Assessment of Saltwater Intrusion Along Coastal Areas of Nellore District, A.P.

M.Mohan Babu, G.K.Viswanadh and S.Venkateswara Rao

Abstract— Studies of seawater intrusion in coastal aquifers have assumed greater importance in recent decades because of the increased demands placed on subsurface water to meet the growing needs of water in large urban areas and agricultural practices located in the coastal areas in the world. The present study aims at assessing the seawater intrusion along the coastal mandals –Alluru, Vidavaluru, Indukurupeta, T.P. Gudur and Muthukuru of Nellore district, Andhra Pradesh. Forty nine groundwater samples were collected from the above mandals during January 2013 and analysed for the following parameters / ions, viz., Hydrogen-ion concentration (pH), EC, TDS, Ca, Mg, K, Na, K, CO_3, HCO_3, Cl, I and SO_4. The general quality of groundwater for drinking purpose was presented. To delineate the seawater intrusion in the study area, Ca/Mg, Cl ($CO3 + HCO_3$), Na/Cl ratios were used. The details of criteria for recognition of saltwater intrusion in coastal aquifers of the study area were presented and discussed. It is observed that Mg is the dominant cation and chloride is the dominant anion in the study area. According to hydrogeochemical ratio the study area seems to be contaminated with salt water intrusion and also this contamination is due to marine source of origin.

Index Terms- Coastal aquifers, coastal areas, coastal mandals, contaminated groundwater, groundwater, hydrogeochemical ratios, Nellore district, seawater intrusion

1 INTRODUCTION

In many parts of the world, coastal aquifers constituent an important source of water. Often, coastal areas are also heavily populated, a fact that makes the demand for freshwater even more acute. Due to the proximity and contact with the sea, the planning and management of such aquifers requires special attention associated with the danger of seawater or saltwater intrusion. In fact, this phenomenon constitutes one of the major constraints in the management of groundwater in costal aquifers. As seawater intrusion progresses, the part of the aquifer close to the sea become saline and pumping wells that operate close to the coast have to be abandoned.

Studies of sea water intrusion in coastal aquifers have assumed greater importance in recent decades because of the increased demands placed on subsurface water to meet the growing needs of water in large urban areas and agricultural practices located in the coastal regions in the world. Invasion of saline water into fresh groundwater due to groundwater withdrawal commonly occurs in coastal aquifers, where sea water moves in land if groundwater levels decline. The present work on "Assessment of Seawater Intrusion along Coastal Aquifers in Nellore District, Andhra Pradesh" has been taken and presented to assess the seawater intrusion in coastal areas of Nellore district, Andhra Pradesh by using various hydrogeochemical parameters.

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2. STUDY AREA

Location

Nellore district is one of the coastal districts of Andhra Pradesh. The district is drained by Pennar, Swarnamukhi, Upputeru and Manneru rivers. The district is bounded by Bay of Bengal in the east with a coastline of 169 km. The study area comprises, five coastal mandals, viz. Alluru, Vidavluru, Indukurupeta, T.P Gudur and Muthukuru situated along eastern part of the Nellore district (Figure. 1).

FIGURE. 1

3 METHODOLOGY

Water samples were collected from forty nine wells during January 2013 in the above coastal mandals taking necessary precautions(1). The collected groundwater samples were analysed for the following parameters / ions, hydrogen-ion concentration (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), carbonate (CO_3), bicarbonate (HCO_3), chloride (Cl), sulphate (SO_4), nitrates (NO_3), fluoride (F) and iodide (I). Various chemical ratios, viz. Ca /Mg, Cl/(CO_3+HCO_3 and Na /Cl were calculated based on equivalent parts per million (epm) of respective cations and anions present in the groundwater to recognize the salt water intrusion in coastal aquifers of Nellore district.

4. RESULTS AND DISCUSSION

The chemical analysis data of the forty nine wells from the study area is shown in Table 1. All the parameters / ions are expressed in mg/l, except pH, which is expressed in units.

General Quality of Groundwater

Hydrogen-ion Activity (pH): Hydrogen-ion activity in water is expressed as pH units. It is negative logarithm base-10 of the H^+ activity in moles per liter. The groundwaters in the study area are alkaline in nature as pH in the study area ranges from 8.1 to 8.85.

Total Dissolved Solids (TDS): Total dissolved solids indicate the general quality of the groundwater. TDS is arrived from specific electrical conductivity (EC) values by multiplying with factor of 0.64. Dissolved solids in groundwater mainly consist of sodium, potassium, calcium, magnesium, bicarbonates, chloride, sulphate etc.

In general, the normal ground waters, the TDS ranges from 19 to 1280 mg/l. In the study area the TDS values are ranging from 192 to 4096 mg/l. The TDS with less than 500 mg/l is observed in only 4 samples belong to T.P. Guduru and Muthukuru mandals. Most of the groundwater is within the permissible limits as per the drinking water standards of (2) of 500 – 1500 mg/l. The minimum value of TDS is noticed in Epuru of Muthukuru mandal and maximum concentration of TDS is observed in East Patupalem, of Indukurupeta mandal.

Total Hardness (TH): Hardness is also considered as total hardness is expressed in mg/l of equivalent $CaCO_3$. Hard drinking water is generally not harmful to one's health, but can pose serious problems in industrial settings, where water hardness is monitored to avoid costly breakdowns in boilers, cooling towers, and other equipment that handles water. In domestic settings, hard water is often indicated by a lack of suds formation when soap is agitated in water. Hardness of ground waters in the study area ranges from 187.5 mg/l to 1025 mg/l. Water is classified with respect to total hardness as shown below (3).

Description	TH (mg/l)
Soft	< 75
Moderately hard	75-150
Hard	150-300
Very hard	>300

In the study area, there are no soft and moderately hard waters. Hard waters are noticed in 6 wells. Most of the area encountered with very hard waters with concentration of more than 300 mg/l.

Calcium (Ca): Calcium concentration in the study area varies from 7.5 - 80 mg/l. Most of the area in the study, Ca is within the highest desirable limit of < 75 mg/l (Table 1). Minimum concentration of 7.5 mg/l is observed in Parlapalli in Vidavaluru mandal. Maximum concentration of 80 mg/l is found in Alluru mandal.

Magnesium (Mg): It is observed that Mg is the dominant cation in the study area. It varies from 177.5 to 986 mg/l with a general range of more than 500 mg/l. The entire study area is above the maximum permissible limits of 100 and 150 mg/l respectively prescribed by (4), (2) and (5).

Generally Mg content is also controlled by the presence of CO_2 like Ca. About 190 mg/l of Mg will remain in the solution under the influence of atmospheric CO_2. Therefore it is possible that all the Mg in the groundwater of the study area remains in solution.

Sodium (Na): Sodium concentration in the groundwaters of the study area varies between 82.5 and 97 mg/l. Interestingly the entire study area shows the similar concentration. When the concentration of TDS is below 1000 mg/l in dilute waters, Na is generally in the form of Na ions.

Chloride (Cl): Chloride is considered as a strong acid. Compare to the other ion the chemical behaviour of chloride in natural water is very tame and subdued. Among anions, chloride is the dominant anion in the groundwater of the study area. Its concentration ranges from 75 to 1193 mg/l. But the study area encountered with general ranges of < 250 mg/l and 250 – 500 mg/l. The lowest concentration of Cl is almost coincides with the lowest of TDS. The next higher range of Cl coincides with similar higher ranges of the TDS.

In the hydrological cycle the circulation of chloride ion is largely through physical process. Therefore it is difficult to remove Cl through the natural process if water once takes it in to solution.

Sulphates (SO_4): Sulphur is widely distributed in reduced form in both metamorphic and sedimentary rocks as metallic sulphides though it is not a major constituent of the earth's outer crust. During weathering in contact with aerated water the sulphides are oxidized to yield sulphate (SO_4) ions which are carried off in the water.

Sulphate is generally less abundant than chloride in most of the natural water; the same is observed in the groundwaters of the study area also.

In the study area the sulphates are ranges from 28 to 666 mg/l with a general range of less than 200 mg/l. According to (2) the limiting values ranges from 150-400 mg/l.

Nitrate (NO_3): Nitrate has low concentration varying from 0.1 to 1.5 mg/l.

Fluoride (F): Fluoride has considerable physiological significance for the biota including human beings. The maximum content of F observed in waters of the study area is 1.1 mg/l falling within the recommended range of 0.6 to 1.5 mg/l (4). However, certain waters are found to possess less than recommended level of fluoride which may cause dental disorders in the children.

CRITERIA FOR RECOGNISATION OF SALTWATER INTRUSION

In order to identify brackish or saline waters hydro geochemical parameters are normally used (6). A few hydrogeochemical parameters that are suggested as criteria for sea water contamination are Ca/Mg, $Cl/(CO_3+HCO_3)$, Mg/Ca, and Na/Cl ratios. In the study area the ratios are ranging by following values. (Table 2)

Ca/Mg Ratio

A low Ca/Mg ratio may be indicative of salt water contamination (7) because magnesium is present in sea water in much greater concentration than calcium. Therefore, Ca/Mg ratio is considered as a parameter for determining sea water contamination. According to Ca/Mg ratio, in the study area all the samples are showing low Ca / Mg ratio (Table 2 and Figure. 2).

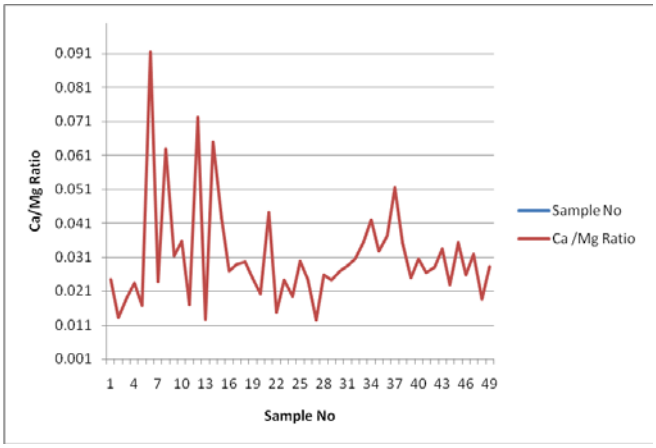

Fig 2. Ca / Mg Ratio values in the Study Area

Cl / (CO_3+HCO_3) Ratio

Cl / (CO_3+HCO_3) ratio used as a criterion to evaluate the salt water intrusion. Chloride is the dominant ion of ocean water and normally occurs in only small amount in groundwater while HCO_3 is usually the most abundant negative ion in ground waters, but it occurs in only minor amounts in sea water. The degree of concentration is as follows

Range of Cl / (CO_3+HCO_3) Ratio	Description
<0.05	Normally fresh ground water
0.05-1.30	Slightly contaminated ground water
1.30-2.80	Moderately contaminated ground water
2.80-6.60	Injuriously contaminated ground water
6.60-15.50	Highly contaminated ground water (near sea water)
>200	Sea water

From the above limit values, there is no fresh groundwater with <0.05 value. Majority of the area shows slightly contaminated groundwater with the value of 0.05 – 1.30 and 6 samples is seems to be moderately contaminated groundwater. There are no waters with injuriously and highly contaminated groundwaters in the study area according to this ratio and details are shown in Table 2 and Figure. 3 and Figure. 4.

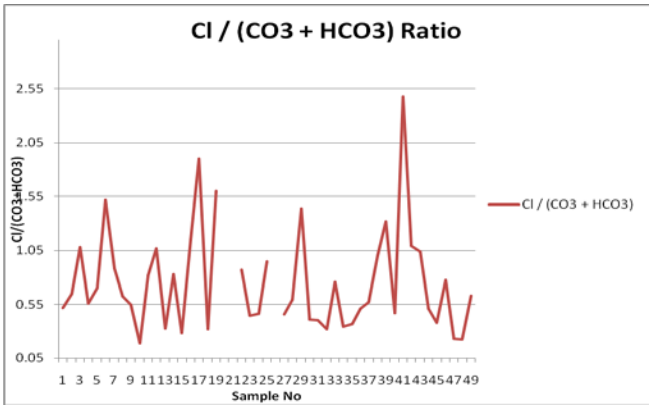

Fig 3: Cl /(CO_3 + HCO_3) ratio values in the Study Area

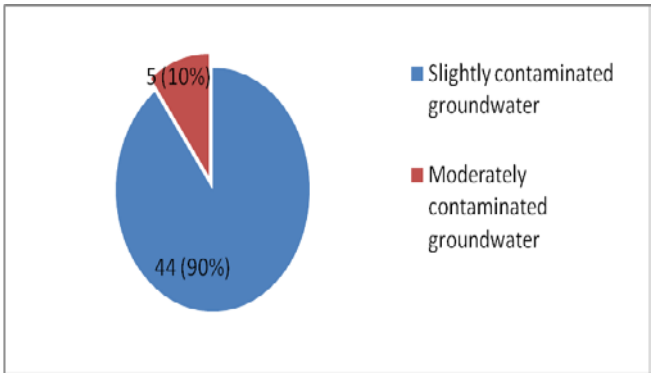

Fig 4: Contamination in the study area based on Cl /(CO_3 + HCO_3)

Na/Cl Ratio: Na / Cl ratios of saltwater intrusion are usually lower than the marine values (i.e., <0.86, molar ratio). On the other hand, high (more than 1) Na/Cl ratios, typically characterize anthropogenic sources like domestic waters. Thus low Na/Cl ratios combined with other geological parameters, can foretell the arrival of saltwater intrusion.

According to Na/Cl ratio, around 87% of the study area is contaminated with marine source of contamination (Figure. 5). Remaining area is may be contaminated due to anthropogenic sources like salt water pans and aquaculture farms.

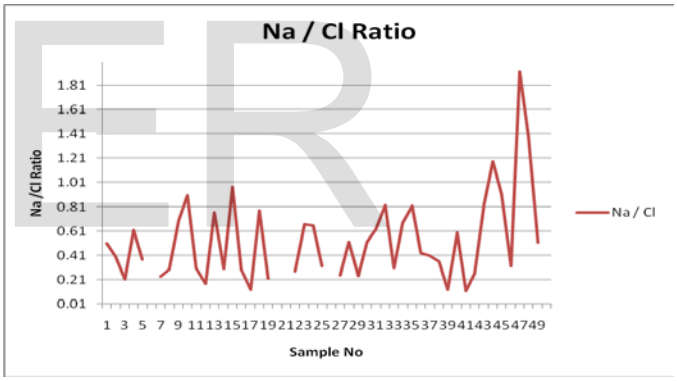

Fig 5. Source of contamination based on Na / Cl Ratio

5. CONCLUSIONS

The study area covering 5 coastal mandals viz., Alluru, Vidavaluru, Indukurupeta, T.P Gudur and Muthukuru of Nellore district. Groundwater development is mainly for drinking purpose and certain areas are for agricultural purposes.

Groundwater quality was assessed by estimating major cations and anions. The dominant cation is magnesium and dominant anion is chloride in the study area. According to drinking water standards, the groundwaters in the study area are potable. Regarding salt water intrusion, the low Ca / Mg ratio may be indicative of salt water contamination. According to Cl / (CO_3+HCO_3) ratio, the study area is found to be contaminated with slightly to moderately contaminated groundwater and there are no fresh groundwaters are encountered. According to Na / Cl ratio, the contamination may be due to marine source of origin.

Table 1 Standards for drinking water and general quality of groundwater in Nellore District, Andhra Pradesh

Constituent (mg/l)	WHO (1971)		ICMR (1975)		ISI (1983)		Study Area		
	Min. acceptable	Max. allowable	Highest desirable	Max. permissible	Highest desirable	Max. permissi-ble	Min. (mg/l)	Max. (mg/l)	General Range (mg/l)
pH (units)	7.0 -8.5	6.5-9.2	7.0-8.5	6.5-9.2	7.0-8.5	6.5-9.2	8.1	8.85	8.0 - 8.5
TDS	500	1500	500	1500	500	1500	192	4096	500-1500
Total Hardness	100	500	300	600	300	600	187.5	1025	> 300
Calcium	75	200	75	200	75	200	7.5	80	< 50
Magnesium	50	150	50	100	30	100	197.5	986	>500
Chloride	200	600	200	1000	250	1000	75	1019	< 250 &
Sulphate	200	400	200	400	150	400	28	666	< 200
Nitrate	50	100	20	45	45	45	0.1	1.5	-
Fluoride	0.9	1.1	0.6	1.5	0.6-1.2	1.5	0.2	1.1	-

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Table 2 Hydrogeochemical Ratios in Nellore District, Andhra Pradesh

S. No	Village	Mandal	Ca/Mg	Cl /(CO_3+ HCO_3)	Na/Cl
1.	Allurupeta Seethama Matam	Alluru	0.0244	0.5156	0.5111
2.	NagladeviGunta		0.0131	0.6524	0.4014
3.	Javagu		0.0190	1.08	0.2123
4.	ArrappaGunta		0.0233	0.5626	0.6170
5.	Singareddy Dinna		0.0167	0.7043	0.3735
6.	UdhuppuGunta		0.0914	1.5167	0
7.	GudivadiGunta		0.0237	0.8807	0.2370
8.	Anadisangam		0.0628	0.6247	0.2950
9.	Alluru govt. Hospital		0.0315	0.5488	0.6988
10.	Vidavaluru	Vidavaluru	0.0356	0.1915	0.9062
11.	Madhuvarthi		0.0171	0.8175	0.3052
12.	Alaganipadu		0.0721	1.0716	0.175
13.	Parlapalli		0.0127	0.3256	0.7663
14.	PalliPalem		0.0649	0.8301	0.2991
15.	KanchanaPalem		0.0427	0.2826	0.9724
16.	Ramathirdham		0.0270	1.1526	0.2966
17.	Dantiguntla		0.0290	1.902	0.1254
18.	Vavilla		0.0297	0.3232	0.7796
19.	Dampur		0.0246	1.6026	0.2190
20.	Indukurpet	Indukurupeta	0.0202	0	NA
21.	East Patapupalem		0.0442	0	NA
22.	Mypadu_		0.0147	0.8725	0.2815
23.	Somarajipalli		0.0242	0.4470	0.6662
24.	Ravooru		0.0194	0.4637	0.6551
25.	Komarika		0.0299	0.9485	0.3230
26.	Lebore		0.0244	0	NA
27.	Nagarajuthopu		0.0126	0.4584	0.2461
28.	Nidumusali		0.0257	0.5963	0.5198
29.	Gangapatnam		0.0242	1.44	0.2411
30.	Ramulapalem		0.0268	0.4135	0.5190
31.	Narkuru	Thotapalli Guduru	0.0285	0.4023	0.6263
32.	Peduru		0.0305	0.3196	0.8241
33.	Chinna Cherukuru		0.0354	0.7585	0.3045
34	Chinthopu		0.0420	0.3446	0.6781
35	Mangaladaruvu		0.0328	0.3675	0.8198
36	Potlapudi		0.0372	0.5124	0.4295
37	Kothapalem		0.0514	0.5744	0.4087
38	VenkanaPalem		0.0352	1.0054	0.3610
39	Chenna PalliPalem (Koduru)		0.0249	1.3185	0.1293
40	Koverapalem		0.0304	0.4726	0.5994
41	Brahmadevam	Muthukuru	0.0265	2.4733	0.1150
42	Narikellapalli		0.0281	1.0936	0.2609
43	Epuru		0.0335	1.04	0.8346
44	Epuru_1		0.0229	0.5154	1.1851
45	Valluru		0.0352	0.3795	0.9146
46	P.V. Kandriga		0.0257	0.7784	0.3239
47	Mallur		0.0319	0.2333	1.922

48	AmudalaPadu		0.0186	0.224	1.3872
49	PidathaPolur		0.0282	0.6342	0.5138