Geo Statistical Analysis in Assessment of Seasonal Variation of Groundwater Quality in Central Delta of Godavari,Andhra Pradesh, India.

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ABSTRACT

Geo-statistical techniques were applied to groundwater quality data to investigate spatial distribution analysis and controlling mechanisms of groundwater chemistry and seasonal variability of groundwater quality parameters in Central delta of Godavari River, East Godavari District, Andhra Pradesh, India. Groundwater samples were collected from 15 observation wells and analyzed for 13 water quality parameters in pre and post monsoon seasons during the year 2015. The results revealed that groundwater quality were distinctly different between two seasons. The finding indicates that concentration of pH, Total Dissolved Solids, Sulphate, Chloride, Alkalinity, Total hardness, Calcium, Magnesium, were found above the standard limits prescribed by BIS. The study also indicates that a moderation in water quality was observed after the monsoon season which can be attributed to a possible dilution due to clear groundwater recharging effect of precipitation by monsoon. The present study suggests that geostatistics is helpful for analyzing the spatial distribution and seasonal variation distinguishing the influences of natural factors on groundwater chemistry.

Key Words: Geostatistics, Groundwater chemistry, Seasonal variation, Central Godavari delta

INTRODUCTION

Water is the artery of our life and one of the most important gifts from our God to mankind. Water covers nearly three quarters of the earth's surface in oceans, lakes, snow and glaciers. It exists also in the atmosphere and underground. Only a tiny portion (4.9 %) of this water is fresh and suitable for direct human uses. Groundwater represents two thirds of this fresh water. The groundwater of the Quaternary aquifer in the central Godavari delta region represents an important source of water after the River Godavari water. Greater demands for water with growing population in parallel with cultivation and industrial activities are increasingly needed. However, even in countries where surface water is abundant, the good quality of groundwater, its accessibility and its relatively low cost are factors that stimulate an increasing level of exploitation of this resource.

Understanding the quality of groundwater with its seasonal variation is important because it is the factor that determines the suitability for drinking, domestic, agricultural and industrial purposes. In many instances the water supply for human consumption is directly sourced from groundwater without biochemical treatment so the level of pollution has become a cause for major concern. During last few years, the utilization of groundwater for drinking, industrial and agricultural purposes has increased manifolds but consequently it is observed that the water is polluted and affecting the human health, soil nutrients, livestock, biomass and environment in certain areas.

Various workers have studied the variations in concentrations of physico-chemical properties with seasonal variations. (Sirajudeen J.et.al.,) assessed groundwater quality on Tamil Nadu and Pondicherry, using Water Quality Index for two different seasons i.e. post monsoon and monsoon season and reported that water quality of post-monsoon season is poor in comparison to monsoon period and not suitable for drinking

purpose. Seasonal variation in groundwater quality of Chandrapur, Maharashtra, India was assessed in pre and post monsoon season by Prashant et al. and reported that upper values of parameters were recorded in pre monsoon season compared to post monsoon season, which indicated seasonal variation and deterioration in groundwater quality in the study area.

Khan et al. studied the seasonal variations in ground water quality of Western part of Muzaffar nagar district in the state of Uttar Pradesh, India. The results of the study revealed that groundwater quality variables were distinctly different between two seasons and found that the post monsoon period seemed to be characterized by relative dilution in comparison to pre-monsoon period. Seasonal groundwater quality variation in Brazzaville, Congo was studied by Matini L. et al. reported that seasonal effect has been observed on some parameters such as EC, TDS, Mg^{2+}, SO_4^{2+}. Seasonal variation in physico-chemical characteristics of Coimbatore, Tamil Nadu have been studied by Sundar Lenin et al. and reported that the values of all the studied parameters were above the standard limits during the post monsoon season compared to the pre monsoon season.

Goyal studied temporal and seasonal changes in groundwater quality in agriculture dominated area Kaithal district of Haryana to analyze temporal changes in groundwater quality, concluded that all the parameters analyzed in this study showed a perceptible moderation in the post monsoon observations. Seasonal variation in physico-chemical characteristics have been studied by Nabanita Haloi et al, A.H. Pejman et al. Narwaria et al. Jain in groundwater of different parts of India. The reason for examining variations comparing two seasons was the considerable differences in climatic and hydrological conditions respectively, of the study area leading to groundwater quality changes. Rainfall is the main recharge source of groundwater in this area. Therefore, it is necessary to investigate seasonal changes in groundwater quality to ascertain the role of dilution due to monsoonal recharge in the study area. The increased knowledge of seasonal changes of groundwater quality could lead to effective management of groundwater resources.

DESCRIPTION OF THE STUDY AREA

The study area lies in East Godavari District of Andhra Pradesh State on East coast of India and forms a Part of Central Godavari Delta. It forms a part of the survey of India Toposheet Nos. 65K/8, 65L1, 65L2, 65H3, 65K3, 65K4, 65H13, 65H14, 65H15. Geographically, the study area of Central Godavari Delta is located between 16°25' to 16°55' N latitude and 81°44' to 82°15'E longitude with its hydrological boundaries as river Gowthami Godavari in the east, River Vasistha Godavari and its branch Vainateya in the west, Bay of Bengal in the South, Alluvial plains on the north (Fig. 1). The study area is accessible by road ways, the sub-divisional town Amalapuram is located in the central part of the area. Rajahmundry town which is situated outside the delta (at 65 kms. North of Amalapuram) is the nearest important rail has adjacent to the study area. (Fig.1).

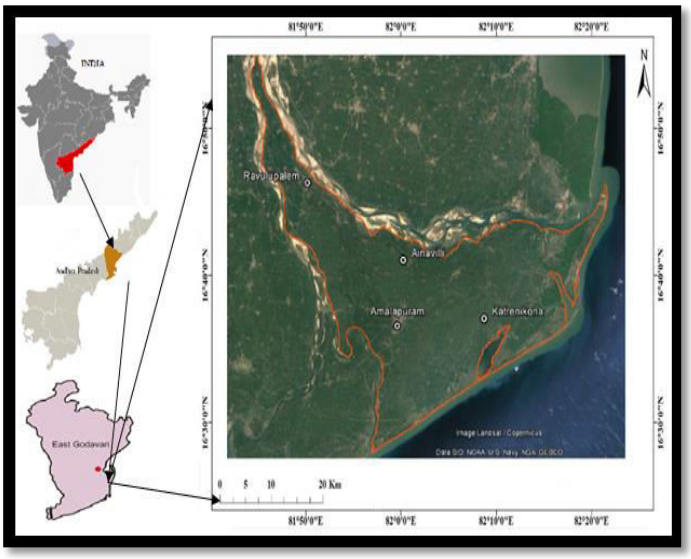

Fig.1 Map of the study area.

CLIMATE

The average annual rainfall in the study area is about 1,137 mm distributed unevenly among an average of 57 rainy days of the year (Gurunadha Rao et al. 2015). About 72 % of the rainfall occurs during the southwest monsoon season (June–September), while the rest occur during the northeast monsoon (October–December).

The Godavari delta region is situated in the East Godavari District of Andhra Pradesh, situated on the east coast of India. The study region, spread over an area of 295 km^2 in the southern part of Godavari delta, is bounded by the Bay of Bengal on the east, the Vainateya River on the west, and alluvial plains on the north (Fig. 1). The exploration wells for oil are located 1.1 km from the coastline of the Bay of Bengal, while the Ravva On-shore Terminal wells are located 0.6 km inland from the coastline. The area has extensive tidal flats and inlets that receive sea water during high tides. The area also experiences periodic flooding by the Godavari River (Gurunadha Rao et al. 2015). Paddy cultivation and fresh water aquaculture are the major land uses within the region. The well-distributed Godavari irrigation canal network acts as a source for irrigation and drinking water throughout the year. Vasalatippa, Kunava-ram, and Pikaleru drains are carrying out the irrigation return flows through the Ravva On-shore Terminal area and flow into the Bay of Bengal. This 100-year-old canal net-work contributes significantly to groundwater recharge, thereby reducing the potential for saltwater intrusion into shallow aquifers (Chachadi and Teresa 2002; Gurunadha Rao et al. 2015; Naidu et al. 2013).

GEOLOGY

The area is underlain by deltaic sediments of early Holocene age with varying proportions of clay, silt, sand, and gravel with a gentle slope of 0.001 km/km toward the coast. Groundwater occurs under water table conditions. However, semi-confined and confined conditions tend to develop in the area where impervious clay layers overlie the saturated granular zones. Groundwater is being tapped from shallow open wells with depth range of 3–8 m as well as filter point wells penetrating up to 20 m depth. A series of marine transgression and regression events have greatly influenced the depositional environments of the delta in the past. The beach ridges are associated with the delta pro-gradation (Rengamannar and Pradhan 1991). The study area includes fluvial landforms such as channels, levees, back swamps, and geologic floodplains as well as land-forms influenced by marine processes, such as tidal flats, beach ridge complexes, and mangrove swamps. The area is rich in Quaternary alluvial sediments derived from the Godavari River (Rao 1993; Bobba 2002). Since the Qua-ternary period, the Godavari River has been discharging large amounts of sediments into the Bay of Bengal, thereby supporting the delta building processes. The upper delta region sediments are essentially fluvial, while those in the lower delta region are fluvio-marine in origin (GSI 2006). The concentrations of iron, manganese, sodium and pH are increased towards the delta where they approach the mar-ine environment. The distribution patterns of calcium and magnesium are mostly controlled by the amounts of shell fragments and clay minerals, particularly montmorillonite (Seetaramaswamy and Poornachandra Rao 1975).

HYDROGEOLOGY

The average annual rainfall in the study area is about 1,137 mm distributed unevenly among an average of 57 rainy days of the year (Vishnu Vardhana Rao and Vinoda Rao. 2016). About 72 % of the rainfall occurs during the southwest monsoon season (June–September), while the rest occur during the northeast monsoon (October–December). The area consists of alluvium with thickness varying from a few

meters to 300 m. Clay is present in varying proportions along with silt and gravel. The alluvium overlies the Rajahmundry sandstones (CGWB 1999). The hydrogeology of the study area is mainly derived from borehole geophysical logs collected at Amalapuram, Vodalarevu, and Surasanayanam villages. Geophysical imaging was carried out with Multi Electrode Resistivity Tomography (ERT) at 13 different locations in the Godavari deltaic region, the results of which indicate that loamy sandy soils are underlain by thick clay beds of about 30–35 m and followed by coarse-grained sands (Gurunadha Rao et al. 2011, 2013; Lagudu et al. 2013). The geophysical logs collected from three locations at Ravva On-shore Terminal revealed that sandy clay is underlain by 45–55-m-thick clay with fine sand followed by medium-to-coarse-grained sands up to a depth of 120 m below which clays saturated with saline water are found up to a depth of 143 m (Gurunadha Rao et al. 2011; Naidu et al. 2013).

GROUNDWATER OCCURRENCE AND FLOW DIRECTION

The occurrence and behavior of groundwater are controlled by topography, soils, climate, geology, and land use of the area. In the central deltaic region, the groundwater slope is very gentle with an average hydraulic gradient of 0.3 m/km. Groundwater levels in the entire Godavari delta fluctuate significantly in response to recharge and groundwater withdrawals (CGWB 1999). Forty-two observation wells were selected to monitor groundwater levels and ground-water quality in the area. In general, the groundwater levels near canals and ditches fluctuate 3–4 m between the pre-monsoon and post-monsoon season (CGWB 1999). How-ever, during the study period (2006–2007), they were observed to be less than 2 m. Maximum groundwater elevation of 5 m above mean sea level (MSL) has been observed at Amalapuram, while a minimum of -12 m (MSL) is observed inside the Ravva On-shore Terminal wells. The groundwater elevation contours during the pre-monsoon (2006) period indicate the groundwater flow direction to be toward the Bay of Bengal coast with a groundwater gradient of 0.43 m/km from Amalapuram to coast (Fig.2), and the same trend was observed for remaining three monitoring periods (Post-monsoon 2006, Pre- and Post-monsoon 2007).

MATERIAL AND METHODS

Fifteen water samples were collected in pre monsoon (May) and post-monsoon (November) seasons during the year 2015. These samples were collected as per the standard methods prescribed for sampling. Plastic bottles of 1.5 liter capacity with stopper were used for collecting samples. Each bottle was washed with 2% nitric acid and then rinsed three times with distilled water. Samples were analyzed to determine the concentrations of pH, total dissolved solids (TDS), electrical conductivity, hardness, chloride, sulfate, alkalinity, fluoride, calcium, magnesium, nitrate, sodium and potassium in the laboratory. All the tests were conducted in accordance with the techniques described by American Public Health Association15. pH was measured by digital pH meter micro processor. Electrical conductivity (EC) and Total Dissolved Solids (TDS) were measured with digital EC-TDS analyzer. Nitrate, sulfate, fluorides, calcium, magnesium ion concentrations were determined by spectrophotometer. Various statistical analyses of the experimental data were performed using Microsoft Excel 2007. The results obtained were evaluated in accordance with the standards prescribed under Indian standard drinking water specification IS: 10500:2012 of Bureau of Indian Standards (BIS).

RESULTS AND DISCUSSION

The temporal changes in groundwater quality were determined taking EC as the general indicator of quality. EC is the measure of salinity which greatly affects the taste and thus has a significant impact on the user acceptance of the

water as potable. The pre and post monsoon mean values of EC of groundwater are shown below (Fig.2).

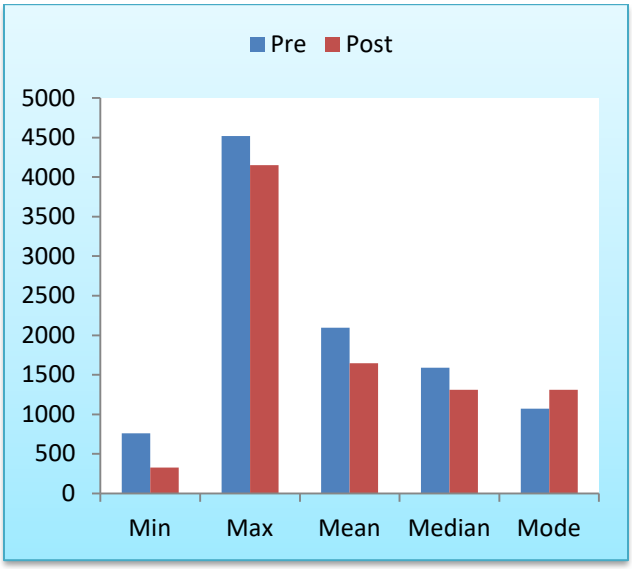

Fig. 2. Seasonal variation of EC

The EC values are within the range of 760-4520 µmohs/cm in pre-monsoon and 327-4150 µmohs/cm in postmonsoon season with a mean value of 2094 and 1645 µmohs/cm respectively (Table 1 and Table 2). Maximum value of EC are above the permissible limit of WHO (1400 µmhocm-1) for the samples. It may be due to the dissolved inorganic solids into water which subsequently percolated to these bore wells polluting the water. The pre monsoon mean value of EC is higher than post monsoon value indicating of a clean recharge of groundwater during monsoon.

The groundwater is of alkaline nature as demonstrated by its pH>7. The mean value of pH is lower in post-monsoon season (8.3) compared to pre-monsoon season (8.8) (Table 1 and Table 2), This decreasing trend in pH values of these ground water samples may be due to the increasing concentration of various salts/ minerals during rains. The comparison of pre and post monsoon values of pH are shown below (Fig. 3).

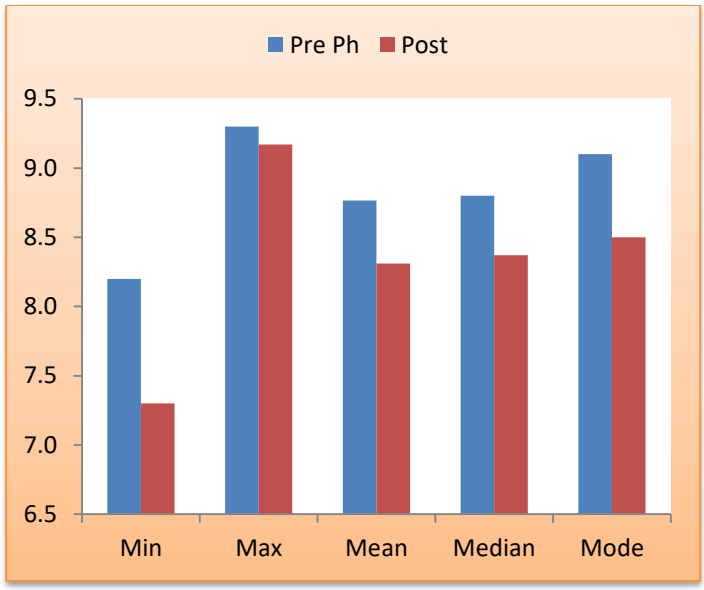

Fig.3. Seasonal variation in pH

The mean value of TDS is lower (1052) in post-monsoon season compared to pre-monsoon season (1445), indicating dilution of concentration towards post-monsoon (Table 1 and Table 2). High levels of TDS may aesthetically be unsatisfactory for bathing and washing. The comparison of pre and post monsoon season values of TDS is shown below (Fig. 4).

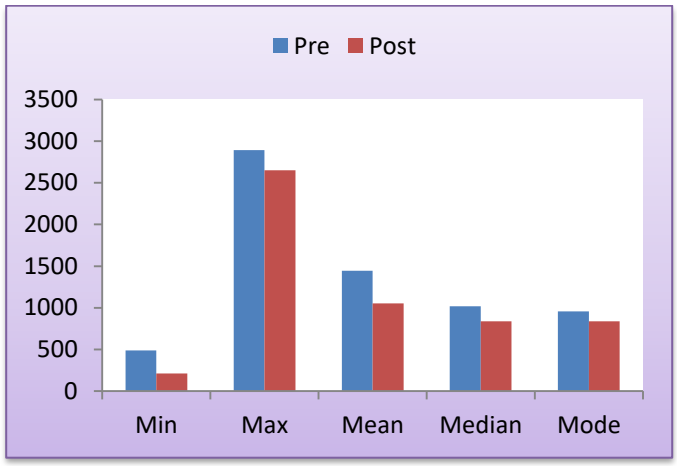

Fig. 4: Seasonal variation in TDS

The hardness values are within the range of 130-1333 mg/l. The mean total hardness value is 588 mg/l in pre-monsoon and 299 mg/l in post-monsoon season (Table 1 and Table 2). The comparison of hardness values in both pre-monsoon and post-monsoon season is shown below (Fig. 5). In both seasons, total hardness is more than alkalinity, which indicates that the groundwater is characterized by non-carbonate hardness

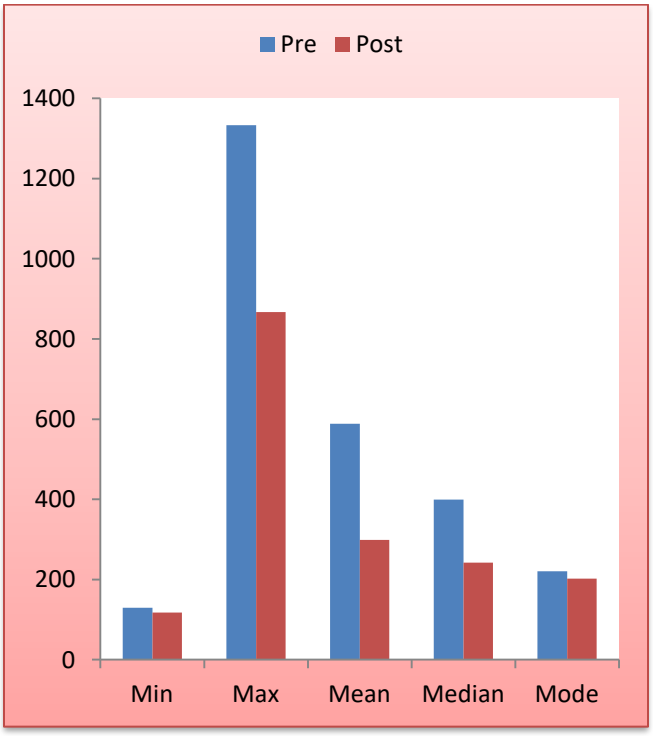

Fig.5. Seasonal variation of Hardness

The mean value of alkalinity is 204 mg/l in post-monsoon season and 259 mg/l in premonsoon season indicating alkaline nature of groundwater (Table 1 and Table 2). The comparison of pre and post monsoon season values of alkalinity is shown below (Fig. 6).

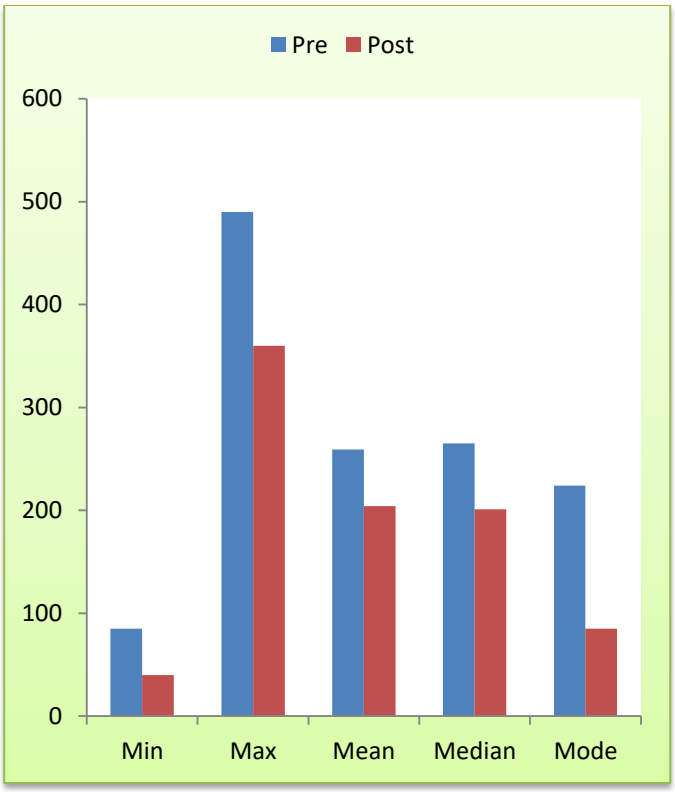

Fig.6. Seasonal variation of alkalinity

Among the cations, $Ca^{2+,}$ Mg^{2+} ions ranged from 8 to 287 and 15 to 162 mg/l with a mean of 107, and 78 mg/l in pre monsoon and 50 and 42 mg/l in post-monsoon respectively. Cl- ranged 48 - 1102, SO42- ranged 55 - 514, NO3 ranged 38 - 198 and F- ranged 0.1 - 0.9, mg/l, with a mean value of 399, 238, 102 and 0.2 mg/l in premonsoon and 197, 144, 93 and 0.1 mg/l in post-monsoon, respectively. Na ranged 26 – 567 and K ranged 4 – 599 mg/l, with a mean value of 257 and 125 mg/l in premonsoon and 140 and 78 mg/l in post-monsoon, respectively. The concentrations of $Ca^{2+,}$ Mg^{2+} Cl^{-}, $SO_4^{2-,}$ NO^{3-} F, Na and K - ions show an increasing trend from post-monsoon to pre-monsoon (Table 1 and Table 2). Comparing the mean values, (Table 1 and Table 2) it can be concluded that Total dissolved solids, pH, EC, NO^{3-} , Cl^{-}, SO_4^{2-} ,F-, alkalinity, total hardness, Ca^{2+} , $Mg^{2+,}$ Na and K were higher in the groundwater samples during pre-monsoon period than in post monsoon period and showed a clear cut seasonal effect.

Table 1. Statistical analysis pre-monsoon 2015

S.No	Parameter	Min	Max	Mean	Median	Mode	SD
1	pH	8.2	9.3	8.8	8.8	9.1	0.3
2	EC	760	4520	2094	1589	1070	1101
3	T.D.S.	486	2893	1445	1017	956	785
4	Alkalinity	85	490	259	265	224	149
5	Cl	48	1102	399	276	48	303
6	F	0.1	0.9	0.2	0.2	0.1	0.2
7	NO3	38	198	102	91	89	43
8	SO4	55	514	238	223	50	142
9	Na	26	567	257	235	380	150
10	K	4	599	125	110	27	152
11	Ca	8	287	107	56	16	108
12	Mg	15	162	78	73	44	49
13	Hardness	130	1333	588	399	221	457

GEOSTATISTICAL ANALYSIS

In this study, descriptive statistical measures were carried out to establish seasonal variations in the concentration levels of groundwater samples as well as to see the relationship among the chemical and physical variables on the pre-monsoon and post monsoon periods. Normal distribution analysis (involved mean, median, standard deviation) is an important statistical tool for identifying the distribution patterns of the different water quality parameters. The statistical analysis summary covering 50 selected sampling locations are presented above (Table 1 and Table 2). Mean values were taken into consideration as characteristics values to see the differences during two seasons. Significant variations found between mean and median for parameters, viz. TDS, EC, Cl-, SO_4^{2-} , NO^3 Na, K, Ca, Mg, alkalinity and hardness were observed (Table 1 and Table 2). It indicates that these parameters were not found normally distributed and symmetric way in the samples.

However, small difference of mean and median for parameters pH and F, indicated that these parameters were seemed to be distributed normally in groundwater samples. The standard deviation measures the absolute dispersion, the greater the standard deviation, for the greater will be the magnitude of the deviations of the values from the mean.

Table 2. Statistical analysis post-monsoon 2015

S.No	Parameter	Min	Max	Mean	Median	Mode	SD
1	pH	7.3	9.2	8.3	8.4	8.5	0.5
2	EC	327	4150	1645	1310	1310	1079
3	T.D.S.	209	2650	1052	838	838	690
4	Alkalinity	40	360	204	201	85	84
5	Cl	40	1050	197	152	40	245
6	F	0.1	0.3	0.1	0.2	0.1	0.1
7	NO3	14	185	93	97	75	42
8	SO4	29	310	144	131	98	70
9	Na	12	543	140	115	42	127
10	K	6	250	78	42	25	78
11	Ca	12	138	50	41	24	35
12	Mg	10	127	42	34	34	30
13	Hardness	118	867	299	242	202	173

CONCLUSION

Comparing the mean values of groundwater quality parameters of Central Delta of Godavari River, it can be concluded that variables TDS, EC, Cl-, SO_4^{2-} , NO^3 Na, K, Ca, Mg, pH, F, alkalinity and hardness are lower during post-monsoon period showing an improvement in quality due to fresh recharge without pollution from external sources and clearly indicated seasonal variation. TDS, EC, Cl-, SO_4^{2-} , NO^3 Na, K, Ca, Mg, pH, alkalinity and hardness found above the standard limit prescribed by BIS: 10500, reveals that the groundwater of the study area is hard and alkaline in nature. The Ca^{2+} and Mg^{2+} values were high in most of the places reveals that groundwater of the study area is hard to very hard and indicates deterioration in groundwater quality of the study area. Hence, groundwater quality analysis should be carried out from time to time to monitor the rate and kind of contamination. This would help to prevent damage to the overall groundwater

system. It is need to expand and promote awareness among the end users to maintain ground water quality. There is urgent need of adopting judicious management strategy to mitigate the problem of deteriorating ground water quality in the study area.

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