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PHYSIO-CHEMICAL, STATISTICAL AND GEOSTATISTICAL CHARACTERIZATION OF WATER QUALITY IN SALINITY AFFECTED AREAS OF EAST GODAVARI DISTRICT, ANDHRA PRADESH, INDIA

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ABSTRACT

Ground water is liable to contamination as it present in an alluvial aquifer, the principal type of aquifer in coastal regions .The quality of the ground water is as important as its quantity. The underground water quality deterioration from both natural and anthropogenic sources, akin to industrialisation, where improper disposal of wastes and also excessive use of fertilizers and pesticides and aquaculture where conversion of agricultural lands into aqua-culture ponds grew to alarming levels. Many more factors are posing to be the major sources for salt-water intrusion into the soil and into the coastal aquifers, which are naturally vulnerable to seawater intrusion, deteriorating the quality of the ground water resources. All these along with others lead to consequent increase in the salinity of ground water resources day by day and even extends into the new surrounding areas. The aim behind this research was to assess the water quality, to measure the level of seawater intrusion if any into the coastal aquifer and to determine the temporal and spatial status of water salinity condition in Godavari district. To ascertain the accuracy and the toxicity levels these parameters were compared with BIS, ICMR and WHO, standards.

Keywords*: *Correlation and Regression, Geo Informatics system, Groundwater Quality, Physio-Chemical parameters, Water quality index.

I. INTRODUCTION

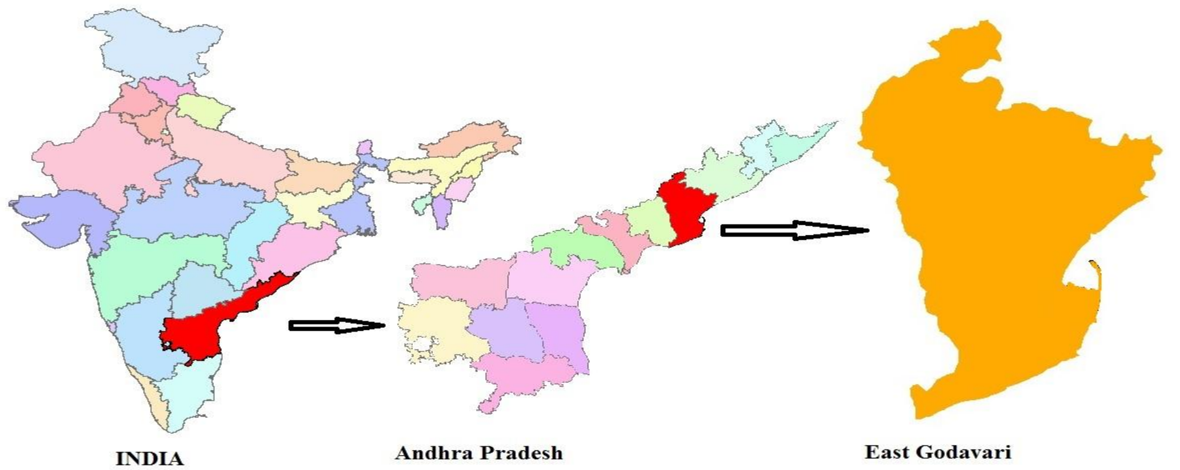
Andhra Pradesh is blessed sumptuously with natural resources, mineral wealth, fertile lands and water resources contributing to agro-climatic conditions making it a prosperous State. It is one of the major rice-producing states in India, where more than 70 percent of the total population largely depend upon agriculture. The state with its total geographical area of 275.04 lakh hectares. Out of which, 22.6 percent is covered by forests, 9.8 percent is by current fallow lands, 9.6 percent by non- agricultural uses and 7.5 percent is barren and uncultivable land. Godavari district is one of the largest districts of the State of Andhra Pradesh, blessed with fertile delta lands, good horticultural resources, abundant marine and fisheries resources and good mineral deposits along with the availability of natural gas deposits. The district owes its prosperity to the longest Peninsular river Godavari that flows through the with the largest drainage basin among the peninsular river basins. The Godavari river stretches up to 1500 km, with its origin from the slopes of the Western Ghats in Nasik district of Maharashtra and drains into the Bay of Bengal. East Godavari district has all the 3 types of geographical formations of forest lands, uplands, fertile delta lands and a Coastline of 144 Kms. Of late these vast fertile lands of east Godavari district has been converted into aquaculture ponds the ground water in this region has been subjected to intensive exploitation for industrialisation and domestic purposes to cater to all the needs of the ever growing population, and accordingly high seasonal hydro chemical modulations were noticed in this part of the delta region. Salts enter groundwater naturally through dissolution of soil, rock, and organic material. Sea water intrusion into the delta region is a global issue[1,2]. Sea water intrusion is the movement of seawater inland into fresh ground water aquifers as a result of higher seawater density than fresh water and heavy withdrawal of fresh water. A natural equilibrium exists between discharging fresh ground water and sea water in a coastal aquifer. This interface depends upon the geological formations, topography and the amount of fresh water moving through the aquifer system. Such intrusion contaminates the ground water and reduces the soil fertility which in turn effects agricultural production[1] due to which most of the fertile land has become wasteland and cultivation rate has also decreased and also because of the growing demand for seafood, has led many farmers to take up aquaculture as it is a more profitable source of income,. The saline nature of the water used for aquaculture gradually infiltrates and reaches the ground water table, and disturbs the natural bionetwork followed by anthropogenic activities causing increased usage of groundwater followed by reduced inflow of fresh groundwater to coastal waters. Salinization is the most widespread form of ground water contamination in coastal aquifers is constituted by the alarming rates of total dissolved solids (TDS) and some specific chemical constituents such as Cl-, Na+, Mg+2 and SO4-2 (Nadler et al., 1981; Magaritz and Luzier, 1985; Dixon and Chiwell, 1992; Morell et al., 1996; Sukhija et al., 1996; Gime nez and Morell, 1997)[3]. Many of the coastal aquifers in the world already experience salt water intrusion caused by both natural and anthropogenic activities.

The amount of dissolved particles and ions in water is a measure of salinity which can be measured in two ways[4], they are: Total Dissolved Solids (TDS): TDS is a measure of all dissolved substances in water, which includes the organic and suspended particles that can pass through a very small filter. The amount of dissolved material in natural waters, land usage, human activities and geologic formation of the hydrologic basin. Electrical Conductivity (EC): EC / specific conductance or specific conductivity is a measure of dissolved ions concentration in water and is reported in µS/cm(microsiemens per centimetre). The ability of an electric current to pass through water is proportional to the amount of dissolved salts in the water – specifically, to the amount of charged (ionic) particles.[5]

Understanding the quality of groundwater with its temporal and seasonal variation is important because it is the factor that determines the suitability for consumption, agricultural, domestic and industrial purposes (Amadi et al., 2008). [6]There are several geochemical, geophysical and remote sensing techniques that are used to directly or indirectly monitor saltwater in coastal aquifers, due to high percentage of chloride in seawater (more than 21,000 mg/L), the concentration of chloride in the groundwater samples is the most commonly used indicator of saltwater occurrence and intrusion in coastal aquifers. Thus, Remote Sensing and GIS, a tool which is used for storing, analyzing and displaying spatial data is used for investigating ground water quality information. GIS has been used by scientists of various disciplines for analysis, integration and spatially supported databases for the last few decades .

II. STUDY AREA

East Godavari district one of the nine coastal districts is situated on the North East of Andhra Pradesh lies between 16° - 30° and 18° - 20° of Northern Latitude and 81° - 30° and 82° - 36° of the Eastern Longitude spreading over an area of 10,807Sq.km. The district is bounded on the North by Visakhapatnam District and Orissa State lying on the East of Bay of Bengal and on the South and West by West Godavari and Khammam districts. It can be broadly classified into three natural zones – Delta, uplands and Agency Tracts. The district headquarters is located at Kakinada town with 60 revenue mandals**.** The Godavari river is the major perennial river that flows along the western boundary of the district **(Source : Brief Industrial Profile of EAST GODAVARY Districts)**



Location Map of the Study Area

III. METHODOLOGY

One hundred and Fifty five groundwater samples were collected from 45 different wells at various locations of the Coastal deltaic region along the district,. during both the pre and post monsoons of 2014- 2015 , these samples belonged to different landforms and from those bore wells which are extensively used by the inhabitants for consumption, agricultural and other domestic purposes. The collected groundwater samples were analysed for pH, Alkalinity , electrical conductivity , Total Hardness, Total Dissolved Solids, and dissolved anions Hardness, Chloride, Phosphate, Sulphate and cations Calcium, Magnesium Potassium, Sodium, hence an Integrated study is taken up to evaluate the hydrogeology, hydrochemistry and geophysical status of water using statistical methods like correlation , regression and geo statistical techniques of remote sensing and Geographic Information System (GIS) for spatial and temporal mapping of water quality parameters in the study area. After analysis ,to ascertain the accuracy and the toxicity levels these parameters were compared with BIS, ICMR and WHO, standards, it is observed that the ground water is not within the permissible limit for pH, Salinity, Turbidity, prescribed by BIS, ICMR, WHO and the parameters like Chlorides (Cl), Sodium (Na), Hardness are exceeding the prescribed limit. an Attribute Database was prepared.

Integrating Spatial with that of the Attribute database, maps for parameters like TDS, E.C Total hardness and Sodium were generated.

3.1 Water Quality Index (WQI)

The water quality data (attribute) is linked to the sampling location (spatial) and maps showing spatial distribution were prepared to easily identify the variation in concentrations of the above cited parameters of the groundwater at various locations of the study area. Water quality index is one of the most effective tools to monitor the surface as well as ground water pollution and can be used to upgrade water quality. The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public. Water quality index provide information on a rating scale from zero to hundred(0 -100). Higher the WQI value better the water quality and lower the value is an indication of poor water quality.

For computing WQI three steps are followed. In the first step, each parameter has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (table-1). The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment. Magnesium which may not be harmful is given the minimum weight of 1. WQI is computed adopting the following formula [(7).]

WQI=Antilog [ΣW^n n=1 log10 q n] **(1)**

Where, W, Weightage factor (W) is computed using the following equation, (Table 3)

Wn =K / Sn **(2)**

and K, Proportionality constant is derived from,

K = [1 / (Σ^n n=1 1/Si)] **(3)**

Sn and Si are the WHO / BIS10500 standard values of the water quality parameter. [8,9]

Quality rating (q) is calculated using the following formula

qni={[(Vactual–Videal)/ (Vstandard – Videal)] * 100} where **(4)**

qni = Quality rating of ith parameter for a total of n water quality parameters

V actual = Value of the water quality parameter obtained from laboratory analysis

V ideal = Value of that water quality parameter can be obtained from the standard tables.

V ideal for pH = 7 and for other parameters it is equal to zero.

V standard = WHO / ICMR standard of the water quality parameter

Based on the above WQI values, the ground water quality is rated as excellent, good, poor, very poor and unfit for human consumption.

3.2 Creation of Database

The study is carried out with the help of two major components: cadastral maps and field data. The cadastral maps collected from the Mandal Revenue Office, demarcating all villages are scanned and digitized to generate a digital output forming a spatial database. Field work was conducted and groundwater samples were collected from various villages of East Godavari District with the help of the map. The results obtained from the samples analysed using standard procedures in the laboratory were tabulated in an excel worksheet. The Water Quality Index for each village when calculated exhibited variation from 23 to 63 for the villages during the premonsoon season and varied from 57 to 72 for the villages during the post monsoon season. Using these water quality

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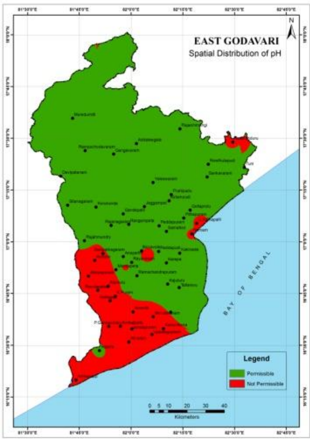
indices the attribute database for the present study was obtained. The data base table consisting of average values of the parameters determined and the calculated water quality index values are given in the Table.nos. 4 and 6.

Table 1: Water quality parameters, their BIS 10500 / WHO standards, and assigned unit weights.

Parameter	Standard (Sn & Si)	Weightage (Wn)
pH	8.5	0.024939
Electrical Conductivity(EC)	2000.00	0.000106
Total dissolved Solids(TDS)	500.00	0.000424
Turbidity	5.00	0.042396
Alkalinity	200.00	0.00106
Hardness	300.00	0.000707
Fluoride	1.00	0.211978
Chloride	250.00	0.000848
Calcium	75.00	0.002826
Magnesium	30.00	0.007066
Sulphate	200.00	0.00106
Iron	0.30	0.706592

3.3 Generation of Maps

The spatial and attribute database generated were integrated for the generation of the spatial distribution maps of all water quality parameters along with the Water Quality Index map. The water quality data (attribute) is linked to the sampling location (spatial) and maps showing spatial distribution were prepared using Arc Map 10.2 version.



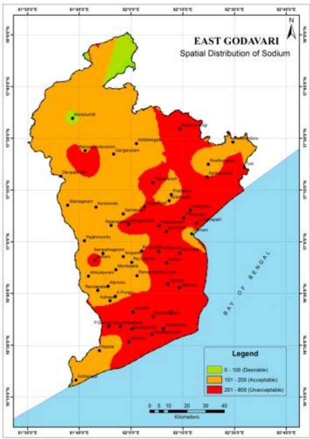
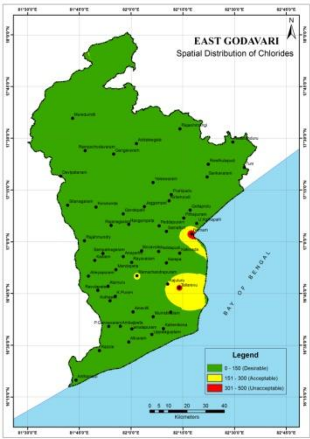


Fig 1: Spatial distribution pH **Fig 2: Spatial distribution Sodium**

IV. RESULTS AND DISCUSSION

Ground water quality has been evaluated for 58 mandals of the east Godavari district of Andhra Pradesh, India. The chemical analysis of all the 58 groundwater samples were evaluated and Water quality index has been calculated based on 11 important water quality parameters (pH, TDS, EC, Nitrates, Sulphates, Calcium, Magnesium, Chlorides, Fluorides, Hardness and Iron. Based upon their water quality index obtained mandals are classified into four types , saline, potable ,unfit for irrigation and potability, semi critical were clearly indicates the level of salinity. Salinity which makes the water unfit for drinking were identified in nine mandals were found to be in moderate to highly saline range, and seven mandals were partially saline in localised areas. One of the major reasons for high salinity can be due to the location and spread of the district along the coast. Encompassed by Water logging and salinity the major problems in the delta region, the absence of significant rainfall during the rabbi season, and the selection of suitable crops and management practices assume considerable importance in all the areas where salinity of the soil or the quality of irrigation water is a problem. The sub-soil water is also found to be generally rich in salt content in certain areas. The intensive irrigation, near flat topography, low ground water development, poor drainage and clayey soils are the factors responsible for the water logging. In the deltaic area and coastal area the brackish/ saline ground water occurs in hydraulic contact with fresh ground water. The quality of ground water varies widely from place to place even within short distances and the deeper aquifers are invariably saline.



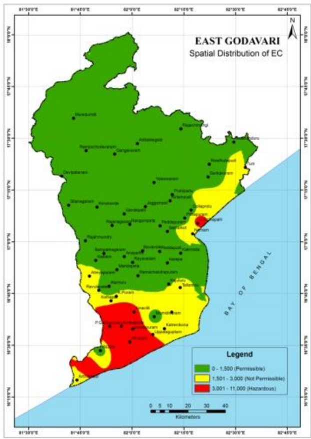


Fig 3: Spatial distribution Cl **Fig 4: Spatial distribution EC**

The salinity of ground water is caused due to geomorphic landform, water logging conditions, sluggish nature in ground water movement and excess use of fertilizers and unregulated growth of aquaculture in the coastal area. The Red areas marked in Fig.5 are Salt affected areas

Taking into consideration three very important parameters viz, Electrical conductivity (E.C), total dissolved solids (TDS and sodium(Na) which play a major role in attributing saline nature to the water quality in the study area .spatial distribution .maps are generated. Except for another ten mandals which are found to be unsuitable for both drinking and irrigation purpose the remaining thirty nine mandals are having good quality of ground water resources.

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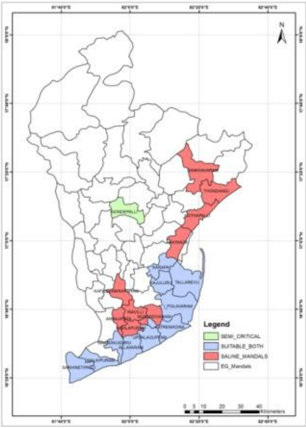

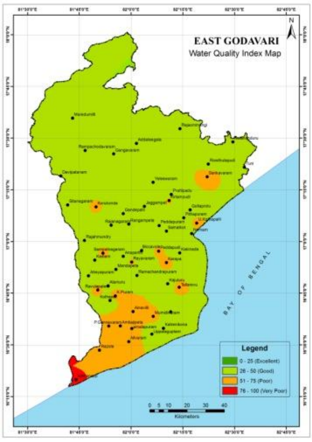

Fig 5: Saline Mandals **Fig 6: WQI Map**

V. STATISTICAL ANALYSIS

Statistical analysis can be applied to represent the data pertaining to the water samples in the research and is useful in understanding the internal relationships of various parameters used for the physicochemical analysis. As initial part of statistical analysis, mean and standard deviation for the values of different parameters were calculated. Correlation matrix for pre monsoon and post monsoon are presented in table numbers 2 and 3. Strong positive correlation between parameters is highlighted. Positive correlation between pH with Ca, Mg, HCO_3, SO_4 and F, EC with TDS, Na, K,+ , Very poor negative correlation was of pH with EC ,TDS ,TH , K ,Cal and Na . Na with Ca, HCO_3, SO_4 and F, Cl- with F.

Correlation is a broad class of statistical relationship between two or more variables. The correlation study is useful to find a predictable relationship which can be subjugated in practice. It is useful in measuring the statistical significance and the strength of the relation between two or more water quality parameters. Hence, it is helpful for the promotion of research activities. In research work It can also put forward possible relationships. Finally the correlation coefficients(r) and correlation matrix was obtained. Here, r is a dimensionless index which is in the range of -1.0 to +1.0 inclusive 0. It exhibits the extent of a relation between variables. The values of r from 0 to 1 and its indications are shown in Table-3. The values of correlation coefficients for different variables for pre monsoon are listed in Table-4., Strong positive correlation was found between TDS and E.C., Na with TDS and EC, Mg with Ca and pH in the pre-monsoon period and in post monsoon Strong positive correlation was found between TDS and Potassium, Na and EC, Cal and Mg. Negative correlation was found between pH, EC, TDS. Very poor negative correlation was found between pH with Sulphate and Fluoride.

.

	PH	EC	TDS	TH	Na	Ca	K	CO3	HCO3	SO4	Mg	Cl	F	NO3
PH	1													
EC	-0.506	1												
TDS	-0.461	0.996	1											
TH	-0.896	0.519	0.513	1										
Na	-0.684	0.956	0.927	0.587	1									
Ca	0.7208	-0.26	-0.27	-0.94	-0.283	1								
K	-0.77	0.676	0.607	0.476	0.8592	-0.143	1							
CO3	0.08	0.392	0.342	-0.41	0.4549	0.707	0.574	1						
HCO3	0.8169	-0.67	-0.67	-0.97	-0.676	0.8918	-0.46	0.3468	1					
SO4	0.6753	-0.62	-0.65	-0.92	-0.57	0.8995	-0.27	0.4637	0.976	1				
Mg	0.926	-0.29	-0.27	-0.95	-0.429	0.9077	-0.47	0.4497	0.852	0.7667	1			
Cl	-0.291	0.485	0.546	0.673	0.3189	-0.757	-0.12	-0.579	-0.79	-0.902	-0.463	1		
F	0.9282	-0.73	-0.67	-0.76	-0.885	0.4794	-0.94	-0.268	0.734	0.5737	0.727	-0.191	1	
NO3	0.0535	0.516	0.59	0.34	0.2688	-0.413	-0.25	-0.348	-0.53	-0.681	-0.063	0.907	0.037	1

Table - 2: Correlation Matrix for Various Parameters -pre-monsoon

	PH	EC	TDS	TH	Na	Ca	K	CO3	HCO3	SO4	Mg	Cl	F	NO3
PH	1													
EC	0.3581	1												
TDS	0.7862	0.68071	1											
TH	0.1787	-0.5229	0.2095	1										
Na	0.3253	0.96466	0.527	-0.712	1									
Ca	0.0031	-0.0002	0.448	0.7583	-0.2629	1								
K	0.4989	0.70334	0.9269	0.2353	0.49954	0.6605084	1							
CO3	0.6162	-0.1934	0.0045	-0.104	-0.0314	-0.648443	-0.3712	1						
HCO3	0.9088	0.28965	0.8835	0.5009	0.15178	0.4182106	0.70596	0.3066	1					
SO4	-0.214	0.38258	0.4182	0.2911	0.15558	0.8424537	0.72619	-0.9	0.13677	1				
Mg	0.6582	0.4372	0.2879	-0.564	0.59959	-0.719553	-0.0262	0.7794	0.29029	-0.644	1			
Cl	0.4543	0.36255	0.0629	-0.708	0.56934	-0.863637	-0.22355	0.7479	0.0455	-0.722	0.969	1		
F	-0.819	0.21464	-0.492	-0.625	0.27523	-0.184232	-0.22243	-0.628	-0.8406	0.2906	-0.29	-0.099	1	

Table -3: Correlation Matrix for Various Parameters-Post monsoon.

VI. CONCLUSION

This research provides some baseline information and understanding with regards to the state of salinity in the study area. The nature of salinity varies from one mandal to another within the same district due to lack of drainage system which has been the main contributing factor, overexploitation of ground water, ingress' of saline sea water and unscientific agricultural practices and aquaculture covering more than fifty percent of the villages of these mandals paved way for further deterioration. Very high values of villages confirm that water is not suitable for drinking or agriculture purpose, it may be inferred that ground water is highly contaminated with salt water and thus not suitable for agriculture. Hence adaptability and remedial measures can be suggested for lessening salinity in this region, Development and implementation of adaptation policies and adopting proper treatment methods for sustainable production are the right ways to respond to salinity level rise impacts.

Parameters	Ainavilli	Ambajipet	Amalapuram	Mumidvaram	Thondangi	N.Kothapalli	Kpuram	Sankavaram
PH	8.40	8.80	8.50	8.70	8.60	8.60	8.65	9.90
HARDNESS	1360.00	72.00	3435.17	33.67	9.10	47.56	994.00	1421.00
FLUORIDE	43.00	32.00	17.40	23.00	3.00	33.03	43.00	58.00
CHLORIDE	754.00	520.00	328.00	373.33	13.00	500.00	754.00	910.00
CALCIUM	1012.00	402.00	301.67	320.67	0.16	376.00	1012.00	1100.00
IRON	3.20	3.20	5.72	5.72	5.72	5.72	3.20	2.00
NITRATE	43.00	86.00	215.00	233.00	196.00	269.00	102.00	78.00
TDS	1107.00	911.00	1096.47	1185.07	33.10	1476.88	5430.00	1010.00
MAGNESIUM	81.0000	72.0000	15.3333	11.3333	254.1100	33.0000	56.0000	67.0000
SULPHATE	54.0000	71.0000	41.0000	37.0000	12.0550	41.1000	85.0000	54.0000
WQI	**23**	**31**	**31**	**62**	**34**	**34**	**63**	**28**

Table 4: Normal statistics of saline affected ground water mandals-PRE MONSOON

Water Quality Index	Description
0-23	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for drinking

Table 5: Water Quality Index Categories

Parameters	Ainavilli	Ambajipet	Amalapuram	Mumidvaram	Thondangi	N.Kothapalli	K.Puram	Sankavaram
PH	9.20	8.50	8.40	8.40	8.80	8.60	8.80	9.90
HARDNESS	1910.00	3435.17	84.00	35.67	30.00	47.56	1200.00	1421.00
FLUORIDE	78.00	17.40	21.00	23.00	9.25	33.03	38.00	58.00
CHLORIDE	1100.00	328.00	720.00	283.33	127.75	500.00	990.00	910.00
CALCIUM	1012.00	301.67	810.00	282.67	71.50	376.00	1180.00	1100.00
IRON	3.20	5.72	3.20	5.72	2.00	5.72	3.20	2.00
NITRATE	58.00	215.00	110.00	196.00	170.00	269.00	110.00	78.00
TDS	1402.00	1096.47	1230.00	1007.80	410.00	1476.88	5900.00	1010.00
MAGNESIUM	98.0000	15.3333	89.0000	19.3333	3.5000	33.0000	43.0000	67.0000
SULPHATE	72.0000	41.0000	64.0000	44.6600	72.0000	41.1000	95.0000	54.0000
WQI	**72**	**57**	***59***	**59**	**52**	**63**	**63**	**69**

Table 6: Normal statistics of Salt effected Ground Water Mandals - POST MONSOON

VII. ACKNOWLEDGMENTS

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