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APPRAISAL OF WATER QUALITY FOR IRRIGATION USE IN WESTERN KRISHNA DELTA, ANDHRA PRADESH, INDIA

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Abstarct: The coastal aquifers of deltas are complex systems driven by different processes varying on several time scales. The proximity of coastal aquifers to sea creates unique issues with respect to contamination and groundwater sustainability. The groundwater resource, in this complex hydro chemical situation restricts the usage of this resource due to salinity hazard. The variability of hydro- geological settings, variation of salinity with depth, influence of geomorphology and anthropogenic activity makes coastal systems even more complex. Addressing the quality and management of groundwater is essential in the coastal aquifers for sustainable exploitation. The agriculture is main occupation in this study area, and hence this paper presents the suitability groundwater for agriculture use. The study shows that only few pockets of groundwater repositories of the delta are suitable for agriculture and there is an immediate need for strategic groundwater management plans.

Keywords: Krishna Delta, Grounwater, Salinity, palaeochannel.

Introduction

The Krishna delta is formed by the river Krishna in the East Coast of India. Krishna river originates at ground elevation of 1400 m above mean sea level in the western ghats and flows in an easterly direction over a length of 1400 km from its place of origin with a catchment area of 2,58,948 km^2. The river flows with an average slope of 1 m per kilometer in its journey and forms the cuspate Krishna delta having an area of about 6322 km^2 before it debouches into the Bay of Bengal. This delta is one of the biggest deltas on the East Coast of India and spread in densely populated Krishna and Guntur districts of Andhra Pradesh, India. Nageswararao and Vaidyanadhan, (1979) presented the evolution of coastal landforms in Krishna delta. The study area is the delta covering western part of river Krishna and is called Western Krishna delta, falls between 15^0 44′ - 16^0 40′ N latitudes and 80^0 20′ - 80^0 50′ E longitudes. The topography of the area is almost plain with the maximum and minimum elevations being 25 and 1 meter above mean sea level (MSL).

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Geomorphology and Geology

Western Krishna delta is broadly classified as palaeochannels, flood plains, back swamps of the delta complex and strand plain of marine sediments. There are at least 4 palaeochannel limbs in the Western Krishna delta and mostly contain sand, silt with a small fraction of clay. Flood plains are present on either side of the river course and palaeochannels. Soils in the area include black cotton soils, coastal sandy saline soils, red sandy soils, and river sands. Black cotton soils occupy a major part of the study area in the northern and eastern parts. The back swamp is developed between fluvial delta and strand plain and is occupied at the time of deposition by both sea water and fresh water for different periods resulting into fluvio-marine deposits with alkaline black clays on top 5-10 m followed by sandy clays with fine sand and silt. The strand plain composed of deposits mainly developed in marine environment characterized by the presence of strand lines (exposed as beach ridges) with associated tidal and mud flats ranging in age from late Pleistocene to Holocene.

Previous studies

Most of the earlier hydro-geochemical studies carried out by various organizations and authors are only at macro level and considered the entire delta as one geomorphic unit i.e. alluvium. For example Paul Prabhakar (2005) classified the area based on the electrical conductivity (EC) of groundwater. Saxena et al (2008) presented the distribution of TDS of the groundwater in Krishna delta. Ramasastri et al (2004) tried to identify the zones of fresh and saline waters based on total dissolved solids (TDS) and isotopes. The nitrate concentration under irrigation agriculture is described by Zaparozec (1983).

Methodology

In spite of the abundant groundwater resources, most of the villages in the delta lack adequate drinking water supplies due to quality constraints. It is noticed that the people in this area are deprived of fresh water and they are forced to drink hard and brackish water, there by suffering from many water related diseases. The sampling locations are selected from different geomorphic units viz. palaeochannels, flood plains, back swamps and strand planes (Figure 1). It is observed that the fresh water depositories are limited to only palaeochannels and in all other geomorphic units the water already became saline and unsuitable for drinking and agriculture.

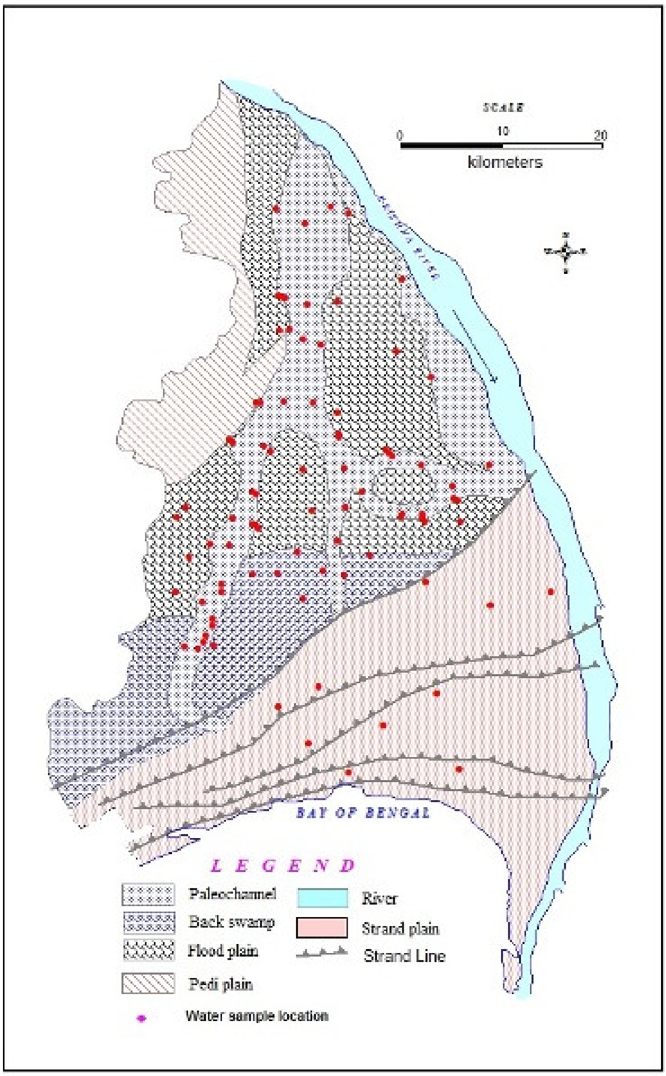

Figure 1: Geomorphic divisions of Westrern Krishna Delta, Andhra Pradesh, India and location of observation wells

The major ion chemistry of ground water is studied in detail in the western Krishna delta. The water samples collected in 88 locations segregated among the identified geomorphic zones viz. palaeochannels, floodplains, back swamps, and strand plains (Figure 1).

Table 1: Concentrations of Ca, Mg, Na, EC and estimated SAR values of western Krishna delta

S.NO	EC	Ca	Mg	Na	SAR		S.NO	EC	Ca	Mg	Na	SAR
	umohs/cm	me/l	me/l	me/l				umohs/cm	me/l	me/l	me/l	
1	1725.0	2.40	6.58	8.70	3.65		45	2300.0	3.19	7.57	12.18	4.61
2	715.0	2.79	1.89	3.05	1.57		46	2690.0	2.79	13.00	12.53	4.11
3	1290.0	1.10	2.70	5.40	3.45		47	3820.0	3.39	13.17	17.40	5.51
4	980.0	1.30	3.62	4.13	2.34		48	4825.0	7.98	16.05	23.01	5.75
5	950.0	4.69	2.22	3.48	1.44		49	5780.0	9.98	22.05	28.01	6.11
6	1160.0	1.60	3.62	6.53	3.53		50	8750.0	10.98	23.04	43.50	9.17

7	1060.0	1.60	1.23	8.05	5.41		51	4690	6.39	15.96	26.19	6.91
8	900.0	1.10	3.79	3.70	2.14		52	6450	11.58	18.35	42.63	9.36
9	1400.0	5.29	2.72		0.00		53	8430	6.99	17.03	47.02	11.94
10	720.0	1.80	2.22	3.48	2.04		54	6575	6.99	17.03	44.02	11.18
11	1000.0	3.19	2.22	4.79	2.31		55	6555	2.79	25.18	36.98	9.43
12	920.0	3.59	2.96	3.52	1.56		56	4380	7.39	7.41	16.01	4.81
13	850.0	1.30	3.29	4.00	2.33		57	4640	3.99	8.97	32.02	11.00
14	620.0	1.50	2.72	2.91	1.72		58	3585	1.60	4.77	23.01	11.53
15	1150.0	0.70	3.87	6.96	4.29		59	10660	17.96	33.00	63.08	10.74
16	785.0	2.20	1.81	3.74	2.12		60	5040	5.99	7.98	24.01	7.60
17	1165.0	1.70	3.29	5.00	2.74		61	10420	13.97	20.00	73.95	15.10
18	1185.0	0.40	1.56	10.44	9.61		62	6455	5.99	13.99	44.02	12.22
19	625.0	1.40	2.88	1.52	0.90		63	9125	4.99	13.99	68.03	19.65
20	1055.0	2.50	1.97	7.18	3.85		64	8815	19.96	27.98	43.50	7.47
21	1345.0	2.30	3.79	6.09	2.98		65	5500	8.18	10.53	26.10	7.12
22	700.0	1.80	1.89	2.61	1.58		66	9790	7.58	12.43	58.73	15.81
23	860.0	2.20	2.22	4.35	2.39		67	5425	11.98	22.38	19.58	4.07
24	1400.0	1.20	3.21	10.01	5.98		68	10400	9.18	16.38	74.04	17.76
25	1200.0	2.00	1.89	8.66	5.05		69	10650	14.37	28.80	82.04	15.29
26	1480.0	1.50	3.21	11.01	6.25		70	11900	5.99	20.98	69.60	17.14
27	540.0	1.90	1.40	2.96	1.84		71	6550	3.99	17.03	29.01	8.20
28	1240.0	1.40	4.20	7.00	3.75		72	14590	19.96	36.04	91.05	14.77
29	910.0	3.59	0.91	3.70	1.84		73	7450	6.39	8.39	47.33	14.55
30	800.0	1.50	1.73	4.79	3.11		74	10270	7.98	20.98	56.03	13.03
31	2315.0	3.19	1.23	14.79	7.58		75	9170	9.98	19.75	40.46	9.08
32	3675.0	2.40	4.61	16.53	7.63		76	9650	3.99	20.00	48.02	12.84
33	3870.0	4.39	7.98	26.01	8.98		77	8900	8.98	23.04	52.20	11.53
34	2750.0	2.79	7.57	17.01	6.63		78	5025	2.00	7.98	32.63	13.33
35	1960.0	0.60	1.40	16.01	14.05		79	7540	14.57	10.04	46.37	10.48
36	2800.0	1.80	1.97	23.40	14.03		80	7780	3.59	4.77	66.99	27.40
37	2220.0	1.60	7.98	9.57	4.05		81	6990	2.40	8.81	54.03	20.72
38	4490.0	3.99	12.01	26.01	8.23		82	7450	5.59	10.04	46.37	14.24
39	2080.0	2.00	3.21	12.01	6.33		83	9100	14.22	18.43	53.72	11.10
40	1990.0	2.40	6.83	6.53	2.71		84	6780	3.59	6.83	31.02	11.72
41	2790.0	4.39	4.03	17.40	6.87		85	6500	15.02	13.82	35.41	7.56
42	1085.0	2.00	3.54	5.22	2.69		86	9230	14.22	18.43	52.77	10.90
43	1510.0	1.40	3.62	8.27	4.61		87	7260	7.98	4.36	55.03	17.26
44	1800.0	1.00	1.40	15.01	11.52		88	12690	9.98	28.23	83.17	16.94

Productivity and quality of agriculture crops are largely dependent on quality of groundwater supplied for its irrigation (USSL, 1973). In order to find out suitability of groundwater for irrigation EC along with sodium play an important role. Sodium Absorption Ratio (SAR) and Electrical Conductivity are used to distinguish different types of water according to the US Salinity Laboratory classification (1954).

To evaluate the suitability of water for irrigation, Sodium absorption ratio (SAR) is a suitable and frequently used parameter. The Electrical conductivity (µmohs), Ca, Mg, Na (meq/l), and the calculated SAR values of the samples are presented in table 1. The US salinity laboratory has constructed a diagram and different classes with reference to Sodium Absorption Ratio

(SAR) as an index for sodium hazard and E.C as an index for salinity hazard. The SAR is defined as

$$SAR = \frac{Na}{\sqrt{(ca + Mg)/2}}$$

Over a period of time high soil Na levels will increase with the high SAR levels in irrigation waters. Due to soil dispersion, these increased Na levels in soil adversely affects soil infiltration and percolation rates. Additionally, excessive SAR levels can lead to soil crusting, poor seedling emergence, and poor aeration.

Results and Discussion

To distinguish different types of waters the calculated Sodium Absorption Ratio (SAR) and estimated Electrical Conductivity of western Krishna delta are subjected to the US Salinity Laboratory Classification (1954). Depending on salinity hazard and sodium hazard they are classified as low, medium, high, very high and are represented by C_1, C_2, C_3, C_4 and S_1, S_2, S_3, S_4 respectively.

Table 2 presents the results of the study furnishing the suitability of groundwater from different geomorphic units in western Krishna delta. The sample which are falling out of the range in diagrams due to extremely high salinity, particularly from back swamps and strand plains, are not shown in the table**.**

The modalities and possible remedial characteristics of the above classification is as follows.

C_1S_1: Low salinity and low sodium waters are good for irrigation and can be used with most of the crops with no restriction on use on most of the soils.

C_2S_1: Medium salinity and low sodium waters are good for irrigation and can be used on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Crops can be grown without any special consideration for salinity control.

C_3S_1: The high salinity and low sodium waters require good drainage. Crops with good salt tolerance should be selected.

Table 2: Abstract of results of U.S. Salinity Diagrams - Suitability of Groundwater for Irrigation, Western Krishna Delta

S.No	Area	Character	No.of samples	Geomorphic unit	Suitability for irrigation
1		Very high SAR and EC more than 5000 us/cms	18	Flood plain (18)	Unsuitable for irrigation
2	C_4S_4	Very high SAR, very high conductivity	2	Cont. Palaeochannel (2)	Unsuitable for irrigation

3	C_3S_4	Very high SAR, high conductivity	0	Nil	Unsuitable for irrigation
4	C_4S_3	high SAR, very high conductivity	4	Cont. Palaeochannel (3) Flood plain (1)	Unsuitable for irrigation
5	C_3S_3	high SAR, high conductivity	1	Cont. Palaeochannel (1)	Unsuitable for irrigation
6	C_4S_2	Med SAR, very high conductivity	1	Cont. Palaeochannel (1)	Unsuitable for irrigation
6	C_3S_2	Med SAR, high conductivity	5	Cont. Palaeochannel (3) Palaeochannel (2)	Suitable for irrigation
7	C_2S_2	Med SAR, medium conductivity	1	Palaeochannel (1)	Suitable for irrigation
8	C_4S_1	Low SAR, very high conductivity	7	Cont. Palaeochannel (6) Flood plain (1)	Suitable for irrigation
9	C_3S_1	Low SAR, high conductivity	16	Palaeochannel (12) Cont. Palaeochannel (4)	Suitable for irrigation
10	C_2S_1	Medium SAR, Med conductivity	5	Palaeochannel (5)	Suitable for irrigation
11	C_1S_1	Low SAR, Med cond.	0	Nil	

C_3S_2: High salinity and medium sodium waters require good drainage and can be used on coarse textured or organic soils having good permeability.

C_3S_3: These high salinity and high sodium waters requires special soil management, good drainage, high leaching and organic matter additions. Gypsum amendments make feasible the use of these waters.

C_4S_1: Very high salinity and low sodium waters are not suitable for irrigation unless the soil is highly permeable and drainage must be adequate. Irrigation waters must be applied in excess to provide considerable leaching. Salt tolerant crops must be selected.

C_4S_2: Very high salinity and medium sodium waters are not suitable for irrigation on fine textured soils under low leaching conditions and can be used for irrigation on coarse textured or organic soils having good permeability.

C_4S_3: Very high salinity and high sodium waters produce harmful levels of exchangeable sodium in most soils and will require special soil management, very good drainage, high leaching and organic matter additions.

C_4S_4: Very high salinity and very high sodium waters are generally unsuitable for irrigation purpose. These are sodium chloride type of waters and can cause sodium hazard. However, these can be used on coarse textured soils with very good drainage. Gypsum amendments make feasible the use of these waters.

The groundwater in the palaeochannels has percent sodium contents ranging from 33 to 79, electrical conductivities 440 to 1480 µS/cm and the SAR values from 1 to 9.6. The ground water samples fall in C_2S_1 -5, C_3S_1 -12, C_2S_2 -1, C_3S_2 -2 fields in the US salinity diagram. In addition some samples in the palaeochannels showing high conductivities (1510 to 8750 µS/cm) with percent sodium contents ranging from 46 to 86. The calculated SAR values range from 2.7 to 14 fro these samples and the groundwater samples fall in C_3S_1 -4, C_4S_1 -6, C_3S_2 -3, C_4S_2 -1, C_3S_3,-1, C_4S_3 -3, C_4S_4 -2, fields in the US salinity classification. The groundwater in palaeochannels have percent sodium contents ranging from 47 and 87, EC from 3585 to 14590 µS/cm and the SAR values from 4 to 36. The groundwater samples fall in C_4S_1 -1, C_4S_3 -1 field in the US salinity classification. Few samples falling out of the range of the diagram indicating unsuitability of water in this unit. Different parameters along with their ranges were given with number of samples from each geomorphic unit and their suitability for irrigation in Table 2.

The study of Sodium Absorption Ratio (SAR) and EC, percent Sodium indicates that the groundwater in palaeochannels are suitable for irrigation. Other than palaeochannels in all other geomorphic units like flood plain, back swamp and strand plain the groundwater is unsuitable or suitable except for the salt resistant plants/trees. Even in the paleochannels some samples showing high range of conductivities and SAR, which are indicted as contaminated palaeochannels in table 1. It is observed that most of these high salinity wells failing in the peripheries of the palaeochannels. This indicates that the palaeochannels are under threat of saline contamination, particularly in the periphery zones. This may be due to improper groundwater pumping and inappropriate usage in these pockets.

The detailed studies of Umamaheswara Rao et al (2012) and Krishnamacharyulu et al (2013) brought out the quality aspects of ground water in this area. Three distinct ground water environs viz. fresh water, brackish water and saline water zones are delineated in western Krishna delta. Palaeochannels are the only fresh water repositories in the area. It is observed that fresh water aquifers of palaeochannel also got contaminated due to anthropogenic activity and the salinity in flood plains, back swamp, strands plains is attributed to depositional history of delta.

Conclusions

The ground water from the palaeochannels is the only groundwater repository available for agriculture purpose in this area. But the alarming situation is that even the palaeochannels are being contaminated with salt water, particularly in the peripheries. Well planned stringent groundwater management exploitation strategies need to be implemented to prevent further contamination of freshwater pockets in this delta area. Thus the study emphasise the need of sustainable groundwater management strategies in the freshwater aquifers of coastal environments to meet the sustainable agricultural requirements.

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