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Evaluation of Spatial Variability in Ground Water Quality using Remote Sensing

Manoj Kumar Karnena, Vara Saritha

Abstract: ***Water quality along Coastal Zones of Srikakulam District in Andhra Pradesh, India was analyzed through seasons of pre and post of monsoon for determining water appropriateness towards consumption by means of water quality index (WQI). Present study included collection of sub-surface water samples from sampling sites which are designated as Mandal headquarters across the coastal line. Towards developing WQI, physicochemical analysis of samples was determined considering nine important parameters that included physical parameters like total dissolved solids, chemical parameters like pH, conductivity, ionic parameters such as calcium and magnesium, sodium and potassium, chloride and sulphate. The sampling sites are mapped using geographical information systems. GPS (Global positioning system) was employed to locate the coordinates in terms of latitude and longitude. Cation-anion correlation matrixes are plotted using piper plots from values of results obtained through physico-chemical analysis. Experimental results were subjected to statistical analysis using one-way ANOVA. The WQI index in the present study was obtained in the range of 57.6 to 989.1, indicating very poor-quality water in these sampling areas. Results illustrated that groundwater of the study area required treatment before used for consumption.***

Key words: ***Water Quality Index, Groundwater, Geographical information system, Pre-Monsoon, Post-Monsoon.***

I. INTRODUCTION

Water is considered as a vital natural resource and an absolute necessity for sustenance of life. Being the most important crucial constituent of plants, animals and other organisms but it is key in survival of mankind [1]. The accessibility and quality of water whether surface or sub-surface is being deteriorated because of factors including population explosion, urbanization, industrialization, etc. [2-3]. Water quality is a governing factor of human health, hence determining water quality before consumption and with changing conditions mandatory [4].

Quality of water from specific area or source can be analyzed and assessed through physical, chemical and biological parameters [5-7]. Concentrations of various physicochemical parameters when exceeding the prescribed limits prove to be detrimental to human health [8].

Furthermore, suitability of water from a source intended for human consumption can be expressed as Water quality index (WQI), which is understood to be one among the most efficient ways in describing water quality [9]. Water quality data expressed in terms of WQI aids in amendment of policies articulated by several environmental monitoring organizations [10]. It is comprehended that use of data regarding individual water quality variable for describing water quality to common public will not be understood easily [11]. One of the major advantages of WQI lies in its ability to reduce bulk information to single value, thus expressing data in streamlined and logical form [12]. It collects data from several sources, combining them for developing complete status of water system [13], which helps in increasing understand towards water quality issues by policymakers along with general public who are consumers of water resources [14]. With advent of geographical information system (GIS) along with satellite technology and simplified mapping sampling area, which eventually enhanced execution of policy decisions or management aspects at specific location [15]. Application of GIS for mapping water quality has been widely appreciated owing to its informative and comprehensible maps [16]. In the present study water quality index was determined as per Tiwari et al., 2018 using weighted arithmetic index method [17-18], which included nine important parameters including physical parameters of total dissolved solids (TDS), chemical parameters such as like pH, conductivity, total hardness, ionic parameters such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sulphates (SO_4), chlorides (Cl^-), sodium (Na+) and potassium (K^+) were considered for analysis.

II. METHODOLOGY

Srikakulam district is the north-eastern district of Andhra Pradesh and is classified as a backward district. The district has a coastline of 192 km and is sandwiched between the Eastern Ghats and Bay of Bengal. The district is present in between the north latitude of 18° 20' and 19° 10' and east longitudes of 83° 05' and 84° 50' with an aerial extent of 5837 km2. Environmental degradation problems have increased over the years due to many reasons.

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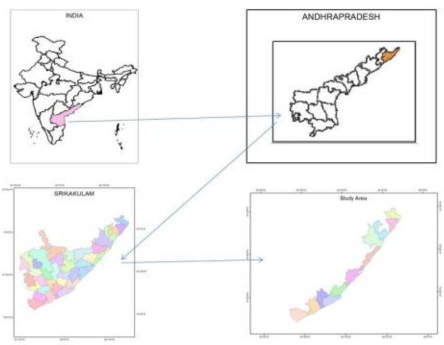
Summer records hot temperatures with an average ranging from minimum of 23^0C to maximum of 45^0C during the months of March to June. Duration of monsoon season is usually between mid of June to mid of September recording rainfall with an average of

93.2cm (36.7 inches). Temperature on an average reduces significantly to as low as 3 to 4^0C during peak of winter. Soil formation of the region is owed to pedogenetic processes or transported soils, which are formed due to long duration exposure to atmospheric factors, physical and chemical weathering and rockslides. Having derived from granite gneissic, schistose and phyllite rocks, these soils obtain high percentage of silica from their parent rock, while the soils formed from the limestone are rich in calcium carbonate.

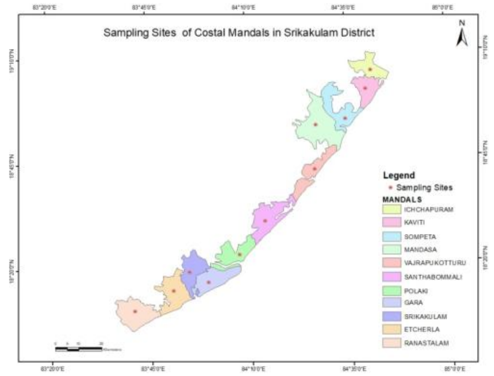
A. Sampling Sites of The Study



B. Sampling

Eleven major drinking water sources of Mandal headquarters of Srikakulam district throughout the coastal line namely Etcherla, Gara, Ichchapuram, Kaviti, Mandasa, Polaki, Ranastalam, Santhabommali, Sompeta, Srikakulam, Vajrapukothuru were selected for water sampling. The GPS coordinates were taken from individual site using GPS (Make: Garmin, Taiwan; Model: GPS map 76CSx) at the same time temperature of water is also noted down (using mercury thermometer). The GPS co-ordinates in terms of Latitudes and Longitudes with are presented in Table 1:

Site No	Sampling Site	Latitude	Longitude
1.	Etcherla	18.2821° N	83.8248° E
2.	Gara	18.3314° N	84.0544° E
3.	Ichchapuram	19.1153° N	84.6852° E
4.	Kaviti	19.0094° N	84.6884° E
5.	Mandasa	18.8724° N	84.4606° E
6.	Polaki	18.3764° N	84.1000° E
7.	Ranastalam	18.2024° N	83.6907° E
8.	Santhabommali	18.5364° N	84.2081° E
9.	Sompeta	18.9456° N	84.5825° E
10.	Srikakulam	18.4285° N	84.0167° E
11.	Vajrapukothuru	18.6908° N	84.4494° E



All the above listed sampling sites serve as a source of primary drinking water to majority of population in the district. Sample collection was taken up during pre (April-May) and post monsoon (October-November) seasons of year 2018. Preference was given to grab sampling for sample collection which were collected in sterile polyethylene of high-density ('Carson' brand) bottles after rinsing for 2-3 times with sample water to be collected. Measurement of pH was performed on site and water samples were transported to laboratory stored at 4°C in the sampling box for measurement of other parameters. Physicochemical analysis was taken up according to the standard methods given by APHA, 2015.UV-VIS spectrophotometer of Merck, Germany (Model: Pharo300) was used for colorimetric analysis. Concentrations of metal ions was determined using flame atomic absorption spectrometer (FAAS) (Australia; Model AA240). Chemicals and reagents of analytical grade purchased from Merck; India were used for analysis. Analytical grade distilled water obtained from Millipore water purification system (Make: Millipore, USA; Model: Elix and Synergy) was used for the preparation of standards and solutions.

C. Piper Plots

Piper plots along with correlation matrix of cation-anion were plotted in the software Origin (Version 9.2) to illustrate distribution of major ions representative of sample sites. Major ions represented in piper plots, are presented as percentages of cation and anion expressed in terms of milliequivalents in two of the base triangles. A piper plot enables comparison of six parameters among many samples. Similar to the plots of trilinear, these also will not represent complete concentrations of ions. Chemical quality of water with reference to its origin is best provided through this method. Values of correlation coefficient (r) were determined using correlation matrix in order to identify highly interrelated and correlated parameters of water quality.

D. Water Quality Index Calculations

WQI provides data of water quality with a rating scale ranging from zero to hundred. Calculation of water quality index has been carried out in three stages.

Initially, individual 9 parameters (pH, TDS TH, Cl, SO_4, NO_3, Ca, Mg, Na, and K) were assigned a weight (wi) with reference to their relative importance over the complete quality of water assigned for consumption purposes in Table 2.

The highest weight of five was assigned to Total Dissolved Solids, Sulphates and chlorides owing to their importance in assessment of water quality. Potassium is awarded least weight of 2 attributed to its trivial role. Other parameters like calcium, magnesium, sodium conductivity, pH and chlorides are given weights between 3 and 5 owing to their importance. In the next step, relative weight (W_i) is computed from the following equations (Equation 1–4).

$$\boldsymbol{W_I = \frac{W_i}{\sum_{i=1}^{n} w_i}} \quad \text{….. (1)}$$

Where W_i = relative weight; w_i = weight of each parameter, respectively, and n = number of parameters. For the final step, quality rating scale (Qi) for individual parameter is allocated by dividing its concentration in individual water sample with its respective standard as per the guidelines put forth by the BIS and the result for the same is multiplied by 100 (Equation 2)

$$\boldsymbol{Q_i = \frac{C_i \times 100}{S_i}} \quad \text{……. (2)}$$

Where Q_i = quality rating;

C_i = concentration of each chemical parameter in each water sample expressed in mg/L.

Also, S_i = drinking water standard for individual chemical parameter in mg/L according to the guidelines of the BIS.

Water samples of this geographical location owing to its trace presence. In order to compute WQI, the SI is determined first for individual chemical parameter, which is in turn used for determining WQI as per the following Equations (3 and 4)

$$\boldsymbol{SI_i = W_i \times Q_i} \quad \text{……. (3)}$$

Table 2: Chemical parameters along with individual relative weights, assigned weights in association to drinking water standards as per WHO 2012 and BIS (2012)

S. No	-Chemical-Parameters (mg/L)	Drinking water standards	Assigned Weight (w_i)	Relative weight (W_i)
1	TDS	500	5	0.1190
2	Chloride	250	5	0.1190
3	Sulphate	200	5	0.1190
4	Calcium	75	3	0.0714
5	Magnesium	30	3	0.0714
6	Sodium	200	4	0.0952
7	Potassium	10	2	0.0476
8	pH	7.5	4	0.0952
9	Conductivity (mmhos)	500	4	0.004

Table 3: Range of water quality index specified for drinking water use in India:

Water quality	WQI range
Excellent water	<50
Good water	50–100
Poor water	100–200
Very poor water	200–300
Water unsuitable for drinking purpose	>300

$$\boldsymbol{WQI \sum_{i=1}^{n} SI_i} \quad \text{……. (4)}$$

Where SI_i is the sub-index of i^{th} parameter, Qi is the rating based on the concentration of i^{th} parameter, n is the number of parameters.

III. RESULTS AND DISCUSSION

A. pH

pH is vital for processes of coagulation and sterilization in drinking water. In order to have effective disinfection using chlorine, pH of water preferably should be less than eight, on the other have pH less than 7 is supposed to be corrosive. Prescribed permissible limit of pH as per Bureau of Indian Standard (BIS) is 6.5–8.5. pH of samples from the present study are reported to be in the range of 7.81-8.52 during pre-monsoon and 7.65-8.62 during post-monsoon. (Fig 1).

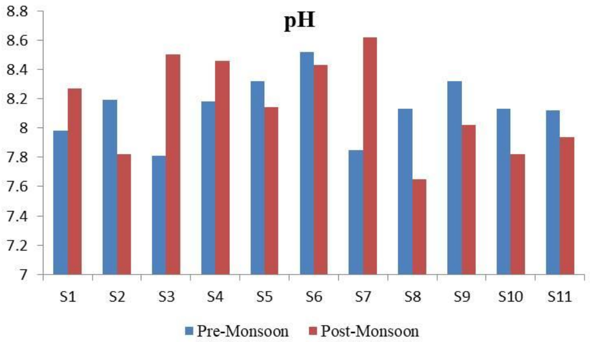
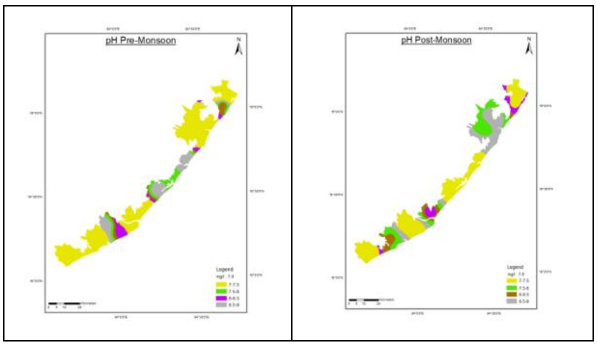


Figure 1: pH trends in the samples during pre and post-monsoon



B. Electrical Conductivity

Conductivity is dependent on the presence of dissolved ions present in the water. Contribution of organic compounds towards conductivity is less as they won't conduct electric current.

Noteworthy changes in conductivity act as indicator of pollution in the water body. Conductivity of collected samples varied between 620 - 5,700 µS/cm in pre-monsoon and 440-5,300 µS/cm in post-monsoon. (Fig 2). Conductivity in sample 7 was recorded to be the highest 5,700 µS/cm in pre-monsoon and 5,300 µS/cm in post monsoon.

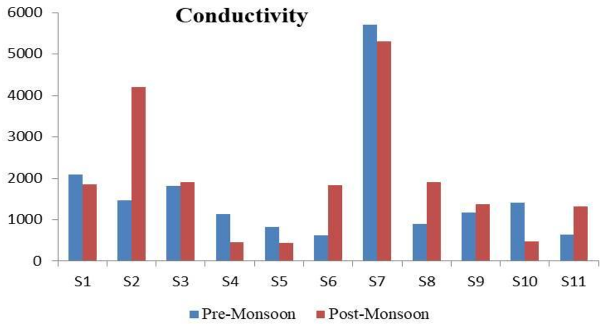


Figure 2: Conductivity trends in the samples during pre-monsoon and post-monsoon

C. TDS

Taste of water is affected due to the presence of dissolved solids. The palatability of water used for consumption in relation to its TDS level is appraised by panels of tasters as follows: excellent < 300 mg/l, good 300-600 mg/l, fair 600-900 mg/l, Poor 900-1200 mg/l and unpredictable > 1200 mg/l. The prescribed acceptable limit of TDS as per BIS is 500 mg/L whereas 2,000 mg/L is the permissible limit for drinking purpose. In the present study, the TDS concentration ranged from 396.8 to 3,648 mg/L in pre-monsoon and 281.6 to 2,688 mg/L in post-monsoon (Figure 3).Highest TDS concentrations were reported by sample 7 with 3648 mg/L in pre-monsoon and sample 2 is 2334.7 mg/L in post monsoon.

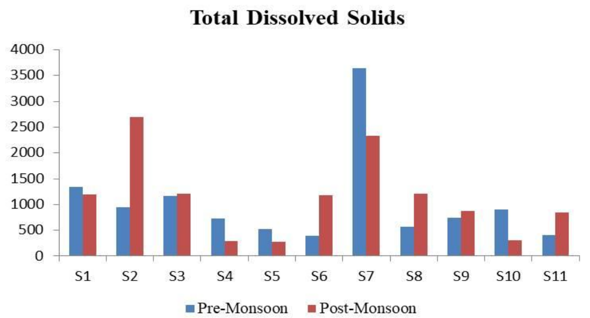
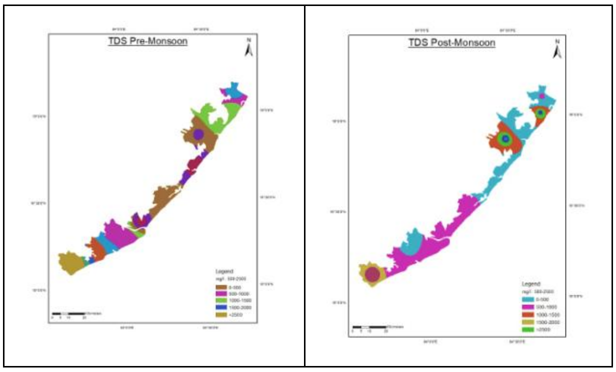


Figure 3: TDS trends in the samples during pre-monsoon and post-monsoon



D. Total Hardness

Hardness in water is owed to the presence of calcium and magnesium salts in freshwater sources. 200 mg/l is the acceptable limit and 600 mg/l is the permissible limit for total hardness in the absence of an alternate source of drinking water as per BIS. The hardness of groundwater samples in the study area is found to be in the range 200-1200 mg/L in pre-monsoon and 140-1200 mg/L in post-monsoon. (Figure 4). Sample 7 recorded hardness of 1200 mg/L as $CaCO_3$, which exceeded permissible limit (600 mg/L), on the other hand 23% of samples from the study fall within 200 mg/l, which is the desirable limit.

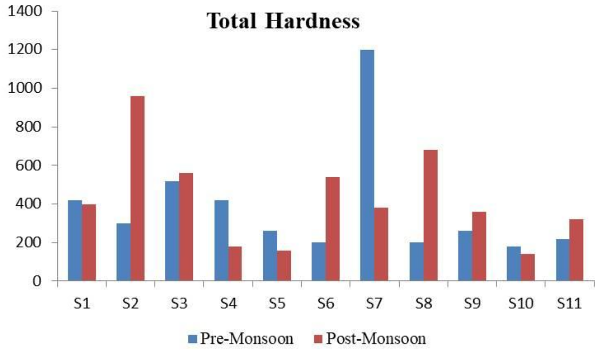


Figure 4: Total Hardness trends in the samples during pre-monsoon and post-monsoon

E. Calcium

Calcium concentrations in the samples ranged from 24 - 160 mg/l during the pre-monsoon season and 32 - 224 mg/L during the post-monsoon season (Figure 5). Acceptable limit as per BIS standard is 75 mg/l whereas permissible limit is 200 mg/L for the purpose of consumption. Except Sample 7 all other samples fall in the permissible limit.

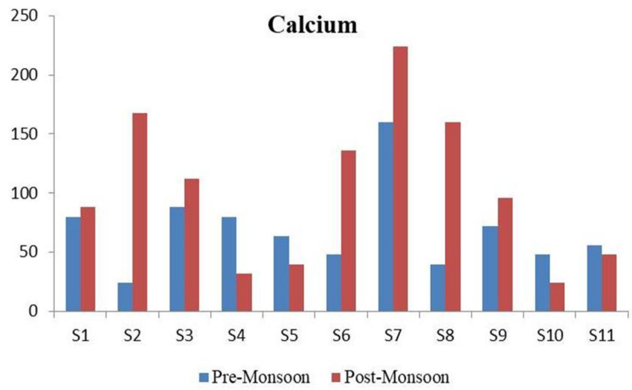
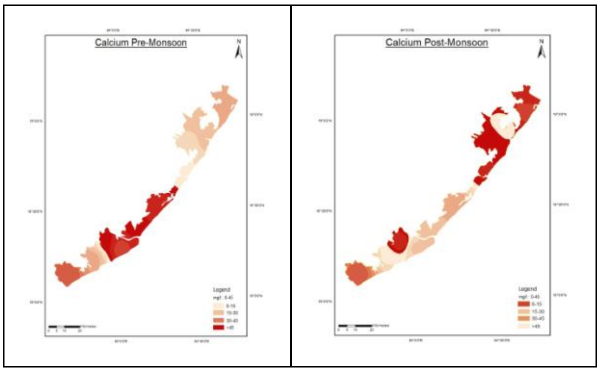


Figure 5: Calcium Hardness trends in the samples during pre-monsoon and post-monsoon.



F. Magnesium

Concentration of magnesium was recorded as 14.586 – 194.48 mg/l during the pre-monsoon and 14.586 – 155.584 mg/l during the post-monsoon (Figure 6). An acceptable value 30 mg/l and 100 mg/L as permissible value are given by BIS standards. More than 90% of pre-monsoon and 81% of post-monsoon samples fall under acceptable limits. Further sample 7 exceeded permissible limits with a concentration of 194.48 mg/L.

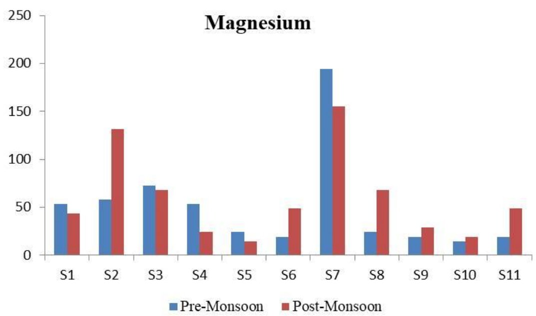
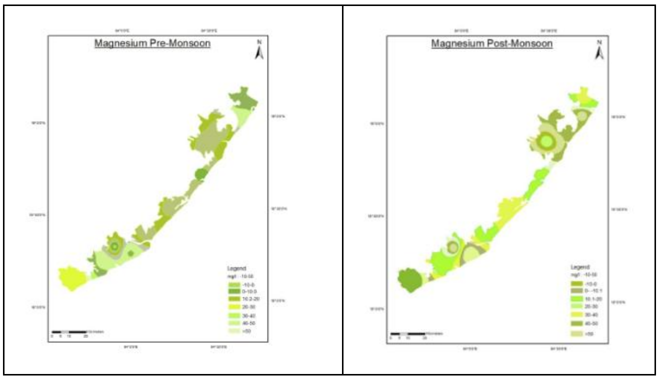


Figure 6: Magnesium Hardness trends in the samples during pre-monsoon and post-monsoon.



G. Sodium

Being reactive metal, sodium does not occur in free form in nature. Enhanced blood pressure and toxemia in pregnant women are two distinct effects of consuming high sodium concentrations. 200 mg/l is the average taste threshold for sodium at room temperature. And hence, the prescribed limit of sodium by WHO is 200 mg/l in drinking water. Sodium concentrations in the present study ranged between 45.48 - 883.4 mg/l during pre-monsoon and 19.1- 804.2 mg/l in post-monsoon (Figure7). More than 70% of samples fall within the limit.

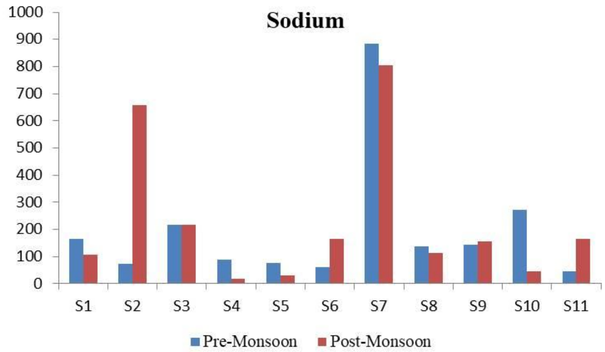
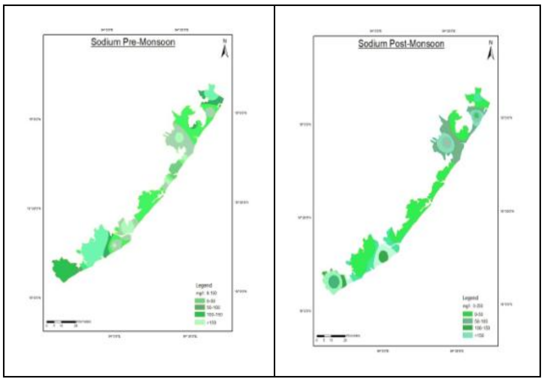


Figure 8: Sodium trends in the samples during pre-monsoon and post-monsoon.



H. Chlorides

Sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$) and potassium chloride (KCl) are some of the common chloride compounds that are available in natural waters. Taste thresholds are governed by the associated cations, where the concentration fall between 200 to 300 mg/L for sodium, potassium and calcium chloride respectively. An acceptable limit 250 mg/l and permissible limit of 1,000 mg/l has been prescribed by BIS. Chloride concentrations in the present study ranged between 50–1200 mg/L during pre-monsoon and 40 - 1360 mg/L during post-monsoon. (Figure 9). 72 % of samples fall within the acceptable limit during pre-monsoon whereas 36% in post monsoon.

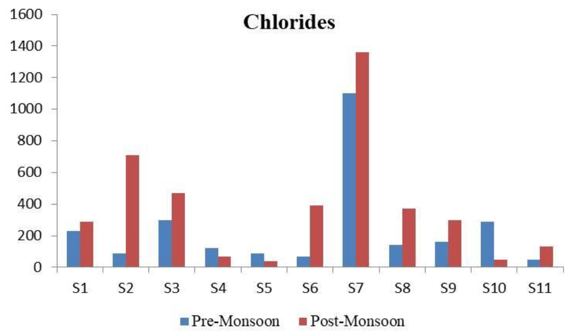


Figure 9: Chloride trends in the samples during pre-monsoon and post-monsoon

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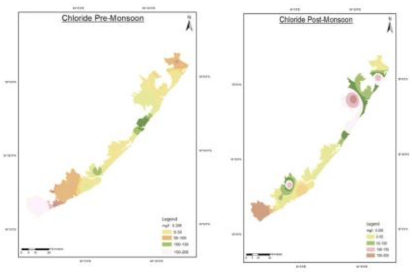


I. *Potassium*

Though potassium is considered an essential element for humans, it is seldom found in drinking water and at levels which might alarm human health. Potassium concentration in the study ranged between 1.7-274.4 mg/L
in pre-monsoon and 0.86 – 260.9 mg/l in post-monsoon (Figure 10). The potassium concentration of 10 mg/l is permissible to limit being prescribed by BIS (2012). Highest concentrations of potassium are observed in sample number 1 which might be attributed to Salinity of the water.

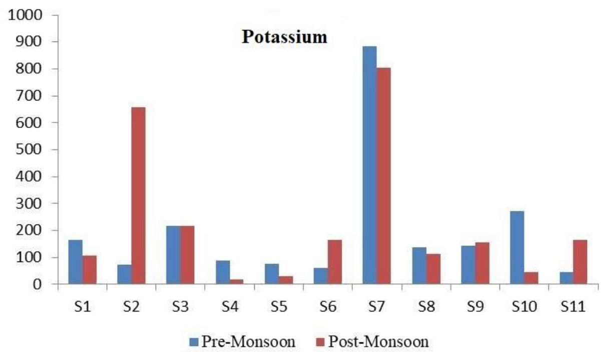
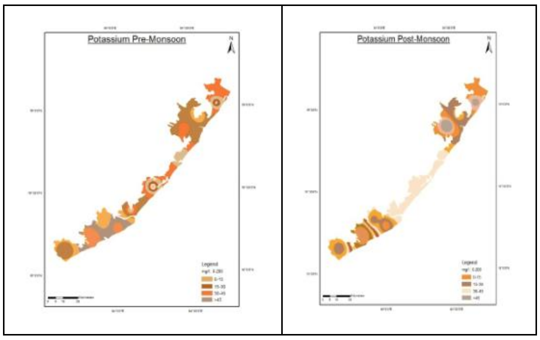


Figure10: Potassium trends in the samples during pre-monsoon and post-monsoon.



J. *Sulphate*

Sulphate is the best basic form of sulfur existing only in oxygenated waters. Noticeable taste is observed due to the presence of sulphate in drinking water. Further, at very high levels it might induce laxative effect in consumers who are not adopted to such waters. Taste thresholds are reported to range from 250 mg/l for sodium sulphate to 1,000 mg/L for calcium sulphate. 200 mg/l is prescribed as acceptable limit and 400 mg/L as permissible limit by BIS. Sulphate concentration of groundwater samples in the study ranged from 12 mg/L to 168mg/L in pre-monsoon and 20 - 122 mg/L in post-monsoon (Figure 11).

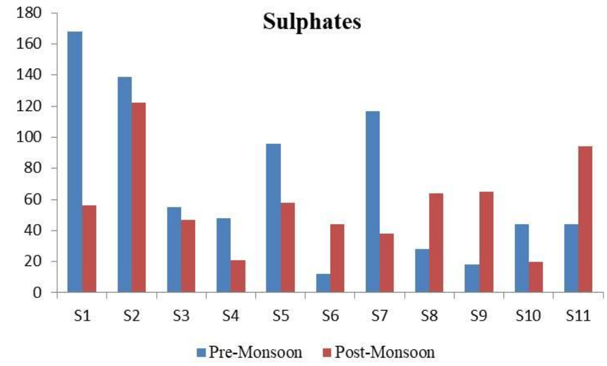
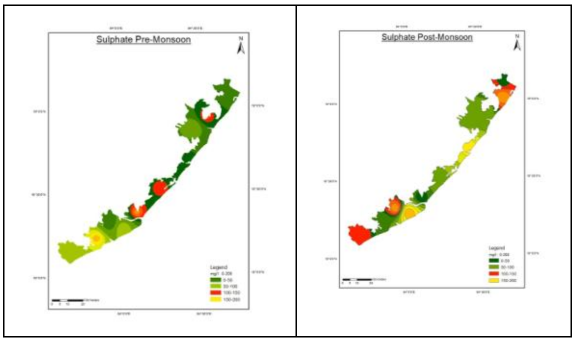


Figure11: Sulphate trends in the samples during pre-monsoon and post-monsoon



K. *Piper Plots*

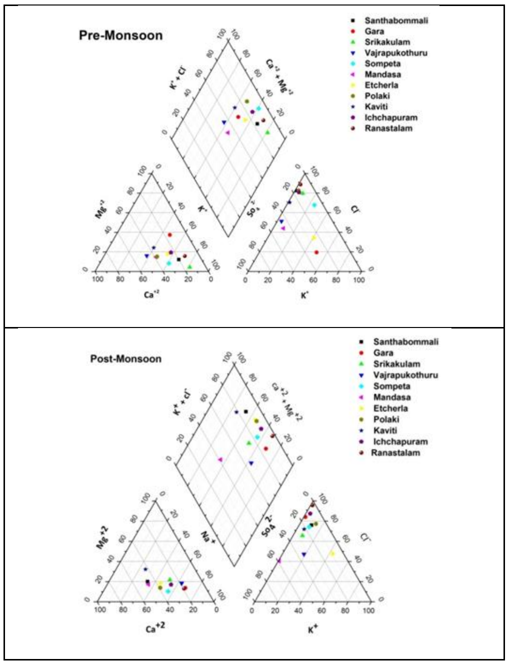


Figure12: Piper plots trends in the samples during pre-monsoon and post-monsoon.

L. *Piper Plots*

The prime focus of piper plots (figure 12) is to present water type and composition present in an area. It is very useful for indicating mixed concentrations of ions such as magnesium (Mg^{2+}), sodium (Na^{+}), sulphate (SO_4) and chloride (Cl^{-}), etc. which vary geographically.

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More than 60% of the samples from the study reported a mixed concentration of cations and anions in piper triangle. The plot presents most water samples falling in mixed composition of Mg-Ca-K-Cl, Mg-Ca-K, and K-SO_4-Cl during the pre-monsoon and a composition of Ca-Mg-K, Ca-Na-Mg,and SO_4-Cl-K,during the post-monsoon. Concentrations of alkali metal (Ca^{2+} + Mg^{2+}) was found to be exceeding in comparison to alkaline earth metal (Na^{+} + K^{+}), similar trend was observed with temporary hardness over permanent hardness.

Correlation coefficient matrix of water parameters

A correlation coefficient (nearly 1 or −1) values lies between −1 and +1 and a correlation coefficient around zero means no relationship. Positive values indicate a positive relationship while negative values of r indicate an inverse relationship. The values of correlation coefficient (r) are given in Table 4 (a& b)

M. Pre-Monsoon

Strong positive and signification correlation was observed with TH, Na^{+}, Cl^{-}, and Mg by Electric conductivity (EC), whereas weak correlation was seen with SO_4. TDS presented maximum correlation with sodium, chloride, magnesium, calcium, potassium and weak correlation with SO_4. Calcium has a strong positive correlation with Mg and total Hardness, Sodium showed a negative correlation with K^{+}. The sodium showed maximum correlation with Ca, Mg, and total hardness. Potassium showed a negative correlation with calcium and total hardness and weak positive with Mg. Chloride has a weak positive correlation with Magnesium calcium and total hardness and negative with Potassium. Potassium showed a negative relationship with calcium and total hardness. Sodium showed Strong positive correlation with calcium, Magnesium and total Hardness and negative with potassium.

N.Post -Monsoon

Electric conductivity (EC) has a strong positive and signification correlation with TDS, Na, TH, and Ca, and Mg, weak correlation with K. The TDS showed max correlation with sodium, chloride magnesium, Total Hardness and weak correlation with SO_4 and potassium. Calcium has a strong positive correlation with Mg and total Hardness; Potassium showed a negative correlation with Potassium and strong positive relation with calcium, total hardness, and Mg. Chloride has a weak positive correlation with SO_4 and strong relationship with Magnesium calcium and total hardness and negative with Potassium. Potassium showed a negative relationship with magnesium and total hardness and positive relationship with calcium. Sodium showed Strong positive correlation with calcium, Magnesium and total Hardness and negative with potassium.

O.Index for Groundwater Quality

During study period i.e. in pre-monsoon (figure 13), too much deprived quality of water has been observed in sample S7 while samples S9 and S1 and S2 were found to be not suitable for consumption purpose was observed. The reason can be attributed to the dominated industrial and Agricultural activities. Deprived water quality is noted in S3 and S10 location from the present study owing to inappropriate dumping of solid waste on land in and around the location. Good water quality was reported in S4, S6, and S11. Excellent water quality is recorded with zone S8. The index rate and quality of groundwater sample of the study area were calculated (Table 6). In post-monsoon, too much deprived quality of water has been reported by samples S7, S8, and S11, this may be due to Industrial activities. Deprived water quality is noted in S2, S3, and S9. Good water qualities have been observed in samples S4, S5, and S10.

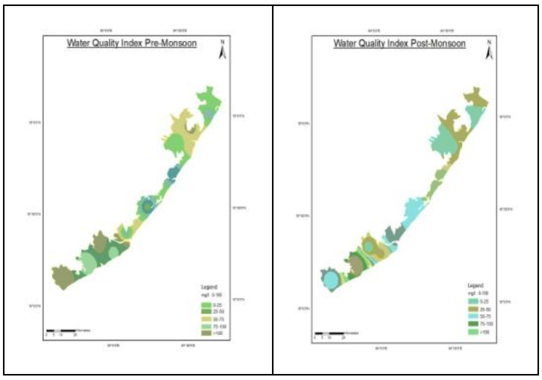

Figure 13: Water Quality Index for pre-monsoon and Post monsoon

IV. CONCLUSION

Groundwater quality of 11 mandals along the coastline of Srikakulam district in Andhra Pradesh was studied during pre and post-monsoon seasons. Experimental results were computed for WQI, which ranged from 46.56 to 1034.54. Among the 11 sampling sites, water samples collected from Etcherla (S1) have shown very poor water quality which is unfit for consumption. Among the tested samples, most of the samples were of poor quality. Wide variation in physico-chemical properties of ground water was found among the samples during the pre and post monsoon seasons. Piper plots indicating anion and cation distribution in the sampling sites were plotted. Majority of water samples fall in mixed Mg-Ca-K-Cl, Mg-Ca-K, and K-SO_4-Cl in pre-monsoon. In the Post-monsoon water, samples fall in mixed Ca-Mg-K, Ca-Na-Mg, and SO_4 -Cl-K. Further, alkali metal (Ca^{2+} + Mg^{2+}) have shown higher concentrations over alkaline earth metal (Na^{+} + K^{+}) and the temporary hardness prevails over permanent hardness. Statistical analysis was performed by one-way ANOVA has proved the experimental results to be true. Thus, from the results, it can be concluded that the water samples require purification to make them fit for consumption. Further, changes in the water quality pre and post-monsoon indicate lesser infiltration of the rainwater, which might otherwise cause dilution and thus deviation in the physicochemical properties. Hence, this study provides a baseline data of water quality of these areas which might help in decision making and executing management aspects.

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Anova Analysis (Table: 5)

S. No	Source of variation	*df*	SS	MS	VR	*F* pr.<0.05
1.	pH	1	6.54545E-4	6.54545E-4	0.00876	0.92634
	Residual	20	1.49365	0.07468		
	Total	21	1.49431			
2.	Conductivity	1	486040.90909	486040.90909	0.21957	0.64443
	Residual	20	4.42713E7	2.21356E6		
	Total	21	4.47573E7			
3.	TDS	1	48673.22909	48673.22909	0.06682	0.79867
	Residual	20	1.45693E7	728466.76369		
	Total	21	1.4618E7			
4.	Chlorides	1	107800	107800	0.91286	0.35076
	Residual	20	2.3618E6	118090		
	Total	21	2.4696E6			
5.	Sulphates	1	890.90909	890.90909	0.49294	0.49071
	Residual	20	36146.54545	1807.32727		
	Total	21	37037.45455			
6.	Sodium	1	4755.45011	4755.45011	0.07663	0.78475
	Residual	20	1.24108E6	62053.78565		
	Total	21	1.24583E6			
7.	Total Hardness	1	79200	79200	0.78822	0.38519
	Residual	20	2.0096E6	100480		
	Total	21	2.0888E6			
8.	Calcium	1	6155.63636	6155.63636	2.25202	0.14906
	Residual	20	54667.63636	2733.38182		
	Total	21	60823.27273			
9.	Magnesium	1	429.8008	429.8008	0.18036	0.6756
	Residual	20	47660.61071	2383.03054		
	Total	21	48090.41151			
10.	Potassium	1	429.8008	429.8008	0.18036	0.6756
	Residual	20	47660.61071	2383.03054		
	Total	21	48090.41151			

Anova was performed for the above samples and we found a significant difference between pre-monsoon and post-monsoon.

Table 6: Details of Water Quality and Index rate of analyzed samples

S.No	Sample Station	Pre-Monsoon		Post-monsoon	
		Index Rate	Water Quality	Index Rate	Water Quality
1.	**Etcherla**	**1034.542**	Unfit for Drinking	**989.1165**	Unfit for Drinking
2.	**Gara**	**897.2064**	Unfit for Drinking	**168.6705**	Poor Water
3.	**Ichchapuram**	**132.3694**	Poor Water	**166.841**	Poor Water
4.	**Kaviti**	**77.72986**	Good Water	**77.7269**	Good Water
5.	**Mandasa**	**122.828**	Poor Water	**46.56437**	Excellent Water
6.	**Polaki**	**67.35543**	Good Water	**328.3696**	Unfit for Drinking
7.	**Ranastalam**	**246.3694**	Very Poor Water	**253.7616**	Very Poor Water
8.	**Santhabommali**	**57.63465**	Excellent Water	**257.128**	Very Poor Water
9.	**Sompeta**	**261.4159**	Very Poor Water	**194.0137**	Poor Water
1(	**Srikakulam**	**158.775**	Poor Water	**57.72825**	Good Water
11	**Vajrapukothuru**	**60.38009**	Good Water	**239.6556**	Very Poor Water

Table 4a: Correlation pre-monsoon

	p H	*Conductivity*	*TDS*	*Cl*	*SO4 mg/L*	*Na Sodium mg/L*	*K Potassium mg/L*	*Calcium as CaCO3 mg/L*	*Mg Magnesium mg/L*	*Total hardness*
p H	1									
Conductivity	0.207756	1								
TDS	0.207816	**1**	1							
Cl	0.367096	**0.962673**	**0.96267**	1						
SO4 mg/L	-0.50041	0.354768	0.354834	0.129807	1					
Na Sodium mg/L	0.201235	**0.971149**	**0.971133**	**0.933564**	0.365156	1				
K Potassium mg/L	**0.090202**	0.01332	0.013362	-0.0529	0.045123	-0.16104	1			
Calcium as CaCO3 mg/L	0.164548	**0.905723**	**0.90575**	**0.90879**	0.265204	**0.812525**	0.028334	1		
Mg Magnesium mg/L	0.163208	**0.981038**	**0.981035**	**0.938573**	0.367644	**0.96434**	-0.09626	**0.88276**	1	
Total hardness	0.168823	**0.975019**	**0.97503**	**0.952981**	0.329982	**0.921316**	-0.03976	**0.965605**	**0.974558**	1

Table 4b: Correlation post-monsoon

	p H	*Conductivity*	*TDS*	*Cl*	*SO4 mg/L*	*Na Sodium mg/L*	*K Potassium mg/L*	*Calcium as CaCO3 mg/L*	*Mg Magnesium mg/L*	*Total hardness*
p H	1									
Conductivity	-0.64659	1								
TDS	-0.64659	1	1							
Cl	-0.61625	**0.977162**	**0.977162**	1						
SO4 mg/L	-0.43664	0.480163	0.480163	0.314513	1					
Na Sodium mg/L	-0.58728	**0.963982**	**0.963982**	**0.997008**	0.280367	1				
K Potassium mg/L	-0.14866	**0.098309**	**0.098309**	-0.08645	**0.790876**	-0.1116	1			
Calcium as CaCO3 mg/L	-0.58803	**0.864394**	**0.864394**	0.872937	0.254869	**0.845998**	-0.16959	1		
Mg Magnesium mg/L	-0.64922	**0.960692**	**0.960692**	**0.920183**	0.473041	**0.894414**	0.054608	**0.853452**	1	
Total hardness	-0.65131	**0.962037**	**0.962037**	**0.935206**	0.421576	**0.908255**	-0.01209	**0.925499**	**0.987263**	1

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