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Salt water intrusion – A case study in Chintapalli, one of the coastal villages of Vizianagaram district of Andhra Pradesh

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ABSTRACT

Chintapalli, a village and panchayat of Poosapatirega mandal of Viziangaram district was selected for the author's present study. Ground water is the main water source of the village. Aquifer of the village cannot be charged properly due to lack of any river, lake or continuously flowing stream. The authors present work was aimed at the study of above source for different constituents such as calcium, magnesium, chloride, sodium, potassium, TDS, pH, conductance, DO and nitrite. Different samples were collected from four bore wells, one tap connected to water storage tank and open well. For such samples analyzed, the chloride ion concentration was found to vary from 80.5 mg/L to 936.9mg/L. The inference is the intrusion of sea water in to the fresh water aquifer of the village. The concentration levels of each of the constituent were compared with the standard values prescribed by ISI and ICMR and the authors found that almost all of the constituents were above the permissible limits, indicating sea water intrusion into water bodies of the village.

KEYWORDS

Water;
Salt water intrusion;
Water quality;
Assessment of water quality.

INTRODUCTION

In an unconfined aquifer that is in contact with the sea at the shoreline, the fresh water being less dense than sea water floats as a convex lens shaped layer on top of the sea water and the weight of the overlying fresh water depresses the sea water below sea level. Generally fresh water recharge in these aquifers moves down gradient and eventually discharges to low lying coastal areas and into the sea. But pumping out fresh water reduces the weight of the overlying fresh water. This migration of sea water in to fresh water aquifer is referred to as *salt water intrusion*[1].

One observable parameter of sea water intrusion is an increased chloride ion concentration in a fresh water aquifer, because chloride, a major constituent of sea water, is chemically stable and moves at about the same rate intruding into sea water. Chloride ion concentration of 100mg/L or higher are assumed to indicate sea water intrusion[2].

The interface between the salty ground water below and fresh ground water above is a transition zone of gradually mixing fresh and salt waters. Under natural conditions, the location of this zone will move slightly as the tide rises or falls and very often recharges fluctuate. However, when a well pumps fresh ground water from

near the transition zone, the equilibrium is disturbed and the ground water flow pattern is changed (Figure 1). As water is pumped out of bearing zone, the transition zone moves upward the well. Prolonged or large-scale pumping can raise the transition zone to the well, which may then draw in salt water (Figure 1a). The location of the transition zone depends upon several natural and human-made conditions[3].

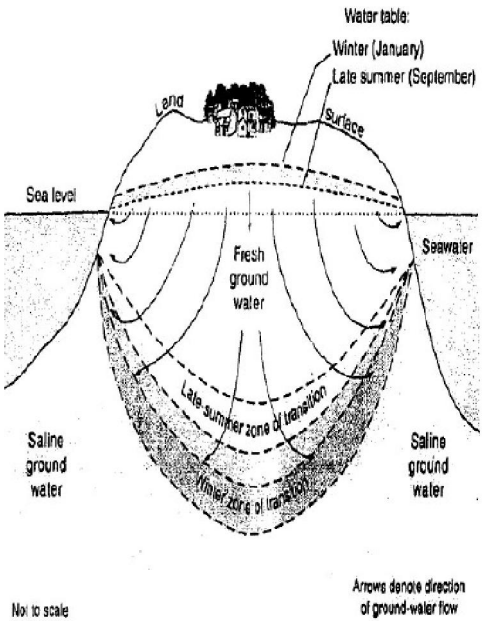

Figure 1 : Movement of salt water into ground water as a lens shaped path

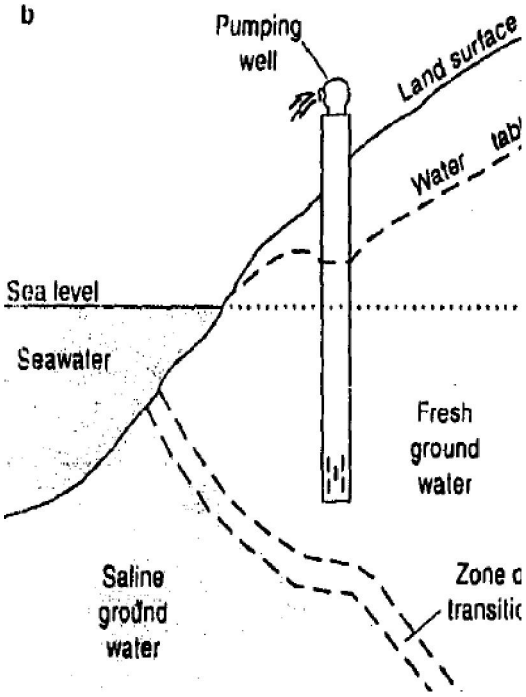

Figure 1a : Movement of fresh water through a bore well

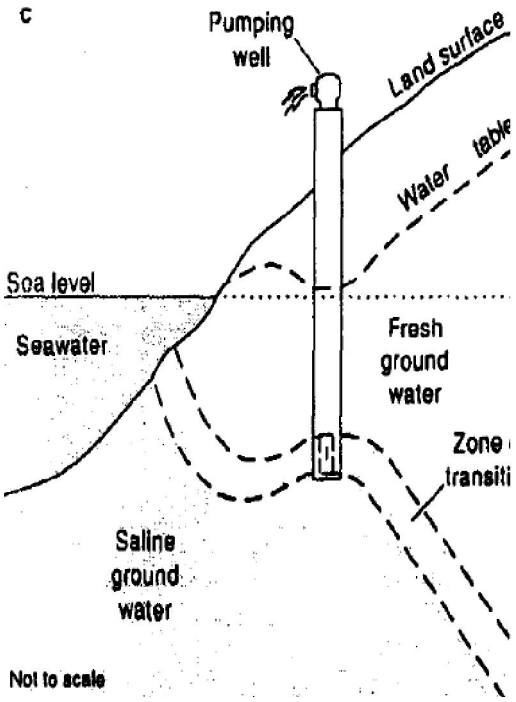

Figure 1b : Movemnet of salt water trhough bore well

On sea water intrusion, three trends are usually present.

1) Chloride ion concentrations at a given site may increase.
2) For wells open at same depth, there may be a strong relation between chloride ion concentrations and distance of the well from the shore line.
3) Chloride concentrations at a given site may increase with depth.

Physical and chemical parameters of water are influenced in every season and environment and some changes in these parameters cause adverse effects to human health. Some parameters like pH, dissolved oxygen, hardness and chloride ion have more influence on human health. Depleted dissolved oxygen will affect aquatic life. The carbonate and bicarbonate salts can cause hardness. A health survey conducted in the village indicated that the children in the village of age group 5-14 years have been suffering from unusual bowl movements, as result of the increased concentrations of magnesium. This made authors probe into the analysis of water in the village.

AREA UNDER STUDY

Vizianagaram (Figure 3) district is in the north coastal

districts of Andhra Pradesh, India., adjoining Bay of Bengal. It is situated within the geographical co-ordinates of 17- 15' and 19 – 15' of the northern latitudes and 83 – 00' and 83-45" of the eastern longitudes (Figure 2).

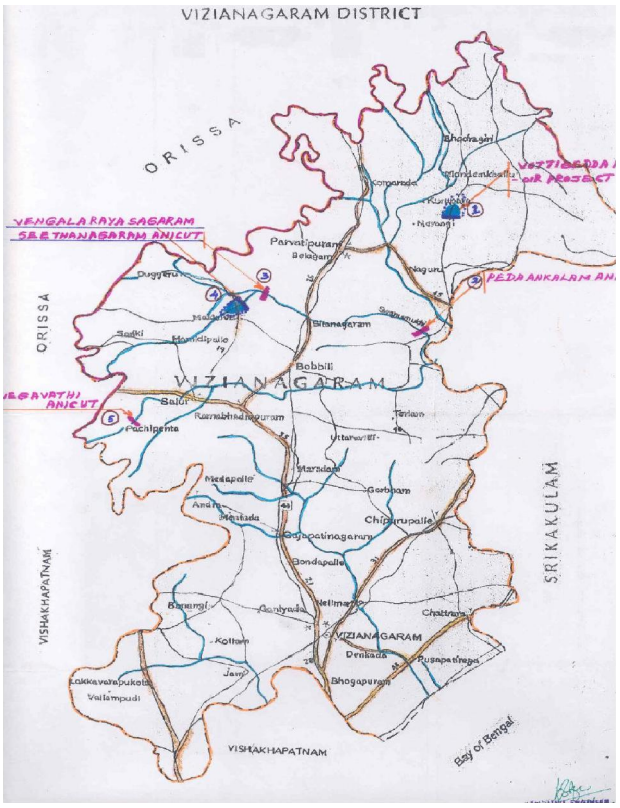

Figure 2 : Vizianagaram district map showing POOSAPATIREGA mandal

The main soils are red soils, sandy loams and sandy clay, which constitute 96 % of the total area. The predominant soils are loamy with medium fertility. The total geographical area of the district is 6300.38 km². About 51.1 % of the land area is for agriculture and another 12.3 % land is non-agricultural land. About 12.3 % of the land is barren. About 4 % land is current and other fallow lands.

The normal annual rainfall of the district is 1,131.0 mm, by south west and north east monsoons. The coast line is 28 kilometers in the district on the east facing Bay of Bengal. There are 8 villages and 16 hamlets consisting of 6,993 fishermen. They are all situated in Pusapatirega and Bhogapuram mandals.

Pusapati-rega ($18^0$05'34.95"N and $83^0$33'03.77"E) is a village (Figure 3) and Mandal in Vizianagaram district of Andhra Pradesh, India. Chintapalli is one of the coastal villages in poosapatirega mandal, where the authors carried present work. The village chintapalli (Figure 3) is situated between $18^0$04'N-$83^0$39'E. The village is 1.0km away from the shore line of Bay of Bengal. The present work was limited to an area of 1.0 sq. km only.

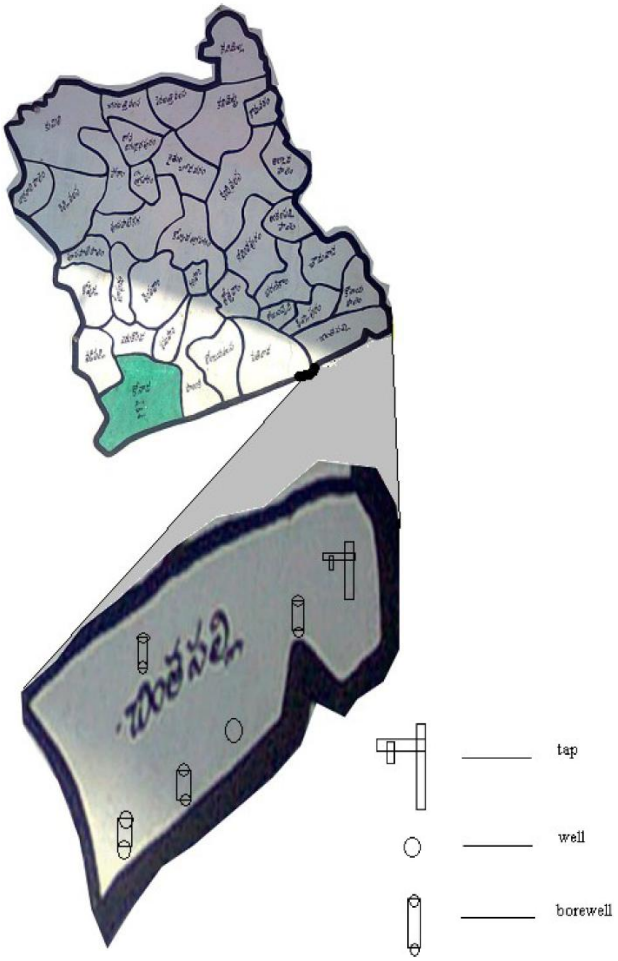

Figure 3 : Chintapalli – area under study

SAMPLING

Six sampling stations were identified in the village including bore wells, open well and panchayt tap water. Composite sampling procedures were carried out for the collection of samples. The samples were collected in clean high quality polyethylene bottles. EC, temperature, pH and DO of the collected samples were measured on the spot. The distance between each of the bore well from the shore line and between themselves is presented in TABLE 1. The present work was carried out from October 2009 to March 2010.

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TABLE 1 : Information about the sampling stations

S. No	Sampling station	Depth (ft)	Distance from shoreline (km)	Purpose
1	B1/street1	90	0.15	Drinking
2	B2/street2	85	0.2	Drinking
3	B3/street/3	90	0.18	Drinking
4	B4/street4	85	0.26	Drinking
5	TW/municipal tap	----	0.25	Drinking
6	WW/ near temple	90	0.14	Drinking

METHODOLOGY

The concentration of chloride ion in water sample was determined by Mohr's method using potassium chromate as indicator. Concentrations of calcium and magnesium were determined by using EDTA with EBT and murexide as indicators. DO of the samples was determined by a DO meter with gold electrode on the spot[4-6].

An ELICO scanning visible spectrophotometer (SL-177) with 1 cm quartz cell was used for the determination of nitrite in the water samples. An ELICO flame photometer (CL-351) is used for the determination of sodium and potassium. For the pH measurements ELICO digital pH-meter (LI-127) and for conductance measurements ELICO conductivity meter (CL-351) was used.

All the chemicals and reagents used were of Analytical grade and the aqueous solutions were freshly prepared by double distilled water.

RESULTS AND DISCUSSION

The results of the analysis of the samples of water by the authors are listed in TABLE 3 and TABLE 4. The mineral composition of sea water is given in TABLE 2. The pH of most of the natural waters fall within the range of 5.5-8.5. Most samples were found to be slightly

TABLE 2 : Main constituents and their concentrations in salt water

Species	Part of salinity %	mmol/ kg
Chloride Cl^-	55.03	546
Sodium Na^+	30.59	468
Sulfate SO_4^{2-}	7.68	28.1
Magnesium Mg^{2+}	3.68	53.3
Calcium Ca^{2+}	1.18	10.4
Potassium K^{2+}	1.11	9.97
Bicarbonate $HCO3^-$	0.41	2.34
Fluoride F^-	0.003	0.068

TABLE 3 : Physical parameters analyzed for the different sampling stations from October 2009 to March 2010

MONTH	SS	pH	t	TDS	EC	NTU	MONTH	SS	pH	t	TDS	EC	NTU
OCTOBER	B1	8.1	19	222	3.52	3	JANUARY	B1	8.1	22	242	3.62	3
	B2	8.6	20	111	2.31	4		B2	8.6	21	138	2.51	4
	B3	8.2	20	72	1.48	2		B3	8.2	22	92	1.68	2
	B4	8.3	21	16	1.1	3		B4	8.3	23	16	1.1	3
	TW	8.5	20	75	1.14	4		TW	8.5	25	86	1.14	4
	WW	7.9	21	20	2.02	3		WW	7.9	24	22	2.22	3
NOVEMBER	B1	8.1	20	232	3.42	3	FEBRUARY	B1	8.2	26	240	3.6	`3
	B2	8.6	19	128	2.21	4		B2	8.5	28	143	2.5	4
	B3	8.2	20	88	1.48	2		B3	8.2	24	90	1.7	2
	B4	8.3	21	16	1.1	3		B4	8.3	27	14	1.1	3
	TW	8.5	19	87	1.14	4		TW	8.6	27	84	1.42	4
	WW	7.9	18	22	2.12	3		WW	7.8	24	18	2.39	3
DECEMBER	B1	8.1	20	212	3.52	3	MARCH	B1	8.3	27	243	3.63	`3
	B2	8.6	19	108	2.41	4		B2	8.6	28	142	2.55	4
	B3	8.2	19	72	1.48	2		B3	8.2	25	92	1.7	2
	B4	8.3	18	16	1.1	3		B4	8.3	27	14	1.13	3
	TW	8.5	19	76	1.24	4		TW	8.7	29	88	1.46	4
	WW	7.9	20	22	2.42	3		WW	8.0	25	18	2.4	3
ISO STANDRDS		7to8.5	---	500	0.5	5			7to8.5	---	500	0.5	5

alkaline. All the pH values of the samples indicated sea water intrusion, as the sea water possesses a pH of 8.2±0.2. The values of turbidity, for the water samples analyzed were found to be in the range of 1.0-5.0NTU. The total phosphates in water samples of the village were found to be 10-19mg/L. The nitrite value in the present investigation was found to be in the range of 0.1-0.3mg/L, which is well within the limit.

TABLE 4 : Analysis report for various chemical constituents of the sampling stations from October 2009 to March 2010.

MONTH	SS	THW	Ca	Mg	Na	K	Fe	NO_2^-	PO_4^{3-}	F^-	DO	Cl-	FRC
OCTOBER	B1	860.4	310.2	550.2	100.8	58.0	28	0.3	19	0.4	5.5	905.2	NIL
	B2	610.6	225.2	385.4	95.2	40.0	26	0.3	19	0.4	5.2	345.2	NIL
	B3	200.8	140.6	60.2	80.5	32.1	28	0.2	18	0.2	5.3	168.2	NIL
	B4	215.4	70.4	145.0	65.2	18.5	26	0.2	18	0.2	5.5	80.5	NIL
	TW	215.7	145.7	70.0	85.8	19.0	26	0.3	19	0.2	5.2	155.5	0.1
	WW	440.5	220.5	220.0	101.0	74.8	28	0.3	18	0.4	5.5	398.2	NIL
NOVEMBER	B1	858.2	307.1	551.1	118.0	61.0	28	0.3	19	0.4	5.5	920.2	NIL
	B2	623.4	230.0	393.4	96.2	40.0	26	0.3	19	0.4	5.2	354.1	NIL
	B3	207.2	146.0	61.2	85.5	31.0	28	0.2	18	0.2	5.3	179.5	NIL
	B4	215.4	70.4	145.0	67.8	18.8	26	0.2	18	0.2	5.5	89.0	NIL
	TW	217.0	147.0	70.0	88.4	19.0	26	0.3	19	0.2	5.2	161.0	0.2
	WW	455.1	229.5	225.6	100.4	75.2	28	0.3	18	0.4	5.5	394.2	NIL
DECEMBER	B1	865.2	309.2	556.0	122.0	65.0	25	0.3	18	0.3	5.1	925.7	NIL
	B2	631.0	234.0	397.0	101.0	43.0	27	0.2	15	0.2	5.2	361.2	NIL
	B3	216.0	151.0	65.0	91.0	34.0	27	0.2	17	0.4	5.5	185.0	NIL
	B4	226.9	75.5	151.4	72.7	20.6	29	0.2	18	0.2	5.1	93.0	NIL
	TW	224.2	151.2	73.0	92.2	21.0	25	0.2	17	0.3	5.3	167.0	0.1
	WW	465.2	235.0	231.2	105.1	81.0	28	0.3	18	0.4	5.5	398.0	NIL
Standards		300.0	100.0	70.0	20.0	10.0	3.0	<1.0	----	<1.2	4.0- 7.0	250.0	0.1-0.2
JANUARY	B1	864.1	310.1	554.0	122.1	65.0	25	0.3	19	0.4	4.8	925.1	NIL
	B2	631.6	235.6	396.0	100.0	44.0	28	0.2	19	0.4	5.2	360.0	NIL
	B3	215.0	150.0	65.0	90.2	32.0	28	0.3	19	0.2	5.2	184.0	NIL
	B4	227.0	75.0	152.0	72.1	20.0	31	0.2	16	0.2	5.5	94.1	NIL
	TW	223.0	151.0	72.0	93.4	21.3	26	0.2	19	0.4	4.9	166.0	0.1
	WW	466.0	236.0	230.0	105.6	80.1	29	0.3	19	0.4	5.5	398.0	NIL
FEBRUARY	B1	888.4	322.4	566.0	130.0	72.0	21	0.2	12	0.4	4.9	930.8	NIL
	B2	649.0	243.4	405.6	180.0	55.0	25	0.1	16	0.2	5.2	370.0	NIL
	B3	235.0	161.0	74.0	97.0	40.0	25	0.3	19	0.4	5.1	192.4	NIL
	B4	244.2	81.0	163.2	82.0	25.0	28	0.2	21	0.4	5.2	106.0	NIL
	TW	241.0	160.0	81.0	102.1	30.2	22	0.2	10	0.4	5.0	176.0	0.1
	WW	484.0	244.0	240.0	116.3	89.0	26	0.2	18	0.2	5.5	405.2	NIL
MARCH	B1	890.7	323.8	566.9	130.2	71.0	22	0.2	10	0.4	4.8	936.9	NIL
	B2	647.7	242.9	404.8	107.0	54.0	25	0.1	18	0.2	4.9	371.2	NIL
	B3	234.9	161.9	73.0	99.6	39.0	26	0.3	19	0.4	5.2	194.4	NIL
	B4	243.8	80.9	162.9	83.8	26.0	28	0.2	22	0.4	5.1	106.0	NIL
	TW	242.9	161.9	81.0	103.3	30.0	22	0.2	10	0.2	5.0	176.7	0.1
	WW	484.0	242.0	242.0	115.7	88.0	25	0.1	18	0.2	5.3	406.6	NIL
Standards		300.0	100.0	75.0	20.0	10.0	3.0	<1.0	-----	<1.2	4-7	250.0	0.1-0.2

FRC- Free residual chlorine

The water samples collected from the village under study were found to have electrical conductivity values from 1100-3630µMhos/cm. The water samples collected from the village showed TDS=16-243mg/L, total hardness= 200-888.4mg/L, calcium=70.4-323.8mg/L, magnesium=60.2-566.9mg/L. The values of total hardness, calcium and magnesium were showing large deviation from the standard permissible limits. The higher values of magnesium indicate that there may be a provision for the intrusion of salty water into the fresh waters of the village, as magnesium is the second highest abundant element in salt water next to chloride. From the present investigation, the ratio of Mg to Ca was also found to be higher than the standard value of 1.0. So, the water is not recommended potable by the authors, due to higher levels of calcium and magnesium.

In the present investigation, the concentration of chloride in the water samples was found to in the range of 80.5-936.9mg/L. For the various samples analyzed the concentration of chloride ion was found to be higher than the prescribed value of 250mg/L. Chloride ion in drinking water is generally not harmful to human beings within limits. To study the reason for the increased levels of chloride ion in ground water, the authors analyzed the free residual chlorine (FRC), in each of the samples collected. The value of free residual chlorine in

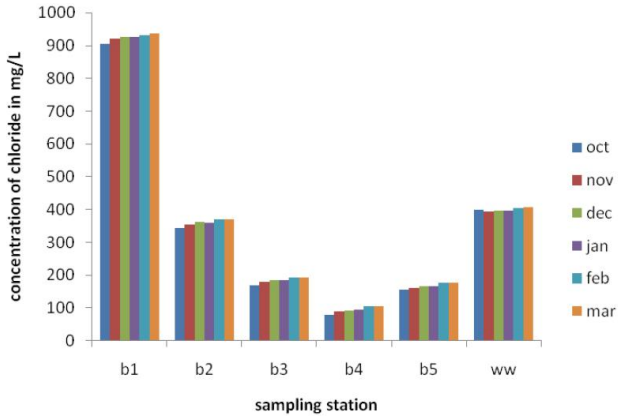

Figure 4 : Varitions in concentration of chloride in different months

the water samples collected from bore wells was found to be nil, whereas the same in panchayat tap water was 0.1mg/L, which lies in the range of standard value. Since it was observed that the concentration of free residual chlorine in the waters of bore wells, the reason for the increased concentration of chloride may be due to the intrusion of salt water into the ground water of the village. The variations in the concentration of chloride in various months were shown in figure 4. The first trend (chloride ion concentration at a given site may increase) was observed in the village. The concentration of chloride was found to be higher, regardless of the season and time of collection.

CONCLUSION

All the above reports indicated the sea water intrusion into the fresh waters of the village, since the free residual chlorine is nill in the water analyzed was found to be nil in all the bore wells.

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