ARSENIC CONTAMINATION OF GROUNDWATER IN GHAZNI AND MAIDAN WARDAK PROVINCES, AFGHANISTAN

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ARSENIC CONTAMINATION OF GROUNDWATER IN GHAZNI AND MAIDAN WARDAK PROVINCES, AFGHANISTAN

SCIENTIFIC INVESTIGATION REPORT

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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^3	Arsenite
As^5	Arsenate
r	Correlation coefficient
WSs	Water Samples

SUMMARY:

In Afghanistan, Arsenic (total As) contamination are an issue of current drinking water supply systems where users have been using groundwater sources. Arsenic contamination is the major environmental health management concerns especially in Ghazni and Maidan Wardak provinces in WASH sector. Increasing human activities and haphazard urbanization have modified the cycle of heavy metal, non-metal and metalloids. The arsenic contaminated groundwater used for drinking can cause adverse effect of human health of study area. The water quality study with 746 samples from drinking water points (DWPs) have been carried in Khwaja Omari district and center of Ghazni province and Jaghato district of Maydan Wardak province results show that the arsenic concentration values in the study area varied between 0.00- 0.99 mg/L and 38% of DWPs samples exceeded the value of the WHO guideline of 0.01 mg/L of As owever, 62% of analyzed water samples exceeded the National drinking water quality standard (NDWQS) of 0.05 mg/L of As.

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 concentration along with other water quality parameters in the DWPs is essential to implement drinking-water supply schemes.

The study carried out analyzing physical and chemical parameters integrates data sets from UNICEFE, ECHO 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,201) and Bureau of Indian drinking water standard for arsenic concentration in the drinking water is 0.01 mg/L. [1, 2, 3], however the NDQWS for 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

The study area is located in the south direction of Kabul and geographically, it is situated between latitude 33.39776 - 33.84776 and longitude 68.26683 - 68.61683 (Figure 1). It covers total area of about 6788 km^2 with population of about 844,765 [5]. It has semi- arid 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 35 °C. The rainfall and snowfall are the main source of groundwater and surface water, and the area receives an average 200 mm rainfall [6]. There are number of seasonal rivers and abandoned channels which are flowing water in rainy seasons.

Groundwater flow direction is from north mountains front hydrogeolgical boundaries (upstream) to south flood plain (downstream) along the Ghazni seasonal river [5, 6 and 7].

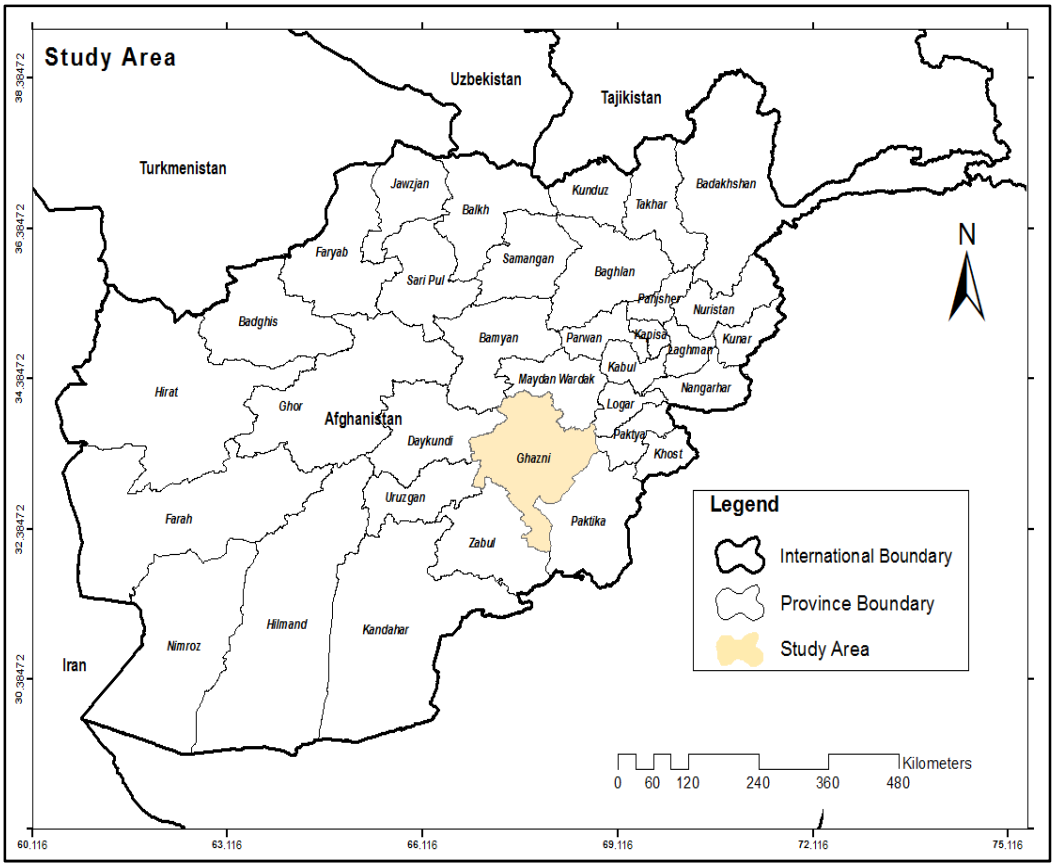

Figure 1.Location of the Study Area

2.2 Surface Geology

The main surface Geology of study area is classified:

- Recent Q: Gravel, sand, silt and clay
- Late- Recent Q: Gravel, sand, silt clay, clay and conglomerate
- Late Q: Gravel mixed with sand, silt and clay, conglomerate and clay
- Middle Q: Conglomerate, sand with sand and silt and clay
- Oligocene: Phase 2, Granite and granodiorite
- Eocene: Dunit, peridotite and serpentines
- Late Permian: Limestone, dolomite, marl,
- Carboniferous-Earl Permian: Siltstone, sandstone, shale, marfic volcanic
- Late Devonian: Siltstone, sandstone and limestone
- Middle Proterozoic: shiest, gneiss, quartz, marble and amphibolites

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

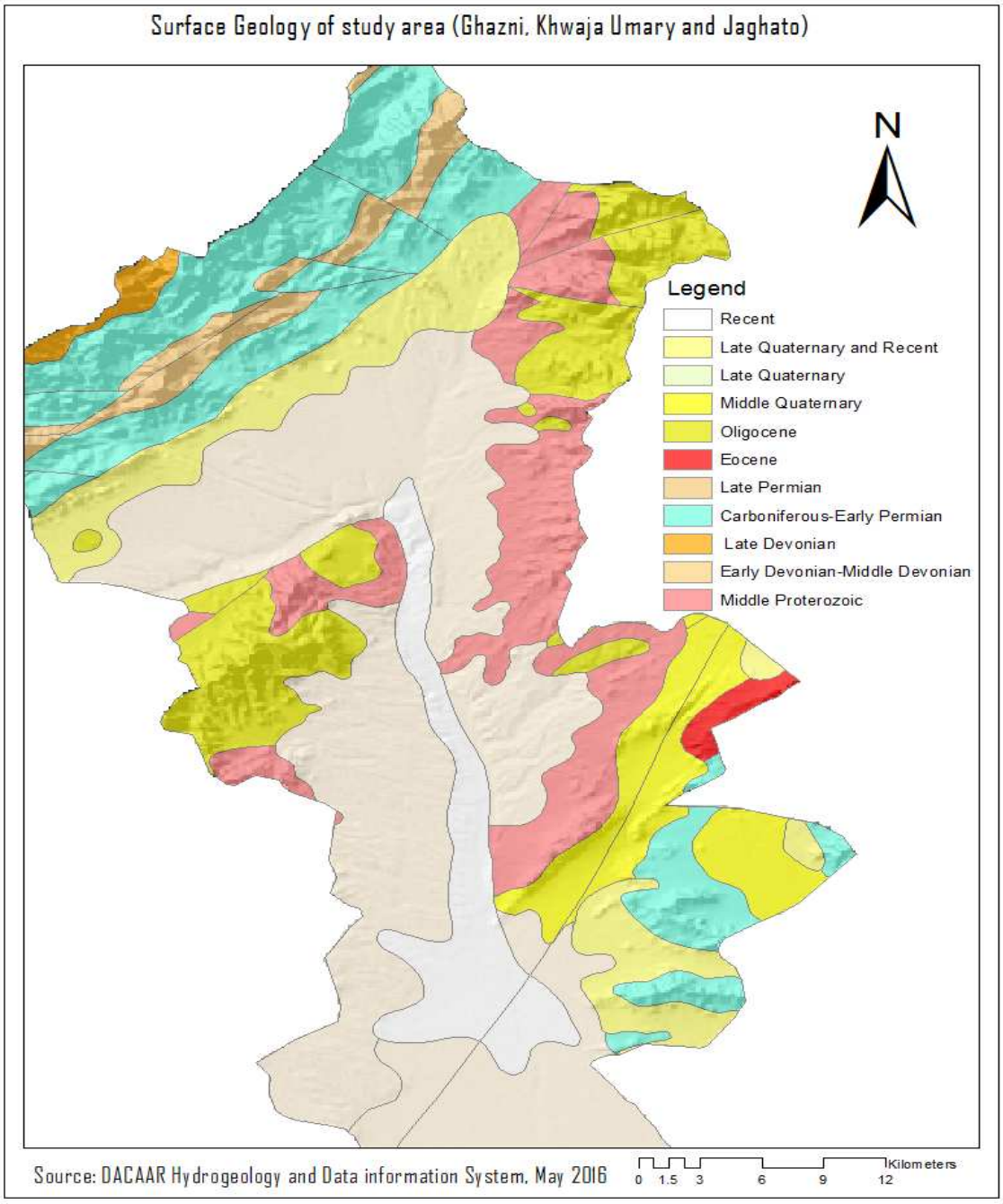

Figure 2. Surface Geology of Study Area.

2.3 Hydrogeology

The recent- late Quaternary deposits (silt clay, silt, sandy clay, sand, gravel and conglomerate) are contained the main aquifers. The rainfall and snowfall are the main source of groundwater recharge. The depth of water table ranged between 12- 42 m.

Groundwater flow direction is from north mountains front hydro geological boundaries (upstream) to south flood plain (downstream) along the Ghazni seasonal river[8 , 9]

2.4 Sampling and field measurement

In total 746 water samples of DWPs (hand pump tube wells and dug wells) 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). 106 out of 746 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 < 5%.

3 RESULTS AND DISCUSSION

3.1 Distribution pattern of Arsenic concentration

Arsenic concentration in the DWPs of study area is mostly Geologic (geogenic) occurrence and its special distribution levels are irregular trough the study areas

In center of Ghazni province, the total arsenic(As^3 and As^5) concentrations ranged between 0.00 - 0.97 mg/L and 36% (403 out of 630) of groundwater samples exceeded the value of NDWQS of 0.05 mg/L of As, however 64% of analyzed water samples exceeded the WHO guideline of 0.01 mg/L of As (Figure 3)

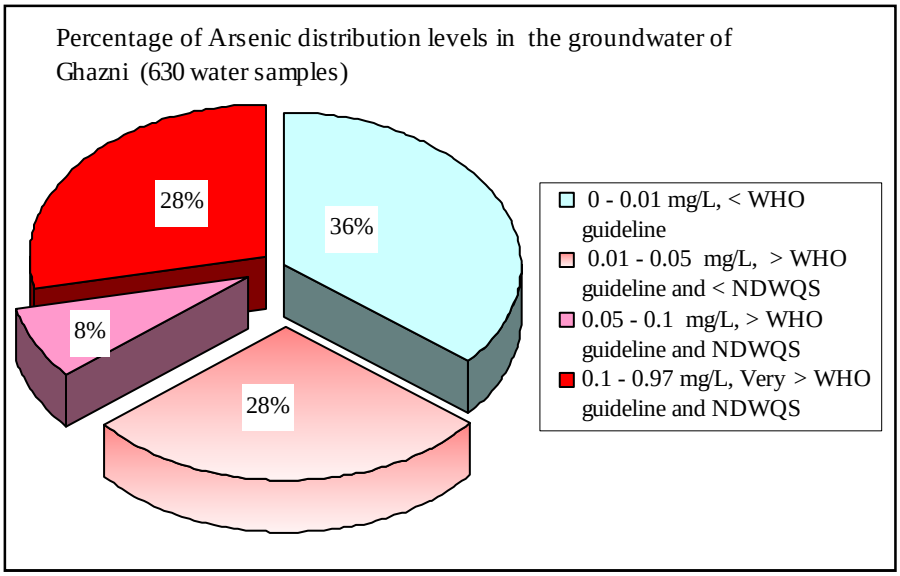

Figure 3.Percentage of Arsenic concentration Level in Groundwater of Ghazni

In Khwaja Umari district of Ghazni province, the total arsenic concentration ranged between 0.00 - 0.99 mg/L and 54% (46 out of 86) of water sample exceeded the value of the NDWQS of 0.05 mg/L of As, however 23% of analyzed water samples are exceeded the WHO guideline of 0.01 mg/L of As (Figure 4)

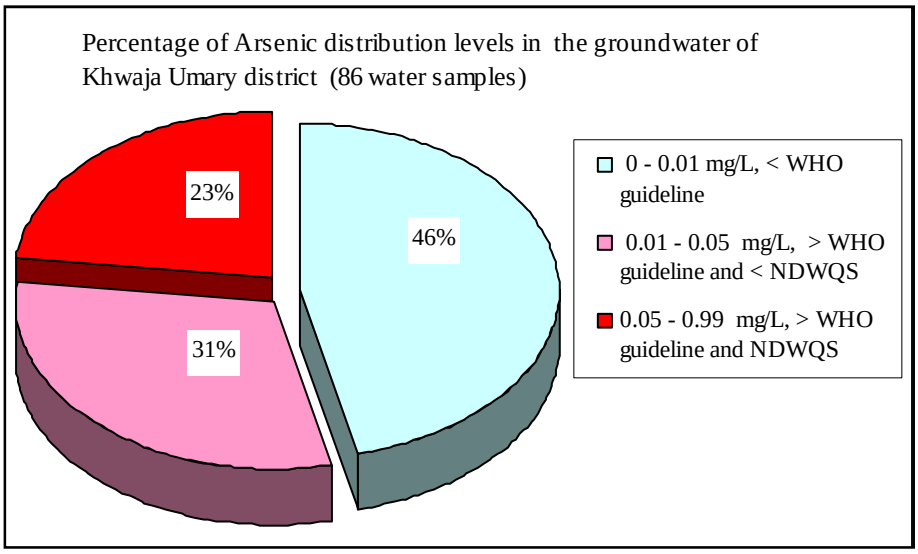

Figure 4.Percentage of Arsenic concentration Level in Groundwater of Khwaja Umary

In Jaghato district of Maydan Wardak province, the total arsenic concentration ranged between 0.0-0.1mg/L and10% (3 out of 30) of water sample exceeded the value of the NDWQS of 0.05 mg/L of As, however 27% of analyzed water samples exceeded the WHO guideline of 0.1mg/L As (Figure 5).

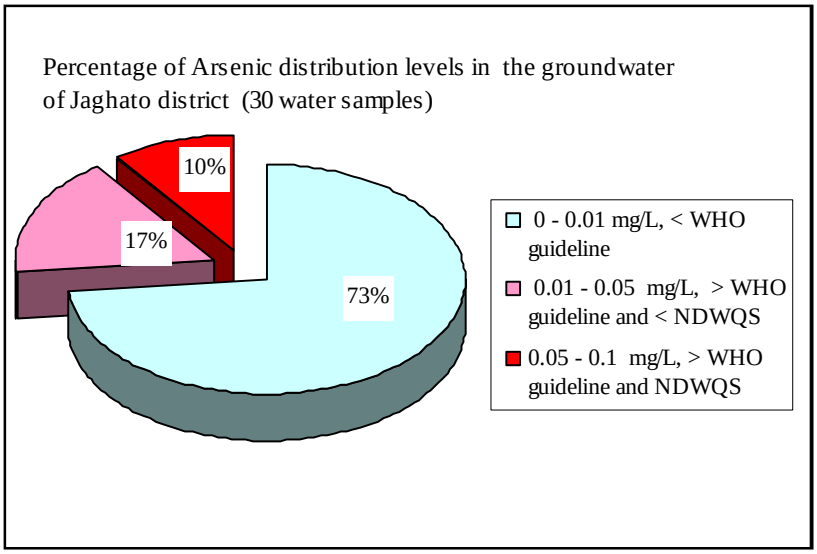

Figure 5.Percentage of Arsenic concentration Level in Groundwater of Jaghato district

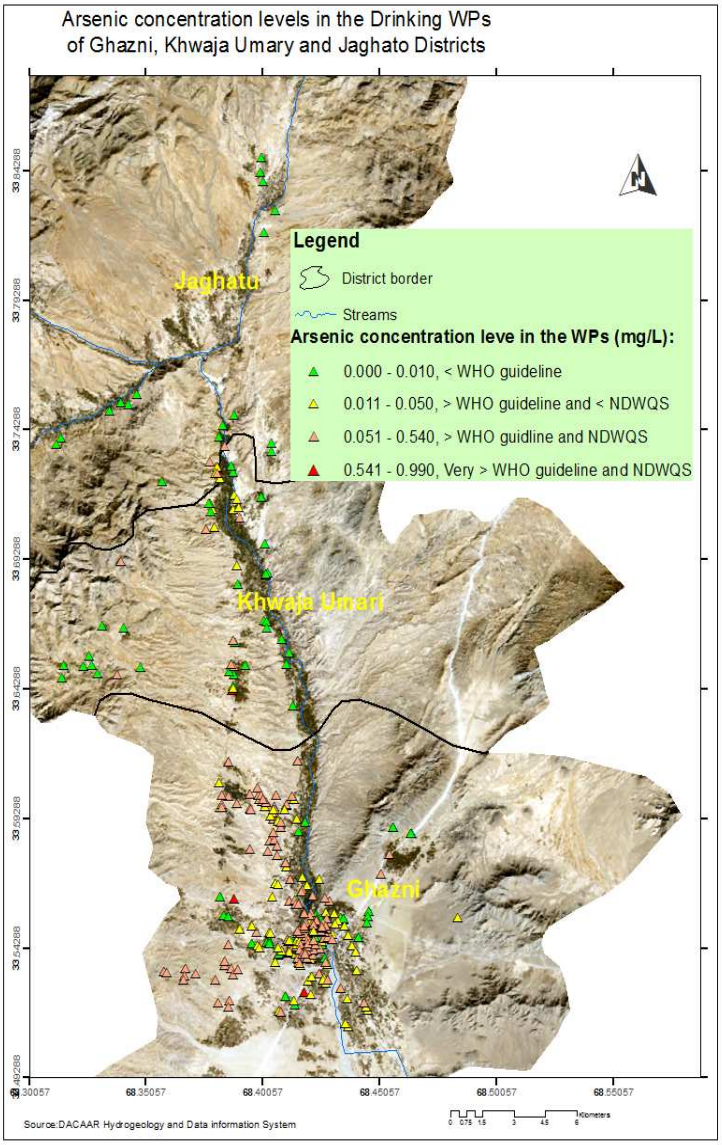

Figure 6.Sampled Location and Arsenic Spatial Distribution Levels

High arsenic content drinking water causes adverse effect health of user and consequently leading to skin, bladder, liver and lung cancers [12].

3.2 Time series arsenic concentration value variation

DACAAR installed GMWs in the study area and the GMWs were monitored from the quantitative and quantitative points of view. The location of GMWs is shown in the figure 7.

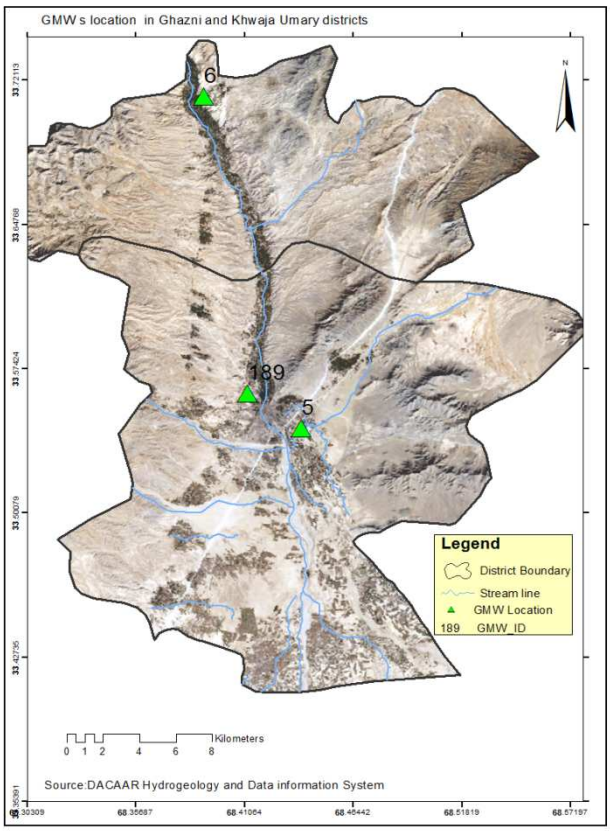

Figure 7.Location of GMWs

The analyzed data result is indicated that the arsenic concentration values varied with time and water table fluctuation.

The time series arsenic concentration values in GMW_ID 5(center of Ghazni province) reneged between 0,01 - 0,061 mg/L and the concentration values varied with time and groundwater table fluctuation. The time series water table fluctuation and arsenic variation are shown in the figure 8 and 9.

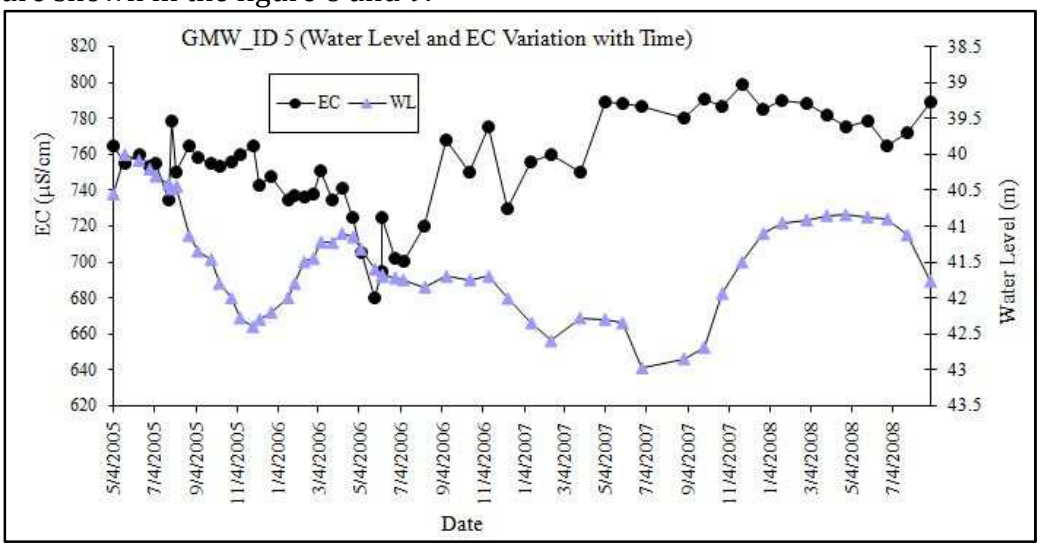

Figure 8.GWM_ID 5 Time Series Water Table Fluctuation

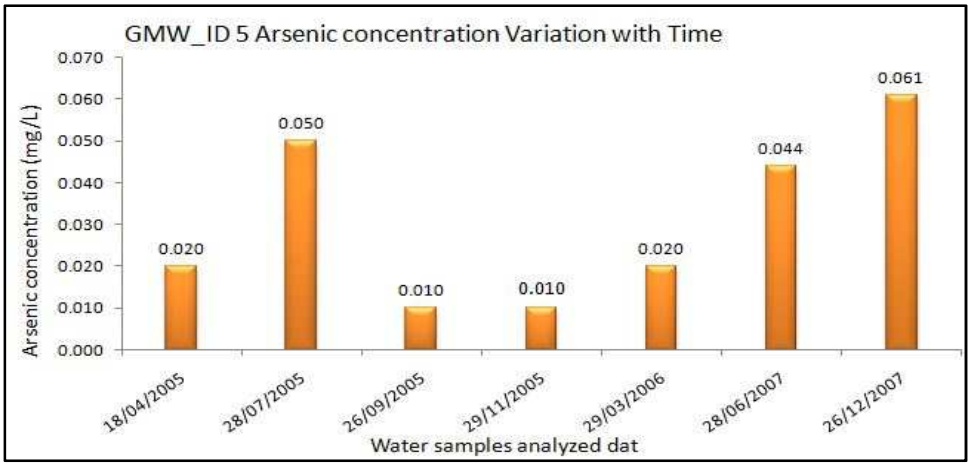

Figure 9. GWM_ID 5 Time Series Arsenic Concentration Variation

The time series arsenic concentration values of GMW_ID 6 (Khwaja Umary district) reneged from 0,025 mg/L to 0,073 mg/L and the concentration values varied with time and seasonally water level fluctuation. The GMW_ID 6 time series water table fluctuation and arsenic variation are shown in the figure 10 and 11.

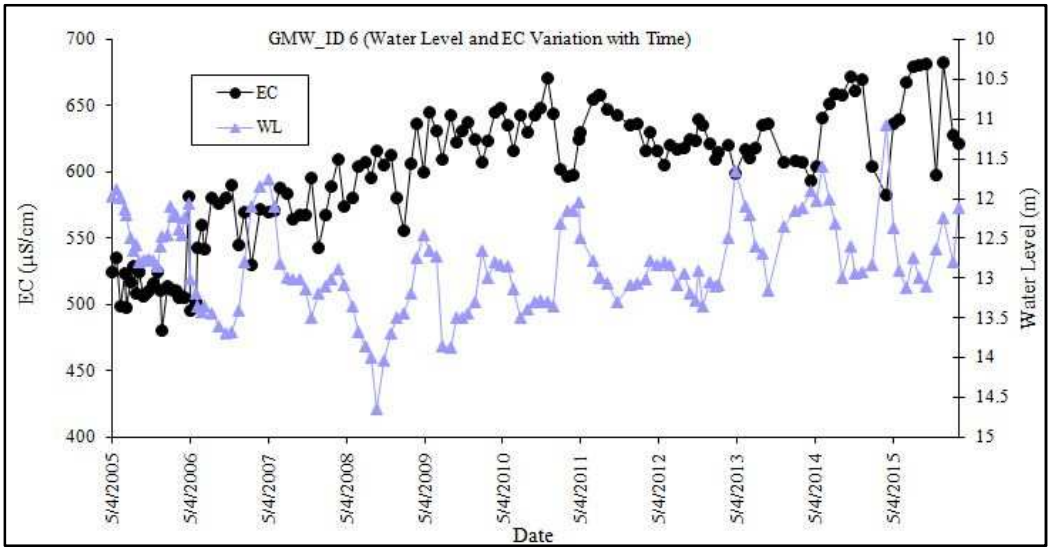

Figure 10. GWM_ID 6 Time Series Water Table Fluctuation

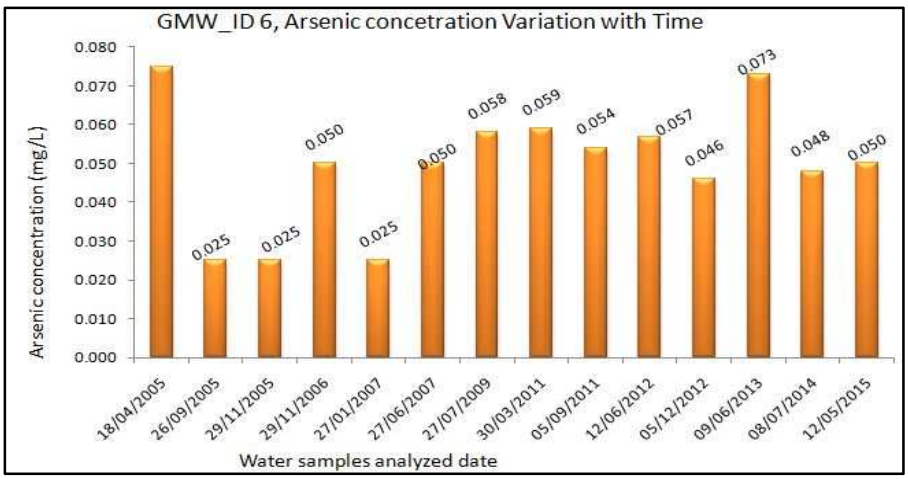

Figure 11. GWM_ID 6 Time Series Arsenic Concentration Variation

The time series arsenic concentration values of GMW_ID 189 (Ghazni center) reneged from 0, 04 mg/L to 0, 07 mg/L and the concentration values varied with time and seasonal fluctuation of water table. The GMW_ID 189 time series water table fluctuation and arsenic variation are shown in the figure 12 and 13.

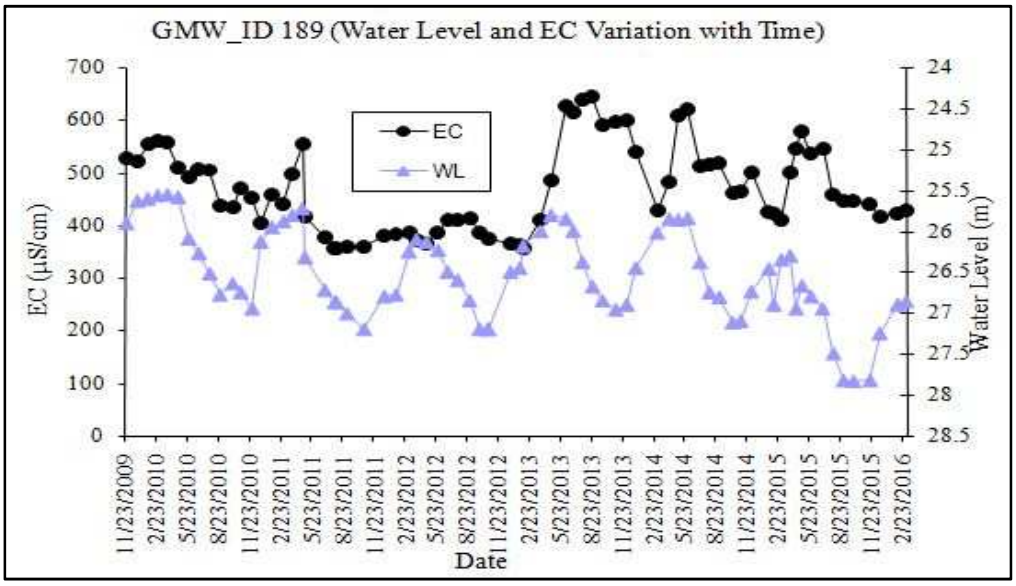

Figure 12. GWM_ID 189 Time Series Water Table Fluctuation

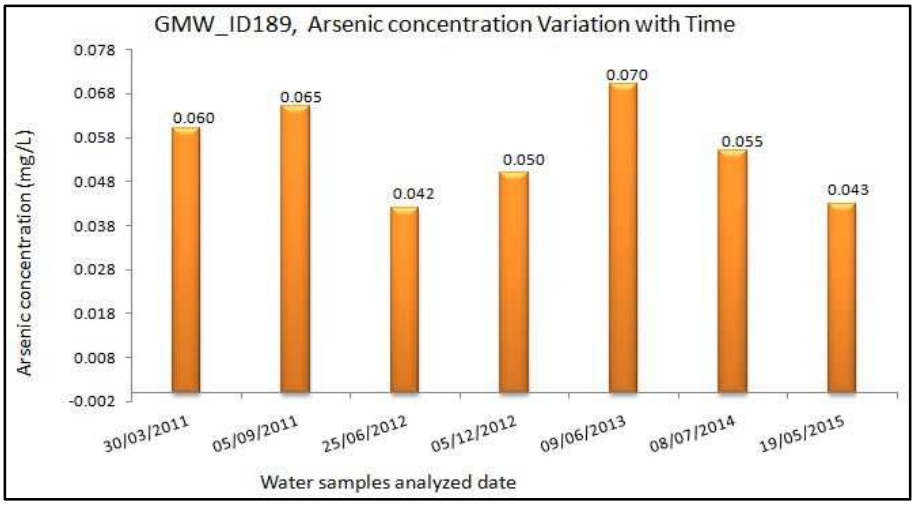

Figure 13. GWM_ID 189 Time series Arsenic Concentration Variation

Time variability of the arsenic concentration in the GMWs (GMW_ID 5, 6 and i89) show dissolution and desorption hydro-chemical processes reaction that the arsenic releases from solid phase into the liquid phase (groundwater) [11].

3.4 Arsenic concentration values in the Surface water

Water samples were taken from upstream (Khwaja Umary district) and downstream (Ghazni center) for chemical analysis. The results show the Arsenic concentration value increased from upstream (0.021 mg/L) to downstream (0.021 mg/L), however, the major ions are not considerably changed. The location of sampled water and Arsenic concentration values with respect other chemical major ion parameters is shown in the Figure 14.

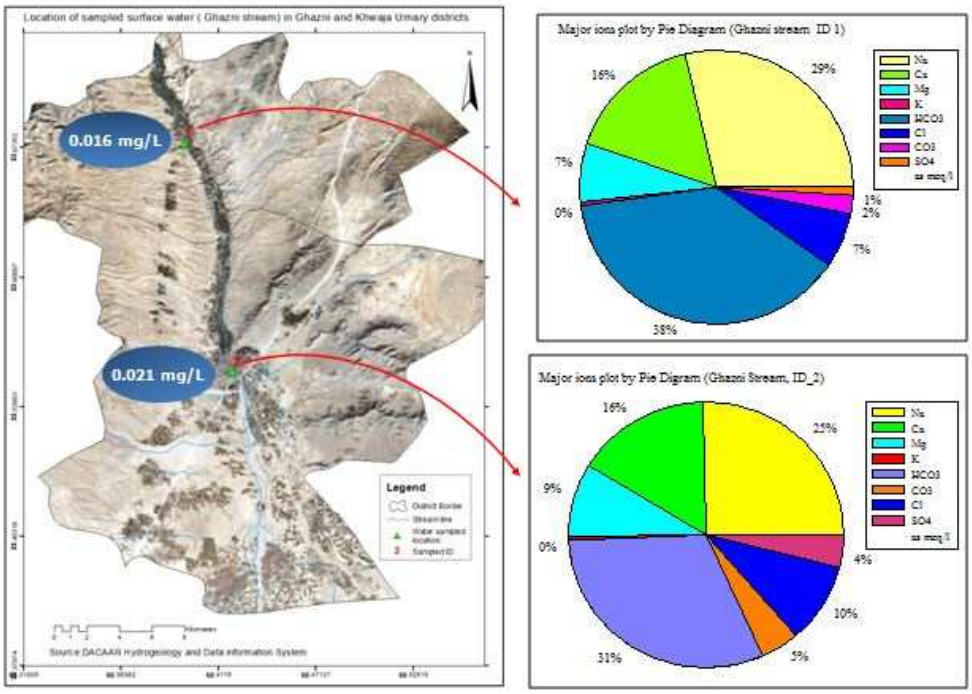

Figure 14. Location of Sampled Water and Arsenic Concentration Variation

4 HYDROCHEMISTRY OF GROUNDWATER

The major ions, pH and EC parameters of groundwater were plotted by Durov diagram (figure 2) using AquaChem 2014.2. The Figure 3 illustrates hydro- chemical facies with respect pH and electrical conductivity of DWPs (groundwater) within the hydro geological boundaries of study areas. The dominant inions in the water samples are $HCO_3^- > Cl^- > SO_4^{-2}$ and the dominant cat-ions in the water samples are $Na^+ > Ca^{+2} > Mg^{+2}$. The main water types are Na-Ca-CO_3, Na-Mg-CO_3, Ca-Mg-Na-CO_3, Na-HCO_3-Cl, Mg-Na-HCO_3-SO_4, Mg-Na-HCO_3-SO_4-Cl, and Mg-Ca-HCO_3-SO_4-Cl. These different chemical compositions may be due to weathering and dissolution of calcite, dolomite, silicate, sulfide and other minerals. However, some water samples show the mixing water types with high chloride (Cl^-), this occurrence may be due to silicate weathering ion exchange and calcite dissolution. High HCO_3 is ubiquitous in groundwater in Afghanistan which, play an important role in hydro chemical evolution and trace metal mobilization

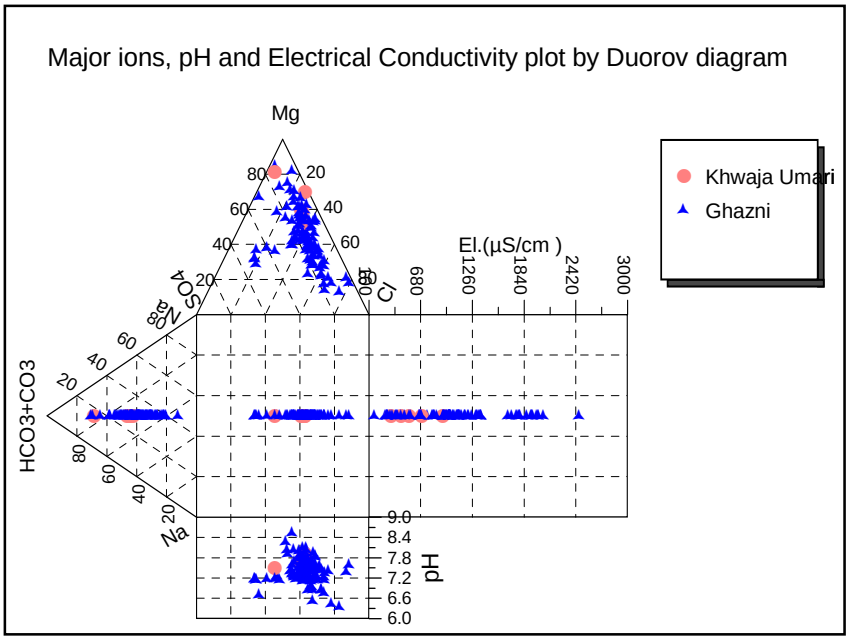

Figure 15. Major Ions, pH and EC Diagram

The water sample is plot on the central of tri-linear diagram, the anion carried in groundwater is mainly of HCO_3^- Cl^- as cat-ion K^+ Na^+ primarily the highest total arsenic concentration contained in this zone in the north mountainous terrain which are contained Oligocene and Eocene igneous rocks (granite, diorite, per diorite and serpentine), because of the steep topography, fairly cycle condition, proceeding the weathering and leaching action, mineral substance dissolve into groundwater. Arsenic and other compounds carried by groundwater into the flow direction along the Ghazni river .The wide variability in the electrical conductivities of sampled water defines the measurement of the dissolved saline of water. The EC ranged from145µS/cm to 2970 µS/cm. The pH values of samples ranged from 6.1 to 8.8 and most of sampled water points are shown alkaline characteristic.

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 (0.01-0.3 m/L), Na^+ (24-570 mg/L), K^+ (1.2-90 mg/L), Ca^{2+} (14-200 mg/L), Mg^{2+} (11-190), Cl^- (2-500 mg/L), SO_4^{2-} (3-248 mg/L), NO_3^- (4.2-127 mg/L), F (0.02-2.40 mg/L), Cu (0.1-0.8 mg/L), NH_4 (0.1-0.9 mg/L), Mn (0.0-0.8 mg/L), Cr (0.0-0.09 mg/L),ORP(177-291mV/L)and HCO_3(115-1170 mg/L).The pH of the groundwater was found to be neutral to slightly alkaline (6.1-8.52) with high EC (145-2970 µS/cm)). The Hydro chemical Statistic Analysis result is shown in Table 1 and figure 16.

Table 1. Water Quality Statistic Analysis Results

No	Elements	Unit	Statistics				Acceptable Limit	
			Count	Min.	Max.	Mean	WHO	NDWQS
1	As	mg/L	106	0.000	0.99	0.037	0.01	0.05
2	Conductivity	µS/cm	106	145	2440	1020	1500	3000
3	pH		106	6.33	8.52	7.43	6.5 – 8.5	6.5 – 8.5
4	ORP	mV	106	0	291	136		
5	Temp	◦C	106	6.50	20.8	24.8		
6	Fe^{++}	mg/L	106	0.00	0.30	0.06	0.3	0.3
7	Mn	mg/L	106	0	0.08	0.00	0.4	
8	Cl^-	mg/L	106	2.5	500	138.2	250	250
9	PO_4^{---}	mg/L	106	0.02	1.80	0.51		
10	HCO_3^-	mg/L	106	115	1170	451		
11	NO_3^-	mg/L	106	4.20	127.20	41.91	50	50
12	Na^+	mg/L	106	24	570	172	200	200
13	K^+	mg/L	106	12	90	17		
14	Ca^{++}	mg/L	106	14	200	75		70
15	Mg^{++}	mg/L	106	11	190	43		30
16	Cu	mg/L	106	0.1	0.8	0	2	2
17	SO_4^{--}	mg/L	106	3	248	70	250	250
18	F^-	mg/L	106	0.02	2.40	0.71	1.5	1.5
19	NH_4^+	mg/L	106	0.1	0.9	0	1.5 - 3.5	
20	Mn^{++}	mg/L	106	0.0	0.8	0.00	0.05	

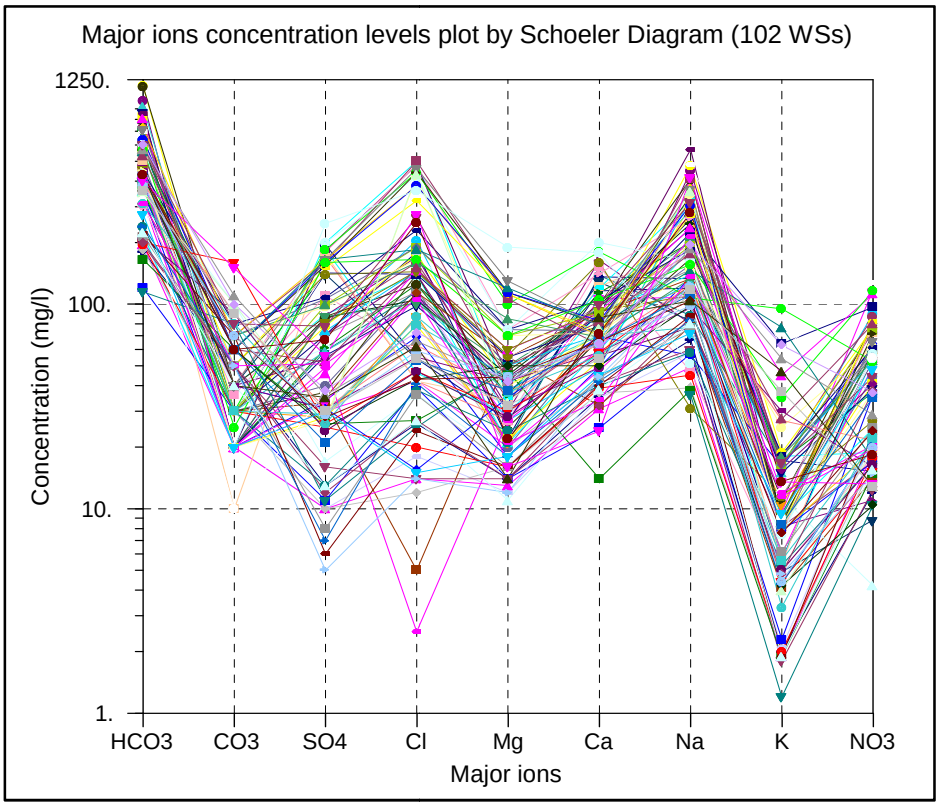

Figure 16. Major Ions Concentration Level in Ghazni

38% of analyzed water samples from drinking water points are exceeding the NDWQS of 50 mg/l of NO_3 (Figure 17 The high concentration of nitrate in the drinking water points is a major concern and potentially affects the health of the inhabitants.

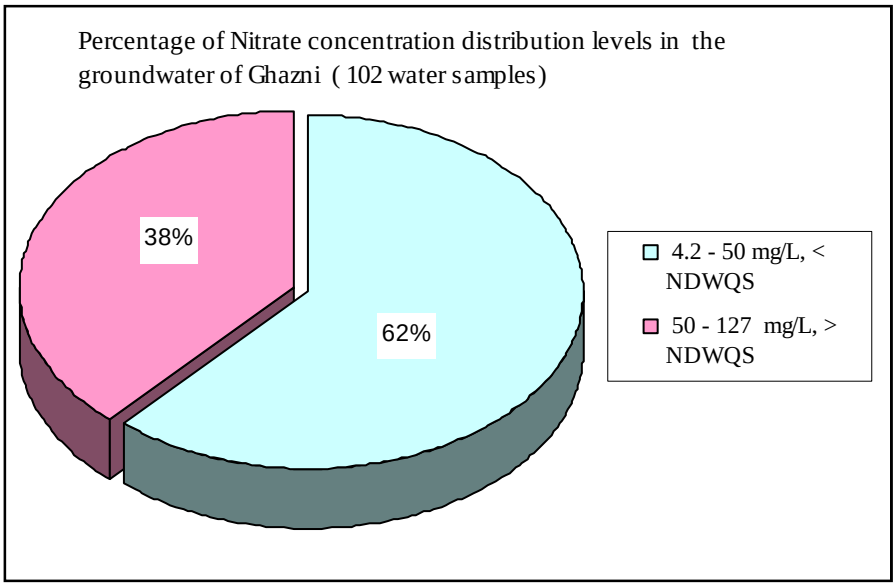

Figure 17. Percentage of Nitrate Concentration in Ghazni

4.2 Correlation Analysis

For understanding the correlation mechanism of As concentration in the groundwater, the correlation coefficient (r) of arsenic with pH (r = -0.18), Ca^{++} (r = -0.214), Mg^{++} (r = -0.176), Na^{+} (r = 0.025), EC (r = 0.049), SO_4^{--} (r = -0162), K^{+} (r= 0.152), Cl^{-} (r = -0.032), HCO_3^{-} (r = -0.118), Mn^{++} (r = 0.140), total Fe (r = -0.301), NO_3^{-} (r = 0.139), NH_4^{+} (r = - 0.290), SiO_2 (r = 0.156) and 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 SO_4^{-2} and pH is negative, which would be the result of sulfide oxidation. The influencing hydro- chemical may be dissolution of total iron and Mn^{++} oxide and sulfide dissolution.

5 CONCLUSIONS

- The arsenic contamination in the DWPs of study area is mostly geologic occurrence and its distribution irregular. 61% (459 out of 746) of drinking water points samples exceeded the values of the NDWQS of 0.05 mg/L of As, and 38% (261 out of 746) of analyzed water samples exceeded the WHO guideline of 0.01 mg/L of As.
- The arsenic concentration values varied with time and seasonal fluctuation of water table.

- The nitrate contamination in the drinking water points is due to Anthropogenic (human activities) and 41% (44 out of 107) analyzed water samples from drinking water points are exceeding the NDWQS of 50 mg/l of NO3. The high concentration of arsenic nitrate in the drinking water points is a major concern and potentially affects the health of inhabitance 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

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