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Assessment of Urban Ground Water Quality in GVMC, Visakhapatnam using Hydrogeo chemical Facies and Statistical methods

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Abstract

Assessment of ground water quality plays an important role is in its protection as well as in its quality conservation not only for present but also for its future consumption. Groundwater is a major source of drinking water in urban areas of Visakhapatnam. Visakhapatnam city is rapidly raising population, changing lifestyle and intense competition among users- agriculture, industry and domestic sectors. The present study area is Greater Visakhapatnam Municipal Corporation area in Andhra Pradesh, India and is aimed to assessing the water quality for the ground water among two season's pre monsoon, and post monsoon (during 2014). Analyzed parameters such as pH, Temperature, Electrical- conductivity, Total alkalinity, Total Dissolved solids, Total Hardness, Calcium, Magnesium, Sodium, Potassium, Chloride, Sulphate, Nitrate, Cobalt using (Apha)standard methods and The results were compared with standard guidelines BIS 2012. In all areas, TDS, Total Hardness, Calcium, and Chromium, are above the acceptable limits in pre and post monsoon periods. This confirms the quality of ground water is controlled by local geochemical reactions. Generally the concentrations of most parameters decreases in the samples collected post monsoon period indicating ground water is recharged during monsoon. Also there is scatter in the concentrations of anions and cations with TDS in different locations. High TDS content in the study area is attributed to leaching of salts from soil and chloride concentration is largely controlled by saline ingress along the coastal region. The study are no more safer side and proper management options for discharging the waste water are suggested to improve the ground water quality. The contamination sources can be identified and the occurrence of groundwater contamination can be assessed, this would be an efficient tool in groundwater management policies to support the sustainable use of groundwater and urban development.

Key Words: *Ground water, Urbanization, Regression, TDS, Piper Diagrams, Monsoon*

Introduction

Increased need of water attributed by the urbanization and the industrial growth resulted in the over exploitation of coastal aquifers. Groundwater is a key source of drinking water among freshwater resources. This relatively small volume is critically important as it represents 98 % of the freshwater readily available to humans (Zaporozec and Miller 2000). Most of the cities/towns situated on the banks of the rivers, discharge their untreated/ partially treated/ treated wastewaters into the rivers. Due to the urbanization and industrial development stress on the environment is well recognized. It is estimated that community waste from human activities accounts for four times as much wastewater as industrial effluents, most of which is discharged untreated/ partially treated into the water courses in India (Sahu, V. P 1993). Groundwater is an important source of water for domestic, industrial and agricultural purposes. It is estimated that more than 90% of the rural population uses groundwater for domestic purposes. Ground water is heavily utilized for both urban and rural water supplies since it is normally of good quality and requires little, if any treatment prior to supply.

Fast moving Urbanization and increased agricultural activities has resulted in the degradation of the water quality. Unused fertilizers, pesticides, effluents discharged from industries and sewage water are the main contaminants of the groundwater (Kamble SR 2011).

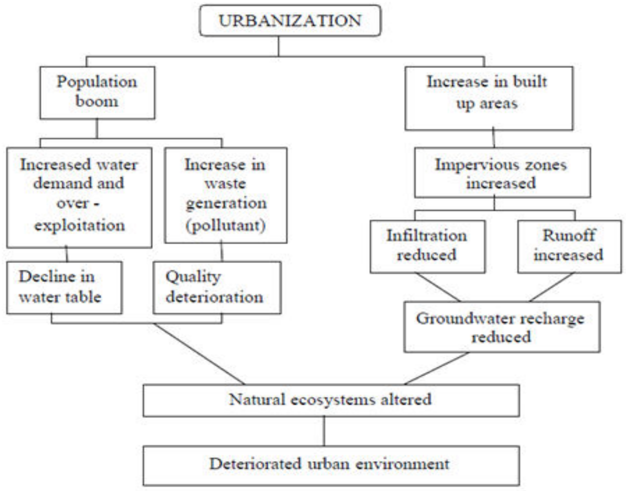


Fig 1: Impact of urbanization process on hydrogeological regime

Urbanization results in important changes to the ground water balance both by replacing and modifying groundwater mechanism and by introducing new discharge patterns due to abstraction from wells. In particular, mains water and sanitation systems can have a significant impact on shallow aquifers that underlie a city and they may become major components of the urban hydrologic cycle as a result of Leakage and/or seepage (Foster 1988). Water quality is determined by analytically measuring the concentrations of the various constituents and the effects or properties caused by the presence of these substances. The ground water resource evaluation, the quality of ground water is of nearly equal importance than the quantity (Hemant, P 2012). The physic chemical characteristics of ground water determine its usefulness for domestic water supply, commercial, Industrial, agricultural and municipal use. Development provides opportunities for pollution study of the ground water and consideration must be given to the protection of quality. The main object of this work is to know the seasonal variation of ground water quality, whether it can be used for potable purpose or not.

Materials and methods

Study area

Visakhapatnam (Latitude 17.42 N and Longitude 82.0 E), located on the eastern coast of India, is hemmed in by the Kailasa hill range towards the North and the Yarada hill on the South. The Bay of Bengal provides the beachfront on the East. The climate is generally tropical and humid. The mean daily maximum temperatures is in the range of 27.7°C to 34.0°C and mean daily minimum temperature varies between 7.5°C and 27.8°C. The annual mean relative humidity is 77 per cent. The dominant wind direction in general is from the SW towards the NE. The average annual rainfall is 974 mm. The two monsoons that cover the area are the South-West monsoon (June to September) and North-East monsoon (October to December). Tatipudi Reservoir, Maghadrigedda Reservoir, Raiwada Reservoir and Yeleru Reservoir, Mudasaralova Infiltration Wells, Gosthani Infiltration Wells are main sources of water in GVMC Area, Visakhapatnam. In recent years, due to increase in domestic sewage, industrial inputs and various anthropogenic activities, water quality has been a serious concern. We are interested now to study of rainy seasonal physicochemical and metallic parameters in Ground water, GVMC Area, Visakhapatnam (Swarna Latha,P 2010). It is imperative to prevent and control the ground water pollution and to have reliable information on its quality for effective management.

The study area is covered in 65 O/1, O/2, O/3, O/5 and O/6 of Survey of India top sheets on 1:50,000 scales bounded (Fig.1). It is nestled among the hills of the Eastern Ghats and faces the Bay of Bengal on the east. Visakhapatnam is the administrative headquarters of Visakhapatnam district and headquarters of the Eastern Naval Command of the Indian Navy (GVMC Website).

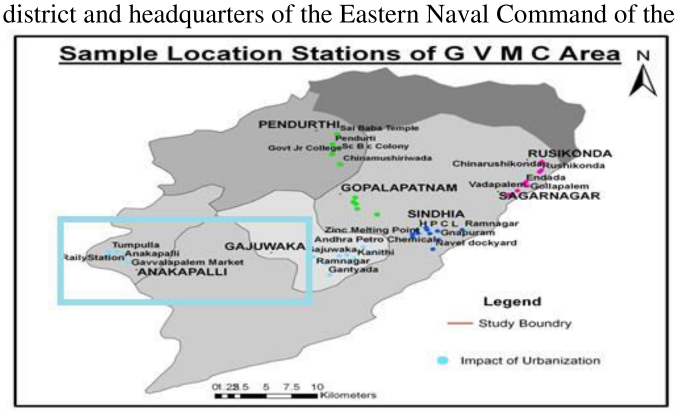


Fig 2. Study Area

Methodology

The sampling is the most important part of any analysis because the final results obtained, even from the most accurate analysis will be misleading, if the samples on such analysis is carried out, whether are not a representative one of the liquids to be tested. As a matter of fact it will be ideal to carry out all analysis the more representative will be the results of analysis of the liquid at the time of samples are taken (Devendra, D 2014). Samples were collected in 15 locations as per standard procedural method and subjected to physic chemical analysis of different parameters like pH, Temperature (0C), Electrical Conductivity (µS/cm), Chlorides (mg/l), Alkalinity (mg/l), Total Dissolved solids (mg/l), Total Hardness (mg/l), Calcium (mg/l), Magnesium (mg/l) , Sodium (mg/l), Potassium (mg/l), Sulphates (mg/l), Phosphates (mg/l), Nitrates (mg/l), Iron (mg/l), Bi carbonates (mg/l) , Chromium (mg/l), Copper (mg/l), Zinc (mg/l), Lead (mg/l), Manganese (mg/l), Cobalt (mg/l) as per standard methods (APHA 1992) . All the reagents used were of analytical grade and solutions were made of distilled water. Total 15 samples were analysed in the year 2014 covering each season (Pre-monsoon & Post Monsoon).

Table 1: Methods Used for Groundwater analysis (Laboratory analytical methods)

S.NO.	Physico-chemical Parameters	Method
1	pH	pH meter (ELICO L1615 Model)
2	conductivity	conductivity meter (ELICO CM180digital conductivity meter model)
3	Alkalinity	titrimetric
4	Total hardness	Complexometric titration
5	Calcium	Complexometric titration
6	Magnesium	Calculated method
7	Chloride	Argentometric titration
8	TDS	Evaporation method
9	Sulphate	Spectrophotometry (SHIMAD2U UV-1800 model)
10	Nitrate	Spectrophotometry
11	Sodium	Flame photo meter (ELICO CM-378 Model)
12	Potassium	Flame photo meter
13	Iron	Spectrophotometry
14	Chromium	Atomic absorption spectro photometer (PERKIN AA 400 Model)
15	Cobalt	Atomic absorption spectro photometer
16	Lead	Atomic absorption spectro photometer
17	Zinc	Atomic absorption spectro photometer
18	Copper	Atomic absorption spectro photometer
19	Manganese	Atomic absorption spectro photometer

It can be seen from the above table that apart from urbanization effect the ground water quality is effected due to various anthropogenic activities such as leakage from sewage , man-made sources such as landfill leachate, feedlots, fossil-fuel combustion, cement-plant emissions, mineral leaching, and waste incineration used in metal plating etc. Main reason for using sodium absorption ratio is that it has good correlation to the exchangeable sodium percentage and much easier to calculate exactly. The relative activity of sodium ion in the exchange process is expressed in terms of a ratio. Sodium percentage in ground water is very important for classifying for the process of Base Exchange replaces calcium in the soil thereby reduces the permeability of soil, which eventually affects the plant growth.

$$\% Na = \{(Na + K)/(Ca + Mg + Na + K)\} X100$$

The Ground Water Classification (GWC) with reference to SAR and the Sodium percentage values are shown in the table 9 below.

Results and Discussions

The physico-chemical, heavy metal & biological parameters of ground-water need to be studied to determine its quality. The study mainly focused on seasonal variation of the physico-chemical characteristics and heavy metal concentration in the ground water from the study area and the results given in table. In the present study the pH values of the ground water samples were ranged from 6.5 to 8.1 and 6.5 to 7.8 in pre and post monsoon season respectively. pH of water is influenced by geology of catchment area and buffering capacity of water. The factors like air temperature bring about changes the pH of water. In both seasons, pH values were within the limit. The conductivity of the ground water indicates its ionic strength and its degree of ionic mineralization, e.g. elevated concentrations of heavy metals. The conductivity values ranged from 520 to 2530 us/cm (Pre Monsoon) and 460 to 2470 us/cm (in post monsoon). High values of conductivity indicate high concentration of soluble salts present in ground water sources and reflect the contribution from seepage of domestic, industrial and municipal sewage. A sudden increase in conductivity of the water is the indication of the addition of pollutants to the water. The concentration of total dissolved solids in water can be approximated in the field by measuring the specific conductance of a sample. The TDS values ranges from 510 mg/l to 2050 mg/l (Pre Monsoon) and 490 to 1880 mg/l (post Monsoon). The EC of all the samples showed almost similar trends like TDS. High TDS in ground water may be attributed to nutrient rich surface waters that contaminate the ground water.

Table:2 Physico-Chemical Characteristics of the Study Area (Pre- Monsoon)

Sample Parameter	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14	U15
PH	7.8	7.4	7.6	7	7.3	7.1	7.4	6.7	6.5	7.3	7.1	7.5	7.1	8.1	7.4
Ec	720	760	810	520	1100	1050	1540	1650	1590	1310	1950	2530	1920	2370	1120
Cl	78	86	115	184	180	110	235	192	135	178	192	262	208	162	167
TA	92	152	171	211	214	196	580	195	221	155	184	334	290	150	215
TDS	510	580	780	1170	1320	1150	1450	1250	1050	2030	2050	2050	1050	1700	720
TH	360	260	280	220	250	260	460	350	160	290	260	600	590	420	325
CaH	40	50	76	70	60	160	80	68	55	65	80	92	95	89	40
MgH	20	28	22	26	16	102	26	16	26	18	24	31	46	32	20
Na	25	33	29	100	85	95	166	81	70	85	90	120	110	98	86
K	15	26	35	16	21	26	20	55	15	16	22	12	32	26	32
SO_4^{-2}	46	43	62	99	92	84	115	79	74	68	78	149	195	191	214
PO_4^{--3}	0.3	3	4	2.7	6	7	3	4	8	3.8	5.2	5.2	4	6	3.5
NO_3^-	0.12	0.25	0.18	1.2	2.4	2	4	1.4	1	1.9	3	2.9	3	3.6	3.5
Fe	0.15	0.2	0.28	0.15	0.26	0.18	0.55	0.32	0.47	0.19	0.3	0.14	0.25	0.29	0.23
HCo_3	60	120	140	180	170	180	480	185	195	130	165	220	240	140	210
Cr	0.05	0.04	0.06	0.19	0.28	0.19	0.14	0.25	0.21	0.14	0.08	0.19	0.22	0.28	0.09
Cu	0.05	0.03	0.04	0.06	0.05	0.06	0.05	0.06	0.05	0.07	0.03	0.12	0.12	0.17	0.06
Zinc	0.07	0.06	0.05	0.05	0.05	0.09	0.04	0.06	0.07	0.03	0.014	0.7	0.09	0.1	0.04
Lead	0.005	0.008	0.007	0.008	0.005	0.006	0.004	0.007	0.006	0.007	0.006	0.006	0.004	0.006	0.007
Mn	0.06	0.08	0.08	0.07	0.06	0.07	0.07	0.14	0.09	0.07	0.05	0.04	0.22	0.09	0.06
Co	0.004	0.005	0.006	0.008	0.005	0.004	0.008	0.007	0.005	0.004	0.006	0.004	0.002	0.004	0.003

All values are in mg/l, except pH & EC (µs/cm)

Table-3: Physico-Chemical Characteristics of the Study Area (Post- Monsoon)

Sample Parameter	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14	U15
pH	7.4	7.1	7.2	6.8	7.1	6.9	7.3	6.5	6.6	7	6..8	7.3	6.9	7.8	7.2
EC	690	740	760	460	1090	980	1410	1580	1480	1270	1790	2470	1870	2240	1080
Cl	71	79	97	161	165	82	215	178	109	162	177	249	189	147	141
TA	83	139	164	186	194	174	484	184	212	133	168	312	270	132	194
TDS	490	560	760	1060	1060	980	1450	1060	1010	1880	1760	1990	950	1590	650
TH	320	205	270	185	230	240	390	280	140	280	220	560	560	360	295
CaH	12	18	24	18	22	14	96	23	12	20	12	20	28	38	29
MgH	20	26	25	93	76	90	154	75	62	72	81	105	92	89	79
Na	20	26	25	93	76	90	154	75	62	72	81	105	92	89	79
K	11	16	30	12	14	24	19	44	13	12	19	9	26	23	27
SO_4^{-2}	39	31	49	82	86	79	105	63	68	51	66	134	183	178	206
PO_4^{--3}	0.5	2	3.6	2.2	5	6	2	2.92	7.2	2.5	4.5	4.9	3.8	5.6	2.9
NO_3^-	0.11	0.21	0.14	1.1	1.9	1.8	3	1.2	0.9	1.8	2.4	2.7	2.9	3.1	2.5
Fe	0.1	0.19	0.23	0.14	0.22	0.12	0.4	0.31	0.37	0.15	0.22	0.08	0.21	0.19	0.2
HCo_3	54	110	136	165	154	160	460	178	186	125	154	216	233	136	201

Cr	0.04	0.03	0.05	0.15	0.21	0.1	0.09	0.21	0.18	0.09	0.06	0.15	0.19	0.21	0.08
Cu	0.03	0.02	0.03	0.04	0.041	0.04	0.042	0.05	0.04	0.05	0.02	0.09	0.1	0.12	0.055
Zinc	0.05	0.048	0.034	0.041	0.042	0.07	0.03	0.06	0.052	0.048	0.012	0.2	0.08	0.06	0.05
Lead	0.004	0.006	0.006	0.005	0.002	0.005	0.002	0.005	0.004	0.004	0.003	0.004	0.002	0.004	0.005
Mn	0.05	0.07	0.05	0.04	0.02	0.04	0.03	0.11	0.05	0.05	0.02	0.02	0.18	0.07	0.02
Co	0.003	0.002	0.004	0.006	0.003	0.005	0.005	0.005	0.003	0.002	0.004	0.002	0.001	0.003	0.002

All values are in mg/l, except pH & EC (µs/cm)

Table 4: Correlation Coefficient Values Of Different Parameters (Urbanization) – 2014(Pre Monsoon)

	pH	**Temp**	**EC**	**Cl (mg/l)**	**TA (mg/l)**	**TDS (mg/l)**	**TH (mg/l)**	**Ca (mg/l)**	**Mg (mg/l)**	**Na (mg/l)**	**K (mg/l)**	**SO4 (mg/l)**	**P04 (mg/l)**	**NO3 (mg/l)**	**Fe (mg/l)**	**Cr (mg/l)**	**Cu (mg/l)**	**Zn (mg/l)**	**Pb (mg/l)**	**Mn (mg/l)**	**Co (mg/l)**
pH	1.00																				
Temp	0.02	1.00																			
EC	-0.27	0.05	1.00																		
Cl(mg/l)	-0.17	0.54	0.60	1.00																	
TA(mg/l)	-0.09	0.47	0.20	0.48	1.00																
TDS (mg/l)	0.09	-0.16	0.33	0.33	0.26	1.00															
TH(mg/l)	0.41	0.45	0.46	0.46	0.34	0.13	1.00														
Ca(mg/l)	0.05	0.34	0.28	0.45	0.86	0.31	0.40	1.00													
Mg(mg/l)	0.17	0.38	0.14	0.29	0.82	0.17	0.28	0.87	1.00												
Na(mg/l)	-0.08	0.46	0.55	0.81	0.66	0.36	0.53	0.73	0.52	1.00											
K (mg/l)	-0.29	0.05	0.20	0.03	-0.14	-0.24	0.16	0.02	0.00	-0.03	1.00										
SO4 (mg/l)	0.25	0.00	0.23	0.22	0.28	0.22	0.45	0.55	0.30	0.32	0.14	1.00									
P04(mg/l)	-0.10	-0.14	0.40	0.27	-0.06	0.15	0.23	0.06	-0.17	0.39	0.31	0.07	1.00								
NO3(mg/l)	-0.11	0.09	0.66	0.45	0.50	0.41	0.31	0.67	0.51	0.65	-0.03	0.55	0.08	1.00							
Fe(mg/l)	-0.05	0.23	0.16	0.34	0.53	0.02	0.08	0.57	0.56	0.45	-0.07	-0.06	0.30	0.15	1.00						
Cr(mg/l)	-0.08	0.46	0.55	0.81	0.66	0.36	0.53	0.73	0.52	1.00	-0.03	0.32	0.39	0.65	0.45	1.00					
Cu(mg/l)	-0.29	0.05	0.20	0.03	-0.14	-0.24	0.16	0.02	0.00	-0.03	1.00	0.14	0.31	-0.03	-0.07	-0.03	1.00				
Zn(mg/l)	0.25	0.00	0.23	0.22	0.28	0.22	0.45	0.55	0.30	0.32	0.14	1.00	0.07	0.55	-0.06	0.32	0.14	1.00			
Pb(mg/l)	-0.10	-0.14	0.40	0.27	-0.06	0.15	0.23	0.06	-0.17	0.39	0.31	0.07	1.00	0.08	0.30	0.39	0.31	0.07	1.00		
Mn(mg/l)	-0.11	0.09	0.66	0.45	0.50	0.41	0.31	0.67	0.51	0.65	-0.03	0.55	0.08	1.00	0.15	0.65	-0.03	0.55	0.08	1.00	
Co(mg/l)	-0.05	0.23	0.16	0.34	0.53	0.02	0.08	0.57	0.56	0.45	-0.07	-0.06	0.30	0.15	1.00	0.45	-0.07	-0.06	0.30	0.15	1.00

Table 5: Correlation Coefficient Values Of Different Parameters (Urbanization) – 2014(Post Monsoon)

	pH	**Temp**	**EC**	**Cl (mg/l)**	**TA (mg/l)**	**TDS (mg/l)**	**TH (mg/l)**	**Ca (mg/l)**	**Mg (mg/l)**	**Na (mg/l)**	**K mg/l)**	**SO4 (mg/l)**	**P04 (mg/l)**	**NO3 (mg/l)**	**Fe mg/l)**	**Cr (mg/l)**	**Cu (mg/l)**	**Zn (mg/l)**	**Pb (mg/l)**	**Mn mg/l)**	**Co (mg/l)**
pH	1.00																				
Temp	0.18	1.00																			
EC	-0.12	0.02	1.00																		
Cl(mg/l)	0.13	0.57	0.56	1.00																	
TA(mg/l)	-0.02	0.25	0.23	0.50	1.00																
TDS (mg/l)	0.13	-0.11	0.37	0.38	0.32	1.00															
TH(mg/l)	0.44	0.14	0.51	0.44	0.34	0.20	1.00														
Ca(mg/l)	0.17	0.19	0.28	0.45	0.83	0.39	0.39	1.00													

Mg(mg/l)	0.24	0.26	0.10	0.29	0.79	0.19	0.24	0.85	1.00												
Na(mg/l)	0.11	0.46	0.53	0.78	0.62	0.34	0.44	0.68	0.50	1.00											
K (mg/l)	-0.01	0.14	0.26	-0.02	-0.07	-0.24	0.19	0.07	0.06	0.07	1.00										
SO4 (mg/l)	0.24	-0.15	0.25	0.17	0.31	0.21	0.47	0.55	0.29	0.27	0.15	1.00									
P04(mg/l)	-0.27	0.00	0.42	0.18	-0.05	0.14	0.23	0.03	-0.24	0.36	0.10	0.11	1.00								
NO3(mg/l)	0.10	-0.09	0.66	0.44	0.48	0.48	0.30	0.61	0.43	0.62	-0.02	0.57	0.12	1.00							
Fe(mg/l)	-0.37	0.18	-0.05	0.19	0.48	0.00	-0.17	0.49	0.52	0.26	0.11	-0.02	0.15	-0.01	1.00						
Cr(mg/l)	-0.32	0.04	0.39	0.15	0.15	0.20	0.06	0.33	0.05	0.12	0.16	0.37	0.23	0.39	0.07	1.00					
Cu(mg/l)	0.13	0.00	0.40	0.34	0.33	0.51	0.49	0.14	-0.03	0.14	-0.23	0.30	0.11	0.27	-0.35	0.21	1.00				
Zn(mg/l)	-0.04	-0.09	0.59	0.27	0.15	0.28	0.38	-0.04	-0.17	0.22	-0.11	0.11	0.24	0.44	-0.40	0.20	0.76	1.00			
Pb(mg/l)	-0.03	-0.27	-0.29	-0.49	-0.46	-0.33	-0.30	-0.41	-0.36	-0.51	0.03	-0.25	-0.12	-0.45	-0.32	-0.17	-0.03	-0.06	1.00		
Mn(mg/l)	-0.08	-0.15	0.13	-0.04	-0.03	-0.21	0.29	0.01	-0.02	-0.12	0.38	0.21	-0.08	0.02	0.10	0.36	-0.12	0.03	-0.13	1.00	
Co(mg/l)	-0.13	-0.11	-0.28	-0.24	0.13	0.07	-0.55	0.18	0.19	-0.01	0.01	-0.26	-0.30	0.04	0.13	0.10	-0.21	-0.15	0.19	-0.23	1.00

Table 6: % of Increase (+) /Decrease (-) - Pre Monsoon to Post Monsoon

Code of the sample	pH+	Temp (0C)	Ec µS/cm	Cl mg/l	Alkalinity mg/l	TDS mg/l	TH mg/l	CaH mg/l	MgH mg/l	Na mg/l	K mg/l	SO_4^{-2} mg/l	PO_4^{-3} mg/l	NO_3^- mg/l	Fe mg/l	HCO3 mg/l	Cr mg/l	Cu mg/l	Zinc mg/l	Lead mg/l	Mn mg/l	Co mg/l
U1	-5.13	-8.33	-4.17	-8.97	-9.78	-3.9	-11.11	-20	-20.0	-20.0	-26.7	-15.2	66.7	-8.3	-33.3	-10.0	-20.00	-40.00	-28.57	-20.00	-16.67	-25.00
U2	-4.05	-6.52	-2.63	-8.14	-8.55	-3.4	-21.15	-15	-10.0	-21.2	-38.5	-27.9	-33.3	-16.0	-5.0	-8.3	-25.00	-33.33	-20.00	-25.00	-12.50	-60.00
U3	-5.26	-4.55	-6.17	-15.65	-4.09	-2.6	-3.57	-8	-14.3	-13.8	-14.3	-21.0	-10.0	-22.2	-17.9	-2.9	-16.67	-25.00	-32.00	-14.29	-37.50	-33.33
U4	-2.86	-4.35	-11.54	-12.50	-11.85	-9.4	-15.91	-9.2	-18.2	-7.0	-25.0	-17.2	-18.5	-8.3	-6.7	-8.3	-21.05	-33.33	-18.00	-37.50	-42.86	-25.00
U5	-2.74	-4.17	-0.91	-8.33	-9.35	-19.7	-8.00	-2.9	-15.4	-10.6	-33.3	-6.5	-16.7	-20.8	-15.4	-9.4	-25.00	-18.00	-16.00	-60.00	-66.67	-40.00
U6	-2.82	-4.35	-6.67	-25.45	-11.22	-14.8	-7.69	-10.0	-12.5	-5.3	-7.7	-6.0	-14.3	-10.0	-33.3	-11.1	-47.37	-33.33	-22.22	-16.67	-42.86	25.00
U7	-1.35	-8.00	-8.44	-8.51	-16.55	0.0	-15.22	-9.4	-5.9	-7.2	-5.0	-8.7	-33.3	-25.0	-27.3	-4.2	-35.71	-16.00	-25.00	-50.00	-57.14	-37.50
U8	-2.99	-4.17	-4.24	-7.29	-5.64	-15.2	-20.00	-6.3	-11.5	-7.4	-20.0	-20.3	-27.0	-14.3	-3.1	-3.8	-16.00	-16.67	0.00	-28.57	-21.43	-28.57
U9	-1.54	-4.55	-6.92	-19.26	-4.07	-3.8	-12.50	-19.1	-25.0	-11.4	-13.3	-8.1	-10.0	-10.0	-21.3	-4.6	-14.29	-20.00	-25.71	-33.33	-44.44	-40.00
U10	-4.11	-4.35	-3.05	-8.99	-14.19	-7.4	-3.45	-10.9	-23.1	-15.3	-25.0	-25.0	-34.2	-5.3	-21.1	-3.8	-35.71	-28.57	60.00	-42.86	-28.57	-50.00
U11	-4.23	-4.55	-8.21	-7.81	-8.70	-14.1	-15.38	-10.8	-33.3	-10.0	-13.6	-15.4	-13.5	-20.0	-26.7	-6.7	-25.00	-33.33	-14.29	-50.00	-60.00	-33.33
U12	-2.67	-6.38	-2.37	-4.96	-6.59	-2.9	-6.67	-5.0	-16.7	-12.5	-25.0	-10.1	-5.8	-6.9	-42.9	-1.8	-21.05	-25.00	-71.43	-33.33	-50.00	-50.00
U13	-2.82	-12.50	-2.60	-9.13	-6.90	-9.5	-5.08	-8.7	-9.7	-16.4	-18.8	-6.2	-5.0	-3.3	-16.0	-2.9	-13.64	-16.67	-11.11	-50.00	-18.18	-50.00
U14	-3.70	-4.55	-5.49	-9.26	-12.00	-6.5	-14.29	-9.5	-17.4	-9.2	-11.5	-6.8	-6.7	-13.9	-34.5	-2.9	-25.00	-29.41	-40.00	-33.33	-22.22	-25.00
U15	-2.70	-4.35	-3.57	-15.57	-9.77	-9.7	-9.23	-14.6	-9.4	-8.1	-15.6	-3.7	-17.1	-28.6	-13.0	-4.3	-11.11	-8.33	25.00	-28.57	-66.67	-33.33

Table-7: Parameters Effect on water quality assessed in 2014

Code of the sample		U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14	U15
Ec	Pre												✓			
	Post															
Cl	Pre												✓			
	Post															
Alkali nity mg/l	Pre				✓	✓	✓	✓		✓			✓	✓		✓
	Post					✓		✓		✓			✓	✓		
TDS	Pre	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Post		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TH	Pre	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Post	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
CaH	Pre				✓	✓		✓	✓				✓	✓	✓	✓
	Post					✓		✓	✓				✓	✓	✓	✓
MgH	Pre							✓						✓	✓	✓
	Post							✓							✓	
K mg/l	Pre		✓	✓					✓			✓		✓	✓	✓
	Post			✓					✓					✓	✓	✓
Fe mg/l	Pre							✓	✓	✓						
	Post							✓	✓	✓						
Cr	Pre			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Post				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cu	Pre				✓				✓		✓		✓	✓	✓	✓
	Post												✓	✓	✓	✓
Mn	Pre								✓					✓		
	Post								✓					✓		

It can be seen from the above table that many locations have characteristics showing the effect of Urbanization.

Table-8: Chemical constituents exceeding the limits present in 2014

	Type of well	Affected Area
EC(μs/cm)	Pre Monsoon	U-12
	Post Monsoon	
Cl(mg/l)	Pre Monsoon	U- 12
	Post Monsoon	
TA (mg/l)	Pre Monsoon	U-4, 5, 6, 7, 9, 12, 13, 15
	Post Monsoon	U-5,7,9,12,13
Mg(mg/l)	Pre Monsoon	U-7, 13-15
	Post Monsoon	U-7, 14
TH(mg/l)	Pre Monsoon	U-1-8, 10-15
	Post Monsoon	U-1-3,5 -8, 10-15
Ca(mg/l)	Pre Monsoon	U-4,5,7, 8, 12-15
	Post Monsoon	U-5, 7, 8, 12-15
TDS	Pre Monsoon	U-1-15
	Post Monsoon	U-2-15
K(mg/l)	Pre Monsoon	U- 2, 3, 8, 11, 13-15
	Post Monsoon	U-3, 8, 13-15
Cr(mg/l)	Pre Monsoon	U- 3-15

	Post Monsoon	U- 4, 6-15
Fe (mg/l)	Pre Monsoon	U- 7-9
	Post Monsoon	U-7,9
Mn (mg/l)	Pre Monsoon	U-8, 13
	Post Monsoon	U-8, 13
Cu (mg/l)	Pre Monsoon	U- 4, 8, 10,12-15
	Post Monsoon	U- 12-15

Table-9: Classification of ground water on the basis of SAR & Sodium Percentage

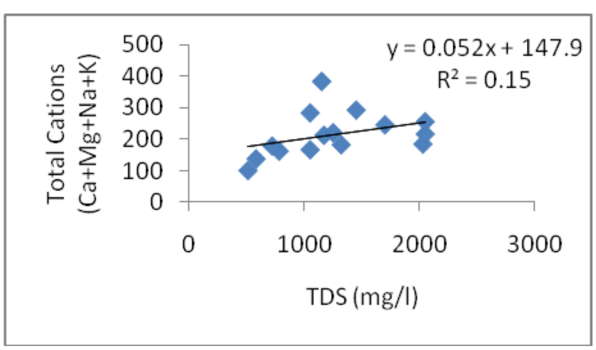
Sampling station	SAR (Sodium Absorption ratio) (Bouwer 1978)				% of Sodium (Na) (Wilcox 1955)			
	Pre	**GWC**	**Post**	**GWC**	**Pre**	**GWC**	**Post**	**GWC**
U1	4.56	No Problem	5.00	No Problem	40.00	Good	49.21	Permissible
U2	5.28	No Problem	5.54	No Problem	43.07	Permissible	48.84	Permissible
U3	4.14	No Problem	5.05	No Problem	39.51	Good	52.88	Permissible
U4	14.43	Severe Problem	12.48	Severe Problem	54.72	Permissible	48.61	Permissible
U5	13.79	Severe Problem	10.86	Severe Problem	58.24	Permissible	47.87	Permissible
U6	8.30	Increasing Problem	12.48	Severe Problem	31.59	Good	52.29	Permissible
U7	22.80	Severe Problem	13.77	Severe Problem	63.70	Doubtful	40.90	Permissible
U8	12.50	Severe Problem	10.71	Severe Problem	61.82	Doubtful	54.84	Permissible
U9	11.00	Severe Problem	10.19	Severe Problem	51.20	Permissible	50.34	Permissible
U10	13.19	Severe Problem	10.62	Severe Problem	54.89	Permissible	47.73	Permissible
U11	12.48	Severe Problem	11.88	Severe Problem	51.85	Permissible	51.81	Permissible
U12	15.30	Severe Problem	13.28	Severe Problem	51.76	Permissible	47.70	Permissible
U13	13.10	Severe Problem	11.88	Severe Problem	50.18	Permissible	49.58	Permissible
U14	12.60	Severe Problem	11.17	Severe Problem	50.61	Permissible	46.86	Permissible
U15	15.70	Severe Problem	10.75	Severe Problem	66.29	Doubtful	49.53	Permissible

TDS beyond 500 mg/L decreases palatability and also favours gastro-intestinal diseases. According to BIS 2003, the TDS value ranges up to 2000 mg/l considered safe for potable purpose in the absence of alternate source. Ground water samples in the study area have TDs values below the limit and are suitable for drinking purpose. Chlorides occur naturally in all types of water but the concentration is very low in natural water.

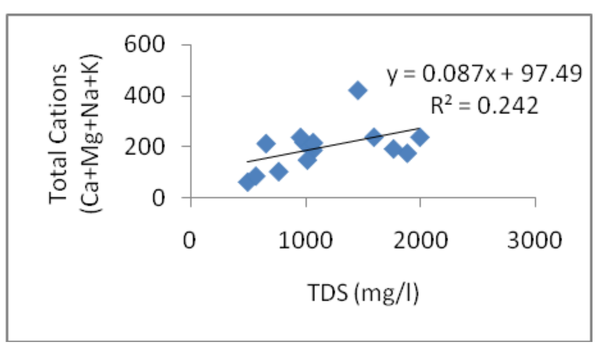
Table 10: Classification of ground water samples on the basis of Total Dissolved Salts (Suggested by Rabinove et al (1958)

Classification of ground water	Total Dissolved Salts in mg/l	Sampling stations	
		Pre Monsoon	Post Monsoon
Non saline	< 1000	U1, U2, U3, U15	U1, U2, U3, U6, U13, U15
Slightly Saline	1000-3000	U4, U5, U6, U7, U8, U9, U10, U11, U12, U13, U14	U4, U5, U7, U8, U9, U10, U11, U12, U14
Moderately Saline	3000-10000	---	----
Very saline	>10000	---	----

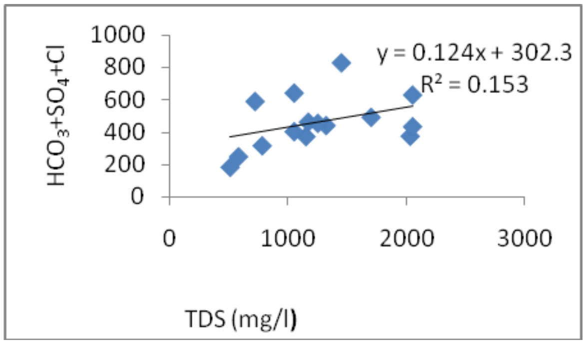
The concentration of chloride in the ground water samples of the study area ranges from 78 mg/l to 262 mg/l (Pre Monsoon) and 71 to 249 mg/l (post Monsoon). Higher values of chlorides indicate pollution of water and give an undesirable taste. Chloride is non-toxic to humans, but elevated levels make water un potable due to the salty taste. The desirable limit for chloride in drinking water is 250 mg/l (WHO 1984). As the observed values are far above the permissible limits, ground waters at sampling sites are affected from chlorine contamination (Priyanka 2010). Sulphate is a natural occurring anion found almost in all types of water. It gets leached into the ground water by many processes. Sulphate values ranged from 43 to 214mg/l (Pre Monsoon) and 31 to 206 mg/l (Post Monsoon). The most Sulphates are soluble in water except the Sulphates of Lead, Barium and Strontium. Daily intake of Sulphate from drinking water is poorly absorbed from the human intestine and slowly penetrates into the cellular membranes of mammals and is rapidly eliminated through the kidneys. Total hardness values are ranged from 160 to 600mg/l (Pre monsoon) and 140 to 560 mg/l (Post Monsoon). Hardness of water is due to the presence of divalent metallic cations, like calcium, magnesium, iron, and manganese ions. Hardness has no known adverse effects on health; however, some evidence has been given to indicate its role in heart diseases (Shivaprasad, H 2014) . The constituents of Alkalinity in natural system mainly include Carbonate, Bicarbonate and Hydroxide. The Alkalinity values ranges from 90 to 580 mg/l (Premonsoon) and 83 to 484 mg/l in Post Monsoon. High values of alkalinity in the water samples indicate pollution of organic nature and give an unpleasant taste. In the absence of alternate source of water. Nitrate in aquatic system usually originates from nitrogenous fertilizers, domestic waste discharge and animal wastes. Nitrate values ranges from 0.1 to 4 mg/l (Pre Monsoon) and 0.11 to 3.1 mg/l. The nitrate contents of ground water samples are well within the desirable limit in the present study. Nitrates usually remain loosely bound with soil and are highly mobile, hence large quantities are leached out from the soil to contaminate ground water. Further, high nitrate level in the ground water samples may be due to contamination by sewage and waste water rich in nitrate. Nitrate is a poisonous component in underground water, which has natural as well as anthropogenic origin. The Chromium values ranged from 0.04 to 0.28 mg/l (Pre Monsoon) and 0.03 to 0.21 Chromium is found naturally in rocks, plants, soil and volcanic dust, humans and animals and anthropogenic sources of chromium-6 in drinking water are discharges from steel and pulp mills, and erosion of natural deposits of chromium-3. High concentrations of chromium are toxic, carcinogenic and teratogenic. Chromium (VI) can enter the body when people breathe air, eat food, or drink water. Certain Chromium (VI) compounds have been found to be carcinogenic in humans, in particular into the lung and that it is dependent on high exposures (Adefemi, S.O 2010). Manganese values ranged from 0.04 to 0.22 mg/l (pre monsoon) and 0.02 to 0.18 (post monsoon). It has been realized that there may be an association between manganese deficiency and the disorders such as anaemia, bone changes and lupus erythematous. Iron values ranged from 0.142 to 0.55 mg/l (pre monsoon) and 0.08 to 0.4 mg/l (Post Monsoon). In general; iron is a common element in arsenic-contaminated waters. Iron is the fourth most common element in the earth's crust and is highly reactive, so naturally occurring and engineered iron oxides serve as a control on the spread of phosphate, arsenic, and other trace metals and anions. Copper is a metal that occurs naturally in rocks, soil, water, and air throughout the environment in form of native copper ores, oxidized minerals or sulphides. Copper values ranged from 0.03 to 0.17 mg/l(pre monsoon) and 0.02 to 0.12 mg/l (post monsoon). Copper has a very high affinity for organic matter and sulphide minerals and is more strongly bound than other trace elements. Zinc values ranges from 0.014 to 0.7 mg/l (Pre Monsoon) and 0.03 to 0.2 mg/l (Post Monsoon). High concentrations (150 µg/L or more) may result in vomiting, dehydration, electrolyte imbalance, nausea, abdominal pain, lethargy, dizziness and lack of muscular co-ordination. In the present study, the concentration of lead ranged from 0.004 to 0.008 (Pre Monsoon) and 0.002 to 0.006 mg/l (Post Monsoon). In human beings, lead is absorbed from the consumed water. It enters the blood and is distributed to soft tissues and bones, which reaches to an equilibrium after prolonged exposure. Bone accumulates lead with time. Lead passes through the placenta easily and foetal blood has almost the same lead concentration as maternal blood. Determination of correlation is important for finding out the strength of the association between the two interdependent variables. In other words it signifies the extent of predictability of one variable from the other. The coefficients of correlation (significant) summarize the strength of association between a pair of elements; hence it serves as tool for comparing and asserting the relationship quantitatively (Sami,G 2011) . Correlation coefficient among variable were determined the value of correlation coefficient greater than or equal to -0.5 or +0.5. A stronger positive correlation was found between alkalinity, chloride, Magnesium, Potassium, Sulphate, Nitrate. Phosphate these variable shows positive correlation with all parameters except Lead and Chromium in pre monsoon. Strong correlation was found between conductivity, chloride, sodium, potassium. Negative correlation was found between pH with chromium and magnesium. In post monsoon positive correlation was found between Conductivity, Chloride, Calcium, Sodium and Potassium.

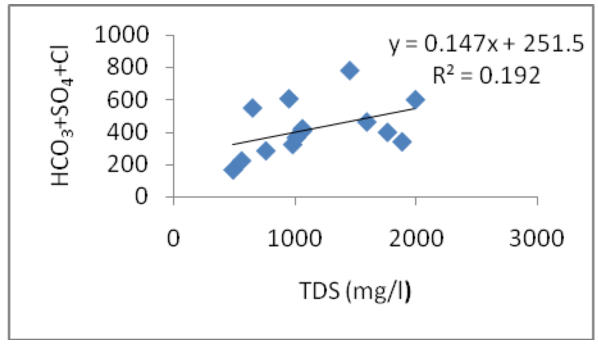


Pre Monsoon



Post Monsoon

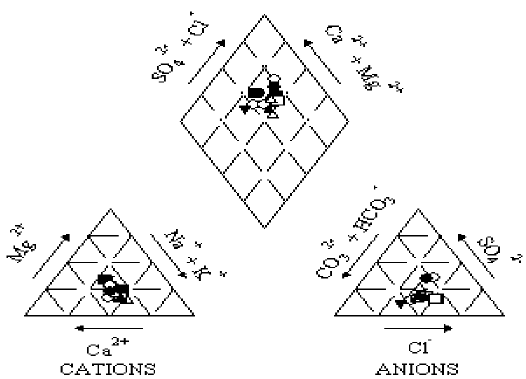




Pre Monsoon **Post Monsoon**

Fig-3: Bivarian plot for major ionic content in the study area; (a) Total Cations vs TDS (b) Cl vs TDS (c) Mg vs TDS (d) Total Anions vs TDS

A systematic statistical study of correlation and regression coefficients of the quality parameters not only helps to assess the overall water quality but also quantify relative concentration of various pollutants in water and provide necessary clue for implementation of rapid water quality management programmes (N.Chandrasekar 2013). The linear regression analyses have been carried out for the water quality parameters which are found to have better and higher level of significance in their correlation coefficient. Multiple plots of single ion relationships show significant correlations and is easily interpreted based on regression analysis for the selected groups of the data of the region. The XY scatter plot is the simplest approach for interpreting the hydrogeochmeical data. The TDS values against total anions have strong positive correlations with R^2 values of 0.153 (Pre Monsoon), 0.192 (Post Monsoon). The TDS values against total cations have strong positive correlations with R^2 values of 0.15 (Pre Monsoon) & 0.242(Post Monsoon). High TDS content in the study area is attributed to leaching of salts from soil and chloride concentration is largely controlled by saline ingress along the coastal region.



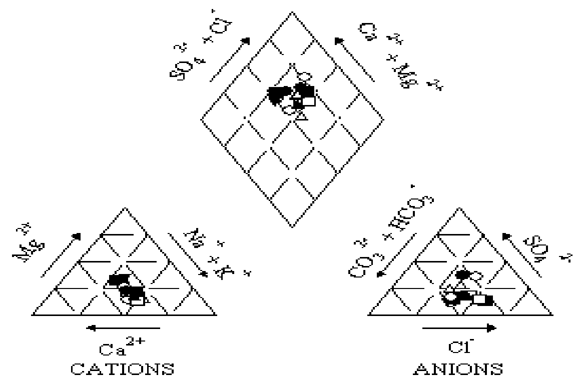


Fig -4 & 5. Piper Diagrams for Ground Water Samples (Pre Monsoon And Post monsoon)

In order to understand the role of various cations and anions in the groundwater chemistry during pre- and post-monsoon period, the data were plotted on the trilinear diagram The concentration of 8 major ions (Na,K,Mg,Ca,Cl,Co_3^{2-},HCO_3- and SO_4^{2}-) are represented on the piper line diagram. The relative concentration of the cations and anions are plotted in the lower triangles, and the resulting two points are extended into the central field to represent the total ion concentration. Piper diagram drawn by using software GW chart (version1.260.0) A Piper diagram (Fig. 4 and Fig.5) was created for the Visakhapatnam area using the analytical data obtained from the hydro chemical analysis15.In pre monsoon season. most of the of the samples are plotted in the Ca+-Mg+Na+HCO_3-Cl -So_4^{2-} field. It indicates alkalinity and hardness. In post monsoon above 60% of the sample showed Ca+Mg+HCO_3 in the region indicates alkalinity, Temporary hardness. 30% of the samples showed this region. Composition of Na+K+Cl. It indicates that salinity.

Conclusions

The study has also indicated that there is no major adverse effect on the quality of ground water in the urbanized area of GVMC in both pre monsoon and post monsoon seasons. Further studies are required to understand whether the deterioration in groundwater quality is temporary or a progressive phenomenon. The difference in the ratios of most of the parameters of post monsoon and pre monsoon has been explained as due to absorption ,dissolution, dissorption and precipitation of certain chemical species and release of certain chemical constituents from the soil minerals. This would help to prevent the irreparable damage to the overall groundwater system. Remediation measures should be adopted to restore the already contaminated groundwater sites. The efforts been made to understand these difference as a function of type of mineral ,chemical environment and concentration of the species etc,. Micronisation maps of concentrations of important chemical constituents of ground water of GVMC have been prepared as a function of longitude and latitude which can form important base level document for researchers working on the ground water quality and geochemistry of the area.

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