



## **ARSENIC CONTAMINATION OF GROUNDWATER IN PANJSHER PROVINCE AFGHANISTAN**

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### **SCIENTIFIC INVESTIGATION REPORT**

Author:

M. Hassan Saffi, Hydro-geologist

Ahmad Jawid Kohistani, Hydro-geologist

Edited by:

Abdul Halim Zaryab

Professor of Engineering Geology and hydrogeology of Kabul Polytechnic University

**March, 2016**

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Paikob-e-Naswar, Wazirabad, PO Box 208, Kabul, Afghanistan

Phone: (+93)(020) 220 17 50 Mobile (+93)(0)70 28 82 32

E-mail: [dacaar@dacaar.org](mailto:dacaar@dacaar.org) Website: [www.dacaar.org](http://www.dacaar.org)

## LIST OF ABBREVIATIONS

DACAAR	Danish Committee for Aid to Afghan Refugee
ECHO	European Commission Directorate General – Humanitarian aid and Civil Protection
UNICEF	United Nation Children Fund
WASH	Water Sanitation and Hygiene
WHO	World Health Organization
USEPA	United State Environmental Protection Agency
DWPs	Drinking Water Points
NDWQS	National Drinking Water Quality Standard
GWMs	Groundwater Monitoring Wells
GWM_ID	Groundwater Monitoring Wells Identity Number
EC	Electrical Conductivity
mg/L	Milligram per letter
°C	Degree Celsius
AquaChem	Integrated water quality data management, analysis, plotting and modeling.
DWPs	Drinking Water Points
µS/cm	Micro-mhos per centimeter
As <sup>3</sup>	Arsenite
As <sup>5</sup>	Arsenate
r	Correlation coefficient
WSs	Water Samples

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## ABSTRACT

In Afghanistan, Arsenic (total Arsenic) contamination is an issue of current drinking water supply systems using groundwater and has recently been one of the major environmental health management issues in Panjsher province as well as in Afghanistan. The community inhabitants still use hand pumped tube wells, dug wells and spring for their daily water requirements, including drinking water. The Arsenic contaminated groundwater used for drinking can cause adverse effect of human health of the study area.

The water quality study with 241 samples from drinking water points (DWPs) have been carried in Bazarak, Dara, Khenj, Paryan, Rukha, Shutul and Unaba districts of Panjsher province. 46 out of 241 water samples were sampled for chemical analyses. The Bazarak, Rukha and Unaba districts sampled waterpoints show arsenic contamination and concentration values range from 0.00 mg/L to 0.4 mg/L. 12% of water samples (46 out of 241 samples) have considerably Arsenic concentration values.

The outcome of this research study shows that Bazarak, Rukha and Unaba districts are vulnerable on the contamination groundwater sources from arsenic. Moreover this report assists to develop a mitigation policy to control potential contamination of arsenic in the water sources of Panjsher province.

Keyword: Sampling Drinking Water Points, *Distribution and Occurrence*, Arsenic Contamination, Hydrochemistry.

## **1 INTRODUCTION**

The inhabitants of study areas are heavily dependent on groundwater containing elevated level of arsenic contamination. Therefore, an understanding of the occurrence, behavior, and sources of arsenic concentrations along with other water quality parameters in the DWPs is essential to implement drinking-water supply schemes.

This study carried out analyzing physical and chemical parameters integrates data sets from UNICEFE (2014), ECHO (2014) funded projects and National Groundwater Monitoring Wells (GMWs) networks to understand the spatial distribution of arsenic concentration along with the hydrochemistry of groundwater in study areas.

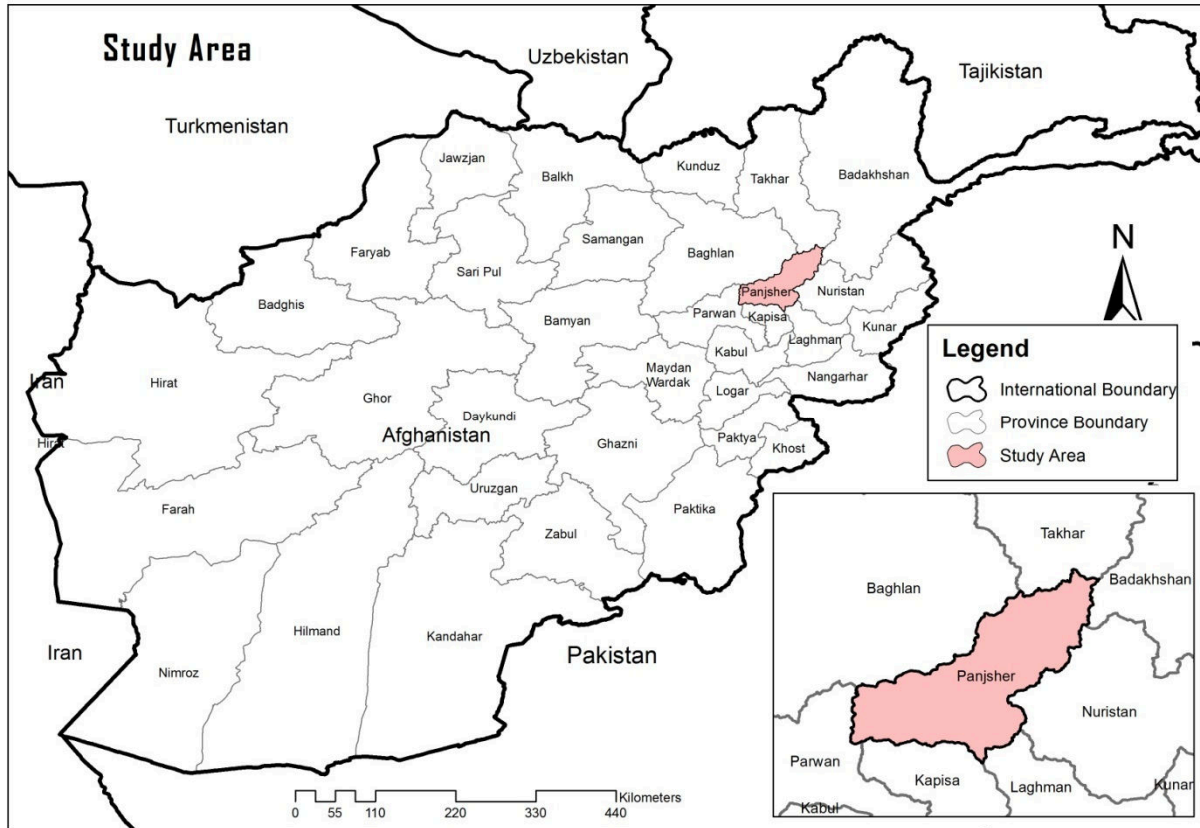
The WHO guideline (WHO, 2004),USEPA standard (USEPA,2001) and Bureau of Indian drinking water standard for arsenic concentration in the drinking water is 0.01 mg/L. [1, 2, 3], however the NDQWSfor drinking water is 0.05 mg/L [4].

This study focuses the distribution and occurrence of high arsenic concentration in DWPs of study areas, but there are no clinical information regarding to the health effect of high arsenic content drinking water.

## **2 METHODS/EXPERIMENTAL**

### **2.1 Description of Study Area**

Panjsher is one of the thirty-four provinces of Afghanistan which is located in the northeastern part of the country. The province is divided into seven districts and contains 512 villages. It is located in the North- east direction of Kabul and geographically, it is situated between latitude 35.90168–35.90168 and longitude 69.23965–70.30276 (Figure 1). It covers total area of about 3,610 with population of about 146, 10 [5]. It has semi- arid and climate with major fluctuation in day- and night-time fluctuations. The winter is characterized by low temperatures of less than -20 °C while the summer is dominated by high temperatures of more than 30°C. The rainfall and snowfall are the main source of groundwater and surface water[6]. The location of study are is shown in the Figure 1.



**Figure 1. Study Area**

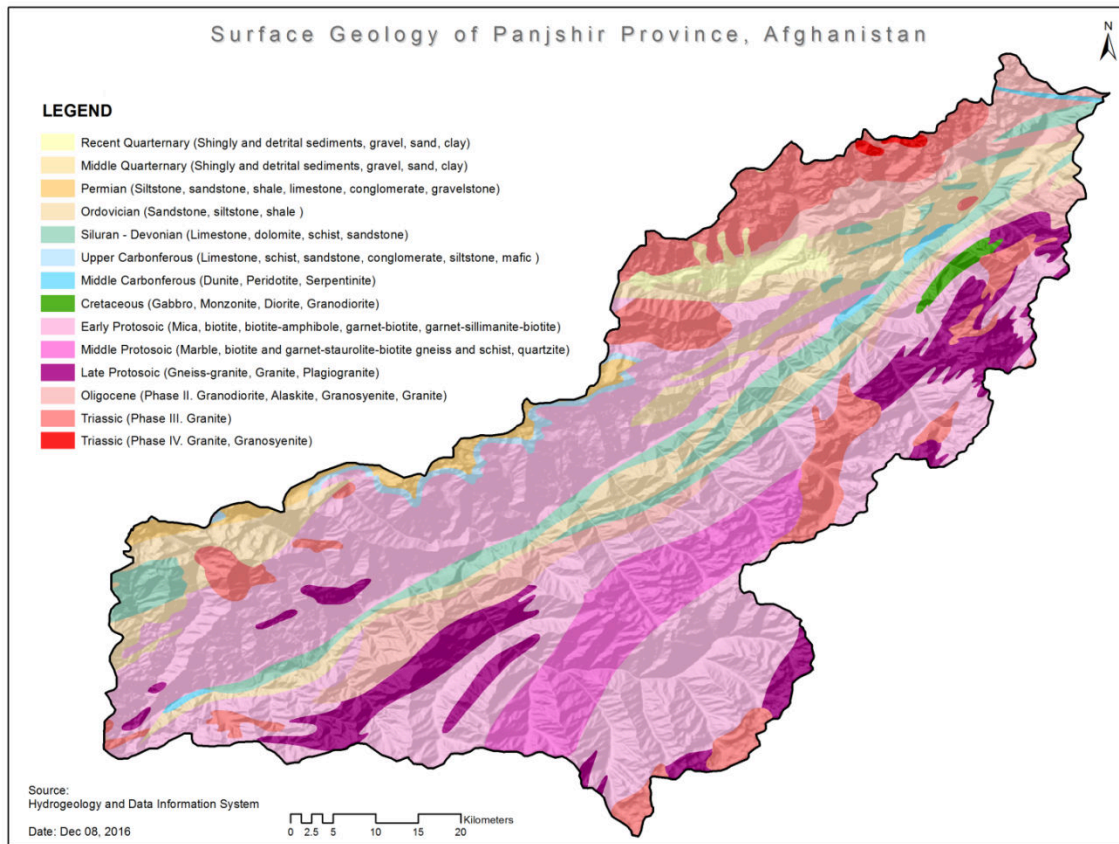
## 2.2 Geology of study area

The main Geology of the study area is classified:

- Recent Quaternary: Shingly and detritus sediments, gravel, sand, clay.
- Middle Quaternary: Shingly and detritus sediments, gravel, sand, clay.
- Permian: Siltstone, sandstone, shale, limestone and conglomerate.
- Ordovician: Sandstone, siltstone and shale
- Silurian – Devonian: Limestone, dolomite, schist, sandstone.
- Upper Carboniferous: Limestone, schist, sandstone, conglomerate and siltstone
- Middle Carboniferous: Dunite, peridotite and serpentines
- Cretaceous: Gabbros, Mennonite, diorite, granodiorite
- Early Protosoic: Mica, biotite, biotite-amphibole, garnet-biotite, garnet-sillimanite-biotite.
- Middle Protosoic: Marble, biotite and garnet-staurolite-biotite gneiss and schist, quartzite, amphibolites)

- Late Protozoic: Gneiss-granite, granite and plagiogranite
- Oligocene: Phase II granodiorite, alaskite, granosyenite and granite
- Triassic: Phase III Granite
- Triassic: Phase IV granite and granosyenite.

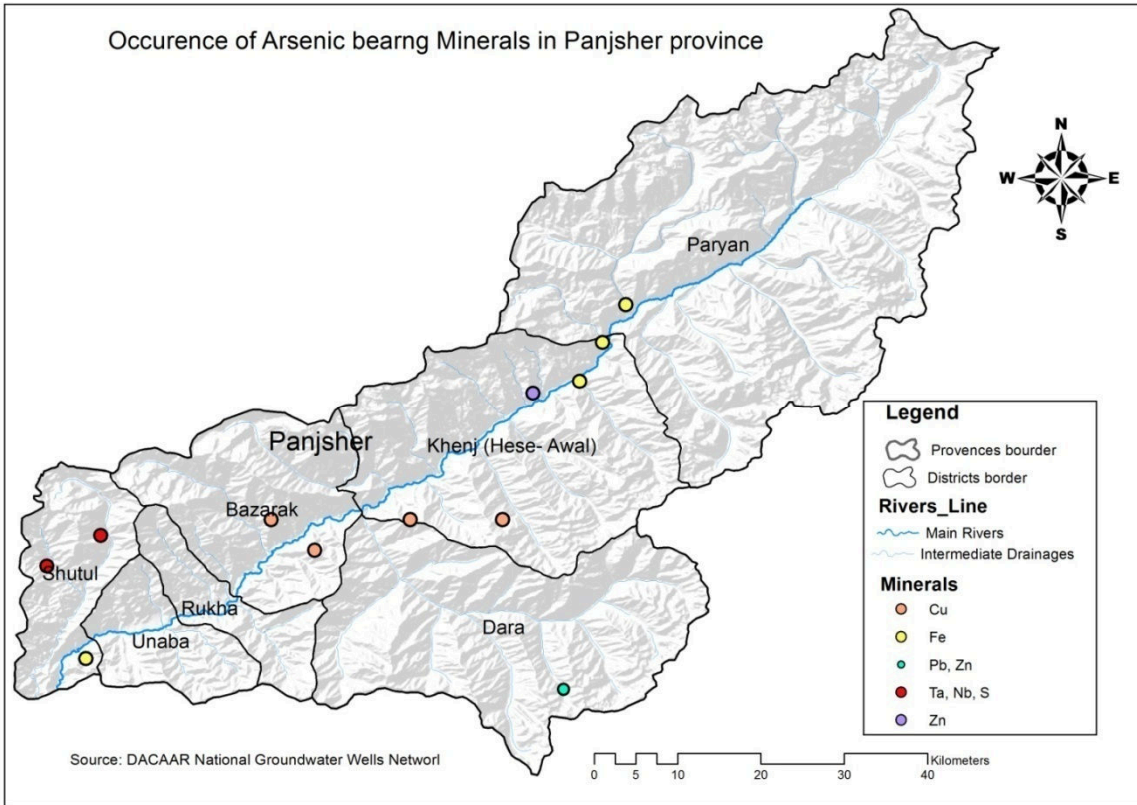
The Geology of the area is shown in the figure 2.



**Figure 2. Surface Geology of Study Area**

### 2.3 Occurrence of Arsenic concentration in groundwater

In the areas where is considered Arsenic concentration in the drinking water points, there are occurred coppers, irons, leads, zincs Mines. Therefore, the Mine deposits most probably caused to contribute to the Arsenic contamination as well as other trace elements in the groundwater. The figure 3 show the occurrence of copped, irons leads and zincs Mines.



**Figure 3. Arsenic Bearing Minerals**

### 2.3 Sampling and field measurement

In total 241 water samples of DWPs (hand pumps tube wells , dug wells and spring) and also from the Panjsher River were collected and tested on site for measurement of arsenic concentration values and physical parameters like temperature, pH and electrical conductivity (EC) using Digital Arsenator and pH/conductivity meter (Figure 3). 46 out of 241 water samples were sampled for chemical analyses.

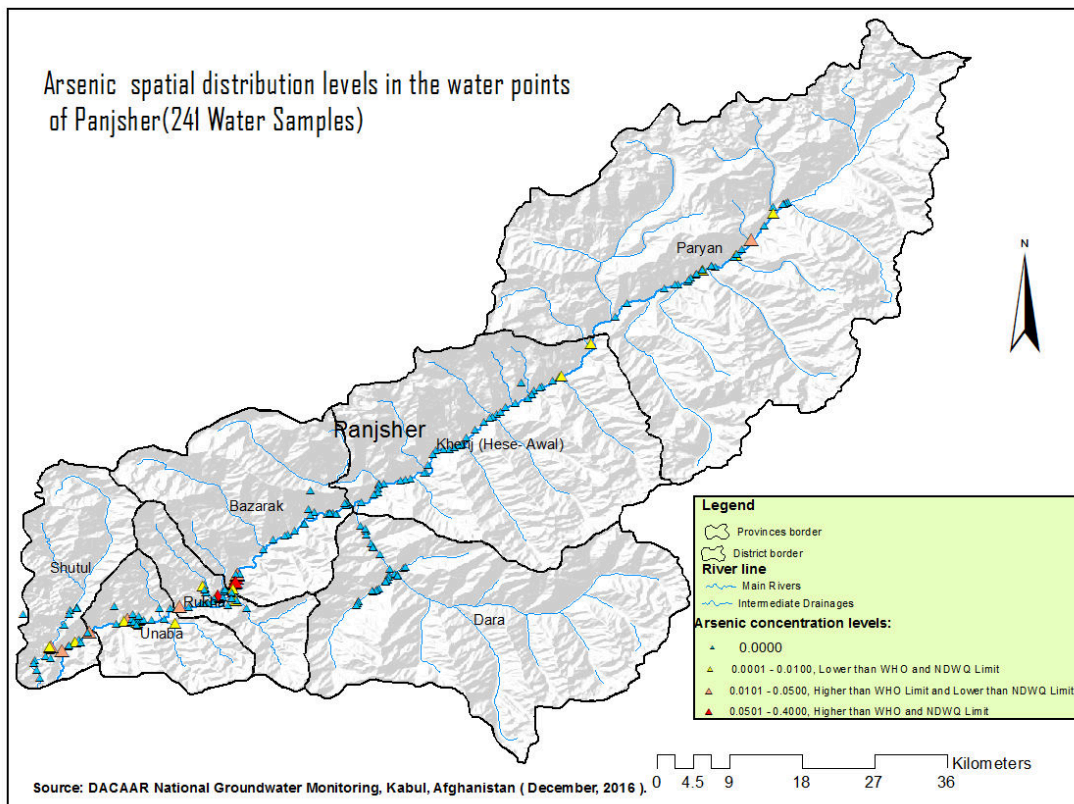
Before collection of samples, each hand-pump was flushed for about 10 minute. The samples were then collected in sterilized 500 mL polyethylene bottle according to the DACAAR’s water sample collection procedure. All samples were immediately shifted to the laboratory and stored to the refrigerator at 4 °C in the dark until analysis. The water samples were chemically analyzed for 34 parameters. The analytical data quality was insured through collection of duplicate samples chemical analysis and comparison. The ionic charge balance of each samples were less than 5%.



### 3 RESULTS AND DISCUSSION

#### 3.1 Distribution pattern of Arsenic concentration

The water samples from Panjsher River and its tributaries didn't indicate any arsenic concentration. Arsenic concentration in the groundwater is Geologic occurrence and its special distribution levels are irregular trough the study areas: 1) the 15 % (5 out of 31) sampled water points of Bazarak district indicated arsenic contamination and the concentration values range between 0.021 mg/L and 0.20 mg/L; 2) 3% (1 out of 30) of sampled water of Khinj district DWPs indicated arsenic contamination and the concentration value is 0.0020 mg/L; 3) the 16.5% (6 out of 35) of sampled water points of Paryan district indicated arsenic contamination and the concentration values range between 0.0020 mg/L and 0.045 mg/L; 4) 12.5% (4 out of 32) sampled water points of Rukha district indicated Arsenic contamination and the concentration values range between 0.002 mg/L and 0.40/L; 5) 11% ( 4 out of 36) sampled water points of Shutul district indicated Arsenic contamination and the concentration values range between 0.005 mg/L and 0.0310 mg/L and; 6) 25% (9 out of 36) sampled water points of Unaba district indicated Arsenic contamination and the concentration values range between 0.005 mg/L and 0.05 mg/L. The Arsenic concentration distribution level is shown in the figure 4.



**Figure 4. Sampled Location and Arsenic Spatial Distribution Levels**

## 4 HYDROCHEMISTRY OF GROUNDWATER

The major ions, pH and EC parameters of groundwater were plotted by Durov diagram (figure 5) using AquaChem2014.2[7]. The Figure5 illustrates hydro- chemical facies with respect pH and electrical conductivity of DWPs (groundwater) within the hydro geological boundaries of study areas. The dominant in ions in the water samples are  $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$  and the dominant cat-ions in the water samples are  $\text{Na}^+ > \text{Ca}^{2+} > \text{Mg}^{2+}$ . The main water types are Na-Ca- $\text{CO}_3$ , Na-Mg- $\text{CO}_3$ , Ca-Mg-Na- $\text{CO}_3$ , Na- $\text{HCO}_3$ -and Mg-Ca- $\text{HCO}_3$ - $\text{SO}_4$ -Cl. These different chemical compositions may be due to weathering and dissolution of calcite, dolomite, silicate, sulfide and other minerals. High  $\text{HCO}_3^-$  is ubiquitous in groundwater in Afghanistan which, play an important role in hydro chemical evolution and trace metal mobilization.

The EC ranged from  $145 \mu\text{S}/\text{cm}$  to  $2970 \mu\text{S}/\text{cm}$ . The pH values of samples ranged from 6.1 to 8.8 and most of sampled water points are shown alkaline characteristic.

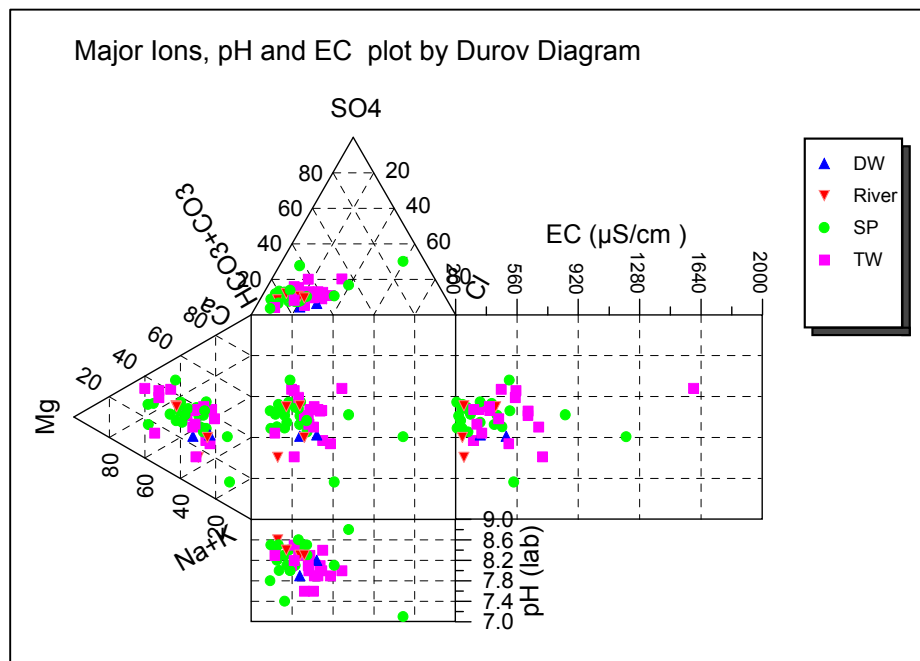


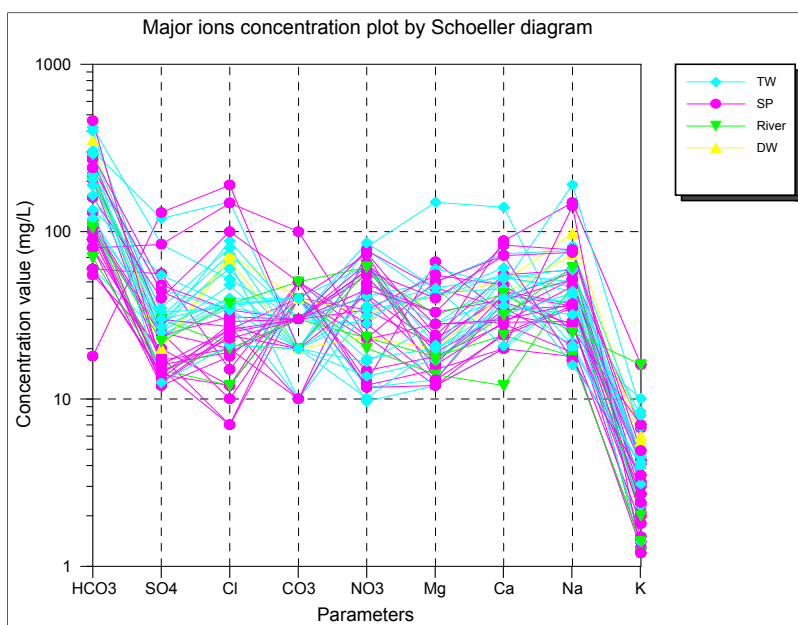
Figure 5. Major Ions, pH and EC Diagram

### 4.1 Hydro chemical statistical analysis

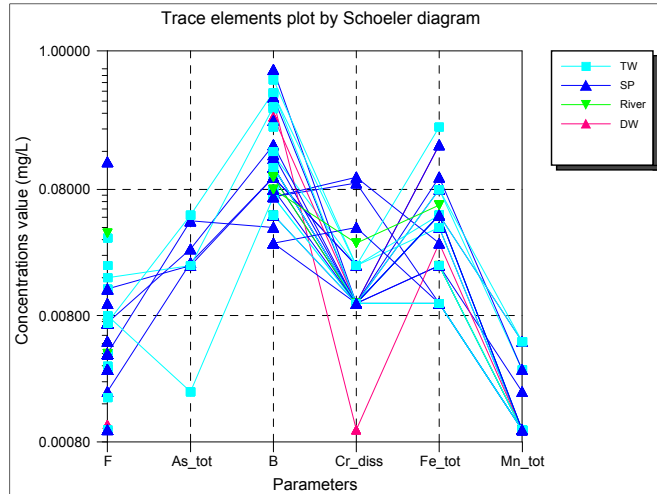
The 106 sampled chemical tested data were analyzed statistically and the characteristic features of groundwater indicated the presence of total As (0.001- 0.999 mg/L), total Fe (0.000-0.0512m/L),  $\text{Na}^+$  (16-191 mg/L),  $\text{K}^+$  (1.2-16 mg/L),  $\text{Ca}^{2+}$  (12-140 mg/L),  $\text{Mg}^{2+}$  (12-150),  $\text{Cl}^-$  (7-190 mg/L),  $\text{SO}_4^{2-}$  (3-248 mg/L),  $\text{NO}_3^-$  (4.2-127 mg/L), F (0.03-1.25 mg/L), Cu (0.00-1.25 mg/L),  $\text{NH}_4$  (0.00-0.610 mg/L), Mn (0.00-0.005mg/L), Cr (0.00-0.0.101 mg/Land  $\text{HCO}_3^-$ (18.00-460.00 mg/L). The Hydro chemical Statistic Analysis result is shown in Table 1 and figure 6 and 7.

**Table 1. Water Quality Statistic Analysis Results**

No.	Elements	Unit	Statistics				Acceptable Limit	
			Count	Mine	Max	Main	WHO	NDWQS
1	Total_As	mg/L	241	0.000	0.4	0.005	0.01	0.05
2	EC		241	130	1595	520	1500	3000
4	pH		241	7.04	8.84	8.15	6.5-8.5	6.5-8.5
5	F	mg/L	241	0.03	1.25	0.24		
6	Turbidity	NTU	241	0.04	8.3	2.43	5	5
7	Na <sup>+</sup>	mg/L	46	16	191	50.52	200	200
8	K <sup>+</sup>	mg/L	46	1.2	16	4.26		
9	Ca <sup>2+</sup>	mg/L	46	12	140	44.04	75	75
10	Mg <sup>2+</sup>	mg/L	46	12	150	30.71	30	30
11	HCO <sub>3</sub> <sup>-</sup>	mg/L	46	18.00	460.00	130.2		
12	Cl <sup>-</sup>	mg/L	46	7	190	44.5	250	250
13	SO <sub>4</sub> <sup>2-</sup>	mg/L	46	12	130.00	30.60	250	250
14	NO <sub>3</sub> <sup>-</sup>	mg/L	46	9.7	85.76	40.80	50	50
15	NO <sub>2</sub> <sup>-</sup>	mg/L	46	0.001	0.132	0.012	3	3
16	PO <sub>4</sub>	mg/L	46	0.000	1.000	0.001		
17	Cu	mg/L	46	0.00	1.25	0.099	2	2
18	NH <sub>4</sub> <sup>+</sup>	mg/L	46	0.00	0.610	0.056		
19	Mn	mg/L	46	0.00	0.005	0.0009	0.3	0.3
20	Cr	mg/L	46	0.00	0.101	0.011	0.05	0.05
21	Br	mg/L	46	0.010	0.980	0.255		
22	Al	mg/L	46	0.00	0.031	0.0043	0.02	0.02
23	B	mg/L	46	0.0300	0.670	0.168	2.4	2.4
24	PO <sub>4</sub>	mg/L	46	0.000	1.001	0.120		
25	Fe	mg/L	46	0.000	0.25	0.0512	0.3	0.3



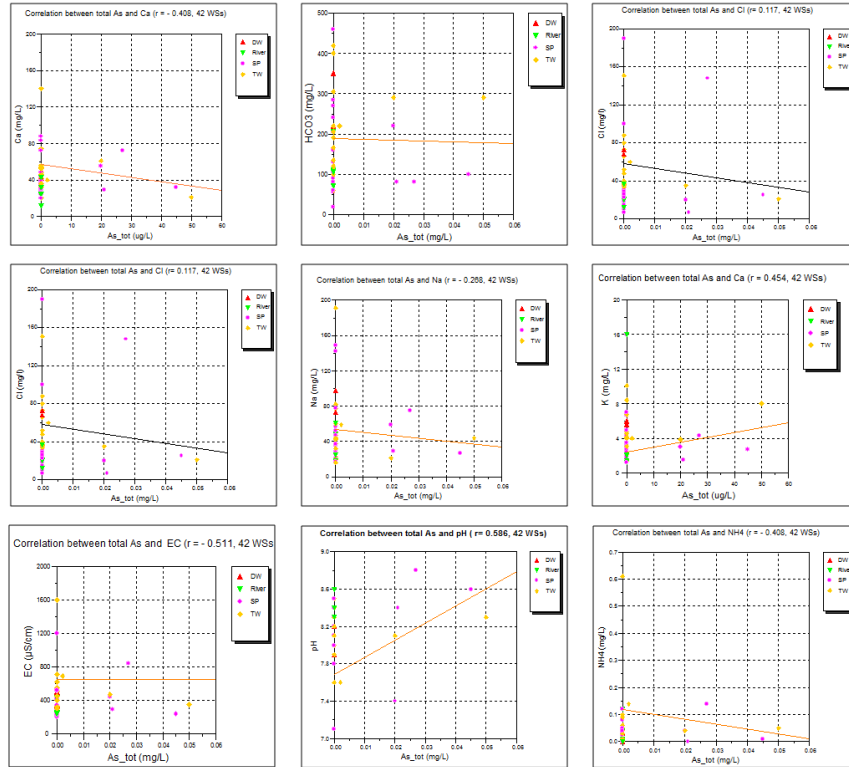
**Figure 6. Major ions Concentration Plot by Schoeller Diagram**



**Figure 7. Trace Elements Plot by Schoeller Diagram**

## 4.2 Correlation Analysis

For understanding the correlation mechanism of As concentration in the groundwater, the correlation coefficient ( $r$ ) of arsenic with pH ( $r = 0.586$ ),  $\text{Ca}^{++}$  ( $r = 0.408$ ),  $\text{Mg}^{++}$  ( $r = 0.182$ ),  $\text{Na}^+$  ( $r = -0.268$ ), EC ( $r = -0.511$ ),  $\text{SO}_4^{--}$  ( $r = -0.267$ ),  $\text{K}^+$  ( $r = 0.454$ ),  $\text{Cl}^-$  ( $r = -0.032$ ),  $\text{HCO}_3^-$  ( $r = -0.037$ ),  $\text{Mn}^{++}$  ( $r = 0.140$ ), total Fe ( $r = -0.706$ ),  $\text{NO}_3^-$  ( $r = 0.317$ ),  $\text{NH}_4^+$  ( $r = -0.579$ ),  $\text{SiO}_2$  ( $r = 0.156$ ) and  $\text{F}^-$  ( $r = 0.058$ ) were plotted by scatter plots using AquaChem 2014.1 software. The correlation analysis of arsenic with other water quality indicated complex hydro-chemical processes which contribute to mobilization of arsenic in groundwater of the study area. The correlation between  $\text{SO}_4^{--}$  and pH is negative, which would be the result of sulfide oxidation. The influencing hydro-chemical may be dissolution of total iron and  $\text{Mn}^{++}$  oxide and sulfide dissolution. The arsenic correlation with other element is shown in the figure 8.



**Figure 8. Arsenic Correlation with Other Analysis Parameters**

### 4.3 Health effect of Arsenic content drinking water

The people used high Arsenic content drinking water, there were considered arsenic related health effects (figure9).



**Figure 9. Health Effect of Arsenic**

## **5 CONCLUSIONS**

- The arsenic contamination in the DWPs of study area is mostly geologic occurrence and its distribution irregular.
- The arsenic concentration values range from 0.00 mg/L to 0.4 mg/L. 12% of water samples (46 out of 241 samples) have considerably Arsenic concentration values.
- The water samples from Panjsher River and its tributaries (surface water) didn't indicate any arsenic concentration.
- The coppers, irons, lead and zinc Mines deposit occurrence is most probably caused to contribute to the arsenic contamination as well as other trace elements in the groundwater.
- The nitrate contamination in the drinking water points is due to Anthropogenic (human activities) and 34% (16 out of 46) analyzed water samples from drinking water points are exceeding the NDWQS of 50 mg/l of NO<sub>3</sub>. The high concentration of Arsenic Nitrate in the drinking water points is a major concern and potentially affects the health of inhabitation of study areas.

- The correlation coefficient of total Arsenic with other chemical parameters indicated complex hydro chemical process which contributes in mobilization of arsenic concentration in groundwater of the study area. The influencing hydro chemical may be dissolution of Iron and Manganese oxide and sulfide dissolution.

## ACKNOWLEDGEMENTS

The author gratefully acknowledges from Khalil Rahman the DACAAR water quality analysis Laboratory supervisor for water samples collection and analysis. I also appreciate the cooperation and efforts of Ahmad Jawid, DACAAR Hydrogeologist for analyzed water quality data recording and management. The author gratefully acknowledges Abdul Halim Zaryab Professor at the department of engineering and hydrogeology of Kabul Polytechnic University for giving a valuable advice, comments and Editing of this report.

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