GROUND WATER QUALITY ASSESSMENT AT INDUSTRIAL AREAS OF GUNTUR, ANDHRA PRADESH, INDIA

[1]Dr.Osama Asanousi Lamma1s, [2]Swamy A.V.V.S2nd * and [3]Subhashini V3rd
Department of Environmental Sciences, Acharya Nagarjuna University,Guntur India

Abstract :Guntur Industrial Complex is considered the one of the source of pollution in Guntur city. Industrial by-products including gas, solid and liquid wastes are being released continuously in the region, affecting not only the health of people, but also agriculture and environment in the vicinity. There is lack of proper studies addressing the industrial environmental pollution in the industrial area of Guntur city. The major objective of this work is to highlight and provide an overview of harmful environmental impacts of Guntur industrial estate on ground water quality of Guntur city. This work represents an impact of physico-chemical pollutants and heavy metals like Ni, Zn, Cr, Cd and Pb on ground water. Ground water was collected from seven sampling stations on a monthly basis for two consecutive years within the target area to describe the effect of Guntur industrial complex on ground water. The results showed that the concentrations of these elements were higher than the permissible limits in areas close to the industries. It was also identified that the dominant cations and anions were $Na^+ > Mg_2^+ > Ca_2^+ > K^+$ and $Cl^- > PO^{3-}_4 > NO^-_2 > F^-$ respectively. From this study it was clear that a detailed investigation of the ground water regime was strongly recommended.

IndexTerms **- Ground water, physico-chemical, heavy metals, industries etc .**

I. INTRODUCTION

Water covers 71% of the Earth's surface and thus is vital for life (Annan 2005). It is estimated that 96.5% of the water is in seas and oceans, 1.7% is groundwater, and 1.7% is fixed in glaciers and ice caps in the Arctic and Antarctic circles. (Khatri and Tyagi 2015). Ground water is a precious natural resource which is getting scarce and polluted due to various human activities in which industries play a major role. It has been reported that approximately one third of the world's population use groundwater for drinking. Hydrogeological and hydrochemical conditions of urban groundwater can be disturbed by human activities (Lerner and Barrett 1996; Yang et al. 1997; Barrett et al. 1999; Lawrence et al. 2000; Jeong 2001; Zilberbrand et al. 2001; Foppen 2002; Lerner 2002; Cronin et al. 2003; Powell et al. 2003; Eiswirth et al. 2004; Vázquez-Suñé et al. 2005; Ellis and Rivett 2007).

Industry has emerged out to be an important part of the Indian economy, especially in the post-independence era starting 1947 (Naik et al., 2007).With the population in the rising trend, small and medium-scale industries are largely promoted because they are labor intensive and create more jobs (Naik et al., 2007). Ground water contamination is generally irreversible i.e. once it is contaminated; it is difficult to restore the original water quality of the aquifer (Singh et al., 2013). Generally, heavy metal pollution is considered to be point source pollution, and is primarily discharged from smelting and heavy industrial enterprises (Zhang et al. 2009). Thus, sophisticated monitoring of quality of such resources would play a key role in achieving globally sustainable development in near future (Edmunds et al., 2003; Nickson et al., 2005; Baghvand et al., 2010). In order to curtail the adverse effects of pollution and to take remedial measures, it is necessary to undertake more number of ground water quality studies and understand the mechanisms of ground water pollution.

II. STUDY AREA

Guntur city within the Andhra Pradesh Capital Region is located 24 km (15 mi) away from the state capital, Amaravati. It is the administrative headquarters of Guntur district and is a municipal corporation as well as the headquarters of Guntur mandal in Guntur revenue division. Situated on the plains at a distance of 40 miles (64 km) to north of the Bay of Bengal, this city is the third most populous one in A.P. with a population of 743,654 as per 2011 census of India.

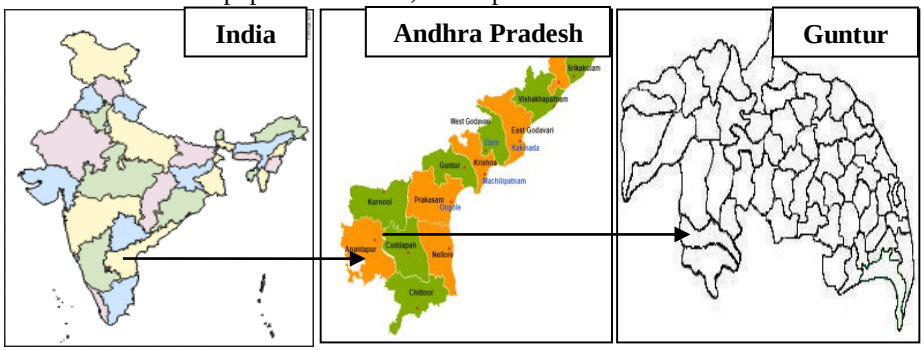

Figure 1: Location map of study area

The present study has been carried out at various industrial estates falling under the Guntur city limits in Guntur district. Monthly analysis of ground water samples was done i.e., from June 2015 to May 2017; from the seven selected sampling stations in and around the Autonagar region in Guntur district of which the Acharya Nagarjuna University near Guntur was chosen as the control station. The sampling stations were bore wells near the industrial locations, spread over a stretch of 22 km approx.

III. Description of Sampling Stations:

Table 1: Sampling Stations

Sampling stations	Location	Description of sampling station	Industries surrounding the stations
Station-I	Yerrabalem	At a radius of half a Kilo meter, India Mark II deep-well hand pump dug into a depth of 150- 200 feet over 5 years ago	Cement factory, PVC pipe manufacturing company, Plywood Company, paper factory and an aluminium company
Station-II	Dolas Nagar	At a radius of 500m, India Mark II deep-well hand pump dug into a depth of 150- 200 feet over 5 years ago	An aluminium company, a plastic company, footwear manufacturing company and a wool company
Station-III	Masjid Omar, Near Autonagar	25-year old deep-well hand pump with a depth of 130 feet	Mechanical workshops for tractors and cars, scrap handlers, plastic companies, tyre retreading companies, car wash garages, wood-based factories and crane repair works
Station-IV	Autonagar plot. No. 127	The deep-well hand pump largely used in this area is 150-170 feet deep and is found to be 25 years old.	Car spare parts manufacturing units, automobile industries, crane and lorry mechanic works, car showrooms, rubber companies, tyre- retreading companies and car wash garages
Station-V	Dargha	A 25 year old deep-well hand pump was used at the fifth sampling station, having a depth of 60 feet.	Car showrooms, car wash and service garages, plastic factories, gas companies, bulb-manufacturing companies, bike companies and marble companies
Station-VI	Stadium road	A 20-year old deep- well hand pump used at the sampling station- IV has a depth of 150 feet.	Welding shops, foundry mechanic shops, battery manufacturing shops, mechanic workshops, iron scrap shops, tyre shops and car spare shops
Station-VII	Acharya Nagarjuna University (Control Station)	At a distance of nearly 20 Kms and free from the sources of pollution. A 20-year old deep- well hand pump, having a depth of 150 feet	-

IV. Methodology

Ground water samples collected near the industrial site premises was taken from pre-cleaned polyethylene bottles. The water was tested using standard APHA water analysis procedures for physical, chemical parameters. Descriptive statistics (including means, maximum, minimum and standard deviations), and correlation was done to analyze the water quality data and their relationships

V. Results and Discussion

The pH groundwater at all stations was observed to be near neutral to alkaline during the study period. The highest pH value was observed at station-VII (control station) and the lowest pH was recorded at station-II, located near Dolas Nagar. These values were presently within the BIS-specified limit. The slightly low pH adjacent to all the polluted sites might be due to the contamination of groundwater due to various industrial activities. But, if pH further increases the permissible level, it may promote corrosion of metals and result in the dissolution on many heavy metals into the water. The mean value of Electrical Conductivity at all stations ranged between 955.625 µmhos/cm at station-V adjacent to Dargha site to 7237.5 µmhos/cm at station-III, located near Masjid Omar, near Autonagar. The Electrical Conductivity values of all the stations were found exceeding the BIS-prescribed standard of 750 µmhos/cm for drinking water. The highest concentration of Electrical Conductivity was observed at Station –III and the lowest concentration of Electrical Conductivity was recorded at Station-I during the three seasons in the present study. The downstream region at the Station-III and distant location of the Station-I might have contributed to high Electrical Conductivity at Station-III and low Electrical Conductivity at Station-I. This indicates that, the effect of mechanic works factories for tractors and cars, scrap factories, plastic companies, tyre manufacturing companies, car wash garages, wood-based factories and crane mechanic works within a diameter of half a kilo meter which were existing for more than 50 years at Station-III might have contributed to high Electrical Conductivity at Station-III. The mean value of Total Dissolved Solids at all stations ranged between 627.875 mg/L at station-V adjacent to Dargha site to 5383.25 mg/L at station-III located near Masjid Omar, near Autonagar. The Total Dissolved Solids values of all the stations were found exceeding the BIS-prescribed standard of 500 mg/L for drinking water. This high TDS and EC values obtained for the groundwater near the sample stations is an indication of its effect on the water quality. The mean of

Total Alkalinity in groundwater samples ranged between 234.875mg/L at station-VII (control station) to 394.458mg/L at station-II located near Dolas Nagar sampling site. It was observed that the Total Alkalinity was more in the groundwater samples collected from the industrial sites and was less in the groundwater samples collected at the control station, clearly indicating pollution from various industries. The mean concentration of Total Hardness in groundwater samples ranged between 256.583 mg/L at station-VII (control station) to 4181.875 mg/L at station-III, located near Masjid Omar, Near Autonagar site. The groundwater at stations II and IV were identified to have more Hardness than the remaining stations during the study period. Except the station-VII (Control Station), rest of the stations were having high mean concentration of Total Hardness, which was much more than the BIS-specified limit of 300 mg/L indicating that the ground water quality was poor, with water labelled as "very hard water". The mean concentrations of Calcium Hardness in groundwater ranged between 138 mg/L at station-VII and 1572.083 mg/L at station-III located at Masjid Omar, near Autonagar site. Similar concentrations were observed at station-IV located at Autonagar plot. no. 127 site. The mean concentration of Magnesium Hardness in groundwater samples ranged between 121.33 mg/L at station-VII (control area) and 2612.5 mg/L at station-III located near Masjid Omar, near Autonagar site. Except station-VII (control area), rest of the stations were having high mean concentration of Magnesium Hardness, which was much more than the BIS-specified limit of 50 mg/L that indicates that the much of the contribution to high Total Hardness of ground is due to Magnesium ions than Calcium ions. On comparision of the Magnesium Hardness with the control station, the Hardness in groundwater was much more from the samples collected at the industrial sites. As other sources of contamination were not observed at all the sites, the major contribution for more Hardness in groundwater was possibly due to leachate contamination from the industrial sources. The mean concentrations of Calcium in ground water ranged between 7.917 mg/L at station-II located near Dolas Nagar site and 644.16 mg/L at station-III located at Masjid Omar, near Autonagar site. The mean concentration of Magnesium in groundwater samples ranged between 29.625 mg/L at station-VII (control area) and 625.083 mg/L at station-III located near Masjid Omar, near Autonagar site. The concentration of Ammonical nitrogen was not detected in any of the sample stations during the study period. The mean of Nitrites in groundwater ranged between 0.0133 mg/L at station-V and 0.021 mg/L at station-VI.

Table 2: Hydro-chemical analysis of ground water samples taken from the study area (For two annual cycles)

No	Sample Stations	Cations				Anions				pH	EC	TDS	Hardness
		Ca	Mg	Na	K	Cl	F	PO_4	NO_2				
1	Yerrabalem	63.833	52	154.125	11.166	164.45	0.729	11.166	0.018	7.312	1446.9	961.42	379.5
2	Dolas Nagar	79.917	67.083	95.13	11.66	219.583	1.258	11.66	0.02	7.117	1915.8	1260	460.25
3	Masjid Omar, Near Autonagar	644.16	625.08	356.75	26.791	5327.5	1.433	26.791	0.017	7.342	7237.5	5383.3	4181.875
4	Autonagar plot. No. 127	534.08	495.5	285.458	16.791	2577.04	1.866	16.791	-	7.384	2314.1	1510	3317.25
5	Dargha	292.88	288.63	172.125	13.208	1472.5	1.629	13.208	0.0133	7.367	955.63	627.88	2087.58
6	Stadium road	131.17	86.33	138.833	13.166	316	0.541	13.166	0.021	7.181	1444.3	997.13	668.166
7	Acharya Nagarjuna University (Control Station)	54.291	29.625	95.833	10.75	107.125	0.941	10.75	-	7.73	2121.3	1384.8	256.583
	Maximum	644.16	625.08	356.75	26.791	5327.5	1.866	26.791	0.021	7.73	2314.1	5383.3	4181.875
	Minimum	54.291	29.625	95.833	10.75	107.125	0.941	10.75	0.0133	7.117	955.63	627.88	256.583
	Mean	257.19	234.89	185.465	14.79	1454.89	1.2	14.79	0.0179	7.3476	2490.8	1732.1	1621.601
	Std Deviation	242.75	241.13	99.0506	5.663	1939.13	0.485	5.663	0.003	0.1959	2143.6	1636.9	1597.458
	BIS Desirable/ PermissibleLimit	75/200	30/100	-	-	250/1000	1/1.5	-	-	6.5-8.5	750	500/2000	300/600

The Nitrate concentrations at all the stations were far below the BIS-specified limit of 45 mg/L, indicating that the Nitrites pollution at the study area is only at a minor scale. The Nitrite concentration was absent at the control station during the study period. The mean of Chlorides in groundwater ranged between 107.125 mg/L at station-VII i.e., at control station and 164.45 mg/L at station-I at Yerrabalem site. On comparision of stations near industrial sites with the control station-VII, it was observed that the leachate contamination to the groundwater was chiefly due to industrial sites during the study period. The lowest concentration of Fluorides was recorded at station-V located near Dargha site, while the highest concentration was recorded at station-VI located near stadium road site. The mean concentrations of Fluorides were identified to be more than the BIS specified limit only at stations-II, III and V. At all the remaining stations, the concentrations of Fluorides were within the specified limit of 1 mg/L. This might be due to the topography of the sites and the stations being located in a downstream region to the source of pollution. The concentration of Iron was not detected in any of the sample stations during the study period. The mean of Sodium in ground water ranged between 95.13 mg/L at station-II i.e., Dolas nagar station and 356.75 mg/L at station-III i.e., Masjid Omar,near Autonagar station. The lowest concentration of Potassium was recorded at station-I located near Yerrabalem site, where as the highest concentration was recorded at station-III located near Masjid Omar, near Autonagar site. The concentration of Iron was not detected in any of the sample stations during the study period.

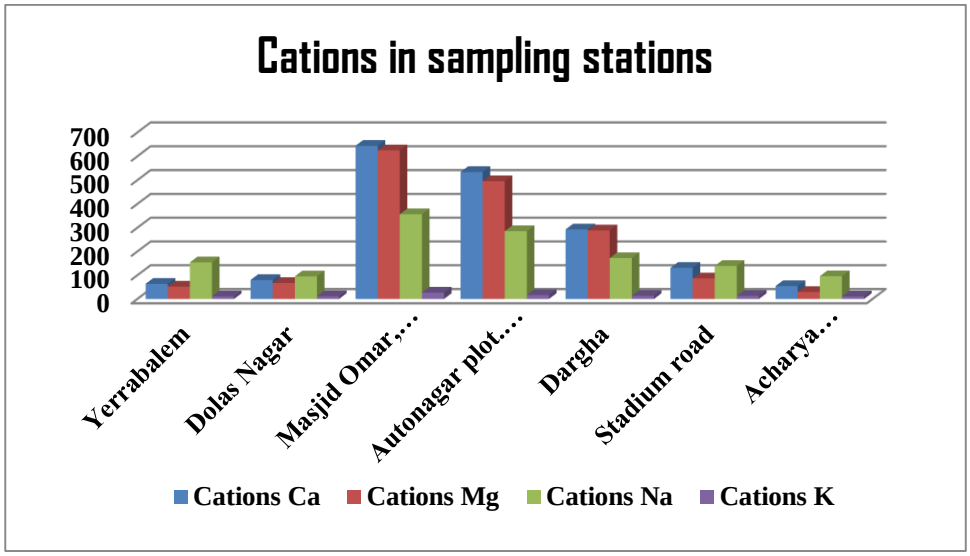

Figure 2: Graph showing cations identified in the seven sampling stations

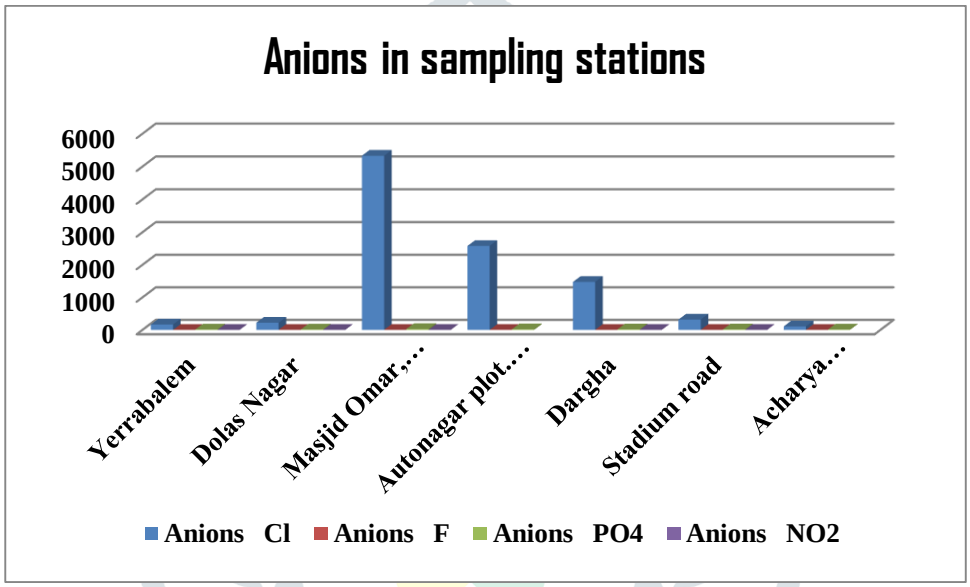

Figure 3: Graph showing anions identified in the seven sampling stations

Table 3: Percentage of contribution of GW samples

Sampling Stations	Cation %				Anion %			
	Ca	Mg	Na	K	Cl	F	PO_4	NO_2
Yerrabalem	22.71	18.50	54.82	3.97	93.25	0.41	6.33	0.01
Dolas Nagar	31.49	26.43	37.48	4.59	94.44	0.54	5.01	0.01
Masjid Omar, Near Autonagar	38.97	37.82	21.58	1.62	99.47	0.03	0.50	0
Autonagar plot. No. 127	40.10	37.20	21.43	1.26	99.28	0.07	0.65	0
Dargha	38.19	37.64	22.45	1.72	99.00	0.11	0.89	0
Stadium road	35.50	23.36	37.57	3.56	95.84	0.16	3.99	0.01
Acharya Nagarjuna University (Control Station)	28.50	15.55	50.31	5.64	90.16	0.79	9.05	0

It was also identified that the dominant cations and anions were Na+ > Mg2+>Ca2+ > K+ and Cl- >PO3-4 >NO-2 >F- respectively from the figures 2 and 3 and table 3.

The concentrations of Nickel were observed to be in traces at all the stations during the study period. Comparatively, the highest annual mean concentration for Nickel was identified at station-III located at Masjid Omar, near Autonagar site, whereas the lowest concentration was found at station-V at Dargha site. No specific limit was specified by BIS for Nickel in drinking water. The mean concentrations of Zinc were far below the limit specified by BIS i.e. 5 mg/L at all the stations. The mean concentrations of

Cadmium were not detected at stations II and VII, while nearly similar concentrations were observed at rest of the stations that ranged between 0.007 mg/L to 0.01 mg/L. All the stations were observed to be slightly higher than the BIS specified limit of 0.003 mg/L for Cadmium during the period of study. The Lead was below detection levels at Stations I, II and VII during the study period. The mean concentrations of Lead ranged between 0.003 mg/L at station-V located near Dargha site and 0.139 mg/L at station-IV located near Autonagar plot. no. 127 site. At all the stations the Lead concentrations were below the BIS specified limit of 0.01 mg/L. The Chromium concentrations were not detected at any of the stations in the study area during the period of study, except at station-III located near Masjid Omar, near Autonagar site, which was comparatively low.

Table 4: Concentration of heavy metals in the ground water samples (in mg/l)

No	Sample station	Ni	Zn	Cd	Pb	Cr
1	Yerrabalem	0.0475	0.053	0.007	-	-
2	Dolas Nagar	0.007	0.209	-	-	-
3	Masjid Omar, Near Autonagar	0.068	0.019	0.007	0.009	0.033
4	Autonagar plot. No. 127	0.02	0.012	0.007	0.039	-
5	Dargha	0.003	0.017	0.01	0.003	-
6	Stadium road	0.007	0.022	0.01	0.007	-
7	Acharya Nagarjuna University (Control Station)	-	-	-	-	-
	Maximum	0.068	0.209	0.01	0.039	0.033
	Minimum	0.003	0.012	0.007	0.003	0.033
	Mean	0.025	0.055	0.008	0.015	0.033
	Std Deviaton	0.026	0.077	0.002	0.017	-
	BIS Desirable/ PermissibleLimit	-	5/5	0.003/0.003	0.01/0.01	0.003

All the ground water stations adjacent to the different industries were observed to be contaminated with high levels of Total Dissolved Solids, high Electrical Conductivity, high Total Hardness and Magnesium Hardness and high values of Total Alkalinity, indicating that the groundwater was near neutral to alkaline and high concentrations of Sodium, Chlorides and Lead. However, most of the parameters like pH, Calcium, Nitrites, Fluorides, Potassium and heavy metals like Nickel, Zinc, Lead, Cadmium and Chromium were found to be within the BIS permissible limits.

Table 5: Matrix of correlation coefficients between the analyzed parameters

	Ca	*Mg*	*Na*	*K*	*Cl*	*F*	*PO4*	*NO2*	*pH*	*EC*	*TDS*	*Hardness*	*Ni*	*Zn*	*Cd*	*Pb*	*Cr*
Ca	1																
Mg	0.998	1															
Na	0.968	0.966	1														
K	0.900	0.900	0.924	1													
Cl$^-$	0.954	0.960	0.956	0.979	1												
F	0.717	0.735	0.570	0.431	0.584	1											
PO4	0.900	0.900	0.924	1.000	0.979	0.431	1										
NO2	-0.199	-0.185	-0.114	0.068	-0.055	-0.435	0.068	1									
pH	-0.001	-0.001	-0.018	-0.067	0.011	0.080	-0.067	-0.807	1								
EC	0.719	0.723	0.771	0.931	0.878	0.252	0.931	0.069	0.056	1							
TDS	0.716	0.721	0.771	0.935	0.880	0.239	0.935	0.097	0.039	0.999	1						
Hardness	0.997	0.999	0.961	0.895	0.957	0.738	0.895	-0.183	0.003	0.711	0.710	1					
Ni	0.545	0.558	0.721	0.730	0.687	0.052	0.730	0.278	-0.133	0.758	0.765	0.544	1				
Zn	-0.365	-0.346	-0.399	-0.265	-0.311	-0.035	-0.265	0.481	-0.618	-0.145	-0.150	-0.361	-0.133	1			
Cd	0.389	0.381	0.431	0.283	0.300	0.058	0.283	0.283	-0.303	-0.021	0.005	0.401	0.236	-0.523	1		
Pb	0.661	0.631	0.609	0.357	0.433	0.608	0.357	-0.525	0.016	0.133	0.114	0.624	0.085	-0.310	0.271	1	
Cr	0.703	0.714	0.763	0.934	0.881	0.212	0.934	0.207	-0.013	0.976	0.984	0.707	0.783	-0.172	0.119	0.022	1

Statistical analysis: Table 5 provides a matrix of correlation coefficients between quality parameters of the analyzed water samples along with heavy metals. Values of high correlation are specified in light yellow colour and low correlation with violet colour. From the table it's observed that there was high correlation between Ca, Mg, Na, K, Cl. But Fluorides correlation was not so strong with Na, K, PO4 and Cl. PO3-4 was strongly correlated with all the parameters except Fluorides. NO-2 was negatively correlated with all the parameters except PO3-4 and K. Whereas pH was negatively correlated with all the water quality parameters except F. Hardness was strongly correlated with all the parameters except NO-2. All the heavy metals were observed to be positively correlated and hence significant with rest of the water quality parameters except that of pH.

VI .Conclusion:

Guntur city as the administrative head quarters of Guntur district of Andhra Pradesh is a rapidly growing city, in terms of industrialization and urbanization. Guntur area is diversely represented by different industries such as Fertilizers, Chemicals, Lead, Battery, Plywood, Packaging, Cotton, Cement, Drugs etc. All the effluents discharged from these industries pose a major threat of groundwater contamination. The present investigation on the ground water quality monitoring has revealed various pertinent facts about the pollution of ground water and the future hazard of accumulation of these contaminants in the aquifers.

The study also revealed that the excess concentrations of the toxic metals like Pb, Cd, Cr and Ni were observed at some stations that were exceeding the BIS permissible limits. The other important fact that was identified during this study was that a progressive increase in the concentrations of certain pollutants was observed in the successive year of the study period.

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