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ORIGINAL RESEARCH PAPER

Seasonal variations of ground water quality and its agglomerates by water quality index

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ABSTRACT: Water is a unique natural resource among all sources available on earth. It plays an important role in economic development and the general well-being of the country. This study aimed at using the application of water quality index in evaluating the ground water quality innorth-east area of Jaipur in pre and post monsoon for public usage. Total eleven physico–chemical characteristics; total dissolved solids, total hardness,chloride, nitrate, electrical conductance, sodium, fluorideand potassium, pH, turbidity, temperature) were analyzed and observed values were compared with standard values recommended by Indian standard and World Health Organization. Most of parameter show higher value than permissible limit in pre and post monsoon. Water quality index study showed that drinking water in Amer (221.58,277.70), Lalawas (362.74,396.67), Jaisinghpura area (286.00, 273.78) were found to be highly contaminated due to high value of total dissolved solids, electrical conductance, total hardness, chloride, nitrate and sodium. Saipura (122.52, 131.00), Naila (120.25, 239.86), Galta (160.9, 204.1) were found to be moderately contaminated for both monsoons. People dependent on this water may prone to health hazard. Therefore some effective measures are urgently required to enhance the quality of water in these areas.

KEYWORDS: *Electrical conductance (EC); Total dissolved solids (TDS); Total Hardness(TH); Water Quality Index (WQI)*

INTRODUCTION

Ground water resources are dynamic in nature and are affected by factors of irrigation activities, industrialization, urbanization and geological processes occurring within them and reactions with aquifer minerals (Chartterjee *et al*., 2010, Nagarajan *et al*., 2010), rainfall patterns, infiltration rate, leaching of pollutants from the landfill (Srivastava and Ramanathan, 2008). Poor quality of water adversely affects plant growth and human health (Subba, 2009). In Rajasthan, 70% of the population is dependent on groundwater resources for drinking, irrigation and other purposes (Yadav *et al*., 2010). Water quality index is the most effective tool to express complex water quality data into a single number as an index (Shanker and Latha, 2008; Chaturvedi and Bassin 2010; Saeedi *et al.,* 2010, Sharma and Chhipa, 2013) and it depends upon normalizing the data parameter according to expected concentrations and interpretation of good versus bad concentrations. Correlation coefficients of water quality parameters not only help to evaluate the overall water quality but also to quantify relative concentration of various impurities in water and provide necessary information for implementation of rapid water quality management programs (Jothivenkatachalam *et al*., 2010; Karbassi and Pazoki 2015). Once a linear relationship has been shown to have a high probability by the value of the correlation coefficient, then the best straight

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line through the data points has to be estimated. This study has been carried out in north east area of Jaipur in India during 2012.

MATERIALS AND METHODS

Samples of drinking water were collected in clean polyethylene bottles from different sources viz. tube well, bore well and hand pump in the pre and post monsoon from north east area of Jaipur and its agglomerates .TDS is calculated by the evaporation method, TH is determined by EDTA titration (Akpabli, 2002). Chloride has been determined using spectrophotometry. The data have been compared with standard values which are given by Indian (BIS (10500: 1991) and WHO (1996) standards. Parameters are weighted according to their perceived importance to overall water quality and the index is calculated as the weighted average of all observations of interest (Bharti and Katyal 2011). Table 1 shows the classification of water quality based on WQI value.

Water Quality Index

For calculation of WQI these steps are followed (Ramakrishnaiah *et al*., 2009)

$$WQI = \Sigma SI_i$$

$$SI_i = W_i q_i$$

$$q_i = (C_i/S_i) \times 100$$

Where C_i = concentration of each parameter
S_i= respective Indian standard value

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

Each of the essential eleven parameters has been assigned a weight ranging from 1 to 5 depending on the relative importance of parameter with respect to drinking purpose. EC, TH, NO_3, F are assigned maximum weight because of their relative importance in water quality. Na, K and temperature are given minimum credit of 2 as they play low significant role in water quality assignment. The weight of other parameters varied from 2 to 5 depending on their importance in water quality determination given in Table 3.

RESULTS AND DISCUSSION

Total Dissolved Solid -TDS in water is a measure of combined chemicals of all inorganic and organic substances present in water as molecule (Sharma and Chhipa 2012), ions or micro granular suspended form. TDS values were varied from 404 mg/L to 4348 mg/L in pre monsoon (Table 2) and 501mg/L to 4670 mg/L in post monsoon (Table 3). Jamvaramgarh locality exhibits low value of TDS and Lalawas shows higher value of TDS in both monsoons. Higher concentration of dissolved solids are in Post Monsoon samples shows poor quality of water predicted to more seepage and movement of ground water in this area

Electrical Conductivity – High Conductivity may arise through natural weathering and anthropogenic sources (Hameed *et al*., 2010). EC values varied from 618 to 5341 μS/cm in pre monsoon and 650 and 7076 μS/cm in post monsoon. High conductivity in this area is due to presence of high amount of dissolved salts.

Total Hardness

Total hardness is the sum of Ca and Mg hardness so only total hardness is determined in this paper. Ca and Mg hardness not separately determined Total Hardness was varied between 158.6 to 1049.3 mg/L in pre and 170.3 to 1240.3 mg/L in post monsoon. The natural sources of hardness in water are dissolved Calcium and Magnesium ions from sedimentary rocks, seepage and runoff from soils.

Chloride

Chloride concentration of the groundwater samples in the study area was varying from 17.53 to 1359.21 mg/L in Pre Monsoon and 19.99 to 1331.33 mg/L in Post Monsoon with average value of 319.19mg/L and 410.12 mg/L. In Jal Mahal chloride concentration extremely increased in post monsoon. High value of Chloride may be due to contamination from a septic system, sewage and agriculture.

Table 1: Classification of water quality based on WQI value (Ramakrishnaiah *et al*., 2009)

S. No.	WQI value	Grade	Water quality
1	50 and below	A	Quality of water is excellent
2	50-100	B	Quality of water is good
3	100 -200	C	Quality of water is poor
4	200- 300	D	Quality of water is very poor
5	300 and above	E	Quality of water is unsuitable for drinking

Nitrate

The concentration of Nitrate in the study area varying from 8.93 to 202.20 mg/L in Pre Monsoon and 7.96 to 209.16 mg/L in Post Monsoon. It is observed that nearly 40%of samples in Pre Monsoon (Table 2) and 60%of them in Post Monsoon (Table 3) exceed the permissible limit. Amer has extremely higher value of Nitrate because this sampling point is very close to domestic area so all municipal sewage discharged here.

Fluoride

The concentration of Fluoride in the study area varies from to 0.33 to 1.87 mg/L in Pre Monsoon and .56 to 2.50 mg/L in Post Monsoon. All samples in study area except Lalawas have below the permissible limit prescribed by IS standards (Table 4). There are slight changes in the value of Fluoride in post monsoon.

Sodium

It is a major component of potable water. The Sodium concentration of the area in groundwater was varying from 38.03 to 524.5 mg/L in Pre Monsoon and 38.69 mg/L to 966.6 mg/L in Post Monsoon. In Pre Monsoon all the samples have lesser valueof Sodium than prescribed WHO standard (200mg/L) exceptinLalawas but in Post Monsoon 5 samples have the above value than permissible limit. Jal Mahal has extreme increment in Sodium value in post monsoon. Sodium has a strong tendency to remain adsorbed on soil particles, but can be easily exchanged by divalent cations like calcium and Magnesium .The percolating water can undergo this type of exchange that can lead to an increase of sodium in ground water(Goyal 2006).

Potassium

The Potassium concentrations vary from 2.59 to 15.76 in Pre Monsoon and 1.28 to 21.95 mg /L in Post Monsoon. The Bureau of Indian Standard has not included Potassium asa parameter in Drinking Water Standards however European Economic Community has prescribed the guideline level of potassium at 10 mg/L in drinking water. Two localities water samples (Amer and Jaisinghpura) shows high value of Potassium in Post Monsoon.

Acidity

pH value in North East varied between 6.5 to 8.17 in Pre Monsoon and 6.49 to 8.09 in Post Monsoon. All the values in both seasons were in the prescribed limit given by Indian Standard. The mean values of pH in pre and post Monsoon were 7.33 and 7.26 given in (Table 4).

Table 2: Data analysis of pre monsoon north east area of Jaipur and itsagglomerates

Study area	pH	TDS	EC	TH	Cl	NO_3	F	Na	K	Turbidity	Temp.
Amer	7.79	1600	2059.6	639	359.54	80	0.92	86.91	15.76	30	38
Jal Mahal	6.91	426	618.3	217.3	52.6	19.73	0.33	38.05	3.96	10	38
Kukas	7.51	808	1188.3	208.1	105.3	15.83	1.37	128	4.08	7.3	37
Jaisinghpura	7.59	2652	3606.6	1049	552.44	202.2	1.71	167.6	6.93	5.67	37
Saipura	7.07	1440	1915.3	221.7	236.78	9.9	1.48	199.5	3.81	7	37
Naila	7.43	961	1394	298.3	192.91	39.33	1.31	97.92	3.67	8	38
Lalawas	8.17	4348	5341	711.7	1359.2	70.13	1.87	524.6	6.95	20.67	37
Heerawala	7.21	896	1415	158.7	87.68	24.3	0.87	86.29	2.59	7	37
Jamvaramgarh	6.5	404	649	239	17.53	8.93	0.53	51.91	3.02	13.67	37
Galta	7.19	1234	1543	585.7	227.99	118.13	1.1	82.61	6.79	7.3	37

Table 3: Data analysis of post monsoonnorth east area of Jaipur and itsagglomerates

Study area	pH	TDS	EC	TH	Cl	NO_3	F	Na	K	Turbidity	Temp.
Amer	7.9	2672	3182	900.6	426.93	209.16	0.95	183.4	21.95	11	22
Jal Mahal	6.53	3795	4134	1240	759.62	52.03	1.45	417.4	7.85	5.3	22
Kukas	7.04	508	650	190.6	59.97	23.96	1.25	124.9	3.51	10.67	21
Jaisinghpura	7.78	2643	3477	940	527.83	152.1	1.14	266.7	12.87	9.67	23
Saipura	6.93	1168	2760	240.6	299.9	10.13	1.63	267.3	1.77	9	23
Naila	7.4	1994	2607.7	840	403.8	121.73	1.47	294.1	4.99	11.33	25
Lalawas	8.09	4670	5876.3	450	1331.3	104.13	2.5	966.7	1.55	11.67	23
Heerawala	7.05	1044	1491.7	170.3	99.95	25.87	0.95	90.46	1.28	8.33	23
Jamvaramgarh	6.49	501	723.66	220.3	19.99	7.96	0.56	38.69	1.63	7.67	25
Galta	7.43	1513	2132.7	760	171.91	197.96	1.24	64.05	4.29	10	23

Table 4: Statistical analysis of pre and post monsoon north east area of Jaipur and its agglomerates

	Pre Monsoon			Post Monsoon			IS	WHO
parameter	Min	Max	Mean	Min	Max	Mean		
pH	6.5	8.17	7.33	6.49	8.09	7.26	6.5-8.5	No guideline
TDS	404	4348	1476.9	501	4670	2050.8	500 mg/L	1000 mg/L
EC	618.3	5341	1973.01	650	5876.3	2703.5	600 µS/cm	No guideline
TH	158.66	1049.3	432.87	170.3	1240.3	595.27	300 mg/L	No guideline
Cl	17.53	1359.21	319.19	19.99	1331.3	410.12	250 mg/L	250 mg/L
NO_3	8.93	202.2	58.84	7.96	209.16	90.5	45 mg/L	50 mg/L
F	0.33	1.87	1.14	0.56	2.5	1.31	1.0 mg/L	1.5 mg/L
Na	38.05	524.57	146.33	38.69	966.67	271.37	Not mentioned	200 mg/L
K	2.59	15.76	5.75	1.28	21.95	6.16	Not mentioned	Not mentioned
Turbidity	5.67	30	11.66	5.3	11.67	9.46	5NTUmax	5NTU
Temperature	37	38	37.3	21	25	23	-	-

Table 5: Computed average WQI values of different sampling station innorth east area in pre monsoon of Jaipur city and its agglomerates

Parameter	Ci (Observed value)	Si (Standard value)	Qi (Quality Rating)	W (weight)	Wi (Relative Weight)	SI (Sub Index)
pH	7.33	7.5	0.08	3	97.73	7.33
TDS	1477	500	0.08	3	295.4	22.15
EC	1973	600	0.13	5	328.8	41.1
TH	432.9	300	0.13	5	144.3	18.04
Cl	319.2	250	0.1	4	127.7	12.77
NO_3	58.84	45	0.13	5	130.8	16.34
F	1.14	1.5	0.13	5	76	9.5
Na	146.3	200	0.05	2	73.17	3.658
K	5.75	10	0.05	2	57.5	2.875
Turbidity	11.66	5	0.08	3	233.2	17.49
Temperature	37.3	25	0.08	3	149.2	11.19
WQI						162.4

Table 6: Computed average WQI values of different sampling station innorth east area in post monsoon of Jaipur city and its agglomerates

Parameter	Ci (Observed value)	Si (Standard value)	Qi (Quality Rating)	W (weight)	Wi (Relative Weight)	SI (Sub Index)
pH	7.26	7.5	0.075	3	96.8	7.26
TDS	2051	500	0.075	3	410.2	30.8
EC	2704	600	0.125	5	450.6	56.3
TH	595.3	300	0.125	5	198.4	24.8
Cl	410.1	250	0.1	4	164	16.4
NO_3	90.5	45	0.125	5	201.1	25.1
F	1.31	1.5	0.125	5	87.33	10.9
Na	271.4	200	0.05	2	135.7	6.78
K	6.16	10	0.05	2	61.6	3.08
Turbidity	9.46	5	0.075	3	189.2	14.2
Temperature	23	25	0.075	3	92	6.9
WQI						203

Turbidity

Turbidity values in North West varied from 5.67 to 30 NTU in Pre Monsoon and 5.30 to 11.67 NTU in Post Monsoon. Average value of turbidity in Pre Monsoon was 11.66 NTU and in Post Monsoon 9.46 NTU. Most of samples are within the permissible limits except than Lalawas, Naila and Amer indicating the presence of organic matter pollution, other effluents, and runoff with high suspended matter content (Yisa and Jimoh, 2010). The overall WQI of all the samples taken in pre

Table 7: Comparison of WQI in pre –post monsoon in north-east area of Jaipur and its agglomerates

S No.	Sampling station	Source of Drinking water	Season	WQI	Results
1.	Amer	Hand pump	pre	221.58	Very poor
			post	277.70	Very poor
2.	Jal Mahal	Tube well	pre	74.90	Good
			post	301.04	Unfit for drinking purpose
3.	Kukus	Hand pump	pre	100.67	Good
			post	82.79	Good
4.	Jaisinghpura	Hand pump	pre	286.00	Very poor
			post	273.78	Very poor
5.	Saipura	Hand pump	pre	122.52	Poor
			Post	131.00	Poor
6.	Naila	Hand pump	Pre	120.25	Poor
			Post	239.86	Very poor
7.	Lalawas	Hand pump	Pre	362.74	Unfit for drinking purpose
			Post	396.67	Unfit for drinking purpose
8.	Heerawala	well	Pre	99.29	Good
			Post	102.28	Poor
9.	Jamvaramgarh	Hand pump	Pre	78.05	Good
			Post	66.73	Good
10.	Galta	Hand pump	Pre	160.9	Poor
			Post	204.1	Very poor

Table 8: Correlation matrix of pre monsoon north-east area of Jaipur and its agglomerates

	pH	TDS	EC	TH	Cl	NO_3	F	Na	K	Tur.	Temp
pH	1	0.795**	0.796**	0.598	0.785**	0.432	0.722*	0.689*	0.557	.442	0.058
TDS	0.795**	1	0.997**	0.726*	0.982**	0.514	0.776**	0.916**	0.350	.346	-0.276
EC	0.796**	0.997**	1	0.736*	0.970**	0.536	0.794**	0.902**	0.331	.311	-0.292
TH	0.598	0.726*	0.736*	1	0.647*	0.936**	0.546	0.406	0.590	.268	-0.111
Cl	0.785**	0.982**	0.970**	0.647*	1	0.404	0.704*	0.941**	0.333	.419	-0.203
NO_3	0.432	0.514	0.536	0.936**	0.404	1	0.452	0.157	0.453	-.003	-0.139
F	0.722*	0.776**	0.794**	0.546	0.704*	0.452	1	0.746*	0.108	-.072	-0.412
Na	0.689*	0.916**	0.902**	0.406	0.941**	0.157	0.746*	1	0.098	.274	-0.351
K	0.557	0.350	0.331	0.590	0.333	0.453	0.108	0.098	1	.798**	0.363
Tur.	0.442	0.346	0.311	0.268	0.419	-0.003	-0.072	0.274	0.798**	1	0.381
Temp.	0.058	-0.276	-0.292	-0.111	-0.203	-0.139	-0.412	-0.351	0.363	.381	1

Table 9: Correlation matrix of post monsoon north-east area of Jaipur and its agglomerates

	pH	TDS	EC	TH	Cl	NO_3	F	Na	K	Tur.	Temp.
pH	1	0.511	0.555	0.223	0.515	0.749*	0.441	0.467	0.444	0.803**	-0.118
TDS	0.511	1	0.963**	0.614	0.958**	0.397	0.676*	0.851**	0.309	0.068	-0.159
EC	0.555	0.963**	1	0.509	0.967**	0.362	0.773**	0.889**	0.230	0.138	-0.109
TH	0.223	0.614	0.509	1	0.401	0.630	0.067	0.170	0.638*	-0.160	-0.092
Cl	0.515	0.958**	0.967**	0.401	1	0.242	0.821**	0.963**	0.107	0.166	-0.103
NO_3	0.749*	0.397	0.362	0.630	0.242	1	0.051	0.066	0.681*	0.498	-0.057
F	0.441	0.676*	0.773**	0.067	0.821**	0.051	1	0.903**	-0.266	0.355	-0.144
Na	0.467	0.851**	0.889**	0.170	0.963**	0.066	0.903**	1	-0.104	0.244	-0.061
K	0.444	0.309	0.230	0.638*	0.107	0.681*	-0.266	-0.104	1	0.152	-0.318
Tur.	0.803**	0.068	0.138	-0.160	0.166	0.498	0.355	0.244	0.152	1	0.016
Temp.	-0.118	-0.159	-0.109	-0.092	-0.103	-0.057	-0.144	-0.061	-0.318	0.016	1

and post monsoon were calculated according to the procedure presented in Table 5 and Table 6). In Jal Mahal water quality changed from good to very poor in Pre to Post Monsoon (Table 7). Sampleof Jal Mahal was taken from nearby JalMahal Lake. All the contamination and exploitation of water from city area move toward lake in Post Monsoon. In Amer, Jaisinghpura, Lalawas drinking water is highly polluted

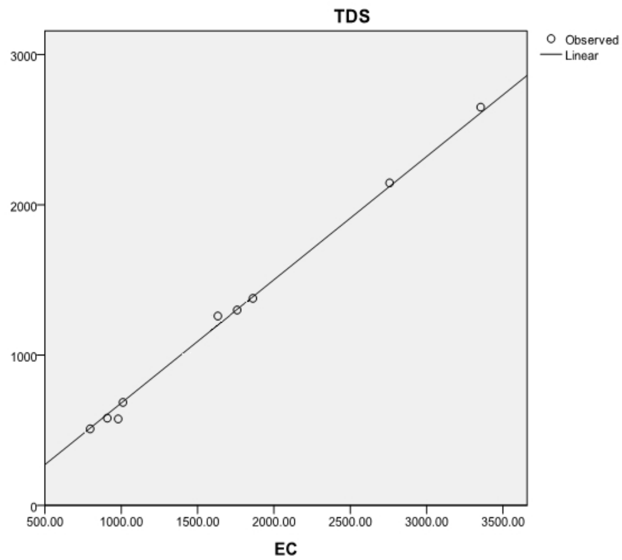

Fig. 1: Correlation between total dissolved solids and electrical conductance in pre monsoon, north-east area of Jaipur and its agglomerates

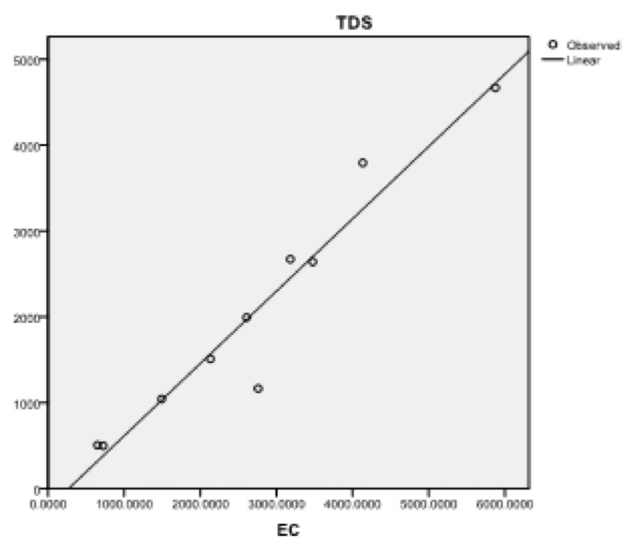

Fig. 2: Correlation between total dissolved solids and electrical conductance in post monsoon, north-east area of Jaipur and its agglomerates

due to high value of TDS, EC, TH, Cl, NO_3, Na in both monsoons. High value of parameter is due to various anthropogenic activities and geochemical processes prevailing in the region. In Galta water quality was changed into poor to very poor in pre to Post Monsoondue to increment of NO_3, TH, TDS and EC in Post Monsoon. Lalawas to Jamvaramgarh (Lalawas, Jaisinghpurakhor, Saipura, Heerawala and Jamvaramgarh) WQI value reduces (Table 7) i.e. water quality changes from unsuitable water to good water for drinking purpose.

It is evident that distribution of TDS, Cl, F, Na was significantly correlated with EC in Pre Monsoon (Table 8) indicating the high mobility of these ions. EC is positive correlated with TH, NO_3, K and turbidity and negatively correlated with temperature. Highly positive correlation is observed between TDS & Cl, TDS & Na (Gajendran and Thamarai, 2008), pH and turbidity, F &

Cl, Cl & F, Na & Cl, Na & F. While highly negative correlation is seen among Temperature and all parameters except Turbidity. Positive correlation occurs between pH and Na, TDS and TH (Udayalaxami *et al.*, 2010). Good relation to Cl and TH indicating that Hardness in groundwater is mainly due to $CaCl_2$ and $MgCl_2$ (Ramakrishna *et al*., 2009).

In post monsoon positive correlation occurs TDS with TH, Cl, Na, K. Thus, the TDS can give a reasonable good indication of a no. of parameters. Table 9 shows that Highly positive correlation occurs between pH and turbidity, TDS and EC, TDS and Cl, TDS and Na, EC and Cl, EC and Na, Cl and Na, Na and F. While negative correlation was observed between Temperature and all parameter except turbidity. TDS shows highly positive correlation with EC in pre and post monsoon indicating in Figs 1and 2.

CONCLUSION

Higher concentration of Total Dissolved Solids during Post Monsoon samples exhibits poor quality of water as compared to Pre Monsoon due to leaching of various salts into Post Monsoon ground water by infiltrating recharge waters.In pre monsoon only one sample out of 10 (Lalawas) shows high value of sodium than the prescribed limit by WHO but in Post Monsoon 5 samples show high value of sodium. According to study inurban area of Jaipur have high value of sodium in post monsoon. In most of the area, nitrate concentration increases in post monsoon. Study of water quality indices revealed that the drinking water in most locations of north-east area was found to be highly contaminated.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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