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Effect of sea water intrusion on quality parameters of ground water

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Abstract: A study was carried out in coastal Ramanathapuram district to find out the influence of sea water intrusion on quality of irrigation water. The analytical results indicated that the ground water in the study area was sodic. The Residual Sodium Corbonate (RSC) value was negative in ninety three percent of the samples analysed. The Sodium Adsorption Ratio (SAR) of irrigation water was found to be positively associated with SAR of the Soil Water Extract (SWE). A wide variations in the other quality parameters *viz.* potential salinity, permeability index, sodium ratio and adjusted SAR were observed due to the intrusion of sea water in to the ground fresh water aquifers of the coastal belt at various degrees. Significant positive correlation was noticed between SAR of irrigation water and the SWE of irrigated surface soils (r=0.231) No relationship existed between SAR and ESP of the coarse taxtured soils in the coastal areas.
(Key words: Sea water intrusion, Quality parameter, Coastal belt, and Irrigation water).

Most of the ground water aquifers situated along the shoreline have hydraulic contact with sea. Under normal conditions fresh ground water from the land mass is discharged into the sea. When the original balance is disturbed by over exploitation, the flow into the sea decreases by different degrees depending on the rate of exploitation by pumping. If the rate of extraction exceeds critical value, depending upon the hydrology of aquifers, the seaward flow ceases completely and reversal of flow sets in. This phenomenon can greatly impair the water quality in the coastal belt. In Tamil Nadu, the problem of ground water salinity or sodicity exist both in coastal areas and inlands. The exact nature and intensity of the problem however, has not been systematically surveyed indetail. Many coastal areas of Tamil Nadu offers problems like salinisation, waterlogging, clay pan formation and sea water inundation. Present study has been carried out to find out the effect of sea water intrusion on quality parameters of irrigation water in the coastal region.

Materials and Methods

The study area covered in the coastal area is about 1, 48, 955 ha. The entire coastal belt of Ramanathapuram gets abundant sunshine in the summer and moderate precipitation in winter leading to high evaporative demands. Places had been marked from coast to inland at various distances, for the collection of water samples. Existing open wells marked in the places had been utilised and one litre of water sample had been collected from each place for laboratory analysis. The water table in the study area and the distance from the sea had also been recorded. The water samples collected were analysed for the chemical constituents and the quality parameters *viz.* RSC, SAR, SSP, PS, PI, Adjusted SAR and Na ratio had been worked out (Table 1) using the standard formulae.

Results and Discussion

Quality parameters of irrigation water

a) Residual Sodium Carbonate (RSC)

The RSC of irrigation water (iw) varied from -92.2 (Ethampadal) to 456 Cmol L^{-1} Ramanathapuram) with a mean value of 8.14 Cmol L^{-1}. Nearly 93 per cent of the water samples recorded negative RSC values indicating its less impact on imparing ground water quality. No distinct correlation was observed between the distance from sea, water table and RSC of ground water, may be due to mixing of ground water. The increased positive values had been noticed in the region where the water contained more of CO_3^- and HCO_3^-, (Kanwar and Kanvar, 1971).

b) Sodium Adsorption Ratio (SAR)

This ratio expresses the relative activity of sodium ion in cation exchange reactions within the soil. The SAR is more significant than the Soluble Sodium Percentage (SSP) for use as an index of the sodium or alkali hazard of the water, because, it relates more directly to the adsorption of sodium by the soil. It was found that SAR of irrigation water varied from 0.35 (Ucliipulli) to 59.34 (Kulathur) with mean value of 12.24. This variation might be due to the presence of sodic water or sea water in the aquifers near the sea. Near the littoral region, the SAR values were found highest than the interior from sea. There was no significant correlation between the water table and SAR of irrigation water. In managing the irrigation water and drainage water for salinity control, it is generally desirable to maintain the SAR of irrigation water below a value of 10. In the present study nearly 33 percent of irrigation water analysed have recorded the SAR values of more than 10.

c) Soluble Sodium Percentage (SSP)

The soluble sodium percentage (SSP) varied from 9.38 per cent (Uchipuli) to 95.14 per cent (Kulathur) with mean value of 60.98 per cent. Highly significant correlations were noticed between the SSP and water table (r = 0.320**), the distance from the littoral region and SSP (r=0.219**). This may be due to sea water influence in the aquifers. The same trend was earlier observed by Lee and Strickland (1988).

d) Potential Salinity (PS)

Potential salinity included all the Ci-, Na^+ and Mg^{2+} and half of the $MgSO_4$. A wide variation in the PS value of irrigation water evidences the sea water intrusion in to ground aquifers. The lowest value (1.19 Cmol L^{-1}) was observed at Moyampuli and the highest value (153.50 Cmol L^{-1}) at Neelamadai with mean value of 38.55 Cmol L^{-1}. Comparing the PS value of irrigation water near the sea and distance from the sea, a significant correlation was found (r=0.382*) Bruington (1958) reported that in some areas of California, salt water had moved up to 4.5 miles inland. No significant correlation was observed between the water table and the PS of irrigation water. In the present study ground water salinity was observed even up to 25 km inland depending upon the type of soil.

e) Permeability Index (PI)

The long term use of irrigation water containing high total salt concentration such as Na^+ and HCO_3^-, affected the permeability of soil, (Paliwal *et al.* 1975). The PI was lowest (29.14 per cent) at Uchipuli and highest (102.56 per cent) at Kulathur with mean value of 70.98 per cent. This variation may be due to intrusion of sea water in to the coastal aquifers and continued pumping may be resulted in further more intrusion.

f) Adjusted SAR

The lowest value (0.08) of adjusted SAR was observed at Mandabam and the highest, value (173.5) at Kanjankudi with mean value of 30.90. The correlation between the watertable and adjusted SAR was found significant (r=0.243).

G) Sodium Ratio (SR)

The sodium ratio (SR) ranged from 0.16 (Uchipuli) to 19.57 (Kulathur) with mean value of 2.74. This variation might be due to the presence of sea water in the deeper, down gradient parts of the aquifers. Lee and Strickland (1988) recorded ground water chemistry of water from non- calcareous and calcareous sand aquifers and found that irrigation water become sodium and chloride dominated by mixing with subsurface brines or sea water present in the deeper, down gradient parts of aquifers. Based on the sodium ratio the water were grouped under class I (less than 1) and Class 11 (more than 1). Sodium. accumulation tended to become a problem, if the sodium ratio exceeds one. In the present study nearly seventy five per cent of samples analysed have recorded sodium ratio value exceeding one.

Conclusions

Based on the water analytical results in the coastal Ramanathapuram district, among the quality parameters studied *viz.* SSP, PS, PI, adjusted SAR and Na^+, except RSC at the different water table levels and distances away from the

Table 1. Effect of sea water intrusion on quality parameters of ground water.

S. No.	Place	Distance from sea (km)	Water table (m)	RSC (m.eq/lit.)	SAR	SSP (%)	PS (m.eq/lit.)	PI	Adj. SAR	Na+ ratio
1.	Mandabam	1.0	3.0	-2.4	8.72	69.11	19.46	79.02	14.02	2.24
2.	Maraikkayar thottam	1.0	2.0	-10.9	7.78	60.24	29.45	64.81	15.56	1.52
3.	Sundaramudayan	1.0	8.0	-2.4	0.49	20.00	2.09	53.54	0.20	0.19
4.	Devipattinam	1.0	10.	-4.6	29.26	85.25	76.23	88.55	78.97	5.78
5.	Athiyoothu	1.0	12.0	-2.2	1.17	25.64	5.47	48.57	1.17	0.34
6.	Keelakkarai	1.0	17.0	-1.8	50.76	91.54	130.22	92.91	157.17	10.82
7.	Uchipuli	1.5	4.0	-3.3	2.90	44.83	8.26	60.00	3.48	0.81
8.	Moyampuli	1.5	3.0	-3.5	9.2	69.47	21.49	77.56	15.64	2.28
9.	Erwadi	1.5	2.0	-8.2	35.06	87.48	94.84	89.25	98.17	6.98
10.	Salaithottam	2.0	4.0	-0.5	1.20	37.50	2.03	75.77	0.60	0.60
11.	Bamban	2.0	4.0	-12.7	2.48	21.19	20.41	38.15	3.97	0.37
12.	Mangammal Salai	2.0	1.0	-2.6	1.21	27.03	4.19	49.64	0.97	0.37
13.	Kanjankudi	2.5	8.0	-6.2	54.22	91.59	144.22	93.16	173.50	10.89
14.	Tiruppullani	2.5	8.0	-6.7	22.20	78.56	84.30	81.99	62.16	3.66
15.	Sethukkarai	2.5	12.0	-5.5	7.38	62.99	21.61	68.83	12.55	1.70
16.	Singarathoppu	3.0	1.0	-7.9	5.25	53.04	21.36	60.45	9.45	1.13
17.	Veadalai	3.0	2.0	-2.2	7.18	64.81	17.27	75.57	11.49	1.83
18.	Udayarvalasai	3.0	1.0	-0.5	3.63	58.97	5.17	80.04	3.79	1.44
19.	Nadumunaikadu	3.0	1.0	-0.0	3.50	58.44	4.21	81.67	2.80	1.41
20.	Tiruppullani	3.0	10.0	-13.1	23.14	79.23	51.96	81.83	62.48	3.82
21.	Pathratharavai	3.0	5.0	-13.3	18.50	72.94	71.36	76.96	79.95	2.69
22.	Regunathapuram	3.0	6.0	-13.1	8.47	57.64	39.49	63.12	18.63	1.36
23.	Thangachimadam	3.0	2.0	-1.1	5.35	60.86	9.17	76.57	6.91	1.63
24.	Akkamadam	3.0	2.0	-0.9	0.54	95.00	1.11	63.27	0.11	0.33
25.	Vannangundu	4.0	2.0	-11.8	3.78	41.88	21.27	47.61	6.00	0.72
26.	Vannangundu	4.0	2.0	-2.6	39.00	90.70	73.11	94.30	109.20	9.75
27.	Panchanthangi	5.0	5.0	-2.9	0.58	17.24	4.11	41.03	0.35	0.21
28.	Ethampadal	6.0	10.0	-92.2	22.40	62.05	245.25	62.62	80.64	1.63
29.	Sempudayarkulam	6.0	11.0	-1.8	7.56	70.11	13.25	80.71	11.34	1.35
30.	Palanivalasai	7.0	1.0	-2.2	1.76	32.65	6.03	54.06	1.76	0.48
31.	Neelamadai	7.0	10.0	-26.8	30.95	78.91	153.50	80.59	99.04	3.74
32.	Sumaithangi	8.0	8.0	-5.0	23.10	82.15	60.30	86.06	60.66	4.60
33.	Rameswaram	10.0	6.0	-5.8	2.04	33.33	10.22	46.13	2.45	0.50
34.	Kuttanendal	10.0	8.0	0.4	4.90	60.42	6.22	75.15	4.90	2.07
35.	Shanmuganathapuram	10.0	7.0	-7.6	7.83	63.64	25.73	66.55	14.88	1.75
36.	Karumal	10.0	22.0	-13.6	23.8	80.45	78.59	82.23	64.26	4.11
37.	Notchivayal	10.0	25.0	-8.3	3.02	36.36	17.04	46.36	5.13	0.57
38.	Pandikkanmai	10.0	27.0	-3.2	13.92	86.42	10.37	100.76	19.49	3.33
39.	R.S. Mangalam	11.0	20.0	-2.88	3.53	56.17	7.61	61.82	3.18	1.28
40.	Chinnakeeramangalam	11.0	10.0	-8.88	6.84	56.55	22.71	64.04	12.31	1.47
41.	Sathankulam	12.0	10.0	-4.2	12.79	73.17	32.91	78.89	26.86	2.73
42.	Paranoor	12.0	10.0	-14.7	6.69	54.52	34.94	57.49	13.38	1.20
43.	Samiyarmadam	12.0	5.0	-1.2	4.13	53.24	9.29	69.64	5.78	1.16
44.	Pattanamkathan	15.0	6.0	-0.2	5.06	63.46	7.32	80.66	5.06	1.94
45.	Kavanoor	15.0	12.0	-10.4	5.76	54.26	26.78	58.85	10.37	1.19
46	Keelakkottai	15.0	11.0	-4.2	23.36	26.19	48.01	88.35	56.06	6.24
47.	Sembadachi	15.0	10.0	-47.6	18.10	64.36	136.16	65.54	56.11	1.81
48.	Kulathoor	16.0	10.0	-4.0	59.34	95.14	91.09	95.61	166.15	19.57
49.	Ramanathapuram	16.0	8.0	4.56	6.90	72.58	4.78	94.66	8.97	2.65
50.	Terinuveli	17.5	10.0	-5.0	10.60	72.92	27.34	77.31	20.14	2.69
51.	Thethangal	18.0	7.0	-10.6	8.90	43.48	18.78	50.21	6.24	0.77
52.	Pandielugai	20.0	21.0	-3.2	5.50	63.38	11.13	72.79	7.70	1.73
53.	Mallal	20.0	17.0	-16.52	9.60	58.30	48.38	62.41	24.00	1.40
54.	Atchudhanvayal	21.5	5.0	-1.0	4.61	60.34	7.36	76.70	5.07	1.52
55.	Chinnackaramesi	22.0	25.0	-5.6	8.30	63.38	20.25	74.11	14.11	2.16

Contd...

Table 1. *Contd...*

56. Puliyangudi	22.0	30.0	4.4	17.10	89.11	14.67	101.44	27.66	8.18
57. Nayinarkoil	23.0	11.0	-1.8	7.16	66.33	13.53	75.45	10.74	1.97
58. Nedunguruchi	25.0	11.0	-4.6	45.30	39.37	77.38	94.46	95.31	8.41
59. Udayarkudiyiruppu	25.0	21.0	-33.0	19.20	69.05	112.88	70.76	57.60	2.23
60. Thabalchavadi	25.0	50.0	-1.3	4.71	61.40	8.21	76.84	4.71	1.59
61. Ettivayal	25.0	50.0	-0.6	7.06	68.67	12.20	81.59	9.88	2.19
62. Sathrakudi	26.0	15.0	-21.8	8.41	53.93	50.45	57.70	95.07	1.17
63. Thinaikkulam	26.0	7.0	-25.4	5.96	42.55	48.68	47.24	14.30	0.74
64. Vanniyavannam	27.0	10.0	-17.00	9.08	65.96	43.84	69.38	20.88	1.63
65. Veerammalthottam	27.0	8.0	-9.2	11.10	68.96	33.90	73.51	23.31	2.22
66. Kunappanendal	27.5	12.0	-1.0	0.79	23.36	2.07	55.75	0.32	0.31
67. Ariyanendal	30.0	15.0	-1.9	3.52	53.11	7.44	70.25	3.52	1.07
68. Tiruvarangam	30.0	13.0	3.54	17.95	82.16	30.43	89.67	39.49	4.60
69. Emaneswaram	35.0	20.0	1.8	8.45	78.13	8.59	89.71	10.99	3.57
Minimum			-92.2	0.35	20.00	1.11	38.15	0.11	0.19
Maximum			4.6	59.34	95.14	245.2	101.4	173.5	19.57
Mean			8.14	12.24	60.98	38.55	70.98	30.90	2.74

sea, confirmed the intrusion of sea water in to the inland at various degrees. Hence, the farmers of Ramanathapuram district having land holding within 25 Km from the littoral region, may be adviced not to dig wells beyond 8 m depth and those who are having wells more than this depth can cultivate only salt tolerant crops like coconut, chillies, cotton and ragi, etc. Besides the farmers in the littoral region should avoid over exploitation of ground water and digging deeper wells in order to prevent further intrusion of sea water in to good quality fresh water aquifers.

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