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Pre-monsoon Assessment of Ground Water Using Water Quality Index (WQI) of Shah Faisal Town, Malir River Basin, Karachi

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Abstract: Groundwater samples (n=15) were collected from various sites of Shah Faisal Town from a variable depth range (70-400 feet). The TDS varied from 766.08 to 5490.24 mg/L with a mean of 3128.16 mg/L. Circum-neutral pH (6.84-7.56) is evident within the WHO guidelines (6.5-8.5) for drinking. All the samples have objectionable (> 500 mg/L) level of hardness content where it shows a wide range (600-1800 mg/l; mean: 1200 mg/l). The samples ' sodium content (Range: 200-1223; mean: 711.5 mg/L) exceeded WHO limit (200 mg/L). Calcium and magnesium concentrations varied between 40-240 and 92.34-340.2 mg/l with a mean of 220 mg/l and 216.27 mg/l, respectively. Both these elements exceed about 5 times the corresponding permissible limits set by WHO for drinking water. On the other hand, two third samples show elevated bicarbonate content (Range: 210-500; Mean: 355 mg/l). Similarly, nitrate varies between 3.758-14.2 mg/l with a mean of 8.97 mg/l. Fluoride concentration varies between 0.78-1.65 mg/L with a mean of 1.215 mg/L where only 2 samples exceed WHO limit (1.5 mg/L). The water quality index (WQI) is found to be87.32 which suggests that the groundwater is very poor and only suitable for irrigation. It is concluded that about half of the samples failed to meet the water quality criteria set by WHO for drinking. The problem is aggravated due to anthropogenic activities mainly by sewage infiltration and water supply conditions.

Key words: Groundwater, Quality, Alluvial aquifers, Shah Faisal Town, Malir River.

Introduction

About 21 million peoples in Pakistan do not have access to clean water. Contamination and shortage of surface water have caused greater consumption of groundwater. Over abstraction of groundwater lowered the water table and consequently reduced aquifers and increased salinity. With the expansion in human population, sudden urbanization and industrial development in world developing countries, the provision of essential and basic needs for life such as water and sanitation has been on decline in the megacities of South Asia mainly due to poor sanitation, contamination of wastewater in surface and groundwater (Rahman et al., 1997). Despite the great importance of water in life, human beings are major cause of this vital element depletion due to anthropogenic reasons. Groundwater is used for drinking purpose by more than 10 percent of the people in Pakistan, including almost everyone who lives in rural areas. The largest use for groundwater is to irrigate crops.

Karachi is Pakistan's largest and densely populated city where water is supplied through pipe lines. However, groundwater has become major source of drinking and domestic use due to rapid population growth, shortage and leakage from municipally supplied water through pipelines.

According to Asian Development Bank, Karachi's population will rise to 50% in the next 15 years. This will switch stress on groundwater resources which are already over exploited due to administrative mishandling. The major sources through which water is being supplied to Karachi city are Keenjhar Lake and Hub dam which provide around 695 MGD water, out of which the major contribution is from Keenjhar Lake as Hub dam is fed by rain water and it may supply about 30-75 MGD only.

Shah Faisal town is located on the western bank of Malir River near Korangi industrial area on eastern bank (Fig. 1). Groundwater of this area is under threat for drinking and other purposes due to agricultural practices in flood plain of Malir River and polluted with sewage water industrial effluent. Despite of the occurrence of flood plain contaminated with industrial effluent and sewage pollution no study has been carried out to delineate the fate of groundwater in Shah Faisal town which is in hydraulic connection with Malir River.

Therefore, the present study aims to assess groundwater quality at the onset of pre-monsoon season when the thermochemical balance of groundwater is assumed to be stabilized and representative. Other objective is to determine the water quality index for its designation to intended uses.

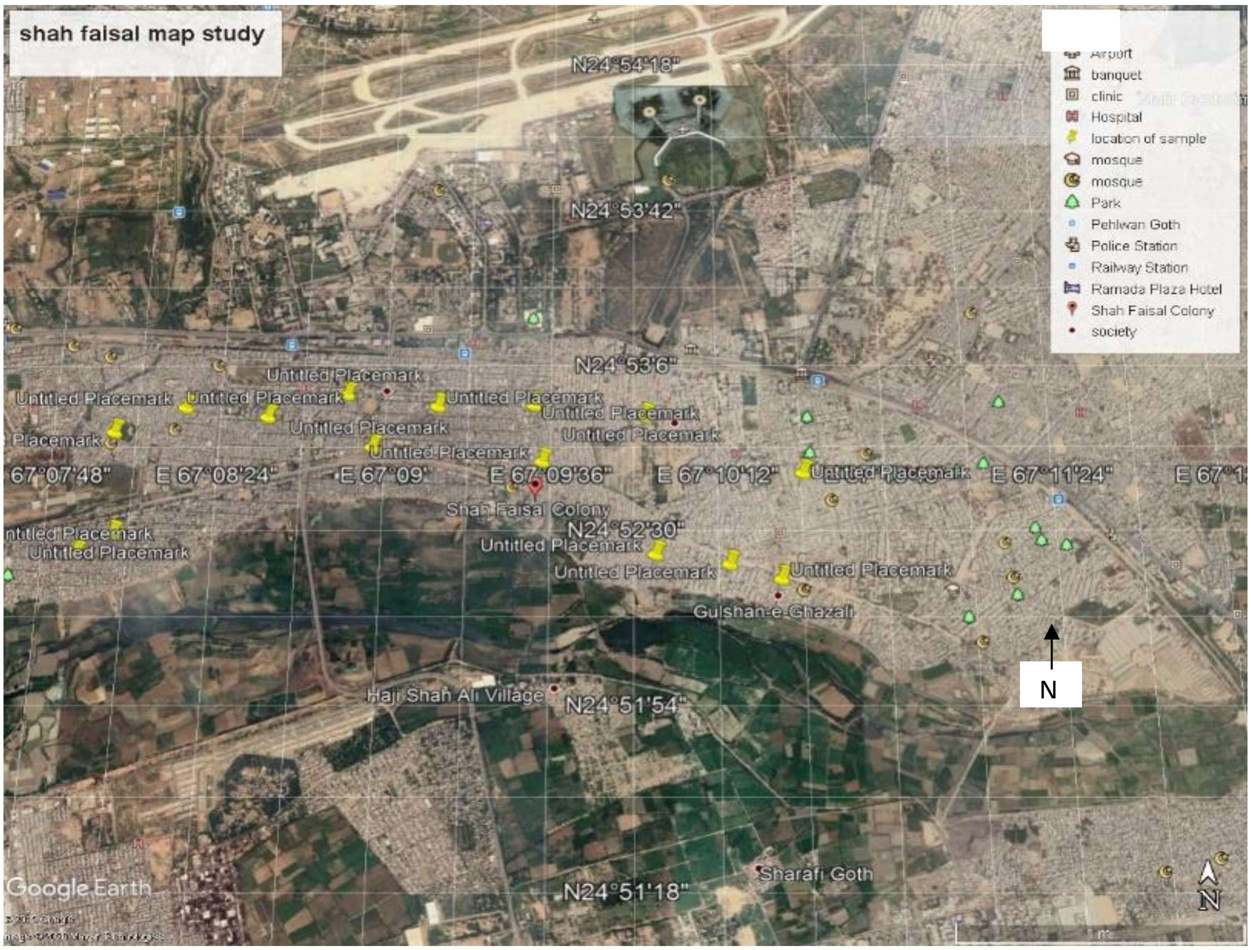

Figure 1 Sample Location Map of study area.

Material and Methods

Study Area

Shah Faisal Town is a commercial and residential area located in district Korangi, Karachi. It is relatively small in size but densely populated area. It occupies an area of about 11.87 sq.km. According to Census 1998, its population is 335,823. The town is surrounded by Malir town to the northeast, Bin Qasim town to the east, Korangi and Landhi towns to the south, and Faisal cantonment and Malir cantonment to the west and northwest, respectively. The Malir River forms the town's southern periphery, and Sharah-e-Faisal highway forms much of the northern periphery with the Jinnah International Airport at the Northern end of the town.

Sample Collection

Groundwater samples (n=15) were collected from a depth range of 70-400 feet. Water was electrically pumped for 2-3 minutes to get representative samples. The Global Positioning System (GPS) was used to record the locations of the boreholes. Water samples were collected in plastic bottles of 1.5-liter capacity for physiochemical analysis. Bottles were rinsed thoroughly with distilled water and subsequently with the sample water on sampling site.

Groundwater Analysis

All the samples were examined for physiochemical parameters in the Department of Geology, University of Karachi laboratory. The pH and TDS of collected samples were determined by using pH and TDS meters respectively. Chloride and bicarbonate ions were estimated by argentometric titration method. EDTA titration method (1992) was applied for the determination of calcium and total hardness. Using standard formula, magnesium was estimated by taking the difference of total hardness and calcium. Sulphate content was determined by gravimetric method. Using Flame Photometer, sodium and potassium concentrations were determined (Model No. JENWAY PFP7). Fluoride was determined by colorimetric method.

Water Quality Index (WQI)

Groundwater quality index of Shah Faisal Town was determined by using weighted arithmetic index method as proposed by (Brown, et al. 1970) to evaluate the water quality status of study area. Physicochemical parameters including pH, TDS, major cations (Na, K, Ca, Mg, F) and anions (HCO3, Cl, SO4, NO3) were used to calculate WQI of groundwater in Shah Faisal Town. WQI is calculated by using following formula.

$$WQI=\sum QnWn/ \sum Wn$$

Where,

Qn is the quality rating of nth water quality parameter.

Wn is the unit weight of nth water quality parameter.

The quality rating Qn is calculated using the equation.

$$Qn=100*[(Vn - Vi) / (Vs- Vi)]$$

Where,

Vn is the actual amount of nth parameter present.

Vi is the ideal value of the parameter, Vi = 0, except for pH (Vi = 7).

Vs is the standard permissible value for the nth water quality parameter.

Unit weight (Wn) is calculated using the formula.

$$Wn= k / Vn,$$

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

$$K= 1/ (1 / \sum Vs)$$

Results and Discussion

Physiochemical Parameters

Table 1. General Properties that have been observed during sample collection.

Sample code	Well age	Well depth (ft.)	Well depth (m)	Uses	Color
MB-1	5-6 years	80	24.384	Domestic	Transparent
MB-2	2-3 years	100	30.48	Domestic	Transparent
MB-3	7 years	200	60.96	Domestic	Transparent
MB-4	39 years	100	30.48	Domestic	Transparent
MB-5	1 year	140	42.672	Domestic	Transparent
MB-6	2 year	75	22.86	Domestic	Transparent
MB-7	1 month	200	60.96	Domestic	Transparent
MB-8	6-7 years	80	24.384	Domestic	Transparent
MB-9	4-5 years	80	24.384	Domestic	Transparent
MB-10	1 year	150	45.72	Domestic	Transparent
MB-11	4 year	70	21.336	Domestic	Transparent
MB-12	2-3 years	100	30.48	Domestic	Transparent
MB-13	3-4 months	180	54.716	Domestic	Transparent
MB-14	4 years	100	30.48	Domestic	Transparent
MB-15	3 months	400	121.92	Domestic	Transparent

Table 2. Mean Value of Physio-Chemical Parameter.

Parameters	Minimum Value	Maximum Value	Mean
TDS	766.08 ppm	5490.24 ppm	5.145 ppm
EC	2.12 ms/cm	9.22 ms/cm	5.67 ms/cm
pH	6.84	7.56	7.2
Eh	21	160	90.5
Hardness	600	1800	1200
Ca	40 mg/l	400 mg/l	220 mg/l
Mg	92.34 mg/l	340.2 mg/l	216.27 mg/l
Na	200 mg/l	1223 mg/l	711.5 mg/l
K	13 mg/l	27 mg/l	20 mg/l
HCO_3	210 mg/l	500 mg/l	355 mg/l
Cl	212.76 mg/l	1430.22 mg/l	821.49 mg/l
SO_4	97.68 mg/l	561.66 mg/l	329.67 mg/l
NO_3	3.758 mg/l	14.2 mg/l	8.979 mg/l
F	0.78 m/l	1.65 mg/l	1.215 mg/l

Groundwater samples (n=15) were collected from various sites through electrically pumped wells (boring well). The results of all the physiochemical parameters have been summarized in Table 3.

Table 3. Physicochemical Parameters of Ground Water Samples (n=15) Collected from Shah Faisal Town.

		Physical Parameters						Major Cations				Major Anions				Trace Element
Sample No.	Well Depth (m)	TDS (mg/L)	EC (ms/cm)	pH	Eh	Hardness	Temperature *C	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	NO_3 mg/l	F mg/l
MB-1	24.384	5490.24	2.12	7.4	160	600	28.6	40	121.5	200	15	240	1430.22	146.52	11.62	1.65
MB-2	30.48	1866.56	3.4	7.63	90	900	29.1	40	194.4	880	17	310	1146.54	301.18	7.09	1.48
MB-3	60.96	1678.08	2.38	7.48	92	800	26.9	40	170.1	912	15	330	295.5	309.32	10.07	1.52
MB-4	30.48	966.72	2.6	7.56	99	800	27.1	40	92.34	480	14	410	567.36	187.22	9.74	1.32
MB-5	42.672	2048.96	2.22	7.35	47	900	26.9	80	170.1	1085	16	340	2127.6	447.7	6.43	1.44
MB-6	22.86	766.08	4.82	7.56	41	700	27.2	80	121.5	420	18	290	330.96	179.08	3.758	1.35
MB-7	60.96	2693.44	2.66	7.18	49	1100	27.1	80	218.7	1090	23	230	2541.3	97.68	7.612	1.34
MB-8	24.384	948.48	2.82	7.7	86	1000	27.1	40	194.4	555	17	380	1028.34	407	8.114	1.16
sMB-9	24.384	1465.28	6.98	7.24	87	1200	26.6	40	243	1223	19	270	283.68	309.32	12.22	1.21
MB-10	45.72	3368.32	9.22	7.07	21	1500	27.5	240	218.7	1205	24	210	1028.34	520.96	8.451	1.42
MB-11	21.336	3696.64	2.72	7.05	140	1800	27.4	400	194.4	1101	27	250	342.78	203.5	14.2	1.29
MB-12	30.48	2018.56	6.44	7.13	128	1100	26.8	80	218.7	956	16	270	697.38	586.08	9.659	0.78
MB-13	54.716	3307.52	4.12	6.97	119	1300	26.7	120	243	1185	15	270	614.64	577.94	8,796	1.16
MB-14	30.48	4645.12	3.78	6.84	131	1700	26.8	120	340.2	1197	13	500	124.11	480.26	12	1.08
MB-15	121.92	2322.56	2.82	7.49	147	1600	26.5	80	340.2	1042	14	210	212.76	561.66	4.757	0.99
WHO limit	-	500	0.2-0.8	6.5-8.5		500	-	200	150	200	30	500	250	250	50	1.5

Shah Faisal colony groundwater TDS ranges between 766.08-5490.24 mg/L with a mean of 3128.16 mg/L. The WHO and Pakistani limit for TDS is 500 and 100 mg/L respectively. TDS of all the samples is beyond permissible limit set by WHO and only three samples fall within Pakistani guidelines (Table 3). High level of TDS content in drinking water is evidence of ionic imbalance which leads to the severe health impacts (Khan et al. 2017). TDS in water is the combination of dissolved minerals, inorganic salts and some biological matter (Basavarajappa and Manjunatha, 2015). In aquifer water, the concentration of TDS fluctuates significantly due to variance in the solubility of minerals according to the different geological settings (WHO, 2004). Since TDS content can limit the water for specific use (Nordstrom, 1987). Hence, its content should be determined before intended use. Ground water pH of study area fluctuates between slightly to moderately alkaline (6.84-7.56) which is within the WHO guidelines (6.5-8.5) for drinking water. The hardness of groundwater exceeds the WHO limit (500 mg/L) which varied between 600-1800 mg/l with mean value 1200 mg/l (Table 3). Calcium and magnesium are two major elements responsible for causing hardness.

Sodium content in Shah Faisal colony samples varied between 200-1223 mg/l with a mean of 711.5 mg/l. Almost all the Shah Faisal area samples violate the WHO limit for sodium content (Table 3). The high value of Na in groundwater of study area may either be due to the chemical weathering of feldspar or over exploitation of groundwater resources (Hem, 1985). High sodium intake in diet and drinking water is reported to have several health consequences. Increment in blood pressure is directly proportional to the elevated sodium concentration through drinking water in children (Tuthill, 1981: Fatula, 1967). The distribution of chloride concentration is very heterogeneous in the samples collected from Shah Faisal area. The concentration of Cl ranges between 212.76-1430.22 mg/l with mean value 821.49 mg/l. In almost all types of rocks, chloride is extensively dispersed in one and many forms, also its attraction is great for sodium. The study area falls in the region with low precipitation and high temperature and the porosity and permeability of soil resulting in migration of very high chloride content (Baravarajappa and Manjunatha, 2015). In drinking water, natural sources are responsible for the origin of Chloride and other sources are sewage, industrial effluents and saline intrusion of urban runoff (WHO, 2004; Hem, 1985; 1991). Potassium content varied 13-27 mg/l with mean value 20 mg/l in the samples collected from Shah Faisal area. All the samples are within the WHO limit. Sulphate concentration in the collected samples ranges between 97.68-561.66 mg/l with mean value of 329.67 mg/l. The high sulphate content in collected samples is attributed to the contamination from the industrial effluents, sewage and domestic wastes (Srivastava et al, 2012). When exposed to drinking, highly contaminated ground water with sulphate results in gastrointestinal problems in people suggested by case studies and subjective reports (Backer, 2000).

Calcium concentration ranges between 40-240 mg/l with mean value of 220 mg/l while Mg concentration varies between 92.34-340.2 mg/l with a mean of 216.27 mg/l. Calcium and magnesium in water originates from the breakdown of aluminosilicates of Ca and Mg, while their elevated concentrations are the result of chemical decomposition of limestone, dolomite, gypsum, magnesite and other accessory minerals. Anthropogenic factors for pollution with Ca and Mg are not common in drinking water. However, drinking water may be deliberately complemented with these elements while treating, as occurs when de-acidification of aquifer water through $Ca(OH)_2$ by various complexes countering acidity like calcium carbonate, magnesium carbonate and magnesium oxide. Similarly, by stabilization of low-mineralized water by adding up calcium oxide and carbon dioxide. Bicarbonate concentration ranges between 210-500 mg/l with mean of 355 mg/l in the samples collected from Shah Faisal. About one third of the samples are within the WHO limit (Table 3). Besides carbonate mineral dissolution, bicarbonate is also released by the degradation of organic matter in anoxic conditions in bedrock aquifer system (Shamsudduha et al, 2008; Jeong, 2001; Lang et al, 2006). Nitrate concentration ranges between 3.758-14.2 mg/l with mean of 8.97 mg/l in the samples collected from Shah Faisal area. The WHO limit is 50 mg/l which indicates all the samples are under WHO limit. The normal range of fluoride is 1.5 mg/l by WHO. Out of 15 samples only 2 samples are positive for fluoride. The range is 0.78-1.65 mg/l with mean 1.215 mg/l.

WQI Index

The WQI considers fourteen weighted parameters including pH, Eh, EC, TDS, Hardness, Na, K, Ca, Mg, HCO_3, Cl, SO_4, NO_3 and F^- to characterize the water quality which has been summarized in Table 4. Weighted arithmetic index method of WQI has been used to assess the quality of groundwater in Shah Faisal Town. It is a simple method that aims at giving a single value to water quality by translating the list of parameters and their relative concentrations present in a sample into a single value. This single value in turn provides an extensive interpretation of the quality of water and its suitability for various purposes like drinking, irrigation, industrial etc. (Abbasi and Abbasi, 2012)

First step for calculating WQI of groundwater is to estimate the quality rating of each parameter using the formula: Qn=100*[(Vn – Vi) / (Vs- Vi)]. If quality rating Qn = 0 means complete absence of pollutants, while Qn ranging between 0 - 100 indicates that the pollutants are within the prescribed standard and in case of Qn >100 implies that, the pollutants are above the standards (Gungoa, 2016).

Table 4. Water Quality Index (WQI) of all collected water samples.

Parameters	Standards (Vs)	Vn	Vi	K	Wn	Vn-Vi	Vs-Vi	Qn	Qn*Wn	WQI
Ph	8.5	7.2	7		0.110	0.2	1.5	13.33	1.47	
Eh	500	90.5	0		0.009	90.5	500	18.10	0.15	
EC	4	5.67	0		0.140	5.67	4	141.75	19.84	
TDS	500	5145	0		0.000	5145	500	1029.0	0.15	
Na	200	711.5	0		0.001	711.5	200	355.75	0.39	
NO3	10	8.98	0		0.088	8.98	10	89.79	7.93	
K	12	20	0		0.040	20	12	166.66	6.61	
Ca	75	220	0		0.004	220	75	293.33	1.05	
Mg	150	216.27	0		0.004	216.27	150	144.18	0.52	
Hardness	500	1200	0		0.001	1200	500	240.0	0.15	
HCO3	300	355	0		0.002	355	300	118.33	0.26	
Cl	250	821.49	0		0.001	821.49	250	328.59	0.31	
F	1.5	1.22	0		0.653	1.22	1.5	81	52.91	
SO4	250	329.67	0	0.79	0.002	329.67	250	131.86	0.31	
Total					1.055				92.13	87.32

In collected samples, Qn of TDS (1029), EC (141.75), hardness (240.0), Ca (293.33), Mg (144.18), Na (355.75), K (166.66), HCO3 (118.33), SO4 (131.86) and Cl (328.59) are above 100 which indicates that these are the main components responsible for deteriorating the water quality (Table 4). Moreover, chloride and bicarbonate of Ca, Na and K are mainly responsible for elevated hardness and very high TDS content in the groundwater of study area. However, the overall result determined by operation on concerned quality parameters of WQI value is 87.32 which according to (Brown, et al. 1970) is of very poor quality and can be used in irrigation purpose only (Table 5).

Table 5. WQI range, status and possible usage of the water samples (Brown et al. 1970).

WQI	Water Quality Status (WQS)	Possible Usage
0-25	Excellent	Drinking, Irrigation and Industrial
25-50	Good	Drinking, Irrigation and Industrial
51-75	Poor	Irrigation and Industrial
76-100	Very Poor	Irrigation
Above 100	Unsuitable for usage	Proper treatment required before usage

Source: (Brown et al. 1970)

Conclusion

The groundwater quality of Shah Faisal area is found to be unfit for drinking purpose. The main parameters deteriorating the quality of groundwater are high hardness and salinity (TDS) due to the excessive amount of corresponding ions (Ca, Mg, Na, Cl and SO_4). WQI value (87.32) also indicates that the groundwater is of very poor quality and can only be used for irrigation. Drinking such polluted water in raw form may harm health and lead to injurious diseases. A few samples showed elevated concentration of fluoride which may increase upon prevalence of conducive environment. Detailed studies are needed on urgent basis to understand the level, spread and distribution pattern of such pollution.

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