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Interpretation of groundwater quality around Ambattur Lake, Chennai, Tamil Nadu

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ABSTRACT

Periodic assessment of groundwater quality is highly necessary to be used for human consumption. Twenty eight bore wells samples are collected during January 2014, and selected parameters like pH, Na, K, Ca, Mg, SO_4, Cl, NO_3, PO_4 F, Fe, TDS and turbidity were analyzed as per standard procedure. Most of the samples are highly deviated from their average value. In Statistical technique, strong positive correlation between Na, K, Ca, Mg with TDS and Turbidity with Fe are an indication of common source. According to water classification, most of the samples are not suitable for drinking purpose. Thus, making it unfit for drinking purpose and requires proper treatment like boiling and filtering of water before its consumption.

Keywords: groundwater quality, GWQI, Correlation matrix

INTRODUCTION

Groundwater is the major source of drinking water in both urban and rural areas [1], it is also used for irrigation and industrial purposes. Increasing population and their needs have lead to the deterioration of surface and sub surface water [2]. The environmental impact of human activity on the groundwater is considered as one of the major hazard in the modern days.

Polluted wastes are affected to all metabolic and physiological activities and life processes of aquatic organisms and hence, it is essential to investigate the physico-chemical characteristics of water. The chemical nature of the groundwater is influenced by several factors such as chemical weathering and interaction of the country rocks [3]. The importance of the hydro chemical analysis underlies the fact that the chemistry of the ground water can directly be estimated with the water resource, climate and geology of the area. However with the increase in urbanization, industrialization, agriculture activity and various human activities has increased the pollution of surface water and groundwater.

EXPERIMENTAL SECTION

STUDY AREA

During early days, Chennai had about 150 small and big water bodies. Now, due to urbanization the water bodies have been reduced to 27. The Ambattur Lake is located in Ambattur municipality of thiruvallur district, Tamil Nadu. It is governed by Chennai Metropolitan Development authority (CMDA) and covers an area of 40.36 sq km. According to 2001 censes, the population is 301,967. In 1976, the lake area was 290 hectare which got reduced to 120 in 2009 [4]. The Ambattur Lake mainly depends on the northeast monsoon rainfall. The average rainfall is around 1108 mm in this district. The weather is pleasant during the period from November to January. The annual mean minimum and maximum temperature are 24.3° and 32.9°C respectively [4]. The area around this lake face several threats such as dense population, eratic weather patterns, waste disposal, water contamination and lack of drinking water, Ayappakkam, which once served as an important water resource for the surrounding areas, has now literally turned into an "open drainage." "The lake was once a main source of drinking water in Chennai city. It was also considered an alternative to Puzhal reservoir. The sewerage from all these houses goes to the Ayappakkam pumping station. Nearly 14 bore wells supplied two lacks liters of water to adjacent area and 50,000 of people were benefited daily. The present study focuses on the quality of ground water surrounding Ambattur lake.

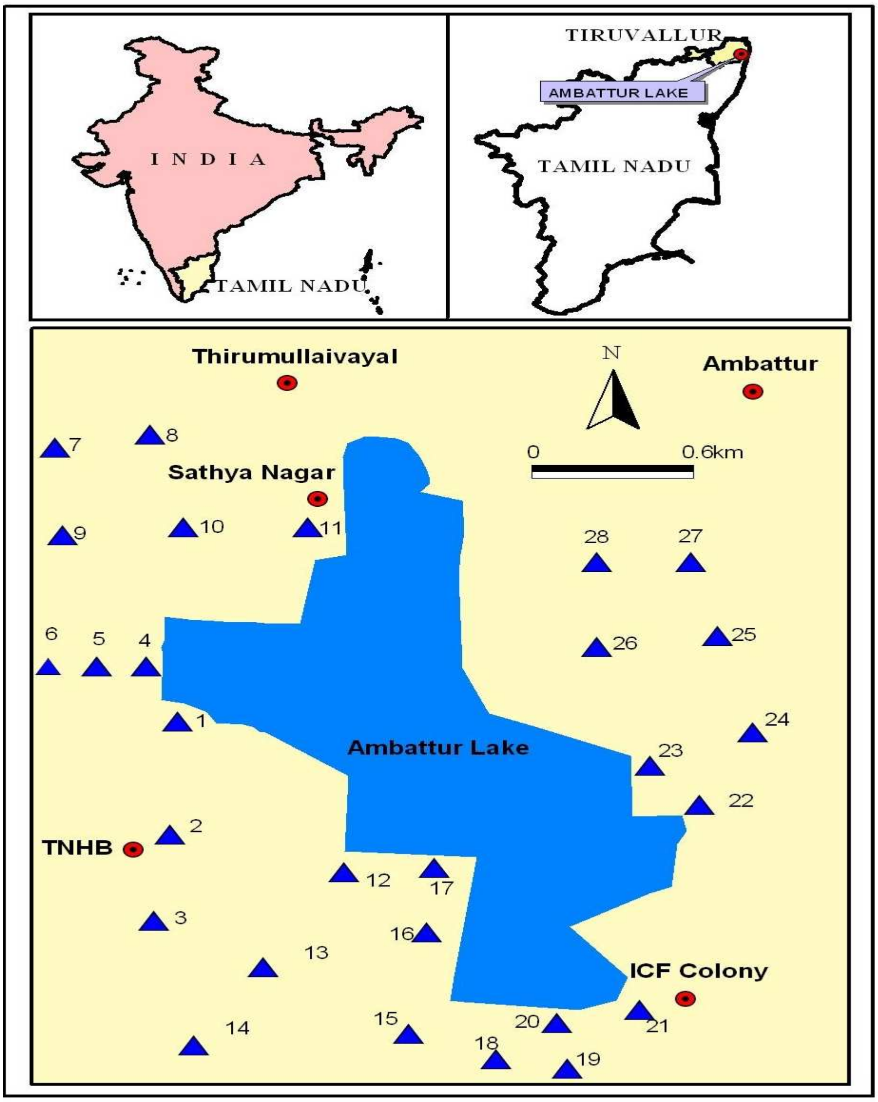

Figure 1 Study area map

GEOLOGY OF THE AREA

The district is underlain by both porous and fissured formations. The important aquifer systems in the district are constituted by unconsolidated & semi-consolidated formations and weathered, fissured and fractured crystalline rocks. The porous formations in the district include sandstones and clays of Jurassic age (Upper Gondwana), marine sediments of Cretaceous age, Sandstones of Tertiary age and Recent alluvial formations. As the Gondwana formations are well-compacted and poorly jointed, the movement of ground water in these formations is mostly restricted to shallow levels. Ground water occurs under phreatic to semi-confined conditions in the inter-granular pore spaces in sands and sandstones and the bedding planes and thin fractures in shales. In the area underlain by Cretaceous sediments, ground water development is rather poor due to the rugged nature of the terrain. Quaternary formations comprising mainly sands, clays and gravels are confined to major drainage courses in the district. Ground water generally occurs under phreatic conditions in the weathered mantle and under semi-confined conditions in the fissured and fractured zones at deeper levels. The thickness of weathered zone in the district is in the range of 2 to 12 m. The depth of the wells ranged from 8.00 to 15.00 m [5].

METHODOLOGY

Groundwater samples were collected from 28 representative bore wells (Figure 1) spread over the study area during January 2014. The samples were collected in polyethylene bottles. The analysis of major ions such as pH, Na, K, Ca, Mg, SO_4, Cl, NO_3, PO_4 F, Fe, TDS and Turbidity were tested in the laboratory. Analyses of groundwater samples were carried out using the standard methods and compared as suggested by the [6]. The physical and chemical parameters exhibit considerable variations from sample to sample. All the analyses were carried out near the temperature of 30°C. Standard solutions and blanks were commonly run to check for possible errors in the analytical procedures. The statistical analysis was done using [7] SPSS 16.0 and it includes minimum, maximum, mean and standard deviation. If the correlation coefficient is nearer to +1 or –1, it shows the perfect linear relationship between the two variables. This method attempts to establish the relationship between the water quality parameters.

Water Quality Index (WQI) was calculated in three stages. In stage 1, each of the 13 parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 1). The maximum weight of 5 has been assigned to nitrate as it is considered as an important parameter in water quality assessment. Magnesium is given the minimum weight of 1 which indicates that, it may not be deleterious. In stage 2, the relative weight (Wi) is computed from the following equation:

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

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters. Calculated relative weight (Wi) values of each parameter are also given in Table 1. Stage 3, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each groundwater sample by its respective standard according to the guidelines given by WHO and the result multiplied by 100:

$$qi=(Ci/Si) \times 100 \quad (2)$$

Where, qi is the quality rating, Ci is the concentration of each parameter in each water sample, and Si is the WHO drinking water standard for each parameter [8].

RESULTS AND DISCUSSION

Groundwater quality variation at sample sites (L1 to L28) for the parameters pH, Na, K, Ca, Mg, SO_4, Cl, NO_3, PO_4 F, Fe, TDS is shown in Figure 1. Turbidity is presented in Table 2. The Turbidity of groundwater samples showed variations from 0.1 NTU to 13.6 NTU, with an average value of 2.0821 NTU. The minimum value of turbidity was recorded at the 5^{th}, 14^{th}, 20^{th}, 23^{rd}, 26^{th}, 27^{th}, $28^{th}$and 6^{th} station (0.1 NTU), while the maximum (13.6 NTU.) was recorded at the 16^{th} station.

Table 1. Relative weight of chemical parameters

		standard permissible Value (s) (WHO. 2004)	Weight (wi)	Relative weight (Wi)
pH	6.99	6.5-8.5	4	0.098
Ca	162.893	75	2	0.049
Mg	50.786	50	1	0.024
Na	149.464	200	2	0.049
K	10.179	200	2	0.049
Fe	0.258	1	4	0.098
F	0.43	1.5	5	0.122
PO_4	0.026	10	1	0.024
Cl	373.393	250	3	0.073
NO_3	14.536	50-70	5	0.122
SO_4	50.857	250	4	0.098
TDS	1420.143	500	4	0.098
Turbidity	2.082	5	4	0.098
			∑wi = 41	∑Wi = 1.000

Table 2. Summary of Physical and Chemical Parameters

Location	pH	Ca	Mg	Na	K	Fe	F	PO_4	Cl	NO_3	SO_4	TURB	TDS
1	6.73	136	46	321	17	0.41	0.52	0.03	465	14	161	7.1	1848
2	7.27	132	41	107	6	0.33	0.45	0	210	14	20	4.9	1102
3	6.98	140	36	128	7	0.2	0.16	0.03	350	6	17	2.8	1199
4	7.29	112	48	161	8	0.24	0.36	0.01	295	15	23	3.6	1292
5	6.63	82	23	45	6	0.11	0.16	0.02	118	15	10	0.1	622
6	7.14	78	25	139	7	0.18	0.29	0.03	178	3	12	0.2	931
7	7.1	180	48	281	19	0.15	0.8	0.01	500	25	83	0.2	1946
8	6.76	360	120	212	17	0.15	0.24	0.01	900	4	93	0.4	2667
9	7.12	620	168	495	39	0.26	0.72	0.02	1875	9	246	3.6	5138
10	6.88	320	82	159	11	0.18	0.62	0.06	570	7	139	0.3	2170
11	6.97	31	8	52	3	0.17	0.08	0.03	92	5	6	0.3	337
12	7.12	72	22	52	4	0.14	0.29	0.04	120	3	22	0.2	582
13	6.68	132	53	126	8	0.87	0.36	0.02	300	8	44	7.8	1286
14	7.1	148	55	71	6	0.16	0.39	0.08	210	8	43	0.1	1097
15	6.59	144	53	75	5	0.25	0.37	0.01	280	2	38	4.2	1077
16	6.52	152	53	111	6	0.97	0.51	0.01	325	9	44	13.6	1263
17	7.26	236	62	166	11	0.42	0.63	0.03	495	11	120	2.7	1876
18	6.85	148	55	81	7	0.31	0.46	0	290	8	14	4.6	1148
19	7.06	168	43	114	7	0.17	0.62	0.01	330	11	17	0.2	1281
20	7.03	156	38	165	8	0.16	0.43	0.06	280	29	31	0.1	1351
21	7.92	85	23	67	6	0.18	0.76	0.01	142	1	6	0.2	697
22	7.28	83	25	71	7	0.2	0.61	0.02	120	23	10	0.2	722
23	7.11	104	41	239	19	0.14	0.47	0.09	305	17	44	0.1	1380
24	6.52	144	53	127	11	0.2	0.32	0.01	405	38	39	0.3	1316
25	6.84	98	28	139	7	0.17	0.33	0.02	170	8	24	0.2	979
26	7.09	132	58	161	13	0.15	0.25	0.02	300	36	73	0.1	1421
27	6.92	144	43	141	11	0.22	0.34	0.02	345	34	15	0.1	1258
28	6.95	224	72	179	9	0.14	0.51	0.03	485	44	30	0.1	1778
Min	6.52	31	8	45	3	0.11	0.08	0	92	1	6	0.1	337
Max	7.92	620	168	495	39	0.97	0.8	0.09	1875	44	246	13.6	5138
Avg	6.99	162.9	50.79	149.5	10.2	0.26	0.43	0.026	373	14.54	50.86	2.082	1420
Std.Dev	0.3	113.8	31.6	95.3	7.1	0.2	0.2	0	340.7	11.9	55.9	3.2	887.4
Median	7	142	47	133.5	7.5	0.2	0.4	0	300	10	30.5	0.3	1272

Table 3. Water Quality Classification Standard (Reza and Singh (2010)

GWQI	STATUS
0-25	VERY GOOD
26-50	GOOD
51-75	POOR
>75	VERY POOR

The Total dissolved solids in the samples showed variations from 337 to 5138 mg/l with an average value of 1507.97 mg/l. The minimum value was recorded at the 11th station (337 mg/l), while the maximum (5138 mg/l) was recorded at the 9th station. More than 95% of the samples were found above the desirable limit but within the maximum permissible limit of 2000 mg/L except for 8th 9th and 10th (>2000) station which is indicating high mineralization in the area. Water containing TDS more than 500 mg/L causes gastrointestinal irritation [9] and laxative effects particularly upon transits [10]. The pH of the water is an important indicator in water quality. From the pH value it is concluded that the samples were alkaline and it is mainly due to bicarbonates.

Magnesium is varied from 8 to 168 mg/l, with an average value of 53.266 mg/l. The minimum value of Magnesium was recorded at the 11th station (8 mg/l), while the maximum (168 mg/l) was recorded at the 9th station. Sodium variations from 45 to 495 mg/l, with an average value of 157.5 mg/l. The minimum value of Sodium was recorded at the 5rdstation (45 mg/l), while the maximum was recorded at the 9th station. Higher sodium concentration (495 mg/l; 9th station) in the groundwater indicates anthropogenic input via landfill leachate is very high. In this location water samples were contains high ionisable salts and the intrusion of domestic sewage probably enhances the sodium concentration. Sodium is found in association with high concentration of chloride resulting in salinity. Sodium concentrations are also influenced by the cation exchange mechanism, while the maximum potassium concentration (39 mg/l) was recorded at the 9th station.

The values of potassium exceed permissible limit of 12 ppm in one third of groundwater samples. The values of potassium in groundwater samples vary station wise. Feldspars, micas, clay minerals, etc are responsible for the availability of potassium in groundwater due to weathering [11]. Lower value of potassium in groundwater is due to greater resistance to its weathering and fixation in the formation of clay minerals. High concentration of potassium in groundwater is due to the presence of silicate minerals from igneous and metamorphic rocks

Table 4. Computed values of GWQI in the study area

Location	GWQI	
1	108.57	VERY POOR
2	70.11	POOR
3	67.3	POOR
4	72.88	POOR
5	37.49	GOOD
6	48.02	GOOD
7	99.16	VERY POOR
8	130.55	VERY POOR
9	252.53	VERY POOR
10	110.97	VERY POOR
11	26.09	GOOD
12	36.76	GOOD
13	86.75	VERY POOR
14	58.99	POOR
15	67.16	POOR
16	101.4	VERY POOR
17	104.32	VERY POOR
18	71.93	POOR
19	69.48	POOR
20	71.45	POOR
21	45.23	GOOD
22	47.29	GOOD
23	70.24	POOR
24	74.61	POOR
25	51.34	POOR
26	74.21	POOR
27	70.44	POOR
28	95.15	VERY POOR

Table 5. Correlation Coefficient Matrix of Water Quality Parameters

	pH	TDS	Mg	Ca	Na	K	SO_4	Cl	NO_3	PO_4	F	Fe	TURB
pH	1												
TDS	-0.05	1											
Mg	-0.14	0.94	1										
Ca	-0.06	0.97	0.97	1									
Na	0	0.89	0.72	0.74	1								
K	0.02	0.91	0.79	0.8	0.95	1							
SO_4	-0.09	0.88	0.79	0.82	0.84	0.83	1						
Cl	-0.07	0.99	0.94	0.96	0.85	0.9	0.84	1					
NO_3	-0.11	0.04	0.02	-0.02	0.15	0.14	-0.1	0	1				
PO_4	0.08	-0.01	-0.06	-0.02	0.07	0.07	0.11	-0.07	0.01	1			
F	0.42	0.43	0.31	0.4	0.43	0.41	0.43	0.36	0.05	-0.1	1		
Fe	-0.34	0.04	0.08	0.02	0.01	-0.1	0.12	0.03	-0.19	-0.2	0.12	1	
TURB	-0.37	0.12	0.14	0.07	0.11	0.01	0.19	0.11	-0.26	-0.3	0.1	0.91	1

The Fe concentrations varied from 0.11 to 0.97 mg/l, with an average value of 0.277 mg/l. The minimum value of Fe was recorded at the 5^{th} station (0.11 mg/l), while the maximum (0.97 mg/l) was recorded at the 16^{th} station, which exceeds the permissible limit of 0.3 mg/L as per Indian standards and 0.1 mg/L as per WHO Standards. All the ground water samples exhibits high Iron contamination which is an indication of the presence of ferrous salts that precipitate as insoluble ferric hydroxide and settles out as rusty silt. High concentration of iron is contributed by industrial estate located at the sampling site, Iron is an essential element in human nutrition**.** Toxic effects have resulted from the ingestion of large quantities of iron, but there is no evidence to indicate that concentrations of iron commonly present in food or drinking water constitute any hazard to human health. At concentrations above 0.3 mg/L, iron can stain laundry and plumbing fixtures and cause undesirable tastes. Iron may also promote the growth of certain microorganisms, leading to the deposition of a slimy coat in piping.

Nitrates concentrations in the ground water samples showed variations from 0 to 1.19 mg/l, with an average value of 0.175mg/l. The minimum value of nitrates was recorded at the 4th, 5th, 6th, 10th, 12th, 13th, 14th, 16th, 26th and 28th station (0 mg/l), while the maximum (1.19 mg/l) was recorded at the 19th station. The Nitrate concentration is within the permissible limit of 45 mg/L as per Indian standards and 50 mg/L. as per WHO Standards.

Table 6. Water classification

(source: Sunil Kumar Srivastava and Ramanathan, A.L., 2008)

RSC(Richard 1954)	Good	<1.25 100
	Medium	1.25-2.5 0
	Bad	>2.5 0
Na% (Wilcox 1955)	Excellent	0-20
	Good	20-40
	Permissible	40-60
	Doubtful	60-80
	Unsuitable	>80
Na% (Eaton 1950)	Safe	<60
	Unsafe	>60
TDS classification (USSL 1954)		< 200
		200-500
		500-1,500
		1,500-3,000
Cl classification (Stuyfzand 1989)	Extremely fresh	<0.14
	Very fresh	0.14-0.85
	Fresh	0.85-4.23
	Fresh brackish	4.23-8.46
	Brackish	8.46-28.21
	Brackish-salt	28.21-282.06
	Salt	282.06-564.13
	Hyper saline	>564.13
SAR (Richard 1954)	Excellent	0-10
	Good	18-Oct
	Fair	18-26
	Poor	>26

Chloride concentrations for the ground water samples showed variations from 92 to 1875 mg/l, with an average value of 414.06 mg/l. The minimum value of Chloride was recorded at the 11^{th}station (92mg/l), while the maximum (1875 mg/l) was recorded at the 9^{th} station. The Chloride content in the water samples was low during the rainy season. According to WHO, maximum permissible limit for chloride is 500mg/l. An excess of chloride in water is usually taken as an index of pollution and considered as tracer for groundwater contamination. High chloride concentration (11^{th} station; 0.08 mg/l) indicates organic pollution. Fluoride concentrations for ground water samples showed variations from 0.08 to 0.8 mg/l, with an average value of 0.431mg/l. The minimum value of Fluoride was recorded at the 11^{th} station, while the maximum (0.8 mg/l) was recorded at the 7^{th} station. Fluoride is released in to the soil and groundwater by the process of weathering of primary rock or leaching of landfill contaminants [12]. When flouride is released into the soil and groundwater, the concentration may increase until saturation is reached [13].

Sulphates in most of the samples were found to be lower than highest permissible level of 400mg/l. Sulphate concentrations for ground water samples showed variations from 6 to 246 mg/l, with an average value of 55.87mg/l. The minimum value of sulphate was recorded at the 11^{th} and 21^{st} station (6 mg/l), while the maximum (246 mg/l) was recorded at the 9^{th} station. High concentration of sulphate is due to the accumulation of soluble salts in soil, anthropogenic activity, and addition of excessive sulphate fertilizer. The present study indicates that there is no harmful effect by sulphate.The minimum value percentage of Phosphate was recorded at the 2^{nd} and 18^{th} station, while the maximum (0.09 mg/l) was recorded at the 23^{rd} station.There is no fluctuation of phosphate values due to increased solar radiations that encourages the biological degradation of organic matter [14].

GROUNDWATER QUALITY INDEX (GWQI)

Based on the standard of classification (Table 3), the groundwater quality index (GWQI) data ranges from poor to very poor except six station are 5, 6, 11, 12, 21 & 22^{nd} samples [15]. The high concentration of GWQI in the wells is mainly due to higher values of TDS, Ca, Cl, Mg, pH, Na, NO_3, F, Fe, SO4, K, Turbidity and PO_4. The high values of this parameter have been influenced by anthropogenic activity such as indiscriminate waste disposal practice and application of chemical fertilizer. The high concentration of fluoride may be due to the watering and leaching of fluoride rich minerals and rocks [16]. Most of the selected sample parameters (EC TDS, Cl. Ca, Na SO4, Mg, NO3, K and turbidity) are highly deviating from their average value except pH, Fe, F and PO_4 (Table 4)

CORRELATION MATRIX

In order to determine the relationship amongst physicochemical parameters of the groundwater samples, correlation coefficients were found and a large number of significant correlations were obtained. The statistical analysis (Table 5) showed that the correlation matrix of the 13 physico-chemical variables. The correlation matrix indicates strong positive correlation between Na, K, Ca, Mg with TDS; and Turbidity with Fe. These strong positive relationships are an indication of common source. Correlation analysis reveals similarities or differences in the behavior of pairs of ions, and does not conveniently identify groups of ions that behave similarly [17]. Most of the samples are deviated from average value except pH, Fe, F, PO4 NO3, Turbidity potassium, but So4, TDS Cl, Na and Ca are highly deviated from their average value (Table 5)

WATER CLASSIFICATION

According to Wilcox [18], water samples can be divided based on the Na %, about 25% of the groundwater samples were doubtful and 75% were unsuitable for drinking condition. Richard [19] classified water quality on the basis of sodium absorption ratio (SAR). According to Richard's classification, 100% of the groundwater samples were poor in condition. Stuyfzand [20] classified water on the basis of Cl– ion concentration into eight divisions as shown in Table 6. According to Stuyfzand, 39.2% of the groundwater samples were brackish salt, 50% were salt in nature and 10.7% were hypersaline. USSL [21] classification is based on the concentration of total dissolved solids as shown in Table 6. According to USSL classification, 71.4% of the groundwater samples showed total dissolved solids concentrations in the range of 500 to 1,500 mg/l, 21.4% were in the range of 1,500–3,000 mg/ l and 3.5% were in the range of 200 to 500 mg/l. Eaton also classified water quality on the basis of percentage of Na in water. According to the Eaton Classification [22], 10.5% of the groundwater samples were safe, while 89.5% were unsafe for use.

CONCLUSION

Ground water quality index indicate that 78.5% of the sample not suitable for drinking purpose (poor to very poor). Strong positive correlation between Na, K, Ca, Mg with TDS and Turbidity with Fe is reveal indication of common source. More than 95% of the samples were found above the desirable limit but within the maximum permissible limit. Most of the samples are highly deviated from their average value concentration. Thus these parameters are needed to be lowered down within prescribed limits before usage for drinking purposes.

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