Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(12):464-470

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Spatial distribution of hydro-chemical groups of groundwater in different geological and geomorphic settings in various sub-basins of Sarada River Basin, Visakhapatnam, India

M. Sujatha[1]*and T. Satyanarayana[2]

[1]*Department of Environmental Sciences, K. L. University, Vaddeswaram, Guntur District, Andhra Pradesh*
[2]*Department of Civil Engineering, S. R. K. Institute of Technology, Enikepadu, Vijayawada, Andhra Pradesh*

ABSTRACT

The present paper deals with the study of different Hydro chemical groups of ground water in Sarada River Basin (SRB). The ground water samples were collected from dug wells and bore wells which were analyzed for cations and anions in different sub-basins of the study area. The SRB was divided into six sub-basins for the purpose of the study. Different hydrochemical groups namely sodium bicarbonate, magnesium bicarbonate, sodium chloride, calcium bicarbonate, sodium sulphate and magnesium chloride, according to their dominant cations and anions, were observed and studied in different types of rock formations, soil groups, geomorphic settings, slopes and ground water aquifers in the area of the investigation. The hydrochemical data indicated that the ground water was contaminated in the southern part of lower Sarada River Basin by sub-surface sea water intrusion, pollution due to the industrial wastes discharged by existing sugar factories and chemical contamination due to over use of fertilizers and further, due to the heavy use of pesticides in the said areas of intensive irrigation. In many locations, maximum parameters were within the permissible limits and some were beyond the limits of drinking water standards. However most of the ground water of the SRB was found suitable for drinking, irrigation and industrial purposes.

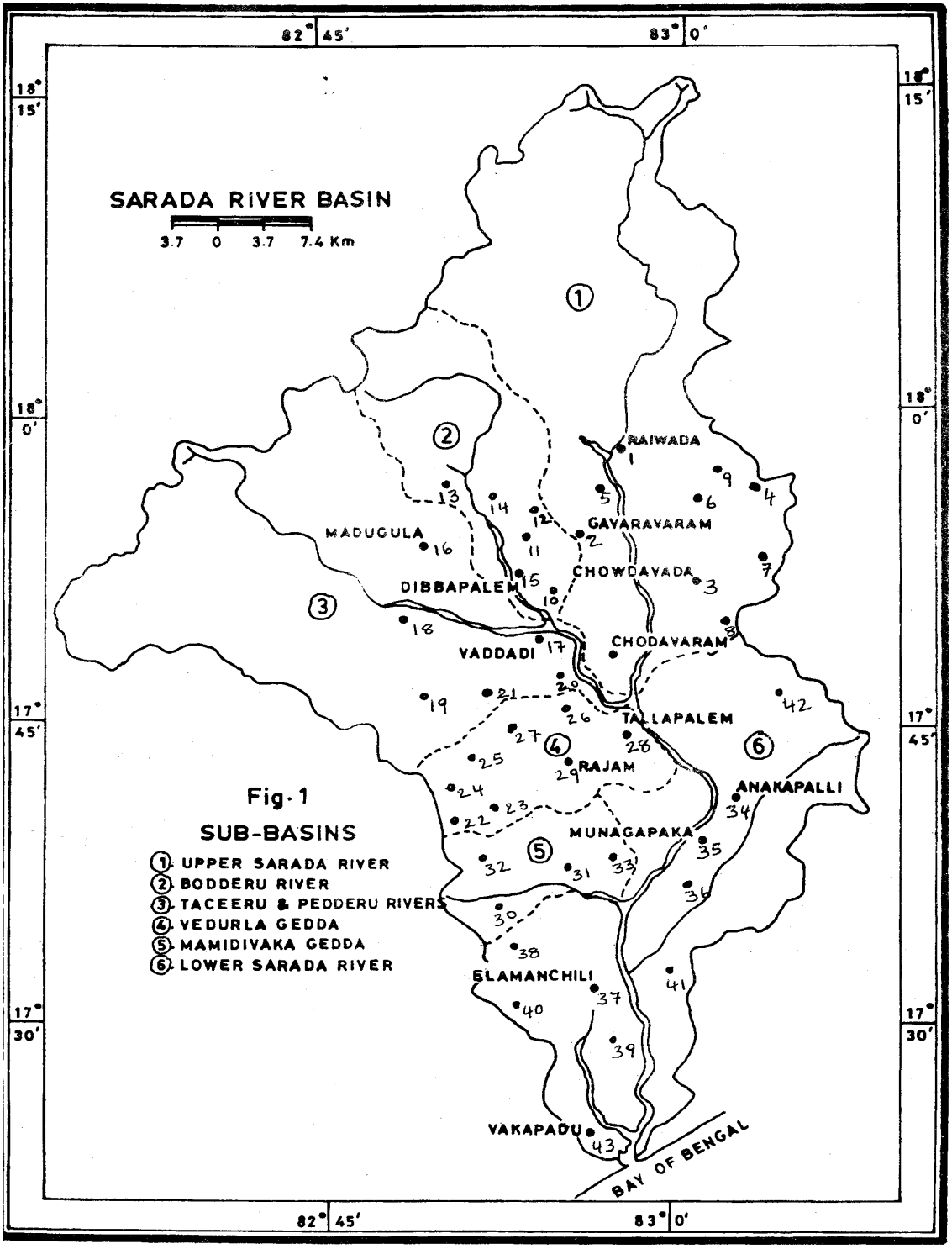
Key words: Hydro-chemical groups, six sub-basins, geological settings, slopes, soils, and groundwater tables.

INTRODUCTION

Agriculture and industries consume large quantities of water for their purposes and discharge their effluents on the adjoining areas without pretreatment. Salinity occurs in the coastal aquifers, where sea water moves inland, if ground water levels decline. It fluctuates by the influences of several factors like precipitation, over exploitation of fresh groundwater, tidal waves and deforestation. Rapid corrosion of steel pipes of pump-sets and drop in crop yield are caused by saline water[1]. Thus the present study area Sarada River Basin has under taken to evaluate the status of ground water in different geological and geomorphic features for human use in and around six sub-basins of SRB.

Study Area:

The Sarada River Basin is located in Vishakhapatnam District of Andhra Pradesh. The River originates in the Madugulakonda and passes through Narasipatnam plains and Vishakhapatnam coast, which are parts of Eastern Ghats. The Sarada River Basin covers under Survey of India toposheet numbers $65\frac{J}{16}$, $65\frac{K}{13}$,$65\frac{K}{14}$,$65\frac{K}{15}$,$65\frac{N}{4}$, and $65\frac{O}{1}$. The river basin lies between latitudes 17^0 25' and 18° 17' N and Longitudes 82° 13' and 83° 05'E.The total area of the basin is 2590 sq.km, in which the actual study area is 1140 sq.km. There are two sugar factories located on the river Sarada, one at Govada and the other at Tummapala."Jaggery" is the biggest cottage industry of Anakapalli town in the Sarada River Basin area.



The geological formations in the river basin consist of Khondalite group of rocks (65%), granite gneisses (20%), charnockites (10%), and quartzites (5%) of Archean age[2]. Charnockite group of rocks are found interbeded with khondalite group of rocks in the most of the basin area. The soil groups of the area are loamy soils, claey soils and red soils. The average rainfall of the basin area is about 1000mm. The basin has been divided into six sub-basins for the present study of hydrochemistry namely upper Sarada, Bodderu river, Tacheru and Pedduru, Vedurlagedda, Mamidivaka gedda and lower Sarada River. Along with sub-basins, major towns or sampling locations were also marked in Fig(1) for study purpose. The list of sampling locations (villages) and their ground water levels in open and bore wells in various sub-basins of the Sarada River Basin is given in Table 1.

Table-1: Ground water levels in open and bore wells in various locations of Sarada River Basin

Subasin - I			Subasin - II			Subasin - III		
S No.	Location	Water Level (bgl)m	S No.	Location	Water Level (bgl)m	S No.	Location	Water Level (bgl)m
1	Raiwada	3.00	10	D Suravaram	2.30	16	Madugula	5.00
2	Gavaravaram	1.50	11	Appalaraju Palem	3.00	17	Vaddadi	2.80
3	Chowdavada	1.30	12	Siripuram	3.50	18	Murapaka	3.50
4	Gullapali	4.00	13	Konam	2.80	19	Ramajogipalem	4.00
5	Annavaram	2.30	14	Jampana	1.50	20	Jannnavaram	1.80
6	Alamanda	3.80	15	Dibbapalem	1.00	21	Guddipa	6.00
7	Adduru	4.00						
8	Narasapuram	5.20						
9	Varada	3.80						

Table - 1 :(continue)

Subasin - IV			Subasin - V			Subasin - VI		
S No.	Location	Water Level (bgl)m	S No.	Location	Water Level (bgl)m	S No.	Location	Water Level (bgl)m
22	Seethaiahpet	2.60	30	Kannurupalem	3.10	34	Anakapalli	1.80
23	Turakalapudi	3.50	31	mamidivaka	1.80	35	munagapaka	1.40
24	Neelakantapuram	1.80	32	Govada	2.10	36	peddapudi	2.30
25	ithampudi	5.10	33	Tallapalem	2.80	37	Elamanchili	1.50
26	Timmannapalem	3.20				38	Vemagiri	4.60
27	Jamathullapalem	4.10				39	Murakada	1.20
28	Tallaplem	2.60				40	Kotturu	3.00
29	Rajam	5.90				41	T Jampanapalem	2.80
						42	Narapadu	4.80
						43	Vakapadu	1.60

bgl:b**elow the **g**round **l**evel*

EXPERIMENTAL SECTION

During field survey, forty three ground water samples from the existing dug wells and bore wells , from various locations of six sub-basins of Sarada River Basin , that lie below an altitude of 80 meters above MSL were collected. Two liters of ground water collected in plastic containers with necessary precautions[3]. The collected water samples were analyzed for cationic and anionic chemical parameters such as Ca^{++},Mg^{++},Na^{+},K^{+},Cl^{-},CO_3^{2-},$HCO_3^{-}$and SO_4^{2-} were evaluated as per the standard procedures[4].The ground water samples were grouped according to their dominant cations and anions[5-7]. The six observed hydrochemical groups in the order of abundance such as 1.Sodium Bicarbonate- ($NaHCO_3$), 2.Magnesium Bicarbonate- Mg $(HCO_3)_2$, 3.Sodium Chloride – (Nacl), 4. Calcium Bicarbonate- Ca $(HCO_3)_2$ 5.Sodium Sulphate-(Na_2SO_4) and 6. Magnesium chloride- ($MgCl_2$) were found in the area of investigation. The geographic distributions of different chemical groups were shown in the fig (2). All parameters were expressed in milli equivalents of TDS per liter.

Table 2: Distribution of cations and anions in ground waters of various sub-basins in Sarada River Basin

S.No.	Name of the sub-basin	Range	Cations (m.eq/lit)			Anions (m.eq/lit)				
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{2-}	CO_3^{2-}	SO_4^{2-}
1.	Upper Sarada River	Max	4.6	15.2	37.4	0.6	11.2	12.8	2.5	0.1
		Min	o.6	0.2	0.5	0.02	0.6	1.2	0.5	0.02
2.	Bodderu river	Max	3.8	6.3	13.0	0.6	17.2	12.7	2.5	6.9
		Min	0.4	0.2	1.7	0.05	1.1	1.9	0.3	0.7
3.	Tacheru and pedduru	Max	4.2	7.1	23.0	0.6	21.6	15.2	8.3	14.4
		Min	0.4	0.3	0.8	0.02	0.1	2.1	0.6	0.04
4.	Vedurla gedda	Max	4.0	10.7	23.0	0.6	20.0	8.7	1.3	3.2
		Min	0.8	0.2	1.8	0.02	1.0	2.2	0.5	0.04
5.	Mamidivaka gedda	Max	9.8	9.1	23.5	0.2	34.4	8.7	2.5	7.6
		Min	1.0	1.0	4.2	0.02	1.2	3.3	0.5	0.5
6.	Lower Sarada River	Max	17.6	14.7	49.8	1.6	70.0	12.2	33.3	29.1
		Min	0.2	0.2	0.8	0.02	0.4	1.2	0.3	0.2

RESULTS AND DISCUSSION

The ranges of hydro-chemical data from six sub-basins of Sarada River Basin were presented in Table 2.

1. Sodium Bicarbonate Group –($NaHCO_3$):

This group is present in ground water samples with a wide range of salinity varying from 9.97 to 69.61 m.eq of TDS/lit. The ionic relationship of the group is $Na^{+}>Ca^{2+}>Mg^{2+}$ and $HCo_3^{-}>Cl^{-}>SO_4^{2-}$. The analytical data shows

that 21(48.3%) ground water samples identified in this sodium bicarbonate group. The sodium bicarbonate water group is more wide spread and dominant in the northern part of the basin. These waters are observed around Vaddadi to the north of Chodavaram, Munagapaka to the south of Anakapalli and to the west of Tallapalem. Increase of salinity is observed at Gavaravaram and Munagapaka.

This hydrochemical group is dominant in khondalite group of gneissic rocks [8].This group of waters mainly seen in substratum with sandy soils as top soil cover. Flood plains, and palaeo-channels have these waters. Shallow aquifers predominantly contain these water.

2. Magnesium Bicarbonate group –$Mg(HCO_3)_2$:

This group is present in ground water samples with a range of salinity between 9.80 and 32.89 m.eq of TDS/lit. The analytical data indicates that 4 (9.3%) ground samples fall in this group. Magnesium is the major cation, while calcium and sodium are minor constituents. The ionic relationship of this group is found to be $Mg^{2+}>Ca^{2+}>Na^{+}>K^{+}$ and $HCO_3^{-}>Cl^{-}>CO^2{}_3^{-}>SO^2{}_4^{-}$, although there are a few cases in which the relationship is $Mg^{2+}>Ca^{2+}>K^{+}$ and $HCO_3^{-}>Cl^{-}>CO^2{}_3^{-}>SO^2{}_4^{-}$.

This group is mostly noticed in upper Sarada River, Bodderu River and lower Sarada sub-basins (fig 2). It is dominant in the sandy and loamy soils of northern part of the study area. These waters are observed in palaeo – channels and flood plains of the region of charnockites to the east of Dibbapalem, west of Chodavaram, Munagapaka and around Anakapalli. The depth of the aquifer is more than 4 mts.

3. Sodium Chloride group- (NaCl):

This group is present in waters having a salinity range of 16.36 to 135.55 m.eq of TDS/lit. The analytical data shows that 10(23.25%) ground water samples fall in this sodium chlo*rid*e group. The water in the lower range of salinity are found to contain high proportion of sodium, calcium and bicarbonates. When the sodium chlorides concentrations increase, the chloride becomes practically the only anion. The ionic relationship of the group is $Na^{2+}>Mg^{2+}>Ca^{2+}>K^{+}$ and $Cl^{-}>HCO_3^{-}>CO^2{}_2^{-}$. In a few cases, calcium has been found to be exceeded magnesium.

Table 3: The percentage distribution of ground water samples above and below the limits in Sarada River Basin

S. No.	Parameter	WHO standard value		% of samples with in	
		Desirable limit	Max. Permissible limit	Desirable limit	Max. Permissible limit
1	pH	7.0 – 8.5	6.5- 9.2	100	-
2	Chlorides	250mg/l	1000 mg/l	79.07	20.93
3	Sulphate	200 mg/l	400 mg/l	93.03	6.97
4	Alkalinity	200 mg/l	600 mg/l	90.70	9.30
5	Total dissolved solids	500 mg/l	3000 mg/l	88.40	11.60
6	Calcium	75 mg/l	200 mg/l	93.80	6.20
7	Magnesium	50 mg/l	150 mg/l	88.20	11.80
8	Potassium	Not Applicable	Not Applicable	Not Applicable	Not Applicable
9	Sodium	400 mg/l	800 mg/l	81.40	18.60

The areal distribution of sodium chloride group in the area of investigation is mostly in the Vedurlagedda and lower Sarada sub-basins. This water group is seen in Dibbapalam to the north of Gavaravaram, to the east of Peddamadina, to the south of Anakapalli, Munagapaka and Elamanchilli. The salinity of this group increased to the south in the lower Sarada River Basin. The sodium chloride waters are dominant in the soils of the charnockite and khondalite terrains. It is observed in the plains having a slope of less than 1^0 and shallow ground waters of 2 to 4 mts depth.

In the lower Sarada River Basin, the discrepancy of hydrochemistry is attributed to mixing of ground water and the sea water due to high tide. The simplest explanation for this discrepancy could be that the sodium chloride groups of waters are noticed in different aquifers with different flow directions. The presence of chloride in the sulphate waters in the lower salinity range indicates that there is some mix-up of these waters. Presence of chloride in the bicarbonate aquifers cannot be ruled out, because of the possible mix-up of these waters with bicarbonate and sulphate waters.

4. Calcium Bicarbonate group-Ca $(HCO_3)_2$:

This group is present in waters varying in salinity range from 5.51 to 23.10 m.eq of TDS/lt. In most cases, the salinity does not exceed 10 m.eq of TDS/lt. The ionic ratio of this group is $Ca_2{}^{+}>Na^{+}>Mg_2{}^{+}>K^{+}$ and $HCO_3^{-}>Cl^{-}>SO_4^{2-}$. In a few cases magnesium exceeded sodium.

The analytical data shows that 2(4.65%) ground water samples fall in this calcium bicarbonate group. These waters are abundant in the eastern part of the lower Sarada River Basin. The calcium bicarbonate group is observed in the soils of khondalitic region to the northeast of Anakapalli and east of Elamanchali. This water group is present in creep built plains of 5^0 to 10^0ground slopes. The ground water levels are generally around 4 to 8 mts below the ground level. A gradual increase of salinity towards downstream side is expected in the study area. This general trend seems to be affected by the direct replenishment of fresh water from the river system to the aquifer. There is an increase of salinity gradually to the south and southwest of the basin. The destruction of calcium bicarbonate waters is easily delineated. This water type is found in a patchy distribution surrounded by the other types of water and probably indicates the effect of fresh water lenses.

5. Sodium Sulphate group-(Na_2SO_4):

This group is observed in waters with salinity ranging from 17.53 to 103.66 m.eq TDS/lt. The average salinity of the group is higher than that of bicarbonate group and low salinities are exceptional. The ionic relationship of this group is $Na^+>Ca^{2+}>K^+>Mg^{2+}$ and $SO_4^{2-}>HCO_3^-> Cl^-> CO_3^{2-}$.

The hydrochemical data indicates that 4(9.30%) ground water samples have the sodium sulphate waters in the entire Sarada River Basin. This group is present mostly in upper Sarada River, Bodderu river, Tacheru and Pedduru rivers, and lower Sarada Sub-basins (fig 1). This group is observed to the north of Gavaravaram, Anakapalli, northeast of Dibbapalem, to the south and south west of Tallapalem. Most of these waters are found in the northern region of the area of investigation. This group is predominant in the soils of the region of granitic gneisses. It is observed in the creep built plains and flood plains with less than 1^0 ground slope and at depths varying from 2 to 6 mts below the ground level.

In this group as well as in the bicarbonate group, sodium is dominant cation, Ca^{++}, Mg^{++} both being minor. In several locations in the south and southeast of the study area, there are indications that the composition of the waters in the aquifers is transitional from bicarbonate to sulphate. The wide range of overlap between the salinities of the bicarbonate and sulphate groups may not be only due to saline environment required for transition from one group to the other. It may be due to availability of sulphate in the rock formations. This group is mainly seen in the eastern side of the basin. The data shows that sulphate and bicarbonate concentrations increase southwards and it may be due to ground water flow in that direction.

6. Magnesium Chloride group-($MgCl_2$):

This group is present in waters with salinity range of 23.45 to 54.66 m.eq of TDS/lt, whereas in general, the salinity does not exceed 10 m.eq of TDS/lt. This discrepancy is obviously due to intrusion of sea water. The ionic relationship of this group is $Mg^{2+}>Ca^{2+}>Na^+>K^+$ and $Cl^->HCO_3^->CO_3^{2-}$, in few cases, sodium may exceed calcium. The data shows 2 (4.65%) ground water samples fall in this group. The magnesium chloride group is noticed in the lower Sarada River Basin only. These waters are observed in the soils of the region of charnockites to the southwest of Munagapaka and west of Elamanchili. The depth of ground water is 4 to 6 mts.

Generally, the suitability of water to be used for irrigation, and domestic purposes is indicated by the total salt content and sodium content present in the water. The major constituents present in irrigation water are sodium, calcium, and magnesium as cations and chloride, sulphate, and bi-carbonate ions as anions may also be present in appreciable amounts in the study area. The percentage distribution of ground water samples for various chemical parameters in the study area as per the standards is given in Table 3.

Chlorides occur naturally in all types of waters. High concentration of chlorides is considered to be the indication of pollution due to salt water intrusion and high organic wastes of animal or industrial origin. Human body releases a very high quantity (6 gram/person/day) of chloride[9]. From the present observation the minimum chloride value 14 mg/l at Anakapali and maximum chloride value 2486mg/l at Murakada. The other places of higher concentrations are Vakapadu (1900 mg/l), Elamanchili (1263 mg/l), and vemagiri (1775 mg/l) in the sub-basin - 6 of the study area. Higher concentration of area may be due to intensive agricultural practices, salt water intrusion, and feeding of salt to certain type of trees like coconuts in the study area.

Sulphate is utilized by all living organisms in the from of both mineral and organic sulphates. From the present study, it is revealed that the concentration of sulphates varying from 2 to 364 mg/l is within the maximum permissible limit except in sub-basin–6 at Munagapaka (1083 mg/l).

The presence of sodium gives bitter taste to water, which is dangerous for heart and kidney patients, corrosive effect to metals, and toxic to the plants. The data indicates that most of the ground water samples in the entire basin varying from 12 to 460mg/l are in permissible limits. A very few samples are in higher concentrations at Gavaram

(800 mg/l), Vemagiri (880 mg/l), and Devanapallem (1145 mg/l) in sub-basin-6 only due to salt water intrusion and over irrigation.

Highly alkaline waters generally unpalatable, the value of alkalinity ranged from 75 to 830 mg/l. The data indicates that a few ground water samples which contain high alkalinity value are at Elamanchili (823 mg/l), and Tallapallem (638 mg/l).

Most of the wells that are observed in the weathered rocks like khondalites, granite gneisses, quartzites, charnockites, and different geomorphic features like creep built pediment, pediment fans , and wash plains have high depth of water level below the ground level, whereas in flood plains and palaeo channels have low ground water levels.

CORRELATION BETWEEN SALINITY AND THE CHEMICAL PATTERNS:

The concentration of the various ions has been observed in the area of investigation as a function of the total dissolved ions. The following trends were observed in the study area.

1. Sodium and chloride ions increased linearly with the increase of total salinity.
2. Calcium and magnesium ions vary in the range of 2.42 to 188 m.eq of TDS/lit, without any correlations to the total salinity.
3. Magnesium is equally abundant as calcium
4. The bicarbonates are observed to increase linearly with salinity in the southern part of the basin
5. Sulphates are relatively low and their variations have no correlation with the total salinity.

GEOCHEMICAL EVOLUTION:

Taking into account the various hydrological and geological observations in the area of investigation, the following steps of the geochemical evaluation appear to fit the ground water under study:

1. Rain water infiltrates directly into the ground and is rich in biogenic CO_2. It reacts with feldspars and heavy minerals present in soils and other silicate rocks of the local aquifers.
2. Depending on types of feldspars with which the water reacts, waters with predominantly dissolved sodium, calcium or potassium bicarbonates are formed.
3. Pyroxenes and amphilroles are heavy minerals in the area of investigation. The reaction of CO_2 present in the water seems to be a major source for the observed magnesium and other cations.
4. The various aquifers are found to contain little or no gypsum. Hence the sulphates in the ground water must have been from outside the area of investigation. Mostly it may be either from sea water or fertilizers.

CONCLUSION

Based on distribution of different hydro-chemical groups, the dominant cations, anions and salinity of different chemical groups in different geological rock formations, geomorphic setting, soils , slopes and different water table setting, and different water table conditions in the ground waters of Sarada river basin, the following conclusions were drawn.

1. Most of ground water is found to be suitable for irrigation and drinking purposes in the study area.
2. The present study reveals that there is a perceptible degree of pollution of ground water resources in areas where there is a large scale of cultivation and use of fertilizers. The effect of fertilizers on the quality of ground waters indicates that there is need for adopting the sound monitoring and preventive practices.
3. There is a general tendency for contamination of ground water with marine sources in the south of the lower Sarada River, which is a normal phenomenon expected near entrance of the river into marine environment.
4. Extensive pollution in middle and lower parts of Sarada River Basin due to discharge of industrial effluents (both chemical and biogenic) and manmade sources have been observed.
5. Higher concentration of chloride, calcium, alkalinity, and sulphate may be due to intrusion of sea water in the southern part of the sub- basin-6. The salinity of the ground water samples is increased as result of over exploitation of ground water from thin sandy aquifers and shallow occurrence of ground water table below the ground level. It is observed that the quality of the ground water in palaeo – channels, pediments, and pediment fans is good, whereas the quality of water in wash plains and flood plains is poor.

REFERENCES

[1] R K Trivedy; P K Geol. Chemical and Biological methods for water pollution studies *Environmental publications*, Karad, India, **1986**.

[2] T Satyanarayana. Hydrochemical Environment of Ground Water Regine of Sarada River Basin, Andhra Pradesh. Ph.D. thesis, Andhra Univerisity, Visakapatnam **1991**.
[3] E Brown, MW Skoughsted; M J Fishman. Methods for collection and analysis of water samples for dissolved minerals and gases. U.S.G.S Techniques of Water Resources, Inv. Book-5,**1970** Chapter A, 160.
[4] APHA., Standard Methods for Examination of Water and Wastewater Analysis.18th ed.American Public Health Association, Washington DC, **1992**
[5] A. Arad; Kafri U. *Journal of Hydrology*, **1975, 25;** 105-127
[6] D Jackson; JW Lloyd. *Journal of ground water.*, **1984, 22,** 735-745
[7] Troester **W** Joseph; William B White,. *Journal of ground water.*, **1986**, 24, **No.4**.
[8] CSV Subhramanya Kumar; B Srikanth; I Yamani Sreevalli., A case study of saline intrusion into coastal aquifers' using chemical parameters.NEPT. **2(1) 2003,** 89-93.
[9] Sharma, S.D. and K.S. Pande. *pollution research* **17(2) 1988,** 201-209.