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Analysis of Quality of Ground Water and Its Suitability for Irrigation Purpose in Visnagar Taluka, Mehsana District, Gujarat

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Abstract: The ground water quality of Visnagar Taluka has been assessed to see the suitability of ground water for drinking and irrigation applications. This is a two part series paper. In an earlier paper, we have examined the suitability of ground water for drinking purpose. This paper examines the suitability of ground water for irrigation applications. Fifty ground water samples were collected during post-monsoon seasons and analyzed for various water quality characteristics. The suitability of ground water for irrigation purpose has been evaluated based on salinity, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Magnesium Hazard Ratio(MHR), Sodium percent (%Na), and Permeability Index(PI). In general the ground water of Visnagar Taluka is safe for irrigation purpose. According to U.S. Salinity Laboratory classification of irrigation water, C3S1 (26%), C3S2 (28%), C4S2 (20%), and C4S3 (20%), with moderately high salinity. About 8% samples fall under water type C4S4 such water cannot be used for irrigation purpose.

Keywords: Groundwater, MH Ratio, RSC, SAR, USSL Classification.

I. INTRODUCTION

Ground water plays an important role in agriculture, for both watering of crops and for irrigation of dry season crops. It is estimated that about 45% of irrigation water requirement is met from ground water sources.[1] The quality of ground water varies from place to place along with the depth of water table. It also varies with seasonal changes and is primarily governed by the extent and composition of dissolved solids present in it. Suitability of ground water for irrigation purposes depends upon its mineral constituents. United States Salinity Laboratory of the Department of Agriculture has classified water samples based on combined Sodium Adsorption Ratio (SAR) and Electrical Conductivity (EC) values.

II. STUDY AREA

Visnagar taluka is located in Mehsana district of north Gujarat, India. It lies between 23°30'-23°55' latitude and 72°20'-72°40'E longitude. It is located 21 KM towards East from District headquarters Mehsana. 63 KM from State capital Gandhinagar towards South. It is located 21 KM towards East from District headquarters Mehsana. 63 KM from State capital Gandhinagar towards South. Visnagar consist of 94 Villages and 65 Panchayats. It is in the 126 m elevation (altitude). . Visnagar taluka is popularly known as 'ShikshanNagari' and also known as Copper city. The climate of Visnagar is tropical arid to marginal semi-arid. It is strongly periodic and seasonal. The average rainfall is 626-875mm.The temperature ranges between max. 42°C and min10°C. Type of soil sandy loam to sandy soils. The Visnagar taluka is especially rich in sub soil water.

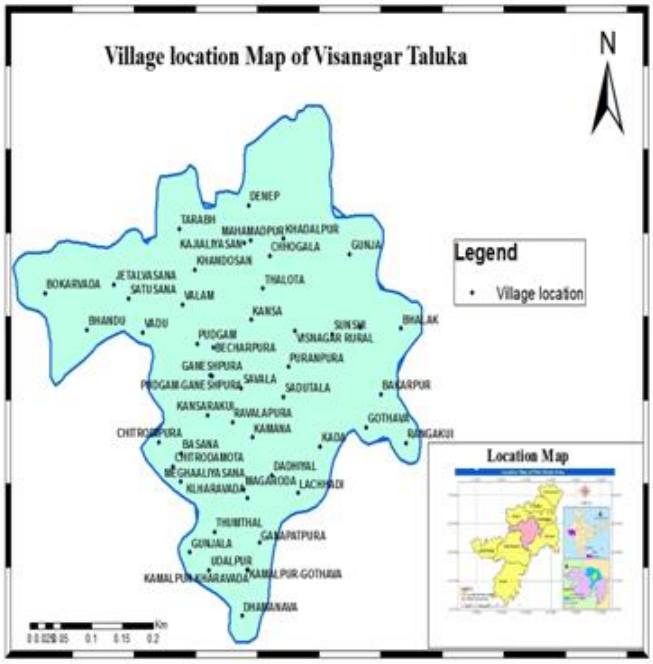

Fig.1. Location Map of the Study Area.

III. EXPERIMENTAL METHODOLOGY

Total fifty ground water samples of different tube wells were collected from Visnagar Taluka (Fig.1) each during post-monsoon seasons. The samples were collected

in plastic containers of 2 liters capacity for physicochemical analysis after pumping out sufficient quantity of water from tube wells. The samples were analyzed as per the methods described by APHA methods. [7] The experimental values were compared to standard values recommended by Indian Standard (2012) for drinking purpose and IS: 11624-1986 for irrigation purpose.

TABLE I: Hydro Chemical Data of Groundwater in the Study Area For Irrigation Post-Monsoon 2015

SR.NO	Habitation Name	PH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}
S1	BAKARPUR	7.78	4000	1832	154	51	780	17.23	0	690
S2	BASANA	8.14	2450	1298	90	35	546	5.67	0	321
S3	BECHARPURA	7.88	2210	1248	85	20	348	1.43	0	200
S4	BHALAK	8.24	1300	781	53	34	153	2.13	0	469
S5	BOKARVADA	8.11	740	272	48	37	254	3.21	0	97
S6	CHHOGALA	7.2	5450	3470	65	120	946	3.18	0	634
S7	CHITRODAMOTA	8.16	2790	1244	66	34	412	6.43	0	326
S8	CHITRODIPURA	8.18	2460	1044	55	31	344	3.76	0	654
S9	DADHIYAL	8.06	1450	847	63	24	170	2.25	0	452
S10	DHAMANAVA	8.03	1100	688	71	17	110	1.26	0	312
S11	GANAPATPURA	8.39	1500	898	85	26	226	2.37	12	296
S12	SUNSHI	7	4010	2580	135	66	636	5.62	0	464
S13	GOTHAVA	8.05	1790	901	77	35	290	2.8	0	260
S14	DENEP	7.1	3920	2510	115	99	570	13.67	0	476
S15	GUNJA	7.91	3980	1996	133	57	780	18.7	0	570
S16	GUNJALA	8.08	1940	984	71	21	310	1.32	0	345
S17	IYASARA	8.32	3310	1604	43	34	520	5.37	12	594
S18	JETALVASANA	8.18	2860	1442	47	33	470	6.34	0	433
S19	KADA	8.1	1560	894	48	33	310	2.45	0	258
S20	PURANPURA	8.34	1490	830	48	21	240	1.64	12	322
S21	KAJIALIYASAN	8.36	2750	1390	35	41	450	5.64	12	465
S22	KAMALPUR-(GOT)	8.31	1570	817	79	32	190	3.45	12	246
S23	KAMANA	7.83	2050	1098	85	15	310	2.56	0	433
S24	KAMALPUR (KHA)	7.95	1760	984	103	23	290	4.31	0	132
S25	KANSA	8.32	3240	1668	45	33	594	5.17	12	365
S26	KANSARAKUI	8.18	1840	980	42	27	470	6.44	0	120
S27	KHANDOSAN	8.13	840	490	58	31	120	1.33	0	144
S28	KLHARAVADA	8.15	2010	813	48	25	329	1.28	0	278
S29	LACHHADI	7.78	1450	754	71	29	160	2.33	0	164
S30	MAGARODA	8.12	2100	916	53	28	320	8.9	0	321
S31	MAHAMADPUR	8.38	2900	1364	34	38	625	3.9	12	376
S32	MEGHAALIYASANA	8.11	2150	1016	63	28	380	6.36	0	257
S33	PUDGAM-GANESHPURA	8.35	2740	1342	55	25	425	3.23	12	342
S34	PUDGAM	8.25	3200	1112	72	44	600	10.5	0	316
S35	RALISANA	7.4	1870	1310	45	24	329	4.14	0	245
S36	KHADALPUR	6.8	5820	3560	245	123	825	15.26	0	268
S37	BHANDU	7.6	1860	1190	55	39	287	2.35	0	195
S38	RANGAKUI	8.04	1920	937	69	30	345	4.43	0	195
S39	RAVALAPURA	8.2	2040	1010	35	21	337	5.21	0	231
S40	SADUTALA	8.13	2500	1510	90	29	420	12.1	0	288
S41	SATUSANA	7.3	2980	1970	60	48	521	3.75	0	464
S42	SAVALA	7.96	2240	1039	45	19	423	2.3	0	355
S43	GANESHPURA	8.32	3500	1750	50	40	870	9.24	12	344
S44	TARABH	8.41	3500	1512	26	31	485	2.1	12	355
S45	THALOTA	8.50	3000	1464	18	24	640	11.43	12	299
S46	THUMTHAL	7.96	2120	1026	82	26	421	3.6	0	276
S47	UDALPUR	8.10	1628	848	59	24	324	5.6	0	234
S48	VADU	7.92	2230	1194	59	24	476	8.45	0	324
S49	VALAM	8.16	4050	1516	35	25	758	19.22	0	410
S50	VISNAGAR RURAL	8.25	3020	1510	68	70	465	5.2	0	255

TABLE II: Sodium Adsorption ratio (SAR), Residual Sodium Carbonate (RSC), Sodium percent (%Na), Magnesium Hazard Ratio (MH) and Permeability Index for various sites of Visnagar Taluka (post-monsoon 2014-15)

SR.NO	Habitation Name	EC	SAR	RSC	%Na	MH	PI
S1	BAKARPUR	4000	13.87	-0.64	74.19	35.56	80.50
S2	BASANA	2450	12.33	-2.15	76.31	39.33	83.17
S3	BECHARPURA	2210	8.80	-2.64	71.94	28.17	80.35
S4	BHALAK	1300	4.02	2.21	55.02	51.67	77.32
S5	BOKARVADA	740	6.67	-3.89	66.99	56.23	74.08
S6	CHHOGALA	5450	15.98	-2.86	75.67	75.47	81.44
S7	CHITRODAMOTA	2790	10.23	-0.79	74.67	46.20	83.53
S8	CHITRODIPURA	2460	9.16	5.39	73.84	48.44	89.43
S9	DADHIYAL	1450	4.61	2.26	59.12	38.83	80.27
S10	DHAMANAVA	1100	3.03	0.15	49.22	28.52	72.01
S11	GANAPATPURA	1500	5.49	-1.16	60.64	33.77	73.78
S12	SUNSHI	4010	11.17	-4.64	69.41	44.90	75.94
S13	GOTHAVA	1790	6.85	-2.50	65.20	43.10	75.45
S14	DENEP	3920	9.37	-6.20	64.22	58.93	70.47
S15	GUNJA	3980	14.20	-2.06	75.11	41.67	80.73
S16	GUNJALA	1940	8.28	0.36	71.83	33.02	84.29
S17	IYASARA	3310	14.32	5.15	82.03	56.86	92.79
S18	JETALVASANA	2860	12.80	2.00	80.15	53.92	89.89
S19	KADA	1560	8.40	-0.92	72.45	53.40	83.11
S20	PURANPURA	1490	7.24	1.53	71.63	42.17	87.05
S21	KAJIALIYASAN	2750	12.17	2.86	79.23	66.13	89.75
S22	KAMALPUR-(GOT)	1570	4.54	-2.18	55.79	40.30	68.62
S23	KAMANA	2050	8.13	1.60	71.12	22.73	84.76
S24	KAMALPUR (KHA)	1760	6.71	-4.90	64.28	27.12	71.16
S25	KANSA	3240	16.33	1.38	83.85	55.00	91.32
S26	KANSARAKUI	1840	13.86	-2.38	82.57	51.72	87.52
S27	KHANDOSAN	840	3.15	-3.12	48.92	47.11	62.92
S28	KHARAVADA	2010	9.55	0.07	76.18	46.47	87.35
S29	LACHHADI	1450	4.03	-3.28	54.04	40.50	66.21
S30	MAGARODA	2100	8.81	0.28	73.94	46.82	84.74
S31	MAHAMADPUR	2900	17.42	1.70	84.86	65.07	92.27
S32	MEGHAALIYASANA	2150	9.98	-1.27	75.26	42.55	83.79
S33	PUDGAM-GANESHPURA	2740	11.89	1.17	79.34	43.10	89.11
S34	PUDGAM	3200	13.69	-2.09	78.39	50.46	84.36
S35	RALISANA	1870	9.81	-0.23	77.22	47.06	87.40
S36	KHADALPUR	5820	10.69	-18.11	61.71	45.56	64.61
S37	BHANDU	1860	7.20	-2.80	67.63	54.17	76.95
S38	RANGAKUI	1920	8.70	-2.75	71.75	42.02	79.70
S39	RAVALAPURA	2040	11.08	0.29	80.86	50.00	90.77
S40	SADUTALA	2500	9.82	-2.20	72.86	34.94	80.17
S41	SATUSANA	2980	12.11	0.61	76.47	57.14	85.42
S42	SAVALA	2240	13.28	1.99	82.80	41.30	93.36
S43	GANESHPURA	3500	22.15	0.21	86.71	57.14	91.58
S44	TARABH	3500	15.13	2.34	84.48	66.52	93.91
S45	THALOTA	3000	23.11	2.40	90.65	68.97	96.84
S46	THUMTHAL	2120	10.34	-1.74	74.59	34.57	82.84
S47	UDALPUR	1628	8.95	-1.11	74.19	40.40	83.66
S48	VADU	2230	13.16	0.36	80.86	40.40	88.93
S49	VALAM	4050	23.80	2.89	89.72	54.35	95.35
S50	VISNAGAR RURAL	3020	9.41	-5.05	68.79	63.18	75.25

IV. RESULT & DISCUSSION

The suitability of irrigation water depends upon several factors, such as, water quality, soil type, plant characteristics, irrigation method, drainage, climate and the local conditions. The following chemical properties shall be considered for developing water quality criteria for irrigation.

A. Total Salt Concentration

It is expressed as the electrical conductivity (EC) as shown in Fig.2. In relation to hazardous effects of the total salt concentration, the irrigation water can be classified into four major groups as given in Table -2.

TABLE III: Salinity Hazard Classes

Salinity Hazards Class	Remark on quality	EC in (micromhos/cm)	Number of Samples
C1	Low	Below 1500	7 (14%)
C2	Medium	1500-3000	29(58%)
C3	High	3000-6000	14(28%)
C4& C5	Very High	Above 6000	---

The total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance. Classification of groundwater based on salinity

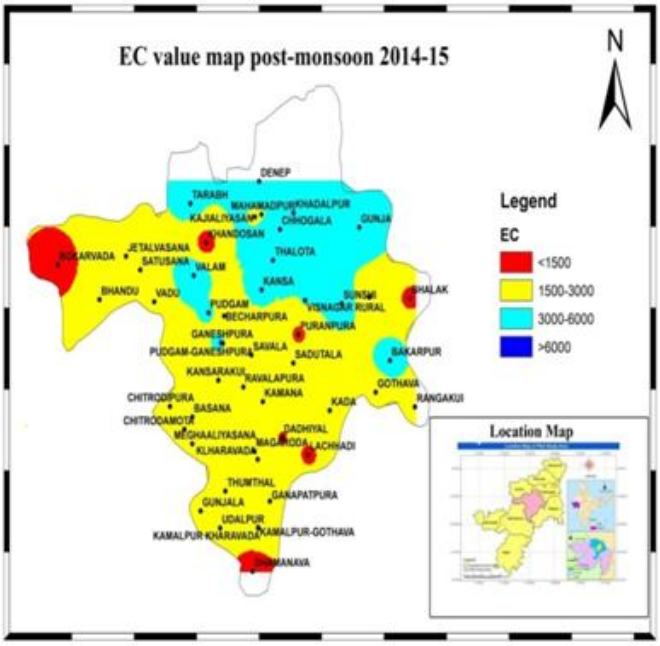

Fig.2. EC concentrations in the study area.

hazard is presented in Table (3). It is found from the salinity hazard classes that 14% of the samples fall in the low category (C1-class), 58% samples fall in medium category (C2-class), 28% samples fall in high category (C3-class) and no fall any sample in very high category (C4 & C5) for irrigation purposes. Groundwater samples that fall in the low salinity hazard class (C1) can be used for irrigation of most crops and majority of soils. However, some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability. Groundwater samples that fall in the medium salinity hazard class (C2) can be used if a moderate amount of leaching occurs. High salinity (C4 and C5) can be suitable for plants having good salt tolerance but restricts its suitability for irrigation, especially in soils with restricted drainage. High salinity water (C3, C4, and C5) cannot be used in soils with restricted drainage. Even with adequate drainage, special management for salinity control is required, and crops.

B. Sodium Adsorption Ratio

The sodium adsorption ratio of water gives the measure of suitability of water for irrigation with respect to sodium (alkali) hazard. It is given by the formula

$$SAR = [Na^+] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2} \quad (1)$$

Where

SAR = sodium adsorption ratio (millimole/litre)1/2

Ca^{2+} = -calcium ion concentration, me/l

Mg^{2+} = magnesium ion concentration, me/l

NOTE : me/l = mill equivalent/litre.

TABLE IV: Water Quality Rating Based on Sodium Adsorption Ratio

Sodium Hazards Class	Remark on quality	SAR in Equivalents per mole	Number of Samples
S1	Low	Below 10	26(52%)
S2	Medium	10-18	21(42%)
S3	High	18-26	3(6%)
S4 & S5	Very High	Above 26	--

Excess sodium in water produces undesirable effects of changing soil properties and reducing soil permeability [2]. High sodium depositing waters are generally not suitable for irrigating crops, as higher deposition of sodium may deteriorate the soil characteristics. SAR of water is directly related to the adsorption of sodium by soil and is a valuable criterion for determining the suitability of the water for irrigation as shown in Fig.3. As per IS: 11624-1986, irrigation water quality rating can be based on SAR (Table 4). Results show that majority of sites have SAR < 10 indicating water class to be low (excellent). 21 samples out of 50 have SAR value greater than 10 but less than 18, hence the groundwater quality is of medium class. 3 samples out of 50 have SAR value greater than 18 but less than 26, hence groundwater quality is of high class.

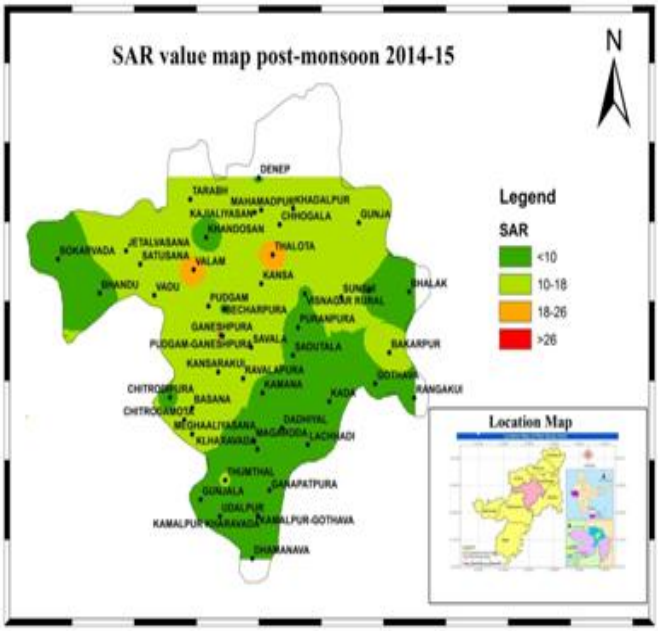

Fig.3. SAR values map post-monsoon 2014-15.

C. Residual Sodium Carbonate or Bicarbonate Ion Concentration

When concentration of carbonates and bicarbonates exceeds that of calcium and magnesium, there may be possibility of complete precipitation of calcium and magnesium. Bicarbonate and carbonate is considered to be detrimental to the physical properties of soils, as it causes dissolution of

organic matter in the soil, which in turn leaves a black stain on the soil surface on drying as shown in Fig.4. Residual sodium carbonate (RSC) shall be determined by the equation:

$$RSC = (CO_3^{2-}+HCO_3^{-})-(Ca^{2+}+Mg^{2+}) \quad (2)$$

Where
RSC = residual sodium carbonate (me/l),
CO_3^{2-}= carbonate ion concentration (me/l),
HCO_3^{-}= bicarbonate ion concentration (me/l),
Ca^{2+}= calcium ion concentration (me/l), and
Mg^{2+}= magnesium ion concentration (me/l).

NOTE - me/l - milliequivalent/litre.

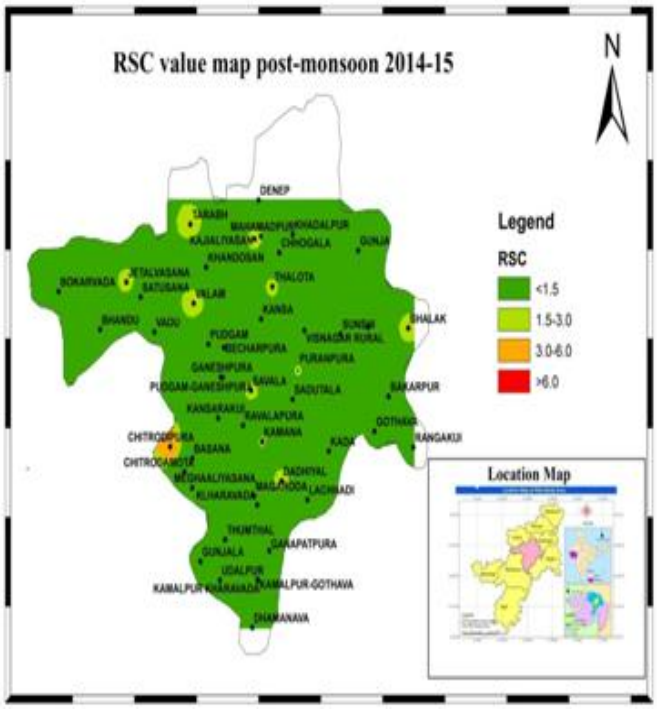

Fig.4. RSC values map post monsoon 2014-15.

TABLE V: Water Quality Rating Based On Residual Sodium Carbonate

Sr no	Class	Range of RSC	Number of samples
1	Low	Below1.5	35(70%)
2	Medium	1.5-3.0	13(26%)
3	High	3.0-6.0	2(4%)
4	Very High	Above 6.0	---

D. Sodium Percent (%Na)

Sodium concentration is important in classifying irrigation water because sodium reacts with the soil to reduce its permeability [6]. The sodium % can be calculated by

$$\%Na = (Na^{+}+K^{+}) / (Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}) \times 100 \quad (3)$$

TABLE VI: Water Classes Based on Percent Sodium

Remark on quality	% Na	Number of Samples
Excellent	Below 20	---
Good	20-40	6(12%)
Permissible	40-60	6(12%)
Doubtful	60-80	26(52%)
Unsuitable	Above 80	12(24%)

High sodium in irrigation water tends to be absorbed by clay particles displacing Ca2+ and Mg2+ ions. According to Wilcox (1955) the sodium percent for 12% sites is between 20-40 (good),12% sites with permissible value between 40 and 60, and 26% samples as doubtful with %Na varied from 60 to 80 and 12% samples with sodium percent greater than 80 termed as unsuitable for use.

E. Magnesium Hazard Ratio

The magnesium hazard (MH) ratio values are calculated by using the equation proposed by Szabolcs and Darb (1964) for irrigation water where

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

The units are in milliequivalent per litre and where MH> 50 the effects are considered to be harmful. The presence of more magnesium in water than calcium increases the degree of magnesium saturation and deteriorates the soil structure and decrease soil productivity [5]. It is observed that 38% samples have MH ratio values greater than 50 percent.

F. Permeability Index

The soil permeability is influenced by long term use of irrigation water containing sodium and bicarbonates. Permeability index is calculated using the formula

$$PI = \{(Na^{+}+(HCO_3^{-})^{1/2} / (Ca^{2+}+Mg^{2+}+Na^{+}+K^{+})\} \times 100 \quad (5)$$

For the study area the permeability index of groundwater ranges from 62.92 to 96.84.

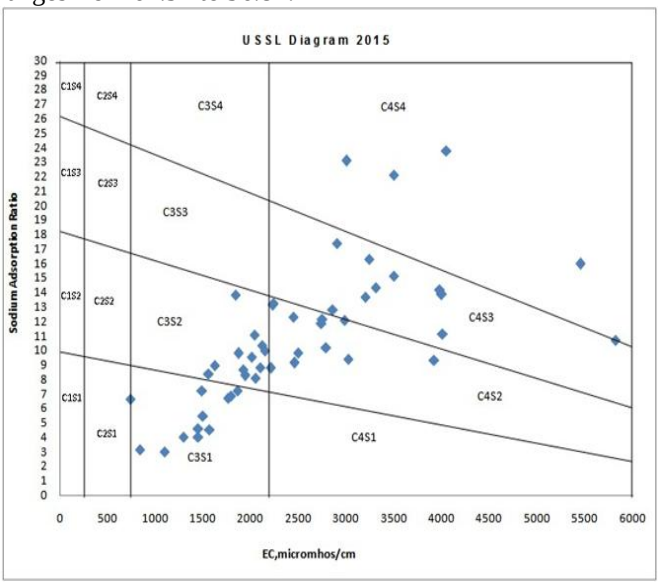

Fig.5. 72 U.S. Salinity Laboratory classifications for irrigation water.

G. USSL Diagram

U.S. Salinity Laboratory classification [4] is used to study the suitability of ground water for irrigation purposes. In classification of irrigation waters, it is assumed that the water will be used under average conditions with respect to soil texture, infiltration rate, and drainage, quantity of water used, climate and salt tolerance of crop. Sodium concentration is an important criterion in irrigation-water classification because sodium reacts with the soil to create sodium hazards by replacing other cations. The extent of this replacement is estimated by Sodium Adsorption Ratio (SAR). A diagram for use in studying the suitability of ground water for irrigation

purposes is based on the sodium adsorption ratio (SAR) and electrical conductivity of water expressed in µS/cm. The chemical analysis data of ground water samples of Visnagar taluka has been processed as per U.S. Salinity Laboratory classification for the two sets of data (Fig.5) and the results have been summarized in Table- 7.

TABLE VII: Summarized Result of U.S. Salinity Laboratory Classification

Classification /Type	No of Samples
C3S1	13(26%)
C3S2	14(28%)
C4S2	10(20%)
C4S3	10(20%)
C4S4	4(8%)

According to USSL classification (Table-7), 50 samples of groundwater of the study area, 13 samples fall into C3S1 (high salinity with low sodium), 14 samples fall into C3S2 (high salinity with medium sodium), 10 samples fall into C4S2 (high salinity with medium sodium).And 10 samples fall into C4S3 (very high salinity with high sodium) Out of 50 samples the 46 samples are suitable for irrigational use in almost all soil types and they facilitate good soil drainage. However, remaining 4 samples fall into C4S4 (very high salinity with very high sodium) sodium. Therefore, they may not be suitable for irrigational use (Table -7).

V. CONCLUSION

In the study area majority of groundwater samples are within permissible limits prescribed for irrigation water by SAR, RSC, and USSL diagram. According to USSL, study area of 50 ground water samples fall under five types i.e., C3S1(26%), C3S2(28%), C4S2(20%), and C4S3(20%), with moderately high salinity whereas four samples were found C4S4(8%) type with moderately high salinity with high sodium. It is found that for salinity control adequate arrangement of drainage and selection of crops with good tolerance is to be adopted. The value of SAR in the study area, 26 samples were of excellent type and 21 samples were good for domestic and agriculture purposes.

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