EFFECT OF GROUND WATER QUALITY DUE TO URBANIZATION IN GREATER VISAKHAPATNAM, ANDHRA PRADESH, INDIA

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Abstract: Groundwater is a very important natural resource for the reliable and economic provision of potable water supply in urban environment. Uncontrolled urbanization and the growing population pressure are essential challenges for the water management in urbanized regions. Urbanized area undergoes groundwater recharge along with the introduction of the new sources discharging often resulting groundwater contamination and fluctuations in groundwater levels. The objectives of the study is to determine impact of urbanization on groundwater quality in Pre monsoon and Post Monsoon seasons to enable suggest better management practice for sustainable use of groundwater. The city marked between 17º42' North latitude and 82º02' East range near Visakhapatnam District of Andhra Pradesh. . Groundwater samples were collected in polyethylene bottles without preservation the samples were collected from boreholes in the study area from both pre and post monsoon. Water samples were collected from fourteen boreholes and analyzed in the laboratory to determine the concentration of some physico-chemical parameters includes pH ,Temperature, Electrical Conductivity, Chlorides, Alkalinity , Total Dissolved Solids, Total Hardness, Calcium Hardness, Magnesium Hardness, Sodium , Potassium, Sulphates, Phosphates, Nitrates, Iron, Bicarbonates, Chromium, Copper, Zinc, Lead, Manganese, Cobalt by using standard methods. As per discussions it was found a considerably worse WQI through the post-monsoon season representing a insufficient quality of the groundwater. In all sampling stations, in pre monsoon water quality index is very poor condition. In post monsoon U-12 station was in good condition. Due to piper diagrams , the appreciable change in the hydro-chemical facies was noticed during the study period (pre and post monsoon), which was might be due to the percolating of alkali salts through precipitation, dissolution of the minerals are the major processes occurring. This is concluded that urbanization effect of the ground water quality is effected due to various anthropogenic activities such as man-made sources such as landfill , leakage from sewage, feedlots, fossil-fuel combustion, cement-plant emissions, leachate, mineral leaching, waste incineration, metal plating etc.

Keywords: Ground water, Water quality Index, Urbanization, Piper Diagram, Dissolution

1. INTRODUCTION

Groundwater is a very important natural resource for the reliable and economic provision of potable water supply in urban environment and it is used for domestic, industrial and irrigational purposes all over the world. Uninhibited urbanization and the rising population pressure are vital challenges for the water management in urban regions of the emerging countries. Municipal area changes groundwater recharge or cycle, with alteration to the present recharge and the introduction of the new bases. Settling of new sources of recharge in urbanized area causes wide but basically diffuse groundwater pollution (Foster et al. 1993). Municipal and Urban development agencies are trying hard to cope with the existing situation with demographics and infrastructure development while the population is still increasing. Visakhapatnam city generates huge amounts of domestic sewage and industrial waste and the most common way of disposal is by landfills and open sewers. The existing infrastructure for waste management is not sufficient to meet the existing needs. The most important and immediate problem the pollution poses is with respect to safe drinking water. Owing to rapid urbanization, growing population and speedy industrialization have lead to the pressure on demand for water. Though, it is strong that human actions in urban areas overawe the groundwater not only due diffuse pollutant loading from urban recharge system, but also due to many other ways. This means that the different forms of use like landfills, urban agriculture, industry, residential types with their consistent wastewater systems effect the emission of pollutants in groundwater, including groundwater recharge (Strohschön et al. 2011). Uncontrolled urbanization and the growing population pressure are essential challenges for the water management in urbanized regions. In terms of the environment, the reciprocal impact of urban development and groundwater represents one of the most important aspects of growing cities. Urbanized area undergoes groundwater recharge along with the introduction of the new sources discharging often resulting groundwater contamination and fluctuations in groundwater levels. An valuation of the risk to groundwater from urban processes needs to take account of the statement between the recharge and discharge pressures and the pollutant loading on the one hand, and the nature of the subsurface environment on the other (Schmoll et al, 2006). Therefore, it is reasonable that the occurrence of groundwater contamination due to urbanization on groundwater quality. Furthermore, identification of the contamination sources and its effect on the groundwater quality would be an efficient tool in groundwater management policies/action to support the sustainable use of groundwater and urban development in the study area. The water also needs to be of adequate quality to maintain health and it must be potable. Poor sanitation or lack of them, improper municipal and industrial waste disposal system could pose pollution problems to groundwater supplies. The objectives were to monitor the main chemical indicators of groundwater quality in the GVMC area, to assess suitability for use, and to determine spatial and temporal patterns in quality. Subsequently the number of wells and types of analyses included in the programme has expanded and to address specific groundwater quality issues such as seasonal variations in groundwater quality. One of the objectives of the study is to determine impact of urbanization on groundwater quality in Pre monsoon and Post Monsoon seasons to enable suggest better management practice for sustainable use of groundwater. A comprehensive chemical analysis of ground water quality in urbanized area for drinking, domestic purpose etc in premonsoon and post monsoon seasons.

II. METHODOLOGY

The city marked between 17º42' North latitude and 82º02' East range near Visakhapatnam District of Andhra Pradesh. Based on topographical conditions, the city and its environs can be divided into four categories viz. Hilly region, Upland tracks, Rolling plains and Plains. Accordingly the area has been divided which forms an ideal sub area for carrying out these objective. On account of rapid industrialization and urbanization there has been tremendous amount of migration into the city. Today the services and information technology contribute significantly to the economy. In this study for the purpose of revealing the water quality of 14 bore wells covering the study area have been established quantitatively by determining the physical and chemical characteristics per season. The assessment of WQI was made using measured Arithmetic file strategy (P. N Rajankar, et al, 2013) in the accompanying developments: Let there be ‘n’ water quality parameters and quality rating (qn) comparing to nth parameter is a number reflecting relative estimation of this parameter in the dirtied water regarding its standard passable worth. qn qualities are given by the relationship.

qn=100 (vn-vi) / (vs-vi)
vs = Standard value,
vn = observed value
vi = ideal value

Much of the time vi=0 aside from in specific parameters like pH, disintegrated oxygen and so forth., Calculation of unit weight : The Unit weight (Wn) to different water Quality parameters are conversely relative to the prescribed benchmarks for the comparing parameters.Wn = k/sn.

Where wn = unit weight for nth parameter
sn = standard permissible value for nth parameter
k = proportionality constant. The unit weight (wn) values in the present study are taken from Krishnan et al., 1995 WQI is calculated by the following equation.

$$WQI = \sum_{n=1}^{n} q_n w_n / \sum_{n=1}^{n} w_n$$

Groundwater samples were collected in polyethylene bottles without preservation the samples were collected from boreholes in the study area from both pre and post monsoon in 2013. Each of the sampling point in pre- clean dry labeled polythene plastic bottles. Water samples were collected from fourteen boreholes and analyzed in the laboratory to determine the concentration of some physico-chemical parameters includes pH , Temperature, Electrical Conductivity, Chlorides, Alkalinity , Total Dissolved Solids, Total Hardness, Calcium Hardness, Magnesium Hardness, Sodium , Potassium, Sulphates, Phosphates, Nitrates, Iron, Bicarbonates, Chromium, Copper, Zinc, Lead, Manganese, Cobalt by using standard methods (APHA, 2011).

III. RESULTS AND DISCUSSION:

The results of the physic-chemical characteristics of ground water given in Table 3 and Table 4**.** The water quality index is a reliable means for understanding the overall water quality of the water resources. The purpose of WQI assistances in determining the appropriateness of several groundwater causes for selected treatment. The water quality index values given in Table 8 and Table 9. During pre-monsoon season from the study area the water quality index values varied from 54.81 to 146.4%, in post monsoon, it was varies between 47.01 to 105.9 % (Sunita Kumari, et.al 2014). It was found a considerably worse WQI through the post-monsoon season representing a insufficient quality of the groundwater. In all sampling stations, in pre monsoon water quality index is very poor condition. In post monsoon U- 12 station was in good condition. Water quality scale with reference to WQI and classification of water given in Table.2. The Piper-Hill diagram is used to understand hydro-geochemical facies. These plots cations and anions. These fields are joined to display a single point in a diamond-shaped field, from which implication is drawn on the basis of hydro-geochemical facies. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods.In this study water types were constrained to the three types in pre-monsoon. In figure 3 and 4, Piper diagrams explained about 57% are plotted in the Ca-Mg-Na-Cl-HCO_3 field in the Piper diagram. 28% of the Ca-Na-Mg- Cl-HCO_3-SO_4 type showed 28%. Remain types are Na-Ca-Cl-HCO_3 & Ca-Na- Cl-HCO_3-SO_4 types. Assessment of the water types using piper plot proposes that there is a clear suggestion of the influence from the weathering of hard rocks. In Post monsoon period, 42% of the samples Ca-Mg-Na-Cl-HCO_3 type, 28.5 % of the samples Ca-Na-Mg-Cl-HCO_3-SO_4 type, 21.4% of samples Ca-Na-Cl-HCO_3, 7% of the samples Ma-Ca-Cl- HCO_3-SO_4 type. The appreciable change in the hydro-chemical facies was noticed during the study period (pre and post monsoon), which was might be due to the percolating of alkali salts through precipitation, dissolution of the minerals are the major processes occurring. It can be understood from the figure that the concetration of all chemical characteristics of ground water quality is very less in the post monsoon season. The percentage reduction is almost same for the constituents indicating the effect of ground water recharge with monsoon. It is however found that the samples of U11 (Old Gajuwaka) are reduced more due to recharge due to monsson. This shows that recharge is more active in this area.

IV. CONCLUSIONS:

It is proven that the quality of the ground water is moderately bad compared to post monsoon period. The recharge in the urbanized may be good due to depletion of ground water more in these areas in summer. There is significant effect of pollutantion in the ground water in the urbanised areas of GVMC from pre monsoon and post monsoon analysis of ground water. It was clear that the concetration of all chemical paramters in the post monsoon season are relatively less. The percentage reduction is almost same for the constituents indicating the effect of ground water recharge with monsoon. This shows that recharge is more active in this area. However the reduction is varied from location to location due to variations in the extent of recharge. This is concluded that urbanization effect of the ground water quality is effected due to various anthropogenic activities such as man-made sources such as landfill , leakage from sewage, feedlots, fossil-fuel combustion, cement-plant emissions, leachate, mineral leaching, waste incineration, metal plating etc.

Table 1: Geo-coordinates of the study area (Urbanization)

Code of the Sample	Sampling Station	Latitude	Longitude
U1	B.S.layout	17.740152°	83.308137°
U2	Murli nagar	17.746624°	83.263893°
U3	Marripalem	17.739165°	83.247831°
U4	Nad junction	17.744696°	83.231659°
U5	Anakapalli-1	17.686128°	83.110875°
U6	Kurmannapalem	17.689482°	83.167580°
U7	R.t.c complex	17.724063°	83.307085°
U8	Maddilapalem	17.737467°	83.321486°
U9	Kancharapalem	17.735816°	83.273325°
U10	Akkayyapalem	17.738356°	83.301540°
U11	Old gajuwaka	17.686628°	83.204952°
U12	New gajuwaka	17.686877°	83.218892°
U13	Peddagantyada	17.661526°	83.210437°
U14	M.v.p colony	17.742475°	83.338861°

Table 2: Water quality scale with reference to WQI (Sundar Kumar et.al.2010)

Water Quality Index	Quality of Water
0-24	Excellent
25-49	Good
50-74	Poor
75-100	Very poor
>100	Unfit for Drinking

Tables-3. Physico- chemical characteristics of ground water samples (Pre-Monsoon)

Code of the sample	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14
pH	7.57	7.53	7.33	7.33	7.20	7.40	7.50	7.33	7.40	7.33	7.63	7.50	7.90	7.87
Temp	24.83	23.07	24.33	24.10	24.33	24.50	24.67	23.67	24.00	23.67	24.00	24.33	24.33	23.50
Ec	597	847	1057	493	1560	1437	1620	1643	1340	1714	2576	1690	2060	1234
Cl	96.00	97.00	115.00	168.33	146.67	225.00	163.33	130.00	167.33	164.00	229.00	207.67	182.33	215.33
Alkalinity	99	151	174	207	229	483	182	214	150	180	300	275	138	222
TDS	422	702	822	1080	1347	1238	1128	977	1589	1673	1892	907	1470	814
TH	300	217	245	205	373	293	280	167	253	223	473	432	341	283
CaH	48	73	64	95	165	145	118	97	92	77	140	113	132	132
MgH	30.00	33.00	33.67	35.00	38.67	92.33	25.67	21.67	34.33	26.67	36.00	39.33	40.00	42.67
Na	29.33	36.00	37.67	89.33	88.33	137.33	69.67	76.00	89.33	85.67	140.33	109.67	97.00	105.67
K	13.33	17.00	27.33	11.67	8.17	14.00	32.67	12.67	14.67	16.33	10.53	25.00	17.33	21.33
SO_4	76.33	45.67	68.00	78.00	105.33	139.67	90.00	70.67	66.33	62.00	165.00	175.00	150.00	171.67
PO_4	0.87	2.05	3.05	2.10	4.00	2.73	2.89	5.40	2.70	3.51	3.53	2.97	4.30	2.70
NO_3^-	1.28	1.57	1.55	2.77	2.93	3.30	2.23	1.87	2.63	3.20	3.03	3.47	3.43	2.87
Fe	0.13	0.18	0.23	0.14	0.24	0.50	0.31	0.43	0.22	0.25	0.13	0.21	0.27	0.24
HCO3	112	127	113	157	190	277	160	178	153	170	239	282	163	255
Cr	0.043	0.033	0.060	0.157	0.050	0.160	0.210	0.210	0.147	0.057	0.130	0.223	0.260	0.073
Cu	0.037	0.023	0.043	0.043	0.033	0.040	0.053	0.037	0.050	0.030	0.330	0.063	0.087	0.060
Zn	0.073	0.057	0.060	0.047	0.033	0.050	0.060	0.060	0.040	0.050	0.350	0.090	0.103	0.060
Pb	0.004	0.006	0.006	0.007	0.003	0.004	0.007	0.007	0.006	0.005	0.005	0.005	0.007	0.014
Mn	0.057	0.057	0.083	0.067	0.050	0.067	0.087	0.060	0.060	0.043	0.063	0.170	0.090	0.053
Co	0.002	0.004	0.008	0.007	0.007	0.005	0.005	0.006	0.006	0.007	0.007	0.006	0.006	0.003

Tables-4. Physico- chemical characteristics of ground water samples (Post-Monsoon)

Code of the sample	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14
pH	7.333	7.300	7.200	7.200	7.167	7.217	7.300	7.500	7.167	7.167	7.300	7.300	7.700	7.367
Temp	23	22	23	23	22	23	24	23	23	23	23	23	23	22
Ec	570	827	1000	467	1467	1340	1565	1570	1295	1598	2474	1627	1887	1165
Cl	88	90	101	150	131	207	146	109	154	148	201	184	168	199
Alkalinity	91	133	160	189	216	396	173	199	149	184	276	245	156	203
TDS	402	682	799	971	1236	1252	959	963	1471	1473	1790	832	1362	749
TH	250	187	228	184	349	263	244	166	248	191	401	413	317	261
CaH	44.7	67.3	57.3	79.0	152.0	125.0	101.0	83.3	80.3	68.3	118.3	104.3	117.3	119
MgH	27.7	27.7	27.7	33.0	37.3	74.0	21.3	18.0	25.3	19.0	34.7	31.3	33.7	37.3
Na	26.7	30.3	37.3	74.0	80.0	129.3	73.3	64.3	79.7	77.7	104.7	101.3	78.0	88.0
K	10.3	11.3	23.3	8.5	6.7	13.3	26.3	12.7	10.3	12.7	9.3	20.0	15.3	18.2
SO_4	71	41	58	68	99	131	79	62	62	61	147	146	135	164.3
PO_4	0.82	1.38	2.76	1.83	3.10	1.96	2.20	4.88	1.80	3.06	3.33	2.80	4.02	2.290
NO_3^-	1.31	1.31	1.38	2.80	2.90	3.10	2.63	1.57	2.33	4.17	3.10	3.60	3.40	2.167
Fe	0.10	0.17	0.20	0.13	0.21	0.36	0.28	0.37	0.18	0.19	0.08	0.17	0.19	0.19
HCO3	107	117	134	146	175	270	160	167	146	161	218	274	159	240
Cr	0.030	0.020	0.047	0.117	0.040	0.113	0.187	0.183	0.117	0.030	0.097	0.193	0.200	0.053
Cu	0.027	0.017	0.033	0.033	0.015	0.037	0.040	0.025	0.034	0.027	0.067	0.047	0.067	0.052
Zn	0.054	0.046	0.047	0.047	0.027	0.040	0.053	0.051	0.037	0.028	0.147	0.073	0.053	0.060
Pb	0.003	0.005	0.007	0.005	0.003	0.003	0.007	0.005	0.004	0.003	0.003	0.004	0.008	0.016
Mn	0.047	0.043	0.063	0.047	0.033	0.043	0.063	0.037	0.040	0.027	0.043	0.137	0.060	0.030
Co	0.002	0.002	0.005	0.006	0.004	0.003	0.004	0.006	0.005	0.006	0.005	0.004	0.005	0.003

Table-5: Correlation study of Physico Chemical parameters (Pre Monsoon)

	pH	*Temp*	*Ec*	*Cl*	*TA*	*TDS*	*TH*	*CaH*	*MgH*	*Na*	*K*	*SO4*	*PO4*	*NO3¯*	*Fe*	*HCO3*	*Cr*	*Cu*	*Zn*	*Pb*	*Mn*	*Co*
pH	1.00																					
Temp	0.07	1.00																				
Ec	0.30	0.22	1.00																			
Cl	0.03	0.08	**0.54**	1.00																		
Alk	-0.18	0.03	0.42	**0.73**	1.00																	
TDS	-0.08	0.16	**0.74**	**0.54**	0.43	1.00																
TH	0.09	-0.04	**0.60**	**0.54**	0.37	0.33	1.00															
CaH	0.13	-0.23	**0.56**	**0.67**	**0.63**	0.46	**0.62**	1.00														
MgH	-0.12	-0.18	0.01	**0.56**	**0.79**	0.15	0.28	0.52	1.00													
Na	-0.07	0.12	**0.57**	**0.93**	**0.87**	**0.62**	**0.51**	**0.74**	**0.61**	1.00												
K	0.15	0.46	0.09	0.07	-0.04	-0.31	0.01	-0.08	-0.15	-0.03	1.00											
SO4	0.31	-0.13	**0.52**	**0.84**	**0.57**	0.25	**0.75**	**0.72**	0.52	**0.72**	0.13	1.00										
PO4	0.50	0.08	**0.68**	0.16	0.20	0.44	0.17	0.36	-0.20	0.26	0.06	0.22	1.00									
NO3¯	-0.06	0.21	**0.56**	**0.68**	0.47	**0.66**	0.45	0.49	0.21	**0.72**	-0.04	0.46	0.30	1.00								
Fe	0.14	0.19	0.11	0.04	0.42	0.00	-0.33	0.24	0.26	0.27	0.29	-0.07	0.37	-0.04	1.00							
HCO3	-0.01	-0.05	0.47	**0.85**	**0.84**	0.25	**0.57**	**0.66**	**0.60**	**0.87**	0.18	0.82	0.22	0.52	0.26	1.00						
Cr	**0.53**	**0.60**	0.43	0.35	0.22	0.19	0.24	0.28	-0.03	0.41	0.36	0.30	0.48	0.31	0.38	0.33	1.00					
Cu	0.50	0.27	**0.60**	**0.71**	0.26	0.39	**0.56**	0.36	0.18	0.49	0.27	**0.76**	0.29	0.40	-0.24	0.46	0.48	1.00				
Zn	0.20	0.14	**0.56**	0.41	0.25	0.29	**0.57**	0.18	0.02	0.27	0.00	0.51	0.18	0.09	-0.42	0.34	0.18	**0.68**	1.00			
Pb	0.37	-0.25	-0.10	0.22	-0.16	-0.30	-0.11	0.15	-0.04	-0.03	0.48	0.37	0.05	-0.20	0.05	0.15	0.04	0.37	-0.01	1.00		
Mn	0.12	0.31	0.12	0.15	0.08	-0.24	0.52	0.01	-0.03	0.14	0.50	0.28	0.03	0.21	-0.10	0.36	0.52	0.28	0.21	-0.09	1.00	
Co	0.02	0.37	0.34	0.11	0.04	0.56	-0.13	-0.02	-0.36	0.20	-0.05	-0.15	0.65	0.40	0.09	-0.06	0.37	0.16	0.03	-0.14	-0.06	1.00

Table-5: Correlation study of Physico Chemical parameters (Post Monsoon)

	pH	*Temp*	*Ec*	*Cl*	*TA*	*TDS*	*TH*	*CaH*	*MgH*	*Na*	*K*	*SO4*	*PO4*	*NO3¯*	*Fe*	*HCO3*	*Cr*	*Cu*	*Zn*	*Pb*	*Mn*	*Co*
pH	1.00																					
Temp	0.07	1.00																				
Ec	0.30	0.22	1.00																			
Cl	0.03	0.08	**0.54**	1.00																		
TA	-0.18	0.03	0.42	**0.73**	1.00																	
TDS	-0.08	0.16	**0.74**	**0.54**	0.43	1.00																
TH	0.09	-0.04	**0.60**	**0.54**	0.37	0.33	1.00															
CaH	0.13	-0.23	**0.56**	**0.67**	**0.63**	0.46	**0.62**	1.00														
MgH	-0.12	-0.18	0.01	**0.56**	**0.79**	0.15	0.28	0.52	1.00													
Na	-0.07	0.12	**0.57**	**0.93**	**0.87**	0.62	0.51	**0.74**	0.61	1.00												
K	0.15	0.46	0.09	0.07	-0.04	-0.31	0.01	-0.08	-0.15	-0.03	1.00											
SO4	0.31	-0.13	0.52	**0.84**	**0.57**	0.25	**0.75**	**0.72**	**0.52**	**0.72**	0.13	1.00										
PO4	0.50	0.08	**0.68**	0.16	0.20	0.44	0.17	0.36	-0.20	0.26	0.06	0.22	1.00									
NO3¯	-0.06	0.21	**0.56**	0.68	0.47	0.66	0.45	0.49	0.21	**0.72**	-0.04	0.46	0.30	1.00								
Fe	0.14	0.19	0.11	0.04	0.42	0.00	-0.33	0.24	0.26	0.27	0.29	-0.07	0.37	-0.04	1.00							
HCO3	-0.01	-0.05	0.47	0.85	**0.84**	0.25	**0.57**	0.66	0.60	**0.87**	0.18	**0.82**	0.22	0.52	0.26	1.00						
Cr	**0.53**	**0.60**	0.43	0.35	0.22	0.19	0.24	0.28	-0.03	0.41	0.36	0.30	0.48	0.31	0.38	0.33	1.00					
Cu	0.50	0.27	**0.60**	0.71	0.26	0.39	**0.56**	0.36	0.18	0.49	0.27	**0.76**	0.29	0.40	-0.24	0.46	0.48	1.00				
Zn	0.20	0.14	**0.56**	0.41	0.25	0.29	**0.57**	0.18	0.02	0.27	0.00	0.51	0.18	0.09	-0.42	0.34	0.18	0.68	1.00			
Pb	0.37	-0.25	-0.10	0.22	-0.16	-0.30	-0.11	0.15	-0.04	-0.03	0.48	0.37	0.05	-0.20	0.05	0.15	0.04	0.37	-0.01	1.00		
Mn	0.12	0.31	0.12	0.15	0.08	-0.24	**0.52**	0.01	-0.03	0.14	0.50	0.28	0.03	0.21	-0.10	0.36	0.52	0.28	0.21	-0.09	1.00	
Co	0.02	0.37	0.34	0.11	0.04	**0.56**	-0.13	-0.02	-0.36	0.20	-0.05	-0.15	0.65	0.40	0.09	-0.06	0.37	0.16	0.03	-0.14	-0.06	1.00

Table-7. Water quality index values calculated in pre monsoon

Code of the sample	BIS (2012) Std (Sn)	Wi	U1 (qiwi)	U2 (qiwi)	U3 (qiwi)	U4 (qiwi)	U5 (qiwi)	U6 (qiwi)	U7 (qiwi)	U8 (qiwi)	U9 (qiwi)	U10 (qiwi)	U11 (qiwi)	U12 (qiwi)	U13 (qiwi)	U14 (qiwi)
pH	7.5	0.0784	7.9	7.9	7.7	7.7	7.5	7.7	7.8	7.7	7.7	7.7	8.0	7.8	8.3	8.2
Ec	2500	0.0784	1.9	2.7	3.3	1.5	4.9	4.5	5.1	5.2	4.2	5.4	8.1	5.3	6.5	3.9
Cl	250	0.0588	2.3	2.3	2.7	4.0	3.5	5.3	3.8	3.1	3.9	3.9	5.4	4.9	4.3	5.1
TA	200	0.0588	2.9	4.4	5.1	6.1	6.7	14.2	5.4	6.3	4.4	5.3	8.8	8.1	4.1	6.5
TH	200	0.0784	11.8	8.5	9.6	8.0	14.6	11.5	11.0	6.5	9.9	8.7	18.5	16.9	13.4	11.1
CaH	75	0.0392	2.5	3.8	3.3	5.0	8.6	7.6	6.2	5.1	4.8	4.0	7.3	5.9	6.9	6.9
NO_3^-	45	0.0980	0.3	0.3	0.3	0.6	0.6	0.7	0.5	0.4	0.6	0.7	0.7	0.8	0.7	0.6
TDS	500	0.0784	6.6	11.0	12.9	16.9	21.1	19.4	17.7	15.3	24.9	26.2	29.7	14.2	23.1	12.8
MgH	30	0.0392	3.9	4.3	4.4	4.6	5.1	12.1	3.4	2.8	4.5	3.5	4.7	5.1	5.2	5.6
Na	200	0.0392	0.6	0.7	0.7	1.8	1.7	2.7	1.4	1.5	1.8	1.7	2.8	2.2	1.9	2.1
K	20	0.0588	3.9	5.0	8.0	3.4	2.4	4.1	9.6	3.7	4.3	4.8	3.1	7.4	5.1	6.3
SO_4	200	0.0784	3.0	1.8	2.7	3.1	4.1	5.5	3.5	2.8	2.6	2.4	6.5	6.9	5.9	6.7
Fe	0.3	0.0784	3.4	4.7	6.0	3.7	6.3	13.1	8.1	11.2	5.8	6.5	3.4	5.5	7.1	6.3
HCO3	200	0.0588	3.3	3.7	3.3	4.6	5.6	8.1	4.7	5.2	4.5	5.0	7.0	8.3	4.8	7.5
Cr	0.05	0.0784	6.7	5.2	9.4	24.6	7.8	25.1	32.9	32.9	23.1	8.9	20.4	35.0	40.8	11.5
Cu	0.05	0.0784	5.8	3.6	6.7	6.7	5.2	6.3	8.3	5.8	7.8	4.7	51.8	9.9	13.6	9.4
Zn	5	0.0784	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.1	0.2	0.1
Pb	0.05	0.0784	0.6	0.9	0.9	1.1	0.5	0.6	1.1	1.1	0.9	0.8	0.8	0.8	1.1	2.2
Mn	0.1	0.0784	4.5	4.5	6.5	5.3	3.9	5.3	6.8	4.7	4.7	3.4	4.9	13.3	7.1	4.2
ΣWi		1.3137														
Σqiwi			72.0	75.5	93.9	108.7	110.3	153.9	137.4	121.5	120.5	103.7	192.4	158.4	159.9	116.8
WQI= Σqiwi/Σwi			54.81	57.45	71.46	82.75	83.95	117.12	104.5	92.46	91.76	78.96	146.4	120.5	121.69	88.93

Table-8. Water quality index values calculated in pre monsoon

Code of the sample	BIS (2012)Std (Sn)	Wi	U1 (qiwi)	U2 (qiwi)	U3 (qiwi)	U4 (qiwi)	U5 (qiwi)	U6 (qiwi)	U7 (qiwi)	U8 (qiwi)	U9 (qiwi)	U10 (qiwi)	U11 (qiwi)	U12 (qiwi)	U13 (qiwi)	U14 (qiwi)
pH	7.5	0.0784	7.7	7.6	7.5	7.5	7.5	7.5	7.6	7.8	7.5	7.5	7.6	7.6	8.1	7.7
Ec	2500	0.0784	1.8	2.6	3.1	1.5	4.6	4.2	4.9	4.9	4.1	5.0	7.8	5.1	5.9	3.7
Cl	250	0.0588	2.1	2.1	2.4	3.5	3.1	4.9	3.4	2.6	3.6	3.5	4.7	4.3	4.0	4.7
TA	200	0.0588	2.7	3.9	4.7	5.6	6.4	11.6	5.1	5.9	4.4	5.4	8.1	7.2	4.6	6.0
TH	200	0.0784	9.8	7.3	8.9	7.2	13.7	10.3	9.6	6.5	9.7	7.5	15.7	16.2	12.4	10.2
CaH	75	0.0392	2.3	3.5	3.0	4.1	7.9	6.5	5.3	4.4	4.2	3.6	6.2	5.5	6.1	6.2
NO_3^-	45	0.0980	0.3	0.3	0.3	0.6	0.6	0.7	0.6	0.3	0.5	0.9	0.7	0.8	0.7	0.5
TDS	500	0.0784	6.3	10.7	12.5	15.2	19.4	19.6	15.0	15.1	23.1	23.1	28.1	13.1	21.4	11.7
MgH	30	0.0392	3.6	3.6	3.6	4.3	4.9	9.7	2.8	2.4	3.3	2.5	4.5	4.1	4.4	4.9
Na	200	0.0392	0.5	0.6	0.7	1.5	1.6	2.5	1.4	1.3	1.6	1.5	2.1	2.0	1.5	1.7
K	20	0.0588	3.0	3.3	6.9	2.5	2.0	3.9	7.7	3.7	3.0	3.7	2.7	5.9	4.5	5.4
SO_4	200	0.0784	2.8	1.6	2.3	2.7	3.9	5.1	3.1	2.4	2.4	2.4	5.8	5.7	5.3	6.4
Fe	0.3	0.0784	2.6	4.4	5.2	3.4	5.5	9.4	7.3	9.7	4.7	5.0	2.1	4.4	5.0	5.0
HCO3	200	0.0588	3.1	3.4	3.9	4.3	5.1	7.9	4.7	4.9	4.3	4.7	6.4	8.1	4.7	7.1
Cr	0.05	0.0784	4.7	3.1	7.4	18.4	6.3	17.7	29.3	28.7	18.4	4.7	15.2	30.3	31.4	8.3
Cu	0.05	0.0784	4.2	2.7	5.2	5.2	2.4	5.8	6.3	3.9	5.3	4.2	10.5	7.4	10.5	8.2
Zn	5	0.0784	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1
Pb	0.05	0.0784	0.5	0.8	1.1	0.8	0.5	0.5	1.1	0.8	0.6	0.5	0.5	0.6	1.3	2.5
Mn	0.1	0.0784	3.7	3.4	4.9	3.7	2.6	3.4	4.9	2.9	3.1	2.1	3.4	10.7	4.7	2.4
ΣWi		1.3137														
Σqiwi			61.8	65.2	83.8	92.0	97.8	131.5	120.3	108.3	103.9	87.9	132.3	139.1	136.5	102.5
WQI= Σqiwi/Σwi			47.1	49.6	63.8	70.0	74.5	100.1	91.6	82.4	79.1	66.9	100.7	105.9	103.9	78.1

Table-9. Water quality index Classification of water in the study area

Sl.No	Station	WQI		Classification as per WQI	
		Pre	Post	Pre	Post
1	U1	54.81	47.1	Poor	Good
2	U2	57.45	49.6	Poor	Good
3	U3	71.46	63.8	Poor	Poor
4	U4	82.75	70	Very Poor	Poor
5	U5	83.95	74.5	Very Poor	Poor
6	U6	117.12	100	Unfit for Drinking	Very Poor
7	U7	104.5	91.6	Unfit for Drinking	Very Poor
8	U8	92.46	82.4	Very Poor	Very Poor
9	U9	91.76	79.1	Very Poor	Very Poor
10	U10	78.96	66.9	Very Poor	Poor
11	U11	146.4	100	Unfit for Drinking	Very Poor
12	U12	120.5	105.9	Unfit for Drinking	Unfit for Drinking
13	U13	121.69	103.9	Unfit for Drinking	Unfit for Drinking
14	U14	88.93	78.1	Very poor	Very Poor

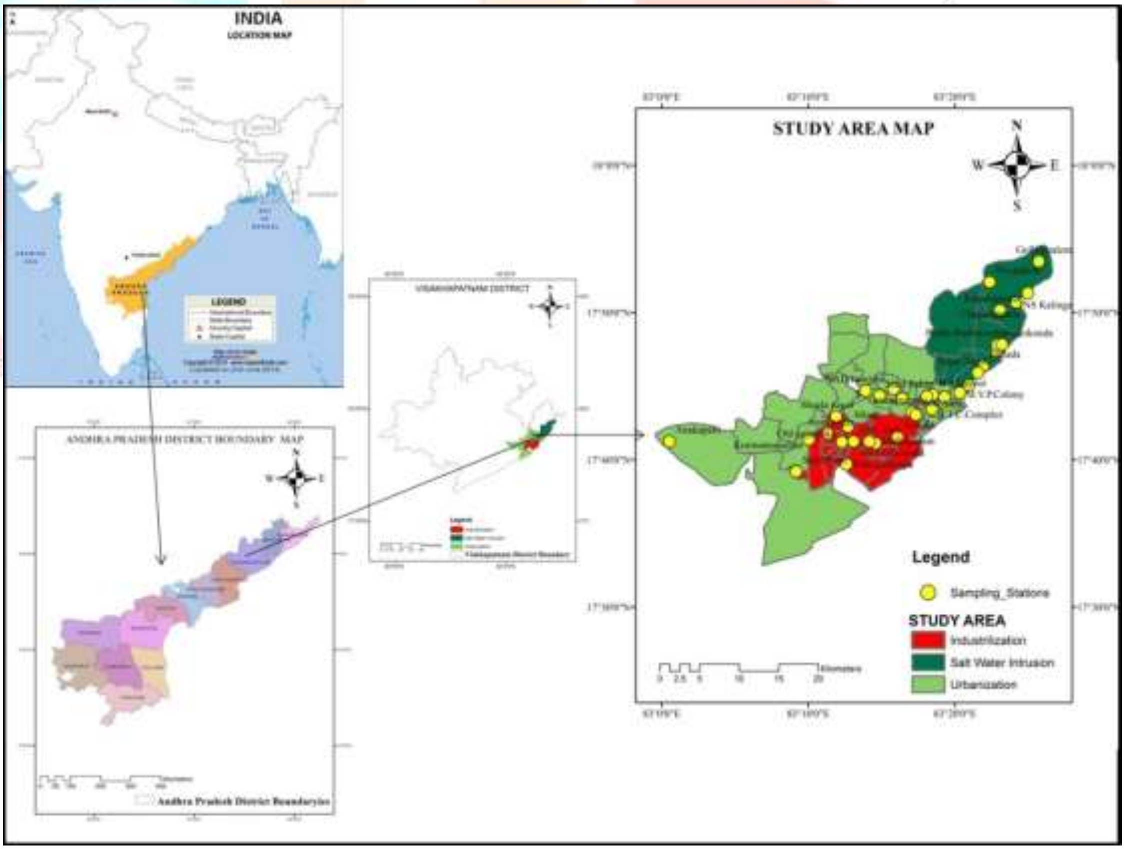

Fig.1: Study area with sampling stations

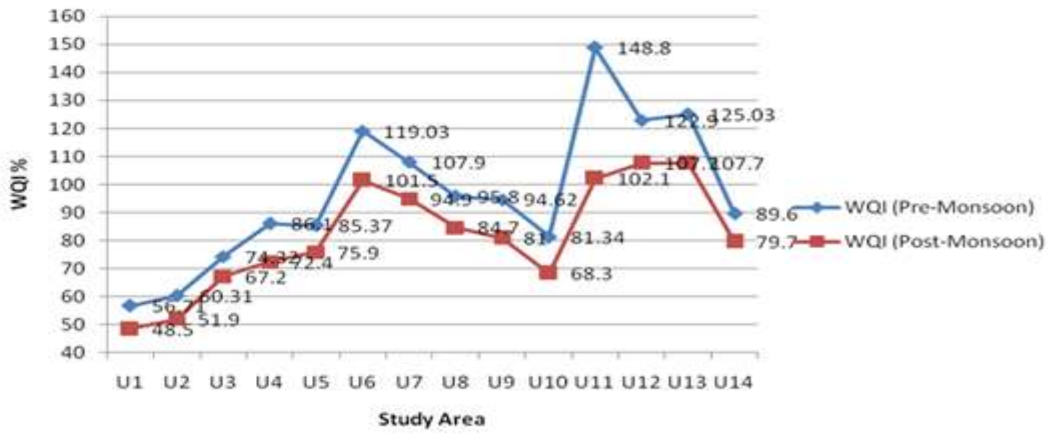

Fig 2. Water quality index values difference between pre and post monsoon

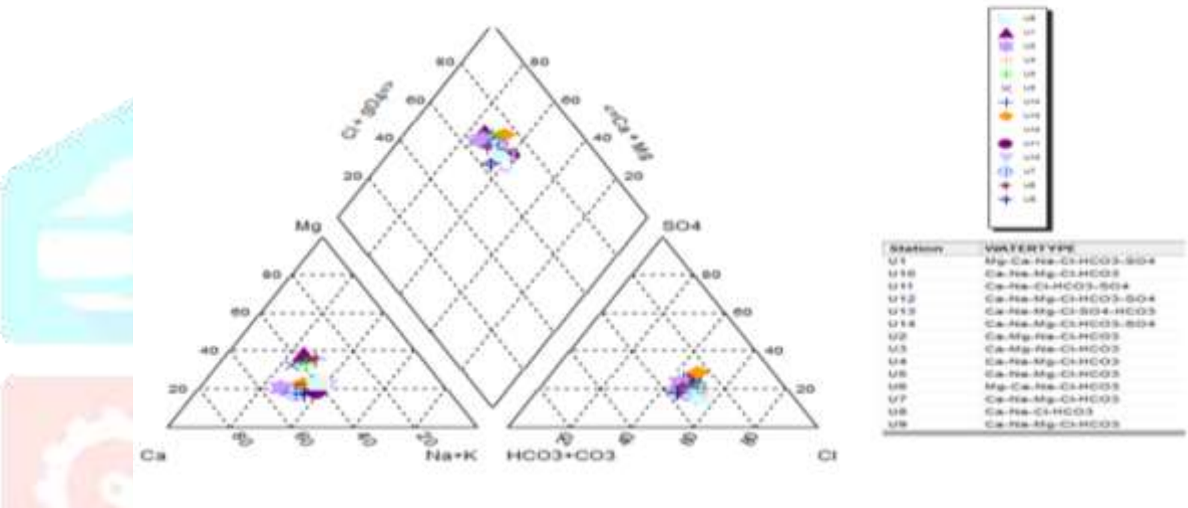

Fig.3 Piper plot of ground water composition due to effect of urbanization (Pre Monsoon)

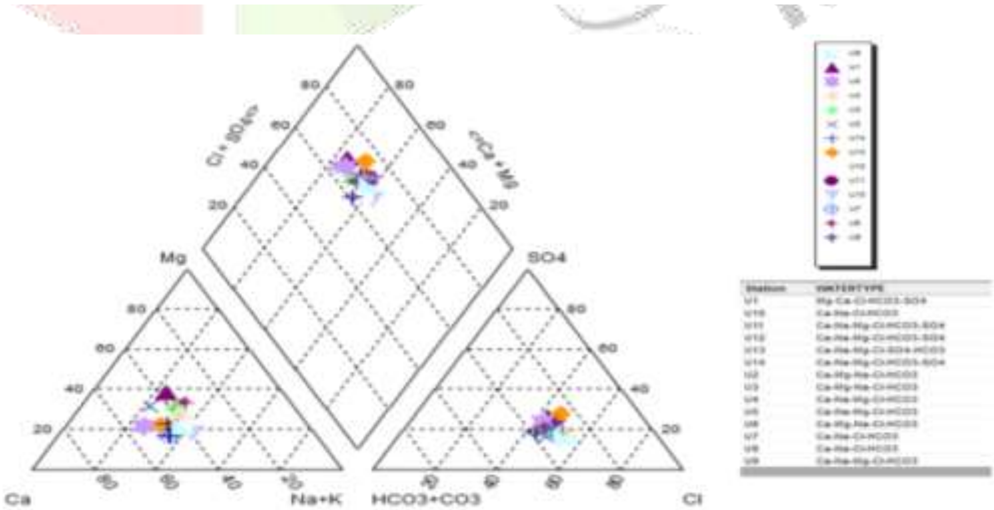

Fig.4 Piper plot of ground water composition due to effect of urbanization (Post Monsoon)

V. ACKNOWLEDGEMENT

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