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Groundwater Quality Assessment in Chak Karstic Sedimentary Basin, Wardak Province, Afghanistan

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ABSTRACT

The research focused on assessing groundwater quality in Jawharkel, Ghanikhel, Chak, Mandukhel, Dawrankhel, Noorkhel, Baba Qala, Sanikhel, Muhkumkhel, and Rasheeddan villages, and specifically intended to measure groundwater physical and chemical parameters in the mountainous areas of the Chak Karstic Sedimentary Basin in Chak District, Wardak Province, located in Afghanistan's central part. The analyzed parameters included electric conductivity, pH, turbidity, odor, taste, color, hardness, as well as chloride (Cl_2), nitrogen (N), fluoride (F), iron (Fe), arsenic (Ar), ammonia (NH_3), and sulfide (SO_4) content. All the analyzed chemical and physical parameters were found to be within acceptable limits. The results obtained were compared with the WHO drinking water quality standards. The study revealed that the values of physical parameters such as color, taste, odor and turbidity fell within the acceptable (recommended standard) limits; that the examined samples demonstrated no toxic elements and/or components; and that the analyzed chemical parameters were likewise within the permissible limits recommended by WHO and ANSA. Water quality in the target rural area proved to be better compared to the concerns of its residents and households, and that local water posed no threat to residents' health and survival. The article emphasizes the importance of properly applying water quality indicators previously not adequately explored in the target area.

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1. Introduction

Water is the elixir of life covering approx. 71% of the Earth's surface with only 2.5% of it as freshwater. Groundwater comprises 99.97% of the total fresh water re-serves, while the remaining is available as lakes, streams, and rivers (Gleick, 1993; Vidvan Vishvam, 2003; Khatri et al., 2020) and plays a vital role in the planet's ecosystem. Groundwater represents one of the most critical, scarce, precious and non-replenishable natural resources (Prasad, 2008). Its quality is the result of physical and chemical interrelated parameters along with other variations determined by its stream.

In urban environment, groundwater is used for drinking, industrial and domestic purposes, and is often overexploited. Rapid industrialization, improper solid and toxic waste management practices in urban areas frequently lead to groundwater degradation turning it into unpotable for future use. Groundwater pollution not only affects the water quality but also threatens human health, economic devel-opment, as well as social prosperity (Milovanovic, 2007).

In many cases, the assessment of water pollution in rural communities is not fo-cused as opposed to that conducted in urban conditions (Khatri et al., 2020). In a rural setting, groundwater, lakes, rivers, and canals serve as the major sources of drinking and irrigation water, as well as water used for cleaning. Out of aforementioned, groundwater is the most widely used for potable purposes (CPCB, 2007). Drinking water must be free of any toxic substances and aesthetically pleasing. Consumption of poor-quality water leads to a number of health issues such as gout, water-borne diseases, kidney stones, etc. (Bhadrecha et al., 2016). The quality of water is generally defined in terms of its physical, chemical and biological parameters (Ketata Mouna et al., 2011), and is measured using the Wa-ter Quality Index (WQI) while assessing whether it is potable or not.

This study concentrated on the groundwater quality in the Chak District's Sedi-mentary Basin in Wardak Province of Afghanistan. The Chak Sedimentary Basin is a watershed where all surface and groundwater is of snowmelt origin (Banks and Soldal, 2002). The Loger River – originating in the Daimirdad Mountain Range (4,500 m ASL) – represents the main basin's water body with multiple tributaries like the Garden Musjed, Abkazar, Araban, Nikpicul, Sabak, Madu, Bigsamand, Ali-sha, Alasang Streams passing through it and merging with the Logar River at dif-ferent points. During the snowmelt season (April-June), the tributaries coming from various parts of the Wardak Mountains transport sediment of different sizes and types (Houben and Tunnermeier, 2003). During the flooding season (May-August), when different sizes of sediment mix, they form various aquifers and sur-face water bodies. In turn, the aquifers recharge different locations of river beds preserving groundwater (Banks et al., 2014; Jain, 2018). The type of sediment depends on the rock that the water streams go through and distance from the surrounding mountains. Sometimes, it discharges from the groundwater to river beds and causes groundwater leakages. When the surface water percolated to the groundwater, different soluble materials leach differently and add different toxic and nontoxic components/elements to it (Torge et al., 2003). Chak District repre-sents a longitudinal fault valley with different thicknesses of the aquifer, aqui-clude, and equipage at different locations - generally, angular materials near sources, and rounded Quaternary period younger gravel conglomerates far from sources. At the Chak Dam, sediment thickness ranges between 1,500-2,000 m (Landell, 2017).

In addition, the basin's soil profile consists of young tertiary sediments and mainly comprises various clay, silt, sands, gravels, as well as surface and basal conglom-erates (Bentley et al., 2006; 18. King and Sturtewagen, 2010). The landforms within the Chak Basin are typical of an arid to semiarid and tectonically active regions. In its central plains, there are local depositional centers for sediments derived from the surrounding superficial deposits and bedrocks outcrops. The central plains gently slope up to the adjacent mountains and hills to piedmonts. The allu-vial fans have developed on the flanks of the mountains surrounding the Chak Wardak Basin and on interbrain ridges (Broshears et al., 2005). The alluvial fans generally grade from coarse materials near the source to finer materials at the distal edge. The physical weathering induced by extreme temperature fluctua-tions has produced slope breaks at the basin edges (Tünnemeier and George, 2005). This continuing weathering process has been maintaining steep and rugged mountain slopes. The Chak Basin is part of the tectonically active Kabul Block in the transpressional plate, a boundary region of Afghanistan (Myslil et al., 1982). The northeastern edge of the Chak Basin is defined by the Paghman Fault System (JICA, 2007), with the fault trends ranging from north to northeast, and evidently continuing fault scarp and piedmont alluvium along the basin's northeastern boundary. The Chak Basin can be characterized as a valley fill basin and range, with the valleys filled with Quaternary and Tertiary sediments, and the ranges composed of uplifted crystalline and sedimentary rock (Bohannon and Turner, 2007). The Quaternary sediments are typically less than 80 m thick in the valleys (Böckh, 1971). The younger deposits and reworked loess series represent reworked loess, gravel, sand, and talus. The gravels are mainly deposited in river channels.

The study of the groundwater in the aforementioned area is important for several reasons, including identifying its quality and, thus, suitability for human consump-tion, and collecting and sharing the information on water quality among the con-cerned households and residents. As per the research findings, the local residents can safely utilize the locally available water as per their needs without any health or welfare concerns.

2. Materials and methods

2.1. Study site

The research aimed to examine the quality of groundwater in Chak District (Fig. 1.) located southwest of Kabul on the side of the Hindu Kush Mountains. The Chak Wardak Basin covers the area of 9,772 km[2] with the maximum elevation of 4,500 m ASL in the Wardak Daimirdad Mountain Range and minimum elevation of 2,092 m ASL in Ambokhak. The Loger is the main river in the area originating (4,500 m ASL) in the Daimirdad Mountains (Wardak Range, Hindu Kush Mountains, Afghanistan), administratively belonging to Wardak Province (Bohannon and Turner, 2007). The river flows from west to east, and passes through Chak and Saidabad Districts of Wardak Province (Bohannon, 2005).

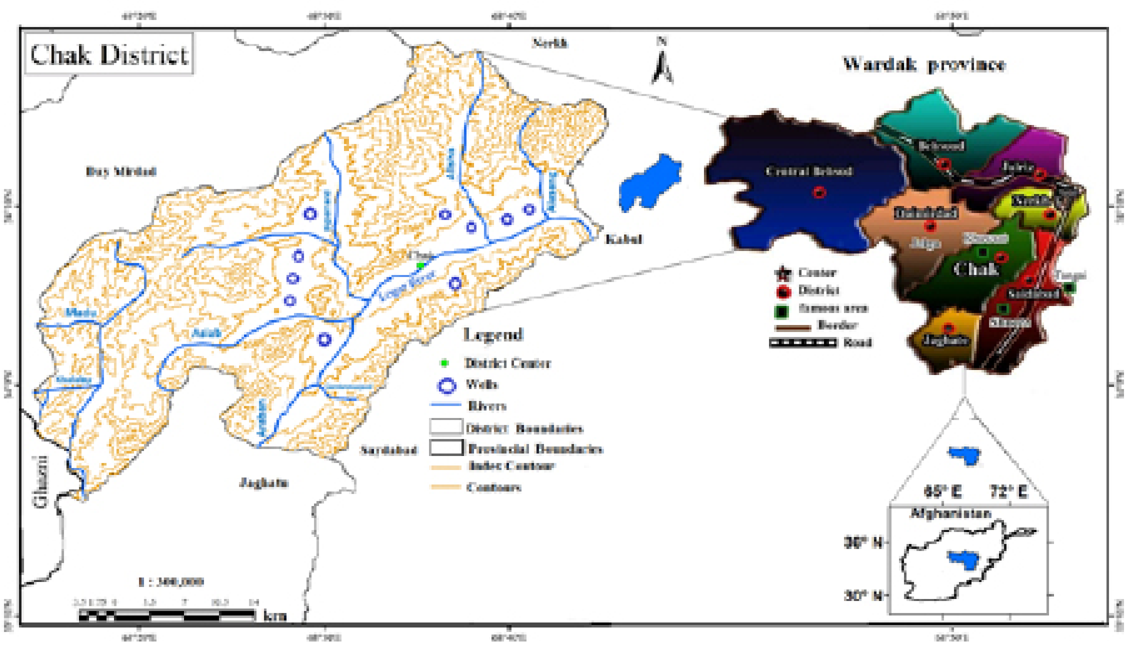

Figure 1. Map of Chak District with the examined wells (Wardak Province, Afghanistan).

2.1.2 Water sample analyses

Under the research, samples from 10 wells were collected and underwent in-situ and laboratory analysis. The in-situ testing included electric conductivity (EC), pH, turbidity (T), odor, color and taste analysis; and lab testing included Cl, hardness (H), NO_3, F, Fe, Ar, NH_3, SO_4, and Cl_2 content analysis. The analyzed physical and chemical parameters are shown in Table I.

Table I. Analyzed physical and chemical parameters and corresponding testing devices.

No	Parameter	Unit	Measurement Device	Test type	Indicator
1	EC	s/cmµ	Electric conductivity meter	Physical	Field and laboratory
2	pH		pH-meter		
3	Turbidity	mg/l	Partible ground		
4	Odor	mg/l	234-CEDTA titrimetric		
5	Color	mg/l	234-CEDTA titrimetric		
6	Taste	mg/l	234-CEDTA titrimetric		
7	Cl	mg/l	Spectra-photo model DR3900	Chemical	Laboratory
8	Hardness	mg/l	Spectra-photo model DR3900		
9	NO3	mg/l	Spectra-photo model DR3900		
10	F	mg/l	Spectra-photo model DR3900		
11	Fe	mg/l	Spectra-photo model DR3900		
12	Ar	mg/l	Spectra-photo model DR3900		
13	NH3	mg/l	Spectra-photo model DR3900		
14	SO4	mg/l	Spectra-photo model DR3900		
15	Cl2	mg/l	Spectra-photo model DR3900		

Physicochemical analysis

In physicochemical analysis, all types of tests were applied as per the Standard Methods for the Examination of Water and Wastewater and guidelines recom-mended by the American Public Health Association (APHA) (Wescoat and White, 2003). To determine sample odor and taste, the Threshold Sensory Method was applied.

Color

Standard solution (crystallized cobaltous chloride ($CoCl_2$) × $6H_2O$ and 1.246 g potassium chloroplatinate (K_2PtCl_6) in distilled water with 100 mL HCL) was prepared and compared to the sample water.

Chemical analysis

The chemical parameters were also tested as per the APHA's Standard Methods for the Examination of Water and Wastewater, 20th edition, 1998, and the relevant tools, instruments and manuals (APHA, 1998).

3. Results and discussion

3.1 Physicochemical parameters

This investigation measured the physical and chemical parameters of groundwater in Jawharkel, Ghanikhel, Chak, Mandukhel, Dawrankhel, Norkhel, Qalay Baba, Sanikhel, Muhkumkhel, and Rasheeddan villages, Chak District, Wardak Province, Afghanistan. The physical and chemical parameters studied in this exercise included pH, turbidity, hardness, EC, and Cl, NO_3, F, Fe, Ar, NH_3, SO_4, and Cl_2 content as mentioned in Table II.

Table II. Parameters in target villages of Chak District, Wardak Province

	Parameters											
Villages	EC (µS/cm)	pH	Turb. (NTU)	Cl (mg/l)	Hard. (mg/l)	NO_3 (mg/l)	F (mg/l)	Fe (mg/l)	Ar (mg/l)	NH3 (mg/l)	SO4 (mg/l)	Cl2 (mg/l)
Jawharkel	718	7.2	4	20	437	4.3	0.38	0.07	0	0	60	0
Ghanikhel	790	7.2	3	20	426	4.3	0.33	0.06	0	0	55	0
Chak	682	7.2	3	20	426	4.2	0.3	0.06	0	0	55	0
Mandukhel	674	7.2	3	20	415	3.9	0.38	0.07	0	0	50	0
Dawrankhel	602	7.1	4.5	25	361	3.7	0.32	0.06	0	0	45	0
Norkhel	601	7.1	3	25	361	3.9	0.3	0.05	0	0	45	0
Qalay Bab	406	7.2	3	22.5	393	3.7	0.35	0.06	0	0	50	0
Sanikhel	513	7.2	4	22.5	372	4.5	0.34	0.06	0	0	50	0
Muhkumkhel	660	7.3	4	23	500	3.8	0.38	0.07	0	0	56	0
Rasheeddan	809	7.4	5	26	435	4.4	0.39	0.08	0	0	63	0

The EC and pH were found to range between 406-809 µS/cm and 7.1-7.4, respec-tively. Turbidity, hardness, and Cl content in different villages fell within 3-5 NTUs, 20-26 mg/l and 361-500 mg/l, respectively. NO_3, F, and Fe content ranged between 3.7-4.5 mg/l, 0.3-0.39 mg/l, and 0.05-0.08 mg/l, respectively. All the analyzed samples were found within the acceptable limits recommended by WHO and Afghanistan National Standard Agency (ANSA) making the tested water suitable for drinking and irrigation purposes.

3.2 Physical parameters

3.2.1 Electric conductivity (EC)

Electric conductivity represents the flow of electricity in water solution, and de-pends on the ion content as well as the temperature during measurement (20-25C°) (Dojlido and Best, 1993). The EC test was done in situ, and its results were then compared against WHO standards (see Fig. 2).

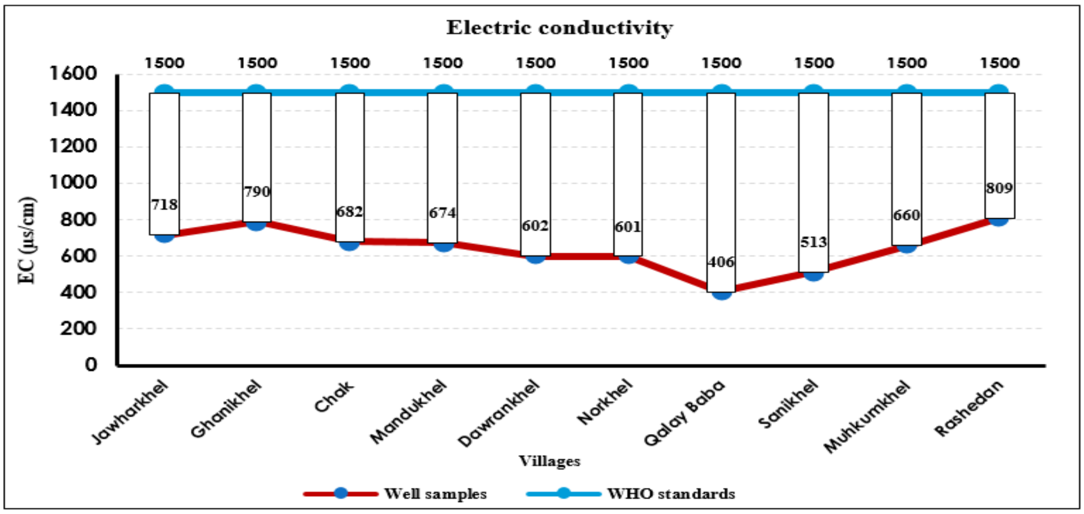

Figure 2. Comparison of EC of tested samples against WHO standards.

3.2.2 Concentration of hydrogen ions (pH)

Under this study, the pH of the samples was compared with the maximum and minimum pH values as per WHO standards. The pH of groundwater samples in Jawharkel (7.2), Ghanikhel (7.2), Chak (7.2), Mandukhel (7.2), Dawrankhel (7.1), Norkhel (7.1), Qalay Baba (7.2), Sanikhel (7.2), Muhkumkhel (7.3), and Rasheed-dan (7.4) villages was neutral. The corresponding WHO standard high pH equals 8.5 and minimum – 6.5 (WHO, 2011), thus making the tested water suitable for drinking and all other life purposes (Fig. 3.).

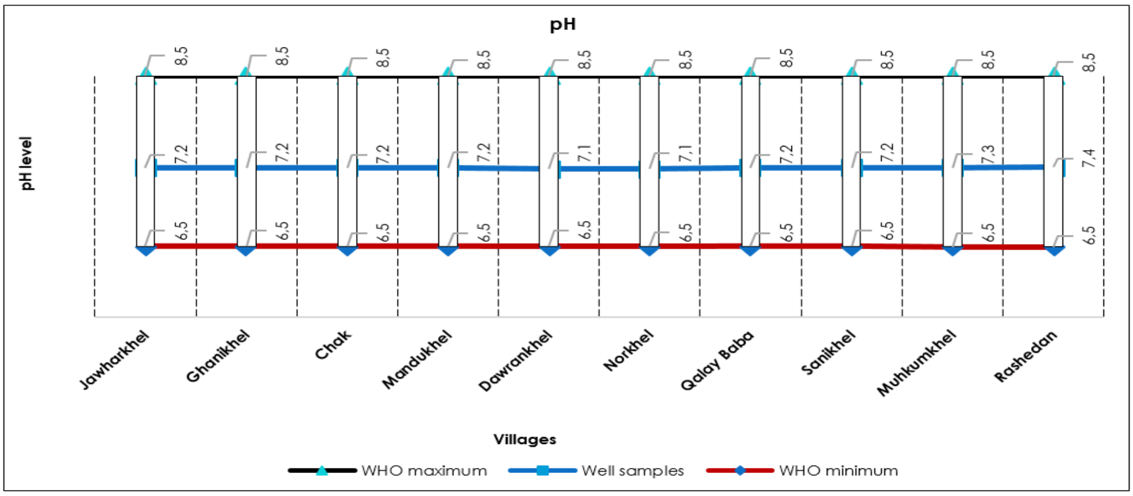

Figure 3. Comparison of pH of tested samples with WHO standard pH maximum and min-imum

3.2.3 Turbidity

Within the framework of this study, the turbidity was measured using a turbidity meter. Turbidity shows the soluble solid materials in water as well as water clari-ty. Generally, turbidity is caused by non-soluble materials and is measured in ppm. According to WHO standards, the turbidity of water should be below 5 ppm. The water sample testing in this research showed the turbidity values between 4 and 3, as shown in Fig. 4. below.

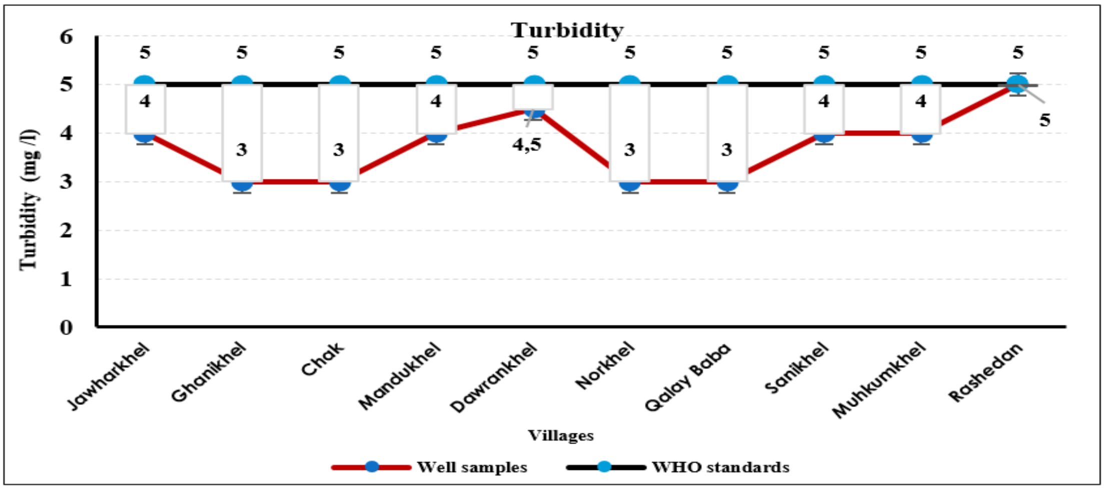

Figure 4. Comparison of turbidity of tested samples against WHO standards.

3.2.4 Odor

The odor of the collected water samples was within the permissible limits. Gener-ally, water odor results from its contact with other materials and can be toxic. The odor of groundwater is usually related to the infiltration and contact with soluble materials contained in the earth crust lithology. Sometimes, the odor is caused by the use of coloring agents exceeding limited conditions (WHO, 2004). In this research, the odor of groundwater was found acceptable, making it suitable for drinking.

3.2.4 Taste

The taste of groundwater depends on the presence of iron, saline, carbonates, an-hydrite, and is sometimes determined by the organic materials leaching during surface water percolation. In certain cases, it is chemical materials and/or rock composition which cause bad taste (WHO, 2004). The taste of the water samples investigated in this study was found acceptable, making the water suitable for drinking.

3.2.5 Color

Generally, the color of the tested water samples was green, with other colors pointing to the presence of soluble organic and/or inorganic materials. The presence of organic materials gave water yellow or yellowish color. The presence of Fe, Mn, and gypsum changed the color of water samples to white or red (WHO, 2004). In this research, the color of groundwater samples was found acceptable, making it suitable for drinking as per this parameter.

3.3 Chemical parameters

Chemical water contamination is determined by the characteristics of a specific solution. It can generally contain solids, acids, basic chemicals, fluorides, metals, organic materials, and nutrients (Dojlido and Best, 1993). When solid materials are dissolved in water, it stimulates such reactions as hydration, hydrolysis, oxidation, and reduction, subsequently facilitating reactions with other materials, and thus changing water quality. Different components can be found in water, and the elements that make water hard and toxic include CO_3-, HCO_3-, OH-, NH_3, Fe^{2+}, Mn^{2+}, Sr^{2+}, Al^{3+}, F, Ar, H, Cd, Pb, Hg, and Cr (Dojlido and Best, 1993).

3.3.1 Hardness (H)

The hardness of groundwater is determined by the presence of salines and certain cations like Ca^{2+}, Mn^{2+}, Al^{3+}, Fe^{2+}, Sr^{2+}, K^+, Mg^{2+} dissolved with inions like HCO_3-, SiO_3^{2-}, NO_3^-, SO_4^{2-}, Cl^- and CO_3^{2-}, and is measured in mg/l (Hessami, 2017). The hardness values for the samples tested in this study are presented in Fig. 5. below.

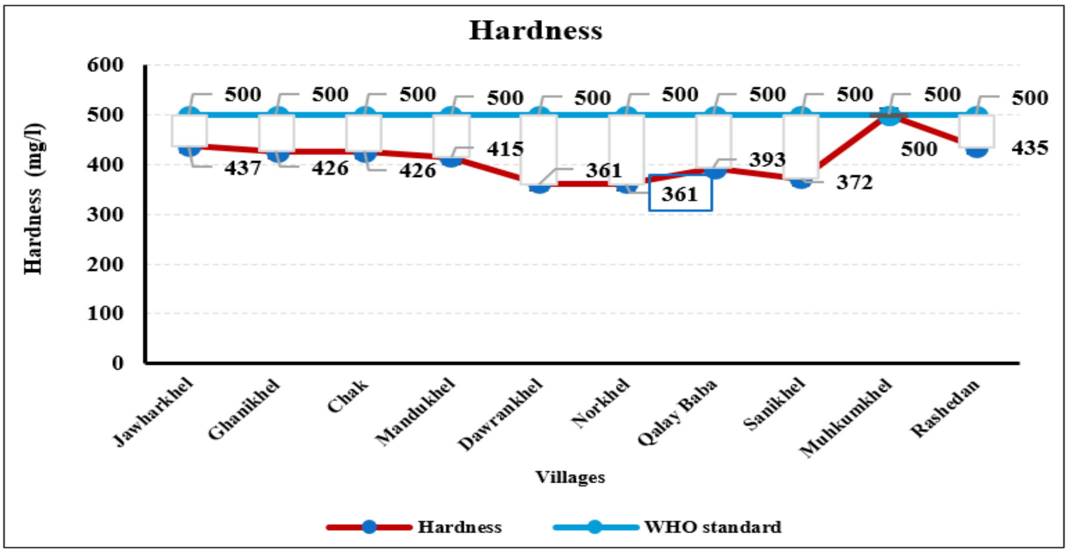

Figure 5. Comparison of hardness of tested samples against WHO standards.

3.3.2 Chlorides

Chlorides have a salty taste, and destroy any tools contacting the saline. The concentration of chlorides in fresh water is less than 10 g/l (WHO, 2010). The concentration of salt in groundwater is higher during the infiltration of surface water from salinized soil layers (WHO, 2004). In this research, the groundwater samples were compared against the ANSA standards (see Fig. 6.).

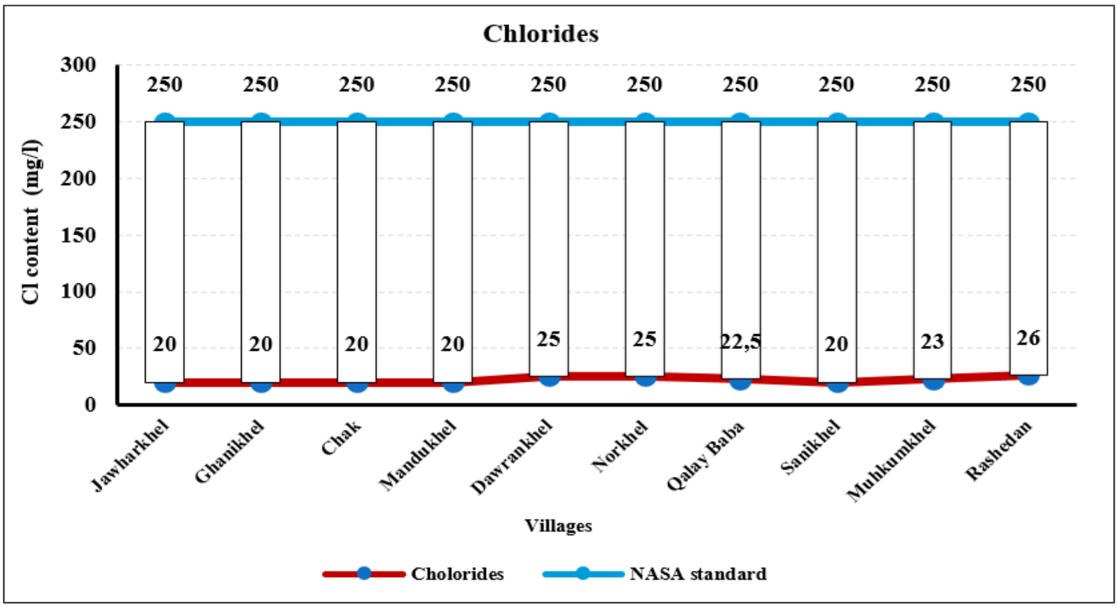

Figure 6. Comparison of chloride content in tested samples against ANSA standards.

3.3.3 Nitrites (NO_3^-)

It can be measured by the content of N (mg/l), nitrites (NO^{3-}), and NH_3 caused by improperly organized bathrooms infiltrating into groundwater. The presence of iron causes the reduction of nitrites, and as a result of decomposition of the or-ganic materials that NH_3 and nitrites (NO_3) produce, it leads to the nitrification of the existing oxygen (Dojlido and Best, 1993). The comparison of the content of NO_3^- in the target samples against ANSA standards is presented in Fig. 7. below.

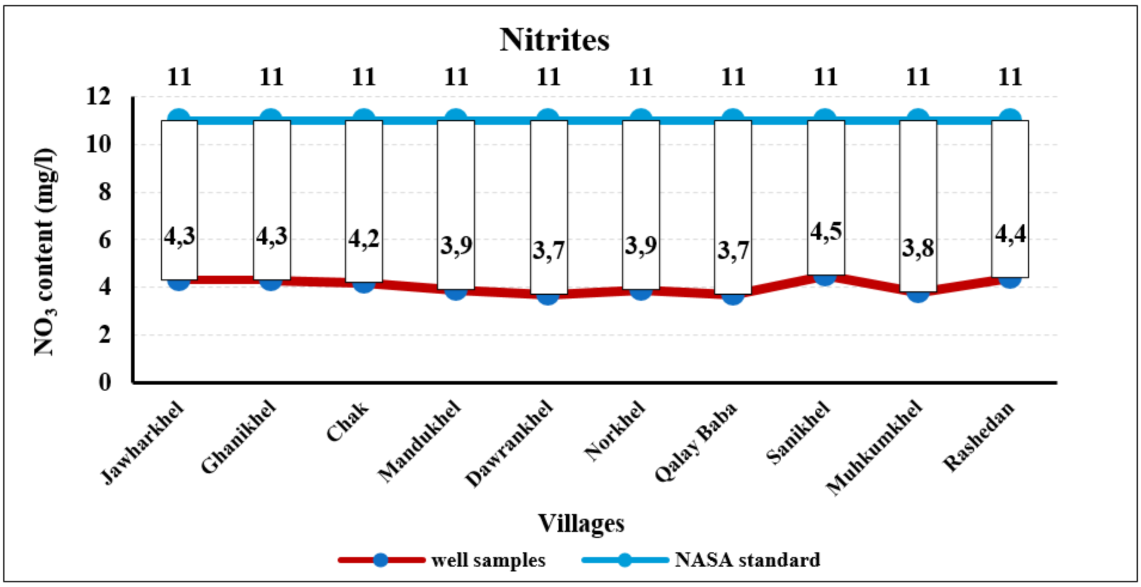

Figure 7. Comparison of nitrite content in tested samples against ANSA standards.

3.3.4 Fluorides (F)

Fluorides may be present in groundwater naturally or added artificially; fluoride content is measured in mg/l. Fluoride is useful for teeth protection and health. If the amount of fluorides in drinking water is high, it may cause teeth cavities in children and bone problems in humans in general. As per WHO standards, the fluoride content in water should be between 0.6-1.7 mg/l (WHO, 2009). The corre-sponding values for the tested samples are shown in Fig. 8.

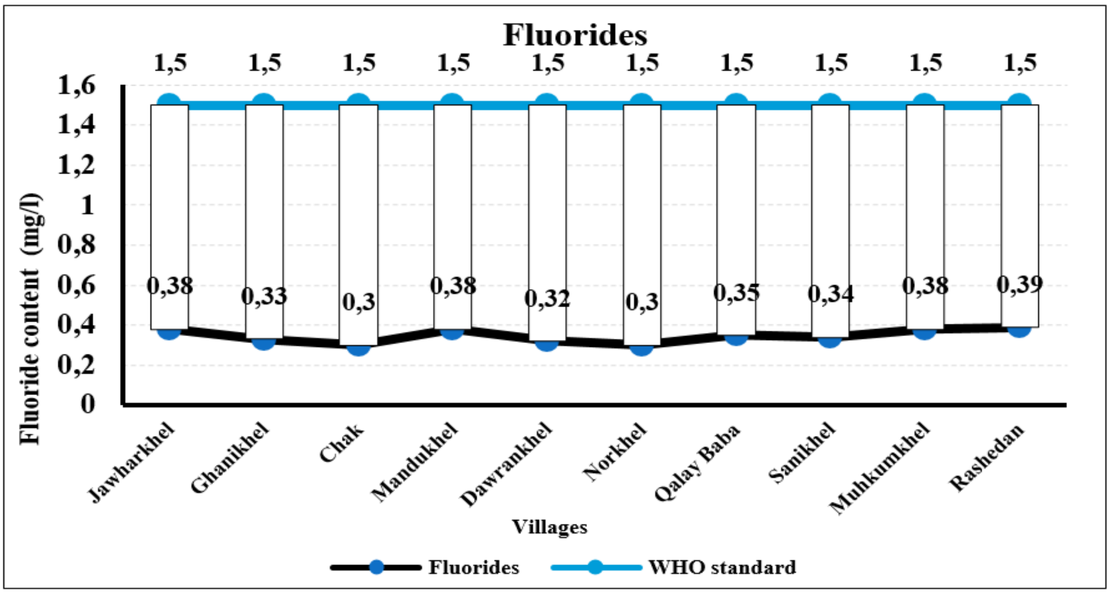

Figure 8. Comparison of fluoride content in tested samples against WHO standards.

3.3.5 Iron (Fe)

Iron can be found in water supply pipes; different types of iron can exist in groundwater; in addition, it can be suspended in water in the form of colloids and/or complexes with organic and inorganic materials. This type of iron cannot harm human health but changes the taste of water. When iron content exceeds normal levels, it precipitates and forms iron oxides. Within the framework of this study, iron content in target groundwater samples was compared against WHO standards (see Fig. 9.).

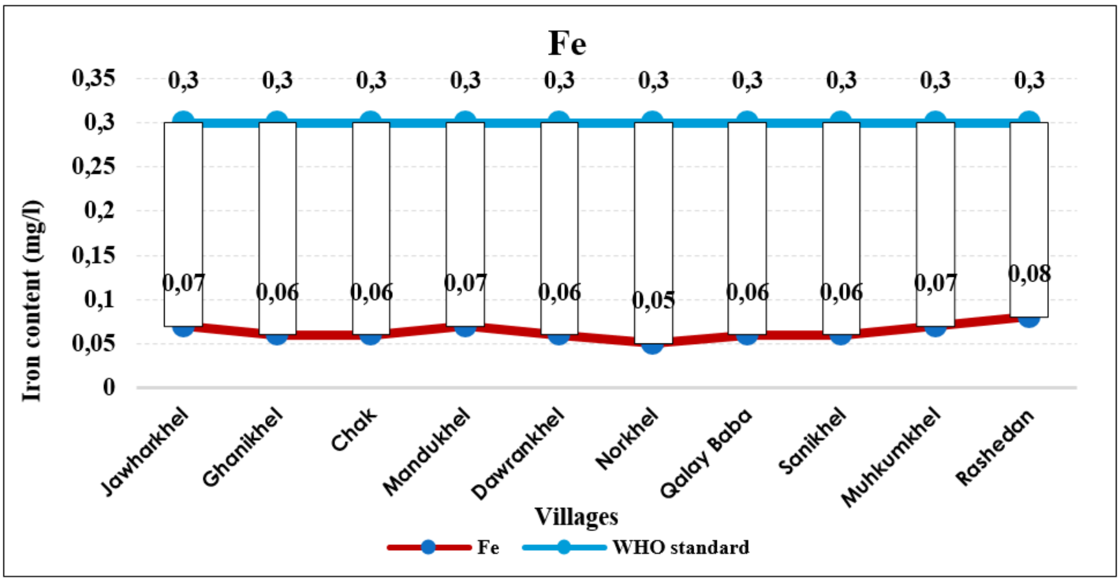

Figure 9. Comparison of iron content in tested samples against WHO standards.

3.3.6 Arsenic (Ar)

Arsenic can be found in water in locations of metal mining and subsequent filtra-tion of surface waters recharging groundwater. Certain plants, animals and ma-rine organisms can likewise cause arsenic in water (WHO, 2011). Drinking water containing significant amounts of arsenic can cause health problems, and may be lethal. The groundwater samples examined for arsenic content under this study were compared with WHO standard, as is shown in Fig. 10.

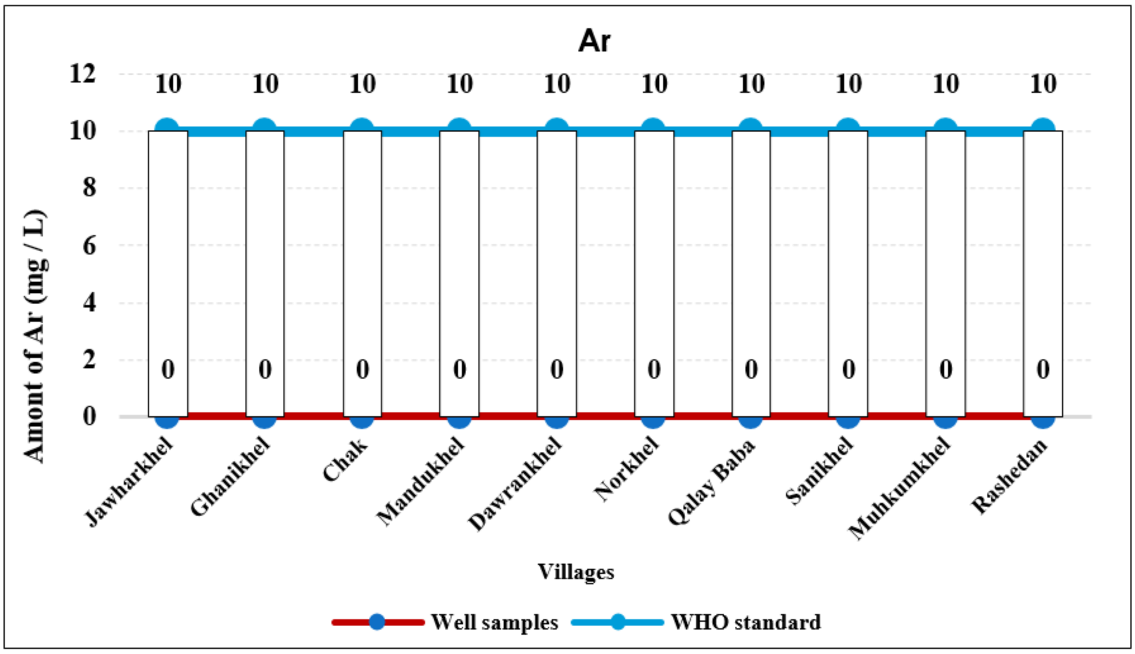

Figure 10. Comparison of arsenic content in tested samples against WHO standards.

3.3.7 Ammonia (NH_3)

Ammonia is an element of the N-group in drinking water measured in mg/l. Deep wells may contain some ammonia due to the presence of certain bacteria, but it does not impose real harm on the human body. Generally, ammonia comes to groundwater as a result of improper garbage and wastewater disposal. In water supply systems, the amount of ammonia should not exceed 0.4 mg/l (Dojlido and Best, 1993). Figure 11. below shows ammonia content in the examined samples.

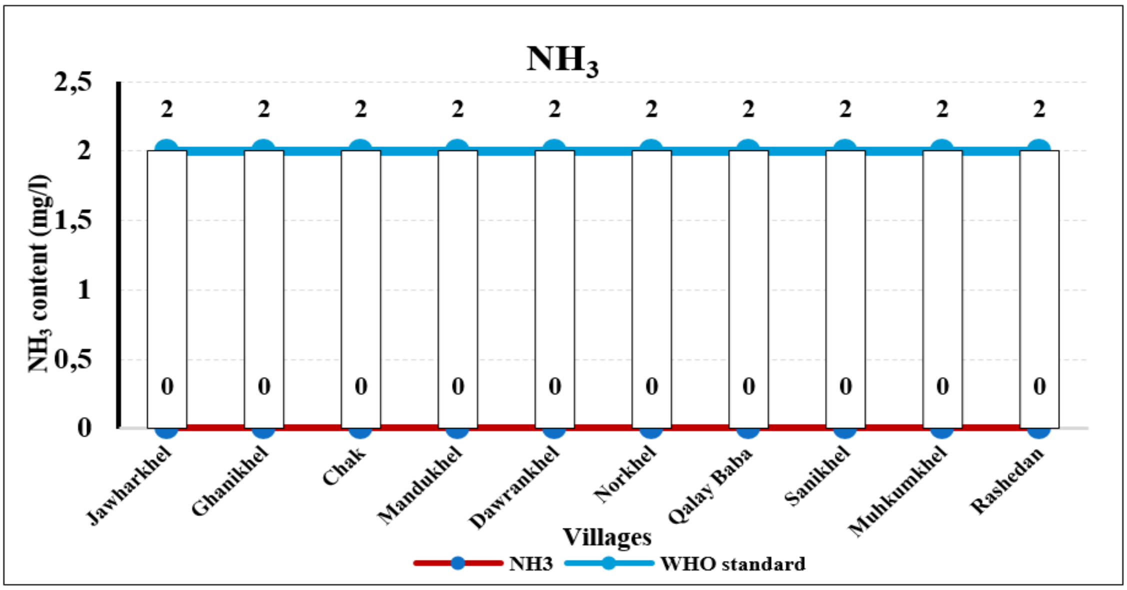

Figure 11. Comparison of ammonia content in tested samples against WHO standards.

3.3.8 Sulfides (SO4)

The concentration of sulfides in groundwater may range between 1.0 and 1,000 mg/l (WHO, 2011). The main source of sulfides is gypsum and other mined materi-als in sediments. In seawater, sulfides form due to the oxidation of sulfides, sul-fites, and neosulfites, as well as industrial factors. Hydrogen sulfides spreading from factory chimneys and by acidic rains come down to the earth's surface forming sulfides. In this research, sulfide content in the target samples was compared against the corresponding WHO standards, as is shown in Fig. 12.

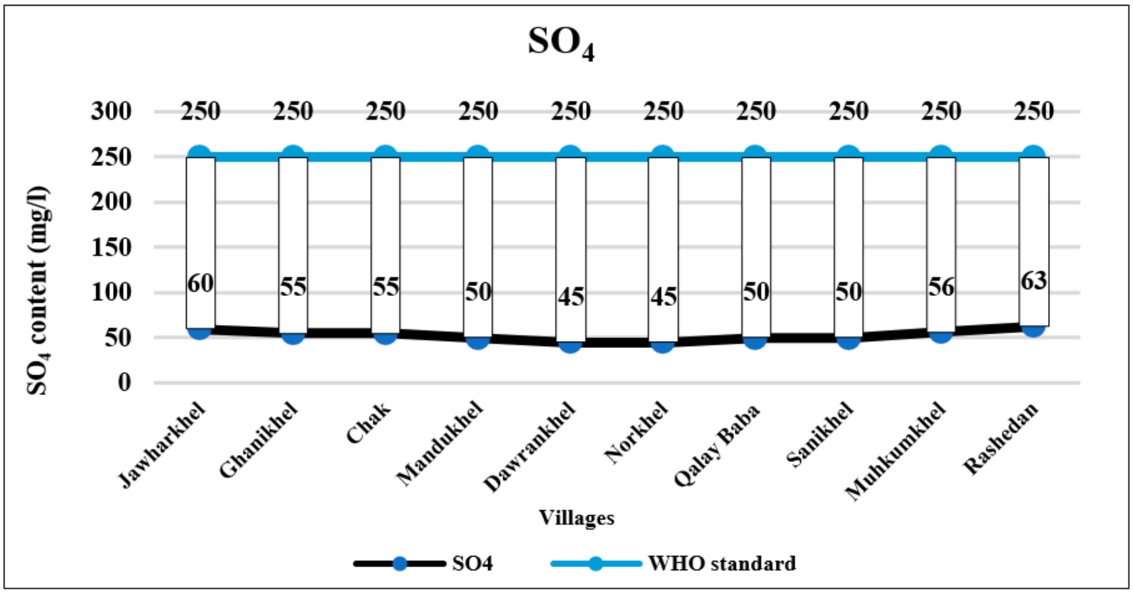

Figure 12. Comparison of sulfide content in tested samples against WHO standards.

3.3.9 Chlorine (Cl_2)

Chlorine acts as a disinfectant for water-borne bacteria, and is often used to clean water of various microbes and bacteria. After coloration the groundwater taste changes. The amount of chlorine should not exceed the norm, as otherwise it may cause different problems. In case the quantity of Cl_2 exceeds standards conditions, it will harm human body and living animals in water. The amount of chlo-rine in groundwater should not exceed 0.2 mg/l (WHO, 2009). Under this study, the target groundwater samples were compared against ANSA standards (see Fig. 13.).

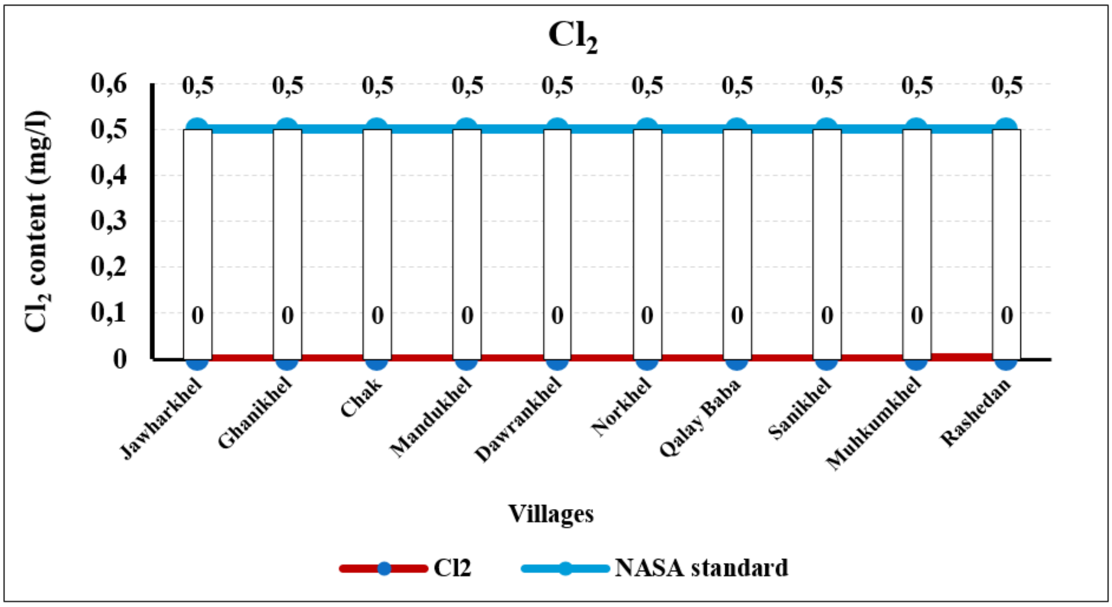

Figure 13. Comparison of chlorine content in tested samples against ANSA standards.

3.3.10 Means of physical and chemical parameters

For measuring the physical and chemical properties described above, the research used mean values for each of the tested parameters based on 10 (ten) groundwa-ter samples to compare them with the standards established by the World Health Organization (WHO) and Afghanistan National Standards Authority (ANSA) (WHO, 2004). The comparison revealed the acceptability of all the parameters to WHO and ANSA benchmarks, as shown in Fig. 14. All the parameters investigated under this research were found falling within the acceptable range, thus proving the suitability of local water for drinking as per national and international criteria.

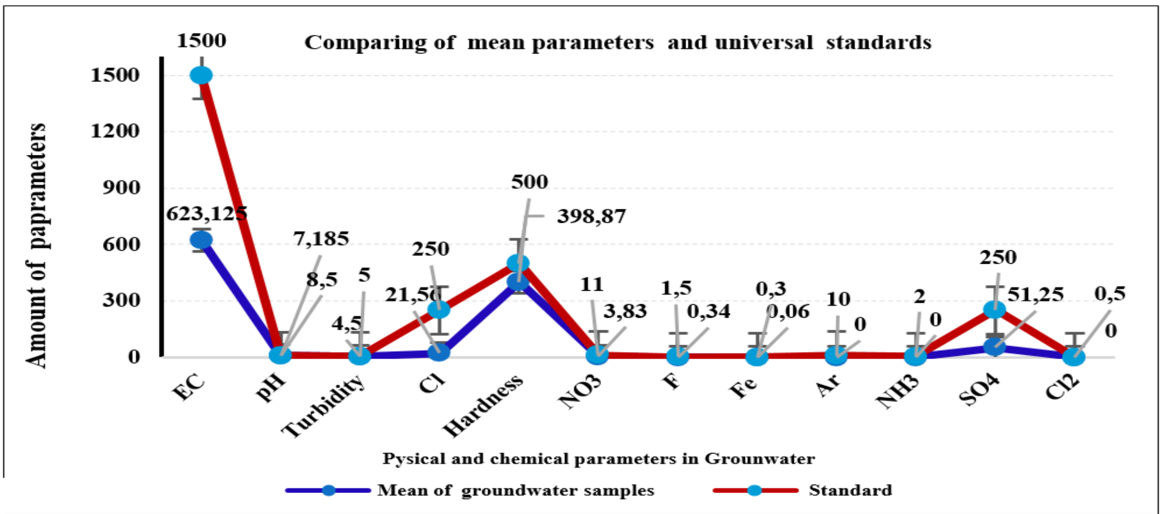

Figure 14. General comparison of groundwater samples against WHO and ANSA standards.

4. Conclusion

Groundwater quality was measured in Chak District of Wardak Province in Afghani-stan. Ten (10) samples were collected in ten (10) different villages. Various phys-ical and chemical parameters were measured to evaluate water quality in the tar-get area. The tested groundwater samples and parameters showed the water quality complying with both national (ANSA) and international (WHO) standards. In addition, no toxic elements and/or components were detected in the examined samples. The study proved that the quality of water in the target area was good. In order to preserve the water quality on its current level, public awareness raising is necessary among local residents.

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