



## RESEARCH ARTICLE

## Groundwater Quality Assessment for Drinking Purpose in Gulistan-e-Johar Town, Karachi, Pakistan

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### Abstract

The main objective of present study is to evaluate the groundwater quality of Gulistan-e-Johar town for drinking. For this purpose, groundwater samples (n=18) through electrically pumped wells were collected from shallow aquifers (mean depth = 36 m). Collected samples were subjected to determine the physical characters (TDS, pH, temperature), major (Na, K, Ca, Mg, Cl, SO<sub>4</sub>, HCO<sub>3</sub>, and NO<sub>3</sub>) and minor ions (Fe, Mn and F). Data reveal very high content of TDS (mean: 2862 mg/L) coupled with elevated concentration of Na (mean: 974.6 mg/L), Cl (mean: 545.3mg/L), SO<sub>4</sub> (mean: 600mg/L), Mn (mean: 0.04 mg/L) and F (mean: 1.7 mg/L). The results indicated that groundwater of Gulistan-e-Johar is not suitable for drinking purpose and may lead to dangerous health impacts. The WQI value of groundwater is found to be 183 which is also endorsing that groundwater of Gulistan-e-Johar is unfit for drinking purpose.

**Keywords:** Groundwater quality, physicochemical parameters, water quality index (WQI), Gulistan-e-Johar.

### 1. Introduction

Water is one of the vital constituents for all lives among other blessings. It can be obtained by surface sources including rivers, canals, lakes, streams etc. and underground sources like groundwater abstraction from wells and borehole (McMurry and Fay, 2004). More than half of the population depends on groundwater for survival worldwide (UNESCO, 1992). Water resources are decreasing as the population is increasing day by day. It is widely believed that about 80% of all the diseases are water borne (WHO, 2011). The attributes of water depend on its chemical composition which is controlled by natural and anthropogenic activities in context of measurable quantities (Kumar, 1997). Thus, the ability to forecast the hazards and pollution resulting from the groundwater flow has dynamic importance for the precise evaluation (Khan et al., 2017).

Karachi is the largest and densely populated city of Pakistan where water is mainly supplied through pipelines. Besides, groundwater is the other major source for domestic use. Due to rapid population growth and up-country migration the balance between water demand and supply has been disturbed. As a result, people are switching over to exploit groundwater for their needs. The over abstraction of groundwater depletes water table and accelerates the contaminant transport from the land to the aquifer (Shah and Roy, 2002) which ultimately pollute the aquifers. Domestic sewage and industrial effluent

contribute to an increase in concentration of different pollutants in groundwater (Reghunath et al., 2002).

Gulistan-e-Johar is newly developed residential area with no industrial activity. Army cantonment areas and air force base coupled with central ordinance depot surround the area. –upper-middle class with satisfactory literacy rate live in this part of Karachi city. This town covers an area of about 10.84 sq. km which serves as the largest centre of flat projects in Karachi. There is a rapid decline in municipally supplied water since last couple of decades. As a result, switch over to groundwater is frequent to meet the domestic needs. Moreover, people are heavily dependent on the bottled water for drinking purpose which is mined from groundwater of study area and processed in the Reverse Osmosis (R.O) plants. Despite of switch over to groundwater for drinking and installation of large number of RO plants no study has been carried so far to screen the quality of groundwater in the study area. Therefore, present study is pilot evaluation of groundwater in study area by determining the physicochemical parameters of collected water samples.

### 2. Geology of Study Area

Geologically, Gulistan e Johar town rests on Gaj Formation of Miocene age which in turn is comprised of four members. Gulistan-e-Johar member is the youngest among all members of Gaj Formation (Fig. 2). This member is spread over the study area where it shows lihtic character as variegated series of shallow marine clastics followed by fossiliferous limestones.

The bed rocks, on which study area, rests are mainly composed of sandstone, siltstone with interbedded shale and subordinate limestone followed by soft to hard sandstone which is highly conductive due to the

dominance of sandy silt (Pithawalla and Martin-Kaye, 1946; Shah, 2009). Due to the occurrence of variable rock resistance and rheology the topography of study area is highly undulatory.

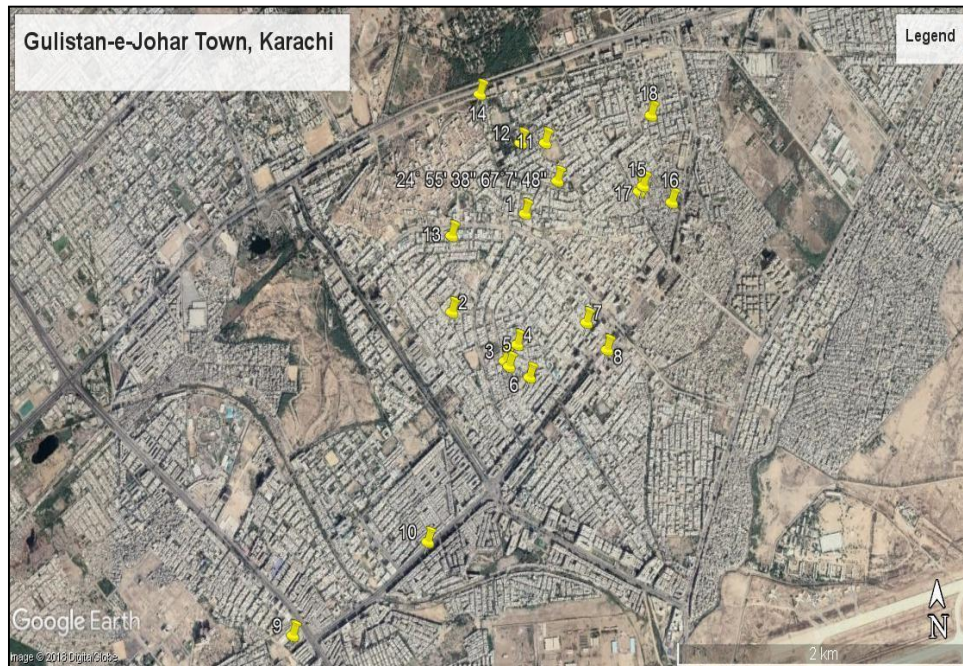


Fig. 1. Map showing sample locations plotted on the Google Earth Image.

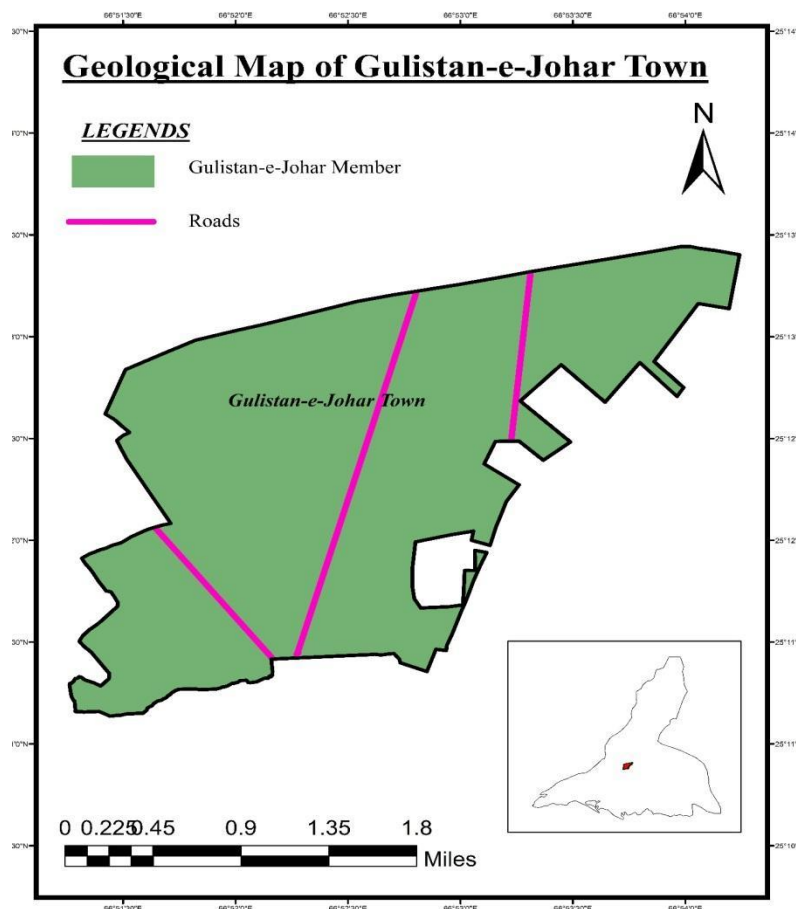


Fig. 2. Geological map of Gulistan-e-Johar town, Karachi.

### 3. Materials and Methods

#### 3.1 Sample Collection

Water samples (n=18) were collected through boring wells at a depth range of 10 to 75 metres from various localities of Gulistan-e-Johar town. Water was electrically pumped for 2-3 minutes to get representative samples. Location of the boreholes were taken by using Global Positioning System (GPS) and marked on the Google image (Fig. 1). Water samples were taken in polyethylene bottles of 1 litre capacity for physico-chemical analysis. Bottles were rinsed thoroughly with distilled water and subsequently with the sample water on sampling site. Samples were separately collected in bottles of 200 ml capacity to determine nitrate content. About 1 ml of boric acid solution was added in each water sample to stop any further reaction.

#### 3.2 Groundwater Analysis

All the samples were examined for physicochemical parameters in the laboratory of Department of Geology, University of Karachi except fluoride test, which was analyzed in Pakistan Council of Research in Water Resources (PCRWR). The pH & TDS of collected samples were determined by using pH meter (ADWA AD 111) and TDS meter (ADWA AD 330) respectively. Sodium and Potassium concentrations were determined by using flame photometer (Model No. JENWAY PFP7). Sulphate concentration was determined by gravimetric method, while chloride and bicarbonate ions were estimated by argenometric titration method. For the determination of calcium and total hardness, EDTA titration method (1992) was applied. Amount of magnesium was determined by taking the difference of hardness and calcium using standard formula. Concentration of nitrate was determined by cadmium reduction method (HA CH-8171) on spectrophotometer while the iron and manganese were determined by using Atomic Absorption Spectroscopy.

#### 3.3 Water Quality Index

One of the most operational techniques to collect information of the water quality for the policy makers and the citizens is Water Quality Index (Yisa and Jimoh, 2010). It was first proposed by Horton in 1965 which was later generalized by Brown et al. in 1970. Water quality index (WQI) is a number that evaluates the quality of water by gathering different parameters, lower values refers to good or excellent quality while higher values refers to the bad or poor quality (Bharti, 2011). Weighted arithmetic index method of WQI proposed by Brown et al (1970) was applied to evaluate the groundwater quality of Gulistan-e-Johar Town. Physicochemical parameters including pH, TDS, major cations (Ca, Mg, Na and K) and anions (SO<sub>4</sub>, Cl, HCO<sub>3</sub>, NO<sub>3</sub>, Fe, Mn and F) were used to calculate WQI of groundwater in study area.

Table 1 WQI range, status and possible usage of the water sample

WQI	Status	Possible usages
0-25	Excellent	Drinking, irrigation and industrial
25-50	Good	Domestic, irrigation and industrial
51-75	Fair	Irrigation and industrial
76-100	Poor	Irrigation
101-150	Very poor	Restricted use for irrigation
Above 150	Unfit for drinking	Proper treatment required before use

It is simple method aimed at interpreting the concentration of parameters present, to express them into a single value. It provides an extensive clarification to rate the quality and its suitability for different purposes including: drinking, irrigation, industrial, restricted etc. WQI is calculated using following formula.

$$WQI = \sum q_n W_n / \sum W_n \quad (1)$$

Where  $Q_n$  is the quality rating of nth water quality parameter,  $W_n$  is the unit weight of nth water quality parameter.

The quality rating  $Q_n$  is calculated using the equation :

$$Q_n = 100 \times [(V_n - V_i) / (V_s - V_i)] \quad (2)$$

Where,  $V_n$  is the actual amount of nth parameter present,  $V_i$  is the ideal value of the parameter,  $V_i = 0$ , except for pH ( $V_i = 7$ ),  $V_s$  is the standard permissible value for the nth water quality parameter.

Unit weight ( $W_n$ ) is calculated using the formula

$$W_n = k/V_n \quad (3)$$

Where, k is the constant of proportionality and it is calculated using the equation

$$k = 1 / \sum V_s = 1, 2, 3, \dots, n \quad (4)$$

### 4. Results and Discussion

#### 4.1 Physicochemical characteristics

Groundwater samples (n=18) were collected from various parts of Gulistan-e-Johar town through electrically pumped wells installed at various depths (range = 34-250 feet). The results of all physicochemical parameters have been summarized in Table 2. Due to large variation in the well depths shallow (depth < 100 feet) and deep (depth > 100 feet) aquifers have been addressed separately.

#### 4.2 Shallow Aquifers

One third of total collected samples have been tapped from shallow aquifers ranging in depth between 34-75 feet (Table 2). The pH of these samples is found to be slightly acidic (mean: 6.8). low pH of these water samples seems to be controlled by the geology of study area as rocks hosting these water bodies are mainly

comprised of sandstone. The lowering of pH is attributed to organic acids, by dissolution of sulphide minerals or decaying of vegetation (Davis and DeWiest, 1966). The study area was densely vegetated before urbanization. Due to construction activities, removal of such plants (herbs/shrubs) may cause plants decaying and organic acid generation which can dissolve silicates more effectively as compared to inorganic acids (Zhang et al., 2009) leading to lower the pH groundwater. Moreover, sewage mixing with such shallow aquifers is also plausible to increase acidity. Sewage mixing is evident by draining such water into the open channels and pits (Fig. 3).

Total Dissolved Solids (TDS) content in these shallow aquifers is found to be very high (mean: 2818 mg/L) which is far above permissible limit of both WHO

(500 mg/L) and Pakistani guidelines (1000 mg/L) for drinking. High salt content in these water samples seems to be associated with acidic pH conditions. Organic matter decomposition is accompanied with the release of a large amount of organic acids into the water phase. When the water enters into the aquifer rocks, the contained organic acids could accelerate the complete decomposition of feldspar. Besides, it also helps to reduce the pH value of pore water in original aquifer rocks, which becomes an important factor for further dissolution of feldspar (Zhang et al., 2009). Total hardness of these wells is very high (mean 359.2 mg/L) which is mainly influenced by chloride content (mean: 433.1 mg/L) of such water as compared to HCO<sub>3</sub> (134.3 mg/L).

Table 2. Physico-chemical parameters of groundwater samples (n=18) collected from Gulistan-e-Johar Town.

S.No.	Physical Parameter				Major Cations				Major Anions				Minor Elements		
	Depth (ft)	pH	TDS (mg/L)	Hardness (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO <sub>4</sub> (mg/L)	HCO <sub>3</sub> (mg/L)	NO <sub>3</sub> (mg/L)	Fe (mg/L)	Mn (mg/L)	F (mg/L)
GJ-1	35	6.86	2140	550	870	57	220	80.19	333.23	639.6	91.145	32	0.03	0.148	1.31
GJ-2	34	6.91	3000	350	1540	42	60	70.47	524.66	558.2	171.35	17.4	0.03	0.022	1.38
GJ-3	40	6.8	2800	280	580	44	172	26.24	177.25	602.4	123.96	18.3	0.02	0.023	1.23
GJ-4	38	6.81	3640	285	76	39	248	8.99	638.1	716.4	109.37	1.88	0.4	0.035	1.57
GJ-5	42	6.8	3420	320	98	45	248	17.49	496.3	935	127.6	18.9	0.03	0.03	1.43
GJ-6	102	7.02	2210	360	68	40	128	56.38	333.23	795.4	58.333	4.32	0.02	0.023	1.14
GJ-7	175	7.19	3750	265	2000	24	232	8.02	726.73	705.2	72.916	0.78	0.04	0.01	1.21
GJ-8	170	6.53	3870	270	2370	23	208	15.1	847.26	814	87.499	0.84	0.25	BDL	1.14
GJ-9	120	7.13	4550	260	2700	29	200	14.58	957.15	739.6	94.791	0.62	0.25	0.013	1.08
GJ-10	75	6.88	1910	370	68	21	128	58.81	428.95	695.4	182.29	9.62	0.28	0.163	2.08
GJ-11	120	7.39	1010	260	44	11	160	24.3	159.53	244.2	123.96	1.33	0.02	BDL	2.01
GJ-12	180	7.23	1360	420	61	15	40	92.34	276.51	407.8	204.16	2.62	0.03	0.037	2.71
GJ-13	130	7.38	3030	730	94	14	112	150.2	726.73	573.5	302.6	35	0.01	0.008	3.01
GJ-14	120	7.07	3260	480	2000	20	80	97.2	868.53	438.4	233.33	10.22	0.31	0.006	2.76
GJ-15	180	7.36	2390	195	1420	8	52	34.75	567.2	237.8	116.67	1.98	0.05	BDL	1.74
GJ-16	170	7.32	1990	290	73	25	164	30.62	194.98	607.3	145.83	3.33	0.05	0.022	1.32
GJ-17	160	7.02	4250	325	1840	20	204	29.4	1169.9	513	131.25	2.56	0.04	0.024	1.86
GJ-18	250	7.24	2930	345	1640	10	140	49.82	389.95	576.1	109.37	0.74	0.24	0.033	1.56
WHO Limit	-	6.5-8.5	<1000	500	200	30	200	150	250	250	NGVS	10	0.3	0.02	1.5



Fig. 3. Sewage water drained into open channel near old track of Karachi circular railway.

Major solutes varied in the order of Na > Ca > Mg > K where Na and K contents are sourced from feldspars of sandstone while Ca and Mg from limestone units of Gaj Formation. Presence of organic acid, decrease of pH value and water salinity favors the dissolution of feldspar. Under acidic conditions; albite shows higher dissolution rate than K-feldspar (Zhang et al., 2009). This may be the reason of high sodium content (538.7 mg/L) as compared to potassium (41.33 mg/L) in the groundwater of study area. Nitrate content is very high in four wells (17.4-32 mg/L) exceeding the WHO permissible limit of 10 mg/L (Table 2). Strong correlation of NO<sub>3</sub> with K ( $r^2 = 0.57$ ) and Mg ( $r^2 = 0.48$ ) clearly indicate that it is mainly sourced from clay minerals where organic matter is available for degradation by bacteria. The oxidation of ammonia to strong acids by nitrifiers leads to pH decrease (Elbanna et al., 2012) which is also evident by the acidic pH in shallow aquifers of Gulistan e Johar.

### 4.3 Minor and trace Solutes

Concentration of Fe and Mn varies in the range of 0.02-0.4 and 0.02-0.16 mg/L respectively. Although mean value of iron (0.13 mg/L) is within permissible limit (0.3 mg/L) but one sample (GJ-4) shows elevated (0.4 mg/L) content. Contrary to this, mean concentration of Mn (0.07 mg/L) is above WHO guidelines (0.02 mg/L) where three samples show objectionable content of Mn (Table 2). Naturally Fe and Mn are sourced by the weathering of minerals possessing Fe and Mn like iron sulphide, amphibolite, and iron bearing clay minerals specially found in reduced environment; both Fe and Mn dissolved in the aquifer water, in the regions where groundwater passes through organic rich soil (Ahmad, 2012). The anoxic condition is favorable for high level of manganese prevailing in lakes, reservoirs and in groundwater. Reported concentration for neutral

groundwater is more than 1300 µg/L, while for acidic groundwater is up to 9600 µg/L (ASTDR, 2012).

In aquifers, water infiltrates through the soils rich in organic matter where dissolved oxygen in soil is utilized by the microbes and decomposition of organic matter takes place. The decomposition process reduces pH due to microbial action. In combination with the oxygen deficiency, the Fe and Mn atoms also gets reduced from Fe<sup>3+</sup> to Fe<sup>2+</sup> and Mn<sup>4+</sup> to Mn<sup>2+</sup> (Ahmad, 2012). Under the pH of 5 to 8 the most occurring form is the soluble Fe<sup>2+</sup> for dissolved iron which is consisting with the low pH of groundwater in shallow aquifers of study areas. The process of oxidation starts which releases carbon dioxide from groundwater to atmosphere, when groundwater pumped up to the surface and gets contact with the air O<sub>2</sub> which enters to the solution. As a result, the values of pH increase and the iron and manganese changed from Fe<sup>2+</sup> to Fe<sup>3+</sup> and Mn<sup>2+</sup> to Mn<sup>4+</sup> into insoluble minerals (Ahmad, 2012).

For the determination of manganese content in groundwater the geological factors for the soil & subsoils are considered as prime factor. In the soils, the origin of manganese found in four phases which are; adsorbed over iron-oxide, as silicates, carbonates and manganese-oxides, in exchanging Mn<sup>2+</sup> and soluted condition and within the organic compounds (Rott and Lamberth, 1993). Anthropogenic sources for iron and manganese are landfill leakages, industrial wastes, acid mine drainage, casing of well, piping, parts of pump, and storage tanks correspondingly serving for Fe and Mn contamination to groundwater (Nova Scotia Environment, 2008). Fluoride content varies in the range of 1.23-2.1 mg/L with a mean of 1.5 mg/L where only one sample (GJ-10) shows objectionable concentration (2.1 mg/L) against WHO guideline value of 1.5 mg/L.

Table 3. Statistical description of the groundwater samples (n=18) from Gulistan-e-Johar Town.

*Parameter	<i>Shallow Aquifers (depth &lt; 100 ft) (n = 6)</i>				<i>Deep Aquifers (depth &gt; 100 ft) (n = 12)</i>			
	Min.	Max.	Mean	St. Dev.	Min.	Max.	Mean	St. Dev.
Depth (ft)	34	75	44	20.5	102	250	156.4	74
pH	6.8	6.9	6.8	0.05	6.5	7.4	7.15	0.45
TDS	1910	3440	2818	765	1010	4550	2883	1770
Hardness	280	550	359.2	135	195	730	350	267.5
Na	68	1540	538.7	736	44	2700	1193	1328
Ca	60	248	179.3	94	40	232	143.3	96
Mg	8.9	80.19	43.7	35.645	8	150.2	50.23	71.1
K	21	57	41.33	18	8	40	19.92	16
SO <sub>4</sub>	558.2	935	691.2	188.4	237.8	814	554.4	288.1
Cl-	177.3	638.1	433.1	230.4	159.5	1117	601.5	478.75
HCO <sub>3</sub>	91.15	182.3	134.3	45.575	58.3	302.6	140.1	122.15
NO <sub>3</sub>	1.88	32	16.35	15.06	0.62	35	5.36	17.19
Fe	0.02	0.4	0.13	0.19	0.1	0.31	0.12	0.105
Mn	0.02	0.16	0.07	0.07	0.01	0.04	0.02	0.015
F	1.23	2.1	1.5	0.435	1.08	3.01	1.79	0.965

#### 4.4 Deep Aquifers

Two third of total collected samples (n=18) are regarded as deep aquifers in the study area where water is tapped from depth range of 102-250 feet. The pH of these wells is slightly alkaline (range: 6.5-7.4; mean: 7.15). TDS content is almost 6 and 3 times higher than the WHO (500 mg/L) and Pakistani guidelines (1000 mg/L) where it is more variable (range: 1010-4550 mg/L) as compared to shallow aquifers. Sodium and potassium contents varied in the range of 44-2700 and 8-44 mg/L respectively. Both the elements show inverse concentration from corresponding shallow aquifers. The highest concentration of Na is almost double (2700 mg/L) in deep well as compared to corresponding shallow well (1540 mg/L). Contrary to this, mean concentration of K in shallow well is double (41 mg/L) its content in the deep well (19.9 mg/L). It suggests the adsorption of ions to clay surfaces screening of ions from surface to aquifer depth. Moreover, pH increase causes formation of clays from decomposed feldspars leading to scavenge the dissolved ions (K, Na). Similarly, high salinity of water favors the formation of clay minerals (Zhang et al., 2009) which is evident by relatively higher salinity in the deep wells as compared to shallow aquifers in the study area.

Calcium and Mg contents fluctuate in a wide range of 40-232 and 8-150.2 mg/L respectively. The concentration of Ca (mean: 143.3 mg/L) is almost three times higher than corresponding Mg content (50.23 mg/L) in these deep wells. Despite large variation, concentration of both the elements is within the permissible limit of WHO for drinking purpose. Nitrate content (range: 0.62-10.22 mg/L) varies within the permissible range (10 mg/L) of WHO for drinking but one sample (GJ-12) shows three-fold higher concentration of  $\text{NO}_3$  (Table 3). On the other hand, iron and manganese concentrations span between 0.1-0.31 and 0.01-0.04 mg/L respectively. Both these ions are within the corresponding permissible guidelines suggesting that deep aquifers are free from any oxidation reaction which is governed by the presence of organic matter and anaerobic bacteria.

##### 4.3.1 Fluoride Content

Fluoride concentration in the deep aquifers of Gullistan e Johar is relatively higher (1.79 mg/L) as compared to corresponding shallow aquifers. It varies between 1.08-3.01 mg/L where about two third of total collected samples from deep wells show elevated fluoride content (1.56-3.01 mg/L). Very strong positive correlation of fluoride with  $\text{HCO}_3$  ( $r^2 = 0.87$ ) and Mg ( $r^2 = 0.75$ ) is observed (Table 4) indicating that beside desorption from clays as a result of hydrolysis in silicate minerals, fluoride is also resulting from the body excretion through urine. For the human health, the consumption of fluoride under the permissible limits of 0.5–1.0 mg/L is beneficial for maintenance of the healthy bones and teeth (Wood, 1974). From all over the world, among 25 nations more than 200 million of people are suffering from endemic fluorosis, which is

caused by the excess consumption of fluoride in drinking water (Ayoob and Gupta, 2006; Fordyce et al., 2007; Gao et al., 2013; Ghosh et al., 2013; Mesdaghinia et al., 2010; Moghaddam and Fijani, 2008; Oruc, 2008).

The importance of defluoridation techniques have been increased because of high concentration of fluoride in drinking water and its effects on human health (Adler and Organization, 1970; EPA, 1975). The measures are being made for defluoridation of drinking water to prevent and control the diseases. Consequently, the extent of the fluorosis is reducing in contesting the devastating fluorosis (AMA, 1975; Chand, 1999). Concerning to public health, fluoride is well recognised element and it exists in almost every type of water especially high content in groundwater, rocks, mineral and earth crust etc. The range of the fluoride concentration in drinking water should be from 1.0 to 1.5 ppm recommended by WHO. Multi-proportional health hazards fallout by the ingestion of fluoride greater than 6 ppm, common occurrence is deformation of bones in children and adults, skeletal and dental fluorosis (Hubner, 1969; Ramamohana Rao and Rajyalakshmi, 1974; Susheela et al., 1993). Permanent suppression of growth is caused by the continuous intake of non-fatal fluoride dose. Usually fluoride ion form complexes with the ions of magnesium and other metal, inhabiting various type of enzymes (Ramesam and Rajagopalan, 1985; Rao, 1992; Rao and Naidu, 1973). Sources of fluoride are fluorite, apatite and fluorapatite in bedrock aquifer system; these minerals occur as detrital grains in sedimentary rocks, as dispersed grains in unconsolidated deposits or as evaporites (Basavarajappa and Manjunatha, 2015). Fluoride in groundwater shows variation due to distinct geological settings. Factors on which concentration of fluoride depend are soil temperature, pH, oxidation-reduction process, amount of soluble and insoluble fluoride in host rocks, size and type of geological formation, anion exchange capacity of aquifer materials (i.e.,  $\text{OH}^-$  for  $\text{F}^-$ ), rainfall, contact of water with rock and its duration (Basavarajappa and Manjunatha, 2015).

#### 4.5 WQI Result

Water quality of collected samples is unfit for drinking purpose, as the value of WQI is above 150 (Table 5). It implies that proper treatment of groundwater is required before its use for drinking purpose.

#### Conclusion

Calculated value of WQI shows that the groundwater falls into the unfit category for drinking. Generally, the groundwater of study area is poor for drinking purpose but relatively deeper aquifers (depth > 100 feet) are better than shallow (depth < 100 feet). However, fluoride contamination is prevailing in deep wells. Detailed studies are needed to trace the source of high fluoride in the deep aquifers and to find out the reasons of changed chemistry of aquifers at both depth ranges.

Table 4. Correlation matrices among all physico-chemical parameters.

	pH	TDS	Hardness	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	Fe	Mn	F
pH	1													
TDS	-0.372966	1												
Hardness	0.125784	-0.129476	1											
Na	-0.136777	0.686071	-0.248508	1										
K	-0.647161	0.148932	0.064019	-0.145062	1									
Ca	-0.444693	0.481252	-0.226802	0.079815	0.448252	1								
Mg	0.29297	-0.311664	0.908285	-0.235727	-0.140723	-0.613452	1							
Cl	-0.161626	0.839011	0.043485	0.694131	-0.175605	0.203578	-0.052127	1						
SO4	-0.647811	0.484761	0.002154	0.020682	0.591416	0.629941	-0.268802	0.15876	1					
HCO3	0.310676	-0.173781	0.69126	-0.25424	-0.346372	-0.547255	0.79559	0.08096	-0.330399	1				
NO3	-0.192392	-0.155926	0.658871	-0.182882	0.566978	0.126667	0.47979	-0.180897	0.109573	0.157279	1			
Fe	-0.333524	0.365949	-0.13351	0.288126	-0.112323	0.167518	-0.180166	0.355197	0.220076	-0.021307	-0.295765	1		
Mn	-0.306951	-0.307614	0.288583	-0.291197	0.362225	0.112208	0.185732	-0.26106	0.213725	-0.007118	0.56127	0.1337	1	
F	0.430868	-0.296476	0.623499	-0.27454	-0.540174	-0.551706	0.742544	0.090892	-0.518584	0.87871	0.047157	0.023336	-0.010757	1

Table 5. Correlation matrices among all physico-chemical parameters.

Parameters	pH	TDS (mg/L)	Hardness (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	NO3 (mg/L)	Fe (mg/L)	Mn (mg/L)	F (mg/L)
Observed Value (Vn)	7.052	2862	353.056	974.6	27.06	155.3	48.05	545.3	600	138.1	11.64	0.117	0.04	1.697
WHO Limit (Vs)	8.5	500	500	200	12	75	150	250	250	300	10	0.3	0.02	1.5
Ideal Value (Vi)	7	0	0	0	0	0	0	0	0	0	0	0	0	0
Qn	3	572	70	487	225	207	32	218	239	46	116	38	199	113
Wn=k/Vn	0.0026	0.0000	0.0001	0.0000	0.0007	0.0001	0.0004	0.0000	0.0000	0.0001	0.0016	0.1587	0.4959	0.8841
Qn*Wn	0.008	0.004	0.00366	0.009	0.153	0.025	0.012	0.007	0.007	0.006	0.184	6.032	98.68	99.9
WQI	3	572	70	487	225	207	32	218	239	46	116	38	199	113
WQI Avg.														

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