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GROUND WATER QUALITY IN THE VICINITY OF INDUSTRIAL LOCATIONS IN GUNTUR, A.P., INDIA

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ABSTRACT : *Physico-chemical investigations, which are significant for the assessment of ground water quality, have been carried out to identify the sources of contamination in the groundwater in Guntur city in Andhra Pradesh, India. In the present study, groundwater was found to be highly contaminated in the industrial area of Guntur. In essence, high Total Dissolved Solids (TDS), Electrical Conductivity (EC), Total Hardness, Total Alkalinity, Sodium (Na^+), Potassium (K^+) and Chlorides (Cl^-) in groundwater reflect additions of pollutants from industrial sources that further deteriorate its quality. The results obtained from the study are compared with the standards suggested by Bureau of Indian Standards (BIS). The results revealed that the water quality parameters failed to meet the drinking water quality standards and were found unfit for drinking purpose, and hence were graded as non-potable.*

KEYWORDS -*Groundwater, physicochemical parameters, seasonal variations, Guntur, industrial pollution etc.*

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I. INTRODUCTION

It is a well known fact that freshwater hold immense value for all species of animals, plant and human beings as it directly reflects their health [1]. Rapid proliferation of industries, increasing urbanization and new age agricultural activities during the last few decades have badly affected surface as well as groundwater quality [2]. In fact, industrial waste and the municipal solid waste have been regarded as a leading cause of pollution in surface and groundwater [3]. The principal factors threatening the chemical properties of groundwater, apart from the influence of anthropogenic activities on this valuable resource is well documented in many parts of India [4][5][6][7].

Groundwater contamination in an urban environment is a major issue, especially in cities with sizeable industrial establishments. Guntur city is one of the most industrialized districts in A.P. and a major automobile hub in south India. An increasing population and copious industrial activities make it essential to assess the quality of groundwater system to ensure the long-term sustainability of resources [8].
The present study has been carried out at three stations in the industrial areas falling within the Guntur city limits, namely, (1) Masjid Omar, (2) Autonagar plot no.127 and (3) Acharya Nagarjuna University. The Acharya Nagarjuna University near Guntur was chosen as the control station.

1.1 Study area

Guntur district is in the central coastal part of Andhra Pradesh, comprising 57 revenue mandals, falling under 3 revenue divisions viz., Narasaraopet, Guntur and Tenali. The district has 729 villages and 1036 hamlets and is spread over a total geographical area measuring 11,328 sq. Kms, located between North latitudes 15^{o}18’ & 16^{o}50’ and East longitudes 79^{o}10’00” & 80^{o}55’00” (Figure 1).

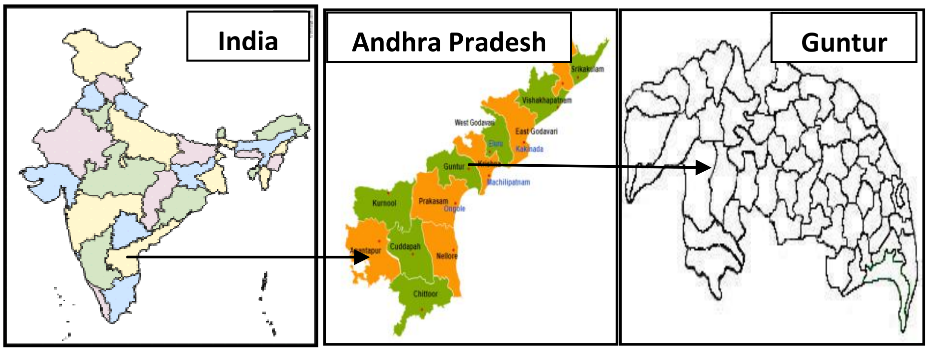


Figure 1: Location map of study area

A brief description of the three stations selected for assessment of groundwater quality is given here under in Table 1.

Table 1: Description of Sampling Stations

Sampling Industrial Area	Masjid Omar, near Autonagar (MOA)	Autonagar Plot. no. 127 (APN)	Acharya Nagarjuna University (ANU)
Type of sampling station	25-year old deep-well hand pump with a depth of 30 feet	25-year old deep-well hand pump with a depth of 150-170 feet	20-year old deep- well hand pump, having a depth of 150 feet
Types of Industries located	mechanic works factories for tractors and cars, scrap factories, plastic companies, tyre manufacturing companies, car wash garages, wood-based factories and crane mechanic works	car spare parts manufacturing units, automobile industries, crane and lorry mechanic works, car showrooms, rubber companies, tyre-manufacturing companies and car wash garages	Control station
Type of Soil	Black soils	Black soils	Red soils
Type of Area	Urban	Urban	Sub-urban

1.2 Physico-Chemical analysis

All the collected samples were analyzed in the laboratory by using standard methods of analysis [9]. A.R. Grade chemicals and double-distilled water were used for preparation of standard solutions for the purpose of analysis. A total of three sampling stations were selected for collection of samples from bore-wells in the industrial locations of Guntur, in a stretch of about 22 km, out of which the third station i.e., Acharya Nagarjuna University site (ANU) is designated as the control station. Various physical parameters like pH, EC, and TDS were estimated on the spot with the help of digital portable pH meter, conductivity meter and TDS meter. The Total Hardness was measured by EDTA titrimetric method by using EBT indicator. Fluoride presence was estimated by the SPADNS method, using Spectrophotometer. The Argentometric volumetric titration method in the presence of Potassium chromate provided reliable results related to the presence of chloride. Sodium and potassium were analysed by using Flame Photometer (ELICO make), while Heavy metals such as Zn, Pb, and Cd in groundwater samples were determined in their total form. Nitric acid (HNO_3) digestion is employed prior to conducting Flame-AAS analysis pre-calibrated with standards.

II. Results And Discussion

The mean values of the measured physico-chemical parameters from the underground water for dry and wet seasons are presented in Tables 3 and 4 respectively**.** The sampling was done for all seasons for two annual cycles from June 2015 to May 2017.

Greater ionic concentration in the groundwater of the post-monsoon period indicates an increasing addition of leachates into the groundwater from the soils in the monsoon and anthropogenic activities, leading to deterioration of groundwater quality as compared to pre-monsoon [10].

Table 2: Physico-chemical analysis of groundwater quality during 2015-2016

S.no	Parameter	2015-2016						
		WET SEASON			DRY SEASON			BIS
1		MOA Mean± SD	APN Mean± SD	ANU Mean± SD	MOA Mean± SD	APN Mean± SD	ANU Mean± SD	
2	pH	7.371± 0.125	7.332± 0.049	7.648± 0.053	6.241±2.711	6.309±2.729	6.646±2.872	6.5-8.5
3	TDS	12217.285± 913.466	6188.571±2697.427	527.142±19.316	10364.596±3170.089	9739.284±3510.344	562.318±213.336	750
4	EC	18378.571±1354.503	9421.428±4057.899	805±26.299	15649.145±5635.968	14756.491±5318.703	852.16±323.478	500
5	TA	284.142±21.881	342.571±36.418	220.714±17.518	247.55±102.78	264.137±100.474	234.596±96.98	200
6	TH	4089.285±221.066	2173.428±1355.605	254.571±16.521	3552.552±1183.311	3359.933±1234.013	263.742±123.555	300
7	Cl^-	5542.857±127.241	1051±120.776	81.857±12.707	4656.044±1714.97	3279.244±2045.588	100.373±56.362	250
8	F^-	1.4±0.081	1.828±0.262	0.814±0.371	1.279±0.441	1.857±0.653	1.011±0.369	1
9	Na^+	363.571±4.755	284.428±3.735	97.857±2.544	312.334±132.274	249.085±107.886	85.141±34.515	-
10	K^+	22.571±0.975	15.428±1.902	9.571±1.397	23.091±9.765	15.269±5.541	9.375±3.474	-
11	Zn	0.017±0.029	0.012±0.007	-	0.018±0.029	0.012±0.006	-	5
12	Pb	-	0.035±	-	-	0.057±0.06	-	0.01
13	Cd	0.007±0.008	0.008±0.010	-	0.008±0.008	0.009±0.01	-	0.003

* All values in mg/L except for pH and EC (p= 0.05 level)

Table 3: Physico-chemical analysis of groundwater quality during 2016-2017

S.no	Parameter	2016-2017						
		WET SEASON			DRY SEASON			BIS
1		MOA Mean± SD	APN Mean± SD	ANU Mean± SD	MOA Mean± SD	APN Mean± SD	ANU Mean± SD	
2	pH	7.414±0.094	7.469±0.126	7.63±0.134	6.499±1.72	6.584±1.76	7.048±1.925	6.5-8.5
3	TDS	11599.429±3466.745	8759.143±2193.847	552.714±104.513	10194.384±3185.187	10239.661±3185.187	715.236±331.242	750
4	EC	18657.143±3186.878	13271.429±3324.011	837.143±157.978	15755.016±4598.843	15482.171±4672.069	1092.234±502.442	500
5	TA	302.857±17.995	332±44.959	204±34.176	252.904±72.71	284.659±85.472	227.368±129.465	200
6	TH	4408.571±959.295	3120±859.535	199.429±54.769	3730.838±1210.455	3944.849±1785.099	253.614±105.307	300
7	Cl^-	5168.571±783.74	1801.714±672.999	89.714±8.902	4658.716±1355.729	3817.833±1180.884	131.819±89.552	250
8	F^-	1.514±0.339	1.5±0.5	0.671±0.407	1.231±89.552	1.859±0.753	1.083±0.467	1
9	Na^+	363.857±12.482	286.857±4.741	92.714±7.274	300.658±78.826	250.996±64.408	84.237±22.345	-
10	K^+	29.571±2.07	18±2.887	11.857±1.773	25.837±8.061	14.83±5.588	9.836±3.531	-
11	Zn	0.013±0.007	0.013±0.004	-	0.026±0.008	0.011±0.003	-	5
12	Pb	-	0.041±0.062	-	-	0.031±0.02	-	0.01

* All values in mg/L except for pH and EC (p= 0.05 level)

2.1 pH

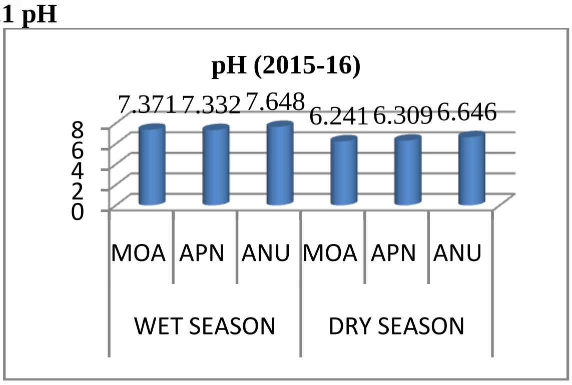


Figure 2

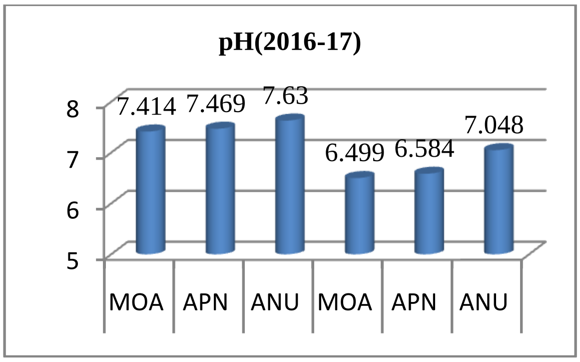


Figure 3

The pH of the groundwater was nearer to neutral during the wet seasons of 2015-16 and 2016-17, while remaining slightly acidic during the dry period at all the three stations that includes the control station. The lowest pH (i.e.7.13) was in April 2017 during the dry period, whereas the highest pH (i.e. 8.5) was recorded in the month of May 2017 during dry season. The low pH value indicates an acidic condition, which could be associated with a combination effect of depleting calcium in the soil, oxidation of sulphide deposits, release of aluminum and presence of organic acids in natural water [11][12][13]. Low pH enhances the solubility of metals in water, some of which are toxic to humans. The pH values reflect hydrogeology of the area since pH can be a fingerprint of samples and their locations [14]. Similar trends in pH distribution from borehole/well have been observed and reported from several parts of India [14][15][16]. In the present study, the pH was found to be near-neutral to alkaline and within the BIS specified range of 6.5-8.5 for drinking water during the three seasons at the MOA. The pH values ranging from 6.84-8.5 indicated an increase in the wet season compared to dry season.

2.2 Total Dissolved Solids (TDS):

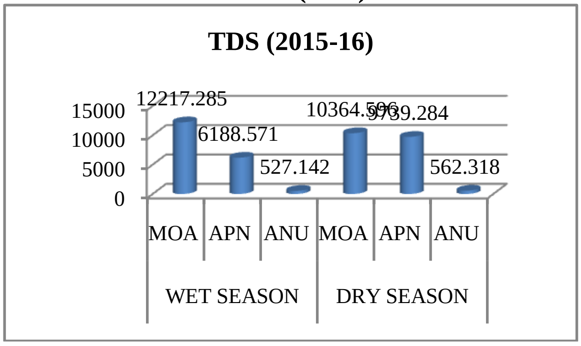


Figure 4

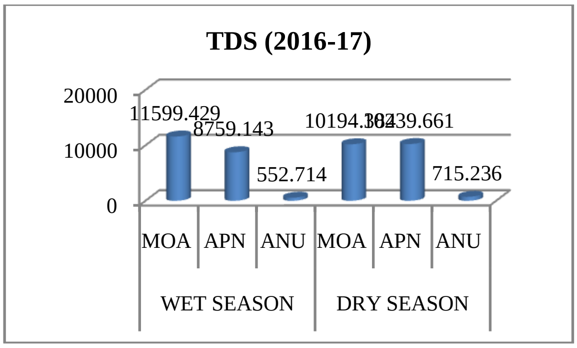


Figure 5

The mean of Total Dissolved Solids (TDS) in the groundwater samples collected from the study area ranged between 356 to 15180 mg/L beyond the permissible limit prescribed by BIS (i.e. 500 mg/L) at all the stations during the study period. The lowest value of Total Dissolved Solids (i.e. 356 mg/L) was in December 2016 and the highest value of Total Dissolved Solids (i.e. 15180 mg/L) was in recorded in September 2016 during the rainy season. The increase of TDS in rainy season is on the higher side than the dry season as surface pollutants mix during the infiltration and percolation of rainwater [17][18].

2.3 Electrical Conductivity (EC):

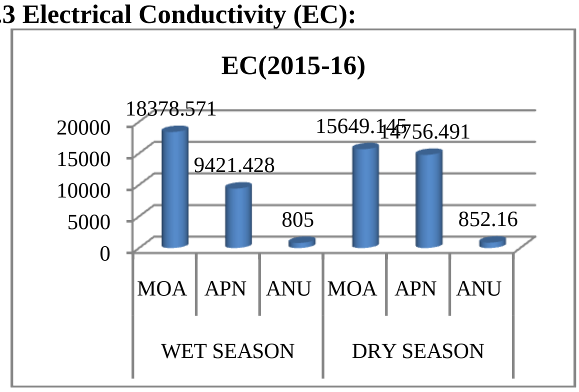


Figure 6

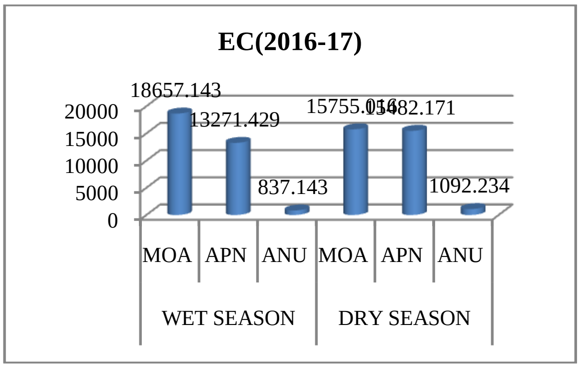
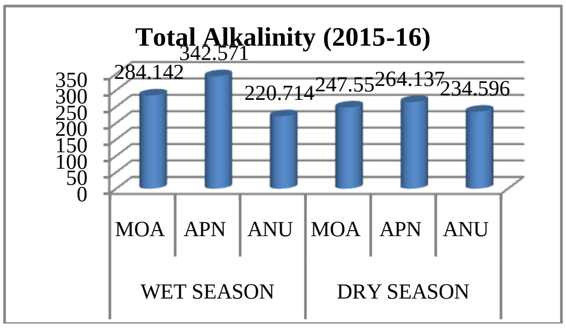


Figure 7

The mean of Electrical Conductivity (EC) was found to be in range between 540 µmhos/cm and 23000 µmhos/cm. The Electrical Conductivity of the groundwater at all the stations exceeded the maximum permissible limit (750 µmhos/cm) as prescribed by BIS. The lowest value of Electrical Conductivity (i.e. 540 µmhos/cm) was in December 2016 and the highest (i.e. 23000 µmhos/cm) was in September 2016 in the rainy season. The Electrical Conductivity was found to be high during rainy season than the dry season at all the stations during the study period. The electrical conductivity within the range i.e. <325µmhos/cm classifies groundwater as potable [19].

2.4 Total Alkalinity (TA):



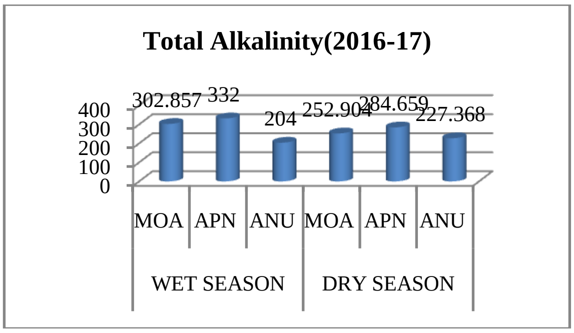
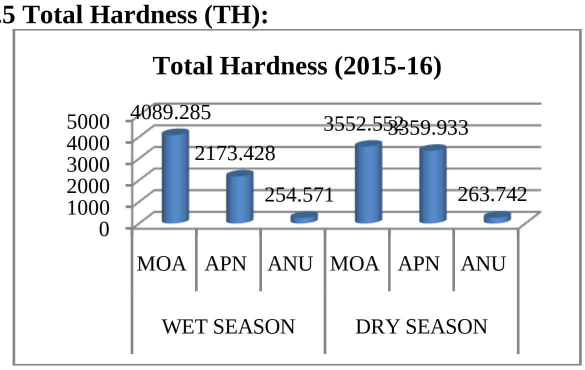


Figure 8 **Figure 9**

The Total Alkalinity was higher than the BIS limit of 200 mg/L. The lowest value of Total Alkalinity (i.e.140 mg/L) was in the months of March 2017 while the highest (i.e.500 mg/L) was in May 2017. At all the stations, the Total Alkalinity was high during the wet season compared to the dry season. And Total Alkalinity was observed to be above the BIS specified limit of 200 mg/L during both the seasons.

2.5 Total Hardness (TH):



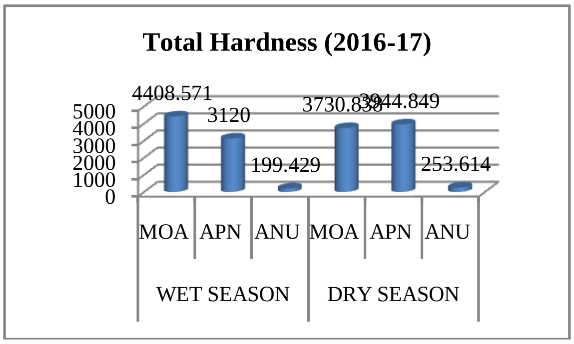
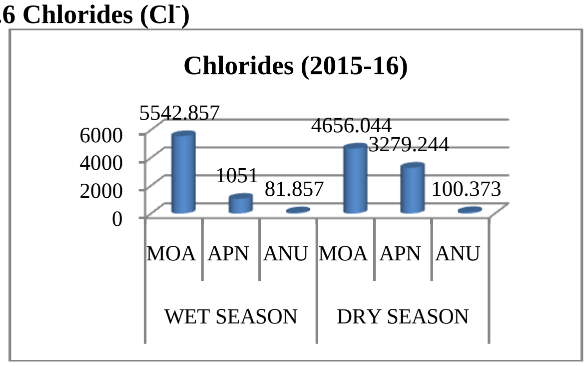


Figure 10 **Figure 11**

Total Hardness (TH) of water depends mainly upon the amounts of divalent metallic cations of which Ca2+ and Mg2+ are more abundant in groundwater. The hardness values in water samples ranged from 140 to 500 mg/L as recorded during the dry season. The low values of TH recorded in the wet season were possibly due to flushing and dilution. The concentration of Total Hardness was very high compared to the BIS specified limit of 300 mg/L during most of the period in the study area. The highest recommended limit of total hardness is 80 mg/L-100 mg/L CaCO3 [20]. The groundwater that exceeds the limit of 300 mg/L CaCO3 is considered to be very hard [21]. The maximum permissible limit of TH for drinking water is 500 mg/L as against the set desirable limit of 100 mg/L as per the WHO international standards. The results indicate that none of the water samples in the study period fall in the very hard water category and are otherwise below the maximum permissible limits.

2.6 Chlorides (Cl^-)



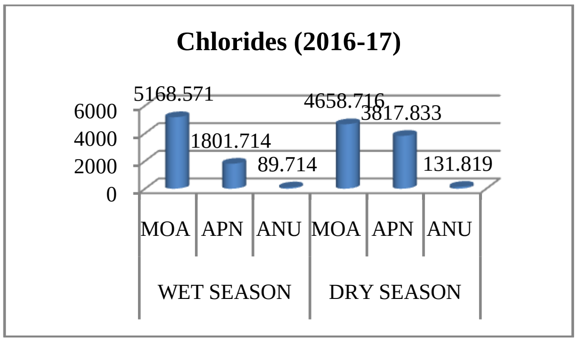
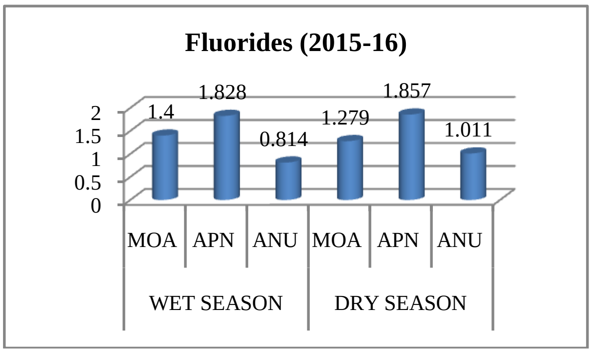


Figure 12 **Figure 13**

The Chlorides in the samples ranged between 72 mg/L at control station i.e., ANU during dry season to 6000 mg/L at APN during wet season which was much more than the permissible limit of 250 mg/L as specified by BIS. Cl^- was higher during the wet season than the dry season due to industrial, domestic wastages and/or leaching from upper soil layers in dry climates [22].

2.7 Fluorides (F^-):



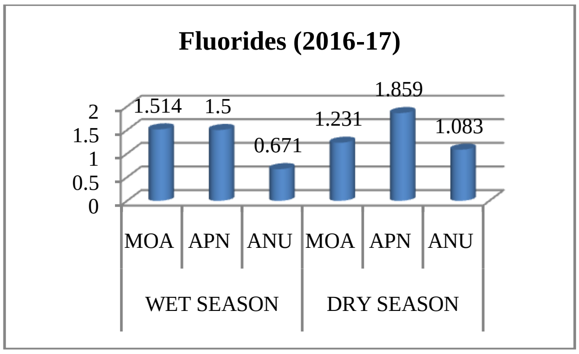
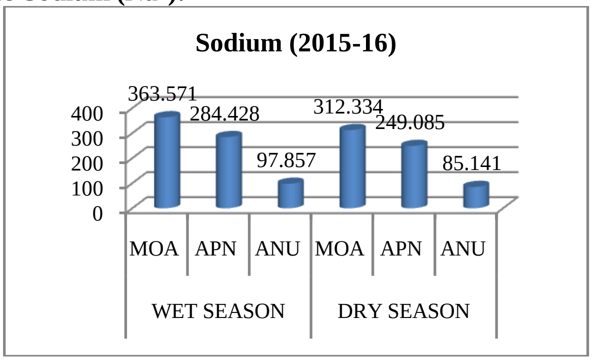


Figure 14 **Figure 15**

Low concentration value of F- i.e., 0.1 mg/L at ANU was recorded in wet season indicating limited lithogenic input of this ion, whiles high value of 2.6 mg/L at APN was achieved during dry season. The Fluoride concentration in groundwater was much higher than the BIS-specified limit of 1 mg/L during most of the study period possibly due to the weathering and leaching of fluoride rich rocks in the study area.

2.8 Sodium (Na^+):



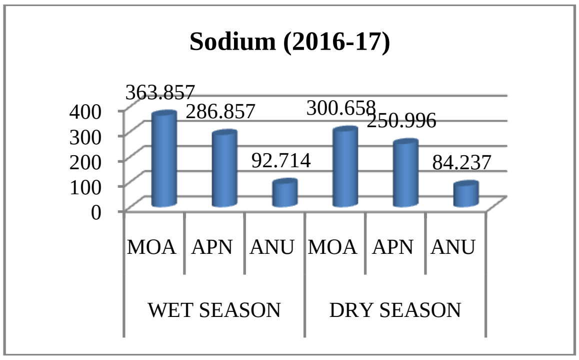
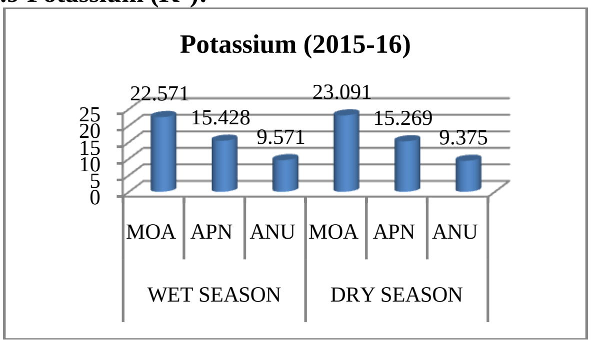


Figure 16 **Figure 17**

Na^+ ranged between 80 mg/L at ANU and 377 mg/L at MOA as recorded during the wet season. Comparatively higher values were observed in the wet season, possibly due to the weathering of feldspar (plagioclase bearing) rocks as well as due to over exploitation of the groundwater resources [23].

2.9 Potassium (K^+):



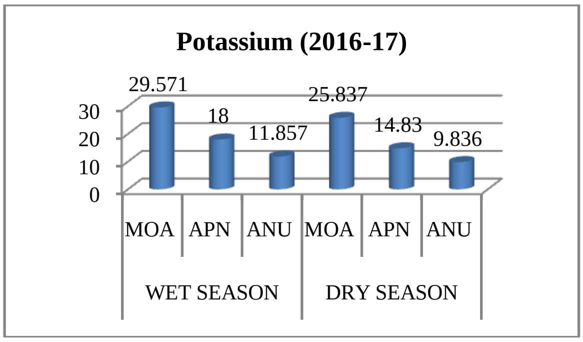


Figure 18 **Figure 19**

K^+ ranged between 8 mg/L at ANU during the wet season and 35 mg/L at MOA as recorded in the dry season. The higher levels of K+ is possibly due to the weathering of K-feldspars and clay minerals from aquifer matrix, apart from the significant anthropogenic sources including salt and animal wastes.

2.10 Heavy metals (Zn, Pb, Cd):

The distribution of metals at all the sampling stations maintained more or less similar concentrations, during both wet and dry seasons, while higher concentrations of the metals from the underground water were found during the dry season than the wet season. This observation could be associated with local concentration during the dry season, a period when most shallow wells get dried up.

2.10.1 Zinc (Zn):

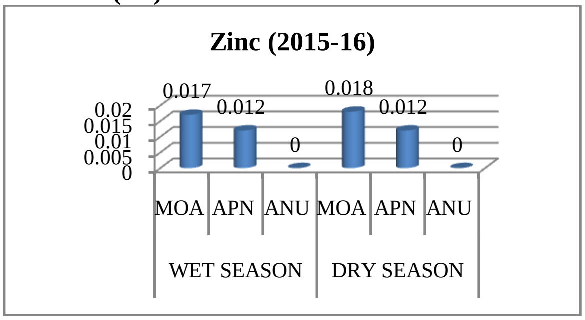


Figure 20

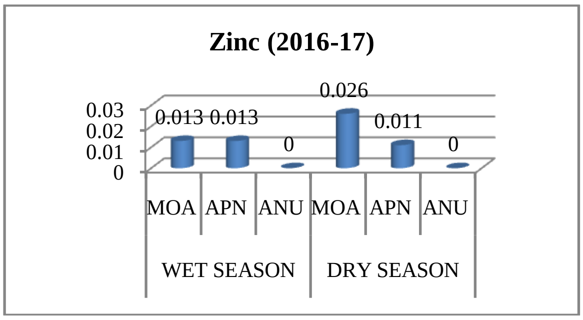


Figure 21

The concentrations of Zn in groundwater at the study area ranged between 0.004 to 0.085 mg/L. Both the highest and lowest values were recorded during dry season at MOA. However, Zn was not detected at the control station i.e., ANU during the study period. Hence, it was observed that the concentration of Zinc showed no significant variation during the dry and wet seasons. The concentration of Zinc in the groundwater was much lesser compared to the BIS-specified limit of 5 mg/L and found to be not harmful, incapable of changing the taste of water. Hence, the potability of groundwater is found unaffected.

2.10.2 Lead (Pb):

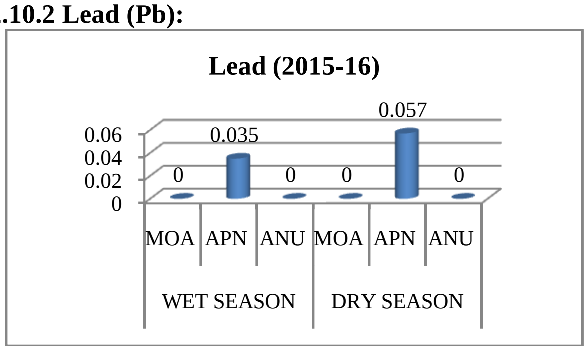


Figure 22

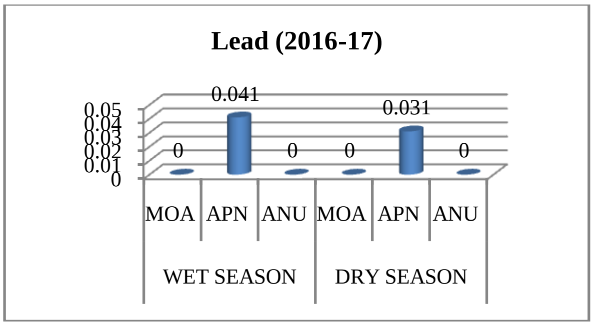


Figure 23

The concentration of Pb in groundwater at the study area ranged between 0.002 mg/L at MOA and 0.19 mg/L at APN. Both the highest and lowest values were recorded during dry season at MOA. However, Pb was not detected at the control station i.e., ANU during the study period. The Lead was absent during wet seasons and was found to be slightly higher than the BIS-specified limit of 0.01 mg/L during the dry season. The presence of lead in water at elevated levels is not desirable due to the toxic effect on consumers and end users in the food chain.

2.10.3 Cadmium (Cd):

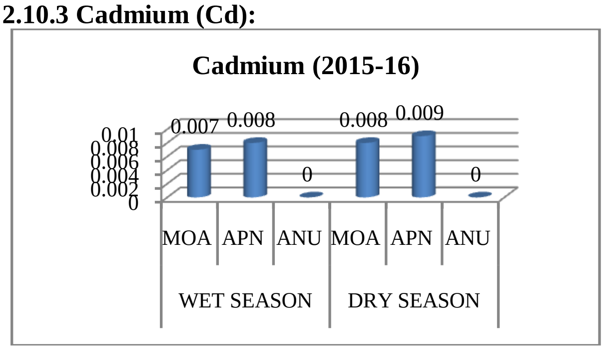


Figure 24

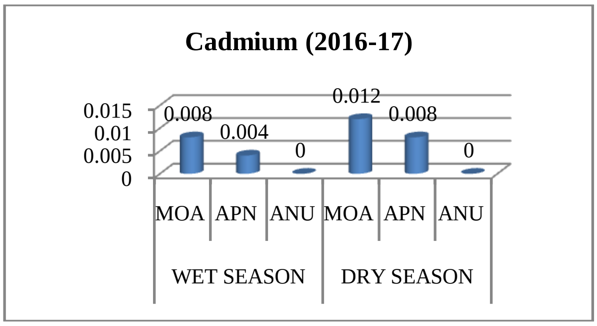


Figure 25

The concentrations of Cd in groundwater at the study area ranged between 0.001 mg/L at APN during dry season and 0.026 mg/L during the wet season at APN. However, Cd was not detected at the control station i.e., ANU during the study period. The solubility of Cadmium in water is influenced by the nature of source of Cadmium and the acidity of water. The concentration of Cadmium showed no significant variation during wet and dry seasons. The concentration was found to be slightly higher than the BIS-specified limit of 0.003 mg/L during both the seasons.

III. Conclusion

The physico-chemical analysis of groundwater quality at the industrial areas of Guntur city reveals that the groundwater was largely affected by various types of contaminants from the industries. The results of the present study revealed that the Total Dissolved Solids, Total Hardness, Total Alkalinity and Chlorides were very high in the groundwater in the peripheral regions around the industrial locations. These parameters, do not directly affect human health, yet indicate an alarming increase in ions in the groundwater through industrial leachate contamination. It further suggests that an evaluation of the environmental impact of human activities as well as strategies for ground water conservation should be considered on a high priority basis. The low pH levels in the groundwater samples during the dry season indicate a future threat that might lead to the dissolution of more heavy metals, thus rendering the water unsuitable for potability. Hence, a continuous monitoring, coupled with lessening the exposure of groundwater to industrial activities will keep this most precious resource at an optimal pH level.

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