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ASSESSMENT OF GROUNDWATER SOURCES FOR SUITABILITY FOR IRRIGATION AROUND SANGANER TEHSIL, JAIPUR, RAJASTHAN

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ABSTRACT

Continuous degradation in the quality of available groundwater resources is due to increasing global pollution. As a result, systematic assessment of water quality appears to become an absolute necessity. For carrying out a systematic study, forty groundwater samples were collected from tube wells, hand pumps and wells of different villages of Sanganer tehsil. Samples were analyzed for physico-chemical characteristics influencing water quality for irrigation such as Total Dissolved Solids (TDS), Electrical Conductivity (EC), Soluble Sodium Percentage (SSP), Permeability Index (PI), Residual Sodium Bicarbonate (RSBC), Magnesium Adsorption Ratio (MAR), Kelly's Ratio (KR) and Sodium Adsorption Ratio (SAR) with observed ranges 283.08 – 1950.20 mg/L, 530 – 4850 µmhos/cm, 16.38 - 82.82%, 48.92 - 833.60%, -16.69 – 10.2 meq/L, 17.50 – 66.67%, 1.78 – 11.03 and 1.26 – 16.34 respectively.

KEYWORDS: Groundwater, irrigation, SAR, degradation, Kelly's Ratio.

INTRODUCTION

Besides direct consumption man uses water for purposes like irrigation, industry, construction work, power generation and waste disposal. The suitability of groundwater for agriculture and domestic purposes mainly depends on site. Uncontrolled application of fertilizers clubbed with indiscriminate disposal of domestic sewage further degrades groundwater quality. Especially where there is accumulation of sodium ion in the soil structure due to extended use of certain irrigation water could cause deterioration in the soil physical properties, and thereby results in the decrease of the crop yield [1]. Both these factors appear to be predominant in Sanganer Tehsil. Hence, this work has been carried out for assessing physical and chemical characteristics of the local groundwater resources around the Sanganer tehsil for determining its suitability for the purpose of irrigation. In order to achieve the above objective different indices for irrigation uses such as Total Dissolved Solids (TDS), Electrical Conductivity (EC), Soluble Sodium Percentage (SSP), Permeability Index (PI), Residual Sodium Bicarbonate (RSBC), Magnesium Adsorption Ratio (MAR), Kelly's Ratio (KR) and Sodium Adsorption Ratio (SAR) were calculated from standard equations and employed to assess groundwater suitability for irrigation purposes in the study area [2].

MATERIALS AND METHODS

Study Area

Jaipur district is one of the 33 districts of Rajasthan in western India. It is located between the North latitude of 26°23' N to 27°51' N and East longitudes74°55' E to 76°50' E. The district has geographical area of 11,151 sq. km which is administered by 13 tehsils and 13 blocks. The district covers about 3.3% of total area of the State. Jaipur, the capital city is also popularly known as Pink City and is situated towards central part of the district. The semi-arid district receives normal annual rainfall of 527mm (1901-71) while average annual rainfall for the last 30 years (1977-2006) is 565 mm. Over 90% of total annual rainfall is received during monsoon [3]. Out of 13 tehsils, Sanganer Tehsil has specifically chosen as study area as already discussed in our earlier communication [4].

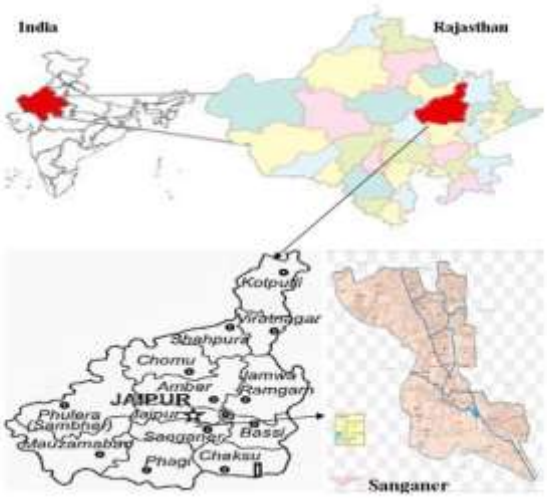

Figure-1: Map of Study area [4]

Methodology

A total number of 40 samples were collected from different wells, tube-wells and hand-pumps from 40 villages of Sanganer tehsil during pre monsoon season, June 05-15, 2014. All samples were labeled properly. Temperature, pH, electrical conductivity, total dissolved solids and salinity were measured on site using potable meter (PCS Testr 35 Multi-parameter). All other parameters were analyzed by using standard methods [5]. Sampling sites with source type are shown in Table-1. All the collected water samples were analyzed for the other physico-chemical parameters: pH, Electrical Conductivity (EC), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Bicarbonate (HCO_3^{-}), Chloride (Cl^{-}), Sulphate (SO_4^{2-}), Nitrate (NO_3^{-}), Soluble Sodium Percentage (SSP), Permeability Index (PI), Residual Sodium Bicarbonate (RSBC), Magnesium Adsorption Ratio (MAR), Kelly's Ratio (KR) and Sodium Adsorption Ratio (SAR). The locations are presented in Figure-2.

Table-1: Source & Location of groundwater samples of different villages of Sanganer Tehsil

Sample No.	Sampling Source	Village	Sample No.	Sampling Source	Village
S1	Hand Pump	Asawala	S21	Hand Pump	Lakhawas
S2	Hand Pump	Bagru	S22	Well	Laxmipura No. 1
S3	Tube Well	Bagru Rawan	S23	Hand Pump	Mahapura
S4	Hand Pump	Baksawala	S24	Tube Well	Mahel
S5	Well	Bamoriya	S25	Hand Pump	Manoharpura
S6	Well	Bar ka Balaji	S26	Hand Pump	Mohanpura
S7	Hand Pump	Beelwa	S27	Hand Pump	Muhana
S8	Hand Pump	Bhankrota	S28	Tube Well	Nevta
S9	Tube Well	Bhatawala	S29	Hand Pump	Pratapnagar
S10	Hand Pump	Dayalpura	S30	Tube Well	Ramchandrapura
S11	Hand Pump	Durgapura	S31	Tube Well	Ramsinghpura
S12	Tube Well	Goner	S32	Hand Pump	Sanganer
S13	Tube Well	Govindpura	S33	Tube Well	Seemliya
S14	Tube Well	Hajiwala	S34	Tube Well	Shikarpura
S15	Hand Pump	Heerapura	S35	Hand Pump	Sirani
S16	Hand Pump	Jagannathpura	S36	Tube Well	Sitapura
S17	Tube Well	Jaranwala	S37	Tube Well	Sukhdeopura
S18	Hand Pump	Khetapura	S38	Hand Pump	Surajpura
S19	Hand Pump	Khori	S39	Tube Well	Teelawas

S20	Hand Pump	Kishorpura	S40	Tube Well	Vatika

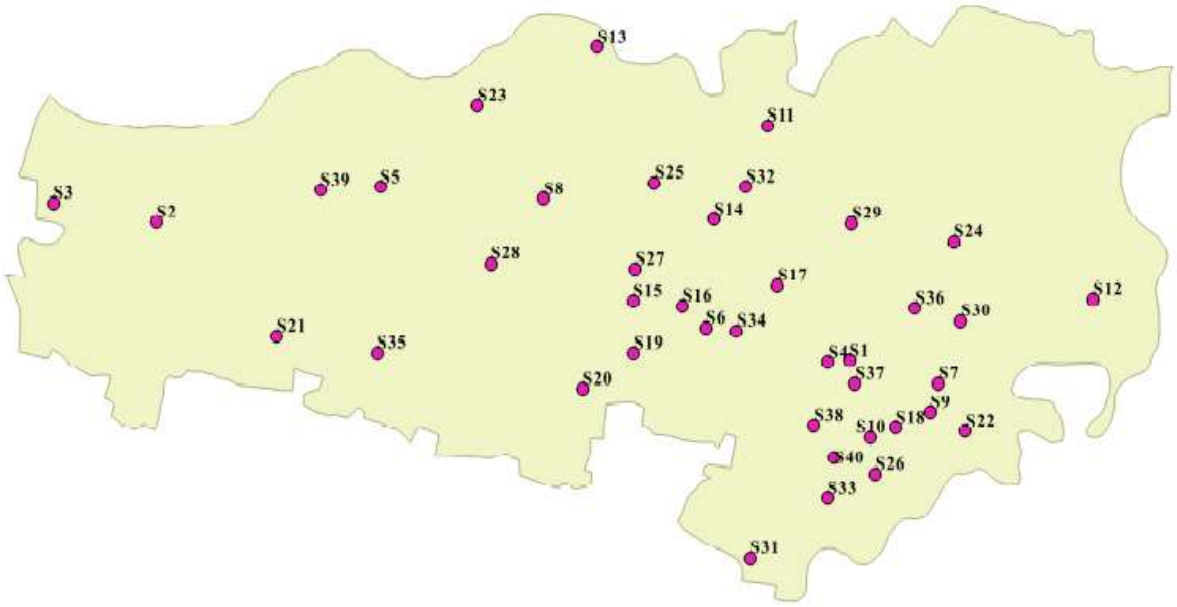

Figure-2: Map of location with different villages of Sanganer tehsil using GIS

RESULTS AND DISCUSSION

Assessment of physico-chemical parameters

Field analytical results

Results for field EC ranged from 530 µmhos/cm to 4850 µmhos/cm with an average of 1499.65 µmhos/cm and exhibit standard deviation of 940.23 µmhos/cm. Most of the samples are safe only with permeable soil and moderate leaching and some are unsuitable for irrigation (Table-2).

Table-2: Quality of irrigation water in relation to Electrical Conductivity (EC) [6]

S. No.	EC(µmhos/cm)	Type of Water	Suitability for irrigation	Remarks
1	Below 250	Low saline water	Entirely safe	Nil
2	250-750	Moderately saline (2)	Safe under practically all conditions	10 Samples (S6,S8,S11,S12,S15,S19, S20,S27,S29,S35)
3	750-2250	Medium to high salinity (3)	Safe only with permeable soil and moderate leaching	24 Samples (S1,S2,S3,S4,S9,S13,S14, S16,S17,S21,S23,S24,S25, S26,28,S30,S31,S32,S33, S36,S37,S38,S39,S40)
4	2250-4000	High salinity	Unsuitable for irrigation	05 Samples (S5,S10,S18,S22,S34)
5	4000-6000	Very high salinity	Unsuitable for irrigation	01 Sample (S7)
6	Above 6000	Excessive salinity class	Unsuitable for irrigation	Nil

Field pH ranged from 7.25 to 8.87 with an average of 8.07 with a standard deviation of 0.50. The field temperature ranged from 28.2˚C to 33.8˚C with an average of 29.97˚C giving a standard deviation of 1.31˚C. Field salinity ranged from 98 mg/L to 994 mg/L with an average of 296.05 mg/L and a standard deviation of 251.28 mg/L. Results for TDS ranged from 298.28 mg/L to 1950.2 mg/L with an average of 705.25 mg/L and a standard deviation of 353.14 mg/L. Most of the samples are fall within the permissible limits and except sample numbers given in Table-3. Complete results are shown in Table-4 & 6.

Table-3: Range of TDS for irrigation use

Classification	TDS (mg/L)	Remarks
Non saline	< 1000	35 Samples
Slightly saline	1000-3000	05 Samples(S5, S7, S31, S34, S40)
Moderately saline	3000-10000	Nil
Very saline	>10000	Nil

Table-4: Temperature, EC, pH, TDS and Salinity field analytical results

Sample No.	Temperature (^{0}C)	EC (µmhos/cm)	pH	Salinity (mg/L)	TDS (mg/L)
S1	28.6	1913	7.32	105	682.8
S2	31.6	1180	8.6	230	652.8
S3	28.5	1330	8.7	310	558.92
S4	29.7	1652	7.92	871	655.6
S5	30.4	3600	8.54	330	1950.2
S6	30.2	660	8.72	200	347.34
S7	31	4850	7.69	250	1418.7
S8	30.6	560	8.5	140	334.7
S9	29.6	1856	7.77	994	801.1
S10	30.2	3080	7.42	168	848.8
S11	29.4	750	8.6	178	483.88
S12	28.7	630	8.2	230	362.9
S13	30	1479	7.25	771	667.14
S14	28.5	860	7.6	130	435.72
S15	29	550	8.5	425	315.02
S16	28.2	1060	8.7	210	693.08
S17	31.5	930	8.6	305	298.28
S18	29.2	2680	7.69	145	860.2
S19	30.2	720	8.5	120	560
S20	30.5	650	8.5	225	722.3
S21	33.8	1530	8.7	140	691.4
S22	31.4	2370	8.87	126	647.8
S23	28.6	987	7.52	136	721.36
S24	29.6	1120	8	98	758
S25	29.5	1735	8.6	158	628.4
S26	28.8	1992	7.83	108	691.81
S27	30.1	690	8	269	400.9
S28	30.5	980	8.2	165	556.7
S29	29.8	530	7.6	109	565.8
S30	29.4	758	7.4	521	625.86

S31	32.7	1619	7.3	856	1164.2
S32	29.8	1260	8.1	485	643.9
S33	33.6	1812	7.59	975	604.72
S34	29	3040	7.25	167	1354.91
S35	28.8	720	8	138	426.86
S36	28.6	1350	8.4	269	519.24
S37	29	953	7.9	235	591
S38	30.3	2180	7.7	118	656.59
S39	29.7	1160	8.7	314	633.08
S40	30.2	2210	7.7	118	1677.97

Major ion analytical results

The major cations include Mg2+, Ca2+, Na+ and K+ while major anions include HCO3-, Cl-, SO42-, NO3- and CO32-. The complete results with their minimum and maximum values mean and standard deviations are presented in Table-5 and Table-6.

Table- 5: Major ion analytical results

Sample No.	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	HCO_3^{-} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	NO_3^{-} (mg/L)	CO_3^{2-} (mg/L)
S1	48	40.8	136	3	126	289	63	12	28
S2	72	16.8	156	2	268	184	24	40	24
S3	36.8	9.12	75	1	278	135	51	92	20
S4	44	33.6	138	3	126	264	56	22	32
S5	88	19.2	651	5	390	808	91	75	18
S6	49.6	12.24	53	3	183	71	25	18	24
S7	84	100.8	254	2	360	264.91	264	245	24
S8	43.2	10.08	58	1	207	35	38	22	24
S9	40	43.2	178	4	138	314.9	92	20	40
S10	28	28.8	240	5	68	416	57	14	26
S11	67.2	13.68	70	2	166	99	0	125	24
S12	36	8.4	93	2	305	35	0	36	0
S13	40	43.2	145	2	368	164.94	30	38	20
S14	25.2	5.52	128	1	198	79	55	43	0
S15	28.8	6.72	68	4	215	35	7	34	24
S16	46	10.08	188	1	220	190	65	65	18
S17	20	5.28	76	2	186	30	28	20	24
S18	36	19.2	250	4	110	325	136	35	0
S19	60	12	106	3	122	160	0	134	24
S20	48	10.8	186	3	225	140	120	80	22
S21	28.4	6	210	5	130	235	67	64	11
S22	24	26.4	178	2	75	294.9	59	26	0
S23	80.4	18.96	148	1	348	118	98	59	24
S24	108	24	118	5	368	234	53	32	0
S25	39.2	7.2	172	4	386	165	0	48	0
S26	32	14.4	191	3	79	244.91	129	18	20

S27	66	8.4	82	2	391	36	0	11	0
S28	46	7.2	149	22	379	106	29	8	0
S29	84	10.8	112	2	400	86	38	15	18
S30	58	9.36	155	3	203	152	105	42	0
S31	132	55.2	210	5	426	354	111	68	16
S32	76	38.4	106	3	205	248	34	36	0
S33	56	16.8	142	2	170	249.92	7	26	20
S34	388	93.6	122	1	165	589.81	36	26	16
S35	38.4	12.96	99	2	305	57	0	65	0
S36	44	30.24	78	1	152	228	12	35	15
S37	90	48	60	1	258	139	84	20	20
S38	28	31.2	45	2	326	339.89	2.5	45	0
S39	39.2	8.88	89	2	422	187	56	18	22
S40	76	33.6	529	2	854	389.87	68.5	134	18

Table-6: Minimum, maximum, mean and standard deviation of field and major ion analytical results

Parameter	Minimum	Maximum	Mean	Standard deviation
Temperature (^{0}C)	28.2	33.8	29.97	1.31
EC (µmhos/cm)	530	4850	1499.65	940.23
pH	7.25	8.87	8.07	0.50
Salinity (mg/L)	98	994	296.05	251.28
TDS (mg/L)	298.28	1950.2	705.25	353.14
Ca^{2+} (mg/L)	20	388	61.86	58.46
Mg^{2+} (mg/L)	5.28	100.8	23.78	21.70
Na^{+} (mg/L)	45	651	156.10	115.96
K^{+} (mg/L)	1	22	3.07	3.32
HCO_3^{-} (mg/L)	68	854	257.52	144.99
Cl^{-} (mg/L)	30	808	212.35	156.23
SO_4^{2-} (mg/L)	0	264	54.77	51.66
NO_3^{-} (mg/L)	8	245	49.15	45.35
CO_3^{2-} (mg/L)	0	40	15.4	11.21

Hydrochemical Facies

Major cations and anions such as Ca2+, Mg2+, Na+, K+, Cl-, SO42-, HCO3- and CO32- in meq/L were plotted in Piper trilinear diagram (Figure-3) to evaluate the hydrochemistry of groundwater of Sanganer Tehsil with the help of Aquachem software. From the Piper diagram [6], it can be interpreted that cation concentration of the groundwater samples of the selected area is dominated by sodium-potassium type, whereas anion concentration is dominated by carbonate-bicarbonate type and chloride type. These factors have a negative impact on water quality with regards to irrigation.

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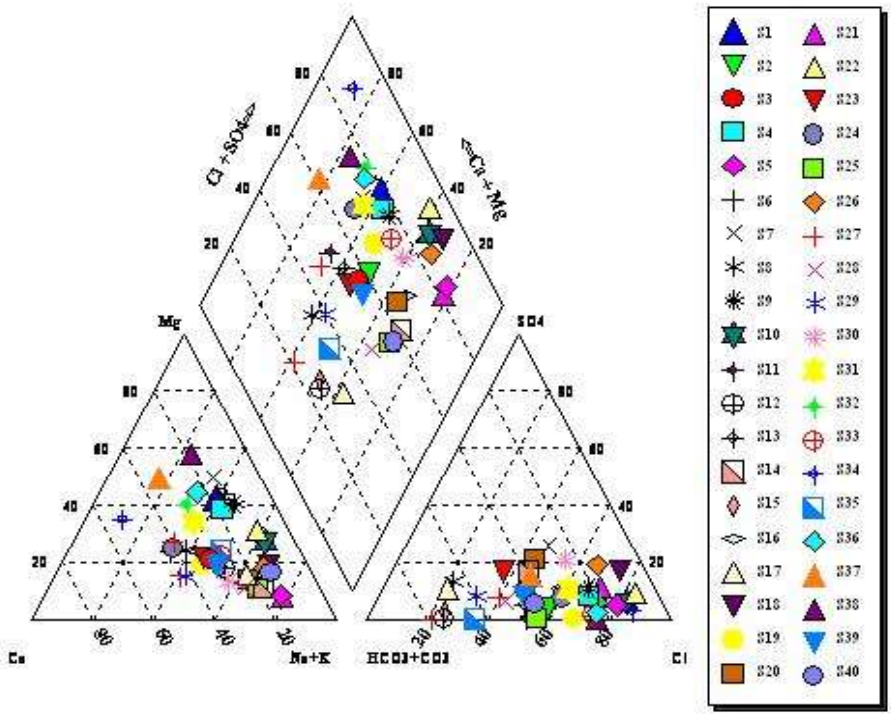

Figure-3: Piper trilinear diagram of groundwater samples

Assessment of groundwater quality for irrigation

Sodium Adsorption Ratio (SAR) [7]: The Sodium Adsorption Ratio (SAR) was calculated by equation-1:

$$SAR = \frac{Na^{+}}{\sqrt{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)}} \quad (1)$$

SAR of groundwater obtained in the present study is generally less than 17 and fall under the category of C3S1 indicating low alkali hazards and good irrigation water.

Soluble Sodium Percentage (SSP) [8]: It was calculated equation-2:

$$SSP = \frac{\left(Na^{+} + K^{+}\right) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \quad (2)$$

SSP values of groundwater in the study area range between 16.38 and 82.82 indicating low alkali hazards and fair (Class III) to excellent (Class I) irrigation quality [9].

Residual Sodium Bicarbonate (RSBC) [8], [10]: RSBC was calculated by using equation-3:

$$RSBC = HCO_3^{-} - Ca^{2+} \quad (3)$$

RSBC values of water samples vary from -16.70 to 10.2 meq/L. All RSBC values are greater than 2.5 and thus are indication o poor quality of water for irrigation purposes (Table 6).

Table-7: Limits of some parameters for rating quality of groundwater and suitability for irrigation

Category	EC (µmhos/cm)	SAR	RSBC (meq/L)	SSP (%)	Suitability for irrigation
I	< 117.51	<10	<1.25	<20	Excellent
II	117.51	10-18	1.25-2.5	20-40	Good
III	508.61	16-26	>2.5	40-80	Fair
IV	>503.61	>26	-	>80	Poor

Magnesium Adsorption Ratio (MAR) [11]: It was calculated by using equation-4:

$$MAR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}} \quad (4)$$

The values of MAR of groundwater in present study area varies from 17.50 to 66.67% indicating that some samples are above the acceptable limit of 50% [12]. As a result, sample numbers S1, S4, S7, S9, S10, S13, S22, S36, S38 appears o be unsuitable for irrigation purposes.

Kelly Ratio (KR) [13]: The Kelly's Ratio was calculated employing the following equation-5:

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \quad (5)$$

KR values of study area ranged between 1.78 and 11.03. These indicate that KR for the groundwater samples is much higher than permissible limit of 1.0 [12] and are considered unsuitable for irrigation purposes.

Permeability Index (PI) [14]: It was calculated employing equation-6:

$$PI = \frac{\left(Na^{+} + \sqrt{HCO_3^{-}}\right)}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100 \quad (6)$$

PI values range is 10.36 to 43.91. The above result therefore suggests that water samples fall within Class II and Class III and indication of groundwater to be suitable for irrigation [14].

The results of the different irrigation indices for rating irrigation water quality are presented in table-8 and summarized in table-9.

Table-8: Different parameters for rating groundwater quality for irrigation

Sample No.	EC (µmhos/cm)	TDS (mg/l)	SAR	SSP (%)	MAR (%)	PI (%)	KR	RSBC (meq/L)
S1	1913	682.8	3.47	50.80	58.62	18.18	5.863	-0.33
S2	1180	652.8	4.28	57.74	28.00	24.57	3.28	0.79
S3	1330	558.92	2.85	55.83	29.23	39.69	2.53	2.71
S4	1652	655.6	3.79	54.86	56.00	19.07	5.52	-0.13
S5	3600	1950.2	16.34	82.57	26.67	35.68	8.03	1.99
S6	660	347.34	1.74	40.48	29.14	32.14	1.94	0.52
S7	4850	1418.7	4.39	46.82	66.67	21.32	11.02	1.70
S8	560	334.7	2.05	45.92	28.00	35.88	2.00	1.23
S9	1856	801.1	4.62	58.33	64.29	19.01	7.46	0.26
S10	3080	848.8	7.57	73.54	63.16	17.85	9.85	-0.28
S11	750	483.88	2.02	40.74	25.33	24.91	2.04	-0.63
S12	630	362.9	3.61	62.09	28.00	38.21	2.94	3.20
S13	1479	667.14	3.76	53.16	64.29	26.94	6.75	4.03
S14	860	435.72	6.00	76.47	26.74	30.30	4.87	1.98

S15	550	315.02	2.95	60.46	28.00	40.83	2.61	2.08
S16	1060	693.08	6.52	72.30	26.75	24.96	4.39	1.30
S17	930	298.28	3.89	69.97	30.56	40.11	3.74	2.04
S18	2680	860.2	8.33	76.34	47.06	20.28	7.63	0.00
S19	720	560	3.25	53.94	25.00	21.04	2.53	-1
S20	650	722.3	6.29	71.21	27.27	24.95	4.26	1.28
S21	1530	691.4	9.31	82.82	26.04	22.34	6.92	0.71
S22	2370	647.8	5.93	69.61	64.71	17.69	8.64	0.02
S23	987	721.36	3.84	53.56	28.21	26.28	3.18	1.68
S24	1120	758	2.66	41.54	27.03	24.73	2.95	0.63
S25	1735	628.4	6.60	74.75	23.44	32.54	4.41	4.36
S26	1992	691.81	7.01	74.95	42.86	18.55	6.39	-0.30
S27	690	400.9	2.52	47.48	17.50	37.03	1.78	3.10
S28	980	556.7	5.37	70.83	20.69	33.06	3.41	3.91
S29	530	565.8	3.04	49.10	17.65	30.56	2.05	2.35
S30	758	625.86	4.96	64.93	21.20	24.25	3.10	0.42
S31	1619	1164.2	3.85	45.25	41.07	22.13	5.98	0.38
S32	1260	643.9	2.46	40.09	45.71	20.40	4.41	-0.43
S33	1812	604.72	4.26	59.71	33.33	22.27	3.60	-0.01
S34	3040	1354.91	1.43	16.38	28.68	10.36	8.07	-16.69
S35	720	426.86	3.51	59.21	36.00	34.92	3.32	3.08
S36	1350	519.24	2.20	41.99	53.39	22.85	4.06	0.29
S37	953	591	1.26	23.65	47.06	21.12	4.57	-0.27
S38	2180	656.59	1.38	33.41	65.00	40.77	3.99	3.94
S39	1160	633.08	3.33	59.21	27.41	43.91	2.71	4.95
S40	2210	1677.97	12.66	77.74	42.42	35.64	8.85	10.2

Table-9: Summary of different parameters of groundwater quality for irrigation

Parameter	Minimum	Maximum	Mean	Standard
SAR	1.26	16.34	4.64	3.03
SSP (%)	16.38	82.82	57.25	15.76
MAR (%)	17.50	66.67	37.20	15.33
PI (%)	10.37	43.91	27.43	8.26
KR	1.78	11.03	4.80	2.42
RSBC (meq/L)	-16.69	10.2	1.129	3.57

Salinity Hazard

According to the salinity hazard classification (Table-7), some samples having medium salinity hazard, most of highly saline and very few samples are very high saline. Figure-4 suggests that samples fall within Class C2-S1, Class C3-S1 and some in Class C4-S1.

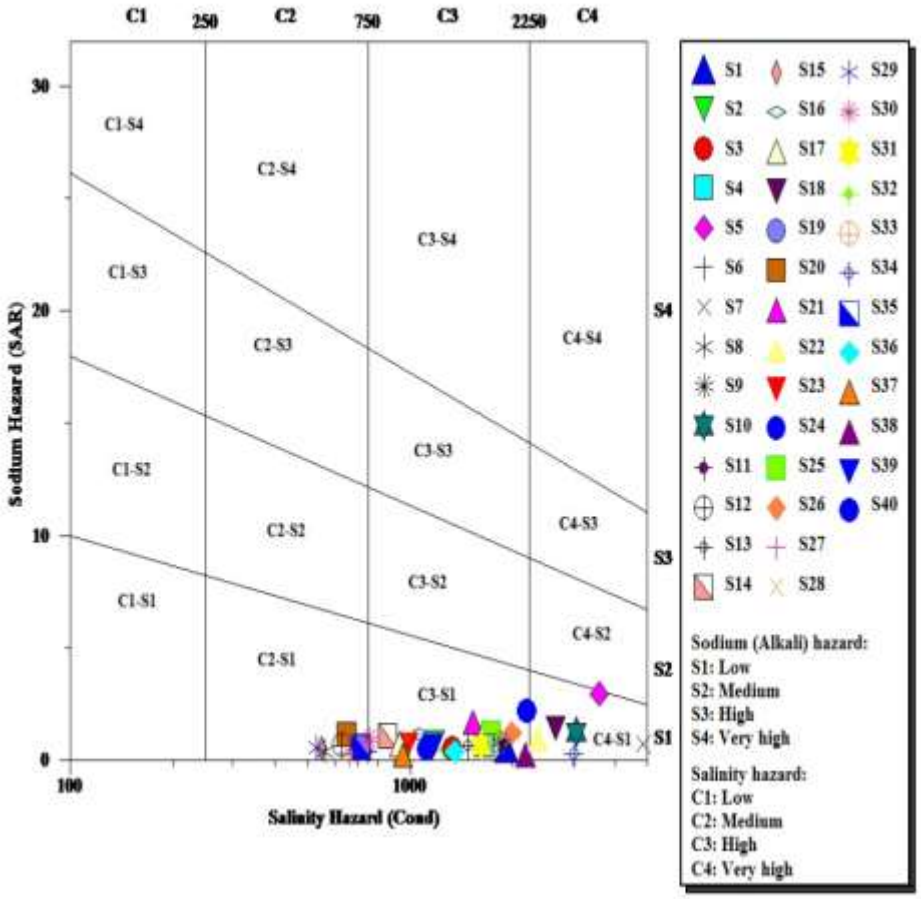

Figure-4: Rating of groundwater samples in relation to salinity and sodium hazard

CONCLUSION

The quality parameters determined from sources are conclusive of the fact that most of the water samples were within safe limits. However, some samples are unsuitable for irrigation. In addition, most of the samples irrigation indices fall within permissible levels indicating medium sodic waters. Salinity hazard is high in few samples and they appear to be unsuitable for drinking as well as agriculture purposes.

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