	Ansar Allah Mosque	725
2	Rishkhor, Qayyum Qudrat Mosque	1018

The groundwater sample collected from the Ansar Allah Mosque well showed an EC value of 725 µS/cm. In comparison, the groundwater sample from the Rishkhor well at Qayyum Qudrat Mosque recorded a higher EC value of 1018 µS/cm. The difference in EC values between the two wells may reflect variations in dissolved mineral content, geological conditions, and local environmental factors affecting groundwater quality in the study area.

Electrical conductivity is an important indicator of water quality because it reflects the concentration of dissolved substances such as salts and minerals. Higher EC values generally indicate higher concentrations of dissolved ions in groundwater. Based on international drinking water standards, the measured EC values in both groundwater samples remain within acceptable limits for drinking and domestic use. However, the higher EC value in the Rishkhor well suggests a greater concentration of dissolved solids in that groundwater source.

DISCUSSION

Based on the experimental research conducted, the required results regarding the physicochemical parameters of groundwater in the two study areas of Kabul city were obtained and are presented in Tables 3, 4, and 5. These results are discussed and interpreted comparatively as follows. Table 6 presents the average values of selected chemical parameters obtained from Tables 3, 4, and 5.

Table 6. *Comparison of Determination of Selected Chemical Parameter Values of Groundwater in the Chehelsoton Area of Kabul City*

pH	Iron (mg/L)	Nitrite (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	EC (µS/cm)	Region well name
6.65	0.02	0.005	0	0.43	725	Ansarullah Mosque
7.3	0.01	0.008	1	0,39	1018	Qayyum Qudrat Mosque
6.975	0.015	0.013	0.25	1.5	1900	WHO

The table presents the measured values of selected physicochemical parameters of groundwater collected from two wells in the Chehelsoton area of Kabul city: the Ansarullah Mosque well and the Qayyum Qudrat Mosque well. The analyzed parameters include pH, iron concentration, nitrite concentration, Sulfate concentration, fluoride concentration, and electrical conductivity (EC). The table also includes World Health Organization (WHO) guideline values for comparison.

The groundwater sample from the Ansarullah Mosque well showed a pH value of 6.65, while the Qayyum Qudrat Mosque well recorded a pH value of 7.3. Both values fall within the WHO-recommended range of 6.5–8.5, indicating that the groundwater is suitable in terms of acidity and alkalinity.

Iron concentrations were 0.02 mg/L in the Ansarullah Mosque well and 0.01 mg/L in the Qayyum Qudrat Mosque well. These concentrations are well below the permissible limits for

drinking water and therefore do not pose aesthetic or health concerns such as staining, discoloration, or unpleasant taste.

Nitrite concentrations were 0.005 mg/L and 0.008 mg/L in the two wells, respectively. These values are very low and indicate that the groundwater is not significantly affected by nitrogen-related contamination sources such as wastewater infiltration or agricultural pollutants.

Sulfate concentrations were 0 mg/L in the Ansarullah Mosque well and 1 mg/L in the Qayyum Qudrat Mosque well. Both values remain within acceptable international standards and do not indicate harmful contamination.

Fluoride concentrations were measured at 0.43 mg/L and 0.39 mg/L, respectively. These concentrations are within safe limits for drinking water and are below the maximum permissible values recommended by WHO. Appropriate fluoride levels benefit dental health, while excessive fluoride may cause adverse health effects; however, the measured values do not indicate such risks.

The electrical conductivity values were recorded as 725 µS/cm for the Ansarullah Mosque well and 1018 µS/cm for the Qayyum Qudrat Mosque well. These values indicate moderate concentrations of dissolved salts and minerals in the groundwater. The comparatively higher EC value in the Qayyum Qudrat Mosque well suggests a greater concentration of dissolved ionic substances than in the Ansarullah Mosque well.

Overall, the results indicate that the groundwater quality in the investigated wells of the Chehelsoton area generally complies with WHO drinking water standards and is suitable for drinking and domestic purposes.

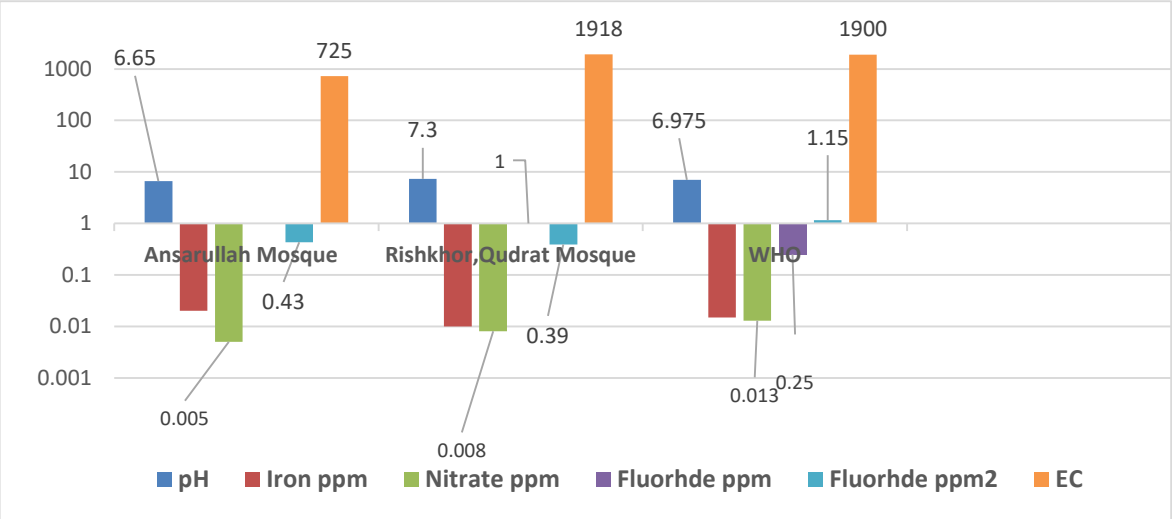


Figure 6. *Comparative Graph of Selected Chemical Parameter Values of Groundwater in the Chehelsoton Area, Kabul City*

The values in the figure show that fluoride concentration in groundwater in the Chehelsoton area of Kabul city is 0.39 mg/L in the Qayyum Qudrat Mosque well and 0.43 mg/L in the Ansarullah Mosque well. According to the World Health Organization (WHO), the permissible limit of fluoride in drinking water is 1.5 mg/L or approximately 0.6–1.7 mg/L. Based on these

standards, the fluoride concentrations in the investigated groundwater samples do not exceed the recommended limit and are considered safe for drinking purposes.

Fluoride at moderate concentrations benefits dental health, particularly by preventing tooth decay in children. However, excessive fluoride intake may cause fluorosis, a condition resulting from fluoride accumulation in the body that can lead to dental discoloration, bone pain, and skeletal complications. The fluoride concentrations measured in the investigated groundwater samples are within acceptable limits and therefore do not pose a fluorosis-related health risk(Abbas, 2013).

The next parameter investigated in this study is Sulfate. The Sulfate concentration in groundwater from the Ansarullah Mosque well was 0.00 mg/L, while the groundwater from the Rishkhor (Qayyum Qudrat Mosque) well was 1 mg/L. According to World Health Organization (WHO) standards, the permissible concentration of Sulfate in drinking water is 5000 mg/L (Al Bomola, 2011). Sulfates commonly enter groundwater through the dissolution of gypsum and other mineral rocks containing Sulfate compounds. In natural waters, Sulfate concentrations generally range from 1 to 1000 mg/L (Habib, 2014).

Sulfates in water may contribute to permanent hardness and can negatively affect the taste and odor of drinking water. Under certain conditions, Sulfates may produce hydrogen sulfide gas, which gives water an unpleasant odor similar to rotten eggs. Although moderate concentrations of Sulfates are not considered highly dangerous to human health, excessive amounts—particularly magnesium Sulfate—may cause gastrointestinal problems such as diarrhea (Brauch, 2005). The Sulfate concentrations measured in the investigated groundwater samples are considerably below the permissible limits and therefore do not present significant health concerns.

Another important parameter analyzed in this study is nitrite. The nitrite concentration in the Ansarullah Mosque well groundwater was 0.005 mg/L, while the Rishkhor (Qayyum Qudrat Mosque) well recorded 0.008 mg/L. Major sources of nitrite contamination include plant and animal residues, agricultural fertilizers, domestic wastewater, and sewage infiltration.

In groundwater systems, nitrite concentrations may range from 1 to 1000 mg/L depending on environmental and anthropogenic conditions. Nitrite concentrations above 100 mg/L may give water a bitter taste and can lead to physiological and health-related complications. Water containing more than 25 mg/L nitrite is generally considered unsafe for drinking purposes. According to WHO standards, the permissible limit of nitrite in drinking water is 10 mg/L (10 ppm) (Verla, 2020). Elevated nitrite levels may cause blood disorders in infants and may also contribute to the development of cancer-related diseases. The nitrite concentrations measured in the investigated groundwater samples are significantly below the permissible limit and therefore do not pose health risks.

Iron was also analyzed as an important groundwater quality parameter. The iron concentration in the groundwater from the Ansarullah Mosque well was 0.02 mg/L, while the

Rishkhor (Qayyum Qudrat Mosque) well showed an iron concentration of 0.01 mg/L. According to World Health Organization (WHO) standards, the permissible limit of iron in drinking water is 0.30 mg/L (Hosseinabadi, 2019). The concentration of iron in clean natural waters generally ranges between 1.00 and 1.50 mg/L, although higher concentrations may occur when groundwater interacts with mineral-rich geological formations.

Iron is an essential element for the human body, and adults generally obtain about 20 mg/day through food. Moderate iron concentrations in water usually do not pose health risks; however, excessive concentrations may affect water color, taste, and suitability for domestic and industrial uses (Soldal, 2002). The measured iron concentrations in the investigated groundwater samples are considerably below the permissible limits and therefore indicate that the groundwater is suitable for drinking, domestic use, and certain industrial applications such as paper production, canning, and photography.

The pH values recorded for the groundwater samples were 6.65 for the Ansarullah Mosque well and 7.3 for the Rishkhor (Qayyum Qudrat Mosque) well. These values fall within the acceptable pH range of 6.5–8.5 recommended for drinking water quality (Younger, 2009). Low pH values below 6.5 are generally observed in areas where acidic runoff from mineral-rich regions enters groundwater systems. Extremely high or low pH values may significantly affect water quality. High pH values may produce a soapy taste, whereas low pH values may result in a sour taste. The effects of abnormal pH are often more noticeable among infants and individuals with sensitive skin.

The pH of drinking water may affect human health both directly and indirectly. Direct effects include irritation and damage to mucous membranes, particularly under highly alkaline conditions. Indirect effects mainly involve corrosion and deterioration of water supply systems, pipelines, and household equipment caused by acidic water conditions. Based on the measured results, the pH values of the investigated groundwater samples remain within acceptable international standards and therefore do not pose health risks to consumers (Xiao, 2017).

This study also evaluated electrical conductivity (EC), which reflects the concentration of dissolved ions and salts in groundwater. The EC values obtained from the groundwater samples were 725 µS/cm for the Ansarullah Mosque well and 1018 µS/cm for the Rishkhor Qayyum Qudrat Mosque well. According to WHO guidelines, the maximum permissible EC value for drinking water is approximately 1900 µS/cm (García-Tejero, 2011).

The measured EC values indicate moderate concentrations of dissolved minerals and salts in the groundwater samples investigated. Since both values remain below the WHO permissible limit, the groundwater from the investigated areas can be considered suitable for drinking and domestic use with respect to electrical conductivity.

The findings of the present study are generally consistent with previous investigations of groundwater and drinking-water quality, while also highlighting some important characteristics of groundwater in the Chehelsoton area of Kabul City. The pH values

measured in the Ansarullah Mosque and Qayyum Qudrat Mosque wells (6.65 and 7.30, respectively) indicate near-neutral groundwater conditions and fall within the commonly accepted range for drinking water. This finding is comparable with observations reported in studies of natural and drinking-water systems, where pH is recognized as an important indicator of groundwater chemistry and its interaction with geological materials (Younger, 2009). Similarly, Nwokem et al. (2023), in their assessment of surface water in Nigeria, reported pH values close to neutrality and emphasized the importance of physicochemical parameters in determining overall water quality. The relatively small pH difference between the two wells in the present study may reflect local variations in groundwater–rock interaction and recharge conditions.

The relatively low iron concentrations observed in the present study (0.02 mg/L and 0.01 mg/L) further indicate good groundwater quality with respect to iron contamination. These concentrations are substantially lower than the commonly applied guideline value of 0.30 mg/L and suggest limited iron mobilization in the investigated groundwater. This result is particularly relevant to Kabul, where groundwater quality can be influenced by geological conditions and increasing anthropogenic pressures. Previous work on groundwater management in Afghanistan has emphasized the importance of routine groundwater chemistry monitoring, including electrical conductivity and other indicators of chemical deterioration (Banks, 2002). The low iron concentrations observed in Chehelsoton therefore suggest that iron is not currently a major constraint on the suitability of the investigated groundwater.

The nitrite concentrations measured in the two wells (0.005 and 0.008 mg/L) were also very low. These results are consistent with Sato et al. (2018), who reported very low or undetectable nitrite concentrations in several drinking-water samples and demonstrated that nitrite is closely associated with nitrogen transformation processes and microbiological conditions in water. The low concentrations found in the present study suggest that substantial contamination from sewage, wastewater, or other nitrogen-bearing sources is not evident at the sampled wells. Nevertheless, this interpretation should be considered alongside the limited number of sampling locations and the absence of nitrate and microbiological measurements in the present investigation.

The fluoride concentrations of 0.43 mg/L and 0.39 mg/L are also relatively low compared with the guideline value commonly applied to drinking water. These concentrations indicate that fluoride does not constitute a significant water-quality concern in the investigated wells. This finding is consistent with the broader conclusions of Lubojanski et al. (2023), who emphasized that fluoride can have beneficial effects at appropriate concentrations but may produce adverse effects when exposure becomes excessive. Thus, the fluoride concentrations detected in Chehelsoton appear to fall substantially below levels associated with excessive fluoride exposure.

Sulfate concentrations were particularly low, ranging from 0 to 1 mg/L in the investigated wells. Such low concentrations indicate that sulfate enrichment is not a significant feature of

the sampled groundwater. This observation is important because sulfate concentrations in groundwater may be influenced by mineral dissolution and anthropogenic inputs. In Afghanistan, groundwater quality is subject to both natural hydrogeochemical processes and increasing human pressures, and previous studies have emphasized the need for systematic monitoring of groundwater resources (Banks, 2002). The very low sulfate concentrations in the present study therefore suggest limited sulfate contribution from the immediate geological or anthropogenic sources affecting the sampled wells.

Electrical conductivity showed the greatest difference between the two sampling locations, with values of 725 µS/cm in the Ansarullah Mosque well and 1018 µS/cm in the Qayyum Qudrat Mosque well. The higher EC at the latter site indicates a greater concentration of dissolved ions and mineral constituents. This spatial difference is consistent with EC's value as a practical indicator of groundwater mineralization and chemical characteristics. Banks and Soldal (2002) specifically identified electrical conductivity as an important parameter for groundwater assessment in Afghanistan and noted that groundwater quality can vary considerably among localities. The observed difference between the two Chehelsoton wells may therefore reflect variations in local hydrogeological conditions, residence time, recharge, or interaction between groundwater and aquifer materials.

Overall, comparison with previous studies indicates that the groundwater investigated in Chehelsoton generally exhibits favorable physicochemical characteristics, particularly with respect to pH, iron, nitrite, sulfate, fluoride, and electrical conductivity. The results are broadly consistent with previous research emphasizing the importance of hydrochemical monitoring for evaluating groundwater suitability and protecting drinking-water resources. However, the relatively higher EC at the Qayyum Qudrat Mosque well suggests greater mineralization and warrants continued monitoring. This is particularly important in Kabul, where groundwater resources face increasing pressure from urbanization, groundwater abstraction, and potential contamination sources. Previous assessments of groundwater in Afghanistan have similarly emphasized the need for sustainable groundwater management and regular chemical monitoring to prevent deterioration of groundwater quality (Banks, 2002). Therefore, although the present results indicate that the investigated wells are generally suitable for drinking and domestic purposes based on the parameters analyzed, continued monitoring involving a broader range of chemical and microbiological indicators would provide a more comprehensive assessment of groundwater safety.

CONCLUSION

This study assessed groundwater quality in the Chehelsoton area of Kabul City using selected physicochemical parameters, including fluoride, sulfate, nitrite, iron, pH, and electrical conductivity. Overall, the investigated groundwater exhibited acceptable physicochemical quality for drinking and domestic use, as the measured parameters were generally within the guideline values considered in this study. The results indicate that, at the investigated

locations, groundwater is characterized by near-neutral pH, moderate mineralization, and relatively low concentrations of the selected potentially harmful constituents. From a scientific perspective, these findings provide useful baseline evidence that the investigated groundwater does not currently show substantial physicochemical deterioration with respect to the parameters analyzed. This information is particularly relevant for groundwater-quality assessment in Kabul City, where increasing urban development and dependence on groundwater may place additional pressure on groundwater resources.

However, the findings should be interpreted within the study's limitations. The assessment was based on a limited number of sampling locations and a restricted set of physicochemical parameters; therefore, the results cannot be generalized to the entire Chehelsoton area or Kabul City. In addition, the study did not assess seasonal changes in groundwater quality, microbiological contamination, or a broader range of major ions, trace elements, and other emerging contaminants. Consequently, although the investigated groundwater appears suitable based on the parameters examined, the study does not provide a comprehensive assessment of overall groundwater safety or long-term resource sustainability.

Future research should therefore expand groundwater-quality monitoring to a larger and spatially representative network of wells, incorporating both dry- and wet-season sampling to evaluate temporal variability. Further investigations should include microbiological indicators, major and trace elements, nutrients, and other relevant contaminants, together with hydrogeochemical and spatial analyses to identify possible natural and anthropogenic sources of groundwater-quality variation. Establishing a long-term groundwater monitoring program would also support the early detection of contamination and provide a stronger scientific basis for sustainable groundwater management and protection in Kabul City.

Recommendations

To reduce groundwater and surface water pollution in Kabul city and to improve water quality management, the following recommendations are proposed based on the findings of this study:

1. Urban runoff contaminated by surface pollutants, as well as untreated wastewater from residential areas, contributes significantly to surface and groundwater pollution. Therefore, wastewater should be properly treated before being discharged into water bodies or groundwater recharge areas.
2. The uncontrolled disposal of waste materials (including organic and inorganic household waste, human and animal excreta, hazardous medical waste, and industrial waste) should be strictly prohibited, particularly near water sources and groundwater recharge zones. Implement proper waste management practices to protect water quality and public health.

3. Kabul city urgently needs to develop and expand effective drainage and sewage systems in residential areas to prevent groundwater contamination and improve environmental sanitation.
4. Relevant environmental and public health authorities should continuously monitor groundwater quality to detect potential contamination early and ensure the long-term safety of drinking water supplies.
5. Public awareness programs should be implemented to educate local communities about the importance of groundwater protection, proper sanitation practices, and the environmental impacts of water pollution.
6. Future research should include seasonal groundwater quality assessment, microbiological analysis, and additional physicochemical parameters to provide a more comprehensive understanding of groundwater conditions in Kabul city.

Authors contribution

Associate Professor Abdul Mohammad Aziz conceptualized and supervised the study, developed the research framework, provided scientific guidance, interpreted the findings, and critically revised the manuscript. Assistant Professor Fazalhaq Hassanzay conducted the field investigation, collected groundwater samples, analyzed and interpreted the data, prepared the initial manuscript draft, and organized the methodology, results, and discussion sections. Faisal Amin contributed to laboratory analysis, data collection, literature review, manuscript editing and formatting, and reference organization. Mohammad Alem Sulaimankhil contributed to field visits and data collection. All authors reviewed and revised the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest associated with this manuscript.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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