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Assessment of Heavy Metal Pollution in Ground Water and its Correlation with other Physical Parameters at Selected Industrial Areas of Guntur, A.P., India

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ABSTRACT
Increased industrialization, urbanization and agricultural activities during the last few decades have deteriorated the quality of both surface water as well as groundwater. The present study seeks to conduct groundwater quality assessment in select industrial areas of Guntur district in Andhra Pradesh. Though a number of studies on groundwater quality assessment have been undertaken around the world, including various parts of India, yet no significant work on groundwater quality assessment to promote sustainability of groundwater ecosystem has been attempted so far in the study area i.e. Guntur district. Hence, in this backdrop, this paper seeks to carry out groundwater quality assessment in the study area as a novel experiment. A monthly analysis of groundwater samples from the selected sampling stations in and around the Autonagar region in Guntur district was done. Amongst the selected stations, AcharyaNagarjuna University near Guntur was chosen as the control station. Various physico-chemical parameters and heavy metals were analysed for two annual cycles i.e., from June 2015 to May 2017; and the results were correlated with each other to understand the industrial impact on the potability of groundwater.

Keywords : Groundwater, Physicochemical Parameters, Heavy Metals, Guntur

I. INTRODUCTION

Water is the vital resource, necessary for all aspects of human and ecosystem survival and health [5]. In areas of high population density and intensive human use of the land, groundwater becomes largely vulnerable. Groundwater is used for domestic, agriculture and industrial purposes in most parts of the world. Human activities like agriculture and domestic release a large number of pollutants into the water bodies. In India, ponds, rivers and groundwater are used for meeting the water needs of domestic and agricultural users [7]. Many industrial activities where chemicals or wastes are released into the environment, either intentionally or accidentally, have the potential to pollute groundwater [12].Heavy metals in water refers to the heavy, dense, metallic elements that occur in trace levels, but are very toxic and tend to accumulate, posing serious health hazards [1]. The major anthropogenic sources of heavy metals in the present study area include mechanic works factories for tractors and cars, scrap factories, plastic companies, tyre manufacturing companies, car wash garages, wood-based factories and crane mechanic works. Many trace metals that are highly toxic to humans, such as Ni, As, Cd, Cr and Zn get released during work at such places. Their presence in surface and groundwater at above background concentrations is undesirable. Some heavy metals such as Hg, Pb, As, Cd, Fe, Co, Mn, Cr etc., have been identified as having deleterious effect on aquatic ecosystem and human health [1].

Study Area

The Guntur city, spread across an area of 168.4 km² is diversely represented by different industries such as, Fertilizers, Chemicals, Lead, Battery, Plywood, Packaging, Cotton, Cement, Drugs, etc. For long, all these factories have been discharging industrial effluents into the groundwater. In the Industrial hub, there are clear signs of severe land, air and water pollution due to the release of soot containing dust and hazardous vapours.

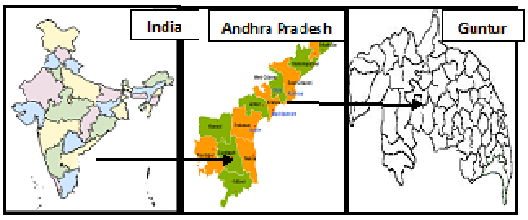

Figure 1. Location map of study area

II. METHODS AND MATERIAL

The ground water samples were collected from bore wells in the study area for a period of two years on a monthly basis i.e., from June 2015 to May 2017. A total of seven sampling stations were selected for collection of samples from bore wells across the industrial locations in Guntur city, in a stretch of about 22 kms. Deionised water was used in the preparation of solution throughout the study. The samples were collected in clean HDPE bottles, prewashed with laboratory-grade detergent followed by adequate rinsing with deionized water. The collected samples were analyzed for physical parameters like pH, TDS and Electrical Conductivity on site by using digital meters. Then, the collected samples were acidified with 1.5ml of nitric acid per litre and stored at 4°C prior to analysis. The samples were analyzed for trace metals like Nickel, Zinc, Lead, Cadmium and Chromium by using atomic absorption spectrophotometer (AAS, Shimadzu AA-6300). After the analysis was carried out in triplicate, the average values were reported.

A brief description of the seven stations in Guntur city selected for the assessment of groundwater quality is given below:

Station-I (Yerrabalem)

The Yerrabalem sampling station is surrounded by a cement factory, pipe manufacturing company, Plywood factory, paper mill and an aluminium company, all within a radius of half-a-kilometre. An India mark-II deep-well hand pump dug into a depth of 150- 200 feet over 5 years ago was used as the sampling station, largely having red soil.

Station-II (Dolas Nagar)

The Dolasnagar station is an industrial area, having the presence of an aluminium company, a plastic company, footwear manufacturing company and a wool company within half-a-kilometre diameter. An India mark-II deep-well hand pump dug into a depth of 100- 110 feet over 10 years ago was used as the sampling station, having red soil.

Station-III (Masjid Omar, Near Autonagar)

The ground water sampling station near Masjid Omar of Autonagar in Guntur is dotted with 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 half- a-kilometre diameter. A 25-year old deep-well hand pump at a depth of 30 feet was used as the sampling station having black soil as the soil type.

Station-IV (Autonagar plot. No. 127)

The ground water sampling station at plot no. 127 in Autonagar, Guntur is surrounded by car spare parts manufacturing units, automobile industries, crane and lorry mechanic works, car showrooms, rubber companies, tyre-manufacturing companies and car wash garages within a diameter of half a kilometre. A 25 year old deep-well hand pump used in this area is 150-170 feet deep with typical black soil.

Station-V (Dargha)

The ground water sampling station at Dargha area of Guntur is surrounded by car showrooms, car wash and service garages, plastic factories, gas companies, bulb-making companies, bike companies and marble companies within a diameter of a km only. A 25 year old deep-well hand pump was used at the fifth sampling station, having a depth of 60 feet. Typically, black soil is found in this area.

Station-VI (Stadium road)

The ground water sampling station at stadium road in Guntur is surrounded by welding shops, foundry mechanic shops, battery manufacturing shops, mechanic workshops, iron scrap shops, tyre shops and car spare shops within a diameter of a km. A 20-year old deep- well hand pump was used as the sampling station- VI having a depth of 150 feet. Here, the soil type is largely black.

Station-VII (AcharyaNagarjuna University-Control Station)

AcharyaNagarjuna University near Guntur was marked as the control station during the study period. This station is at an average distance of nearly 20 km from the sources of pollution at all the sampling stations. The typical soil type is red soil here. A 20-year old deep- well hand pump, having a depth of 150 feet wasused at the sampling station-VII.

III. RESULTS AND DISCUSSION

The mean values of the measured physical parameters and heavy metals from the underground water for two annual cycles from June 2015 to May 2017 are presented in Table 1 and Table 2 below.

The **pH** of all the stations of groundwater was observed to be near neutral to alkaline during the study period. The highest pH value was observed at station-IV near Autonagar plot, whereas the lowest pH was recorded at station-II, located near Dolasnagar. The seven stations were found to be in similar pH ranges during the study period. The slightly low pH adjacent to all the polluted sites is possibly due to the contamination of groundwater due to various industrial activities. The pH values reflect hydrogeology of the area since pH can be a fingerprint of samples and their locations [10].

The **Total Dissolved Solids** followed a similar trend of high values at station-VI (near stadium road) as well as station-III (near Masjid Omar, Near Autonagar). The Total Dissolved Solids values of all the stations were seen exceeding the BIS prescribed standard of 500 mg/L for drinking water. 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 near values of TDS had also been reported earlier by [2]in a similar study.

The **Electrical Conductivity** also followed a similar trend of high values at station-VI (near stadium road) and station-III (near Masjid Omar, Near Autonagar), as there were high mean concentrations of Total Dissolved Solids at these two stations compared to the rest. The Electrical Conductivity values at all the stations were seen exceeding the BIS prescribed standard of 750 μmhos/cm for drinking water. The mean value of Electrical Conductivity at all stations ranged between 955.625 μmhos/cm at station-V adjacent to Dargha siteto 7237.5 μmhos/cm at station-III located near Masjid Omar, Near Autonagar. The EC values which were quite nearer to the present study had also been reported by [11]in a study in Busan city, South Korea that identified the electrical conductivity of ground water samples to be in range of 227 to 21400 μS/cm, largely due to the influences of sea water and sewage leaked from sewers.

Table 1. Physical Analysis Of Ground Water At Seven Stations

Stations	Distance from the pollution source	pH		TDS		EC	
		Mean	SD	Mean	SD	Mean	SD
Station-I	1.2 KM	7.312	0.186	961.416	125.017	1446.917	190.419
Station-II	1.2 KM	7.117	0.207	1260	151.189	1915.75	236.419
Station-III	1.2 KM	7.342	0.122	11751.21	1935.691	18164.58	1961.712
Station-IV	1.2 KM	7.384	0.148	9178.5	2922.383	13910.42	4398.616
Station-V	1 KM	7.367	0.184	5383.25	1753.071	7237.5	1340.607
Station-VI	1 KM	7.181	0.130	1509.958	372.306	2314.083	557.803
Station-VII	20 KM	7.730	0.206	627.875	179.075	955.625	271.746

* All values are expressed in mg/L except for pH andEC

Many of the **Nickel** salts are soluble in water. The mean value of Nickel concentrations were observed to be in traces at all the stations during the study period. The highest annual mean concentration 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. [13]also carried out a study on the assessment of heavy metals in industrial groundwater in and around Vijayawada, Andhra Pradesh and identified that sixty water samples had measurable concentrations of Ni between 0.093-0.157 mg/l but none of the samples exceeded the Ni maximum contaminant limits stipulated for drinking water. [4]had alsoanalysed seasonal variations in heavy metal contamination of groundwater in and around Uyyakondan channel, Tiruchirappalli district, Tamil Nadu. In fact, their study had shown nickel to be in the range of 0.02 to 0.04 ppm in monsoon and between 0.02 to 0.03 ppm in the post-monsoon period.

Zinc is a sparingly soluble salt, while the highly soluble chloride salts tend to hydrolyse to form Zinc hydroxide, resulting in naturally low concentration of Zinc in water. The mean concentrations of Zinc were far below the limit specified by BIS i.e. 5 mg/l at all the stations. It was also observed that the variations were comparatively negligible among all the stations. The concentration of Zinc was particularly high at stations, II and IV, whereas at all other stations, the concentrations were almost similar during the study period. An earlier study done by [2]to investigate the concentration of heavy metals in the groundwater in Badnapur, Jalna Dist. had found zinc in a range of 0.008 to 0.088 ppm which was near to the present study.

The solubility of **Cadmium** in water is influenced by the nature of source of Cadmium and the acidity of water. The mean concentrations of Cadmium were not detected at stations II and VII, whereas 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. Similar results had also been reported by [3] in a study to analyse 15 samples of well water, soil and stream sediments for physico-chemical analysis to determine the distribution of heavy metals in Keffi situated about 50 km south of the Federal Capital Territory, Abuja, Nigeria. It had found the Cd concentration to be in the range of 0.0010-0.0220mg/L.

Table 2. Heavy metal analysis of ground water at seven stations

Stations	Nickel		Zinc		Lead		Cadmium		Chromium	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Station-I	0.047	0.012	0.053	0.011	BDL	BDL	0.007	0.002	BDL	BDL
Station-II	0.007	0.002	0.209	0.247	BDL	BDL	BDL	BDL	BDL	BDL
Station-III	0.068	0.009	0.019	0.022	0.002	0.0007	0.009	0.007	0.033	0
Station-IV	0.020	0.031	0.012	0.005	0.039	0.053	0.007	0.008	BDL	BDL
Station-V	0.003	0.001	0.017	0.006	0.003	0.002	0.010	0.005	BDL	BDL
Station-VI	0.007	BDL	0.022	0.009	0.007	0.003	0.010	0.006	BDL	BDL
Station-VII	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

* All values are expressed in mg/L

Higher **Lead** levels may result when water is aggressive, soft or has low pH. 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. On comparing the seasonal variations, it was observed that the highest concentrations of Lead were found during winter season at station-IV located near Autonagar plot. No.127 site.And during summer season, the highest concentration was observed at station-IV located near Autonagar plot. No. 127 site and lowest concentration at station-III located at Masjid Omar, Near Autonagar site. In this study, the Lead concentrations were observed only at the stations nearer to the industrial sites, as the Lead concentrations were below detection levels at station-VII, which was comparatively far away from the industries. [6] also analysed the physico-chemical characteristics and heavy metal concentrations in the underground water from Afuze, Edo State, Nigeria during dry as well as wet seasons and identified the Pb concentration to be in the range of ND-0.030 mg/L.

The **Chromium** solubility in water is usually low, hence the levels in water is low. 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. [8]also did a similar work by analyzing the physico-chemical and heavy metal levels of surface water collected from Kampani River, Wase Local Government area of Plateau state and found the concentrations of chromium in the range of 0.32 -0.48mg/l.

Statistical Analysis

Statistical analysis can be applied to represent the data analysis of groundwater which is useful in understanding the inter-relations among various physical parameters used for analysis. As the initial part of statistical analysis, the mean and standard deviation for the values of different parameters was calculated as shown in **Tables 1&2.** Correlation is a broad class of statistical relationships between two or more variables. Hence, it can be considered as a normalized measurement of covariance. The correlation study is useful to find a predictable relationship that can be used in practice. It is used for the measurement of the strength and statistical significance of the relation between two or more water quality parameters.

Table 3. Correlation of pH with heavy metals

	pH	Nickel	Zinc	Lead	Cadmium	Chromium
pH	1					
Nickel	-0.13559	1				
Zinc	-0.62049	-0.13005	1			
Lead	0.017834	-0.05046	-0.27676	1		
Cadmium	-0.29465	0.335222	-0.53464	0.236473	1	
Chromium	-0.01248	0.783234	-0.17347	-0.15503	0.270267	1

Note: Correlation is significant from 0.5 to 1.0 and -0.5 to -1.0

From Table 3, it is clear that the pH has a negative correlation with heavy metals like Ni, Zn, Cd and Cr., while pH was found to have a positive correlation with Pb.

Table 4. Correlation of tds with heavy metals

	TDS	Nickel	Zinc	Lead	Cadmium	Chromium
TDS	1					
Nickel	0.566995	1				
Zinc	-0.3452	-0.13005	1			
Lead	0.490796	-0.05046	-0.27676	1		
Cadmium	0.482013	0.335222	-0.53464	0.236473	1	
Chromium	0.720353	0.783234	-0.17347	-0.15503	0.270267	1

Note: Correlation is significant from 0.5 to 1.0 and -0.5 to -1.0

From Table 4, it is clear that the TDS has a negative correlation with Zn, while TDS is found to have a positive correlation with rest of the measured heavy metals like Ni, Pb, Cd and Cr.

Table 5. Correlation of ec with heavy metals

	EC	Nickel	Zinc	Lead	Cadmium	Chromium
EC	1					
Nickel	0.591619	1				
Zinc	-0.33567	-0.13005	1			
Lead	0.489008	-0.05046	-0.27676	1		
Cadmium	0.462494	0.335222	-0.53464	0.236473	1	
Chromium	0.740554	0.783234	-0.17347	-0.15503	0.270267	1

Note: Correlation is significant from 0.5 to 1.0 and -0.5 to -1.0

From Table 5, it is clear that the EC has a negative correlation with Zn, while TDS is found to have a positive correlation with rest of the measured heavy metals like Ni, Pb, Cd and Cr.

IV. CONCLUSION

It is evident from the obtained results that among the analysed heavy metals, a majority were presently within the BIS standards and the metal ion concentrations were not at such high levels that could be hazardous for human beings. But the study clearly points out that the excess concentrations of the toxic metals like Pb, Cd, Cr and Ni were present at some stations with a progressive increase in concentration in successive years during the study period. At all stations, the physico-chemical parameters showed an alarming increase in 2016-17 than the previous year. A proper evaluation of the environmental impact of human activities as well as groundwater conservation strategies could help us in achieving optimal environmental and human health.

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