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RESEARCH ARTICLE

HYDROCHEMICAL ANALYSIS OF GROUND WATER SAMPLES OF COASTAL REGION OF SRIKAKULAM DISTRICT, ANDHRA PRADESH, INDIA

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Abstract

In this study, ground water quality data for 12 physical and chemical parameters collected from 11 monitoring stations were analyzed. Water quality modelling software Aquachem, surfer and ArcGIS9.1 was used to analyse data set. The results revealed highly variable hydrochemistry. The groundwater recorded a wide range in TDS. For the major anions, the chloride is found to be most predominating. The major elements data were plotted on Piper′s diagram for working of hydrochemicalfacies. The pH part of the Durov diagram reveals that groundwater in study area is alkaline and electrical conductivity of most of samples lies in the range of drinking water standards. From the SAR and conductivity plot it was found that most of groundwater cannot be used on soil without restricted drainage and special management for salinity control.

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Introduction:

In many coastal towns or cities, groundwater seems to be the only source of freshwater to meet domestic, agricultural and industrial needs. Groundwater is an important water resource in both the urban and rural areas of srikakulam but in the rural, pipeborne water is also available. Basically rural dwellers rely on hand-dug wells for potable water supply as the streams usually dry up in dry season. These resources are under threat from pollution either from human life style manifested by the low level of hygiene practiced in the developing nations [1-3]. But groundwater is under constant threat of saline water incursion, which seems to have become a worldwide concern (4). Environmental health involves all the factors, circumstances and conditions in the environment or surroundings of humans that caninfluence health and wellbeing. The neglect of rural areas in most developing countries in terms of basicinfrastructures such as pipe-borne water and sanitationfacilities, expose the villagers to a variety of health related problems such as water – borne diseases [5].

In this study, the levels of some physical and chemical water quality parameters in hand-dug wells located in the residential areas and in thevicinities of rural settlement, srikakulam districtsoutheast AP, were assessed.

Study Area:-

The study area lies between 18°10′ N and 18°22′ N latitudes and 83°70′E and 83°89′E longitudes (Figure 1) wide range of 70 kms in etcherlamandal, srikakulamdistrict,Andhrapradesh. The northern and southern boundaries of the

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basin are defined by the Pddagadda and Mahendratanaya Rivers which confluence into Bay of Bengal. Major part of the study area is devoted to agricultural activities, which include paddy and cashew cultivation.

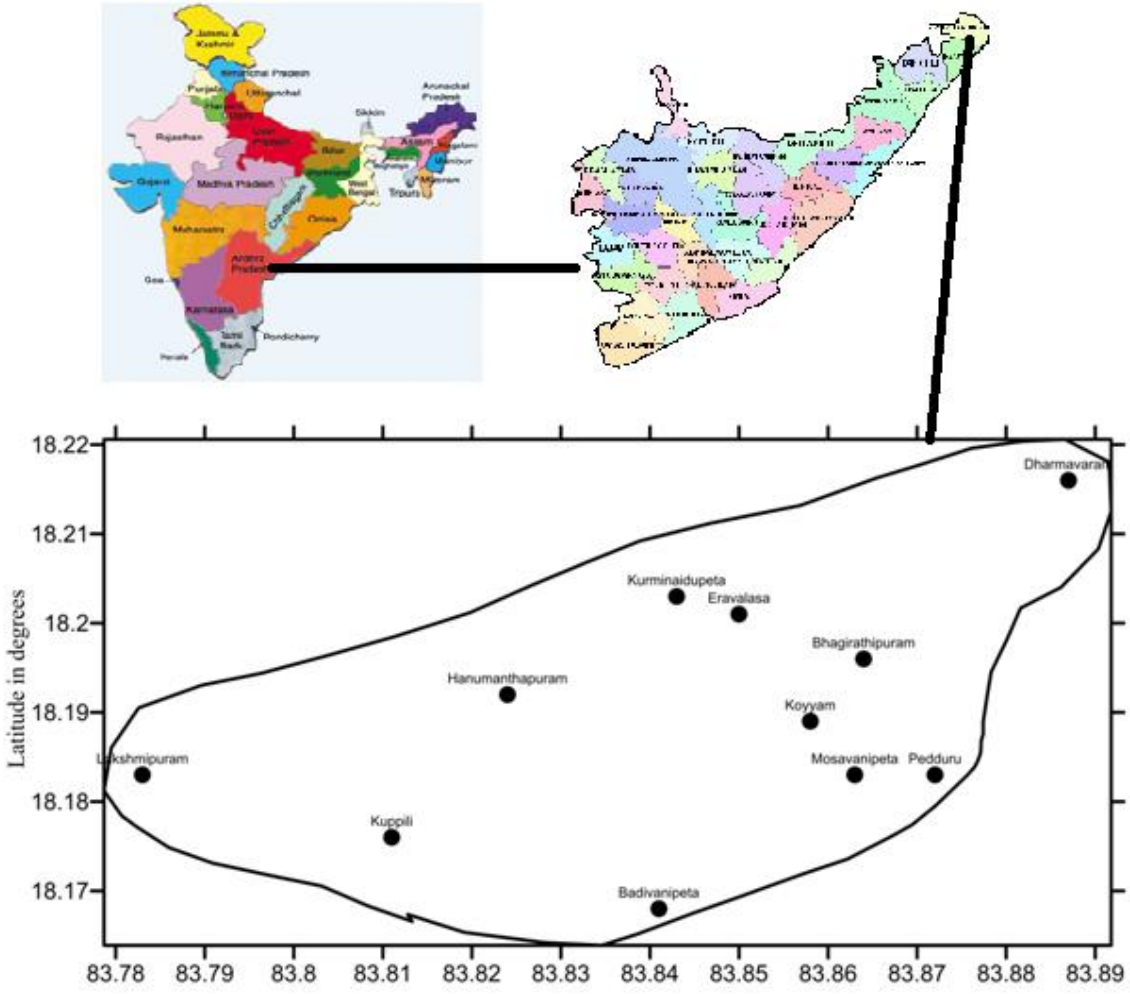

Figure 1:- shows the map of the study area.

Materials and methodology:

Groundwater samples were collected after well inventory survey from 11 representative wells during July 2015 (Figure 1). The samples were collected after 10 min of pumping and stored in Poly Ethylene bottles at 25°C. Immediately after sampling, pH and electrical conductivity were measured in the field. Total dissolved solids (TDS) were calculated from EC multiplied by 0.64 (Brown, Skougstand, & Fishman, 1970). Nitrate (NO_3)andortho-phosphate (PO_4) by spectrophotometer, sulphate (SO_4) analysedusing Nephelometer, sodium (Na) and potassium (K) studied by flame photometer, bicarbonate (HCO_3), calcium (Ca), and Total hardness (TH) were determined by volumetric methods. High purity analytical reagents were used throughout the study, and chemical standards (Merck, Germany) for each element were prepared separately.

Table 1:- Analytical Data for the Water Samples.

S. No	sample ID	longitude	latitude	type of well	pH	EC	TDS	NO_3	Mg	Ca	TH	Cl	HCO_3	Na	K	SO_4
1	Dharmavaram	83.887	18.216	Open well	8.1	4490	2873.6	36.42	61.31	183	696.71	1680	521	649.00	28.2	340.93
2	Bhagirathipuram	83.864	18.196	Bore well	7.3	730	467.2	33.64	38.68	91	380.86	370	139	199.00	15.2	38.09
3	Pedduru	83.872	18.183	Open well	8.2	3700	2368	12.73	25.69	60	251.90	1330	264	535.80	26.1	285.94
4	Mosavanipeta	83.863	18.183	Open well	8.0	2300	1472	24.96	50.02	80	402.09	790	248	372.80	25	214.36
5	Koyyam	83.858	18.189	Bore well	6.9	1440	921.6	20.71	38.36	92	381.92	400	144	190.14	14.2	67.91
6	Badivanipeta	83.841	18.168	Bore well	7.9	3400	2176	20.26	32.36	152	500.72	1120	276	411.00	27.68	253.04
7	Kurminaidupeta	83.843	18.203	Open well	7.1	1020	652.8	38.63	35.69	88	361.10	360	132	198.90	11.6	111.14
8	Kuppili	83.811	18.176	Open well	6.9	790	505.6	12.78	16.86	77	255.60	270	348	301.90	16.4	145.56
9	Lakshmipuram	83.783	18.183	Bore well	7.2	520	332.8	11.60	36.00	72	324.00	190	108	117.10	8.2	61.20
10	Hanumanthapuram	83.824	18.192	open well	7.0	1520	972.8	16.73	31.34	61	278.03	330	208	267.32	11.28	98.75
11	Eravalasa	83.850	18.201	Bore well	6.8	2210	1414.4	60.37	29.20	56	257.02	610	224	383.37	12.89	35.87

Electrical Conductance:-

Electrical conductance (EC) is the conductance of one centimetre cube of the substances and is represented in micromhos/cm at 25ºc. The presence of ions in solution increasesconductivity of water. The ECof water samples from the study area varies between 520 to 4490micromhos/cm.

Total Dissolved Solids (TDS):-

TDS is defined as the residue of filtered water sample after evaporation. The bulk TDS include bicarbonates, sulphates and chloride of calcium, magnesium,sodium, potassium, silica, potassium chloride, nitrate and boron. According to Hem (1959) [6] TDS was calculated using the relationship given below TDS (in ppm) = 0.64 * EC (in micromhos/cm).Analysis of water samples of the study area revealed that the presence of TDS varies between .333 to 2874 ppm. Among all, only dharmavaramsample exceeds the limit due to brackish water.Subsequently, four classes of water were proposed based on the procedures adopted from Carroll (1962) [7] and is givenin Table **2** which confirms majority of samples belongs to fresh water category.

Table 2:- Water Quality Classification Based on TDS Content byCarroll (1962).

TDS in ppm	Water Quality
0 -1000	Fresh water
1000 – 10, 000	Brackish water
10, 000- 100, 000	Salty water
> 100, 000	Brine

Results and Discussions

Chemical Constituents:-

Calcium:

Calcium is a major constituent of igneous rocks. The major sources of calcium in ground water around basalts are plagioclase and pyroxene. The range of calcium content in ground water is largely dependent on the solubility of calcium carbonate, sulphide and rarely chloride. The maximum acceptable limit of calcium for domestic use is 75ppm [8]. The calcium content of the water samples were estimated by EDTA titration method. The water samples ($500cm^3$) were acidified with 10 cm^3 of concentrated nitric acid and concentratedto 25 cm^3 using evaporation method [9]. After chelation, extraction and subsequent mineralization, calcium ionwas determined by atomic adsorption spectrophotometer. The range of calcium varies from 56 to 183 ppm. All samples are within range.

Magnesium:

Magnesium is an important constituent of basalt. It's solubility in water is around five times that of calcium. Calcium and Magnesium together cause the hardness of water. EDTA titration was used to determine the magnesium concentration in the samples. The range of magnesium varies from 16.86 to 61.3 ppm. All samples are within range of Mg limit.

Sodium:

Sodium is an important constituent for determining the quality of irrigation water. Sodium bearing minerals likealbite and other members of plagioclase feldspars, naphthalene and sodalite weather to release the primary soluble sodium products. Most sodium salts are readily soluble in water, but take no active part in chemical reactions. Sodium has wide variations in its concentration in ground water. The sodium content of the samples was determined by a flame photometer. Sodium content in the water samples varies between 117
to649 ppm.Majority of collected water samples shows exceed limit range because of the wells are near to the sea.

Potassium:

Although potassium is nearly as abundant as sodium in igneous rocks, its concentration in ground water is comparatively very less as compared to sodium (nearly one-tenth or one-hundred that of sodium). This is due to the fact that the potassium minerals are resistant to decomposition by weathering. The potassium concentration in the water was determined with the help of Flame photometer. Analysis of water samples in the study area indicates that potassium value varies between 8.2 to 28.2 ppm. Half of the water samples lies in the potassium acceptable limit.

Chloride:

Chloride ion is a predominant natural form of chlorine and is extremely soluble in water. The major sources of chloride in natural water are sedimentary rocks particularly evaporates. Igneous rocks contribute only a fraction of total chloride. Other sources are industrial and domestic wastewater. The limit for domestic purposes is fixed at 250mg dm^{-3} [10]. The chloride content in the samples was determined by using 0.1N AgNO3 solution. In the present study chloride ion content in all the ground water samples ranged from 190 to 1680 ppm. Among 11 collected water samples, pedduru, mosavanipeta and badivanipeta shown high content of chloride due to effect of cashew industries more.

Sulphate:

The sulphate content in the atmosphere precipitation is only about 2ppm, but a wide range in sulphate content inground water is made possible through reduction, precipitation, solution and concentration. The primary mineralsources of sulphate ions include evaporate minerals such as calcium, gypsum and sulphates of magnesium and Sodium. The sulphate concentrations in the water samples were determined by Nephelometer and results revealed that all analysed samples in permissible limit. The sulphate content in the samples varies between 35.9 to 340.9 ppm.

Total Hardness (TH):

Hardness is often referred to as the soap consuming property of water. Hardness may be divided into two types,carbonate and non-carbonate. Carbonate hardness includes portions of calcium and magnesium, and certain amount of bicarbonates. Total hardness is defined as TH= (2.497*Ca + 4.11*Mg); where Ca and Mg are expressed in ppm [11]. Totalhardness of the study area varies between 85.06 to 551.34ppm. Classification of water was done based on hardnessgiven by Sawyer (1960) [12] and is listed in Table **3** suggested that all water samples in the category of hard.

Table 3:- Water Classes Based on Hardness by Sawyer (1960).

Hardness as CaCO3	Water Class
0 -75	Soft
75- 100	Moderately hard
150 – 3000	Hard
> 3000	Very hard

Chemical Parameters

Hydrogen Ion Concentration (pH):

The pH of a solution is defined as the negative logarithmicof the ion concentration and is normally expressed inmoles per liter at a given temperature. pH of a solution canaffect the toxicity of other elements and has very pronouncedeffect on many chemical reactions which are important toindustry, irrigation and domestic water treatment. Thisalso accelerates the corrosion rate of metallic substances inwater. The pH value was determined in the field using a pHpaper and the values vary between 6.8 to 8.2

Piper Trilinear Diagram:

In the present study, various cations and anions compositions of many samples were represented by drawing piper trilinear diagram [13]. This diagram permitted the cations and anions compositions of many samples by representing on a single graph in which major groupings or trends in the data can be discerned visually. Because of each analysis is represented by a single point, water with very different total concentrations can have identical representations on this diagram (Fig. **2**). After plotting cations and anions of eleven analyzed samples in the piper diagram, it can be observed that the plots mostly fall in sodium, Magnesium and Chloride field.

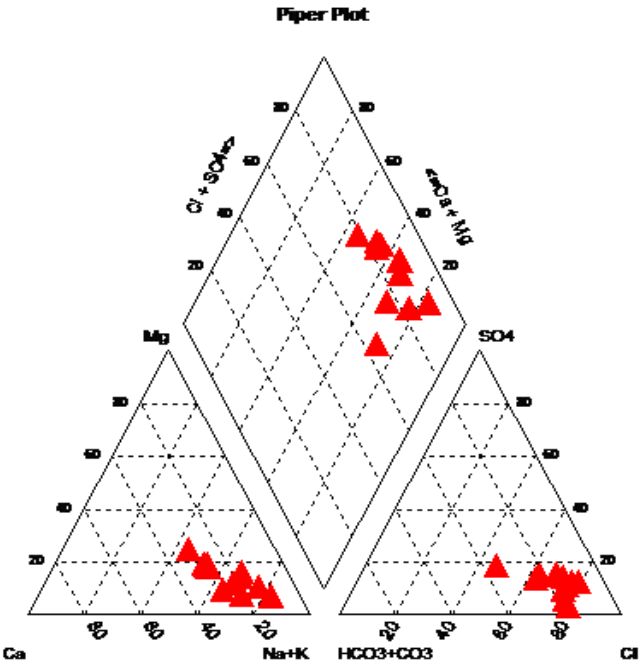

Figure 2:- shows the piper diagram for the various cations and anions composition of the water samples

Water Quality for Domestic Purposes:

Drinking water standards recommended by world health organization [8], Public Health Examination (PHE) Committee of Govt. of India (1963) and Indian Council of Medical Research (ICMR, 1975) [13-15] are given in Table **5**. It also list down the range of concentration of substances in the water samples of studied area. Water quality problems in irrigation include salinity and toxicity. The total dissolved solids content gives the salinity hazard of irrigation water. Presence of excessive sodium content in water makes it unsuitable for irrigation purposes. The sodium hazard in irrigated water is expressed by determining the sodium adsorptionratio (SAR) as stated below

SAR = Na/ sqrt ((Ca + Mg)/2)

In which, the concentrations are expressed in milliequivalents per liter and function 'sqrt' is used for determination of square root. The sodium concentration in water was calculated and is expressed in terms of percentage of sodium and is given by

%Na= ((Na + K)*100 / (Na + Ca + Mg + K))

Where, all ionic concentrations are expressed in milliequivalents per liter. Increase in percentage of sodium makes water unsuitable for irrigation purposes. The US Ionic Regional Salinity Laboratory has constructed a diagram for classifying irrigation water with reference to Sodium Adsorption ratio as an index for sodium hazards and EC as an index for salinity hazard.

Table 4:- Drinking Water Standards Recommended by World Health Organization (WHO, 1971), Public Health Examination (PHE) Committee of Govt. of India (1963) and Indian Council of Medical Research (ICMR, 1975) Along with the maximum Concentration of Substances from the Water Samples of Study Area

Chemical Constituents (ppm)	**WHO Std.**		**PHE Std.**		**ICMR Std.**		**Maximum Concentration in the Study Area**
	A	**B**	**A**	**B**	**A**	**B**	
Calcium	75	200	75	200	75	200	183
Magnesium	30	150	50	150	50	100	61.3
Chloride	200	600	250	1000	200	1000	1680
Sulphate	200	400	250	400	200	400	340.9
TH	100	500	300	600	300	600	696.7
TDS	500	1500	500	1500	500	1500	2873.6

a = maximum acceptable limit b= maximum allowable limit

Sodium Hazard:

According to the US Ionic Regional Salinity Laboratory, alkanity hazard classes are described as follows Table **5**:

1. Low sodium water (s1): It can be used for irrigation purpose for all types of soils with little danger of development of harmful level of exchangeable sodium.
2. Medium sodium water (s2): It represents an appreciable amount of sodium hazards in fine textured soils.These soils constitute higher cations exchange capacity especially under low leaching conditions. This water can be used for coarse textures organic soil with good permeability conditions.
3. High sodium water (s3): It may produce harmful levels of exchangeable sodium in most soils.
4. Very high sodium water (s4): it is unsatisfactory for irrigation purposes, except at the salinity level.

According to this depict most of the water samples benign for irrigation with good permeability conditions except pedduru, mosavanipeta and badivanipeta water samples.

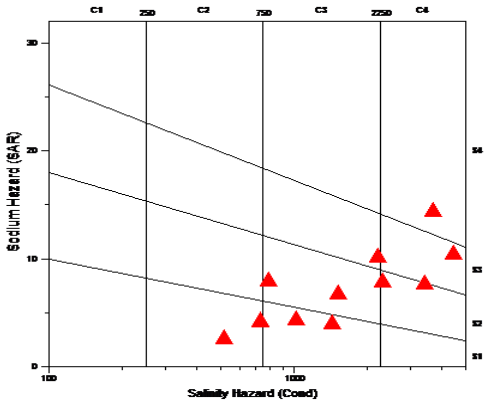

Figure 3:- shows the sodium hazard of the water samples.

Table 5:- Quality of Water Based on SAR by US Ionic Regional Salinity Laboratory

Alkalinity	SAR (meq/l)	Remark on Quality
S1	10	Excellent
S2	10-18	Good
S3	18-26	Doubtful
S4	>26	Unsuitable

Durov Diagram:-

Durov, (1948) introduced another diagram which provides more information on the hydrochemicalfacies by helping to identify the water types and it can display some possible geochemical processes that could help in understanding quality of groundwater and its evaluation. The diagram is a composite plot consisting of 2 ternary diagrams where the cations of interest are plotted against the anions of interest sides form a binary plot of total cationvs. total anion concentrations expanded version includes electrical conductivity (µS/cm) and pH data added to the sides of the binary plot to allow further comparisons. The Durov Diagram for the major cations and anions was plotted using AquaChem software as given in Figure 4. The Duorv plot for groundwater samples indicates that the pH part of the plot reveals that gropundwater in study area is alkaline which is preferred for drinking. The electrical conductivity of most of groundwater samples lies in the range of drinking water standards adapted in srikakulam district, Andhra pradesh.

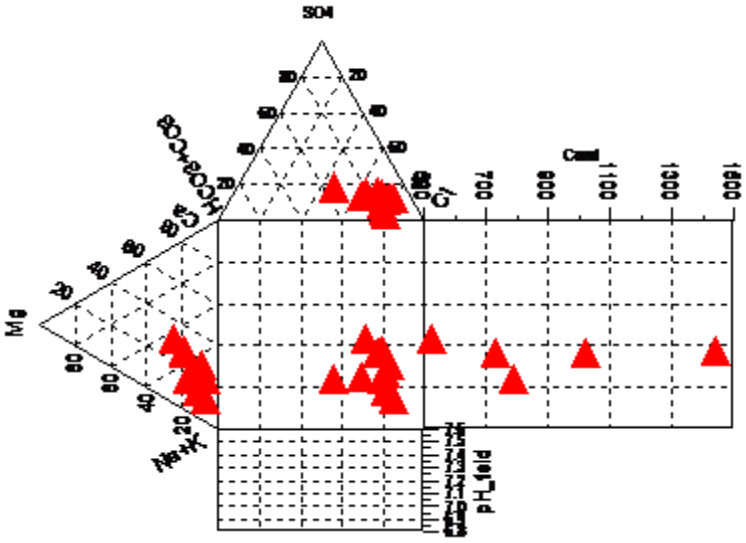

Figure 4:- shows the Durov diagram of the water samples.

Conclusion:-

During last decades Pressure on groundwater was increased continuously with population and water demands. In the present study, 11 ground water samples were collected from 11 villages in srikakulam District of Andhra pradesh. Groundwater major ions of the coastal aquifers indicate that the groundwater quality is safe in the central part, but it is not safe for consumption/irrigation purposes towards the coastal line. Thereare two distinct groundwater types, i.e., freshwater and saline water, but the salinity strength nearby the canal and sea is increasing over time. Representative ionic ratios, such as Mg^{2+}/Ca^{2+},$Cl^{-}=HCO_3^{-}$, Ca^{2+}/Na^{+} and TDS levels, differentiate groundwaterstrongly which is affected by the saline/seawater intrusion from that not or less affected. Interpretation of hydro-chemical analysis reveals that: -The pH values range between 6.8 and 8.2 Geochemistry of groundwater displays Na>Ca>Mg>K and HCO_3>Cl>SO_4 trend. The major elements data were plotted on Piper′s diagram indicated that the plots mostly fall in sodium, Magnesium and Chloride field.

Out of 11 groundwater samples, only 4 samples have shown TDS values more the maximum permissible limit. The Durov plot for groundwater samples indicates that most of the samples pH is alkaline and EC of most of groundwater samples lies in the range of drinking waterwithcomparisons of data (WHO 2011) standards for drinking

water indicate that the groundwater in the most of study area are suitable for drinking purposes except some few places.

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