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RESEARCH ARTICLE

GROUND WATER QUALITY ASSESSMENT BY USING GEOGRAPHICAL INFORMATION SYSTEM AND WATER QUALITY INDEX: A CASE STUDY OF CHOKERA, FAISALABAD, PAKISTAN

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ABSTRACT

Water quality is considered as a major issue in mega cities of developing countries. The city of Faisalabad has over 4 million population. Groundwater is the main source of drinking water in Faisalabad. The groundwater quality should be regularly monitored in order to cope with the drinking water quality issues. An attempt has been made to understand the groundwater quality by using water quality index (WQI) at Chokera area, Faisalabad, Pakistan. It is a technique of rating water quality, is an effective tool to assess spatial and temporal changes in groundwater quality. Sixty groundwater samples were collected and analyzed for physico-chemical parameters using standard method of analysis. From the data obtained, the water quality index was calculated by adopting the method developed by Tiwari and Mishra. Water quality index rating was carried out to quantify overall ground water quality status of the area. The WQI index of the same has been calculated and the values ranged from 73 to 272. The WQI values from present study indicate the very poor water quality in the area. The analysis reveals the fact that the groundwater of the Chokera area needs a degree of treatment before consumption and needs to be protected from further contamination.

KEYWORDS

Groundwater quality, Water quality index, Waste water impact, GIS

1. INTRODUCTION

Pakistan's population at the time of independence was only 32.5 million and increased rapidly up to 184.35 million in 2013. This increasing trend in population poses serious threats on limited natural resources of country [1].

Depletion and deterioration of surface and ground water resources made Pakistan a water deficit country. This situation is due to shortage of surface storage and shift of fresh water use from agriculture to domestic as well as industrial use [2].

Improper disposal system of domestic and industrial wastewater causing serious threats for water resources and human health [3]. This situation is more critical in those urban and industrial areas where ground water deterioration caused various water-borne diseases and irremediable damage to environment.

Groundwater is an important source of water supply throughout the world. Groundwater occurs almost everywhere beneath the earth surface not in a single widespread aquifer but in thousands of local aquifer systems and compartments that have similar characters. Knowledge of the occurrence, replenishment and recovery of groundwater has special significance in arid and semi-arid regions due to discrepancy in monsoonal rainfall, insufficient surface waters and over drafting of groundwater resources.

The ground water quality is very important to the community, therefore it is important to ensure its high quality at all time so that the consumer's health is not compromised. Groundwater resources are affected in principle by three major activities. First of these activities is excessive use of fertilizers and pesticides in agricultural areas. The second one is untreated/partially treated wastewater to the environment. Finally, excessive pumping and improper management of aquifers [4]. The activity of solid waste disposal in open un-engineered landfill is the one of the factors that cause the ground water pollution due to lack of pollution control interventions such as water proof layer, leachate treatment pond, monitoring wells, etc. [5].

Due to improper wastewater management, the wastewater seeps into the ground along with many chemicals and heavy metals. The same water we pump for drinking which is a main cause of many diseases. Besides, this water is also used for irrigation near the cities without any treatment. In this way, these chemicals and metals enter into our food chain through soil and crops resulting into many diseases such as blood pressure, liver and urinal cancer, blindness, skin cancer and mental stress. It is estimated that about 40% of diseases in Pakistan are caused by drinking of polluted water [6].

Water quality index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters. A previous researcher has firstly used the concept of WQI, which was further developed by another researcher and improved by Deininger (Scottish Development Department, 1975) [7,8]. WQI is most effective tools to communicate information on the quality of any water body. WQI is a mathematical equation used to transform large number of water quality data into a single number. WQI is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy-makers. The advent of satellite technology and geographical information system (GIS) has made it very easy to map the sampling area. GIS has wide application in water quality mapping using which informative and user-friendly maps can be obtained [9].

The water quality of the study area was determined for all samples using the weighted arithmetic index method [10]. In this method, the fourteen important parameters such as pH, EC, TDS, TSS, DO, Carbonates, Bicarbonates, Chloride Contents, Arsenic (As), Lead (Pb), Cadmium (Cd), Copper (Cu), Chromium (Cr) and Zinc (Zn) were taken for assessment.

2. MATERIAL AND METHODS

2.1 Study Area

The study area was selected beside Chokera Treatment Plant in 2 km radius around the treatment plant in Faisalabad.

Faisalabad is located in the Rachna doab i.e. the area between the rivers Ravi and Chenab. The total geographical area of the Faisalabad district is 5,856 km^2 with a total population of more than 4 million.

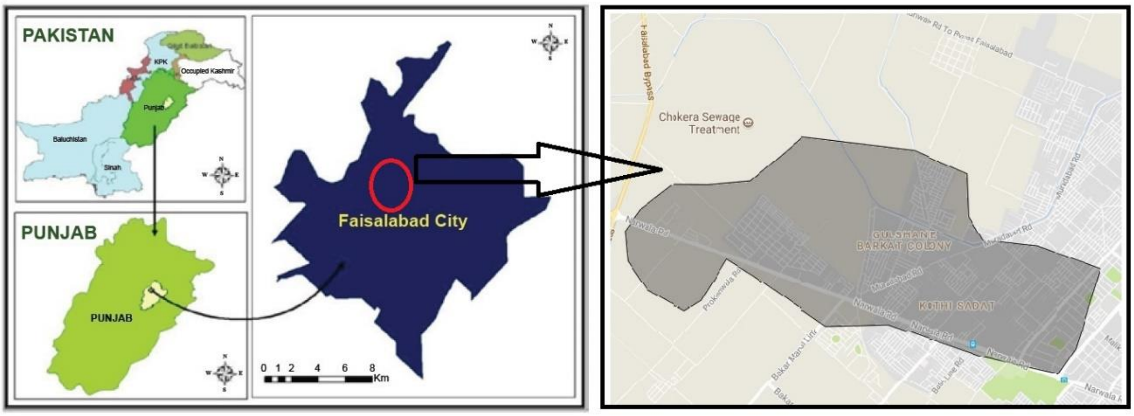

Figure 1: Study Area

2.2 Sampling Plan

Groundwater samples were collected randomly throughout the study area on both sides of the Chokera Treatment Plant from 60 different points. GPS coordinates were taken at each sampling point. Total 60 groundwater samples were collected. Groundwater samples were collected from pumps, motors and hand pumps. The samples were collected in PVC bottles. The quantity of each sample was 500 ml. For groundwater sampling PVC bottles and GPS meter was used.

2.3 Water Quality Index (WQI)

WQI is calculated from the point of view of the suitability of groundwater for human consumption. Water quality index is one of the most effective tools to communicate information on the quality of any water body. WQI is a mathematical equation used to transform large number of water quality data into a single number. It is simple and easy to understandable for decision makers about quality and possible uses of any water body. It serves the understanding of water quality issues by integrating complex data and generating a score that describes water quality status.

To develop the Water Quality Index (WQI) the following four steps were performed

Step I
Each parameter will be assigned a weightage and then the Relative weightage W_i for each parameter will be found by formula

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

Where,
W_i = Relative Weightage
w_i = Weightage of each Parameter
n = No. of Parameters

Step II
Quality Rating will be found by following Formula

$$Q_i = \frac{c_i}{s_i} \times 100$$

Where,
Q_i = Quality Rating
c_i = Concentration of each parameter in each water sample
s_i = Permissible Value of each parameter

Step III
Sub Index will be found by following formula

$$SI_i = W_i \times Q_i$$

Where,
SI_i = Sub Index of ith parameter
Q_i = Quality Rating of ith parameter

Step IV
Water Quality Index will be found by using formula

$$WQI = \sum_{i=1}^{n} SI_i$$

Table 1: Relative Weights of Parameters for WQI

Sr. No.	Parameter	WHO Standard	Weight (*wi*)	Relative Weight (Wi)
1	pH	6.5-8.5	3	0.058
2	EC	2 dS/m	3	0.058
3	TDS	1000 mg/l	2	0.038
4	TSS	500 mg/l	2	0.038
5	DO	5 mg/l	2	0.038
6	Carbonates	75 mg/l	2	0.038
7	Bicarbonates	250 mg/l	3	0.058
8	Chloride Contents	250 mg/l	5	0.096

9	Arsenic (As)	0.01 mg/l	5	0.096
10	Lead (Pb)	0.01 mg/l	5	0.096
11	Cadmium (Cd)	0.05 mg/l	5	0.096
12	Copper (Cu)	0.05 mg/l	5	0.096
13	Chromium (Cr)	0.05 mg/l	5	0.096
14	Zinc (Zn)	0.05 mg/l	5	0.096
			∑=52	**∑=1.000**

Table 2: WQI Range and Water Quality

Sr. No.	WQI Range	Water Quality
1	<50	Excellent Water
2	50-100	Good Water
3	100-200	Poor Water
4	200-300	Very Poor Water
5	>300	Unsuitable for Drinking

3. RESULTS AND DISCUSSION

3.1 pH

It plays an important role in clarification process and disinfection of drinking water. For effective disinfection with chlorine, the pH should preferably be less than eight, however, lower-pH water (<7) is more likely to be corrosive. Failure to minimize corrosion can result in the contamination of drinking water and adverse effect on its taste and appearance. World Health Organization (WHO) has pre-scribed permissible limit of pH to be 6.5–8.5. The pH value of groundwater samples in the present study has been analyzed and it lies in the range 6.6–8.8 (Figure 2).

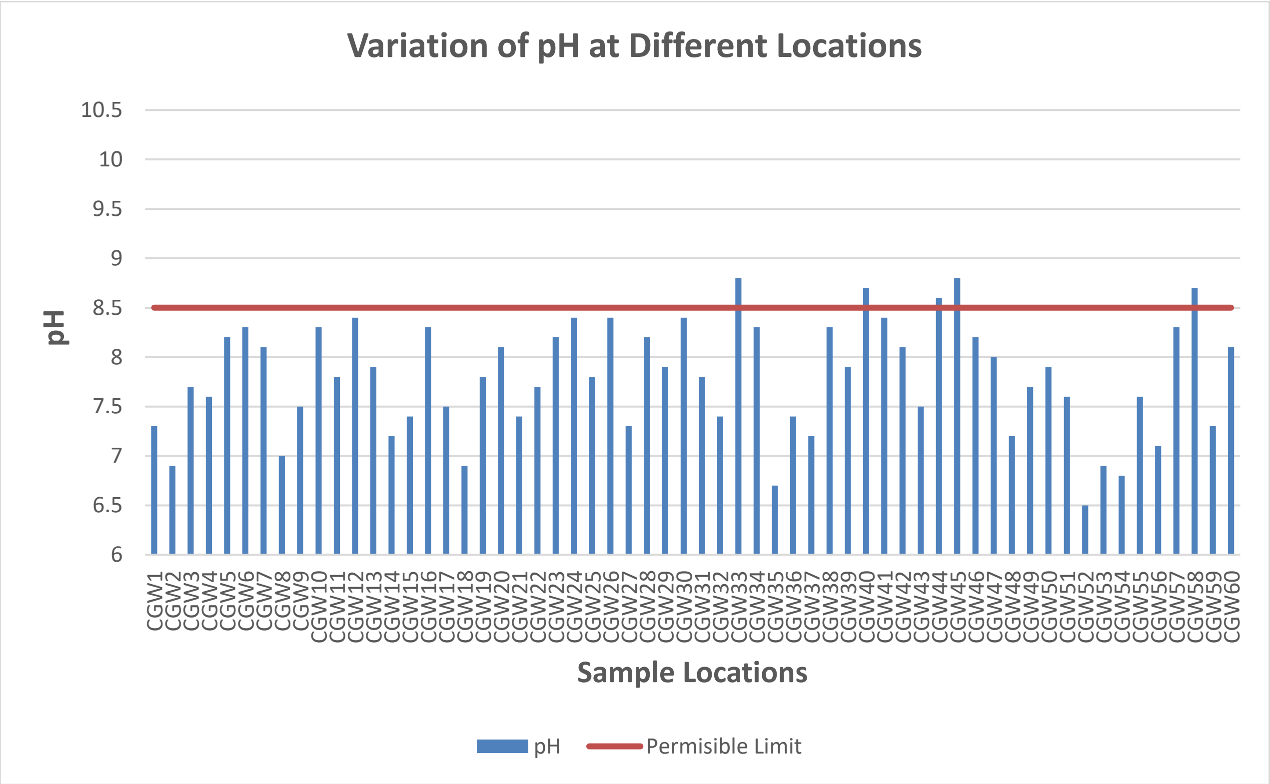

Figure 2: Variation of pH at Different Locations

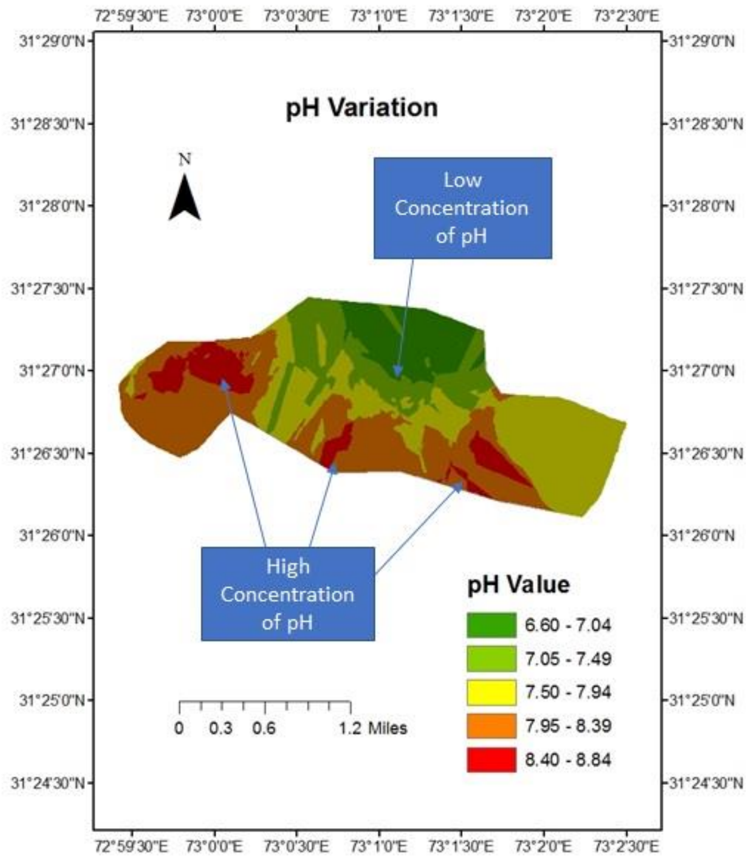

Figure 3: Variation of pH in Different Groundwater Samples

3.2 TDS

The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent (less than 300 mg/l), good (300–600 mg/l); fair (600–900 mg/l), poor (900–1,200 mg/l) and unacceptable (>1,200 mg/l). WHO has prescribed 1000 mg/L as the permissible limit for TDS for the water to be used for drinking purpose. In present study, the TDS concentration of analyzed samples lies in the range of 128–3010 mg/L (Figure 4).

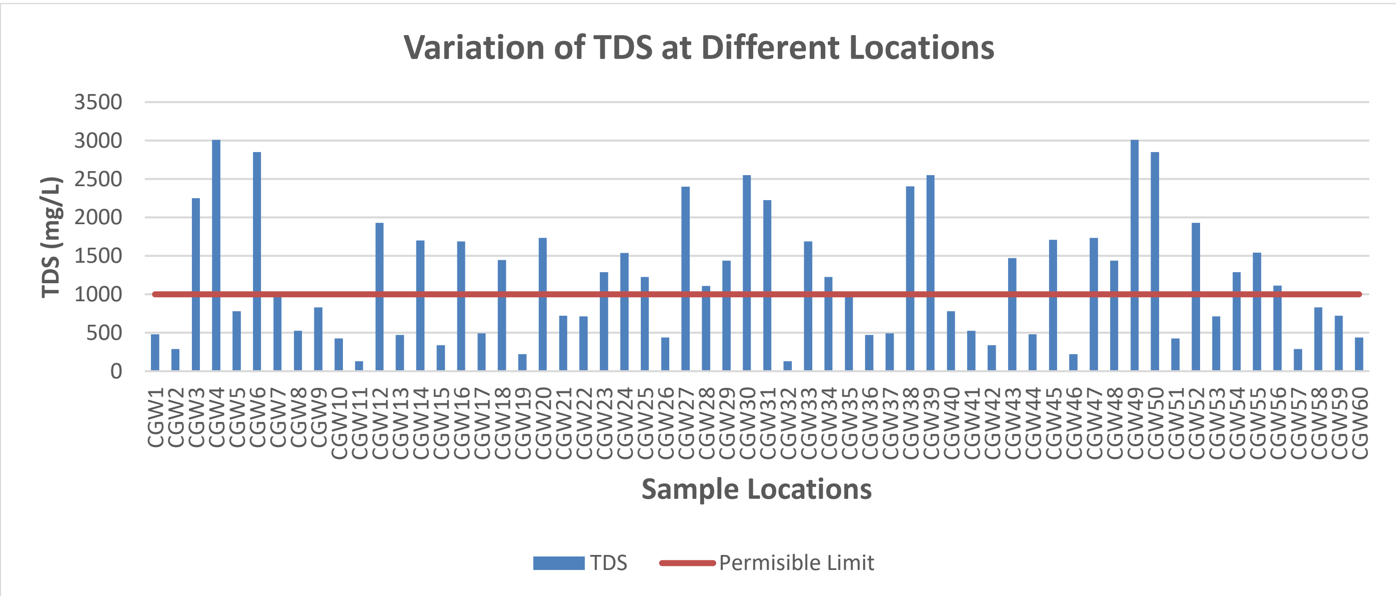

Figure 4: Variation of TDS at Different Locations

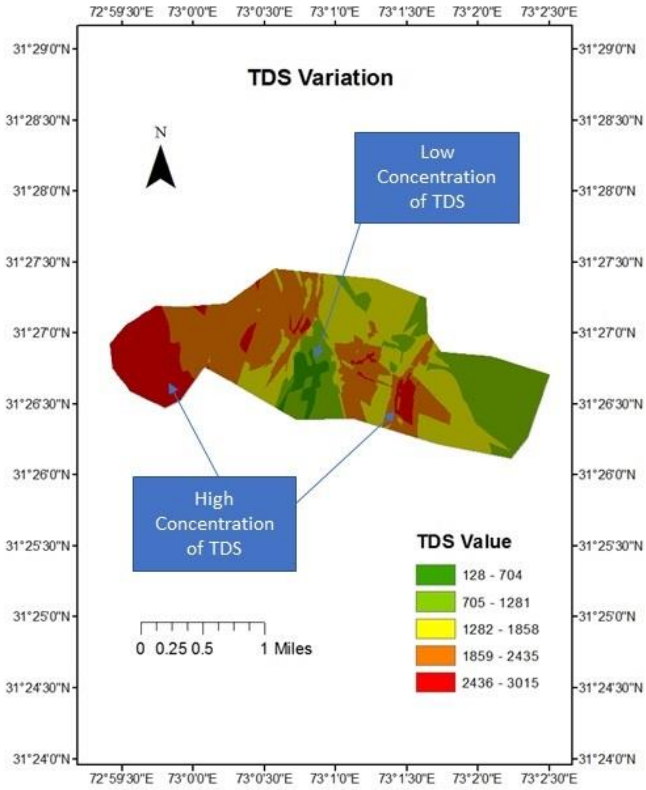

Figure 5: Variation of TDS in Different Groundwater Samples

3.3 TSS

Total suspended solids in water may consist of inorganic and organic particles. Suspended solid are objectionable in water as it is aesthetically displeasing and provides sites to chemical and biological agents. TSS results varied from 61 mg/l to 1455 mg/l in groundwater of study area as shown in Fig. 6.

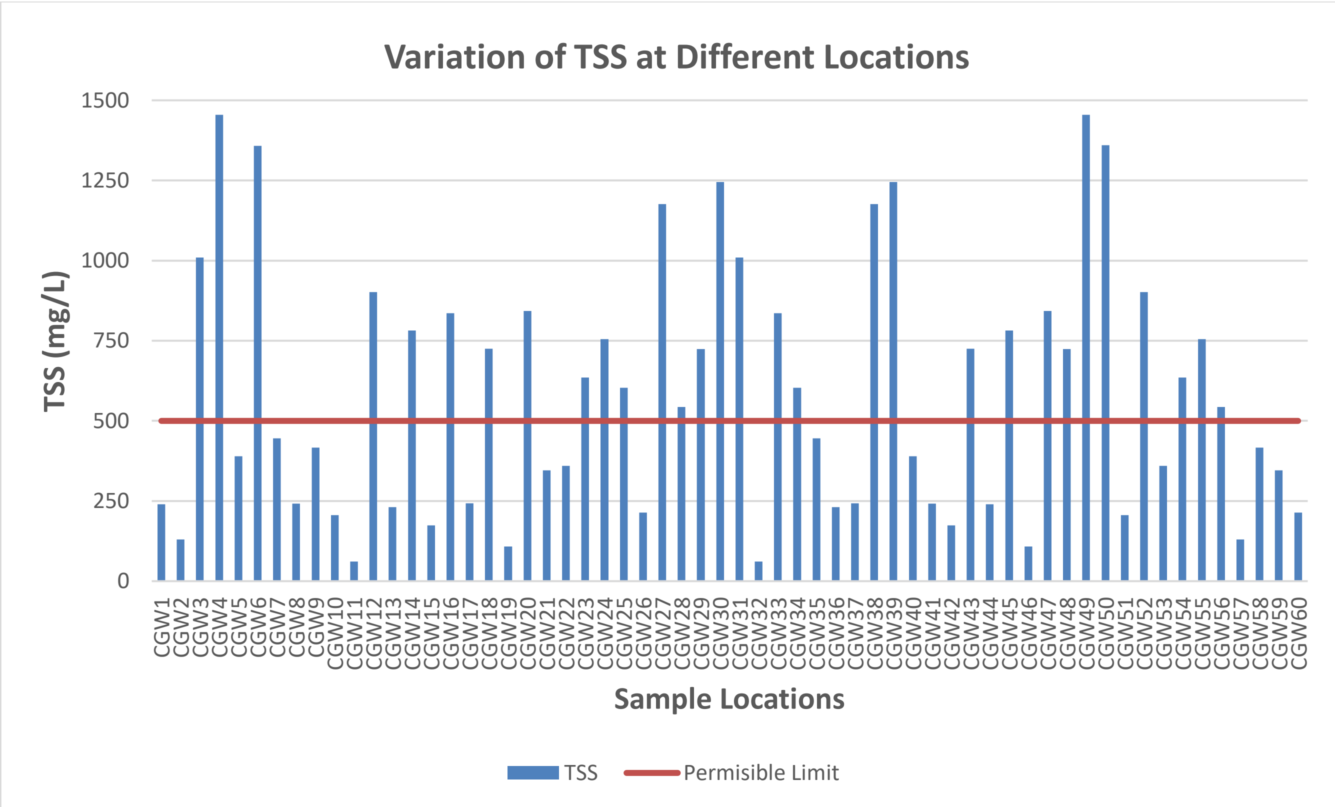

Figure 6: Variation of TSS at Different Locations

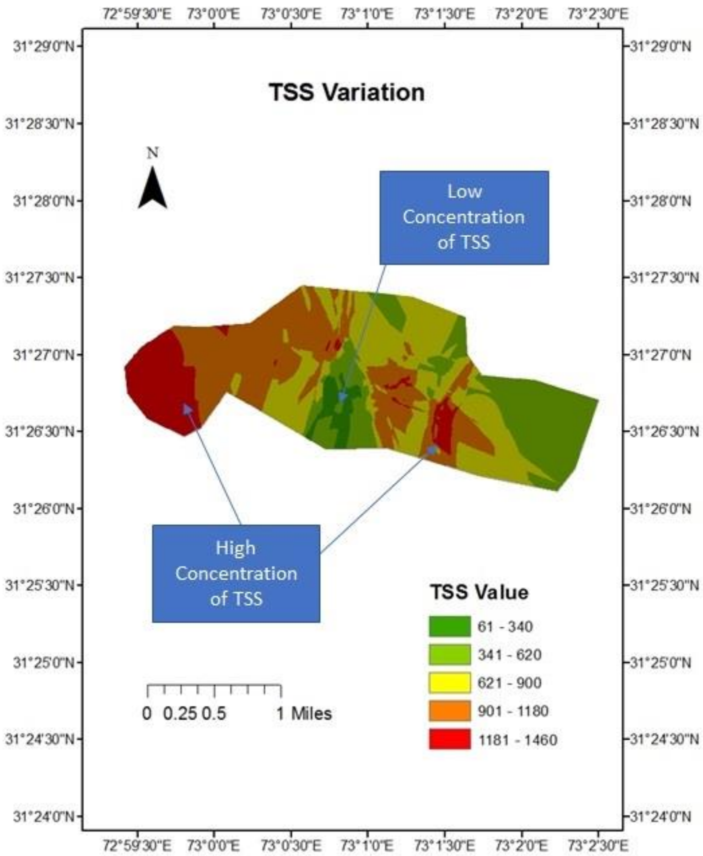

Figure 7: Variation of TSS in Different Groundwater Samples

3.4 DO

Dissolved Oxygen (DO) measures the quantity of oxygen that is dissolved in water. Oxygen enters into water by aeration and photosynthesis process.

DO level was measured from 7.3 mg/l to 13.5 mg/l as shown in Fig. 8.

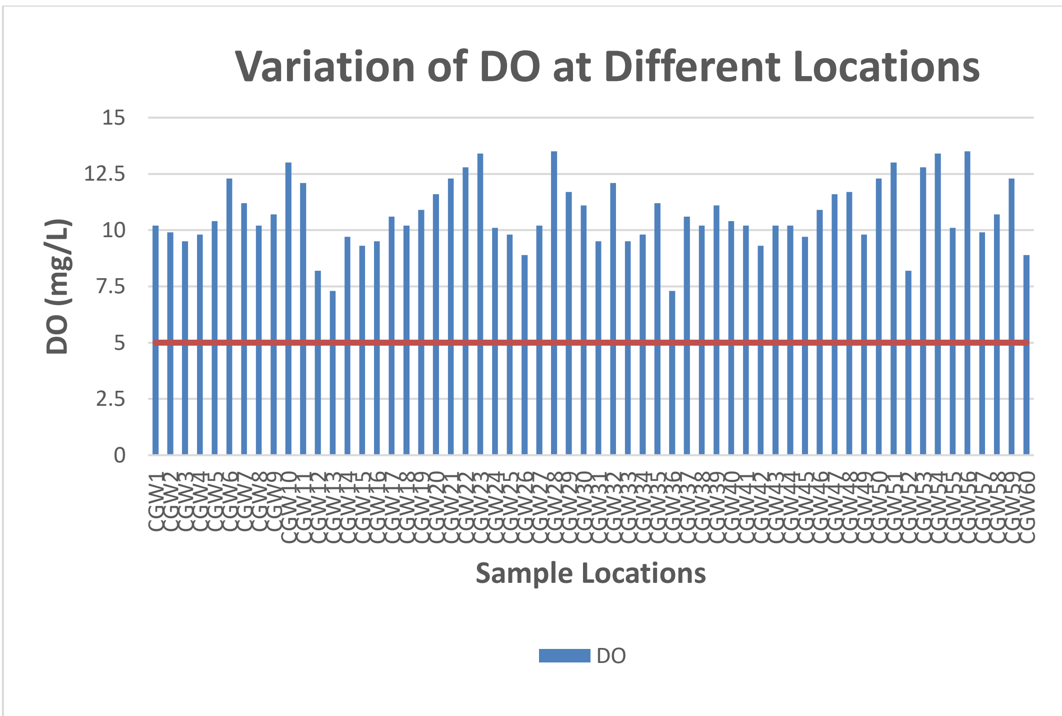

Figure 8: Variation of DO at Different Locations

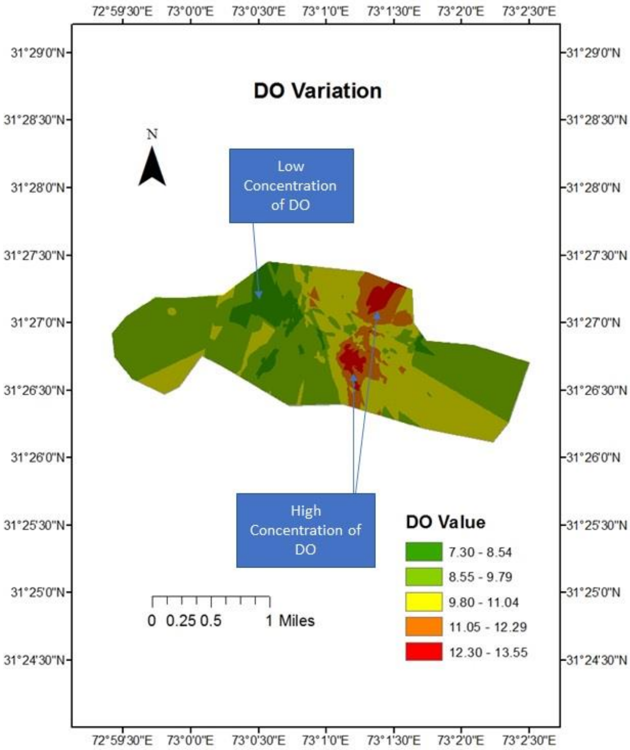

Figure 9: Variation of DO in Different Groundwater Samples

3.5 Carbonates and Bicarbonates

Carbonates and bicarbonates were determined to find out the Residual Sodium Carbonate (RSC) for groundwater analysis. More over Carbonates and Bicarbonates are used to find out drinking water quality standards.

The concentration of carbonates and bicarbonates varied from 19 to 384 and 65 to 1285 respectively.

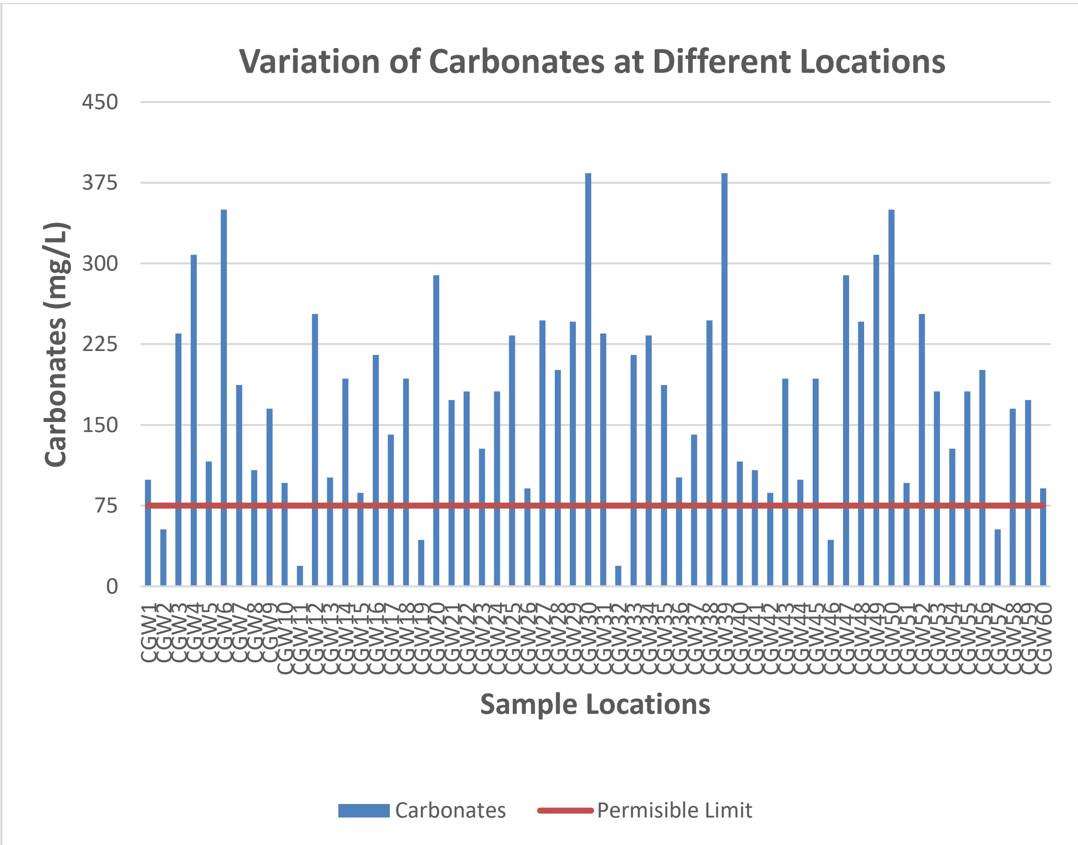

Figure 10: Variation of Carbonates at Different Locations

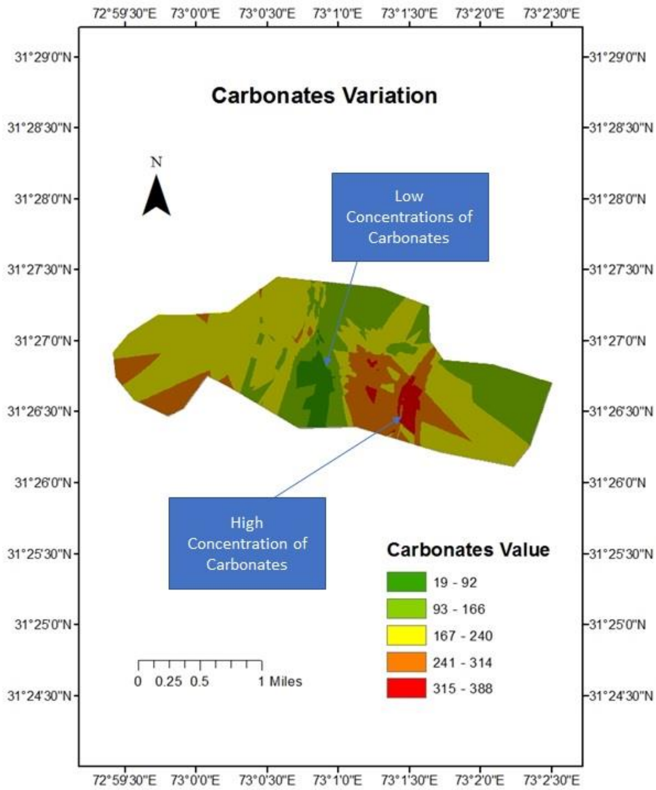

Figure 11: Variation of Carbonates in Different Groundwater Samples

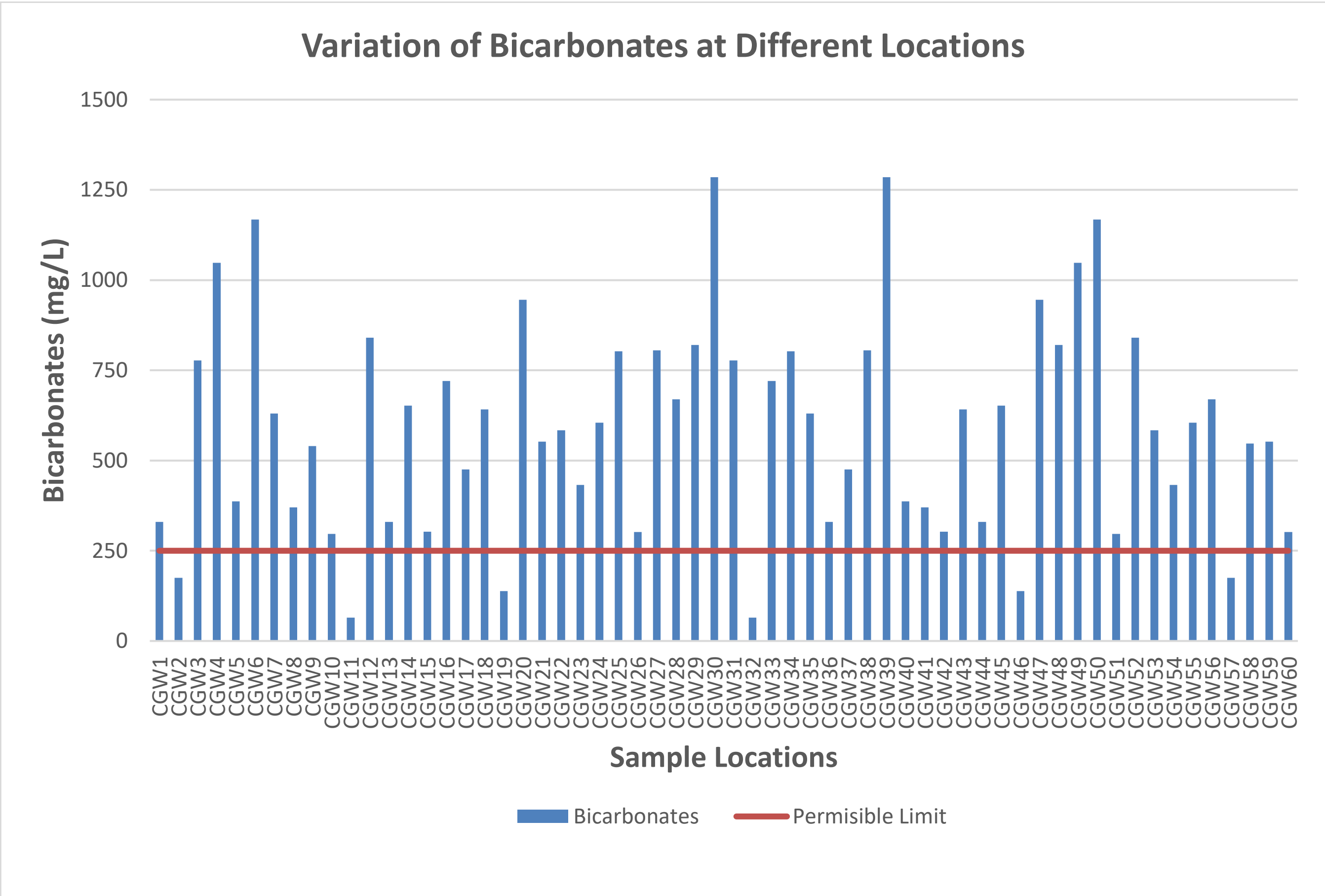

Figure 12: Variation of Bicarbonates at Different Locations

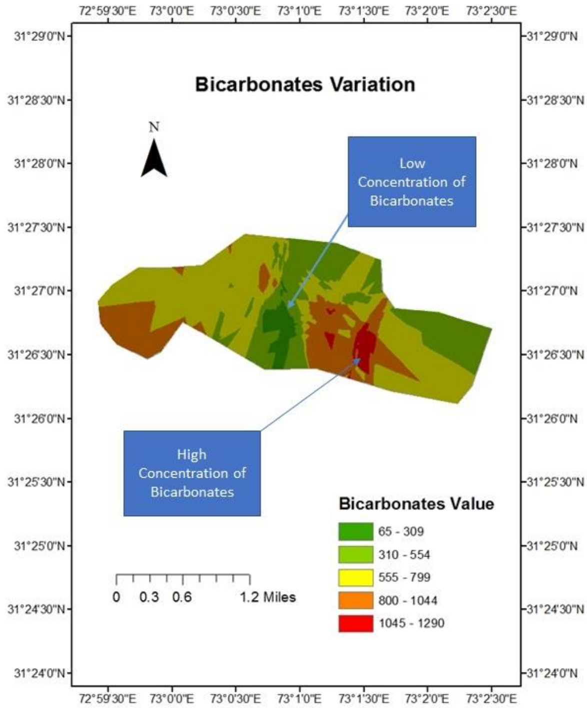

Figure 13: Variation of Bicarbonates at Different Locations

3.6 Chloride Contents

Some common chloride compounds found in natural water are sodium chloride (NaCl), potassium chloride (KCl), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). Taste thresholds for the chloride anion depend on the associated cations and the concentration ranges from 200 to 300 mg/L for sodium, potassium and calcium chloride. Based on taste threshold, WHO has prescribed 250 mg/l as the acceptable limit for chloride. The concentration of chloride in the collected samples were in the range of 32–960 mg/l (Figure 14).

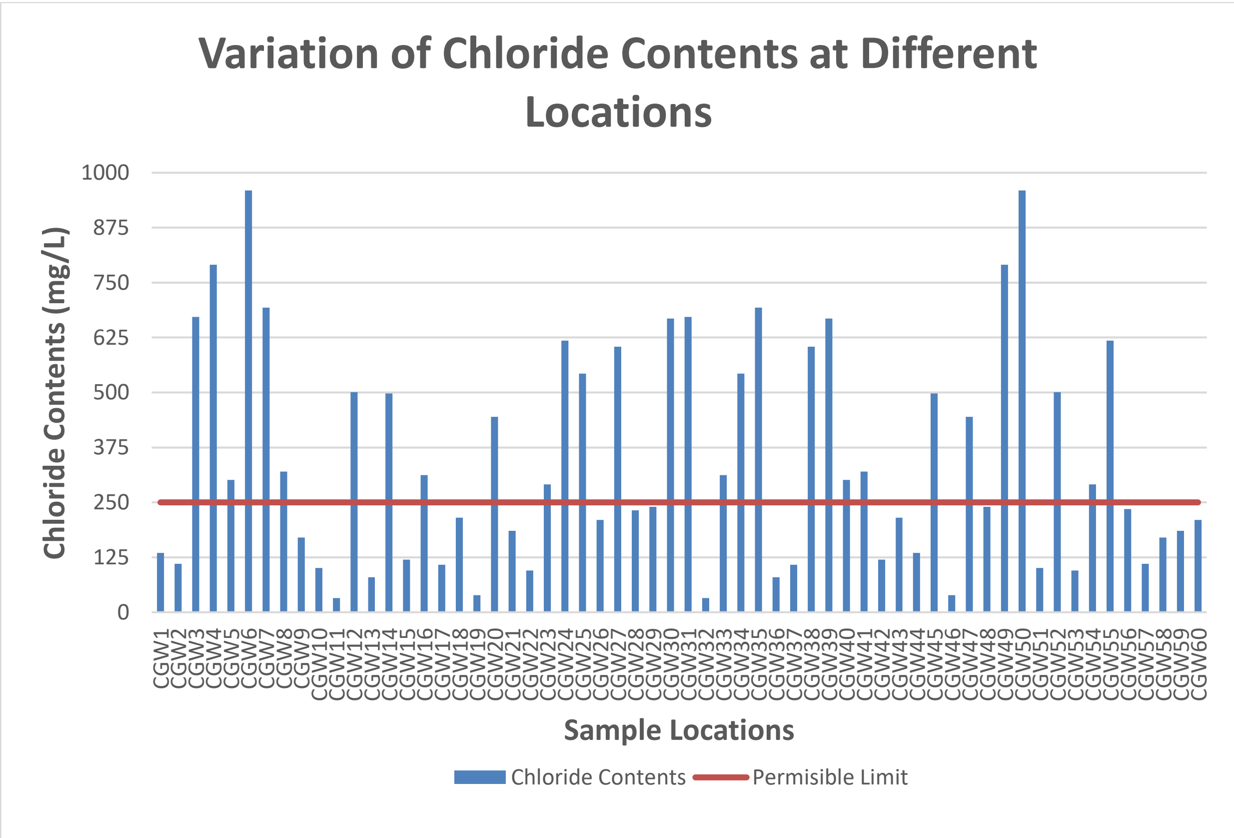

Figure 14: Variation of Chloride Contents at Different Locations

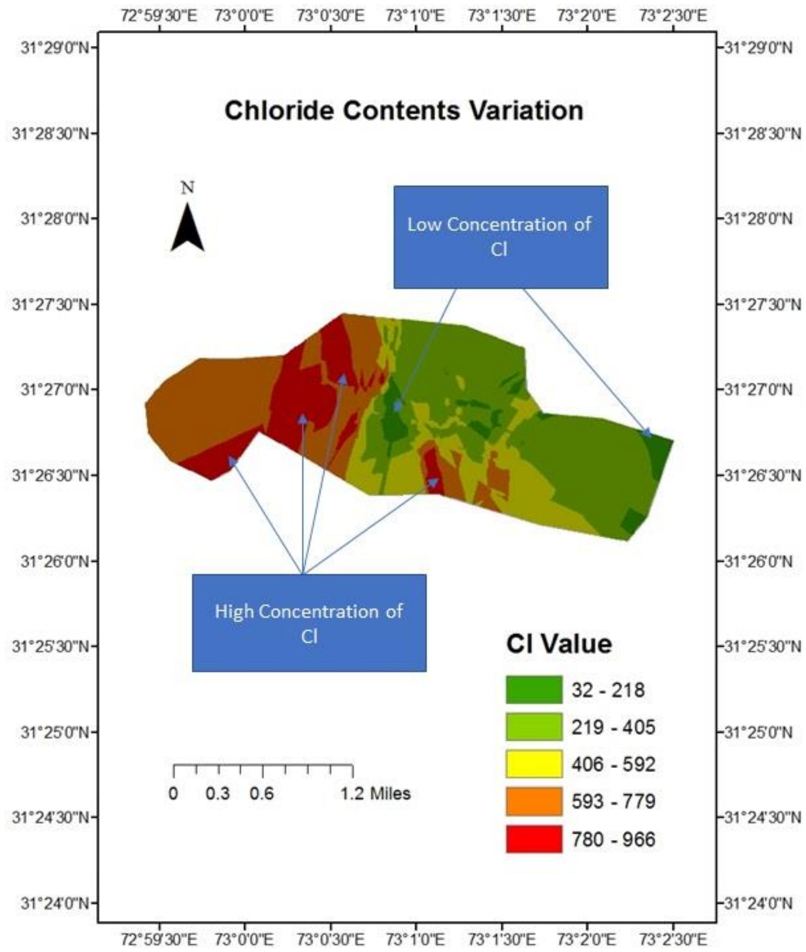

Figure 15: Variation of Chloride Contents in Different Groundwater Samples

3.7 Arsenic

The value of arsenic in the groundwater samples varied from 0 to 0.07 mg/l with the average value of 0.04. The permissible limit is 0.01 mg/l by WHO. Fig. 10 tells the whole scenario of arsenic variation in the study area. Most of the water samples have the arsenic value above the permissible limit. The red colored area as shown in the Fig. 16 possesses the highest concentration of arsenic.

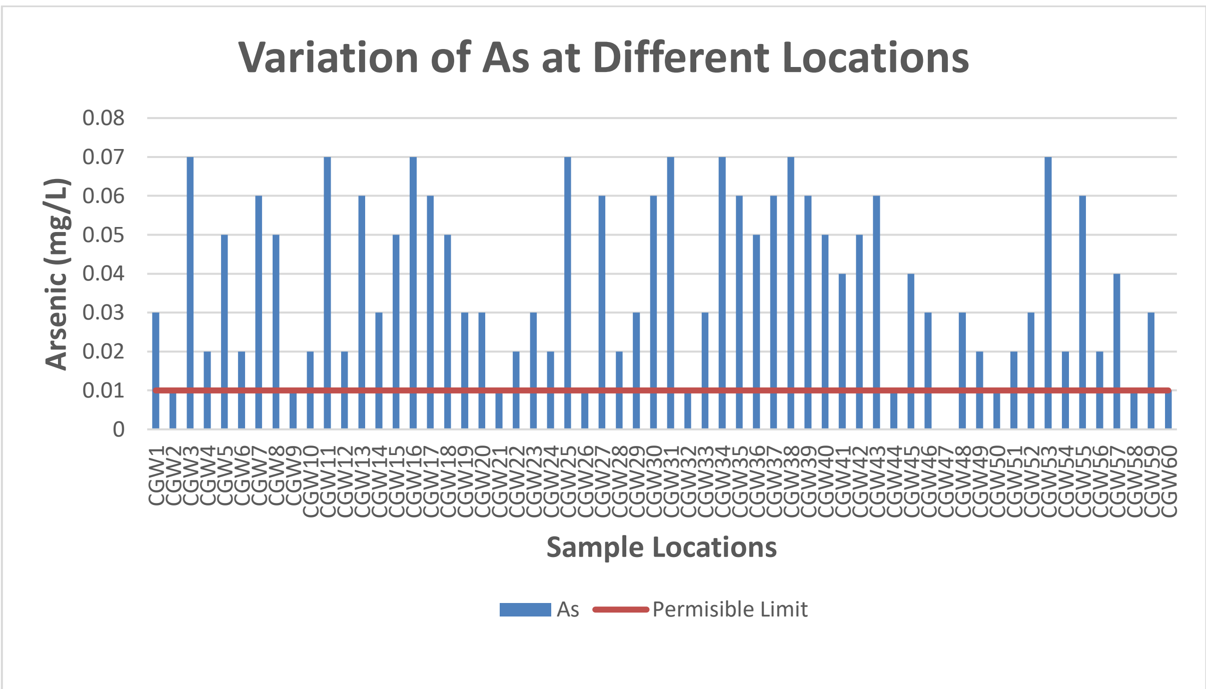

Figure 16: Variation of As at Different Locations

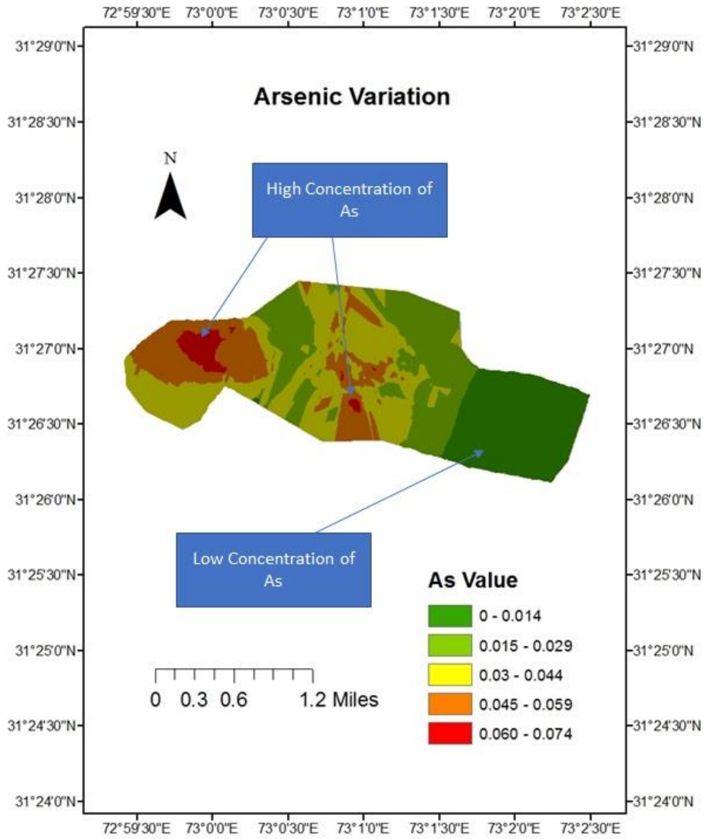

Figure 17: Variation of As in Groundwater Samples

3.8 Lead

The main sources of lead in water are dyes, gasoline, batteries waste, manufacturing and pipe industries. It is a serious body poison. Guideline value for lead is 0.01 mg/l (WHO, 2011). Lead in groundwater samples in the study area is varied between 0.01 and 0.08 mg/l. Fig. 18 indicates the value of lead in study area. The area having a high concentration of lead is indicated by yellow color on map.

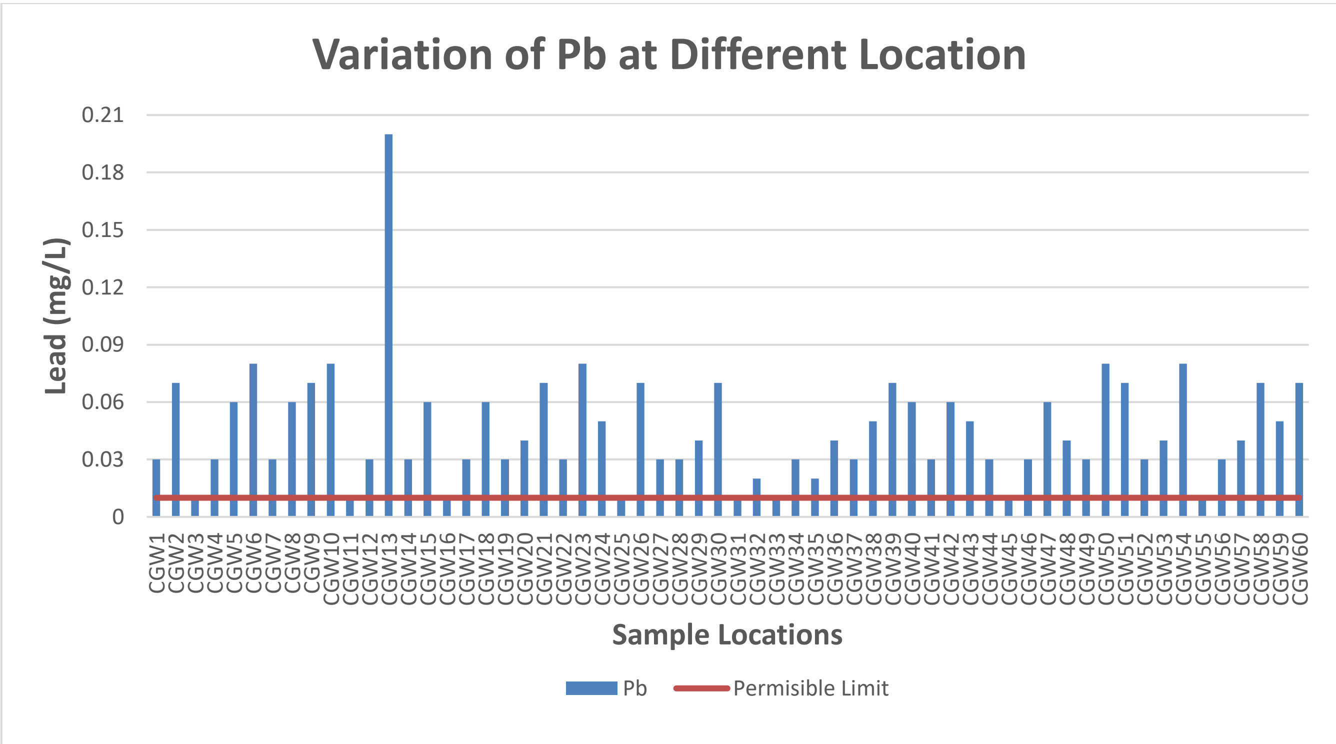

Figure 18: Variation of Pb at Different Locations

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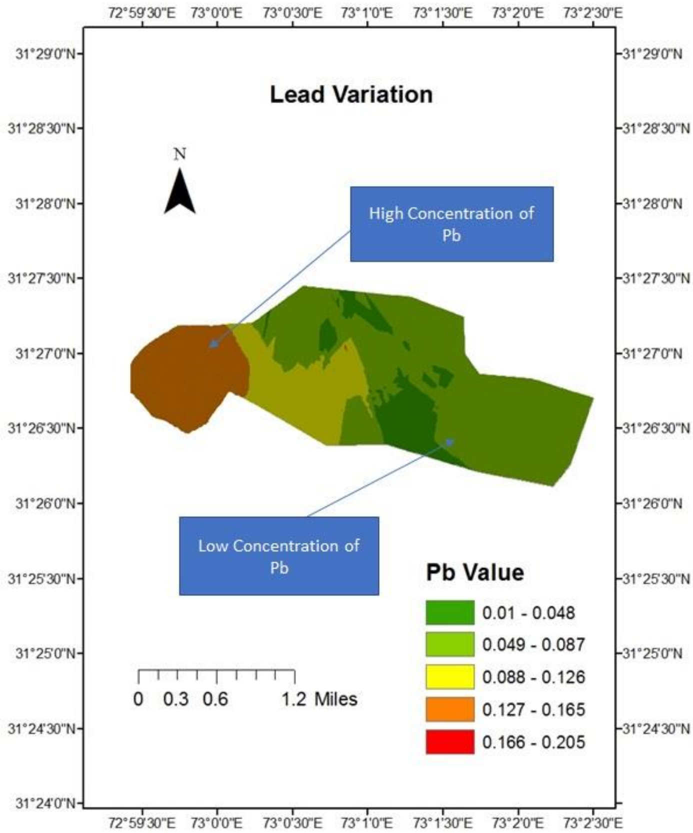

Figure 19: Variation of Pb in Groundwater Samples

3.9 Cadmium

The value cadmium in groundwater samples of Chokera varied between 0 and 0.08 mg/l. The average value of cadmium variation was recorded as 0.04. Permissible limit for cadmium is 0.01 mg/l [11]. Figure 20 shows the spatial variability of cadmium in groundwater samples of study area.

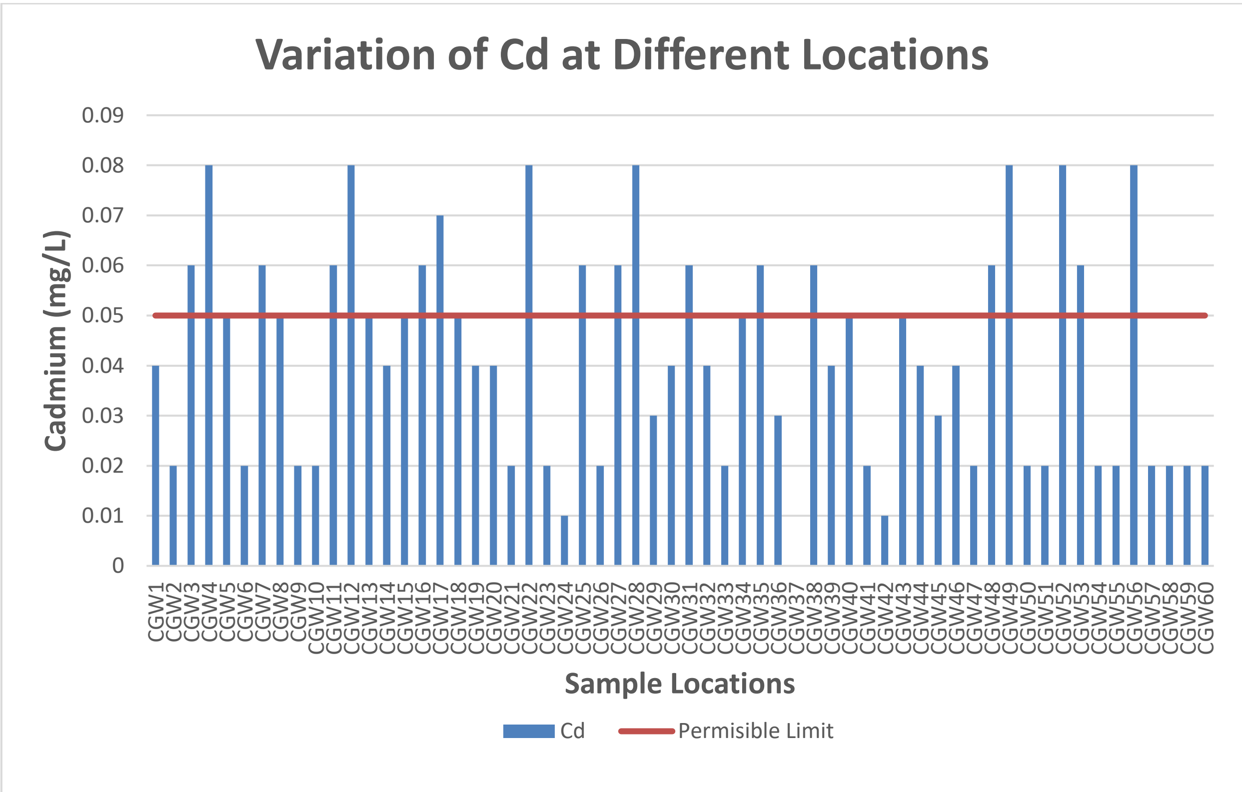

Figure 20: Variation of Cd at Different Locations

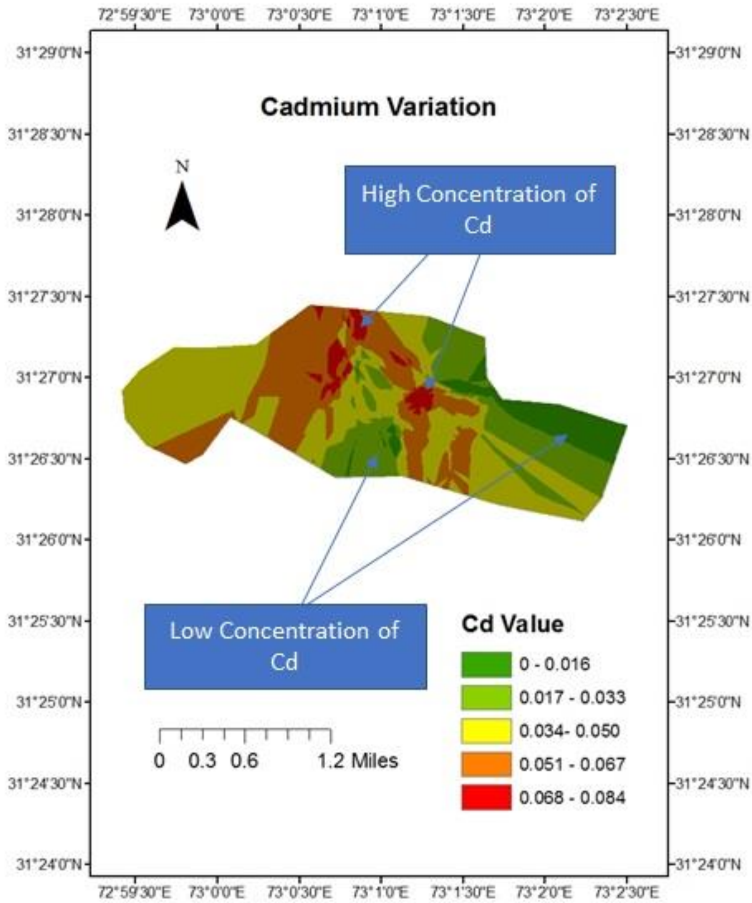

Figure 21: Variation of Cd in Groundwater Samples

3.10 Copper

The value of copper in groundwater samples of Chokera varied between 0 and 0.08 mg/l. The average value of cadmium variation was recorded as 0.04. Permissible limit for copper is 0.05 mg/l. Figure 22 shows the spatial variability of copper in groundwater samples of study area.

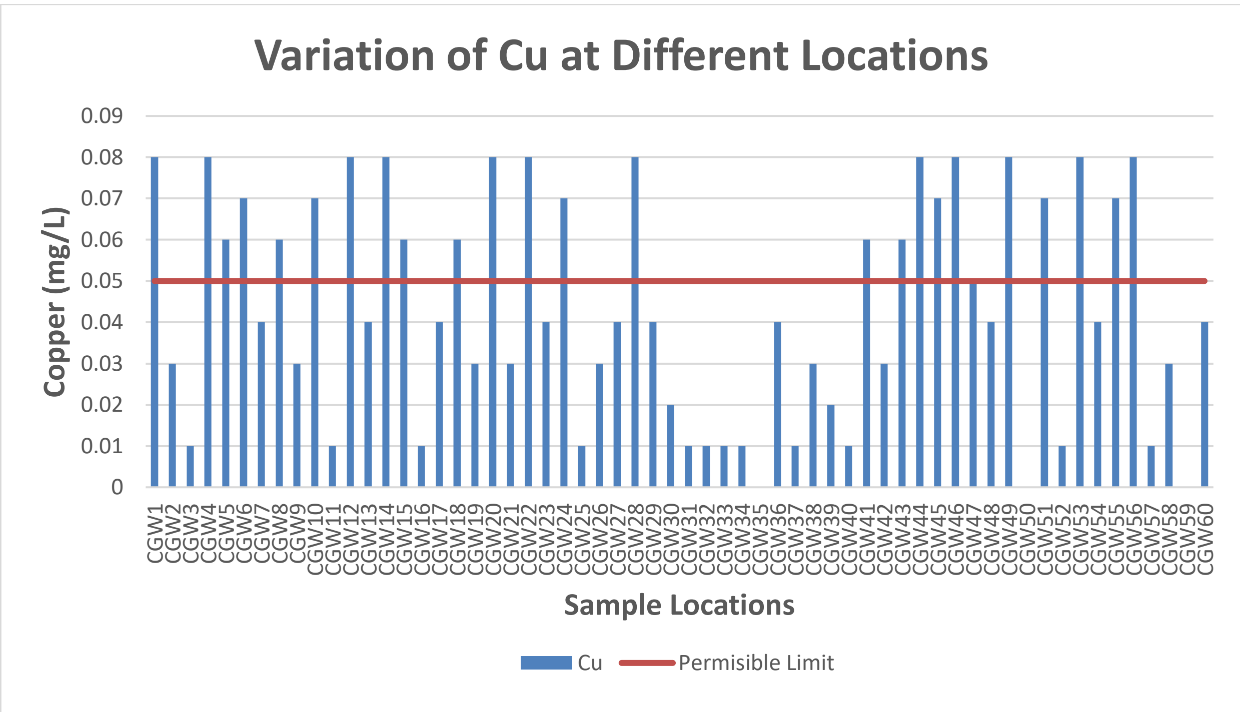

Figure 22: Variation of Cu at Different Locations

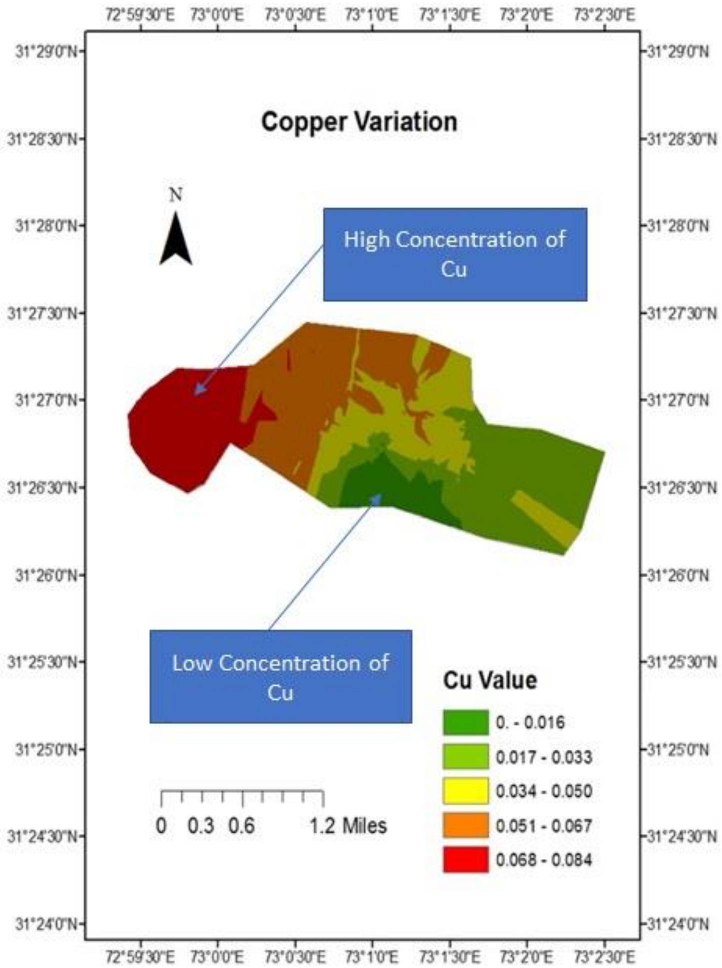

Figure 23: Variation of Cu in Groundwater Samples

3.11 Chromium

The chromium concentration of groundwater samples obtained from Chokera ranged from 0.01 to 0.08 mg/l. The average value of all the samples was 0.04. Figure 24 shows the spatial variability of chromium in the groundwater samples. The sources of chromium in water includes; mining, garbage disposal, soaps and detergents, industrial effluents and agricultural activities [12]. Long term exposure to chromium posed threat to human life and can cause kidney, liver circulatory and nerve tissue damages.

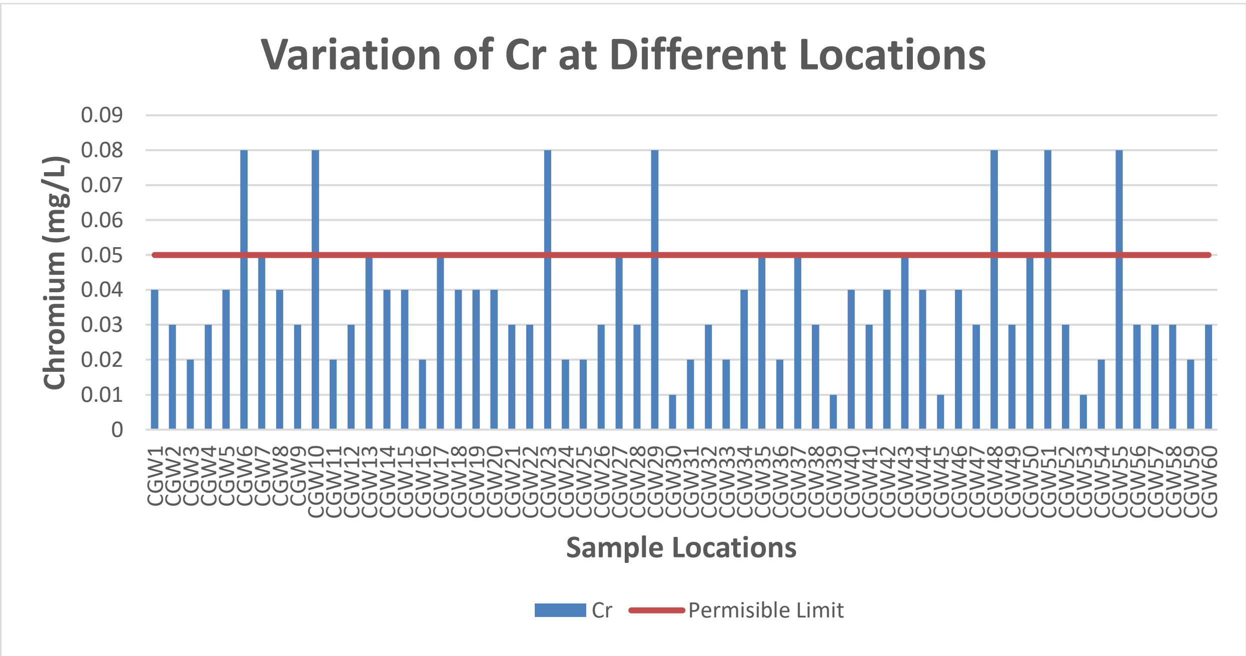

Figure 24: Variation of Cr at Different Locations

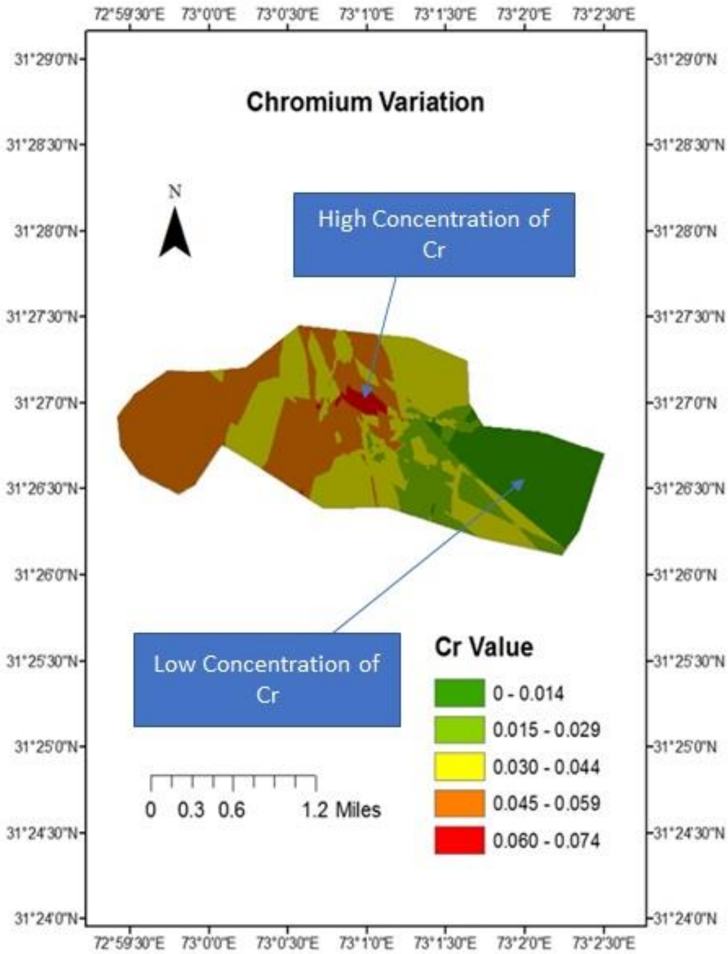

Figure 25: Variation of Cr in Groundwater Samples

3.12 Zinc

Zinc values for groundwater were ranging between 0.01 to 0.07 mg/l. GIS map shows the concentration of Zinc (Zn) in groundwater as shown in Fig. 26. The GIS study explores that Zn level was found high in the groundwater samples at the western side.

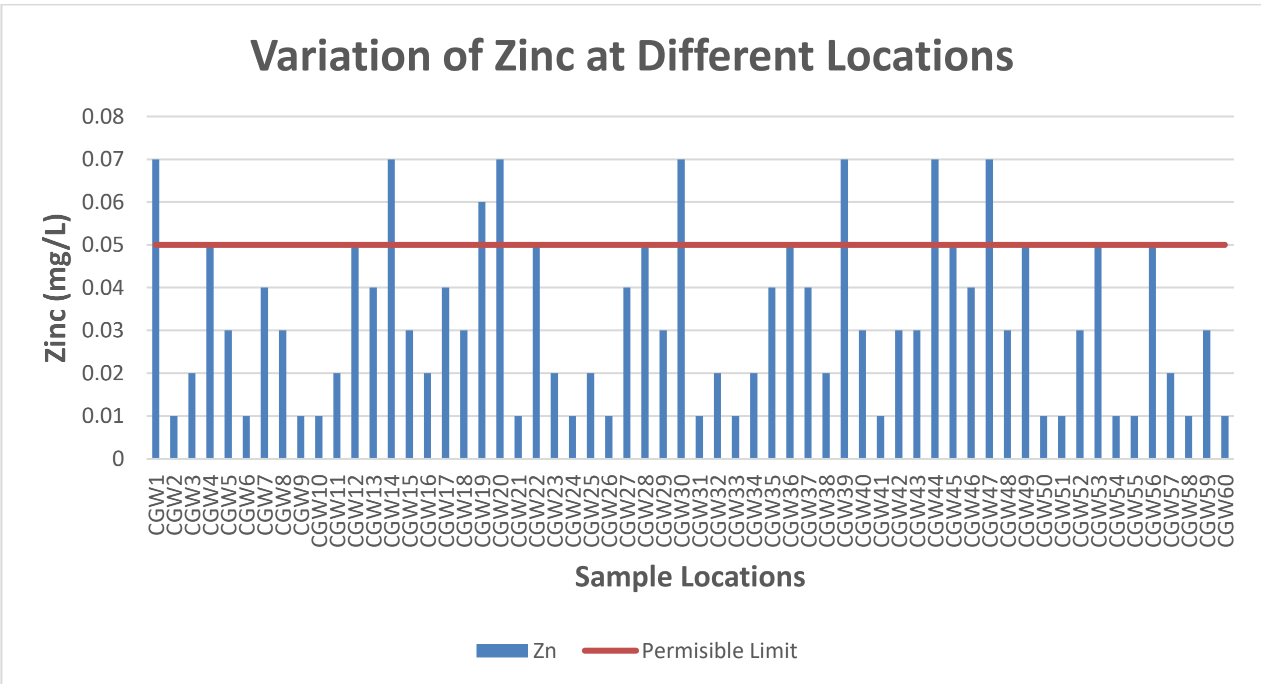

Figure 26: Variation of Zn at Different Locations

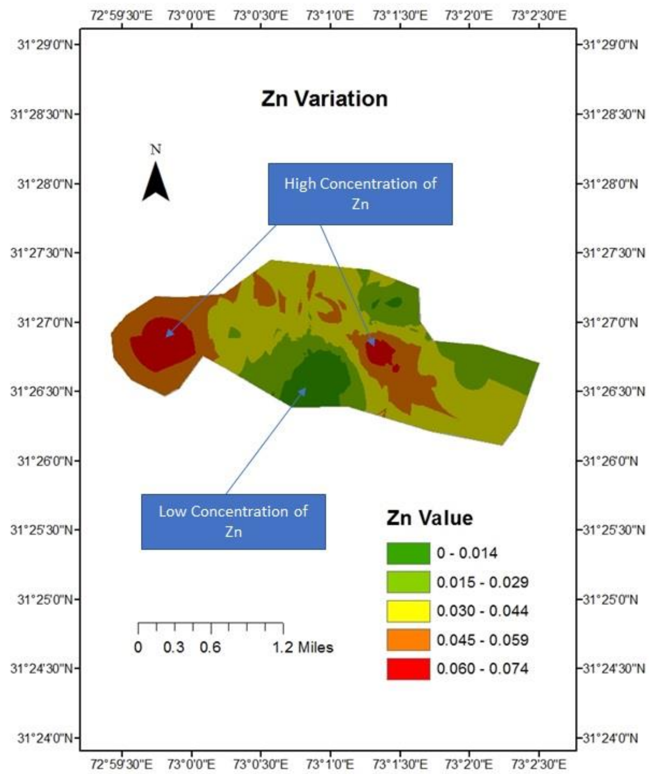

Figure 27: Variation of Zn in Groundwater Samples

3.13 WQI

In this study, the computed WQI value ranges from 73 to 272 as shown in Table 3. It can be categorized into poor and very poor water.

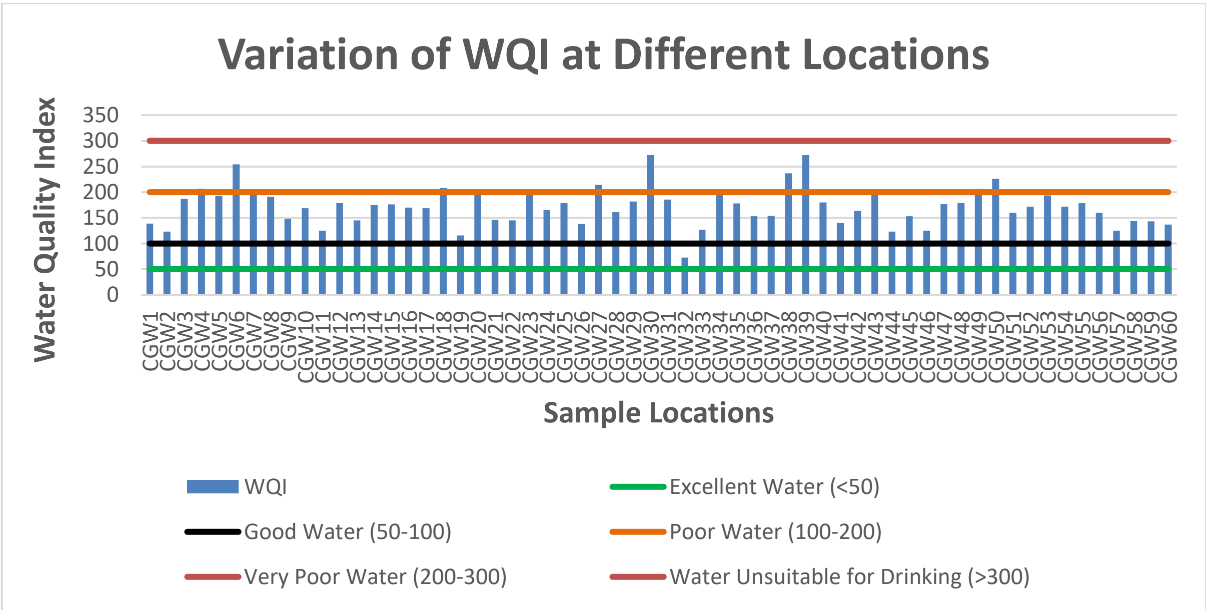

Figure 28: Variation of WQI at Different Locations

Table 3: Details of Water Quality and Index Rate of Analysed Samples

Sr. No.	Sample Code	Index Rate	Water Quality	Sr. No.	Sample Code	Index Rate	Water Quality
1	CGW1	139	Poor Water	31	CGW31	185.7	Poor Water
2	CGW2	123	Poor Water	32	CGW32	73	Good Water
3	CGW3	187	Poor Water	33	CGW33	127	Poor Water
4	CGW4	207	Very Poor Water	34	CGW34	205	Very Poor Water
5	CGW5	193	Poor Water	35	CGW35	178	Poor Water
6	CGW6	254	Very Poor Water	36	CGW36	153	Poor Water
7	CGW7	200	Very Poor Water	37	CGW37	154	Poor Water
8	CGW8	191	Poor Water	38	CGW38	237	Very Poor Water

9	CGW9	148	Poor Water	39	CGW39	272	Very Poor Water
10	CGW10	169	Poor Water	40	CGW40	180	Poor Water
11	CGW11	125	Poor Water	41	CGW41	140	Poor Water
12	CGW12	179	Poor Water	42	CGW42	164	Poor Water
13	CGW13	145	Poor Water	43	CGW43	201	Very Poor Water
14	CGW14	175	Poor Water	44	CGW44	123	Poor Water
15	CGW15	176	Poor Water	45	CGW45	153	Poor Water
16	CGW16	170	Poor Water	46	CGW46	125	Poor Water
17	CGW17	169	Poor Water	47	CGW47	177	Poor Water
18	CGW18	208	Very Poor Water	48	CGW48	179	Poor Water
19	CGW19	116	Poor Water	49	CGW49	206	Very Poor Water
20	CGW20	197	Poor Water	50	CGW50	226	Very Poor Water
21	CGW21	146	Poor Water	51	CGW51	160	Poor Water
22	CGW22	145	Poor Water	52	CGW52	172	Poor Water
23	CGW23	195	Poor Water	53	CGW53	194	Poor Water
24	CGW24	165	Poor Water	54	CGW54	172	Poor Water
25	CGW25	179	Poor Water	55	CGW55	179	Poor Water
26	CGW26	138	Poor Water	56	CGW56	160	Poor Water
27	CGW27	214	Very Poor Water	57	CGW57	125	Poor Water
28	CGW28	161	Very Poor Water	58	CGW58	144	Poor Water
29	CGW29	182	Poor Water	59	CGW59	143	Poor Water
30	CGW30	272	Very Poor Water	60	CGW60	137	Poor Water

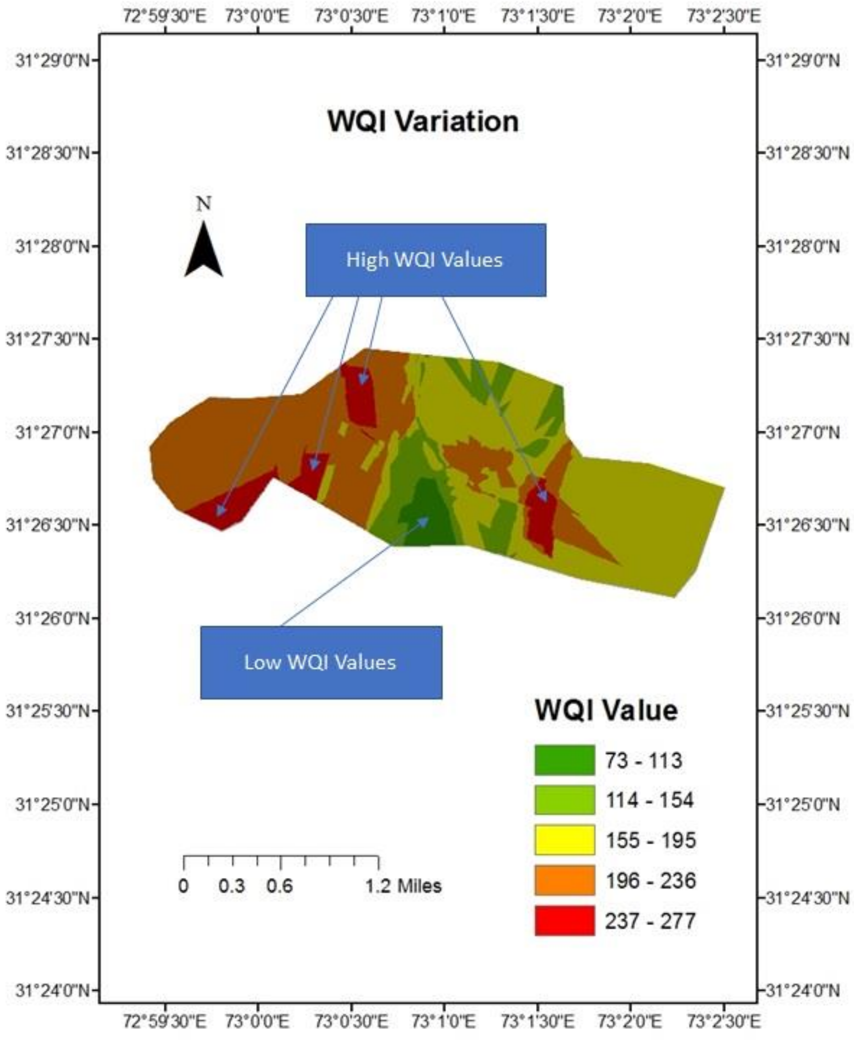

Figure 29: Variation of WQI in Different Groundwater Samples

4.CONCLUSION

The ground water which were taken from the various places from Chokera area were analyzed and the analysis reports shows that the water quality parameters like pH and Total Dissolved Solids of few samples lies within the permissible limit prescribed by WHO, but many other parameters were reported beyond the permissible level, which have an impact on the water to use for drinking purpose. The analysis of experimental investigation on quality of groundwater using fourteen physico-chemical parameters of the study area indicate that the water quality was poor and very poor for drinking purpose. In this study, the computed WQI values ranges from 73 to 272. The overall view of the Water Quality Index of the present study zone had a higher WQI value indicating the deteriorated water quality.

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