Research Article
Volume 14:05, 2023

Hydrology: Current Research

ISSN: 2157-7587 **Open Access**

Hydrogeological Investigation of Six Asiab Regions in Wardak Province of Afghanistan

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Abstract

Hydrogeological investigations are carried out in six Asiab regions in Chack, Wardak Province of Afghanistan. The Asiab region is located longitudinally to a valley that is parallel to the Wardak mountain range. In earlier times, the entire region was a big lake and as the water body receded along the width of these regions, this converted the entire region into one big fault at the Alishang Village. Currently, the Asiab River runs in a very steep area inside a valley causing erosion of the river all the way down to the riverbed. This river flowed from northeast to southeast and at the Alishang village; it changed direction from north to south and joined with the Gardan Masjid River. In these regions, all aquifer layers are located between the valleys and these formations are filled with gravel, sands, silts, loams, etc. and their accumulation along the river. Due to its accumulation on both sides of the river, the terraces (upper, middle and lower) consist of different types of conglomerates with different matrix materials which are found in different types of aquifers (aquifer, aquiclude and aquifuge). Since the residents use the water for general consumption, we tested water samples from 10 different wells in Alishang, Tapor, Kaday, Makhtoma, Kazian and Hakemkhel villages and assessed different parameters based on the different for- mations of stratigraphy according to their profiles. Due to regional conflict, the water quality and groundwater management have been ignored in this region, thus necessitating this research to provide necessary information to the local and state government for decision-making and management.

Keywords: Aquifers • Wells • Taluses • Terraces • Longitudinal valley • Breccia • Conglomerates

Introduction

Wardak province in Afghanistan is in the central and eastern region of Afghanistan; bordering Parwan to the northeast, Kabul and Logar to the east, Ghazni to the south and Bamyan to the west [1,2]. The Asiab region is located longitudinally in a valley parallel to the Wardak mountain range [3]. In earlier times, the entire region used to be a big lake and as the water body receded along the width of these regions, this caused the entire region to convert into one big fault at the Alishang Village [4,5]. Currently, the Asiab River runs in a very steep area inside a valley causing erosion of the river all the way down to the riverbed. The river flows from northeast to southeast and at the Alishang village; it changes direction from north to south and joins with the Gardan Masjid River [6]. In fact, the river drains in different places depending on the course it follows. In addition to years of war in the region, the regional water scarcity issue has largely been ignored and has impeded any development. In addition, water sharing through rivers in Afghanistan has led to territorial disputes leading to water treaties signed by individual countries. Hence the main objective of this investigation is to find sources of water and assess the quality of drinking water for the residents of Wardak province for their daily survival. The objectives of this investigation are consistent with the sustainable development goals and the future of water resources management.

The Chack sedimentary basin consists of diverse sizes of deposits that are spread and positioned alongside mountain ranges in longitudinal valleys. The depth of the residues is related to the slope and distance from the mountain range [7]. The ones that are found generally close to the mountain and in sloped areas are gravel and angular materials, but for those found far from mountains, the deposits are rounded and fine materials, such as bolder, cobbles, pebbles, granules, sands and silts [8-10]. In the Chack sedimentary basins, more sediment are transferred along the way in valleys viz., Konghare, Alishang, Araban, Gardammujed and Abkazar. Additionally, in the Chack Sedimentary Basin, some sediments are transported from surface streams [11] from Araban, Khalili, Madu, Alisha and Bigsamand. Thus, in the chack Sedimentary Basin, such sediments transported from different parts of mountain ranges are categorized since their depth and composition vary according to their locations. For instance, sediments from the upper and steep areas of this basin are not very thick and these sediments are from the Quaternary period and generally consist of conglomerates, but the lower basin consists of young tertiary sediments. Generally, the lithology of these valleys also consists of diverse clay, silt, sand and gravel [12].

The present investigation consists of identifying soil profiles and river sediments and the geology of neighboring mountain rocks at different locations. The landforms within the chack Basin are, typically, arid to semiarid and tectonically in active regions. In the central plains of the Chack Basin, there are several local sediment deposit sites that are derived from the surrounding sub-surface deposits and bedrocks and their heterogeneity reflects the variability of hydrodynamic conditions and sediment sorting [13-15]. The central plains gently slope up to the Piedmont hills. Sedimentary fans have developed on the flanks of the mountains surrounding the Chack Wardak Basin and on inter-basin ridges [13-18]. The alluvial fans usually range from coarse materials close to the source to finer materials at the distal edge. Physical weathering in conjunction with extreme temperature fluctua- tion has produced pronounced breaks in slope at the edge of the basin [19,20]. This phenomenon of continuing weathering process maintains the steep, rugged mountain slope. The Chack Basin is part of a tectonically active region of Kabul Block in the transgressional plate boundary region of Afghanistan [21]. The East eastern edge of Chack Basin is defined by the Paghman fault system [22,23]. The Paghman fault trends north to northeast and is evident in the

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Received: 01 September, 2023, Manuscript No. hycr-23-113140; **Editor Assigned:** 04 September, 2023, PreQC No. P-113140; **Reviewed:** 18 September, 2023, QC No. Q-113140; **Revised:** 23 September, 2023, Manuscript No. R-113140; **Published:** 30 September, 2023, DOI:10.37421/2157-7587.2023.14.477

continuous fault scarp and piedmont alluvium along the northeastern boundary of Chack Basin. The Chack Basin can thus be described as a basin where the valleys are filled with Quaternary and Tertiary Sediments and the ranges are composed of uplifted crystalline and sedimentary rocks [24]. Quaternary sediments are typically less than 80 m thick in the valleys [25]. The underlying tertiary sediments have been estimated to be as much as 800 m thick in Chack District of Wardak Province [26]. As per some estimates, it may be well over 1000 m thick in some areas of the valley [27]. The relatively recent deposits are described as reworked loess, gravel, sand and talus. The loess, gravel, sand and talus are deposited mainly in the river channels [28].

Methodology

Sites under investigation

In the present investigation, we obtained different groundwater samples from different wells in the Asiab region. We collected several samples and conducted their analysis in our laboratories to determine different Chemical and physical characteristics such as electroconductivity, pH, turbidity and hardness in the different locations of the region under investigation. For such determinations, we collected samples from Alishang, Tapor, Kaday, Makhtoma, Kazian and Hakemkhel) in Chack, Wardak Province. It is instructive to provide a topological over- view of the region and hence a coordinate map of the Asiab region showing wells and dams is shown in Figure 1 (a and b), to highlight the region under investigation.

The geology of Chack Basin, in general, consists of different types of rocks, such as Granite, Gneiss, Schist, Limestone and Reefs, as well as near the lateral edge, that can be observed as different types of conglomerates, sandstone, siltstone and shale. The plain areas consist of sediments of Neogen and its thickness at the plain re- gions is about 1000m, however, in the mountain areas, the thickness of sediments is much smaller. The sizes of sediments, as observed, depend upon the slope of the area and velocity of the river, because due to high velocity only larger sizes of sediments remain while smaller sizes of sediments are transported farther. Furthermore, since the velocity of the river is slower, the thickness of deposited sediments is larger than the areas with slopes (Figure 1).

In sloped areas, the sizes of sediments consist of a variety of gravels such as boulders, cobbles, pebbles and gran- ules, but in plain areas, it generally consists of sand, silts and clay, as expected. In some areas, we can find loam,

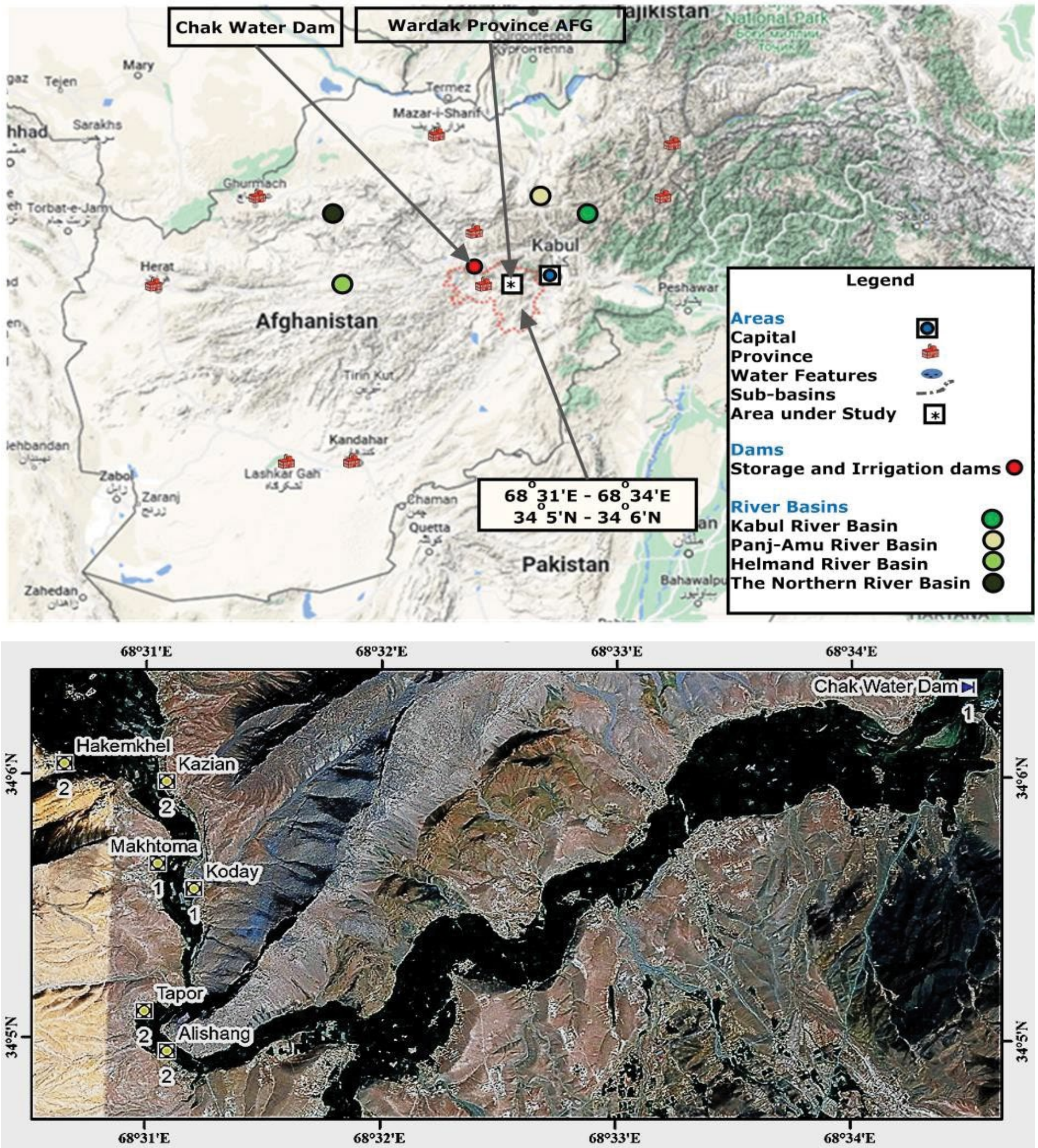

Figure 1. Regional map of the site under study: Coordinate system of the region under investigation, showing dams and wells in the Asiab region.

sandy loam, silty loam and clayey loam. Almost all the aquifers are located along the rivers and streams and additionally, there are more swamps and marshland areas, as shown in Figures 2 and 3 below.

Types of valleys: In Chack Basin, we observe different types of valleys such as longitudinal, diagonal and transverse, but in this investigation, we focused more on the longitudinal valleys which are parallel to the mountain range. The total length of the Asiab region is 5 Km and its mean width is about 0.5 Km. There are more aquifers inside the valley along the Asiab River which consists of gravel, sand, silt and loam sediments. The total depth of these sediments inside the valley is about 500m. Generally, in the valley's middle parts, we can find round gravels that are trans- ported by the Asiab River at different distances, but on both sides of the valley near the mountain range where we observe angular gravels (talus), which are transported by the action of gravitational force. On both sides of the valley, we observe terraces and these terraces have been made of different types of conglomerates such as basal and basement conglomerates. Most of the aquifers are located near the streams of the river, but the sides of the terrace consist of the aquifer, aquiclude and aquifuge and it consists of a matrix material of conglomerates and breccias, such as clay, iron oxides, silica (SiO_2) and carbonates. Figures 2 and 3 show aquifers on both sides of the Asiab River stream and different types of structures and valleys in the Asiab and Khawat Regions (Figures 2 and 3).

Aquifers in Asiab regions: In the Asiab region, all aquifers are in the longitudinal valley, which consists of gravel, sand, silt and loam along the river, but near both sides of the river, there are terraces (upper, middle and lower) that have been made by different types of conglomerates with different matrix materials and made from different types of aquifers such as aquiclude and aquifuge.

Terraces, breccias and conglomerates: In a terrace, we generally observe a basal conglomerate with its granular gravel since it consists of silts, carbonates and matrix materials as found in aquiclude and aquifuge aquifers. From the sampling of the flow patterns of gravel analysis, it is observed that there is more quartzite, limestone, gneiss (a foliated metamorphic, such as feldspathic, plutonic rock), biotite (group of phyllosilicate minerals within the mica group) and sandstone and also, we can find some angular gravels that show gravity-transported materials because this terrace sloped at 30° and is located near the mountain range and more gravels show physical weathering materials. When we studied the area from the analytical point of view, the consolidated breccia and conglomerates are due to mountain ranges and are far from river streams. It is worth noting that on this terrace, we observe a historical house, which is about three thousand years old (Figure 4).

This terrace is different from others because the upper parts of this terrace consist of fine materials such as sands, silts and carbonates, called basal conglomerates, however, the lower parts of this terrace consist of more gravel such as boulders, cobbles and granules and the matrix material are carbonates, silts and very fine sand. The angle of slope of this terrace is about 90° and in this terrace, we can see erosional unconformity since it is observed by guff of sedimentation. Our observation indicates that the velocity in the lower part of the stream is more than the upper part due to the larger material size as compared to fine materials in the lower part of streams (Figure 5).

A terrace, as shown below in Figure 6, is completely different from others, as it generally consists of fine materials, viz. sands, silts and carbonates. In our observation, for all layers of aquifuge, did not indicate any storage of groundwater. From this observation, we assess that this must be due to slow velocity stream flows. The cementation or matrix materials of this terrace consist of carbonates and other materials. However, on this terrace, we also observe some fractures and joints, where the angle of the slope of this terrace is about 90°. In this terrace, all materials are of homogeny and only in some parts, we can find some gravel and others are fine materials, such as sands and silts. Furthermore, on this terrace, we also observe some karst (formed from the dissolution of soluble carbonate rocks such as limestone, dolomite and gypsum) caves, as seen by carbonated rocks and karst aquifers, which is a unique hydrogeology that are highly productive but extremely vulnerable to contamination (Figure 6).

Figure 2. The aquifers on both sides of Asiab River stream at the different parts of Asiab regions.

Figure 3. Different types of structures and valleys in the Asiab and Khawat regions.

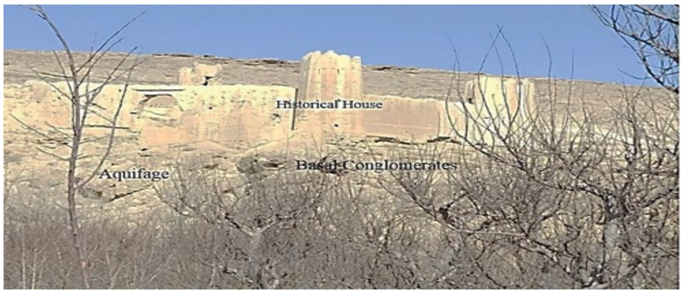

Figure 4. Terrace part 1 at the Alishang village.

Figure 5. Terrace 2 with different materials of conglomerates.

The terrace in Figure 7 is made from sandstone and siltstone, which enables us to find some aquifer layers. From this terrace observation, we can assess the period of sedimentation formation, which may be due to the low velocity of streams. This is further supported by the observation that on this terrace, we did not observe any gravel. Thus, it shows its progression from mountains and slope areas. It is located in a plain area and the slope of this terrace is at 45° angles. On this terrace, we can find some caves and fracture zones. From this observation, we find that the amalgamation of materials is different according to their formation (Figure 7).

The last terrace observation is completely different from the others since it consists of sandstone and other fine materials. But inside this terrace, we can find some angular boulders, which indicate that this terrace is located near the slope areas and mountain ranges and these boulders are transported by gravity. On this terrace, we can find more carbonate materials and for that reason on this terrace, we can find more Karstic caves and Karstic aquifers, as shown in Figure 8 A typical Karst hydrogeology is exemplified by a network of interconnected fissures, fractures and conduits embedded in a relatively low-permeability rock matrix formation. Most of the groundwater flow and transport occurs through the network of openings, while most of the groundwater storage occurs in the matrix. Hence, most karst aquifers are highly heterogeneous and anisotropic (Figure 8). The research on karstic aquifers is focused on developing innovative approaches for better understanding and managing these valuable water resources, especially for arid regions.

In this following observation, we have different structures such as terraces, horst and faults and in this area; the terrace is very long and has different slopes. Generally, the slope of such a terrace is about 45° and we can see some springs in the different parts of this terrace. From that, we can find some aquifers at the different parts of this terrace. In this area, we observe a higher horst structure and, on both sides and some slickenside surfaces, with fault mylonite (fine-grained compact metamorphic rock produced by dynamic recrystallization of the constituent minerals) and breccia (Figure 9).

In the Asiab region, most of the gravel is estimated to be at the mountain skirts and the sediments are believed to be transported by gravity, also called talus materials. This gravel is angular because most of these sediments are formed by physical weathering. Between these talus materials, we found different sizes of gravel such as boulders, cobbles, pebbles and granules and it is due to the consolation of mother (origination) rocks and from other broken rocks. During the snow melting season, more snow meltwater infiltrates between these talus materials and adds to the groundwater. The thinness of talus materials pertains to the slopes of mountain skirts. Hence, in this case, the thickness in slope areas is generally rather small and it arranges the ground for the storage of groundwater.

Types of springs: In Asiab Regions, we observe different types of springs and generally, these regions contain faults and talus regions. Formed by the infiltration of surface water into the groundwater, the region consists of different types of springs (as shown in Figure 11). From these springs the people of villages extract water for drinking, bathing, animal feed, irrigation and, sometimes, swimming. In some places, these springs are reconstructed by municipality organizations to control the water for other useful reasons for the community, such as irrigation, industry and infrastructure. As we continue to focus on these studies, it benefits local communities in their daily needs for reliable water resources (Figures 10 and 11).

Results and Discussion

Having identified several sources of water, the next step is to assess physical and chemical characterizations of the groundwater from Alishang, Tapor, Kaday, Makhtoma, Kazian and Hakemkhel villages of Chack District of Wardak Province, Afghanistan. Our attempt has been to establish a relationship between the water column and well depth with their Electroconductivity (EC), pH, Turbidity and Hardness, which were measured and are described as follows. The results presented here are our initial observations and over a period, we plan to start continuous monitoring of these parameters, using smart sensors and Internet of Things (IoT) technology [29,30].

Relationship between the water column and well depth: Here, we have measured the water quality at the 10 different wells at the different villages Alishang, Tapor, Kaday, Makhtoma, Kazian and Hakemkhel. The depth of wells indicates the distance and slopes of areas under investigation. Generally, these villages are in the slopes and mountain skirts areas and the depth of wells is far from mountains in the plain areas with wells that are smaller in depth. The relationship between well depth and water column in the Asian

Figure 6. Terrace 3 with homogeny materials and aquifuge.

Figure 7. Terrace 4 with sandstone materials.

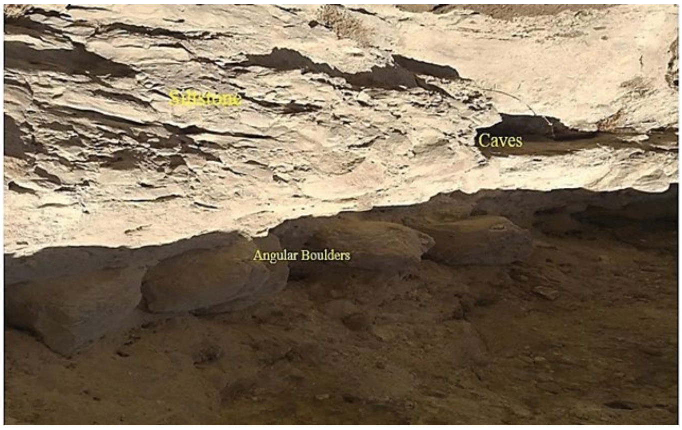

Figure 8. Terrace 5 with sandstone and angular boulders.

Figure 9. Terrace 5 with sandstone and angular boulders.

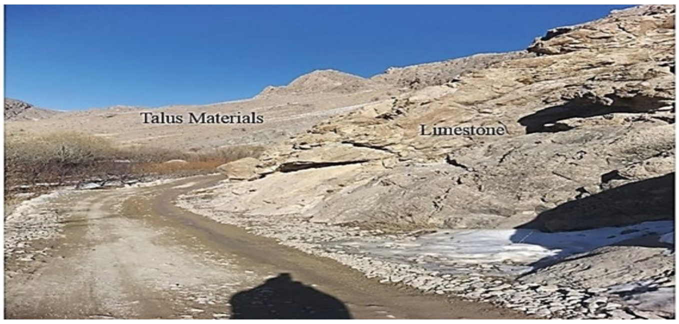

Figure 10. Talus materials at the mountain's slope.

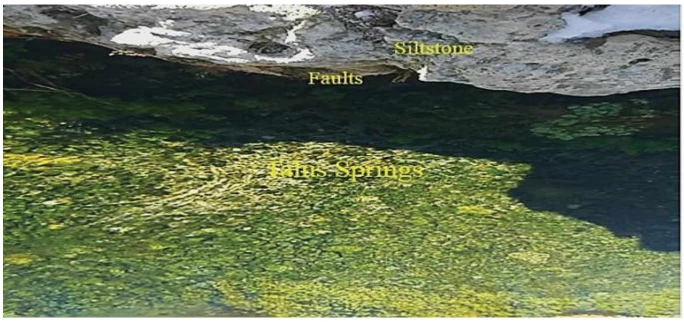

Figure 11. Different types of springs at the Alishang village.

regions is provided in (Table 1) and is also shown in (Figure 12).

We also measured the temperature of groundwater, which varied between 5-15 ℃, which is related to the depth and other activities such as volcanic eruptions and geographical locations. The temperature range was di- vided into several categories, viz., very cold (5 ℃), lightly cold (10 ℃), light warm (18 ℃), almost warm (25 ℃), Warm (37 ℃) and very warm (more than 40 ℃). For this investigation, the groundwater temperature is around 22 ℃ as shown in Figure 13, which is suitable for drinking and all general-purpose uses (Figure 13),

Electroconductivity: The Electroconductivity (EC) is measured to identify the quantity of salt in (μs/cm). In this study, we measured EC using an electroconductivity meter (Orion Lab Star EC112 Conductivity Bench Meters, Lab Star series, Thermo Fisher Scientific, USA) for the measurement of groundwater, at the same time the electroconductivity related also to the water temperature having at the period of measurement. The EC of this investigation is normal and can be used for drinking water. EC of samples from these well and their comparison with the WHO standards are shown in Table 2 for the Asiab region and shown in Figure 14. According to the WHO standards, the EC is ~1500, but for these six regions under consideration, the amount of EC is lower in terms of locations, lithology and distance from the river flows (Table 2) and (Figure 14).

Potential of hydrogen: In general, pH (potential of Hydrogen) demonstrates a scale used to specify the acidity or basicity of an aqueous solution. In this investigation, we found that the pH of the water using a pH-meter (model #: Multi 340i, Wissen- schaftlich-Techische Werkstätten GmbH (WTW), http://www.WTW.com). The pH of all these sites shows a neutral value of ~7, which we normally use for drinking and irrigation applications. The pH values of the well sample in the Asiab regions, Wardak province are shown in Table 3 and Figure 15. At the acidic condition, there are increasing amounts of H^+, but the basic belongs to the hydroxyl (OH-). In this figure, the well samples are neutral at pH= 7 and we can use them for drinking and other general purposes. Also, according to the WHO, the normal range for groundwater is (pH= 6.5 - 8.5) (Table 3) and (Figure 15).

Turbidity: The turbidity of water is affected by several factors, including the presence of dissolved and suspended solids, size and the shape and composition of particles. Their amount in solution and size changes their color. In this investigation, we have measured the turbidity of water using a turbidity meter (mg/L) (model: Turbimeter Plus, Company: Wagtech, www. waghtech.co.uk). Using the apparatus, we can use TDS (Total Dissolved Solid) in the samples under investigation. Generally, the turbidity of water for this investigation presented no problem and all groundwater seemed to be clear to the point that one could even use it for drinking. The turbidity in all well and groundwater water was practically zero which is equal to the international standards for groundwater. Table 4 shows the turbidity of the well sample and its WHO comparison at the Asiab regions, for a better understanding of the region. In Figure 16, the results of groundwater turbidity analyzed are lower than WHO maximum standard (Turbidity= 5μs/cm) (Table 4) and (Figure 16).

Hardness: For the hardness measurement, we used EDTA Titrimetric Method for Total Hardness. The method uses Eth- ylenediaminetetraacetic acid and its sodium salts (abbreviated EDTA) to form a chelated soluble complex when added to a solution of certain metal cations, a small amount of complex of metrically neutral magnesium salt of EDTA is added to the buffer; which automatically introduces sufficient magnesium and obviates the need for a blank correction We used buffer of (NH_4 OH+NH_4 Cl), in addition, the pH=10.0-10.1. The Maximum amount of hardness in the Alishang village well is 437 mg/L and the minimum amount in Koday and Makhtoma which is 361(mg/L). The main reason for the high amount of hardness in Alishang is due to the presence of Cl in ground- water, which is acidic. However, in Koday and Makhtoma Villages, the values are at ~8. The hardness of the Well sample and its comparison at the Asiab regions is shown in Table 5 and Figure 17. The hardness of the wells samples analyzed is lower than WHO standards (H=500mg/L) and it is safe for drinking and other general purposes, such as irrigation and animal feed (Table 5 and Figure 17).

Table 1. Relationship between well depth and water column at the Asian regions.

Village	Alishang	Alishang	Tapor	Tapor	Koday	Makhtoma	Kazian	Kazian	Hakimkhal	Hakimkhal
Column	16.6	36.2	20.2	10.4	22.3	23.4	17.2	20.2	25.2	34.8

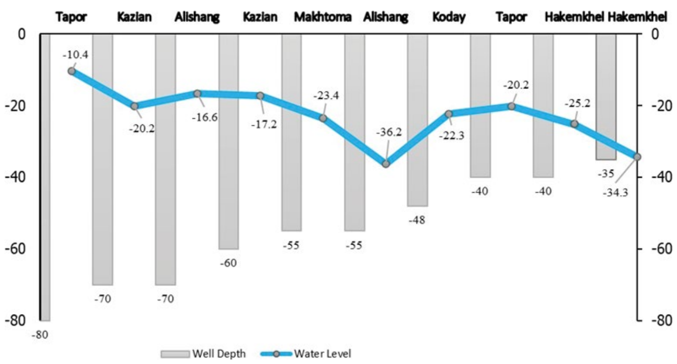

Figure 12. Relationship between the water column and well depth at the different villages of Asiab.

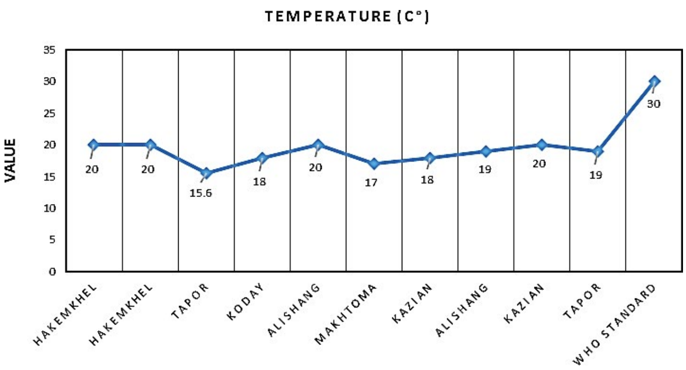

Figure 13. Groundwater temperature in Asiab regions.

Table 2. EC of well sample, and its comparing to the WHO standards at the Asiab regions.

Village	Alishang	Alishang	Tapor	Tapor	Koday	Makhtoma	Kazian	Kazian	Hakimkhal	Hakimkhal
Well Sample	718	790	682	674	602	601	406	513	660	809

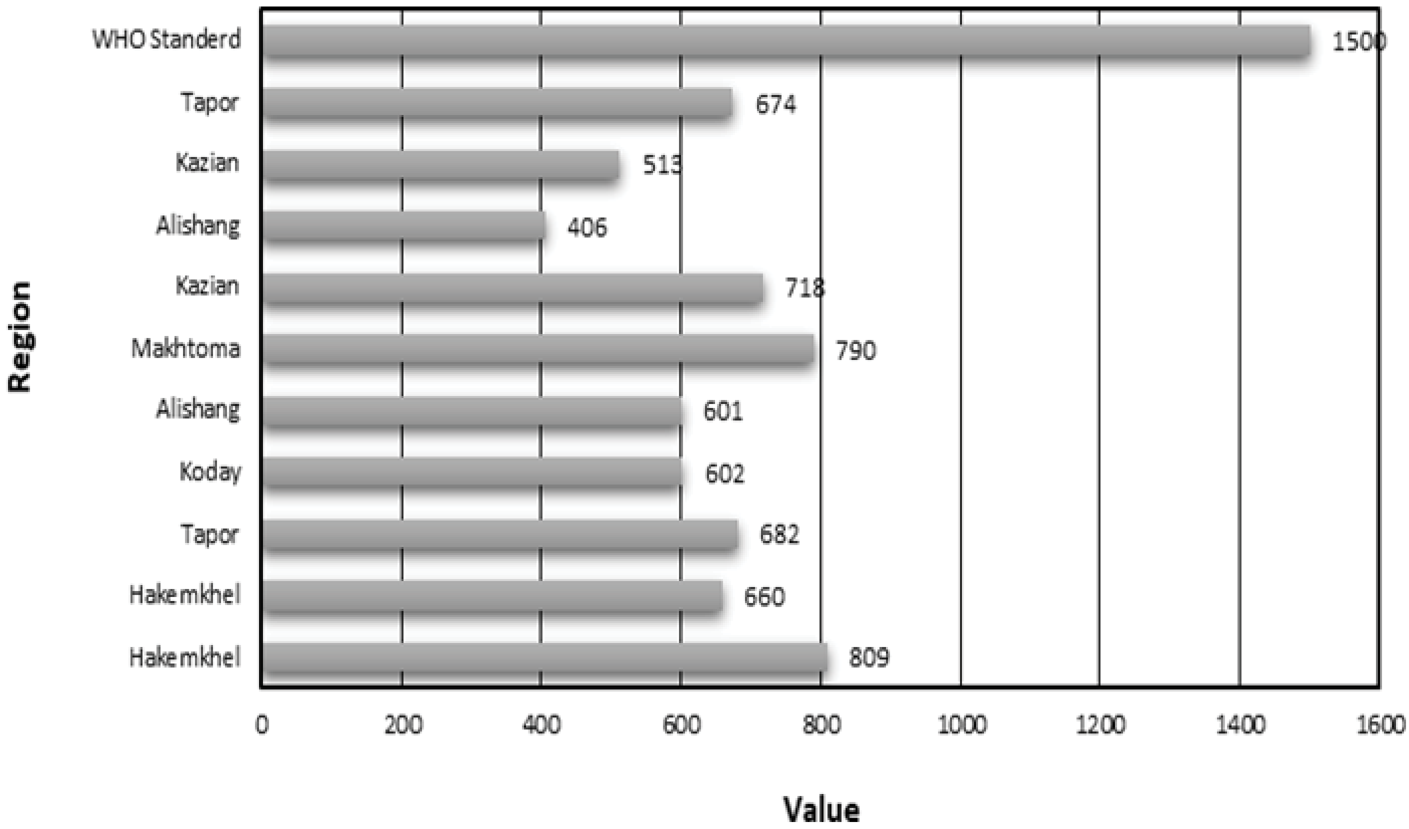

Figure 14. EC in different wells of Asiab regions.

Table 3. pH and well sample, at the Asiab regions, Wardak province.

Village	Alishang	Alishang	Tapor	Tapor	Koday	Makhtoma	Kazian	Kazian	Hakimkhal	Hakimkhal
Well Sample	7.2	7.2	7.2	7.2	7.1	7.1	7.2	7.2	7.3	7.4

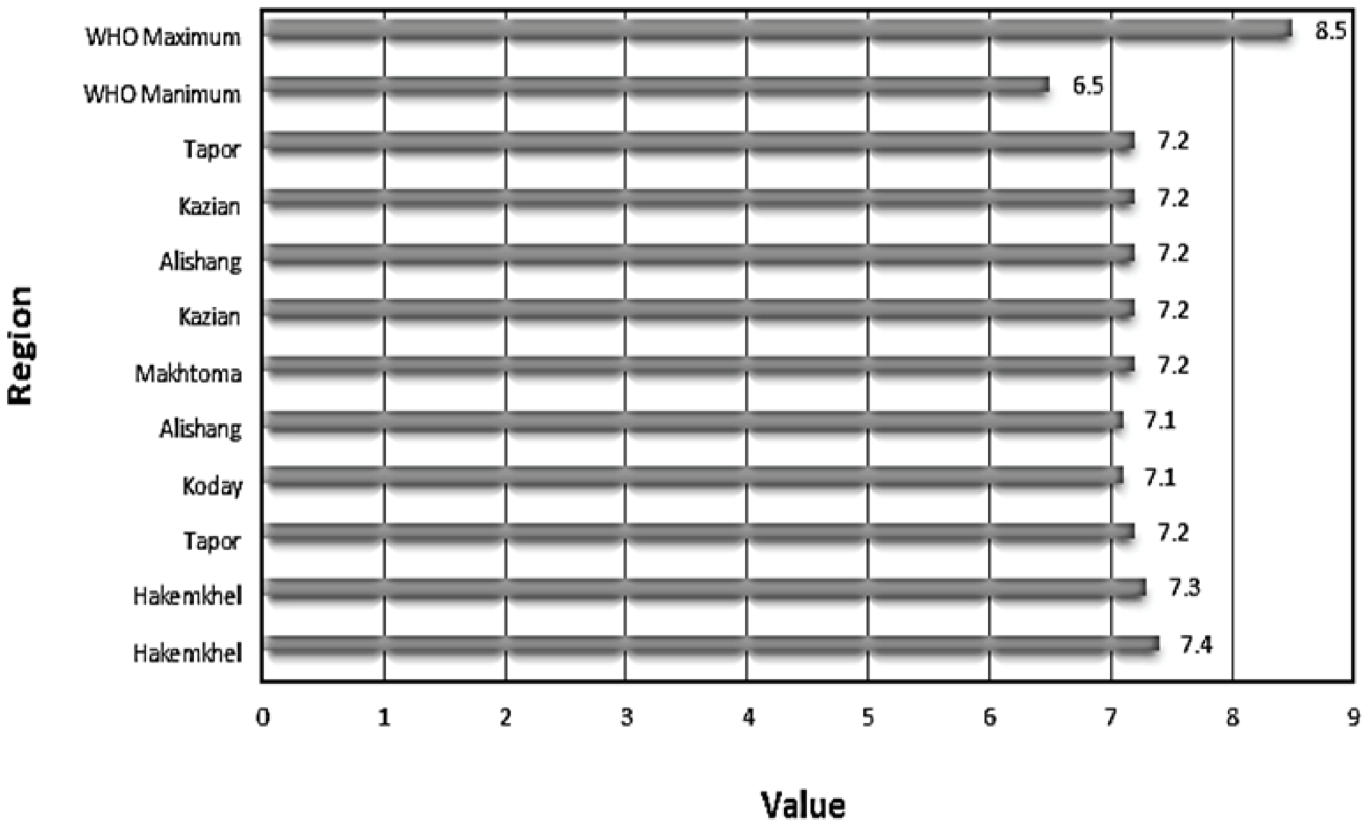

Figure 15. pH and its maximum and minimum rates according to WHO in different wells of Asiab regions.

Table 4. Turbidity of well sample and its comparison to the Asiab regions.

Village	Alishang	Alishang	Tapor	Tapor	Koday	Makhtoma	Kazian	Kazian	Hakimkhal	Hakimkhal
Well Sample	4	3	3	4	4.5	3	3	4	4	5

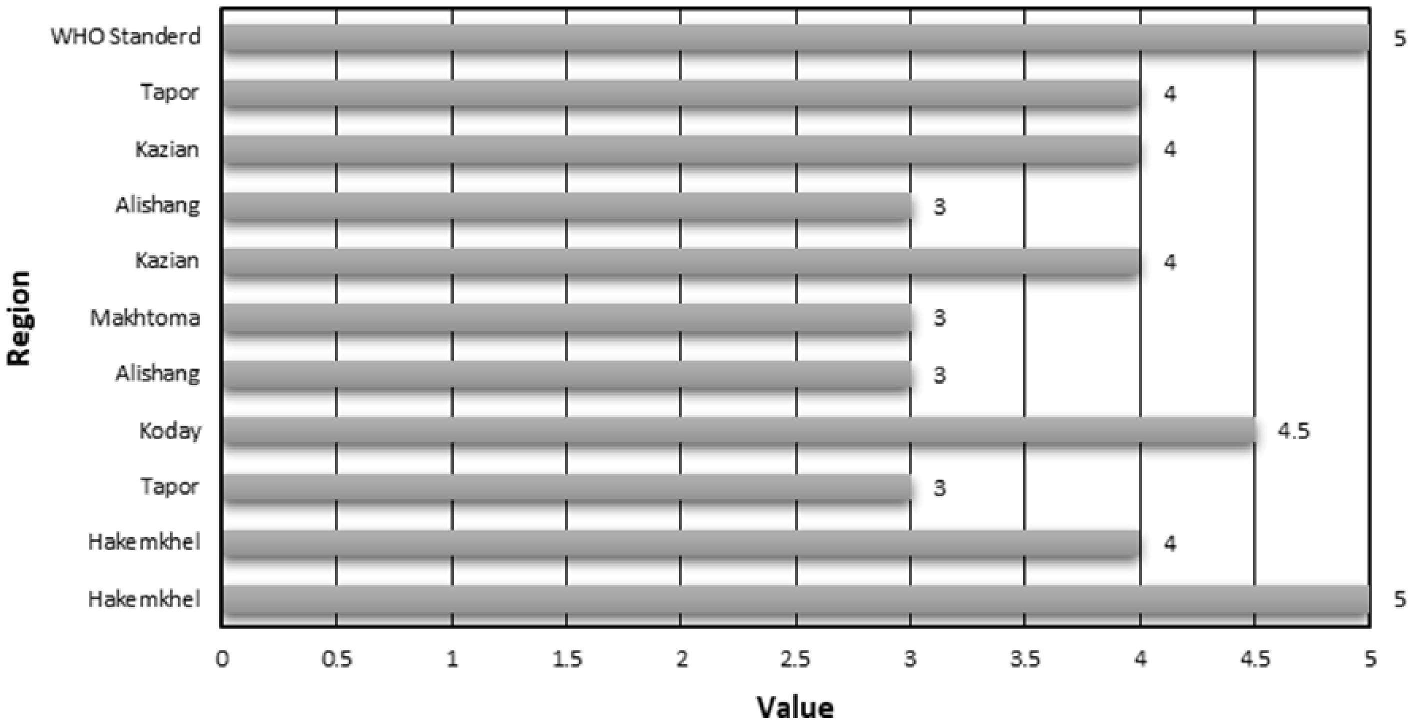

Figure 16. Turbidity in different wells of Asiab regions.

Table 5. The hardness of well sample and its comparison at the Asiab regions.

Village	Alishang	Alishang	Tapor	Tapor	Koday	Makhtoma	Kazian	Kazian	Hakimkhal	Hakimkhal
Well Sample	437	426	426	415	361	361	393	372	500	435

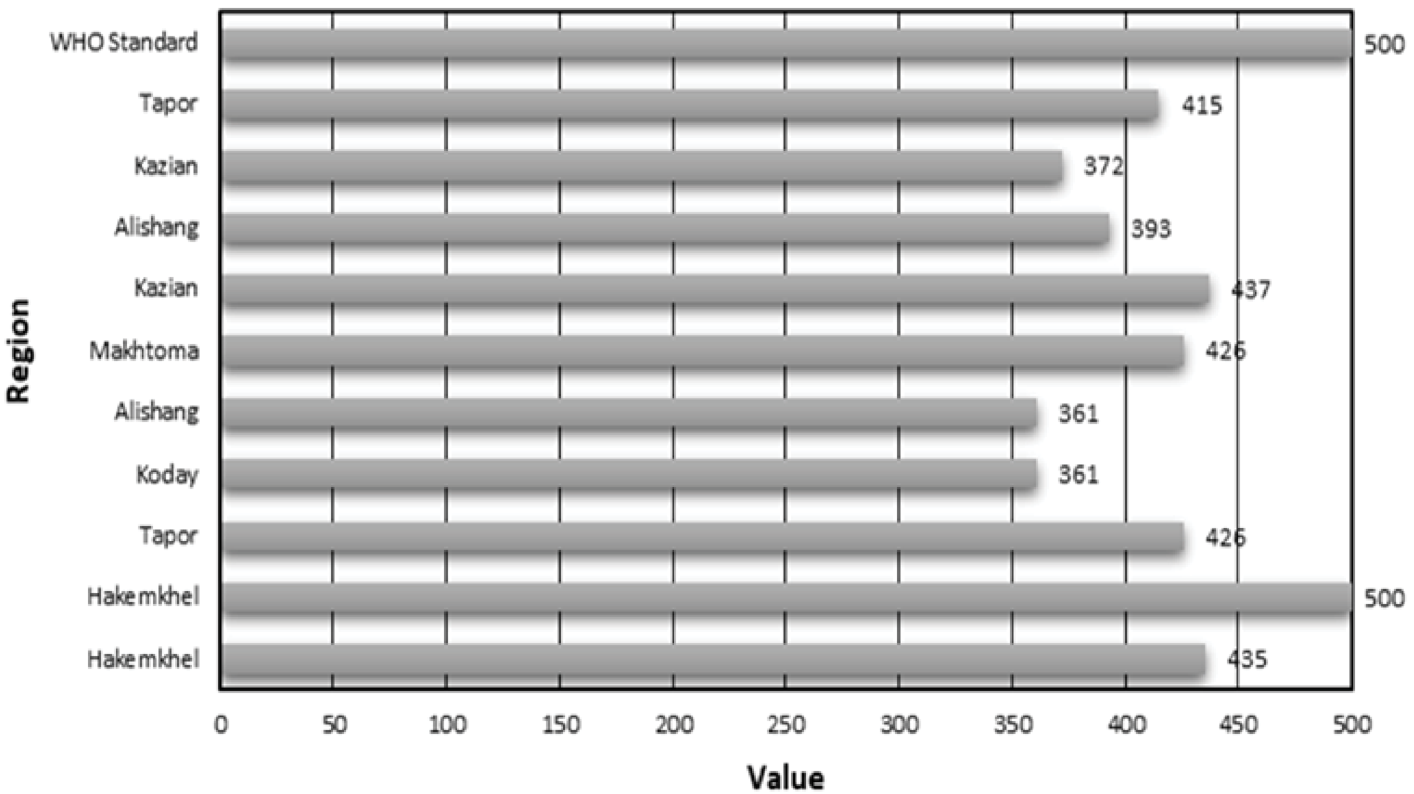

Figure 17. Hardness in different wells of Asiab Regions and its comparison to WHO standards.

In addition, other measurements such as Total Dissolved Solids (TDS), salinity, color and concentrations of Ca, Mg, Na, K, Nitrites, Fe, Mn, Co, Al, As, cyanide, Chlorides, Sulphates, Phosphates and $CaCO_3$ were also measured. Such data will be made available as part of data availability upon request.

Conclusion

The hydrogeological investigation is carried out on the six regions of Asiab (Alishang, Tapor, Kaday, Makhtoma, Kazian and Hakemkhel), in Chack, Wardak Province. Previous studies related to the hydrogeology of the Asiab region are scarce, primarily due to conflict in the region. Since the water consumed by residents and industries for irrigation and water supply purposes is rapidly increasing, it requires more accurate and scientific studies for future planning. Therefore, this investigation sheds some light on this region. For the completion of this research, we used samples of water from 10 wells in these six villages of the Asiab region, which is located at a longitudinal valley parallel to the Wardak mountain range. According to this study, the mean Static Water Level (SWL) is about 25m but in some places 50–70 m. In places near where the river flows, there are more aquifer layers, but are far from the river consisting of aquiclude and aquifuge layers. The aquifer layer is made of unconsolidated materials, but in conglomerates, we can find aquiclude and aquifuge layers. In these regions, more unconsolidated materials are transported hydrologically by gravity and by river streams. Generally, the mountain range and slope areas have bigger sizes, but the plains and regions far from the mountain range consist of fine materials. Those materials accumulated at the skirt of mountains are called talus materials. The river generally consists of gravel, sands and silts and is made from aquifer layers. Furthermore, in plains and in the middle of the longitudinal valleys the thickness of sedimentary materials is greater than in the slope areas. The groundwater quality analysis is used to determine physical and chemical parameters from Asiab regions (drinking water 10 rings of wells), Wardak Prov- ince, in Afghanistan. The relationship between the water column and well depth, Electroconductivity (EC), pH, Turbidity and Hardness are within international standards, which is safe for drinking and irrigation purposes. The results obtained suggest that the water quality can be used efficiently in the other provinces of Afghanistan. The result of the current study could be useful for irrigation water management and as a solution for the current challenges, as Afghanistan recovers from years of conflict in the region and gains knowledge to provide independent sources of clean water and irrigation infrastructure. Based on our extensive experience, the authors can provide policy guidance to local, state and Federal governments in terms of use, reuse, recycling and resource conservation. Also, the data presented here is limited pertaining to the time of measurement, a continuous monitoring network of surface and ground-based sensors is planned to monitor round-the-clock data using smart and connected sensors and cyber-physical systems.

Acknowledgment

The authors extend gratitude to the anonymous reviewers for their valuable comments, as well as to other faculty members who have helped with this project in one capacity or the other.

Conflicts of Interest

The authors declare no conflict of interest – financial or otherwise.

Author Contribution

Conceptualization, H.R. and A.V.; methodology, H.R.; software, H.R., A.V., M.C.; validation, H.R., A.V., M.C.; formal analysis, H.R..; investigation, H.R.; resources, H.R., A.V.; data curation, H.R.; writing—original draft prep- aration, H.R., A.V.; writing—review and editing, A.V.; visualization, M.C.; supervision, H.R.; project administration, H.R., A.V.; funding acquisition, A.V. All authors have read and agreed to the published version of the manuscript."

Funding

This research received no external funding.

Data Availability Statement

Data Availability Statements are available in the Results and Discussion section. Data concerning hydro-chemical investigation results such as water type, hydro-chemical processes, etc. are available upon request. Additional supporting information may be requested by the authors.

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How to cite this article: Vaseashta, Ashok, Hafizullah Rasouli and Mohan Bahadur Chand “Hydrogeological Investigation of Six Asiab Regions in Wardak Province of Afghanistan.” *Hydrol Current Res* 14 (2023): 477.