International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 62.86 | Impact Factor (2015): 3.791

Assessment of Groundwater Quality for Irrigation Use Chemical Analysis of Konaseema in the Godavari River Basin, East Godavari District, Andhra Pradesh, India

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Abstract: ***The present paper deals on ground water quality and Hydrochemical anamoly, The Markanda river basin occupying an area of about 1726.3 km^2 is a part of the alluvial deposits of the Godavari deltaic plain which is dominated by wave in Godavari river basin in the east coast India. The region is associated with active agricultural activities and makes significant contribution to the country's agricultural products. Assessment of groundwater quality for irrigation use and hydrochemical evolution of groundwater has been studied. Hydrochemical analysis has been carried out based on concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, CO_3^{2-} and HCO_3^{-}. Sodium adsorption ratio (SAR), percent sodium (%Na), permeability index (PI) have been studied to evaluate suitability of irrigation use in study area apart from that we generate the spatial maps of pre monsoon and post moon seasons ground water maps with the help of new technologies like Geographical information system (Arc Gis 10.4.1) and Remote sensing.***

Keywords: Groundwater quality for Agriculture use, Hydrochemical parameters, Hydrochemical facies, Land use pattern, Arc GIS 10.4.1

1. Introduction

Groundwater forms one of the primary resources for development activities. In recent times, there has been tremendous demand for fresh water due to population growth and intensive agricultural activities. Assessment of groundwater quality requires determination of ion concentrations which decide the suitability for drinking, domestic, agricultural and industrial uses. The Konaseemaregion in which is a part of the Godavari deltaregion inlies southern part of the peninsular India, is a fertile tract where intensive cultivation is done (Lunkad and Sharma, 2008). Since the groundwater being the prime source of water for irrigation in the region, the understanding of Hydrochemical reactions in shallow aquifer waters is necessary. Groundwater has to be classified on the basis of concentrations of cations and anions. Analysis on Hydrochemical facies and its evolution is also required in order tounderstand the type and genesis of water and suggest remedial measures. Thus, the present work is an attempt of the same. The Konaseema region lies between the two lobes of the Godavari Riverand 16° 18' 15'' and 16° 56' 14" North latitudes and 81°43' 01'' and 82°23' 50''East longitudes (Fig. 1). After passing through a narrow and deep gorge through thekhondalites and charnockites of the Eastern Ghats, the Godavari River enters the east coast plains near Rajahmundry city. The River builds alarge fan-delta spread over 5820 km^2 with its apex near Rajahmundry (kakani Nageswararao et all 2015). The landward boundary is marked by the Pleistocene terracealong the foothills of the Eastern Ghats. The Konaseema plain exhibits a gentlegradient and three sampels are at 17 m elevation, four sampels at 14 m, one sample at 13 m, one sample at 11 m, 1 sample at 10 m, 6 samples at 7 m, two samples at 6 m and finally one sample at 4 m above the sealevel, which is controlled by the basement, towards thecoast over a length of about 75 km (Fig.1). The Godavari River branches intotwo distributaries: the Gautami and the Vasishta at about 7 km downstreamof Rajahmundry near Dowlaiswaram. The Vasishta bifurcatesinto two to form the third distributary: the Vainateyam, while theterminal branching of the Gautami leads to the formation of the fourthdistributary: the Nilarevu. The delta front shoreline, bordering the Bayof Bengal is 170-km-long from northeast of Kakinada to the west of Upputeru mouth in the southwest intersected by the four distributary mouths. The delta receives an annual rainfall of 1000 to 1100 mm. Theannual average maximum temperature is about 33 °C and the minimumis around 24 °C. The summers are very hot with the maximum temperature touching more than 45 °C in May whereas the winters are mild with minimum temperatures of 17 °C to 18 °C in December. The mean discharge through the river at Dowlaiswaram during the four-month peak monsoon was 2584 m^3/s with a maximum discharge of 5607 m^3/s in 1990 and a minimum of 1124 m3/s in 1974. The water discharges through the two major distributaries of Gautami and Vasishta are distinctly different. Out of the mean annual discharge of 3060 m^3/s during a 16 year period of 1988–2003, about 2048 m^3/s (67%) was through the Gautami and remaining 1012m^3/s (33%) flowed through the Vasishta (Nageswara Rao et al., 2005).

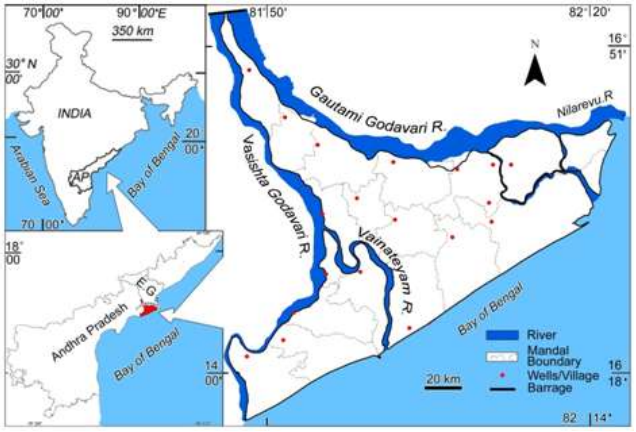

Figure 1: Location map of study area

2. Methods

For assessment of groundwater quality, analysis of hydrochemical facies and its evolution, water samples werecollected from shallow hand-pumps and wells extracting water from the first aquifer through field work twice in the year of 2015. 19 groundwater samples distributed all over the Konaseema collected in the pre-monsoon season and post-monsoon season, where as exact lat long values of sample locations and mean sea level (2015) as shown in the above location map (Fig.1) and to identify the exact location based on the toposheets which we used they are 65L1, 65K3, 65K4, 65L2, 65K/4, 65K/8, 65H3, 65H13, 65H14 and 65H15respectively.Major ion concentrations were determined by using standard methods (APHA, 1989). For determnation of suitability region for irrigation use SAR, %Na and PI were calculated and plotted on C-S diagram (Richards, 1954; Hem, 1985), Wilcox diagram (1955) and Doneen diagram (1961; 1964) respectively. Major ions like calcium (Ca_2^+), magnesium (Mg_2^+), sodium (Na^+), potassium (K^+), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl) and sulphate (SO_4^{2-}) were determined for identification of hydrochemical Facies.

Table 1. Chemical analysis results of pre-monsoon season groundwater samples in the Konaseema region in the Godavari basin, in East Godavari district

Sample Location	pH	SEC (µS/cm)	TDS (mg/l)	SAR	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	CL^-	So_4^{2-}
Mandapalli	8.2	1070	684.8	0.49	25.56	0.86	80	72.9	0	40.8	147	207
Kattunga	8.49	2253	1441.92	6.66	307.2	26.8	56	63.2	20.4	30.6	637	50
Ethakota	8.98	760	486.4	1.36	39.81	110.53	16	29.1	61.2	102	49	29
Kundalapalli	9.3	3870	2476.8	8.44	359	599.4	8	77.7	142.8	204	588	305
Mungada	9.16	1494	956.16	7.13	180	177.2	16	19.4	81.6	193.8	127.4	38
Ainavalli	8.56	1589	1016.96	4.23	195	3.6	24	82.6	20.4	51	256.5	122
Machavaram	7.29	1081	691.84	3.06	113.6	26.8	88	9.7	0	40	275.5	3
Anathavaram	9.07	1063	680.32	3.45	118	91.4	32	34.0	81.6	173.4	47.5	30
Mumadivaram	9.09	1428	913.92	6.69	228.8	13	16	43.7	81.6	153	161.5	25
Razolu	8.85	1378	881.92	6.81	198.6	79.5	16	29.1	20.4	122.4	225.4	67
Mamidikuduru	8.63	680	435.2	2.49	77.06	2.14	24	29.1	20.4	51	137.2	24
Amalapuram	8.94	1473	942.72	6.58	235	4.2	24	43.7	61.2	102	199.5	83
Cheyyeru	8.56	1586	1015.04	2.87	145	15.8	120	43.7	40.8	51	342	30
I.Polavaram(Delta)	8.72	3750	2400	11.92	626.7	27.2	16	116.6	81.6	71.4	893	275
Malikipuram	8.86	2171	1389.44	6.25	257.7	123.1	32	58.3	61.2	142.8	294	44
Kottalanka	8.06	1360	870.4	4.05	156	56.3	24	53.4	0	173.4	190	22
Uppalaguptam	7.83	1428	913.92	2.45	118.8	44.2	32	87.5	0	265.2	142.5	21
Sakinetipalli	8.19	1883	1205.12	5.74	251.1	15.1	32	68.0	0	214.2	362.6	35
Bendmurlanka	8.98	1742	1114.88	8.41	245	150.4	24	24.3	81.6	153	190	69

Table 2. Chemical analysis results of post-monsoon season groundwater samples in the Konaseema region in the Godavari basin, in East Godavari district.

Sample Location	pH	SEC (µS/cm)	TDS (mg/l)	SAR	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	CL^-	So_4^{2-}
Mandapalli	8.13	997	435	0.48	14	10	13	26	25	19	30	53
Kattunga	8.15	2131	1221	6.73	370	17	98	80	0	101	728	67
Ethakota	8.73	715	375	0.95	32	98	35	30	51	118	37	15
Kundalapalli	9.12	2954	1987	8.3	365	500	17	87	54	270	497	227
Mungada	9.01	1324	851	5.67	210	207	42	37	0	319	153	64
Ainavalli	8.25	1436	914	2.92	120	50	25	61	23	64	150	102
Machavaram	6.58	933	571	5.4	200	150	26	42	43	171	176	104
Anathavaram	8.91	987	505	2.4	71	47	44	25	0	162	45	15
Mumadivaram	8.9	1334	809	3.32	103	30	60	20	21	142	56	17
Razolu	8.5	1290	708	7.5	220	85	17	32	98	123	152	110
Mamidikuduru	8.05	675	323	2.8	130	7	180	37	0	224	224	95
Amalapuram	8.24	1407	831	5.32	185	120	25	50	24	167	210	106
Cheyyeru	8.09	1432	923	1.88	52	40	94	27	22	77	186	17
I.Polavaram(Delta)	8.08	3165	2133	8.4	560	192	140	130	0	271	1097	315
Malikipuram	7.93	1987	1206	6.02	241	138	50	70	55	213	306	123
Kottalanka	7.08	1288	721	3.78	142	7	60	48	0	165	198	24
Uppalaguptam	8.21	1390	814	3.6	160	35	90	37	0	221	121	25
Sakinetipalli	8.11	1731	1101	6.7	301	20	70	60	0	264	423	110
Bendmurlanka	8.75	1643	1026	6.9	220	245	60	20	57	231	221	115

Table.3. Pre monsoon Statistical parameters of chemical indices derived from chemical analysis of groundwater samples in the Konaseema region East Godavari district Andhra Pradesh, east coast of India.

Parameters	pH	SEC (µS/cm)	TDS (mg/l)	SAR	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	CO_3^{2+} (mg/l)	HCO_3^- (mg/l)	CL^- (mg/l)	So_4^{2-} (mg/l)	Na (%)	PI (%)
Min	7.29	680.00	435.20	.50	25.56	.86	8.00	9.72	.00	30.60	47.50	3.00	.62	1.11
Max	9.30	3870.00	2476.80	11.92	626.70	599.40	120.00	116.69	142.80	265.20	893.00	305.00	57.75	11.88
Avg	8.61	1.68	1.07	5.21	2.04	82.50	35.78	51.94	45.0	1.228	2.77	77.84	18.97	2.73
Median	8.72	1.473	9.42	5.74	1.95	27.2	24.0	43.758	40.8	1.22	1.9950 E2	38.00 00	11.73 00	2.83
Mode	8.56	1428.0	913.9	.50	25.56	26.80	16.0	29.17	.00	51.0	190.0	30.0	.62	0.82
Std.Dev	.51	8.520	5.45	2.85	1.345	1.36	2.94	2.75	4.056	7.018	2.156	8.796	1.885	1.239
Range	2.01	3190.00	2041.60	11.42	601.14	598.54	112.00	106.96	142.80	234.60	845.50	302.00	57.13	5.52
Skewnes	-1.0	1.69	1.69	.408	1.68	3.33	1.85	.609	.623	.301	1.691	1.825	.965	0.965
Kurtosis	1.0	2.787	2.787	.101	4.664	12.60	2.901	.031	-.064	-.964	2.797	2.322	-.227	0.227
Percentiles 25	8.20	1.08	6.91	2.87	1.18	13.00	16.0	29.17	.0000	51.0	1.42	25.0	4.25	1.77
Percentiles 50	8.7	1.473	9.42	5.74	1.95	27.20	24.0	43.75	40.8	1.224	1.99	38.0	11.7	2.83
Percentiles 75	8.98	1.883	1.205	6.81	2.511	1.105	32.0	72.9	81.60	1.734	3.42	83.0	33.61	3.58

Table 4. Post monsoon Statistical parameters of chemical indices derived from chemical analysis of groundwater samples in the Konaseema region east coast of India India.

Parameters	pH	SEC (µS/cm)	TDS (mg/l)	SAR	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	CO_3^{2+} (mg/l)	HCO_3^- (mg/l)	CL^- (mg/l)	So_4^{2-} (mg/l)	Na (%)	PI (%)
Min	6.58	675.00	323.00	.48	14.00	7.00	13.00	20.00	.00	19.00	30.00	15.00	8.67	38.10
Max	9.12	3165.00	2133.00	8.40	560.00	500.00	180.00	130.00	98.00	319.00	1097.00	315.00	39.85	89.27
Mean/Avg	8.2537	1.51	9.18	4.68	1.94	1.05	60.31	48.36	24.89	1.74	2.63	89.6	19.6	68.16
Median	8.2100	1.39	8.31	5.32	1.85	50.0	50.0	37.0	22.0	1.67	1.86	95.0	17.7	68.5
Mode	6.58	675.00	323.00	.48	220.00	7.00	60.00	37.00	.00	19.00	30.0	15.00	8.67	38.10
Std.Dev	.62962	6.62	4.78	2.43	1.34	1.205	4.42	2.79	2.80	7.99	2.65	7.65	7.86	1.56
Range	2.54	2490.00	1810.00	7.92	546.00	493.00	167.00	110.00	98.00	300.00	1067.00	300.00	31.18	51.17
Skewnes	-1.115	1.313	1.38	-.111	1.123	2.148	1.374	1.570	1.062	-.114	2.128	1.641	1.411	-.639
Kurtosis	1.921	1.675	2.044	1.126	1.729	5.726	1.835	2.803	.815	-.602	4.882	3.400	2.4	-.345
Percentiles 25	8.0800	9.97	5.71	2.80	1.03	20.0	25.0	27.0	.00	1.18	1.21	24.0	14.48	60.56
Percentiles 50	8.2100	1.39	8.31	5.32	1.85	50.0	50.0	37.0	22.0	1.67	1.86	95.0	17.78	68.5
Percentiles 75	8.7500	1.73	1.10	6.73	2.41	1.50	90.0	61.00	51.0	2.31	3.06	1.10	22.38	83.73

3. Results and Discussion

pH, SEC and TDS:

The analytical results and statistical parameters derived from hydrochemical parameters in the groundwater of the Konaseema region is presented in Tables 4 and 5 respectively. pH varies from 7.29 to 9.30 while in the postmonsoon water samples, it ranges from 6.58 to 9.12 indicating well permissible limits but one sample rings the danger bells to reach the 9.5 which is indicate high alkalinity in pre-monsoon season of 2015. solutions with a pH below 7.0 are termed acidic and solutions with a pH above 7.0 are termed basic it means most of the sample locations water is basic nature in premonseason whereas in the post-monsoon season except machavaram rest of the sample water location is basic in study area during 2015 (Table 1 and 2) .The specific electrical conductance (SEC) values range from 675µS/cm to 3165µS/cm in post-monsoon season whereas 435.20 to 2476.80 µS/cm in pre-monsoon season in Konaseema region during 2015 (Table 4 and 5). Total dissolved solids (TDS) vary from 323 mg/l to 2133 mg/l in post-mosoon season and 435.20 mg/l 2476.80 mg/l in pre-monsoon season (Table 3 and 4). The pH range is around 2.01 followed by SEC and TDS are 2490.0 and 1810.60 in post-monsoon season while in pre-monsoon season have 2.01, 319.0 and 2041.60. These results indicate groundwater is of fresh quality.

Na^+, K^+, Ca^{2+}, Mg^{2+} and $CO3^{2+}$ (Cations):

Table 1 shown the the analytical results and statistical parameters which derived from hydrochemical parameters in the groundwater of the Konaseema region such as Sodium, Photasium, Calcium, and magnesium those cations has recorded the maximum and minimum about the concentrations are vary from 626.70 mg/l to 25.56 mg/l, 599.40 to 0.86, 116.69 to 9.72, 142.80 to 0.0 respectively pre-monsoon season.Where as the above mentioned cations recorded in the post-monsoon seasonalso their ranges between 560.0 to 14.0, 500.0 to 7.0, 180.0 to 13.0, 130.0 to 20.0 and 98.0 to 0.00 respectively.(Table.4) Total hardness is a measure of the capacity of water to the concentration of calcium and magnesium in water and is usually expressed as the equivalent of $CaCO_3$concentration in the present study.

HCO_3 CL^- So_4^{2-}(Anions) :

Table 3 and 4 shown the the analytical results and statistical parameters which derived from hydrochemical parameters in the groundwater of the Konaseema region such as HCO_3CL^- So_4^{2-} (Anions)those cations has recorded

the maximum and minimum, the concentrations are vary from 265.20 mg/l to 30.60 mg/l, 893.0 to 47.50, and 302.00 to 3.0, respectively pre-monsoon season. Where as the above mentioned chemicals recorded in the post-monsoon season also their ranges between 319.0 to 19.0, 1097.0 to 30.0, and 315.0 to 15.0, respectively.(Table.6)

Groundwater Quality for Determination of Irrigation Use:

Sodium Adsorption Ratio (SAR):

To determine the suitability for irrigation use, the sodium or alkali-hazard expressed in terms of sodium adsorption ratio (SAR) was used.

SAR is calculated as:

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

Where, the concentrations are expressed in meq/l. SAR values of groundwater vary from 0.50 to 11.92 with an average value of 5.21 in pre-monsoon season and vary from 0.48 to 8.40 with an average value of 4.68 in post-monsoon season (Table 5&6). The plotting of SAR values in C-S diagram indicates that all the samples have low SAR value except one sample which has SAR value of 11.92. Out of 19 samples whereas in post-monsoon season the maximum value of SAR is 8.40, two samples lies in C_2-S_1type of water, 7 samples in C_3- S_1, 7 samples in C_3-$S_2$and one sample in C_3-S_2type, 2 samples in C_4S_3 in post-monsoon season only 2 are lies in C_2S_1, 9 are in C_3S_1, 5 are lies in C_3S_2, 2 are $C_4S_2$and one in C_4S_3, this classification is very useful for identify the ground water quqlity estimation for agriculture use. here, The C_2-S_1 C_3-S_1 type are considered as good water in both the seasons (Table.5)

Table 5: Classifications of groundwater samples based on sodium adsorption ratio in the Konaseema region east coast of India

Type of Water	Pre-monsoon Sample location villages	Post-monsoon Sample location villages
Good Water (C_2S_1)	Mamidikuduru, Mandapalli	Ethakota, Mandapalli
Good Water (C_3S_1)	Ethakota, Ainavalli, Machavaram Anathavaram, Cheyyeru Kottalanka, Uppalaguptam	Mungada, Ainavalli, Machavaram Anathavaram, Mumadivaram, Mamidikuduru, Cheyyeru, Kottalanka, Uppalaguptam
Bad Water (C_3S_2)	Mungada, Mumadivaram, Razolu, Amalapuram, Malikipuram, Sakinetipalli, Bendmurlanka	Razolu, Amalapuram, Malikipuram, Sakinetipalli, Bendmurlanka
Bad Water (C_4S_2)	Kattunga	Kattunga, Kundalapalli
Bad Water (C_4S_3)	Kundalapalli, I.Polavaram (Delta)	I.Polavaram (Delta)

Percent Sodium:

Another method for determination of suitability for agricultural use in groundwater is by calculating Na^{+} percentage (Wilcox, 1955), because Na^{+} concentration reacts with soil to reduce its permeability (Todd, 1980).

Percent sodium is calculated as:

$$\text{Percent sodium} = \frac{(Na^{+} + K^{+}) \times 100}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}$$

Where, the concentrations are expressed in meq/l. Percent sodium values of groundwater samples indicate that most of the groundwater samples show excellent to permissible category for irrigation use except none of the samples not under doubtful to unsuitable permission to doubtful categories of study area. Percent sodium plotted on Wilcox diagram indicates that out of 19 samples, 5 samples belong very good to good permissible category, 6 samples belong to good to permeable category and 9 samples belong to doutble to unsuitable none of the samples lies in permissible to doubtful and unsutable category in pre-mosoon season whereas the post-monsoon season also shows out of 19 samples belongs to very good to good category 2 samples belongs to good to permesible, 5 samples belongs to permissible to doutbtful, 1 sample lies in doubtful unsuitable category and none of the ssamples lies in unsuitable category during 2015(Table.5).

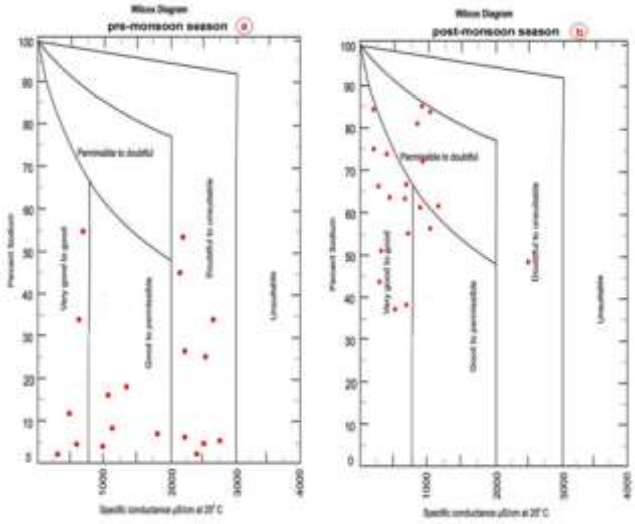

Figure 2(a-b): Wilcox diagram for classification of groundwater quality in the Konaseemaregion East Godavari district, east coast India.

Permeability Index (PI)

Permeability index (Doneen, 1964) has been used as an important parameter for determination of suitability for groundwater in irrigation use. It is defined as: Where, the concentrations are expressed in meq/l. PI values of groundwater samples range from 1.1% to 11.9% with an average value of 4.5 % pre-monsoon season and 8.67 % to 39.85 with an average of 19.69 % in post-monsoon season during the period of 2015 (Table 3 and 4). Analytical data of PI values plotted on Doneen diagram revealed that 58% of the groundwater samples fall in Class I and 42% fall under Class II and rest of the classes doesnt have in pre-monsoon season while in post-monsoon season 100% lies in class I category only(Fig.2.a b). The waters of Classes I and II in the Doneen diagram are generally good for irrigation purposes in pre-monsoon and post-monsoon season.

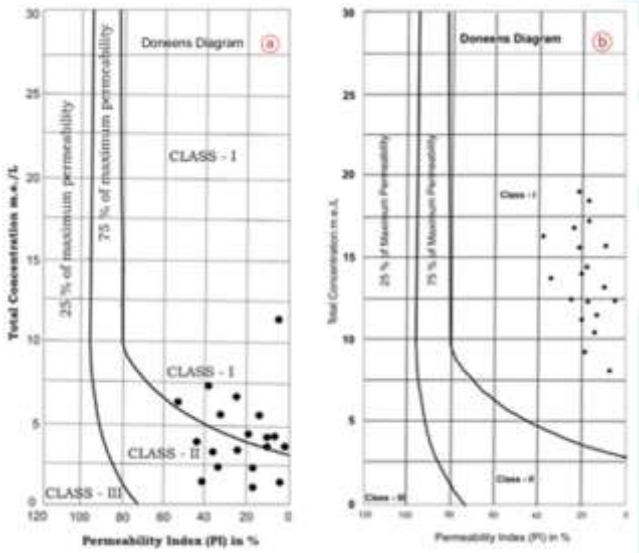

Figure 2: Wilcox diagram and Doneen's diagramfor classification of Post monsoon season groundwater quality in the Konaseema region, East Godavari district, east coast India

4. Conclusion

The study has demonstrated the utility of GIS technology combined with laboratory analysis in evaluation and mapping of groundwater quality in Konaseema region. An interpretation of hydrochemical analysis for groundwater quality and evolution of hydrochemical faciesin the Konaseema in The Godavari river basin reveals that concentrations of the major ions and important physical parameters are within the permissible limits for irrigation. SAR values range from 0.50 mg/l to 11.92 mg/l and the waters fall in C_2S_1 and C_3S_1fields on C-S diagram indicating good category for irrigation use. Percent sodium values indicate the groundwater belongs to very good to permissible category for irrigation. PI values show 58% of the samples fall under class I and 42% under class II and none of the samples fall in III and IV categories on Doneen diagram indicating the water of good category for irrigation use. The groundwater in the Konaseema region which is situated in The Godavari river basin on east coast of India.basin shows six different hydrochemical facies namely (1) HCO_3^-- Ca^{2+}- Mg^{2+}(2) Ca^{2+}- Mg^{2+}(3) HCO_3^-- $CO3^{2-}$(4) Na^+- K^+- Cl^-- $SO4^{2-}$(5) Cl^-- $SO4^{2-}$- $Na^+$and (6) Ca^{2+}- Na^+- Cl^-. Ingeneral, the basin is dominated by the facies belonging to$HCO3^-$- Ca^{2+}- Mg^{2+}.

Acknowledgements

The authors are grateful to Prof. B.Hemamalini(Emeritus), Department of Geography, Andhra University, Visakhapatnam.

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