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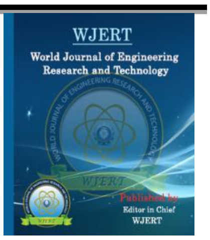

HYDROCHEMICAL ANALYSIS OF GROUNDWATER IN AND AROUND MANGALORE, DAKSHINA KANNADA DISTRICT, KARNATAKA STATE, INDIA

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ABSTRACT

Water quality assessment is essential to ensure viable, safe use of the resource for drinking or domestic, agricultural, and industrial purposes. Forty two groundwater samples were collected systematically during pre and post monsoon seasons in and around Mangalore, Dakshina Kannada district, Karnataka state in order to understand the geochemistry of the groundwater and to assess the overall physicochemical faces. The physical and chemical parameters of groundwater were compared with the standard guideline values recommended by the Bureau of Indian Standards (BIS) and World Health Organization (WHO) standards for irrigational suitability, domestic usage, the hydrogeochemical data have been plotted in standard graphs such as United State Salinity Laboratory (USSL) and Wilcox's diagrams, and the quality aspects of groundwater have been discussed.

KEYWORDS: Geochemistry, USSL, Wilcox's, Burea of Indian standards, USSL, Irregation suitability.

1. INTRODUCTION

Groundwater is the primary source of water supply for human activities such as domestic, industry and agricultural needs. The present study area lies between 12° 45’, 13° 0’ latitude and. 74° 47’ & 75° 0’ East longitude with a coastal belt of about 26 km extending from

Talapady in the southeast to Surathkal in the North West coast of Karnataka, India. It is dissected by two major rivers, are Netravati and Gurupur. The elevated portions of this region are flat- topped, owing to the lateritic cap. The climate of Mangalore is hot and humid due to its proximity with the Arabian Sea. The temperature ranges from 25˚to 35$^{\circ C}$ but the weather is pleasant during morning and night especially during December and January. During the monsoon, there is a heavy down pour between June and September, which ranges from 3500 mm to 4000 mm during the calendar year. This area is peculiar in that both the river water as well as ground water are prone to contamination owing to seawater intrusion and seepage of polluted river water in to the wells. The Mangalore coast is affected by this problem and hence an attempt has been made to analyze the situation. The chemical analysis of forty-two stations of both pre-monsoon and post-monsoon water samples were collected from open wells and analyzed. The degree of saltwater intrusion varies widely among localities and hydro geologic settings. Specific conductance and total dissolved solids were found to be exceeding the highest desirable limit of the World Health Organization (WHO) and Indian Standards (ISI)

1.1 STUDY AREA

The study area lies between 12° 45’ , 13° 0’ latitude and. 74° 47’ & 75° 0’ East longitude (Ref: Survey of India Toposheet No. 48, L/13). This stretch of land covers an area about 600 sq km, with a coastal belt of about 26 km extending from Talapady in the southeast to Surathkal in the North West. (Fig.1) as the study area belongs to a coastal zone, there are possibilities to determinate the groundwater quality due to saline intrusions.

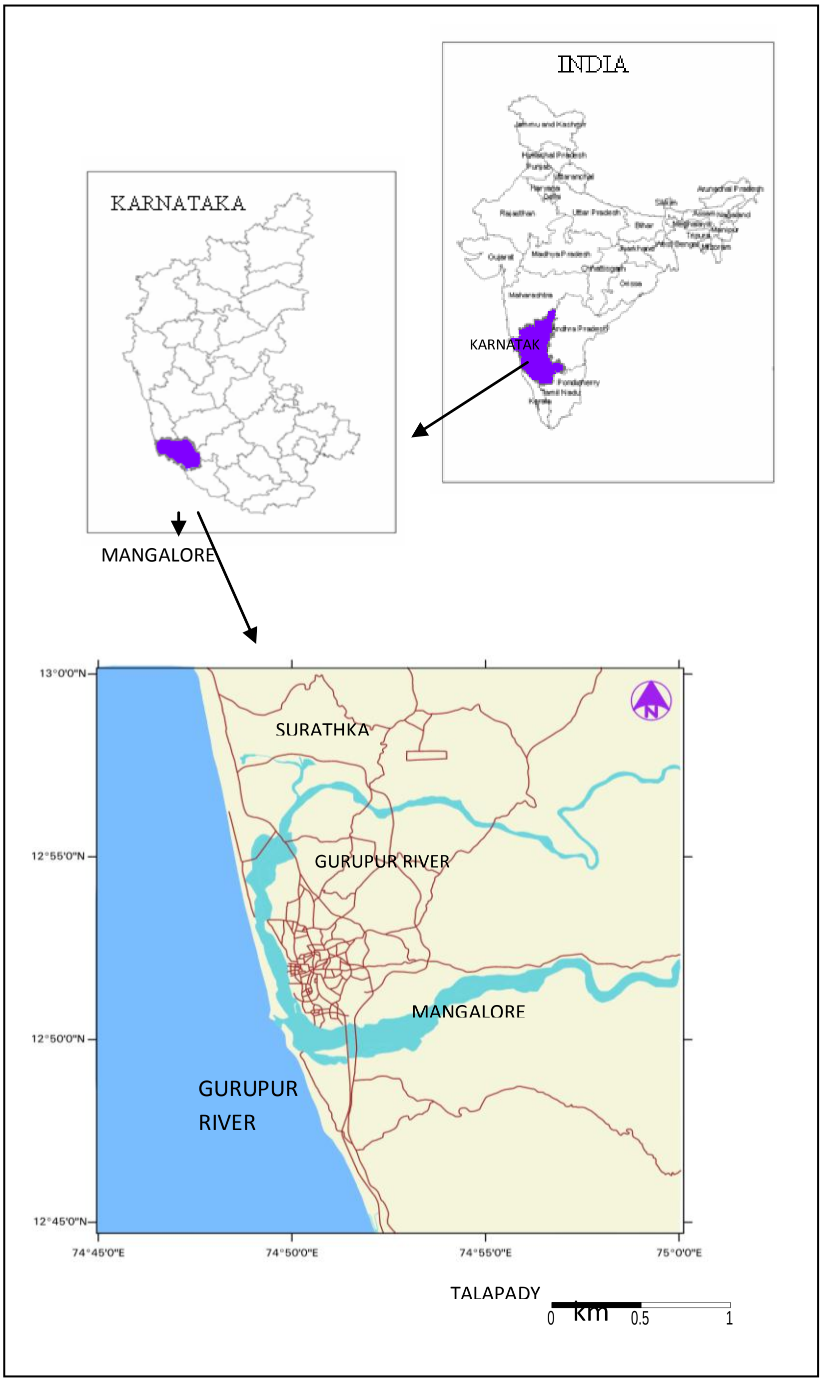

Fig. 1: Study Area Map.

1.2 GEOLOGY OF THE STUDY AREA

The area is characterized by extensively developed laterites on both Archean as well as Tertiary litho units. The area (Dakshina Kannada coastal tract) forms the western most part of the WesternGhat belt (also termed, west coast belt) of Karnataka craton. The WesternGhat belt could be divided into two divisions based on both physiography as well as on geology: (1) The WesternGhat proper and (2) the coastal tract.The WesternGhat proper is a mountain like terrain having a scrap of more than 1000 m facing the west. The folded rocks of Dharwar Super Group consisting of mica schists and contemporaneous traps with sub ordinate quarzites (i.e., Meta volcanics with inter bedded quartzites over the basal oligomict quartz – pebble conglomerate) and hematite – magnetite. Quartzites resting on the uneven surface of the Archean granitoid gneisses, having the beds tilted to north are exposed (forming many terraces) along the scarp and highlands of the ghat (Ramakrishnan and Harinanda Babu, 1981). The ironstones (hematite – magnetite- quartzites) of the bababudan group, Domes / batholiths of peninsular Gneiss form some of the foothills of the scarp. In contrast, the coastal tract of Dakshina Kannada, between the shoreline and the Ghat scarp is devoid of younger greenstone cover and it mainly reveals extensively developed Peninsular Gneiss. (Fig 2).

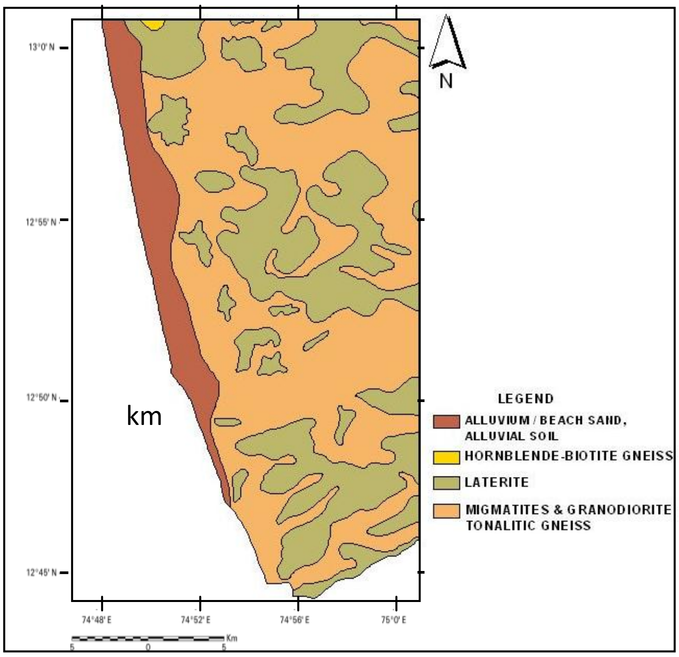

Fig. 2: Lithology of The Study area

2. MATERIALS AND METHODS

1. To prepare base map of the Location
2. Collection of water samples
3. HYCH computer programme has been used for interpretation of water quality.
4. Geographical Information System (GIS) is used to prepare spatial distribution of ground water quality analysis maps.

Sample collection, preservation and analysis were done as per standard methods (APHA, 1998). About two liters of water samples from 42 stations were collected in plastic cans with tight fitting plugs. These containers were acid washed and thoroughly rinsed with distilled water. The parameters like pH and temperature were analysed insitu and water samples were then carried to the laboratory and refrigerated to prevent the alteration of results. The obtained data were subjected to processing using HYCH computer programme (Balasubramanian, et.al., 1991). This programme is capable of providing mostly the needed output using the major ion chemistry data. It gives the interpretation of water quality based on water chemistry, facies, mechanisms of origin, type, suitability and usage factors like corrosivity and permeability. In this programme, hydrochemical facies classification is also attempted using the criteria of Handa (1964), Piper (1944), Stuyfzand (1989) and USSL (1954).

3. GROUND WATER SAMPLING AND CHEMICAL ANALYSIS

Groundwater samples that have been collected from forty-two locations (Fig.3) for both Premonsoon (may 2008) and Post monsoon (November 2008) following the standard sampling procedure given by Palmquist (1973) Murdoch and Azcue, (1995), were subjected to chemical analysis to determine the electrical conductivity, pH, total dissolved solids and major ions Ca, Mg, Na, K, HCO_3, CO_3, Cl, SO_4, and NO_3 using the standard analytical procedures given by ISI (1965) APHA (1998) (Chapman,1992; Fakayode, 2005; Dwivedi and Pathak, 2009). The results of chemical analysis of groundwater for Pre-monsoon and Post monsoon have been shown in Tables.1 and 2.

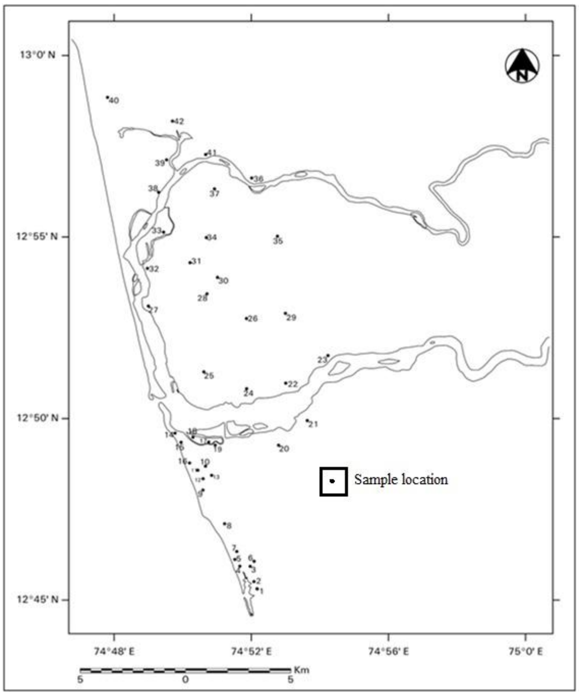

Fig. 3: Location Map of the water samples.

Table 1: Different Chemical Characteristics of groundwater post-monsoon (tds in ppm and Ec in micro mhos/c^{0}m).

Sl no	**Location**	**TDS**	**EC**	**Indices of base Exchange**		**Schallar's Water Type**	**RSC**	**SAR**	**Saturation Indices**		**Handa's class**	**Ground Water facies**	**Water type**	**Sub type (Based on ALK)**	**Sig. Enmt**	**Gibbs plot**
				IBE-1	**IBE-2**				**Ca**	**Phd-Phc**						
1	Near bridge tlpdy	360	595	-0.124	-0.038	II	-1.171	1.060	-2.902	0.228	$A_1C_2S_1$	Ca HCO_3	F	ALK-MODERATE	(-)	ROCK INTERACTION
2	Nalini res tlpdy	1035	1695	0.290	1.063	III	-5.324	5.109	-47.866	-0.819	$A_3C_3S_2$	NA+K Cl	B	ALK-MODERATLY LOW	(-)	ROCK INTERACTION
3	Sharada res someswara	1455	2405	0.005	0.019	IV	-3.922	11.179	-211.60	-1.177	$A_3C_4S_3$	NA+K Cl	B	ALK-MODERATLY LOW	(-)	ROCK INTERACTION
4	Rlwy trck someswra	5495	9735	0.225	2.059	IV	-26.93	17.708	-15.935	-0.528	$A_3C_5S_3$	NA+K Cl	B	ALK-MODERATE	(-)	EVOPARATION
5	Kelaginamane somesswara	665	1075	-0.141	-0.190	III	-.7322	5.195	-4.742	-0.259	$A_3C_3S_1$	NA+K Cl	f	ALK-MODERATE	(-)	ROCK INTERACTION
6	Ucchila	85	145	0.537	0.445	III	-.273	.386	-911.58	-1.920	$A_1C_1S_1$	Ca HCO_3	g	ALK-LOW	(-)	PRECIPITATION
7	Kotekar	165	290	-0.130	-0.024	III	-.250	.462	-19.183	-0.424	$A_1C_2S_1$	Ca HCO_3	g	ALK-MODERATLY LOW	(+)	ROCK INTERACTION
8	Aloysious hostle, someswra	60	95	-0.438	-0.266	III	2.766	1.263	-2964.9	-2.671	$B_3C_1S_1$	NA+K Mixed	g	ALK-VERY LOW	(-)	PRECIPITATION
9	Abbakka crl, ullal	285	440	-0.177	-0.208	III	-.364	2.903	-27.246	-1.010	$A_3C_2S_1$	NA+K Cl	F	ALK-MODERATLY LOW	(-)	ROCK INTERACTION
10	Yogashri, ullal	900	1345	-0.970	-0.404	II	-5.444	4.864	-20747.67	-3.816	$A_3C_3S_1$	NA+K SO_4	f	ALK-LOW	(+)	ROCK INTERACTION
11	Near koustuba, ullal	1405	2100	-2.221	-0.375	II	-11.41	4.350	-10665.60	-3.378	$A_2C_4S_2$	Ca SO_4	F	ALK-LOW	(+)	ROCK INTERACTION
12	Kelaginamane , ullal	145	225	0.166	0.175	IV	-.5326	1.177	-22430.23	-3.510	$A_2C_1S_1$	Mg Cl	F	ALK-LOW	(-)	ROCK INTERACTION
13	Near vydyanath tmpl, ullal	655	1009	-0.964	-0.295	II	-3.164	2.946	-8.328	-0.349	$A_2C_3S_1$	Ca SO_4	F	ALK-MODERATLY LOW	(+)	ROCK INTERACTION
14	Nr bus stop kotepura	355	515	-0.224	-0.145	III	-1.213	2.124	-160.77	-0.888	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATLY LOW	(-)	ROCK INTERACTION
15	Nr refractory, kotepura	275	405	-0.001	0.904	III	-1.053	.9802	-9.895	-0.587	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATLY LOW	(-)	ROCK INTERACTION
16	Nr veerabhadra temple, ullal	120	195	-0.407	-0.142	III	.1189	.8976	-53.699	-1.267	$B_1C_1S_1$	Ca HCO_3	g	ALK-LOW	(-)	ROCK INTERACTION
17	Near uliya bridge ullal	465	805	0.212	0.161	III	-1.628	1.443	-7.987	-0.942	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATE	(-)	ROCK INTERACTION
18	Prem prakash res	975	1725	0.283	1.223	IV	-4.579	5.039	-18.370	-0.747	$A_3C_3S_2$	NA+K Cl	B	ALK-MODERATLY LOW	(-)	ROCK INTERACTION
19	Bandikotya	220	325	-0.166	-0.086	II	-.9565	1.322	408.0	-1.971	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
20	Munnuru	245	330	0.691	0.464	III	-1.949	.338	-1347.13	-2.689	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
21	Ambalamogaru	225	331	0.8126	0.117	II	-2.253	1.211	-440.20	-1.604	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
22	Bajala	251	331	0.5095	0.422	III	-2.334	.7327	-539.89	-1.792	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
23	Kannuru	345	395	0.400	0.261	II	-2.134	.7598	-772.71	-1.748	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
24	Jeppinamogaru	246	329	-0.541	-0.050	II	-.878	.290	-1976.2	-2.155	$A_2C_1S_1$	Mg Mixed	g	ALK-LOW	(+)	ROCK INTERACTION
25	Attavara	315	445	0.306	0.089	II	-1.455	.390	-173.46	-1.201	$A_2C_1S_1$	Mg SO_4	g	ALK-LOW	(+)	ROCK INTERACTION
26	Maroli	385	440	0.383	0.260	II	-2.578	.9229	-20.570	-0.093	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
27	Kodialbail	225	326	0.675	0.399	III	-1.686	.313	-1418.8	-2.412	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
28	Kadri	295	385	-.5029	-0.228	II	-.6172	1.764	-18.238	-0.444	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATLY LOW	(-)	ROCK INTERACTION
29	Kulashekara	320	420	0.524	0.397	III	-2.667	.6997	-18.77	-0.356	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
30	Yeyyadi	445	430	0.669	0.460	III	-3.140	.4568	-48.29	-1.152	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
31	Derebail	345	395	0.647	0.462	III	-2.597	.4925	-43.86	-0.8117	$A_2C_2S_1$	Mg Mixed	F	ALK-MODERATLY LOW	(+)	ROCK INTERACTION
32	Boluru	219	324	-0.216	-0.110	II	-1.021	1.390	-438.39	-1.602	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
33	Bangrakudru	225	326	-0.059	-0.053	III	-.6262	1.748	-448.37	-1.712	$A_3C_2S_1$	NA+K Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
34	Kavuru	285	345	-0.365	-0.278	II	-.9644	3.0455	-51.33	-1.278	$A_3C_2S_1$	NA+K Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
35	Pachnady	320	395	0.306	0.249	III	-1.905	1.054	-761.66	-1.842	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
36	Malavur	740	1695	0.376	4.369	IV	-5.526	4.369	-184.36	-1.527	$A_3C_3S_1$	NA+K Cl	B	ALK-VERY LOW	(-)	ROCK INTERACTION
37	Kunjaithbail	325	425	-0159	-0.027	II	-6.522	.6868	-32.89	-0.490	$A_2C_3S_1$	Mg SO_4	F	ALK-LOW	(+)	ROCK INTERACTION
38	Panambur	345	335	-0.466	-0.238	II	-.7199	1.883	-59.66	-0.942	$A_3C_2S_1$	NA+K Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
39	Baikampady	220	325	-0.083	-0.042	II	-1.382	1.097	-455.29	-1.919	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
40	Hosabettu	245	330	-0.027	-0.020	III	-.955	1.438	-452.96	-1.716	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
41	Kenjaru	215	326	0.646	0.424	II	-2.147	.4016	-1411.3	-2.509	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
42	Tokuru	270	355	0.212	0.117	II	-1.709	.9075	-467.30	-1.530	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION

Table 2: Different Chemical Characteristics of groundwater pre-monsoon (tds in ppm and Ec in micro mhos/c^{0}m)

Sl no	**Location**	**TDS**	**EC**	**indices of base Exchange**		**Schallar's Water Type**	**RSC**	**SAR**	**Saturation Indices**		**Handa's class**	**Ground Water facies**	**Water type**	**Sub type (Based on ALK)**	**Sig. Enmt**	**Gibbs plot**
				IBE-1	**IBE-2**				**Ca**	**Phd-Phc**						
1	Near bridge tlpdy	365	600	-0.0924	-0.0303	II	1.451	1.090	2.847	0.284	$A_1C_2S_1$	Ca HCO_3	F	ALK-MDRT	(-)	ROCK INTRACTION
2	Nalini res tlpdy	1040	1700	0.28	1.014	III	6.067	5.000	47.533	0.766	$A_3C_3S_2$	NA+K Cl	B	ALK-MODARATELY LOW	(-)	ROCK INTERACTION
3	Sharada res someswara	1460	2410	-0.010	-0.030	IV	4.501	10.78	-171	-1.036	$A_3C_4S_3$	NA+K Cl	B	ALK-MODARATELY LOW	(-)	ROCK INTERACTION
4	Rlwy trck someswra	5500	9740	0.228	2.047	IV	27.25	17.56	15.14	0.458	$A_3C_5S_3$	NA+K Cl	b-brakish-salt	ALK-MODERATE	(-)	EVAPORATION
5	Kelaginamane somesswara	670	1080	-0.161	-0.210	III	1.311	4.977	-4.118	-0.159	$A_3C_3S_1$	NA+K Cl	F	ALK-MODERATE	(-)	ROCK INTRACTION
6	Ucchila	90	150	0.383	0.333	III	.259	.6209	-673	-1.708	$A_2C_1S_1$	Ca Mixed	g-oligohaline	ALK-LOW	(-)	PRECIPITATION
7	Kotekar	170	295	-0.072	-0.016	III	.530	.548	-18.17	-0.352	$A_1C_2S_1$	Mg HCO_3	g	ALK-MODERATELY-LOW	(+)	ROCK INTRACTION
8	Aloysious hostle, someswra	65	100	-0.310	-0.205	III	-2.404	1.371	-1569.1	-2.345	$A_3C_1S_1$	NA+K Mixed	g	ALK-LOW	(-)	PRECIPITATION
9	Abbakka crl, ullal	290	445	-0.238	-0.251	III	-.548	3.014	-21.544	-0.852	$A_3C_2S_1$	NA+K Cl	F	ALK-MODERATELY-LOW	(-)	ROCK INTRACTION
10	Yogashri, ullal	905	1350	-0.762	-0.349	II	-5.375	4.524	-1955.4	-3.741	$A_3C_3S_1$	NA+K $S0_4$	f-fresh-brackish	ALK-LOW	(+)	ROCK INTRACTION
11	Nr koustuba, ullal	1410	2110	-1.813	-0.366	II	-10.73	4.192	-10214.52	-3.319	$A_2C_3S_2$	Ca SO_4	F	ALK-LOW	(+)	ROCK INTERACTION
12	Kelaginamane , ullal	150	230	0.221	0.221	IV	-8149	1.081	-12443.36	-3.2247	$A_2C_1S_1$	Mg Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
13	Near vydyanath tmpl, ullal	660	1015	-1.011	-0.321	II	3.743	2.998	-7.178	-0.246	$A_2C_3S_1$	Ca SO_4	F	ALK-MODERATELY-LOW	(+)	ROCK INTERACTION
14	Near bus stop kotepura	360	520	-0.231	-0.147	III	1.592	2.103	-147.29	-0.801	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATELY-LOW	(-)	ROCK INTERACTION
15	Nr refractory, kotepura	280	410	-0.114	-0.049	III	1.152	1.190	-9.467	-0.559	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATELY-LOW	(-)	ROCK INTERACTION
16	Near veerabhadra temple, ullal	125	200	-0.814	-0.310	III	-4.857	1.361	-37.518	-1.085	$B_1C_1S_1$	Ca HCO_3	g	ALK-MODERATELY-LOW	(-)	ROCK INTERACTION
17	Near uliya bridge ullal	470	810	0.237	0.181	III	1.761	1.439	-7.474	-0.358	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATE	(-)	ROCK INTERACTION
18	Prem prakash res	980	1730	0.019	6.238	IV	-4.862	4.924	-15.03	-0.604	$A_3C_3S_2$	NA+K Cl	B	ALK-MODERATELY LOW	(-)	ROCK INTERACTION
19	Bandikotya	225	330	-0.145	-0.078	II	1.286	1.322	-367.18	-1.865	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(-)	ROCK INTERACTION
20	Munnuru	250	335	0.630	0.451	III	1.967	.4432	-989.47	-2.555	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
21	Ambalamogaru	230	336	0.175	0.113	II	2.386	1.272	-37.68	1.047	$A_2C_2S_1$	Mg Mixes	F	ALK-LOW	(+)	ROCK INTERACTION
22	Bajala	256	336	0.548	0.369	III	2.413	.579	-746.70	-2.433	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
23	Kannuru	350	400	0.494	0.335	III	-2.447	.6770	-683.44	-2.295	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
24	Jeppinamogaru	251	334	0.622	0.428	III	-1.951	.443	-969.66	-2.446	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
25	Attavara	320	450	-0.233	-0.080	II	-1.181	.9113	-67.44	-1.295	$A_2C_2S_1$	Ca SO_4	g	ALK-LOW	(+)	ROCK INTERACTION
26	Maroli	390	445	0.671	0.462	III	-3.423	.4684	-36.07	-0.928	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
27	Kodialbail	230	329	-0.218	-0.132	III	-.0794	1.629	-310.10	-2.052	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(.)	ROCK INTERACTION
28	Kadri	300	390	-0.106	-0.050	II	-1.091	1.281	-21.244	-0.907	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATLY LOW	(+)	ROCK INTERACTION
29	Kulashekara	325	425	0.725	0.548	III	-3.295	.394	-31. 35	0.548	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(.)	ROCK INTERACTION
30	Yeyyadi	450	435	0.712	0.490	III	-3.469	.4072	-513.81	-1.371	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
31	Derebail	350	400	0.066	0.047	III	-1.343	1.662	-13.82	-0.531	$A_2C_2S_1$	Ca Mixed	F	ALK-MODERATELY LOW	(.)	ROCK INTERACTION
32	Boluru	224	329	-0.362	-0.192	II	-.9594	1.751	-313.03	-2.056	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(.)	ROCK INTERACTION
33	Bangrakudru	230	331	0.093	0.102	III	-.544	1.589	-402.52	-2.165	$A_2C_2S_1$	CaCl	F	ALK-LOW	(.)	ROCK INTERACTION
34	Kavuru	290	350	0.049	0.037	II	-2.154	1.655	-58.51	-1.334	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
35	Pachnady	325	400	0.644	0.521	III	-2.676	.505	-952.32	-2.439	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
36	Malavur	750	1700	0.369	3.031	IV	-5.676	4.465	-163.77	-1.776	$A_3C_3S_1$	NA+K Cl	B	ALK-VERY LOW	(.)	ROCK INTERACTION
37	Kunjaithbail	330	430	-0.644	-0.11	II	-5.116	1.211	-19.145	-0.7641	$A_2C_3S_1$	Mg SO4	F	ALK-LOW	(+)	ROCK INTERACTION
38	Panambur	350	340	-0.642	-0.340	II	-.5084	2.466	-43.488	-1.208	$A_3C_2S_1$	NA+K Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
39	Baikampady	225	330	-0.145	-0.077	II	-1.286	1.322	-367.18	-1.865	A_2C_2S1	Ca Mixed	F	ALK-LOW	(.)	ROCK INTERACTION
40	Hosabettu	250	335	0.630	0.451	III	-1.967	.4432	-989.47	-2.555	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION
41	Kenjaru	220	331	-0.067	-0.043	II	-1.287	1.530	-3403.74	-2.191	$A_2C_2S_1$	Ca Mixed	F	ALK-LOW	(.)	ROCK INTERACTION
42	Tokuru	275	360	0.229	0.130	II	-1.908	.9374	-396.81	-2.059	$A_2C_2S_1$	Mg Mixed	F	ALK-LOW	(+)	ROCK INTERACTION

4. Hydrogen ion concentration (pH)

The pH or hydrogen ion concentration is expressed on a logarithmic scale and represents the negative base -10 logarithm of the hydrogen ion concentration. Waters are considered acidic when the pH is less than 7.0 and basic when the pH exceeds 7.0. Water with pH of most ground water generally ranges between 5.0 and 8.0 (Davis and Dewiest, 1966). The types of dissolved constituents in ground water can influence pH levels. Dissolved carbon dioxide ($C0_2$), which forms carbonic acid in water, has an important control on the pH of natural waters (Hem, 1985). The pH of ground water can also be lowered by organic acids from decaying vegetation, or by dissolution of sulfide minerals (Davis and De Weist, Op.Cit). The United States environmental protection agency (USEPA, 1973) recommends a pH range between 6.5 and 8.5 in waters used for public supply.

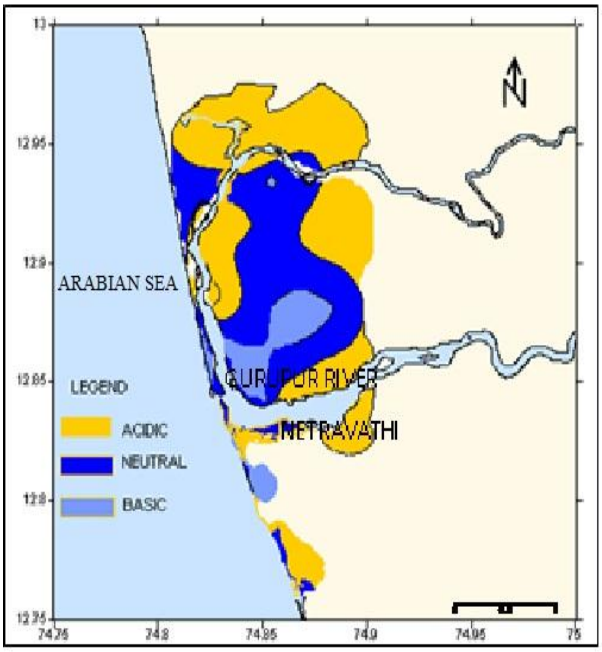

Fig. 4: pH Map of the study area.

It is observed from the pH value (Fig. 4) spatial distribution shows that about 81% of the area covers an acceptable range according to WHO scale and only 19% of the area is under acidic in nature and it is not suitable for drinking purpose.

5. TOTAL DISSOLVED SOLIDS

As ground water moves slowly through an aquifer the composition of water continues to change, usually by the addition of dissolved constituents (Freeze and Cherry, Op.Cit). A longer residence time will usually increase concentrations of dissolved solids. Because of short residence time, ground water in recharge areas often contains lower concentrations of dissolved constituents than water occurring deeper in the same aquifer or in shallow discharge areas. The simplest classification of water is based on the total concentration of dissolved solids (Freeze and Cherry, Op.Cit).The value for total dissolved solids in the study range from 65-5500 mg/l. Thirty-three samples are under the acceptable value (78%) according to WHO standard table and remaining samples are under the rejection values (22%). Lowest value is 65 mg/l and highest is 5500 mg/l. In order to get the spatial variation of Total Dissolved Solids maps were generated from the chemical analysis for the Post monsoon and Pre-monsoon data (Fig 5 & 6).

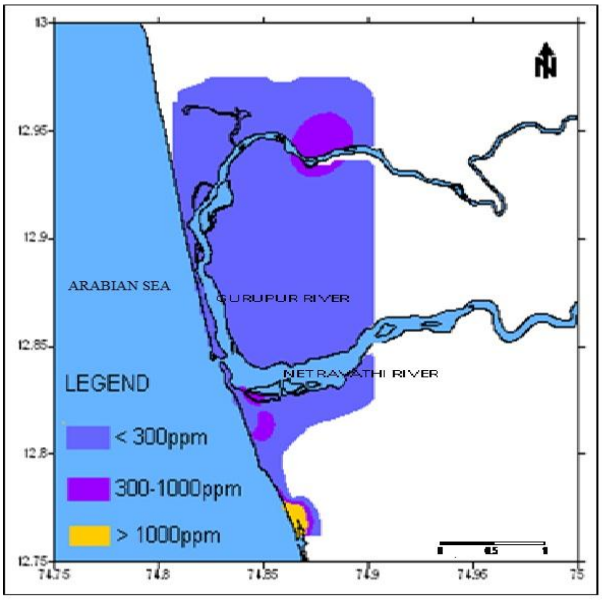

Fig. 5: Total Dissolved Solids of Post Monsoon.

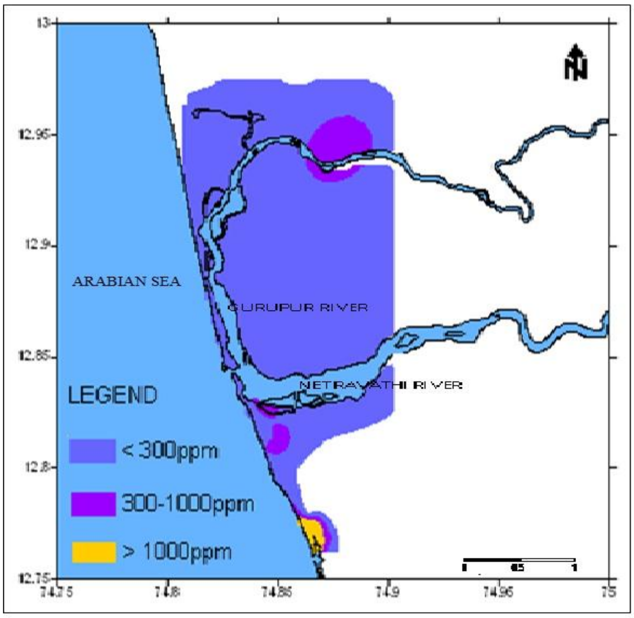

Fig. 6: Total Dissolved Solids of Pre Monsoon.

6. Calcium

Calcium is the most abundant of the alkaline- earth metal and is a major constituent of many common rock forming minerals. Calcium is an essential constituent of many igneous rocks minerals, especially of the chain silicates pyroxene and amphibole. Calcium also occurs in other silicate minerals that are produced in metamorphism. Some calcium is, also expected in water that has been in contact with igneous and metamorphic rocks. The most common forms of calcium in sedimentary rocks are carbonates. Concentrations of calcium in normal potable groundwater generally range between 10 and 100 ppm. Most of the water samples in the area are lies within the permissible limits; only two of them are out of the range.

7. Magnesium

Magnesium is an alkali-earth metal and in some aspects of water chemistry, calcium and magnesium may be considered as having similar effects, as in their contributions to the property of hardness. In igneous rocks, magnesium is typically a major constituent of the dark-colored ferromagnesian minerals. Specifically, these include olivine, the pyroxenes, the amphiboles and the dark-colored micas, along with various less common species. Sedimentary forms of magnesium include carbonates such as magnesite and hydromagnesite, the hydroxide brucite and mixtures of magnesium with calcium carbonate. Except 5 water samples, almost all water samples are within the limit of permissible concentrations of magnesium ranges from 1 to 40 ppm, in the study area.

8. Sodium

In igneous rocks, sodium is slightly more abundant than potassium, but in sediments, sodium is much less abundant. Much of the sodium in the earth’s crust comes from the weathering of plagioclase feldspars, which yields the cation to solution and from a clay mineral (Hem, 1985). Areas of igneous and metamorphic rocks that are also in regions of moderate to high rainfall generally have water with 1 to 20 ppm of sodium.

9. Potassium

Potassium is slightly less common than sodium in igneous rock but more abundant in all the sedimentary rocks. In most natural water, the concentration of potassium is much lower than the concentration of sodium. The principal potassium minerals of silicate rocks are the feldspars orthoclase and microcline, the micas and the feldspathoid leucite. Water with a total dissolved solids concentration of 2000 ppm will have less than 20 ppm potassium.

10. Bicarbonate and Carbonate

The amount of a standard concentration of sulfuric acid, which is needed to titrate a water sample to an end point of pH 4.5, is a measure of the alkalinity of the water. Alkalinity is produced exclusively by bicarbonate and carbonate ions and alkalinity is a reliable measure of carbonate and bicarbonate ions for most natural waters. The dissociation of bicarbonate is effective largely above a pH of 8.2. Below this pH, most of the carbonate ions add hydrogen to become bicarbonate ions and the ratio of bicarbonate ions to the ratio of bicarbonate and carbonate ions increases to more than 100 to1 (Davis and DeWiest, Op.Cit).

11. Chloride

Chloride is a minor constituent of the earth's crust, but a major constituent of most natural water. The circulation of chloride ions in the hydrologic cycle is largely through physical processes. Chloride concentrations found in natural water vary between about 0.1 ppm in arctic snow to 150,000 ppm in brines. Shallow ground water in areas of heavy precipitation generally contains less than 30 ppm of chloride (Davis and DeWiest, Op.Cit). In the study area water, 32 water samples are exceeding the limit, and only 10 samples are within the limit of 30 ppm.

12. Nitrate

Although igneous rocks contain small amounts of soluble nitrate or ammonia, most nitrates in natural waters comes from organic sources or from industrial and agricultural chemicals. Normal groundwater contains 0.1 to 10 ppm of nitrate. (Davis and DeWiest, Op.cit).

13. Fluoride

Concentrations of fluoride in most natural waters generally range between 0.1 mg/l and 10 mg/l (Davis and DeWiest, Op.Cit). Hem (Op.Cit) noted that fluoride levels generally do not exceed 1 mg/l in most natural with TDS levels below 1000 mg/l.

14. Classification of Groundwater

Durov (1948) suggested a division of groundwater on the basis of its Ca/Mg ratio, bicarbonate concentration, salinity etc. Handa (1964a) suggested a modification of Durov's method. The U.S. Salinity Laboratory (1954) proposed a diagram of irrigation waters in arid and semi- arid regions. Handa (1964a, 1965a) modified this diagram by combining it with the Hill- piper diagram for presenting water analysis data. The characteristic of various classes proposed by Handa (1964a, 1965a, 1965b).

15. Groundwater Hardness in the study area

The chemical characteristics of water determined on Handa's classification have been drawn thematically. Both permanent hardness (A_1, A_2, A_3) and temporary hardness (B_1, B_2, B_3) are reported from the area for Post-monsoon as well as Pre-monsoon. The area is dominated by A_2 type.

Table 3: Characteristics of Various Classes in Handa's Classification.

Class	**Characteristics in ml/l**	**Remarks**
	Ca & Mg Ca & Mg Cl & SO_4 res.$NaHCO_3$	Hardness
A_1	>HCO_3 >Na & K <HCO_3 nil	Permanent
A_2	>HCO_3 -do- >HCO_3 nil	Permanent
A_3	>HCO_3 <Na & K -do- nil	Permanent
B_1	<HCO_3 >Na & K <HCO_3 Present	Tempoorary
B_2	<HCO_3 >Na & K < HCO_3 Present	Tempoorary
B_3	<HCO_3 -do- >HCO_3 Present	Tempoorary

	TSC or TSA (epm)
C_1 low salinity waters	<2.5
C_2 low to medium salinity waters	2.5- 7.5
C_3 Medium to high salinity waters	7.5-22.5
C_4 high to very high salinity waters	22.5- 37.5
C_5 extremely high salinity waters	>37.5

	Sodium hazard (%)
S_1 low sodium water	0-30.0
S_2 low to medium sodium water	30.0- 57.5
S_3 medium to high sodium water	57.5- 100

16. Salinity and Sodium hazard in the study area

Six types of salinity and sodium hazard classes have been reported in the pre-monsoon and seven types in the post monsoon It is interesting to note that the eastern part of the study area is dominated by the C_2S_1 type, which changes to C_3S_1 and C_1S_1 towards the western part of the area.

17. Classification of Irrigation Water

Irrigation water quality refers to the kind and amount of salts present in the water and their effects on crop grown and development. Different classification schemes have been put forth to classify irrigation waters (Wilcox, 1955: Doneen, 1966: Handa, Op.Cit: Richards, 1954).

The diagram proposed by the U.S Salinity Laboratory for classification of irrigation water uses the Sodium Adsorption Ratio (SAR) and conductivity (EC x $10^{6)}$ values for classifying water. The salinity hazard is assessed based on conductivity and the sodium hazard is assessed based on the Sodium Adsorption Ratio, which is given by the relation:

$SAR= Na/\sqrt{}Ca+Mg/2$

18. Salinity Hazard

Low- salinity water (C_l) can be used for irrigation on most crops in most soils with little likelihood that soil salinity will develop: medium- salinity water (C_2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases, without special practices for salinity control. High- salinity water (C_3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerances should be selected. Very high-salinity water (C_4) is not suitable for irrigation under ordinary conditions, but it may be used occasionally under very special circumstances i.e. the soils must be permeable, drainage adequate, irrigation water applied in excess to provide considerable leaching and only salt tolerant crop selected.

19. Sodium Hazard

Low- sodium water (S_1) can be used for irrigation on almost all soils. Medium- sodium water (S_2) may cause an alkalinity problem in fine- textured soils under low leaching conditions. It can be used on coarse textured soils with good permeability. High sodium water (S_3) may produce harmful levels of exchangeable sodium and may require special soil management (good drainage, heavy leaching, and organic matter additions). Very high sodium water (S_4) is usually unsatisfactory for irrigation purposes.

20. Residual Sodium Carbonate

The quantity of bicarbonate and carbonate in excess of alkaline earths influence the suitability of water for irrigation purposes. This excess is denoted as residual sodium carbonate (RSC) and is determined using the formula (Richards, Op.Cit);

$$RSC = (HCO^{-}_{3} + CO_3^{2-}) – (Ca^{2+} + Mg^{2+})$$

Where the concentrations are expressed in epm.

If the RSC exceeds 2.5 epm, the water is generally unsuitable for irrigation. If the value is between 1.25 and 2.5 epm, the water is marginal in its quality, while a value less than 1.25 epm indicates that the water is probably safe.

21. Stuyfzand's Classification

Stuyfzand's (1986, 1980a) proposed a hydrochemical classification system for the determination of a water type helps in successive identification of the main type, sub types and the class of a water sample.

Chlorinity determines the main type as indicated in the Table 4. Each main type is divided into eleven types according to salinity. For most natural waters with 4.5 < pH< 9.5 alkalinity equals $HCO_3 + CO_3$ in meq/l. the most important cation and anion determine the subtype in a specific way (Stuyfzand's, Op.Cit). The spatial distribution of water type in the study area, based on Stuyfzand's classification.

Table 4: Division in main types on the basis of chloride concentration (Stuyfzand's, 1989).

Main type	**Code1**	**Cl (meq/l)**	**Main type**	**Code**	**Cl (meq/l)**
Extremely fresh	G	< 0.141	Brackish	B	8.462 -28.206
Very fresh	g	0.141- 0.846	Brackish salt	b	28.206 – 282.064
Fresh	F	0.846 – 4.231	Salt	S	282.064 – 564.127
Fresh – brackish	f	4.231 – 8.462	Hyperhaline	H	> 564.127

Type	**Alkalinity**	**Code**	**Type**	**Alkalinity**	**Code**
Very low	<1/2	*	very high	16 -32	5
Low	½ - 1	0	rather extreme	32- 64	6
Moderately low	1-2	1	extreme	64-128	7
Moderate	2-4	2	very extreme	128-256	8
Moderately high	4-8	3	Extraordinary extreme	> 256	9

22. Sodium Adsorption Ratio (SAR)

The study area based on SAR values 88% the groundwater of the area belonging to excellent irrigational water quality and rest of the 12% under unsuitable.

SAR	**NO. of Samples**	**%**
>5	37	88.00
<5	5	12.00
Total	**42**	**100.00**

23. Corrosivity Ratio

Corrosion is basically an electrolytic process, which severely attacks a metal surface. The rate at which corrosion proceeds depend upon a variety of chemical equilibrium reactions as well as upon certain physical factors like the temperature, pressure and velocity of flow (Ayers and Westcot, 1985). It has also been reported that the absence of Carbonate mineral increases the concentration of chlorides and sulphates of minerals and in turn increases the corrosion rate (Raman, 1983). Most corrosion problems are associated with low salinity waters (Rengarajan and Balasubramanian, 1990), used the corrosivity ratio to evaluate the corrosive tendencies of river basins. The ratio is of the form

$$C.R = \frac{\dfrac{Cl\ (mg/l)}{35.5} \ X\ \dfrac{SO_4\ (mg/l)}{96}}{\dfrac{2HCO3 + CO3\ (mg/l)}{100}}$$

Water having corrosivity ratio less than 1 is considered non-corrosive while above 1 is corrosive.

24. CONCLUSION

In view of increasing demand of water for various purposes like agricultural, domestic, industrial etc., a greater emphasis is being laid for a planned and optimal utilization of water resources. Due to uneven distribution of rainfall, both in time and space, the surface water resources are unevenly distributed. Also, increasing intensities of irrigation from surface water may result in alarming rise of water table creating problems of waterlogging and salinization, affecting crop growth adversely and rendering large areas unproductive.Hence people adopt minor irrigation methods using groundwater resources. Quality of groundwaters is yet another dimension to be considered

The chief mechanisms controlling the chemistry of ground waters of this area are rock interaction and precipitation. Effective managemaent of groundwater requires the ability to predict subsurface flow and transport of solutes, and the response of fluid and solute flux to changes in natural or human-induced stresses.

The intrusion of saline water in wells upto a distance of 1 kilometer from coastline in sandy areas and upto 500 mts from the tidal tract of estuaries in alluvial zones is a serious threat to groundwaters. The coastal alluvial aquifers are highly permeable and are in hydraulic continuity with sea/ estuarine water. Therefore indiscriminate pumping from wells here leads to salinity intrusion. The high level of ground water exploitation and pumping in the coastal zone, accentuates the problem.

The intrusion of saline water in to groundwater aquifers and the ingression of seawater to the rivers/estuaries are adversely affecting the availability of potable water especially during dry season. Therefore, corrective measures with proper planning and management of groundwater resources in the area need to be initiated at this stage so that it may not turn to be a major water quality problem in the coming times. This study is useful in making management decisions to monitor and control saltwater intrusion and planning of groundwater development in the area.

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