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Seasonal Variations in the Quality and Chemistry of groundwater in Erravagu Sub-basin, Guntur District, Andhra Pradesh

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***Abstract*- An investigation was been carried out in Erravagu sub-basin of Guntur District, Andhra Pradesh by collecting a total of 40 groundwater samples for two seasons namely pre-and post monsoon to decipher hydrogeochemistry and groundwater quality for determining its suitability for drinking and irrigation purposes. The study area is underlain by peninsular gneissic complex and granite intrusives of Archaeans, and shales, phyllites, limestone and quartzites of Proterozoic age. The quality of groundwater is characterized by alkaline nature, fresh to brackish and moderate hard to very hard during pre- and post-monsoon periods. This is not suitable for drinking as well as for irrigation in most locations. The chemistry of groundwater in the study area is controlled by rock weathering, mineral dissolution, ion exchange and evaporation. This is also supported by the dominance of Na+: HCO facies. The sources of anthropogenic origin appear to be caused for elevation of various chemical variables, which is responsible for brackishness in the water. Pipers diagram also suggest that the groundwater quality is initially fresh and is subsequently modified to brackish.**

***Index Terms*- Groundwater Quality, Erravagu Sub-basin,rock weathering, brackish.**

INTRODUCTION

Groundwater utility has been rapidly increased due to unavailability of the surface water and failure of the seasonal monsoons. If water is suitable for drinking then it is suitable for every purpose. Determination of groundwater composition is of utmost importance from the point of view its suitability for various uses like drinking, irrigation and industries etc. An attempt has been made to understand the geo chemical evolution of groundwater and assess its suitability for drinking and irrigation. Recent studies related to the chemistry and quality of groundwater has been carried out in river basins in different parts of the country. The present study is on Erravagu sub-basin of Guntur district, Andhra Pradesh.

STUDY AREA

The Erravagu sub-basin is located in between North latitudes of 16020'20"-16027'45" and East longitudes of 790 52' 06" - 80o 04' 30" in the central part of the Guntur District of Andhra Pradesh (Fig. 1). The climate of the area is semi-arid with an average annual temperature of 18.50C (winter) to 430C (in summer). The average annual normal rainfall is 782 mm. The Erravagu originating from hill ranges located in the southwest and northwest flows towards the northeast. The drainage pattern shows dendritic to sub-dendritic. Canal irrigation is common.

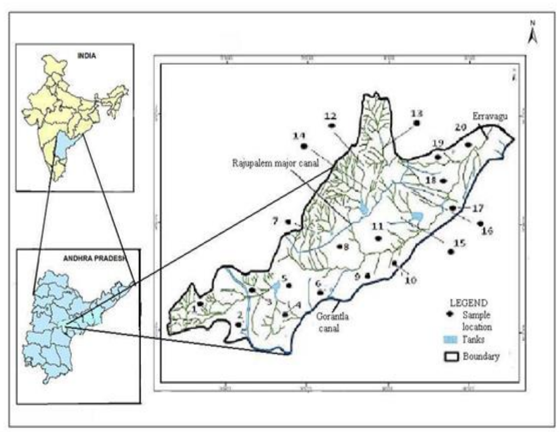


Fig.1 Location Map of the Erravagu Sub-basin.

The area is characterized by undulating topography, sloping towards the northeast. The altitude varies from 349 m amsl (in the south-west part) to 95 m amsl (in the northeastern part). The Study area exposes peninsular gneissic complex (grey pink granites) as basement rocks, unconformably overlain by the quartzites, shales, phyllites and limestones belong to Nallamalai and Kurnool groups of Proterozoic age. The Nallamalai formation is intruded by younger granites. The basement rocks occur on the northeastern part, while the Cumbhum quartzite, shale and phyllite exposes in the southeastern and southwestern parts of the area. The Narji Limestone and Owk shales occur in the south central and northwestern portions of study area. The gneisses and granites are highly fractured and weathered. The crystalline rocks, calcareous and argillaceous formations are the main aquifers and control the groundwater chemistry of the study area.

METHODOLOGY

A total of 40 groundwater samples collected during May 2010 and November-2010 were used for determination of pH and electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA) as $CaCO_3$, total hardness(TH) as $CaCO_3$, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-) and fluoride (F^-), following the standard procedure of APHA (1992), in the Panchayit Raj Department, Guntur and Lam Agricultural Form, Guntur. The analytical precision of the measurements of major cations and anions was determined by computing the ionic balance error, which is, generally, within +5 % (Domenico and Schwartz, 1990).

RESULTS AND DISCUSSION

Groundwater quality

The pH ranges from 7.6 to 8.9, 7.2 to 8.6 during pre- and post-monsoon periods indicating alkaline nature, Most of the samples are within the standard drinking water quality limit of 6.5 to 8.5 (BIS, 2003), except two samples (2 and 14) during both the seasons. The EC is in between 540 and 4640 µS/cm(pre-monsoon),465 to 4400 µS/cm(post-monsoon) reflecting a wide variation in the activities of geochemical processes. The TDS varies from 346 to 2970 mg/l (pre-monsoon), 298 to 2816 (post-monsoon). According to the TDS classification (Fetter, 1990), 50% of the total groundwater samples during the pre-monsoon and 60% of the samples during post-monsoon belong to fresh category while the rest to brackish. The TA value ranges from 190 to 513 during pre-monsoon and 172 to 412 during post-monsoon. 10%, 35%,55% during pre-monsoon and 5%,35% ,60% during post-monsoon come under Moderately hard, hard and Very hard water type based on TH.(Table 1) (Sawyer and Mc Carty,1967) The very hard type of water develops soap lather.

Table.1 Criteria for groundwater quality for drinking and irrigation based on TDS and TH

Parameter	Range	Pre-monsoon		Post-monsoon		Water Quality
		Sample Nos	% of samples	Sample Nos	% of samples	
TDS (mg/l)	<1 000	4-7,12-13,16-19	50	1,4-7,12-13,16-19	60	Fresh
	>1 000	1-3,8-11,14-15,20	50	2,3,8-10,14,15,20	40	Brackish
TH (mg/l)	<75	-	-	-	-	soft
	75-150	1,13	10	1,13	10	Moderately hard
	150-300	2,7,12,14,16-18	35	2,5,12,14,16,17,19	35	Hard
	>300	3-6,8-11,15,19,20	55	1,3,4,6-11,15,18,20	60	Very hard

During pre-monsoon the concentrations (mg/l) of Ca^{2+}, Mg^{2+}, Na^+ and K^+ vary from 16 to 96, 10 to 112, 78 to 454 and 3 to 404, respectively ,while during post-monsoon they vary from 24 to 84, 26 to 110, 65 to 346, 4 to 262 respectively indicating that Na^+ and K^+ ions are the dominant ions in the groundwater. The concentration of Na^+ to the total cations ranges from 37.5 – 87.89% (pre-monsoon),32.01 – 80.92% (post-monsoon) due to silicate weathering and/or dissolution of soil salts stored by the influences of evaporation and anthropogenic activities (stallard and Edmond, 1987; Meyback,1987; Subba Rao 2008), in addition to agricultural activities and poor drainage conditions. Moreover, the higher content of Na^+ than that of Ca^{2+} is because of ion exchange and high solubility of Na^+ than the later. The second dominant cation is K^+, which contributes 0.48 to 43.48% (pre-monsoon), 1.03 to 34.4% (post-monsoon) to the total cations. The high concentration of K^+ is mainly derived by the weathering of K-feldspar and mica.

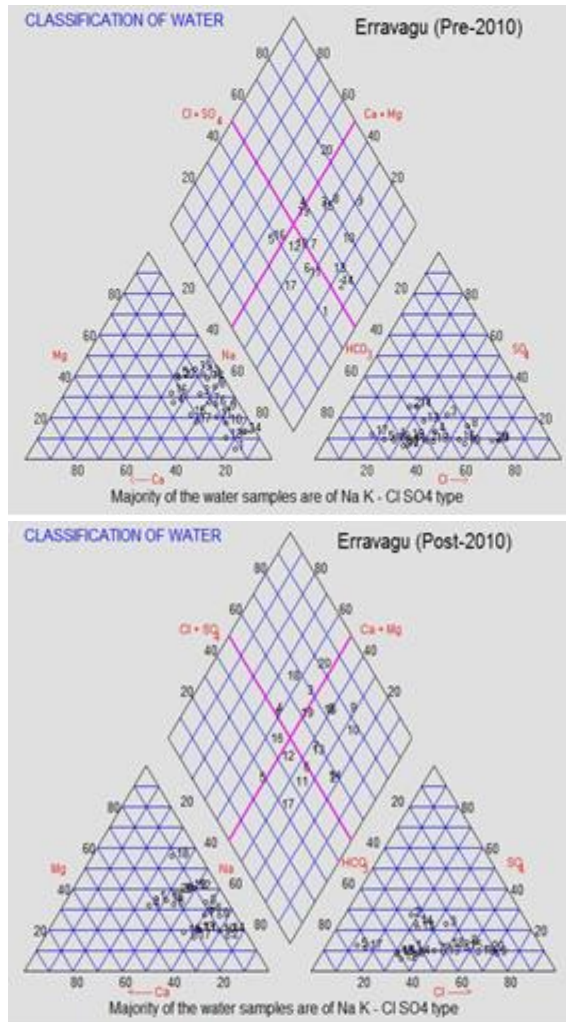
The contribution of Ca^{2+} and Mg^{2+} to the total cations is 3.65 to 25% and 2.8 to 27.67% respectively in the pre-monsoon, while it in the post-monsoon ranges from 5.78-33.5%, 9.48-39.56% respectively. The concentrations of Ca^{2+} and Mg^{2+} ions in the groundwater are due to the country rocks, which are composed of limestone, dolomite and peninsular gneiss.

The concentration of HCO_3^-, Cl^- , SO_4^{2-}, NO_3^- and F^- are in between 190 and 513 mg/l, 80 and 920 mg/l, 32 and 195 mg/l, 10 and 145 mg/l and 0.6 and 2.8 mg/l, respectively during pre-monsoon, while during post-monsoon values in mg/l ranges from 178 to 518, 40 to 840, 16 to180, 8 to 20 and 0.5 to 2.5 respectively. The HCO_3^- plus CO_3^{2-} content dominants in the groundwater, which is due to dissolution and leaching of calcareous aquifers, and decay of plants and organic matter. The contribution of HCO_3^- to the total cations is 29.7 to 75.8% during pre-monsoon, 28.71 to 81.07% during post-monsoon period. The origin of Cl^- is derived mainly from the domestic waste waters, septic tanks, and irrigation-return-flow and chemical fertilizers (Todd, 1980; Hem, 1991). Cl^- is the second largest anion contributing 12.24 - 54.82 % (pre-monsoon), 7.86 – 59.11% (post-monsoon) to the total anionic concetration. The SO_4^{2-} may be derived from gypsum (Todd, 1980) which contributes 6 to 23% during pre-monsoon and 3 to 25 % during post-monsoon. The concentration of NO_3^- more than 10 mg/l in the water reflects the man-made pollution (Cushing et al., 1993; Ritzit et al., 1993). The contribution of NO_3^- to the total anions ranges from 0.7 to 12.9% during pre-monsoon, 0.7 to 13.1% during post-monsoon. The F^- content during pre-and post-monsoon in the groundwater ranges from 0.6 to 2.8,0.5 to 2.5 respectively. The F^- contribution to the total anions during pre-monsoon is 0.05 to 0.38%, while during post-monsoon it ranges from 0.05 to 0.5% which is due to host rocks that may contain the minerals such as apatite, hornblende, fluorite, clay and chemical fertilizers.

GEOCHEMICAL CHARACTERISTICS OF GROUNDWATER

Hydro geochemical characteristics of groundwater are evaluated by Piper Trilinear diagram (Piper, 1944). Figure2 indicates that the 10% of the samples during pre-and post-monsoons is characterized by carbonate hardness (field 5) due to dominance of Ca^{2+} and Mg^{2+} with HCO_3^- + CO_3^{2-} ions over the Na^+ + K^+ and Cl^- +SO_4^{2-} ions, 50%(pre-monsoon),45% (post-monsoon) by non-carbonate alkali (field 7) due to abundance of Na^+ and Cl^- ions which exceed 50% of Ca^{2+} + Mg^{2+} and HCO_3^- +CO_3^{2-} ions, and 40% (pre-monsoon),45% (post-monsoon) by mixed type (field 9) due to no-cation-anion ion pair exceeding 50%(Table2)

Figure.2 Geochemical classification of groundwater of the study area (after Piper, 1944)



Water infiltrates through the soil cover and percolates into the weathered/fractured rocks and attains this concentration. During this journey of water, anthropogenic activities play a major role in the change of groundwater quality and there by the chemistry of groundwater varies from place to place. Thus, the groundwater samples fall in the different fields in the Piper's trilinear diagram. The Na+HCO3- Cl- and Na+ Cl-HCO3- are the dominant water types based on Pipers diagram.

Table.2 Geochemical characteristics of groundwater of study area (after Piper, 1944)

Zone	Geochemical characteristics	Pre-monsoon		Post-monsoon	
		Sample Numbers	% of samples	Sample Numbers	% of samples
1	Alkaline earths exceed alkalies	4,5,16,20	20	3,4,5,8,16,20	30
2	Alkalies exceed alkaline earths	1,2,3,6,7,8,9,10,11,12,13,14,	80	1,2,5-7,9-15,17-19	70
3	Weak acids exceed strong acids	1,5,6,11,12,16,17,18	40	5,6,11,12,16,17	30
4	Strong acids exceed weak acids	2,3,4,7,8,9,10,13,14,15,19,20	60	1-4,7-10,13-15,18-20	70
5	Carbonate hardness exceeds 50% of alkaline earths and weak acids	5,16	10	5,16	10
6	Non-carbonate hardness exceeds 50% of alkaline earths and strong acids				
8	Carbonate alkali exceeds 50% of alkalies and weak acids	2,3,7-10,13-15,19	50	2,7-10,13-15,19	45
9	No cation and anion pair exceeds 50% of the total ions	1,4,11,12,16,17,18,20	40	1,3,4,6,11,12,17,18,20	45

Table 3 Comparison of groundwater quality with drinking water quality Standards of WHO (1984) and BIS (2003)

Chemical parameter	WHO (1984)	BIS (2003)	Pre-monsoon: Groundwater samples exceeding the safe limit		Post-monsoon: Groundwater samples exceeding the safe limit	
			Sample numbers	% of samples	Sample numbers	% of samples
pH (units)	7-8.5	6.5-8.5	2,14	10	2,14	10
TDS (mg/l)	500	500	1-4, 6-20	95	1-4, 6-20	95
TH (mg/l)	100	300	3-6, 8-11, 15,19,20	55	1,3,4,6-11,15,18,20	60
Ca^{2+} (mg/l)	75	75	15,20	10	15,20	10
Mg^{2+} (mg/l)	50	30	2-12,14-20	90	1-16, 18-20	95
Na^{+} (mg/l)*	200	-	1-3,8-10,13-15,20	50	2,8-10,14	25
Cl^{-} (mg/l)	200	250	8-10,15,20	25	8-10,15,20	25
SO_4^{2-} (mg/l)	200	150	2,3,8,9	20	2,3,9	15
NO_3^{-} (mg/l)	45	45	2,14	10	2,14	10
F^{-} (mg/l)	1.5	0.6-1.2	1,2,10,11,13,14,15	30	1,2,10,11,13,14,15	30

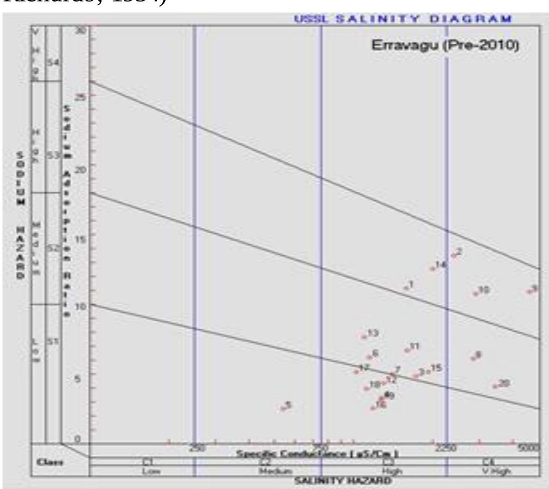
To ascertain the suitability of groundwater quality for drinking and Public health purpose, the analytical results of the chemical parameters of groundwater of the study area is compared with the standard drinking water quality guide line values recommended by BIS (2003) and WHO (2004).

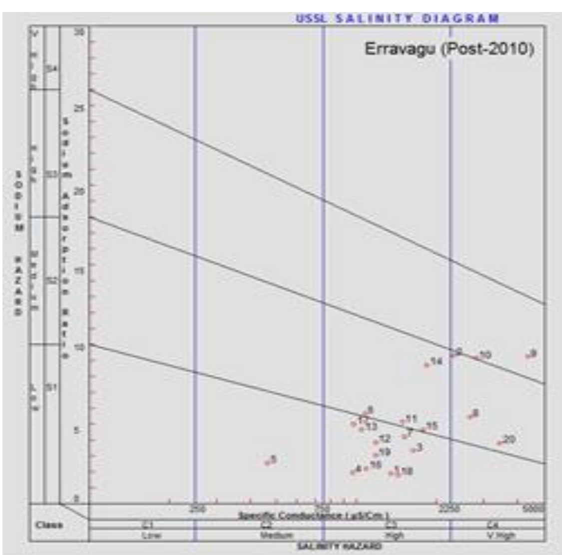
The permissible range of pH is 7.1 to 8.5 for drinking water. Beyond this limit, it may affect the mucous membrane and water supply system. 10 % of the samples during pre-and post-monsoon are exceeding the permissible limit (Table.3). Based on TDS 95% of total samples during both the seasons are not-potable. Water with high TDS, has is inferior palatability and may induce an unfavorable physiological reaction in the transient consumer and gastrointestinal irritation in the human system. 10% of the total ground water samples are considered as unsafe with reference to Ca2+ for drinking (Table 3). The permissible limit of Mg2+ is 30 mg/l. for drinking. About 90% of the total ground water samples during pre-monsoon and 95% of the samples during post-monsoon are unsuitable for drinking. The prescribed safe limit of Na+ for drinking water is 200 mg/l. The concentration of Na+ in excess allowed limit of 200 mg/l for drinking water may cause Hypertension. 50%, 25% of the samples exceeds to this limit during pre-and post-monsoon seasons respectively. The recommended limit of Cl- for drinking water is 250 mg/l. If this value exceeds it imparts bitter taste to water and may cause Cardio Vascular problems. About 25% of the total ground water samples during both the seasons exceed the safe limit. Sulphate is unsuitable, if it exceeds the permissible limit of 150 mg/l and causes a laxative effect on humans, together with Na+ or Mg2+ in drinking water. 20% of total ground water samples during pre – monsoon and 15% of the total groundwater samples during post-monsoon exceed the prescribed limit. Water, with more than 45 mg/l of NO3-, is not suitable for drinking. Beyond this limit in potable water, it may cause methamoglobinemia or blue baby disease in infants. 10% of the samples during both the seasons are exceeding the desired limit. Considerable amount of F- in the potable water is very essential for normal growth of bones in human system. The safe limit of F - is 0.6 to 1.2 mg/l, less than 0.6 mg/l F - causes dental caries, while more than 1.2 of F - results fluorosis. About 30% of the total samples during both the seasons are found to contain excess Fluorides than safe limit.

GROUNDWATER QUALITY FOR IRRIGATION

As per the United States Salinity Laboratory (Richards, 1954) diagram used widely for classification of water quality for irrigation, 5%, 30%, 30%, 15% and 10% fall in the zones of C2S1, C3S1, C3S2, C4 S3 and C4S2 during pre-monsoon. 5%, 50%, 20%, 15% and 10% fall in the zones of C2S1, C3S1, C3S2, C4 S2 and C4S3 during post-monsoon. There was an increase in the water quality from pre- to post-monsoon. They come good (C2S1), moderate (C3 S2) and poor (C4S2 and C4S3) categories for irrigation. Thus, the application of gypsum, CaCl with organic manure and other methods of de-salinization and dealkalinization are necessary to improve the water quality.

Figure.3 Classification of irrigation waters of the study area (after U.S.Salinity Laboratory Staff (after Richards, 1954)





CONCLUSIONS

The observed quality of groundwater in the Erravagu sub-basin of Guntur district, Andhra Pradesh shows alkaline nature with fresh to brackish and moderate hard to very hard type. The TDS, TH, Ca2+, Mg2+, Na+ , Cl- , SO42,-, NO3- and F- exceed the drinking water standards in most groundwater samples. Anthropogenic activities cause the deviation from the quality of groundwater derived from the rock-weathering. This is supported by the Pipers' diagram. Thus, the groundwater shows Na+: HCO3- and Na+: Cl- facies, being a dominant of the first facies. Seasonally the groundwater quality is showing slight variation from pre-to post monsoon seasons.

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