International Journal of Modern Agriculture, Volume 10, No.1, 2021
ISSN: 2305-7246

Study Report on the Impact of Industrial Estates on Surface and Ground Water Quality – with special reference to Vijayawada city, A.P., India

P. Sumalatha[1] ,
Asst. Prof., Gudlavalleru Engineering College, Gudlavalleru, A.P.
Dr. P. Brahmaji Rao[2],
HoD – Environmental Sciences Department, Acharya Nagarjuna University, Guntur, A.P.

Abstract:

Urbanization and industrialization leads to increasing density of human population due to which natural resources are under tremendous pressure. Hence conservation of our water resources which is vital for our survival is a critical challenge faced by the humankind in the society. Both the quantity and quality of our water resources are two very important factors that determine its suitability for drinking, domestic, agriculture and industrial purposes. To meet the rising demand for the safe and clean water it is crucial to identify the fresh water resources and also discover the remedial methods for enhancement in water quality. The industrial hubs in and around Vijayawada city are responsible for the worsening of the quality of water resources (surface and ground). As there is lack of proper water quality monitoring data till date in this fast growing capital city of new Andhra Pradesh.The present study could pave a way for the better understanding the necessity for such water quality monitoring studies that could save a precious natural resource from contamination. A comparison between ground water and surface water at the selected sampling stations near industries was also done to know the more susceptible source of water to pollution due to the industrial activities.The heavy metal concentrations ranged in order of magnitude as Zn > Fe > Cd > Cu. Lead and Nickel were found to be absent in the samples collected from the samples in the study area.

Keywords: Surface water, Ground water, Physico-chemical parameters, heavy metals etc.,

Introduction:

It is affirmed and confirmed in number of research works that man made activities are considered as one of the significant drivers of pollution in all spheres of the environment (Akimoto 2003; Volkamer *et al.*, 2006; Masood *et al.*, 2016; Schlacher *et al.*, 2016). Pollution of water bodies by domestic, industrial effluents and agricultural activities is a severe threat faced by developing worldin the present time(Bano 2017; Benrabah *et al.*, 2016; Darapu *et al.*, 2011; Hamad *et al.*, 2018; Zahri *et al.*, 2016).Most of the works were carried out to evaluate the existing levels of heavy metals and ions in ground and surface water, to separate natural and anthropogenic sources that disrupt the quality of potable water (Chen *et al.*, 2016; Cao *et al.*, 2016; Ethya and Marbouti 2016; Gu *et al.*, 2015). Discharge of untreated or partially treated sewage or industrial effluents, improper urban garbage disposal and leachate from landfills are the major sources of pollution of ground water and about 2.3 billion people around the world experience diseases caused by dirty water (Okpara *et al.*, 2011)

The present work aimed to investigate the impact of industrial effluents on ground and surface water at selected sampling stations located in the areas of industrial hubs. Physico chemical and heavy metals were analyzed for both surface and ground waters.And a comparision was done between the surface and ground water quality due to the impact of industrial estates in the Vijayawada city of Andhra Pradesh (A.P.).

A. Study Area

The present study has been carried out at various industrial estates falling under the Vijayawada city limits in Krishna district. The ground water quality was monitored at five sampling stations, of which a residential area near Mogalrajpuram far away from industries was chosen as the control station.

B. Site Description

Figure 1: Location map of the study area with Autonagar and NTPS Power station at Vijayawada

Table 1: Sampling Stations

Sample No	Period	Mandal	Location	Source	Industry type
Station-I	June-2016 to	Vijayawada	Autonagar		Electroplating

	June-2019			Surface and Ground water collected from municipal taps and bore wells	Alloys
Station-II	June-2016 to June-2019	Vijayawada	Autonagar		Automobiles and Electrical work shops
Station-III	June-2016 to June-2019	Vijayawada	Ibrahimpatnam		Chemicalfactory
Station-IV	June-2016 to June-2019	Vijayawada	Kondapalli		Power Plant
Station-V	June-2016 to June-2019	Vijayawada	Mogalrajpuram		Residential

Ground and surface water sampling stations i.e., Station-I and II were identified at the Industrial estate of Jawaharlal Nehru Auto Nagar. Jawahar Autonagar is an industrial estate located in the eastern side of Vijayawada of Andhra Pradesh. Autonagar is the first largest auto industrial hubs of Asia with lot of important activities like clutch and break servicing, servicing of radiators, vulcanizing, retreading of tyres, automobile body building works, electrical works, upholstery, blacksmith work, tinkering, carpentry, painting etc are performed.

Despite the city having plenty of water at source as well a treatment and distribution systems, thousands of people still grapple with drinking water crisis in this industrial unit. Scores of workers in the unorganised sector working at the automobile shops and factories in Autonagar are facing a harrowing time due to lack of drinking water supply from Vijayawada Municipal Corporation (VMC). Several workers complain that they continue to manage with groundwater and private water resources.The industrial situation of the city is also dominated by the agro based industries. Various agro based industries like oil mills, rice mills, dal mills, solvent extraction plants etc are found in Vijayawada. Several representations have been submitted by Autonagar Industrial Area Local Authority (AILA) to officials of the civic body to supply drinking water for the locality. With no option left, most automobile owners are purchasing mineral water cans to quench their thirst,'' said association member of AILA on condition of anonymity. A ground and surface water sampling station i.e.

And another ground and surface water sampling station i.e. Station-III was selected at the thermal power plant situated near Ibrahimpatnam which nearly 17 km away from the Vijayawada city. This thermal power plant meets the huge requirements of water from the Prakasham Barrage build across the Krishna River with stagnating capacity of 2 TMC of water. The water used from various purposes of NTPS is being taken from the impounding waters of Prakasham Barrage and after use this effluent water is being discharged into Krishna river. From here the water is being diverted to three canals namely Bandar, Eluru and Buckingham canals that runs miles in different directions fulfilling the needs of people across the city.

Station-IV was selected at a Chemical factory at industrial park, Kondapalli Vijayawada of Andhra Pradesh. Another important industrial suburb of Vijayawada is Kondapalli having largest industrial estates in Andhra Pradesh spread over 450 acres and supporting 800 industrial enterprises.

A ground and surface water sampling station i.e. Station-V was selected at Mogalrajpuram, a residential area in Vijayawada which is 5 km away from industrial estates. This station was considered as a control station.

Materials and Methods:

The samples were analyzed various water quality parameters such as Temperature, pH, Total dissolved solids (TDS), Electrical conductivity (EC), Total hardness (TH), Calcium hardness (CH), Magnesium hardness (MH), Total alkalinity (TH), Fluorides (F^-), Sodium (Na^+), Potassium (K^+), Chlorides (Cl^-), Nitrates (NO_3^-), Phosphates (PO_4^-), Dissolved oxygen (DO), Biological oxygen demand (COD), Chemical oxygen demand (BOD), Cadmium (Cd), Copper (Cu), Ferrum (Fe), Lead (Pb), Nickel (Ni), Zinc (Zn)using standard procedures described in NEERI Manual (1984).The results of the analysis were presented as mean ± Standard Deviation (SD) on an annual basis for three consecutive years from June 2016 to June 2019. Statistical tools were applied to find out the correlation among the parameters.

Table2: Standard analytical methods used for physico-chemical parameters

Sl. No.	Parameters	Methodology	References
1	Temperature (^oC)	Direct, Mercury Thermometer	
2	pH	Electrometric method Digital pH meter (Hanna make of model PHEP)	APHA (1998)
3	Electrical Conductivity (µmhos/cm)	Electrometric method Conductivity meter (Hanna make with model number DiST-4)	APHA (1998)
4	Totlal Dissolved Solids (mg/L)	Electrometric, (Hanna make with model number DiST-4)	APHA (1998)
5	Total Alkalinity (mg/L)	Volumetric analysis, Titrimetric	Grasshoff (1999)
6	Total Hardness (mg/L) EDTA	Titrimetric method	APHA (1998)
7	Calcium Hardness (CH)	Titrimetric method	APHA (1998)
8	Magnesium Hardness (MH)	Titrimetric method	APHA (1998)
9	Sodium (Na^+)	Flame Photometer (ELICO make)	APHA (1998)
10	Potassium (K^+)	Flame Photometer (ELICO make)	APHA (1998)
11	Chloride	Argentometric, Titration	APHA (1998)

12	Nitrate - N (mg/L)	Phenol Disulfonic Acid (PDA) method	Grasshoff (1999)
13	Total Phosphorous (mg/L)	Stannous chloride method Spectrophotometric	Grasshoff (1999)
14	Dissolved Oxygen (mg/L)	Modified Winkler's method	APHA (1998)
15	Biological Oxygen Demand (mg/L)	Winkler modified, Titration	APHA (1998)
16	Chemical Oxygen Demand (mg/L)	Open Reflux Method	APHA (1998)
17	Heavy metals (Cd, Cu,Fe, Pb, Ni & Zn)	AAS (Perkin Elmer-AAnalyst 300)	APHA (1998)

Results and Discussion:

Analytical results for surface and ground water for specific parameters like Temperature, pH, Total dissolved solids (TDS), Electrical conductivity (EC), Total hardness (TH), Calcium hardness (CH), Magnesium hardness (MH), Total alkalinity (TH), Fluorides (F^-), Sodium (Na^+), Potassium (K^+), Chlorides (Cl^-), Nitrates (NO_3^-), Phosphates (PO_4^-), Dissolved oxygen (DO), Biological oxygen demand (BOD), Chemical oxygen demand (COD), Cadmium (Cd), Copper (Cu), Ferrum (Fe), Lead (Pb), Nickel (Ni), Zinc (Zn) are provided for three complete annual cycles from June 2016 to June 2019.

Table 3: Annual means±SD for three consecutive years for Ground and Surface water at Station-I

S.No	Parameters	BIS Standards	Station -I(Autonagar 1)					
			2016-17		2017-18		2018-19	
			GW	SW	GW	SW	GW	SW
1	Temperature (°C)	26	27.942± 2.326	27.25± 1.664	27.292± 1.462	27.292± 1.462	28.175± 1.884	26.942± 2.1
2	pH	8.5	6.817±0.147	7.11±0.12	7.042±0.323	7.125± 0.263	6.933± 0.352	7.185± 0.234
3	Total Dissolved Solids	500	2964.167± 295.051	294±30.32	2891.083± 432.155	288.75± 43.136	1471.667± 214.299	145.75± 22.41
4	Electrical Conductivity(µmhos/cm)	750	4424.129± 440.375	438.806± 45.253	4315.05± 645.008	430.97± 64.383	2264.103± 329.691	217.537± 33.448
5	Total Hardness	300	2896.167± 1385.863	363.667± 91.058	3738.333± 1352.182	396± 141.264	3448.333± 829.522	370.5± 107.322

6	Calcium Hardness	75	59.333± 14.926	159.333± 14.926	46.333± 14.926	146.333± 14.926	51.75± 11.561	151.75± 11.561
7	Magnesium Hardness	30	2836.833± 1395.189	204.333± 94.021	3692± 1357.638	249.667± 146.134	3396.583± 833.312	218.75± 110.449
8	Total Alkalinity	200	560.083± 153.181	262.583± 24.422	449.5± 141.909	257.167± 20.949	508± 194.883	258.917± 24.047
9	Chlorides	250	1188.963± 138.149	76.25± 11.986	1176.263± 138.149	87.25± 6.837	1679.733± 178.508	89.5± 6.23
10	Nitrates	45	0.416±0.515	1.135± 0.434	0.592±0.5	1.425± 0.154	0.868±0.475	1.442± 0.168
11	Phosphates	0.5	0.292±0.183	0.262± 0.094	0.775± 0.181	0.348± 0.089	0.478±0.36	0.379± 0.097
12	Sodium	200	576.225± 104.002	88.917± 11.325	665.133± 92.387	79.758± 13.197	408.817± 231.806	85.833± 5.54
13	Potassium	10	91.25± 5.32	9±1.206	54.475± 6.521	9.583± 1.165	74.883± 19.043	9.25± 1.357
14	DO	3	0.983± 0.493	0.733± 0.36	1.325± 1.491	1.325± 1.491	0.942± 1.057	0.942± 1.057
15	BOD	5	0.508± 0.657	1.05± 0.579	0.975± 0.349	1.583± 0.791	1.083± 0.262	1.708± 0.713
16	COD	10	10.735± 5.813	13.083± 1.782	8.257± 5.968	13.278± 1.067	10.608± 6.243	11.667± 1.155
17	Cadmium	0.003	0.003± 0.001	0.001± 0.001	0.003± 0.002	0.001±0	0.003± 0.001	0.001±0
18	Copper	0.05	0.023± 0.007	0.01±0	0.025±0.004	0.01±0	0.013±0.012	0.01±0
19	Ferrum	0.3	0.337± 0.16	0.043± 0.006	0.365±0.098	0.04± 0.009	0.361±0.125	0.01± 0
20	Lead	0.01	ND	ND	ND	ND	ND	ND
21	Nickel	0.02	ND	ND	ND	ND	ND	ND
22	Zinc	5	0.054± 0.01	0.383± 0.103	0.054± 0.013	0.367± 0.089	0.057± 0.056	0.392± 0.124

(All the values are expressed in mg/L except where specifically mentioned)
GW – Ground Water; SW – Surface Water

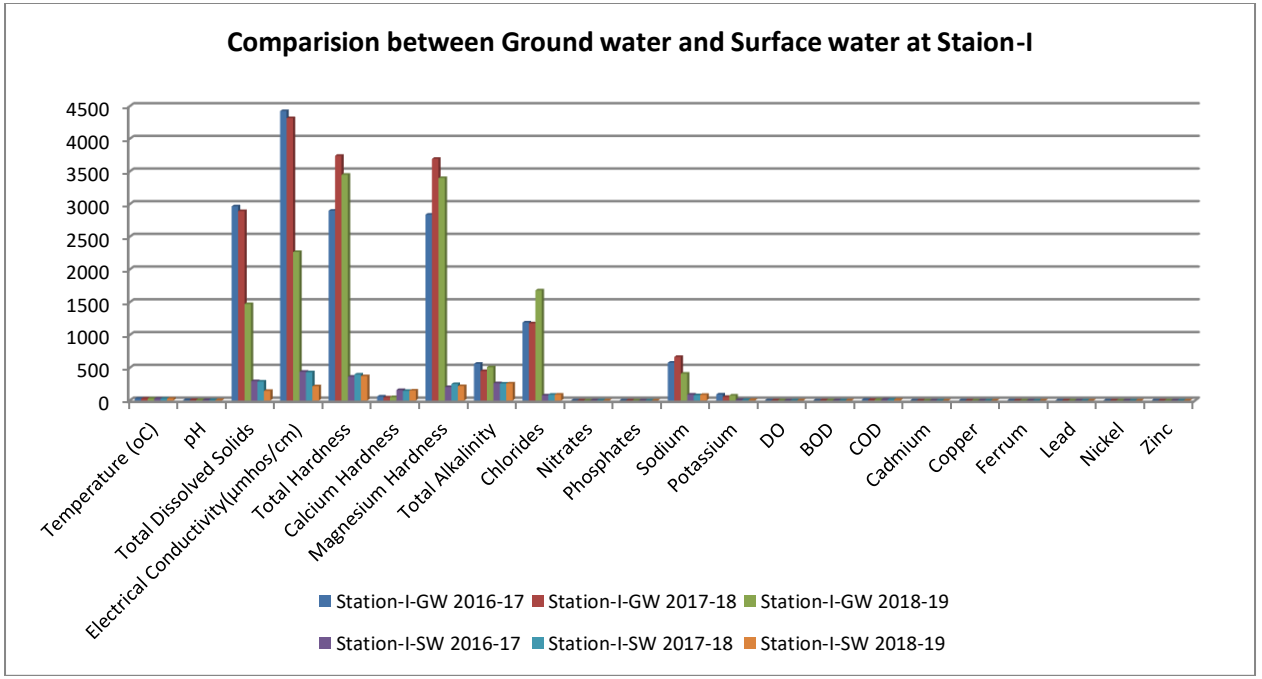

Figure 2: Graph indicating the comparison between ground and surface water at Station-I

Table 4: Annual means±SD for three consecutive years for Ground and Surface water at Station-II

S.No	Parameters	BIS Standards	Station -II(Autonagar-II)					
			2016-17		2017-18		2018-19	
			GW	SW	GW	SW	GW	SW
1	Temperature (oC)	26	29.25± 0.934	27.858± 2.43	28.608± 0.909	28.608± 0.909	28.633± 1.403	26.742± 1.923
2	pH	8.5	7.033±0.29	7.075± 0.238	7.067± 0.242	7.067± 0.242	7.025±0.29	7.228± 0.173
3	Total Dissolved Solids	500	4483.333± 345.292	446.333± 35.595	4580.25± 224.905	461.667± 18.729	1905± 274.64	190.5± 27.464
4	Electrical Conductivity(µmhos/cm)	750	6691.542± 515.36	666.169± 53.126	6836.194± 335.68	689.055± 27.954	2930.769± 422.523	284.328± 40.991
5	Total Hardness	300	2396.167± 881.648	348.667± 161.557	1779± 724.309	427.917± 98.931	1838.667± 621.001	319.25± 43.399

6	Calcium Hardness	75	57.417± 11.658	157.333± 11.578	49.417± 13.534	149.417± 13.534	47.833± 16.32	47.833± 16.32
7	Magnesium Hardness	30	2338.75± 878.916	191.333± 160.49	1729.583± 718.133	278.5± 90.471	1790.833± 612.893	271.417± 48.329
8	Total Alkalinity	200	509.167± 103.251	248.583± 26.438	478.333± 99.852	252.833±37.18	507.083± 102.114	266.417± 32.553
9	Chlorides	250	902.448± 100.843	87.667± 4.979	1670.522± 2831.799	87.833± 5.323	785.208± 204.964	83.667± 7.203
10	Nitrates	45	1.883± 3.046	1.05± 0.552	1.783± 3.046	1.879± 0.792	1.841± 3.06	1.821± 0.79
11	Phosphates	0.5	0.386± 0.083	0.239± 0.061	0.348± 0.089	0.455± 0.079	0.379± 0.097	0.243± 0.146
12	Sodium	200	558.108± 80.066	54.25± 4.393	633.533± 23.173	64.667± 2.462	659.742± 55.831	66.833± 4.13
13	Potassium	10	73.483± 8.251	12.333± 1.775	78.65± 7.374	13.5±1.977	70.483± 11.795	12±2.045
14	DO	3	0.767± 0.396	1.567± 0.235	1.033± 1.136	1.033± 1.136	0.658± 0.46	0.658± 0.46
15	BOD	5	0.367± 0.403	1.658± 1.232	1.658± 1.232	0.95±0.995	1.75± 1.368	1.942± 0.938
16	COD	10	9.891± 4.845	14.388± 2.4	4.563± 2.257	14±1.477	7.026± 3.833	14.583± 2.353
17	Cadmium	0.003	0.002± 0.001	0.001±0	0.003± 0.001	0.001±0	0.002± 0.001	0.001±0
18	Copper	0.05	0.037± 0.008	0.01±0	0.036± 0.007	0.01±0	0.012± 0.017	0.01±0
19	Ferrum	0.3	0.015± 0.009	0.041± 0.008	0.015± 0.013	0.043± 0.007	0.015± 0.004	0.01±0
20	Lead	0.01	ND	ND	ND	ND	ND	ND
21	Nickel	0.02	ND	ND	ND	ND	ND	ND
22	Zinc	5	0.337± 0.291	0.392± 0.124	0.082± 0.09	0.383±0.103	0.035± 0.031	0.367± 0.089

(All the values are expressed in mg/L except where specifically mentioned)
GW – Ground Water; SW – Surface Water

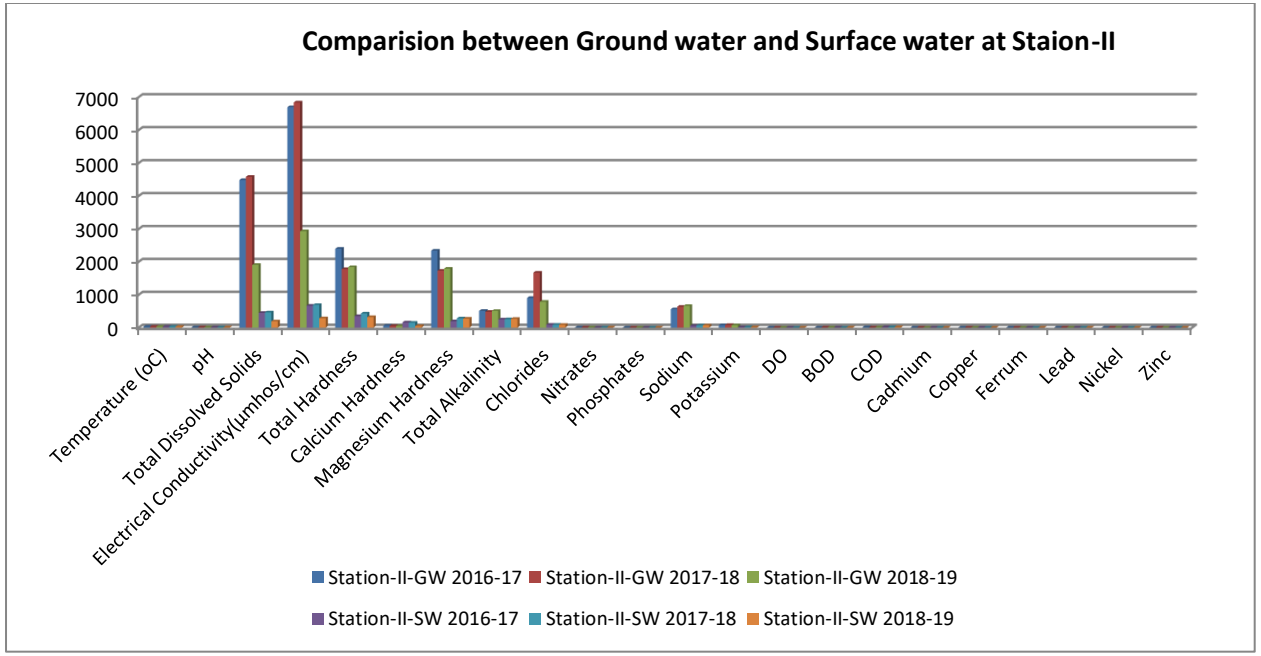

Figure 3: Graph indicating the comparison between ground and surface water at Station-II

Table 5: Annual means±SD for three consecutive years for Ground and Surface water at Station-III

S.No	Parameters	BIS Standards	Station –III (Ibrahimpatnam)					
			2016-17		2017-18		2018-19	
			GW	SW	GW	SW	GW	SW
1	Temperature (oC)	26	28.317± 1.104	28.183± 1.313	28.467± 0.935	28.467± 0.935	28.633± 0.734	28.467± 0.935
2	pH	8.5	7.525± 0.201	7.5±0.181	7.542±0.323	7.542±0.323	7.55±0.318	7.542± 0.323
3	Total Dissolved Solids	500	4429.333 ± 606.144	423.5± 59.011	4514.167± 577.844	4514.167± 577.844	12720.833 ± 5091.323	465.583±46.353
4	Electrical Conductivity(µmhos/cm)	750	6610.945 ±	632.09± 88.076	6737.562± 862.454	6737.562± 862.454	19570.513 ±	694.9± 69.184

			904.692				7832.805	
5	Total Hardness	300	1912.333 ± 128.164	345.75± 29.425	2794.75± 691.053	2794.75± 691.053	2256.25± 642.21	315± 92.827
6	Calcium Hardness	75	38.833± 10.098	38.833± 10.098	34.25±6.917	34.25±6.917	37.25± 10.446	34.25± 6.917
7	Magnesium Hardness	30	1873.5± 133.623	306.917± 34.784	2760.5± 689.023	2760.5± 689.023	2219± 643.15	280.75± 90.972
8	Total Alkalinity	200	456.833± 141.599	139.167± 19.803	494.167± 103.251	494.167± 103.251	469.167± 66.48	158.917± 28.843
9	Chlorides	250	515.448± 100.843	59.25± 12.743	1283.522± 2831.799	1283.522± 2831.799	426.008± 206.086	65.5±16.15
10	Nitrates	45	1.514± 0.825	ND	1.414± 0.825	1.414± 0.825	1.473± 0.839	ND
11	Phosphates	0.5	0.282± 0.094	ND	0.272± 0.043	0.272± 0.043	0.313± 0.069	ND
12	Sodium	200	530.817± 110.508	64.583± 19.024	620.517± 89.07	620.517± 89.07	532.742± 113.757	69.167± 18.235
13	Potassium	10	47.892± 12.46	5±0.853	38.967± 6.532	38.967± 6.532	47.442± 14.365	5.667±0.985
14	DO	3	3.9±0.497	4.358± 0.739	4.092± 0.466	4.092± 0.466	3.7± 0.471	4.725± 0.439
15	BOD	5	1.683± 0.677	1.692± 0.713	1.05± 0.579	1.05± 0.579	1.175± 0.654	1.383±0.589
16	COD	10	6.6±5.953	13.017±2.435	8.839±2.819	8.839±2.819	6.667±3.2	14.466±3.602
17	Cadmium	0.003	0.002± 0.001	0.002±0	0.002± 0.001	0.002± 0.001	0.002± 0.001	0.002±0
18	Copper	0.05	0.018± 0.011	0.03± 0.011	0.019± 0.011	0.019± 0.011	0.011± 0.012	0.031±0.011
19	Ferrum	0.3	0.102± 0.09	0.04± 0.009	0.072± 0.044	0.072± 0.044	0.144± 0.087	0.043±0.006
20	Lead	0.01	ND	ND	ND	ND	ND	ND
21	Nickel	0.02	ND	ND	ND	ND	ND	ND
22	Zinc	5	0.013±	0.475±	0.012±	0.012±	0.017±	0.458±0.1

			0.006	0.062	0.003	0.003	0.01	

(All the values are expressed in mg/L except where specifically mentioned)
GW – Ground Water; SW – Surface Water

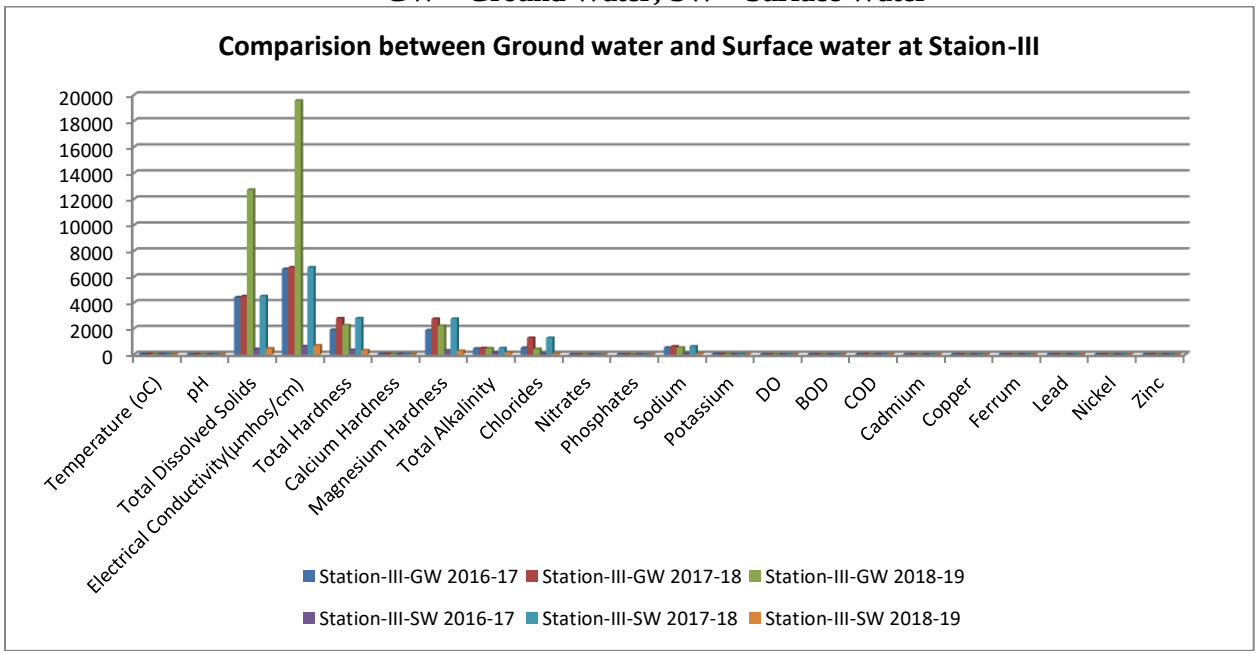

Figure 4: Graph indicating the comparison between ground and surface water at Station-III

Table 6: Annual means±SD for three consecutive years for Ground and Surface water at Station-IV

S.No	Parameters	BIS Standards	Station –IV-Kondapalli					
			2016-17		2017-18		2018-19	
			GW	SW	GW	SW	GW	SW
1	Temperature (oC)	26	28.817±0.86	29.075± 0.897	29.692± 0.643	29.692± 0.643	28.85±1.102	27.458± 1.747
2	pH	8.5	7.725±0.148	7.683± 0.164	7.642±0.207	7.642± 0.207	7.633±0.15	7.582± 0.217
3	Total Dissolved Solids	500	4308.5± 646.176	430.667± 63.72	4467.167± 577.844	443.083± 64.372	6675± 301.888	667.5± 30.189
4	Electrical Conductivity(µmhos/cm)	750	6430.597±	642.786±	6667.413±	661.318±	10269.231±	996.269±

			964.442	95.105	862.454	96.077	464.443	45.058
5	Total Hardness	300	2396.167± 881.648	221.083± 65.893	2478.917± 729.863	241.75± 58.54	2245.833± 404.611	207.75± 30.374
6	Calcium Hardness	75	33.333±7.82	89.833± 5.167	55.5± 8.174	80.833± 10.179	48±13.578	91.583± 6.895
7	Magnesium Hardness	30	2362.833± 877.048	131.25± 64.963	1723.5± 723.197	160.917± 55.963	2197.833± 407.051	116.167± 28.399
8	Total Alkalinity	200	635.5± 120.894	144.75± 27.559	675.833± 132.095	160.833± 30.626	665.417± 137.236	179.583± 50.653
9	Chlorides	250	680.539± 433.539	70.667± 17.788	738.206± 433.926	67.083± 19.893	772.498± 397.499	68.417± 17.516
10	Nitrates	45	30.45±7.564	ND	33.017± 9.251	ND	30.183± 9.175	ND
11	Phosphates	0.5	0.543±0.187	ND	0.565±0.08	ND	0.632± 0.122	ND
12	Sodium	200	888.525± 182.298	85.667± 13.753	843.35± 185.164	78.167± 16.574	797.408± 152.3	75.5± 17.064
13	Potassium	10	55.05± 13.715	7.25± 0.866	43.2± 16.968	6.667± 0.778	50.308± 15.511	7.333± 0.778
14	DO	3	4.458± 0.472	1.367± 1.092	4.7±0.475	0.658± 0.574	4.233± 0.446	0.758± 0.36
15	BOD	5	1.767± 0.996	4.358± 0.739	1.433± 0.74	4.725± 0.439	1.642± 0.761	3.775± 0.475
16	COD	10	8.503± 5.48	7.761± 3.887	7.361± 3.887	8.903± 5.48	7.344± 3.667	8.322± 4.126
17	Cadmium	0.003	0.008± 0.005	0.001±0	0.011± 0.007	0.001±0	0.005± 0.005	0.001±0
18	Copper	0.05	0.003± 0.001	0.017± 0.005	0.008± 0.008	0.018± 0.005	0.016± 0.006	0.018± 0.005
19	Ferrum	0.3	0.031± 0.017	0.044± 0.007	0.031± 0.017	0.041± 0.008	0.026± 0.011	0.018± 0.005
20	Lead	0.01	ND	ND	ND	ND	ND	ND
21	Nickel	0.02	ND	ND	ND	ND	ND	ND
22	Zinc	5	0.015± 0.005	0.433± 0.098	0.02± 0.007	0.342± 0.1	0.061± 0.092	0.392± 0.108

(All the values are expressed in mg/L except where specifically mentioned)
GW – Ground Water; SW – Surface Water

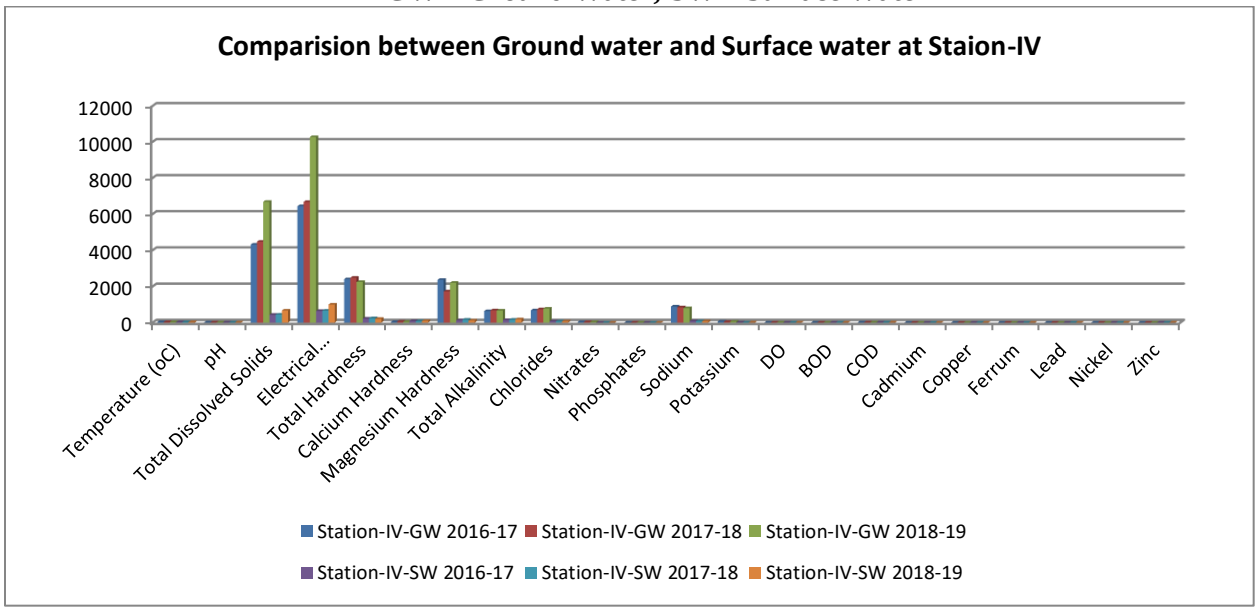

Figure 5: Graph indicating the comparison between ground and surface water at Station-IV

Table 7: Annual means±SD for three consecutive years for Ground and Surface water at Station-V

S.No	Parameters	BIS Standards	Station -V(Control Station-Mogalrajpuram)					
			2016-17		2017-18		2018-19	
			GW	SW	GW	SW	GW	SW
1	Temperature (^oC)	26	26.942±2.1	27.092± 1.696	27.25±1.664	28.175± 1.884	27.292± 1.462	27.942± 2.326
2	pH	8.5	7.525±0.201	7.492± 0.183	7.375±0.336	7.375± 0.336	7.067±0.277	7.239± 0.13
3	Total Dissolved Solids	500	3500± 893.41	350± 89.341	3391.667± 832.803	339.167± 83.28	3391.667± 832.803	339.167± 83.28
4	Electrical Conductivity(µmhos/cm)	750	5384.615± 1374.477	522.388± 133.345	5217.949± 1281.235	506.219± 124.299	5217.949± 1281.235	506.219± 124.299

5	Total Hardness	300	2011.417± 554.95	209.167± 60.938	1871.5± 454.173	347± 122.96	2794.75± 691.053	268.167± 68.686
6	Calcium Hardness	75	50.25± 14.833	145.167± 20.81	53.917± 11.164	148.083± 22.785	50.417± 12.258	150.417± 12.258
7	Magnesium Hardness	30	1961.167± 557.722	64±57.055	1817.583± 454.676	198.917± 109.861	2744.333± 685.25	117.75± 62.937
8	Total Alkalinity	200	462.833± 80.693	149.417± 34.658	560.083± 153.181	154.833± 27.866	506.25± 146.976	167.083± 20.952
9	Chlorides	250	176.417± 88.511	64.417± 14.113	277.583± 97.388	72.833± 14.244	490± 130.155	74.833± 14.064
10	Nitrates	45	0.493± 0.577	1.008± 0.326	0.706± 0.488	1.217± 0.18	0.65±0.505	1.283± 0.153
11	Phosphates	0.5	0.457± 0.208	ND	0.623± 0.262	ND	0.619± 0.302	ND
12	Sodium	200	577.575± 124.67	31.833± 4.387	679.9± 81.45	29.333± 3.701	215.417± 33.727	37.167± 4.064
13	Potassium	10	71.225± 20.696	6.583± 0.793	66.025± 16.505	7.25± 0.866	60.75± 14.137	6.667± 1.073
14	DO	3	1.367± 1.092	1.65± 0.334	0.658± 0.574	1.617± 0.262	0.758± 0.36	1.533± 0.246
15	BOD	5	0.975± 0.349	1.325± 0.226	0.917± 0.451	1.275± 0.242	1.6±1.212	1.575± 0.249
16	COD	10	8.741± 6.608	11.733± 1.198	10.822± 6.273	11.917± 1.084	13.433± 6.795	12± 1.044
17	Cadmium	0.003	0.003± 0.001	0.002±0	0.003± 0.001	0.002± 0.001	0.002± 0.001	0.002± 0.001
18	Copper	0.05	0.036± 0.007	0.036± 0.007	0.037± 0.008	0.037± 0.008	0.037± 0.008	0.037± 0.008
19	Ferrum	0.3	0.015± 0.013	0.044± 0.007	0.015± 0.009	0.042± 0.007	0.015± 0.004	0.037± 0.008
20	Lead	0.01	ND	ND	ND	ND	ND	ND
21	Nickel	0.02	ND	ND	ND	ND	ND	ND
22	Zinc	5	0.182± 0.256	0.408± 0.131	0.196± 0.261	0.383± 0.094	0.112± 0.123	0.4± 0.141

(All the values are expressed in mg/L except where specifically mentioned)

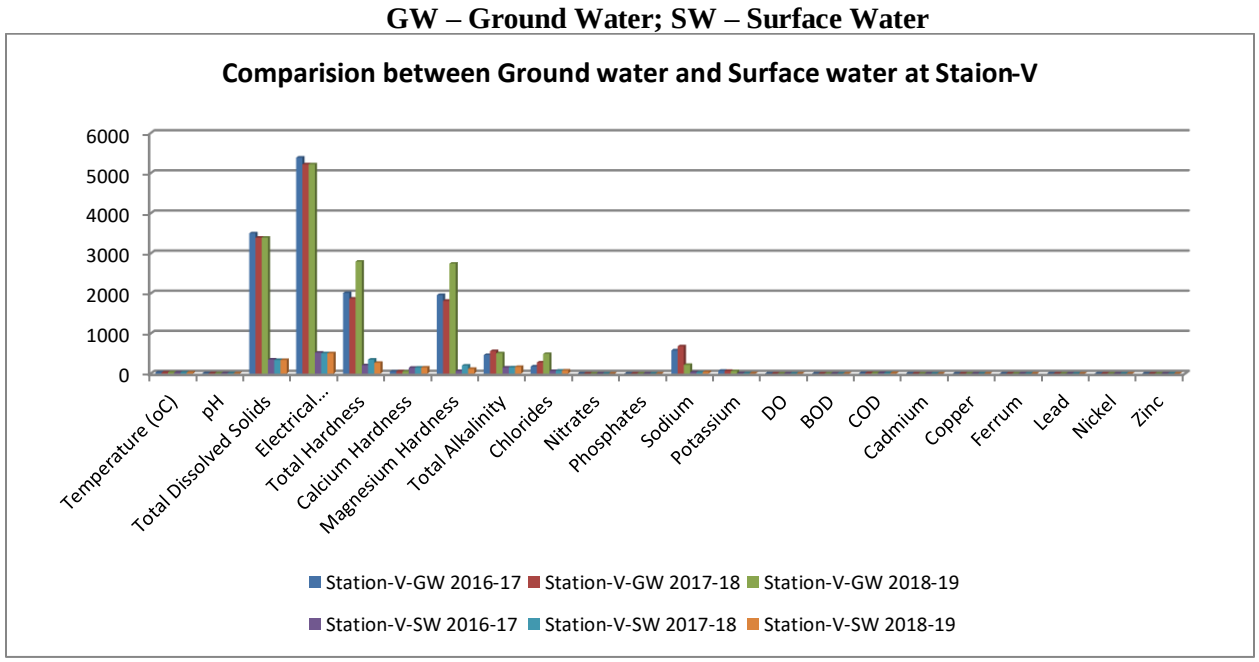

Figure 6: Graph indicating the comparison between ground and surface water at Station-V

Temperature (^{o}C):

Temperature was observed to be in a range of 26.942±2.1 ^{o}C to 29.692±0.643 ^{o}C in ground water whereas 26.742±1.923 ^{o}C to 29.692±0.643^{o}C in surface water during the study period. The temperature values were very much near to the BIS standard limit of 26^{o}C. Seasonal variations resulted in slight variation in the temperature of surface and ground water. Temperature is said to be one important factor determining the solubility of pollutants in water (Niloufer *et al.*,2013).

pH:

pH was observed to be in a range of 6.817±0.147 to 7.725±0.148in ground water whereas 7.067±0.242 to 7.683±0.164 in surface water during the study period which was within the BIS standard limit of 6.5 to 8.5. pH of ground and surface water was detected to be alkaline in nature during the period of study.

Total Dissolved Solids (mg/L):

Total Dissolved Solids were observed to be in a range of 1471.667±214.299mg/L to 12720.833±5091.323mg/L in ground water whereas 145.75±22.41mg/L to 667.5±30.189mg/L in surface water during the period of study. All the stations were observed to have high concentrations of TDS values for both ground and surface water during the totalstudy period which was exceeding the BIS standard limit of 500 mg/L. The TDS values were observed to be high in ground water when compared to surface water during the study period of three consecutive years. The elevated values of TDS in the water samples analyzed represented the contamination from the industrial sources. High levels of TDS in water may lead to laxative effects and gastrointestinal irritations (Cao *et al.*, 2016; Li *et al.*, 2015).

Electrical Conductivity (µmhos/cm):

Electrical Conductivity was observed to be in a range of 2264.103±329.691 µmhos/cm to 19570.513±7832.805 µmhos/cm in ground water whereas 217.537±33.448µmhos/cm to 996.269±45.058 µmhos/cm in surface water during the study period. Most of the stations were observed to have high levels of EC values for both ground and surface water during the study period which was exceeding the BIS standard limit of 750 µmhos/cm. The EC values were identified to be high in ground water when compared to surface water during the study period of three consecutive years, which might be due to percolation of high dissolved solids in the ground water.

Total Hardness (mg/L):

Total Hardness was observed to be in a range of 1779±724.309 mg/L to 3738.333±1352.182 mg/L in ground water whereas 207.75±30.374mg/L to 427.917±98.931 mg/L in surface water during the study period which was exceeding the BIS standard limit of 300 mg/L.Disposal of untreated and improperly treated sewage may be definitely attributed to high degree of water hardness at all the stations (Shanker *et al.*, 2008).

Calcium Hardness(mg/L):

Calcium Hardness was observed to be in a range of 33.333±7.82 mg/L to 59.333±14.926mg/L in ground water whereas 34.25±6.917mg/L to 159.333±14.926 mg/L in surface water during the study period which was exceeding the BIS standard limit of 75 mg/L at some of the stations (I, II & IV) for surface water. The similar trend of calcium hardness occurred in ground water in the work done by Ramakrishnaiah *et al.*, (2009) and can be significantly correlated with hardness of drinking water on health of human beings.

Magnesium Hardness(mg/L):

Magnesium Hardness was observed to be in a range of 1723.5±723.197mg/L to 3692±1357.638 mg/L in ground water whereas 64±57.055mg/L to 306.917±34.784 mg/L in surface water during the study period which was exceeding the BIS standard limit of 30 mg/L at all the stations during the study period. High levels of Mg^{2+} ions has been reported of causing dehydration (Fingl 1980).

Total Alkalinity(mg/L):

Total Alkalinitywas observed to be in a range of 449.5±141.909mg/L to 1679.733±178.508 mg/L in ground water whereas 139.167±19.803 mg/L to 266.417±32.553 mg/L in surface water during the study period which was exceeding the BIS standard limit of 200 mg/L at all the stations during the study period.

Chlorides(mg/L):

Chlorides was observed to be in a range of 176.417±88.511 mg/L to 1679.733±178.508mg/L in ground water whereas 59.25±12.743 mg/L to 89.5±6.23 mg/L in surface water during the study period which was exceeding the BIS standard limit of 250 mg/L at all the stations during the study period.Chlorides have a low health risk in drinking water as per World Health Organization (WHO) permissible limit of 250mg/L(WHO 2011). Relatively high concentration of Cl^- ion will affect the taste of drinking water that may be a major concern (Olasoji *et al.*, 2019).

Nitrates(mg/L):

Nitrates were observed to be in a range of 0.416±0.515mg/L to 33.017±9.251mg/L in ground water whereas 0mg/L to 1.879±0.792mg/L in surface water during the study period. The concentration of Nitrates were observed to be within the standard limit of BIS Standard i.e., 45 mg/L

Phosphates(mg/L):

Phosphates were observed to be in a range of 0.272±0.043mg/L to 0.775±0.181mg/L in ground water whereas 0 mg/L to 0.455±0.079 mg/L in surface water during the study period.

Sodium (mg/L):

Sodium was observed to be in a range of 215.417±33.727 mg/L to 888.525±182.298 mg/L in ground water whereas 29.333±3.701 mg/L to 88.917±11.325 mg/L in surface water during the study period which was exceeding the BIS standard limit of 200 mg/L at all the stations in ground water. The ground water pollution by sewage, irrigation and salt deposit erosion and sodium bearing rocks may possibly be the outcome of high concentrations of Na^+in ground water (Achieng *et al.*, 2017).

Potassium(mg/L):

Potassium was observed to be in a range of 38.967±6.532 mg/L to 91.25±5.32 mg/L in ground water whereas 5±0.853 mg/L to 13.5±1.977 mg/L in surface water during the study period which was exceeding the BIS standard limit of 10 mg/L.

Dissolved Oxygen(mg/L):

Dissolved Oxygenwas observed to be in a range of 0.658±0.46 mg/L to 4.7±0.475 mg/L in ground water whereas 0.658±0.46 mg/L to 4.725±0.439 mg/L in surface water during the study period. The dissolved oxygen was observed to be less than 3 mg/Lat stations (I, II)in the ground water and stations (I,II, III, & IV) in surface water due to high organic load in the water.

Biological Oxygen Demand(mg/L):

Biological oxygen demand was observed to be in a range of 0.367±0.403mg/L to 1.767±0.996mg/L in ground water whereas 0.95±0.995 mg/L to 4.725±0.439mg/L in surface water during the study period. BOD is commonly used as an indication of the degree of organic pollution in the

aquatic systems, which adversely affect the water quality (Jonnalagadda and Mhere, 2001). BOD was observed to be exceeding the BIS standard limit of 5mg/L at station-IV in ground water and surface water.

Chemical Oxygen Demand(mg/L):

Chemical Oxygen demandwas observed to be in a range of 4.563±2.257mg/L to 13.433±6.795mg/L in ground water whereas 7.761±3.887 mg/L to 14.583±2.353mg/L in surface water during the study period. COD values were exceeding BIS standard of 10 mg/L at stations (I, II & III) indicating more organic load in the water due to industrial effluents.

Cadmium(mg/L):

Cadmium was observed to be in a range of 0.002±0.001 mg/L to 0.011±0.007mg/L in ground water whereas 0.001±0 mg/L to 0.001±0 mg/L in surface water during the study period. The concentrations were observed to be within the range of BIS standards i.e., 0.003 mg/L except at Stations IV and V.

Copper (mg/L):

Copper was observed to be in a range of 0.003±0.001mg/L to 0.037±0.008 mg/L in ground water whereas 0.01±0mg/L to 0.037±0.008 mg/L in surface water during the study period. The concentrations were observed to be within the range of BIS standards i.e., 0.05 mg/L.

Ferrum(mg/L):

Ferrum was observed to be in a range of 0.015±0.009 mg/L to 0.365±0.098mg/L in ground water whereas 0.01±0 mg/L to 0.044±0.007 mg/L in surface water during the study period. The concentrations of Ferrum were observed to be higher than BIS standard limit of 0.3 mg/L at Station-I in ground water. Whereas in surface water the Ferrum concentrations were recorded to be within the BIS standard limit during the study period. Though the Ferrum may be of slight health concern for human beings but it might be classified as an irritant according to the studies done by Achieng *et al.*, 2017 and Li 2016.

Lead (mg/L):

Lead was observed to be absent in the samples collected during the study period.

Nickel(mg/L):

Nickel was observed to be absent in the samples collected during the study period.

Zinc(mg/L):

Zinc was observed to be in a range of 0.012±0.003 mg/L to 0.337±0.291 mg/L in ground water whereas 0.342±0.1 mg/L to 0.475±0.062 mg/L in surface water during the study period which was well within the BIS standard limit of 5 mg/L. The concentration of zinc was predominantly high followed by Zn > Fe > Cd > Cu. This could be as a result of uncontrolled industrial effluents discharged on ground from electroplating industries located in the study area. Exposure to high concentrations of Zn and Cu levels may cause hypertension, heart diseases, pulmonaryproblems and granuloma (Fang et al, 2010).

Correlation between the parameters for the complete ground water and surface water data from June 2016 to June 2019:
Correlation of physico chemical parameters Pearson's correlation coefficients were calculated for all the parameters that is displayed in Table 8. Temperature had negative correlation with calcium hardness, phosphates, chemical oxygen demand, copper, ferrum and Zinc. pH had positive correlation with DO, whereas negative correlation with total hardness, calcium hardness, magnesium hardness, total alkalinity, chlorides, phosphates, potassium, chemical oxygen demand, copper, ferrum and zinc.

Table 8: Correlation between the parameters for the complete ground water and surface water data from June 2016 to June 2019

	Temp	*pH*	*TDS*	*EC*	*TH*	*CH*	*MH*	*TA*	*Cl*	*NO3*	*PO4*	*Na*	*K*	*DO*	*BOD*	*COD*	*Cd*	*Cu*	*Fe*	*Pd*	*Ni*	*Zn*
Temp	1																					
pH	0.339	1																				
TDS	0.325	0.232	1																			
EC	0.319	0.232	1	1																		
TH	0.168	-0.172	0.637	0.631	1																	
CH	-0.307	-0.262	-0.576	-0.572	-0.666	1																
MH	0.139	-0.183	0.636	0.63	0.994	-0.686	1															
TA	0.241	-0.061	0.695	0.69	0.87	-0.612	0.846	1														
Cl	0.283	-0.291	0.453	0.443	0.834	-0.554	0.835	0.703	1													
NO_3	0.423	0.405	0.339	0.335	0.27	-0.221	0.211	0.561	0.163	1												
PO_4	-	-	0.441	0.44	0.723	-0.33	0.703	0.802	0.475	0.425	1											

	0.075	0.282																				
Na	0.339	0.114	0.709	0.702	0.83	-0.68	0.812	0.936	0.705	0.558	0.688	1										
K	0.128	-0.328	0.572	0.568	0.85	-0.61	0.857	0.854	0.757	0.17	0.662	0.807	1									
DO	0.425	0.639	0.443	0.438	0.21	-0.448	0.188	0.265	0.131	0.538	-0.008	0.372	-0.053	1								
BOD	0.252	0.455	-0.296	-0.293	-0.469	0.078	-0.461	-0.446	-0.364	-0.035	-0.465	-0.36	-0.452	-0.142	1							
COD	-0.473	-0.332	-0.616	-0.611	-0.484	0.499	-0.475	-0.524	-0.532	-0.311	-0.225	-0.696	-0.512	-0.22	-0.196	1						
Cd	0.398	0.312	0.375	0.368	0.469	-0.372	0.396	0.657	0.335	0.88	0.473	0.683	0.382	0.513	-0.187	-0.385	1					
Cu	-0.177	-0.075	-0.054	-0.054	0.018	-0.073	0.044	-0.135	0.003	-0.378	-0.177	-0.087	0.163	-0.176	-0.207	0.056	-0.174	1				
Fe	-0.054	-0.402	0.142	0.14	0.569	-0.217	0.577	0.24	0.543	-0.151	0.258	0.229	0.398	-0.059	-0.272	-0.113	0.048	-0.086	1			
Pd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
Ni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Zn	-0.251	-0.007	-0.723	-0.717	-0.887	0.65	-0.875	-0.887	-0.772	-0.393	-0.643	-0.879	-0.782	-0.324	0.316	0.659	-0.528	0.178	-0.4	0	0	1

Note: Correlation is significant from 0.5 to 1.0 (indicated in red) and -0.5 to -0.1 (indicated in green)

Total dissolved solids had significantly positive correlation with electrical conductivity, total hardness, magnesium hardness, total alkalinity, sodium and potassium whereas negative correlation with calcium hardness, BOD, COD, copper and zinc.Electrical Conductivity had positive correlation with total hardness, magnesium hardness, total alkalinity, sodium and potassium whereas negative correlation with calcium hardness, BOD, COD, copper and zinc.Total Hardness had positive correlation with magnesium hardness, total alkalinity, Chlorides, phosphates sodium, potassium and ferrum whereas negative correlation with calcium hardness, BOD, COD and zinc.Calcium Hardness had positive correlation with zinc whereas negative correlation with magnesium hardness, total alkalinity, chlorides, nitrates, phosphates, sodium, potassium, DO, cadmium, copper and ferrum. Magnesium Hardness had positive correlation with total alkalinity, chlorides, phosphates, sodium, potassium and ferrum whereas negative correlation with DO, BOD, COD and zinc. Total Alkalinity had positive correlation with chlorides, nitrates, phosphates, sodium and potassium whereas negative correlation with BOD, COD and zinc. Chlorides had positive correlation with sodium, potassium and ferrum whereas negative correlation with BOD, COD and zinc. Nitrates had positive correlation with sodium, DO and cadmium whereas negative correlation with BOD, COD, copper, ferrum and zinc. Phosphates had positive correlation with sodium and potassium whereas negative correlation with DO, BOD, COD, copper and zinc. And the further correlations that are found to be significant are as mentioned in the Table 8 shown above.

Conclusion:

In the present study it was analyzed that Total hardness, Electrical Conductivity, Total hardness, calcium and magnesium hardness, DO, BOD, COD, Sodium, Potassium and Ferrum have not favored the permissible value of drinking water quality which existed in ground and surface water at sample stations near to industrial areas in and around Vijayawada. Hence, the existing drinking water quality has been found to be contaminated by the leaching and overflowing of industrial effluents in the city. From the present work it is clear that the demand for a suitable drinking water which is a major issue should be taken care of. The impact of water quality on human health is yet to be explored in the study area.

References:

1. Akimoto, H., 2003. Global air quality and pollution. Science 302, 1716–1719
2. Volkamer, R., Jimenez, J.L., San Martini, F., Dzepina, K., Zhang, Q., Salcedo, D., Molina, L.T., Worsnop, D.R., Molina, M.J., 2006. Secondary organic aerosol formation from anthropogenic air pollution: rapid and higher than expected. Geophys. Res. Lett. 33.
3. Masood, N., Zakaria, M.P., Halimoon, N., Aris, A.Z., Magam, S.M., Kannan, N., Mustafa, S., Ali, M.M., Keshavarzifard, M., Vaezzadeh, V., et al., 2016. Anthropogenic waste indicators (AWIs), particularly PAHs and LABs, in Malaysian sediments: application of aquatic environment for identifying anthropogenic pollution. Mar. Pollut. Bull. 102, 160–175
4. Schlacher, T.A., Lucrezi, S., Connolly, R.M., Peterson, C.H., Gilby, B.L., Maslo, B., Olds, A.D., Walker, S.J., Leon, J.X., Huijbers, C.M., et al., 2016. Human threats to sandy beaches: a meta-analysis of ghost crabs illustrates global anthropogenic impacts. Estuar. Coast. Shelf Sci. 169, 56–73.
5. BANO N. 2017. Assessment of physicochemical characteristics of groundwater quality used for drinking water supply of Firozabad City, India using index method. Journal of Applied Science and Environmental Management. Vol. 21. Iss. 4 p. 728–731.
6. BENRABAH S., ATTOUI B., HANNOUCHE M. 2016. Characterization of groundwater quality destined for drinking water supply of Khenchela City (eastern Algeria). Journal of Water and Land Development. Vol. 30 (VII–IX) p. 13–20. DOI 10.1515/jwld2016-0016.
7. DARAPU S.S.K., SUDHAKAR E.B., KRISHNA K.S.R., RAO P.V., SHEKHAR M.C. 2011. Determining water quality index for the evaluation of water quality of river. International Journal of Engineering Research and applications. Vol. 1. Iss. 2 p. 174– 182.
8. HAMED Y., HADJI R., REDHAOUNIA B., ZIGHMI K., BÂALI F., EL GAYAR A. 2018. Climate impact on surface and groundwater in North Africa: A global synthesis of findings and recommendations. Euro-Mediterranean Journal for Environmental Integration. Vol. 3. Iss. 1. DOI 10.1007/s41207-018-0067-8.
9. ZAHRI F., BOUKELLOUL M., HADJI R., TALHI K. 2016. Slope stability analysis in open pit mines of Jebel Gustar career, NE Algeria – A multi-steps approach. Mining Science. Vol. 23 p. 137−146.
10. Chen X, Zhou WQ, Pickett STA, Li WF, Han LJ, Ren YF (2016) Diotoms are better indicators of urbanstream conditions: a case study in Beijing, China. Ecol Ind 60:265–274
11. Cao Y, Tang C, Song X, Liu C, Zhang Y (2016) Identifying the hydro chemical characteristics of rivers and groundwater by multivariate statistical analysis in the Sanjiang Plain, China. Appl Water Sci 6:169–178.

12. Ehya F, Marbouti Z (2016) Hydrochemistry and contamination of groundwater resources in the Behbahan plain, SW Iran. Environ Earth Sci 75(1):455-464
13. Gu Q, Wang H, Zheng N, Zhu W, Li K (2015) Ecological footprint analysis for urban agglomeration sustainability in the middle stream of Yangtze River. Ecol Model 318:86–99
14. Okpara, C.G., N.F.Oparaku and C.N.Ibeta, 2011. An overview of water disinfection in developing countries and potentials of renewable energy, Journal of environmental Science and Technology, 4(1): 18-30.Scheffé, Henry, 1959. The Analysis of Variance. New York: Wiley.
15. Shaheda Niloufer*1 , Dr. A.V.V.S.Swamy2 , K. Syamala Devi3, Ground Water Quality In The Vicinity Of Municipal Solid Waste Dump Sites In Vijayawada, A.P. International Journal of Engineering & Science Research, IJESR/August 2013/ Vol-3/Issue-8/419-425.
16. Li Y, Li Y, Qureshi S, Kappas M, Hubacek K (2015) On the relationship between landscape ecological patterns and water quality across gradient zones of rapid Urbanization in coastal China. Ecol Model 318:100–108.
17. Shanker, B.S.; Balasubramanya, N. and Reddy, M. T. M. (2008). Impact of industrialization on ground water quality- a case study of Peenya industrial area, Bangalore, India. Environ. Monit. Assess. 142:263-268.
18. Ramakrishnaiah, C. R.; Sadashivaiah, C. and Ranganna, G. (2009). Assessment of water quality index for the ground water in Tumukpur taluk Karnataka state, India. E. J. of Chem. 6(2):523-530.
19. Fingl E (1980) Laxatives and cathartics. In: Gilman AG et al (eds) Pharmacological basis of Therapeutics. New York, NY, MacMillan Publishing.
20. WHO. Guidelines for Drinking Water Quality: Training Pack; WHO: Geneva, Switzerland, 2011
21. **(**Water Quality Assessment of Surface and Groundwater Sources Using a Water Quality Index Method: A Case Study of a Peri-Urban Town in Southwest, Nigeria Samuel O. Olasoji 1 , Nather O. Oyewole 2 , Bayode Abiola 3 and Joshua N. Edokpayi 4,*) Environments 2019, 6, 23; doi:10.3390/environments6020023)
22. Achieng A, Raburu O, Kipkorir E, Ngodhe S. Obiero K, Ani-Sabwa J (2017) Assessment of water quality using multivariate techniques in River Sosiani, Kenya. Environ Monit Assess 189:280- 289. https://doi. org/10.1007/s10661-017-5992-5
23. Jonnalagadda, S., Mhere, G., 2001. Water quality of the odzi river in the eastern highlands of Zimbabwe. Water Res. 35 (10), 2376.
24. Li P (2016) Groundwater quality in Western China: challenges and paths forward for groundwater quality research in Western China. Expo Health 8:305–310.
25. Fang, G.C., Huang, Y.L., Huang, J.H., 2010. Study of atmospheric metallic elements pollution in Asia during 2000–2007. Journal of Hazard Materials 180, 115–121.
26. Manikandan, R and Dr.R.Latha (2017). "A literature survey of existing map matching algorithm for navigation technology. International journal of engineering sciences & research technology", 6(9), 326-331.Retrieved September 15, 2017.
27. A.M. Barani, R.Latha, R.Manikandan, "Implementation of Artificial Fish Swarm Optimization for Cardiovascular Heart Disease" International Journal of Recent Technology and Engineering (IJRTE), Vol. 08, No. 4S5, 134-136, 2019.
28. Manikandan, R., Latha, R., & Ambethraj, C. (1). An Analysis of Map Matching Algorithm for Recent Intelligent Transport System. Asian Journal of Applied Sciences, 5(1). Retrieved from https://www.ajouronline.com/index.php/AJAS/article/view/4642

29. R. Sathish, R. Manikandan, S. Silvia Priscila, B. V. Sara and R. Mahaveerakannan, "A Report on the Impact of Information Technology and Social Media on Covid–19," 2020 3rd International Conference on Intelligent Sustainable Systems (ICISS), Thoothukudi, India, 2020, pp. 224-230, doi: 10.1109/ICISS49785.2020.9316046.
30. Manikandan, R and Dr.R.Latha (2018). "Map Matching Algorithm Based on a Hidden Markov Model for Vehicle Navigation" International Journal of Advanced Technology in Engineering and Science, 6(6), 36-42.
31. Manikandan, R and Dr.R.Latha (2018). "GLOBAL POSITIONING SYSTEM FOR VEHICLE NAVIGATION" International Journal of Advances in Arts, Sciences and Engineering (IJOAASE), 6(13), 1-9.
32. Prabu, A. V., &Sateesh, G. (2019). Kumar Performance Analysis and Lifetime estimation of Wireless Technologies for WSN (Wireless Sensor Networks)/IoT (Internet of Things). Application Jour of Adv Research in Dynamical and Control Systems, 11(1), 250-258.
33. Prabu, A. V., & Kumar, G. S. (2019). Hybrid MAC based adaptive preamble technique to improve the lifetime in wireless sensor networks. J. Adv. Research in Dynamical & Control Systems, 11(1), 240-249.
34. Srinivas, K., Prabu, A. V., &Sambasivarao, K. (2019). A Real Time Prototype Model for Enhancing the Security Features in the ATM Units International. Journal of Innovative Technology and Exploring Engineering (IJITEE), 8(7), 1936-1939.
35. BhavyaTadikonda ,A.V.Prabu, K.Raghava Rao .,&P S G Aruna Sri(2018). Secured door lock system based on fingerprint authentication. J. Adv. Research in Dynamical & Control Systems, 10(2), 473-480.