A Perspective on the Water Resources of Harirud Marghab and Investigation of the Quality of Groundwater in Rural Areas of Herat Province

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***Abstract*—In terms of water resources, Afghanistan has the most suitable and safe water for drinking. Most of the Afghan population's drinking water comes from groundwater. About 90 percent of these people use deep and semi-deep wells, springs, and karezes for drinking. Unfortunately, population growth and technological development in Afghanistan, particularly in the city of Herat, have resulted in groundwater contamination from industrial effluents and a lack of wastewater treatment plants, which affect groundwater levels. A study conducted by the Ministry of Energy and Water on the groundwater level in Herat city has shown that the groundwater level in some areas has dropped by 4 meters in 5 years. However, the main focus of this study is to analyze the groundwater quality surveys conducted by different organizations in the districts of Herat province to determine the current situation of groundwater at district and city levels. After data analysis from different districts of Herat city on some important parameters such as PH, conductivity, and total hardness $CaCO_3$, calcium as $CaCO_3$, magnesium as $CaCO_3$, aluminum as Al, ammonia as NH_4, copper as Cu, fluoride as F, arsenic (As), phosphate (PO_4), iron (Fe), manganese (Mn), nitrate (NO_3), nitrite (NO_2), zinc (Zn), silica (SiO_2), TDS, Turbidity, Temperature shows that the highest value for $CaCO_3$ is 204 mg/l and the highest value for Fe is 0.88 mg/l. To the range $CaCO_3$ and Fe after the WHO is determined, respectively, 150 mg/l and Fe 0.10 mg/l with regard to some arsenic levels, Guriyan district is considered to exceed the standard.**

***Keywords*—groundwater, water quality, contaminations, investigation, turbidity**

I. INTRODUCTION

There are five major basins in Afghanistan, Amu Darya or Northeastern, Kabul or Eastern, Helmand or Southern, Western and Northern [1, 2]. In western basins, there are Hari Rud, Kushk, Murghab, Farha Rud and other small rivers. In 10% area of Afghanistan, there is no drainage system [3]. Amu Darya covers 14% area and contributes 57% water resources. Likewise, Helmund basin covers 41% area contributing 11% water, Northern basin covers 11% area contributing 2% water and Kabul basin covers 11% area and contributes 26% water [4]. Hari Rud-Koshk-Murghab river basins cover 12% area but contribute only 4% water resources [5–8].

Although Afghanistan is located in a semi-arid environment, it is still rich in water resources, mainly because of the high mountain ranges such as the Hindu Kush and Baba, which are covered with snow. Natural snow storage at elevations above 2,000 m represents 80 percent of Afghanistan's water resources, excluding fossil groundwater [9–11]. The amount of water received in these areas through precipitation is estimated to be in the order of 150 billion m^3. The rest of the country receives only 30 billion m^3 annually through rainfall, resulting in a total of 180 billion m^3 for the whole country. Ten percent of this is assumed to be groundwater (Table 1). There is no consistency in groundwater estimation Table 2 [12, 13].

Table 1. Afghanistan's water scenario in billion m^3 (Billion Cubic Meter) —International Water Management Institute, 2002

Resources	Current Scenario	Use	Remained
Surface Water	57	20	37
Groundwater	18	3	15
Total	75	23	52

Table 2. Groundwater scenario in million m^3 (MCM)—Afghan human Dev report, 2011

	Uhl-2003	FAO-1996	
Basin	**Recharge**	**Recharge**	**Use**
Kabul	1920	2870	530
Helmand	2480	3650	1500
Western	500	1850	300
Hari Murghab	640	980	160
Northern	2140	2900	210
Panj-Amu	2970	4500	100
Total	10,650	16,750	2,800

The Hari Rud River originates in central Afghanistan, flows west for 560 km, forms a 90 km border with Iran, and serves as the boundary with Turkmenistan, with a downstream altitude near Herat of 930 m [14]. There this river disappears in Tedjen oasis that could be the reason this is called Tedjen in Turkmenistan. The catchment area within Afghanistan is 39,000 sq km. Its width varies from 40 to 100 km. Discharge of Hari Rud is high in April-May as high as 180 cumecs (Rabat-e-Akhond) [15]. In another month it is as low as 0.1 cumecs (Tirpul) [16–18]. Tributary system is better developed in left bank. Main left bank tributary is Kawgan river about 260 km long with a catchment area of 7,820 sq km. Main right bank tributary is Karukh river, confluencing few kilometers upstream of Herat. It is 95 km long and has 1,720 sq km catchment area [19–21].

II. METHODOLOGY

Groundwater wells were first drilled in the Hari Rud River in 1967 by Germans, followed by British efforts in 1972 and Soviets in 1975, all indicating groundwater potential. However, this study primarily focuses on water quality tests conducted by organizations such as DACAAR, WHO, FAO, and HMRB. Samples from 12 districts of Herat city were tested for parameters like EC, TDS, pH, and water temperature using the YSI multiparameter device in the field, offering a comprehensive analysis of critical parameters for water quality assessment [22]. Additionally, the methods of data collection are done differently by the organizations; site testing is mostly done by government organizations, such as the Ministry of Energy and Water, by geologists, and lab testing methods are done by non-government organizations.

III. RESULT AND DISCUSSION

According to the sample analysis from 11 wells in Karukh district, 11 wells in Pashton Zarghun, 182 wells in Guzara, 6 wells in Enjil, 8 wells in Zindajan, 17 wells in Ghoryan, 10 wells in Kohsan, and 19 wells in Gulran districts, the results are shown in Fig. 2 as the maximum and min range of EC, and also Fig. 3 shows the range of PH in the mentioned wells from different districts.

As per the DACAAR data base, in Karukh district, there are 173 dug wells constructed between 1995 and 2002, ranging in depth from 6 to 45 m and varying in water level from 4 to 42 m. Likewise, there are 78 deepened wells constructed between 1995 and 1998, showing their depths vary from 7 to 48 m and their water level from 5.5 to 46.8 m. Regarding water quality, some 11 dug wells have data. Two wells show 10 ppb arsenic content. pH is between 7.4 and 8.2. A 81-meter-deep tube well-constructed in 2007 by RECOL has some hydrogeological data. On 81 m deep tube well-constructed in 2007 by RECOL has some hydrogeological data.

This well is 10 inches in size and has 13 m of screened zones from 36 to 44 m and 70 to 75 m. There are permeable zones from 33 to 45 m and 69 to the total drilled depth of 81 m. The static water level then was 22 m, and with 18 m of drawdown, the discharge was 15 l/sec. The specific capacity of the well is 0.83 l/s/m. Two aquifers are clearly visible. Both are confined and separated by a 24-meter clay layer. However, the separated testes are explained in the Table 3: Result of water chemical analysis from the depth research well in Herat Province [21, 23].

In Pashtun Zarghun District, groundwater infrastructure comprises 163 dug wells (1998–2004, depth: 4.2–56 m), 230 deepened wells (1998–2000, depth: 7–58 m), and 103 tube wells (2001, depth: 14.7–62 m). Water quality analysis from 11 dug wells indicates an Electrical Conductivity (EC) range of 478 to 1130 S/cm, with two wells showing 50 ppb arsenic content. pH levels range from 7.66 to 7.9. Lithological logs from tube wells and hydrogeological information from a 68m RECOL well (2007) provide insights into screened and permeable zones, static water levels, and discharge rates. Notably, two confined aquifers separated by an 8m clay layer are discernible. (See Table 4)

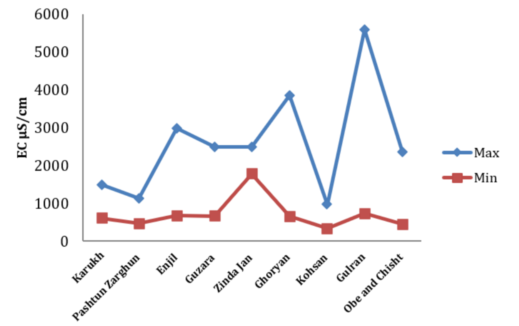

Fig. 2. The maximum and minimum range of EC in 9 districts of Herat City.

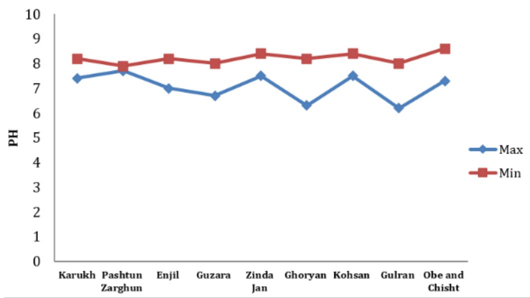

Fig. 3. The maximum and minimum range of PH in 9 districts of Herat City.

Table 3. Result of water chemical analysis from the depth research well in Herat Province

Parameters	Awgha-Zandijan	Eid Gah Zindajan	Dashti House Injil	Guzara No1	Guzara No2	Guzara No3	Herat Center	Kosan City	Ghuryan City	Roj Ghuryan	Units
PH	7.75	7.5	6.74	7.91	6.94	7.64	6.84	6.51	6.72	6.83	–
Conductivity	1897	1225	1606	986	1510	612	915	1121	1480	616	µs/cm
Total $CaCO_3$	316	392		280	444	315.79		189.33	116		mg/L
Calcium as $CaCO_3$	136	236	114.24	144	216	165.64	142.8	78.67	32	159.12	mg/L
Magnesium as $CaCO_3$	180	156	159.12	136	228	150.15	204	110.66	84	142.8	mg/L
Almumium as Al	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Ammonia as NH_4	0.05	0.1	ND	ND	ND	ND	ND	ND	0.01	ND	mg/L
Copper as Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Fluoride as F	ND	ND	0.06	ND	0.03	0.07	0.05	ND	ND	0.08	mg/L
Arsenic as As	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Phosphate as PO_4	0.06	0.04	0.04	0.03	0.01	0.06	0.05	0.09	0.03	0.03	mg/L
Iron as Fe	0.07	0.1	0.74	0.13	0.12	0.64	0.88	0.05	0.18	0.29	mg/L
Manganese as Mn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Nitrate as NO_3	13.45	1.95	17.41	8.97	9.84	21.63	19.84	9.07	ND	27.46	mg/L
Nitrite as NO_2	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.03	Nil	mg/L
Zinc as Zn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Silica as SiO_2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L

(Details of the table: ND = Not Detected, Nil = No zero of each sample = 1.5; L) WHO limits of drinking water have been reported. [24, 25].

Table 4. Result of analysis water sample from the depth research well in Herat Province

Parameters	Awgha-Zandijan	Eid Gah Zindajan	Dashti House Injil	Guzaa No1	Guzaa No2	Guzaa No3	Herat Center	Kosan City	Ghuryn City	Roj Ghuryn	Units
PH	7.75	7.5	6.74	7.91	6.94	7.64	6.84	6.51	6.72	6.83	–
Conductivity	1897	1225	1606	986	1510	612	915	1121	1480	616	µs/cm
Total Hardness $CaCO_3$	316	392		280	444	315.7		189.3	116		mg/L
Calcium as $CaCO_3$	136	236	114.24	144	216	165.6	142.8	78.67	32	159.12	mg/L
Magnesium as $CaCO_3$	180	156	159.12	136	228	150.1	204	110.6	84	142.8	mg/L
Almumium as Al	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Ammonia as NH_4	0.05	0.1	ND	ND	ND	ND	ND	ND	0.01	ND	mg/L
Copper as Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Fluoride as F	ND	ND	0.06	ND	0.03	0.07	0.05	ND	ND	0.08	mg/L
Arsenic as As	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Phosphate as PO_4	0.06	0.04	0.04	0.03	0.01	0.06	0.05	0.09	0.03	0.03	mg/L
Iron as Fe	0.07	0.1	0.74	0.13	0.12	0.64	0.88	0.05	0.18	0.29	mg/L
Manganese as Mn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Nitrate as NO_3	13.45	1.95	17.41	8.97	9.84	21.63	19.84	9.07	ND	27.46	mg/L
Nitrite as NO_2	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.03	Nil	mg/L
Zinc as Zn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
Silica as SiO_2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	mg/L
TDS	730	560	830	450	640		830	710	690	1660	mg/L
Turbidity											NTU
Temperature	24	17	21	22	23		18	24	27	26	°C

IV. Conclusion

This thorough investigation into Herat province's groundwater dynamics, spanning districts like Enjil, Guzara, Zinda Jan, Ghoryan, Kohsan, and Gulran, provides valuable insights into the diverse well structures employed. The array of dug wells, deepening wells, and tube wells underscore the region's reliance on a multifaceted groundwater network. Water quality assessments across districts reveal notable variability in Electrical Conductivity (EC) levels and pH values. In Enjil, the observed EC spans 681 to 4100 S/cm, with a pH range of 7 to 8.2. Guzara displays EC variations from 668 to 2500 S/cm, accompanied by a pH range of 6.69 to 8. In Zinda Jan, EC levels range between 1780 and 2500 µS/cm, with pH values from 7.5 to 8.4. Ghoryan exhibits EC fluctuations between 663 and 3850 µS/cm, with a pH range of 6.3 to 8.2. Kohsan's water quality data indicates EC variations from 972 to 16,340 µS/cm, and a pH range of 7.5 to 8.4. In Gulran, EC levels span from 745 to 5590 µS/cm, with a pH range of 6.2 to 8.

Hydrogeological insights derived from key tube wells deepen our understanding of discharge capacity, drawdown levels, and seasonal variations in the aquifer dynamics across the lower Hari Rud River basin. While the specific numerical estimates of aquifer recharge are not explicitly provided, the study indicates a potential for sustainable groundwater utilization. Water quality considerations, aligned with WHO drinking water standards, uncover challenges such as elevated iron content in specific districts. The identified iron removal methods offer practical solutions to enhance water quality for safe consumption, emphasizing the study's relevance to real-world applications.

In essence, this research underscores the significant groundwater resource potential in the lower Hari Rud River basin, providing a comprehensive understanding of aquifer characteristics, well infrastructure, and water quality. The specific water quality data presented here adds granularity to the findings, facilitating informed decision-making and setting the stage for future research endeavors in groundwater dynamics in Herat province.

Conflict of Interest

The authors affirm that they have no conflicts of interest to disclose.

Author Contributions

Each author has made substantial contributions to the article, and all are considered equal contributors.

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