Chapter – IV

Discussion

DISCUSSION

A prospective analysis on seasonal variation of physico-chemical contributing factors to bore well and reservoir water samples around Champavati River during years 2010 to 2013 is incorporated in this chapter.

Total hardness (TH): The magnitudes of numerical values of total hardness were above the prescribed tolerable limits [169] for bore wells except the station numbers 16, 18 26-28 and 36. Maximum values of TH were found at Saripalli (2330 mg/L), Nadipalli (2700 mg/L) and Konada (7480 mg/L). The sampling points nearer to estuarine region are one of the reasons for the values beyond permissible limits. On the other hand, the water in the two reservoirs is soft (200-300mg/L) and thus is useful as it is for human consumption and also for agricultural chores. It was also found that the values of EC and TDS are the highest for these villages only. The water from these villages was rated as very hard and unsuitable for drinking, agricultural and industrial purposes. The highest values of total hardness of water were found in the groundwater of the villages which are close to the estuary point of the river Champavathi.

Calcium (II) and magnesium (II): The concentrations of calcium (II) in ground water samples were within the acceptable limits (Ca(II): 70mg/L IS: 10500 standards [165]) only for a limited number of sampling points viz. Station numbers 12, 16, 18 and 20 during the four year period of investigation. Both Ca (II) and Mg (II) exceed the standard values (Mg (II): 30-50 mg/L): for all other sites during three seasons of 2010 to 2013. The latitude and longitude covering the study area is composed of sandy and loamy soils and geology points out limestone and calcium-rich minerals with a consequence of higher amount of calcium in ground water profile [156, 170].

Coming to reservoirs, levels of the Ca (II) (40 to 115 mg/L) and Mg (II) (24.1-42.5mg/L) are not in danger zone.

Chloride ion: The bore well water samples at Nadipalli and Konada villages have very high amounts of chloride throughout the study period. The proximity of these sampling points nearer to estuarine region increases the intrusion of saline water into surface and ground levels.

The reservoir water is free of chloride excess [Andra: 86.2-100.3mg/L; Denkada: 52-135 mg/L], and thus can be employed straight for potable and industrial purposes.

Electrical conductance (EC): The electrical conductivity values are within the IS stipulated range only at station numbers 4, 5, 16, 27 and 37 during entire period of sampling. All other values exceed the tolerable limits and the EC is highest in bore wells of four villages viz. Saripalli, A T Agraharam, Nadipalli and Konada. The latter two locations are geographically located on the shoreline of Bay of Bengal. The larger values of EC are obvious as a consequence of the seepage of brackish water into the bore wells.

The values of EC in Andra Reservoir are in the range of 150-300 µS/cm (Fig.3.1.2) inferring that the quality of water is acceptable for irrigation. However in Denkada anicut, the electrical conductivity (380-525 µS/cm) exceeds the range prescribed by Indian standards IS: 2296-1992 [171].

Total dissolved solids (TDS): The magnitudes of TDS are within the tolerable range for stations labelled as 10-11, 13-14, 16 and 26-29 except for minor deviations. For sampling points at station numbers 31-34, 38-41, 44-46 and 49-50, the values exceed the IS prescribed limits for over the four year period. Although, TDS values are not acceptable for remaining water samples, there is no clear observed trend. In August 2010 most of the water samples have the highest TDS compared to all the other seasons. In all the seasons the highest values of TDS were reported in the villages Nadipalli and Konada. The two villages located in the proximity of the shoreline of Bay of Bengal. Higher values of TDS can be a consequence of sea water intrusion in these areas.

The water samples from both reservoirs contain TDS (Andra: 200-300mg/L; Denkada: 100-575 mg/L) below the threshold. It infers that the water is of acceptable quality from TDS for drinking and agricultural activity (Fig.3.1.3).

pH: pH and alkalinity are two influencing water quality descriptors for use in potability, agriculture and industry. The pH of most of the water samples are within in the acceptable limits (6.5 to 8.5) with exceptions for stations numbers 48-50 during 2011. In the case of reservoirs, three odd samples were detected in 2010 December at Andra, Nadipalli and Aagaru with pH values of 9.4,10,0 and 9.1 respectively. The first level inference is that water is potable and can be used for other purposes with a little care.

Total alkalinity: The contamination of carbonates, bicarbonates and hydroxides render water bodies basic and in extreme cases alkaline. The measured alkalinity values are within the limits (200 mg/L) for samples from stations 8-16, 26-29 and 36 over the entire period of study. The water samples in reservoirs at Andra (159.5-165mg/L) and Denkada have acceptable alkalinity values. Highest values of total alkalinity were found in the villages Nadipalli (807.6 mg/L) and Konada (752.6 mg/L), making them unsuitable.

Nitrite and fluoride: The amounts of nitrite and fluoride (0.1-1.2 mg/L) both in bore well and reservoir water samples in the entire time period of present study were within the safe limits for potability, industrial application and irrigation. The higher values of nitrite in the villages Nellimarla, Saipalli, A T Agraharam, Nadipalli and Konada (0.1-0.8 mg/L) compared to those in the villages Andra, Aaguru, Mentada, Gajapathinagaram and Seetharampuram (0.05-0.1 mg/L) are attributed to excess use of nitrogenous fertilizer use and associated agricultural runoff. (Fig.4.1a-4.1c)

Phosphate ion: In the present study around Champavati river, the bore well water samples contain phosphate (> 5mg/L) exceeding the safe limits at all stations during the entire four year period. But, the water in reservoirs is not contaminated with phosphorous.

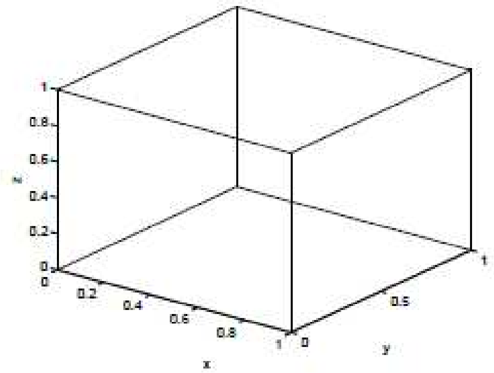
Sodium (I): Most of the bore well water samples studied contained sodium ion in the range of 24.1 to 250 mg/L, well within the tolerable limits from utility stand point. Only samples from Nadipalli and Konada had Na^+ to an extremely high extent of 2235 mg/L. The two villages being nearer to estuarine region, salt water intrusion and seepage are the major contributors to the pollution. The samples from reservoirs (Andra: 15-92 mg/L; Denkada: 30-58.5 mg/L) are well within standard limits of unpolluted water bodies.

Potassium: The concentrations of potassium cation in all the water samples are outside the permissible limits during the years 2011 to 2013 based on the stipulations of Indian standards. Further, very high amount of this metal ion was found in bore wells of the villages Andra, Aaguru, Mentada, Gajapathinagaram, Seetharampuram, Nellimarla, Saripalli, AT Agraharam, Nadiappli and Konada.

Iron: All water samples, both from bore wells and reservoirs, contained iron (II) well within the tolerable range during three seasons in all four years.

Correlation matrix

The variation of physical, chemical and physicochemical variables of water samples for four years studied is a multivariate tensor (chart 1).



Rows	:	Space (Samples)
Columns: Response	:	Variables (Physico-chemical etc)
Tubes (3rd dimension)	:	(Time) seasons

Chart 1: Tensorial data representation of spacio-temporal physico-chemical parameters of water analysis

The frequency plots reveal the statistical distribution of each variable in time (seasons) and space (sampling stations). If the distribution were Gaussian (i.e. normal in statistical terminology), classical statistical tests hold good. The observed variations in water quality parameters have several anthropogenic, environmental and chemical implicit reasons. Thus the linear/pseudo linear plot between only two variables is either due to implicit linear physico-chemical process model or just a numerical trend with no valid physical/chemical reason. In statistical multivariate regression, the explanatory variables should be uncorrelated (correlation coefficient < 0.2) to arrive at unbiased regression parameters. Yet, in water analysis, it is customary to look into the linear (Pearson) statistical correlation between each pair of variables and Tables 4.1.1-4.1.11 show lower triangular matrices with pair wise correlation coefficients. This display is optimum as the correlation matrix is a square symmetric one. The ones (1s) in the diagonal in each matrix is obvious in that the variation of i^{th} variable with itself is completely linearly correlated. The highly correlated variables in the present study are given in table 4.1.12 in the form of information bits.

	[pH]	[EC]	[TDS]	[THW]	[Ca]	[Mg]	[Na]	[K]	[Fe]	[Cl]	[PO4]	[NO2]	[F]	[TA]
[pH]	1													
[EC]	0.571	1												
[TDS]	0.545	0.791	1											
[THW]	0.35	0.492	0.39	1										
[Ca]	-0	-0.06	-0.1	0.62	1									
[Mg]	0.438	0.783	0.65	0.51	-0.1	1								
[Na]	0.237	0.257	0.21	0.07	-0.2	0.28	1							
[K]	0.256	-0.15	-0.1	-0.07	-0	-0.2	0.24	1						
[Fe]	0.091	0.148	0.09	-0.09	-0.1	-0.02	0	-0.02	1					
[Cl]	0.5	0.841	0.67	0.43	-0.1	0.872	0.27	-0.21	0.04	1				
[PO4]	0.119	0.211	0.26	0.18	-0	0.246	-0.05	-0.39	-0.2	0.195	1			
[NO2]	0.29	0.452	0.18	0.3	-0	0.435	0.23	-0.06	-0	0.549	-0.01	1		
[F]	-0.23	0.224	0.06	0.24	0.05	0.221	-0.04	-0.26	0.01	0.315	-0.09	0.424	1	
[TA]	0.187	-0	0.13	0.23	0.43	-0.15	0.14	0.21	-0.1	-0.13	-0.21	0.114	0.062	1

[pH] [EC] [TDS] [THW] [Ca] [Mg] [Na] [K] [Fe] [Cl] [PO4] [NO2] [F] [TA]

Table 4.1.1 Pearson correlation matrix during August 2010

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	-0.07	1												
[TDS]	0.018	0.802	1											
[THW]	0.142	0.524	0.381	1										
[Ca]	0.344	-0.05	-0.06	0.646	1									
[Mg]	-0	0.781	0.627	0.673	-0.05	1								
[Na]	0.236	0.342	0.287	0.183	-0.01	0.372	1							
[K]	0.049	-0.16	-0.13	-0.2	-0.09	-0.18	0.328	1						
[Fe]	-0.19	0.074	0.106	-0.18	-0.24	-0.03	-0.01	-0.11	1					
[Cl]	-0.07	0.829	0.671	0.459	-0.16	0.865	0.358	-0.16	0.07	1				
[PO4]	0.332	0.238	0.328	0.104	-0.05	0.278	-0	0.07	0.002	0.19	1			
[NO2]	-0.07	0.204	-0.05	0.086	-0.17	0.242	0.309	0.07	-0.03	0.29	-0.4	1		
[F]	-0.15	0.131	0.168	0.123	-0.17	0.297	0.085	-0.01	-0.09	0.23	0.044	0.027	1	
[TA]	0.215	-0.01	0.101	0.209	0.44	-0.13	0.16	0.12	-0.27	-0.17	-0.14	0.12	-0.05	1
	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*

Table 4.1.2 Pearson correlation matrix during December 2010

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	0.229	1												
[TDS]	0.209	0.908	1											
[THW]	0.566	0.356	0.345	1										
[Ca]	0.607	0.104	0.112	0.95	1									
[Mg]	0.424	0.757	0.801	0.618	0.455	1								
[Na]	0.028	0.86	0.89	0.227	-0.03	0.766	1							
[K]	0.181	0.681	0.734	0.387	0.193	0.714	0.82	1						
[Fe]	-0.03	-0.01	0.045	-0.01	-0.029	-0	0.15	0.44	1					
[Cl]	0.416	0.62	0.63	0.385	0.287	0.82	0.52	0.57	-0	1				
[PO4]	0.029	0.219	0.285	0.136	0.104	0.236	0.28	0.37	0.135	0.18	1			
[NO2]	0.347	-0.07	-0.077	0.237	0.316	0.025	-0.29	-0.09	-0.23	0.19	0.128	1		
[F]	-0.1	0.277	0.17	0.162	0.084	0.131	0.24	0.31	0.149	0.07	0.518	-0.02	1	
[TA]	-0.19	-0.04	-0.037	-0.14	-0.164	-0.18	-0.15	0.07	0.285	0.04	0.048	0.021	0.222	1

[pH] [EC] [TDS] [THW] [Ca] [Mg] [Na] [K] [Fe] [Cl] [PO4] [NO2] [F] [TA]

Table 4.1.3 Pearson correlation matrix during April 2011

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	0.371	1												
[TDS]	0.411	0.924	1											
[THW]	0.278	0.755	0.78	1										
[Ca]	-0.11	0.364	0.21	0.41	1									
[Mg]	0.367	0.663	0.77	0.618	0.024	1								
[Na]	0.539	0.878	0.93	0.713	0.051	0.7784	1							
[K]	0.42	0.587	0.66	0.505	0.036	0.5119	0.721	1						
[Fe]	0.112	-0.19	-0.04	-0.317	-0.51	0.0793	0.016	0.086	1					
[Cl]	0.323	0.602	0.71	0.567	0.153	0.9406	0.675	0.525	0.046	1				
[PO4]	0.154	0.012	-0.03	-0.018	-0.02	0.0185	0.017	-0.11	0.037	0.025	1			
[NO2]	-0.35	-0.08	-0.2	-0.163	0.174	-0.214	-0.275	-0.2	-0.27	-0.11	0.197	1		
[F]	0.161	0.337	0.33	0.383	0.303	0.1408	0.238	0.345	-0.19	0.21	0.116	0.19	1	
[TA]	0.256	-0.14	-0.13	-0.041	-0.05	-0.17	-0.04	0.441	0.053	-0.06	-0.05	-0.04	0.18	1
	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*

Table 4.1.4 Pearson correlation during August 2011

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	0.34	1												
[TDS]	0.34	0.93	1											
[THW]	0.27	0.77	0.776	1										
[Ca]	0.2	0.35	0.192	0.442	1									
[Mg]	0.25	0.65	0.762	0.634	0.007	1								
[Na]	0.36	0.87	0.926	0.701	0.022	0.765	1							
[K]	0.29	0.55	0.637	0.484	-0.02	0.478	0.693	1						
[Fe]	-0.1	-0.12	-0.05	0.059	2E-04	0.054	-0.07	-0.184	1					
[Cl]	0.26	0.6	0.714	0.569	0.135	0.928	0.671	0.501	0.053	1				
[PO4]	-0.5	-0.2	-0.23	-0.17	-0.11	-0.087	-0.16	-0.404	0.151	-0.14	1			
[NO2]	-0.4	-0	-0.09	-0.08	0.106	-0.201	-0.22	-0.204	-0.11	-0.09	0.08	1		
[F]	0.24	0.27	0.253	0.373	0.344	0.09	0.138	0.237	0.06	0.142	-0.43	-0.01	1	
[TA]	-0	-0.2	-0.18	-0.09	-0.08	-0.185	-0.08	0.367	-0.13	-0.1	0.14	-0.07	0.075	1
	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*

Table 4.1.5 Pearson correlation matrix during December 2011

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	0.342	1												
[TDS]	0.297	0.931	1											
[THW]	0.228	0.76	0.766	1										
[Ca]	0.254	0.348	0.204	0.437	1									
[Mg]	0.19	0.675	0.781	0.557	0.014	1								
[Na]	0.288	0.869	0.92	0.682	0.017	0.787	1							
[K]	0.394	0.595	0.617	0.471	0.057	0.502	0.685	1						
[Fe]	0.082	0.275	0.286	0.286	0.087	0.213	0.297	0.1614	1					
[Cl]	0.211	0.602	0.714	0.558	0.122	0.95	0.67	0.4997	0.211	1				
[PO4]	-0.305	-0.21	-0.25	-0.107	0.031	-0.18	-0.25	-0.497	-0.052	-0.2	1			
[NO2]	-0.269	-0.09	-0.2	-0.075	0.191	-0.24	-0.3	-0.167	-0.177	-0.2	0.221	1		
[F]	0.307	0.194	0.234	0.28	0.236	0.091	0.197	0.2883	-0.051	0.11	-0.34	-0.048	1	
[TA]	0.169	-0.21	-0.21	-0.107	-0.07	-0.2	-0.1	0.3428	0.011	-0.1	-0	0.0643	0.241	1
	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*

Table 4.1.6 Pearson correlation matrix during April 2012

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	0.5	1												
[TDS]	0.45	0.933	1											
[THW]	0.29	0.726	0.729	1										
[Ca]	0.18	0.331	0.189	0.087	1									
[Mg]	0.31	0.651	0.754	0.673	-0.01	1								
[Na]	0.47	0.874	0.918	0.742	-6E-04	0.7599	1							
[K]	0.46	0.595	0.609	0.558	0.0494	0.4576	0.671	1						
[Fe]	0.06	0.118	0.131	0.224	0.2339	0.1912	0.039	0.094	1					
[Cl]	0.26	0.563	0.678	0.494	0.1109	0.8939	0.639	0.458	0.194	1				
[PO4]	0.07	-0.13	-0.21	-0.147	0.1671	-0.093	-0.19	-0.367	0.039	-0.05	1			
[NO2]	-0	0.062	-0.08	-0.096	0.1841	-0.212	-0.2	-0.149	0.095	-0.23	0.2356	1		
[F]	0.26	0.298	0.329	0.316	0.0064	0.2292	0.282	0.326	0.225	0.221	-0.467	-0.11	1	
[TA]	0.13	-0.21	-0.23	-0.035	-0.066	-0.208	-0.1	0.349	-0.058	-0.13	-0.077	-0.06	0.015	1
	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*

Table 4.1.7 Pearson correlation matrix during August 2012

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	0.404	1												
[TDS]	0.367	0.915	1											
[THW]	0.272	0.753	0.761	1										
[Ca]	0.201	0.342	0.175	0.436	1									
[Mg]	0.253	0.684	0.755	0.621	-0.02	1								
[Na]	0.424	0.85	0.919	0.675	-0.01	0.76	1							
[K]	0.302	0.577	0.59	0.471	0.061	0.437	0.647	1						
[Fe]	-0.25	0.149	0.281	0.271	-0.06	0.213	0.197	0.08	1					
[Cl]	0.202	0.664	0.714	0.56	0.121	0.926	0.668	0.482	0.197	1				
[PO4]	-0.08	-0.129	-0.21	-0.112	0.206	-0.12	-0.19	-0.42	0.013	-0.1	1			
[NO2]	-0.05	0.139	-0.06	0.052	0.311	-0.18	-0.21	-0.01	-0.17	-0.1	0.143	1		
[F]	0.336	0.205	0.26	0.242	0.041	0.185	0.254	0.227	-0	0.19	-0.37	-0.21	1	
[TA]	-0.1	-0.074	-0.13	-0.056	-0.11	-0.1	-0.07	0.065	0.085	-0.1	-0.03	0.092	-0.1	1
	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*

Table 4.1.8 Pearson correlation matrix during December 2012

	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*
[pH]	1													
[EC]	0.298	1												
[TDS]	0.258	0.913	1											
[THW]	0.252	0.755	0.76	1										
[Ca]	0.206	0.339	0.16	0.429	1									
[Mg]	0.269	0.709	0.79	0.774	-0.02	1								
[Na]	0.241	0.845	0.92	0.675	-0.02	0.788	1							
[K]	0.306	0.552	0.56	0.458	0.06	0.427	0.61	1						
[Fe]	-0.07	-0.08	0.04	-0.07	0.011	-0.11	-0.04	0.09	1					
[Cl]	0.376	0.666	0.72	0.562	0.115	0.806	0.67	0.461	0.09	1				
[PO4]	-0.39	-0.09	-0.2	-0.1	0.207	-0.18	-0.15	-0.34	-0.04	-0.175	1			
[NO2]	0.229	0.065	-0.1	-0.07	0.203	-0.2	-0.24	-0.03	-0.05	-0.131	0.0534	1		
[F]	0.022	0.29	0.25	0.255	0.365	0.106	0.14	0.095	0.128	0.246	0.1019	-0.07	1	
[TA]	-0.01	-0.21	-0.2	-0.12	-0.05	-0.2	-0.1	0.369	-0.01	-0.121	-0.125	0.051	-0.09	1

[pH] *[EC]* *[TDS]* *[THW]* *[Ca]* *[Mg]* *[Na]* *[K]* *[Fe]* *[Cl]* *[PO4]* *[NO2]* *[F]* *[TA]*

Table 4.1.9 Pearson correlation matrix during April 2013

	[pH]	[EC]	[TDS]	[THW]	[Ca]	[Mg]	[Na]	[K]	[Fe]	[Cl]	[PO4]	[NO2]	[F]	[TA]
[pH]	1													
[EC]	0.24	1												
[TDS]	0.19	0.912	1											
[THW]	0.25	0.76	0.7633	1										
[Ca]	0.14	0.361	0.1742	0.438	1									
[Mg]	0.24	0.706	0.7848	0.773	-0.014	1								
[Na]	0.18	0.847	0.9166	0.677	-0.003	0.789	1							
[K]	0.29	0.561	0.5549	0.466	0.1003	0.434	0.604	1						
[Fe]	-0.06	0.116	0.1124	0.155	0.0239	0.106	0.077	0.001	1					
[Cl]	0.25	0.667	0.7147	0.563	0.1255	0.804	0.67	0.4624	0.013	1				
[PO4]	-0.39	-0.122	-0.139	-0.1	0.0891	-0.148	-0.117	-0.315	0.126	-0.12	1			
[NO2]	0.14	0.028	-0.043	-0.01	0.1535	-0.142	-0.18	-0.026	-0.04	-0.1	0.138	1		
[F]	0.21	0.195	0.1492	0.057	0.1991	0.04	0.075	0.0879	-0.21	0.222	-0.09	-0.02	1	
[TA]	0.04	-0.19	-0.224	-0.1	-0.004	-0.198	-0.107	0.3737	-0.13	-0.11	-0.06	0.066	-0.161	1
	[pH]	*[EC]*	*[TDS]*	*[THW]*	*[Ca]*	*[Mg]*	*[Na]*	*[K]*	*[Fe]*	*[Cl]*	*[PO4]*	*[NO2]*	*[F]*	*[TA]*

Table. 4.1.10 Pearson correlation matrix during August 2013

	[pH]	[EC]	[TDS]	[THW]	[Ca]	[Mg]	[Na]	[K]	[Fe]	[Cl]	[PO4]	[NO2]	[F]	[TA]
[pH]	1													
[EC]	0.238	1												
[TDS]	0.183	0.91	1											
[THW]	0.25	0.75	0.761	1										
[Ca]	0.156	0.34	0.163	0.4377	1									
[Mg]	0.251	0.71	0.78	0.7779	-0	1								
[Na]	0.178	0.85	0.917	0.6789	-0	0.787	1							
[K]	0.298	0.56	0.555	0.4807	0.09	0.441	0.607	1						
[Fe]	-0.17	0.04	0.044	0.0093	0.09	0.037	-0.06	-0.3	1					
[Cl]	0.255	0.67	0.708	0.5632	0.12	0.8	0.669	0.47	-0	1				
[PO4]	-0.44	-0.2	-0.252	-0.219	0.11	-0.24	-0.3	-0.4	0.23	-0.178	1			
[NO2]	0.249	0.09	-0.042	0.0207	0.23	-0.11	-0.16	0.06	0.05	-0.088	0.148	1		
[F]	0.189	0.07	0.105	0.2383	0.32	0.023	-0.02	0.06	0.12	0.092	0.016	0.1	1	
[TA]	0.04	-0.2	-0.222	-0.091	-0.01	-0.18	-0.1	0.39	-0.4	-0.105	-0.08	0.11	-0.1	1
	[pH]	[EC]	[TDS]	[THW]	[Ca]	[Mg]	[Na]	[K]	[Fe]	[Cl]	[PO4]	[NO2]	[F]	[TA]

Table 4.1.11 Pearson correlation matrix during December 2013

Parameter	Positively correlated with
EC	TDS, Na, Cl
TH	Ca (II), Mg (II),
Phosphate ion	Ca(II), Fluoride
Fluoride ion	Phospahte and Ca (II)
Chloride ion	EC, TH, TDS, Na (I), K (I), Ca (II), Mg (II)

Table 4.1.12 Pearson pairwise correlation between parameters

4.2 WATER QUALITY INDEX

The operating measure of suitability of water for potability, agriculture and/or industry is expressed by a single numerical dimensionless quantity called "Water quality index" (WQI) [172, 173]. Different scales and methods of calculations are in vogue adhering with national and international environmental stipulations. The quantitative estimations of physical, chemical, physicochemical and biological parameters of a water sample in a specified location/source at an instant of time are the multivariate input. A software program in JAVA was developed for the calculation of WQI.

The typical WQI methods of calculation, categorical discrimination of quality of water are given in Table 4.2.1-4.2.2. The intermediate values in the calculation of WQI by Brown [172] method for one village, Mentada, during Aug 2010 are in Table 4.2.3-4.2.4. Seasonal variation in WQI for the villages was presented in Table 4.2.5 and reservoirs in 4.2.6. The variation of WQI parameters for bore well samples in two villages (V1 and V4) are given in bar diagrams (Fig.4.2.1-4.2.2). It is clear that WQIs for V1 and V4 exhibit high values over eleven seasons of study period. Further, a perusal of Fig. 4.2.3 reveals that water quality of in all villages (V1 to V10) is either poor or extremely bad. Fig.4.2.4 reveals the water quality I the two reservoirs.

WQI	Algebraic Formulae	Ref
Brown	$$WQI = \frac{\sum_{i=1}^{i=n}(WiQi)}{\sum_{i=1}^{i=n}Wi} \quad \text{or} \quad \frac{\sum_{i=1}^{i=n}(SI)i}{\sum_{i=1}^{i=n}Wi}$$ $Q_i = 100 * \frac{(V_n - V_i)}{(V_s - V_i)}$ — Vn : Estimated value Vi : Ideal value (Mostly 0.0 *) Vs : Permissible value N :Number of estimated variables Q_i :Ratio of variable to its permissible limit Wn = k/sn — Wn : Unit weight Reciprocal of permissible value k : constant Sn: standard permissible value q pH = 100 (v pH – 7.0) / (8.5 – 1.0) q DO = 100 (VDO – 14.6) / (15.0-14.6).	*172* *175*
Weighted arithmetic mean	$WQI = \sum_{i=1}^{n} SIi * Wi$	
Weighted geometric mean	$WQI = \prod_{i=1}^{n} SIi \wedge Wi$	*173* 182 179
Un-weighted harmonic square mean	$WQI = \sqrt{\frac{n}{\sum_{1=1}^{n} \frac{1}{SI_i^2}}}$ *SIi* : Sub-index i *n* : Number of sub-indices *Wi* : Weight given to sub-index i	
$NSFWQI_a$	$WQI = \Sigma\ SI_i\ W_i$	183 178
$NSFWQI_m$	$WQI = \Pi\ SI_i\ W_i$	183 177
OWQI	$[n/ (\Sigma 1/S12]^{1/2}$ n : number of parameters	183
CCME WQI	WQI = 100- $\{(F_1^2+F_2^2+F_3^2)^{1/2}/1.732\}$ F1 : (Number of failed variables/ total no of variables) *100 *F2* : (Number of failed tests/ total no of tests) *100 *F3* (nse / 0.01nse+0.01) nse:	174

Table 4.2.1: Typical water quality index (WQI) parameters

WQI	**Rating**	**If WQI is in the range**	**Ref**
Brown Razziuddin	Excellent	0-25	172 176 181
	Good	26-50	
	Poor	51-75	
	Very poor	76-100	
	Unsuitable for drinking	>100	
NSFWQI	Excellent	91-100	180
	Good	71-90	
	Medium	51-70	
	Bad	26-50	
	Very bad	0-25	
OWQI	Excellent	91-100	
	Good	71-90	
	Medium	51-70	
	Bad	26-50	
	Very bad	0-25	
CCME WQI	Excellent	95-100	
	Good	80-94	
	Fair	65-79	
	Marginal	45-64	
	Poor	0-44	

Table 4.2.2: Categorical classification of ranges of WQI

S.No.	Parameter	Std Value		Wi
1	pH	8.5	0.117647	0.016565
2	EC	500	0.002	0.000282
3	TDS	500	0.002	0.000282
4	THW	300	0.003333	0.000469
5	Ca (II)	75	0.013333	0.001877
6	Mg (II)	30	0.033333	0.004693
7	Na (I)	200	0.005	0.000704
8	K (I)	12	0.083333	0.011733
9	Fe (II)	0.3	3.333333	0.469331
10	Cl	250	0.004	0.000565
11	PO4	2	0.5	0.0704
12	No2	0.5	2	0.281598
13	F	1	1	0.0140799
14	TA	200	0.005	0.000704
			7.102314	

Table 4.2.3 Unit weight calculations

Mentada August 2010										
Parameter	1	2	3	4	5	Vi	Si	Qi	Wi	WiQi
pH	8.5	8.6	8.5	8.7	8.5	8.56	8.5	104	0.016565	1.722719
EC	720	850	565	640	200	595	500	119	0.000282	0.03351
TDS	480	270	1060	440	250	500	500	100	0.000282	0.02816
THW	362.8	422.5	352.8	478.5	455.5	141.42	300	138.14	0.000469	0.064833
Ca	110.5	131	110.5	111	111	114.8	75	153.0667	0.001877	0.287355
Mg	42.3	42.3	24.5	45.8	45.8	40.14	30	133.8	0.004693	0.627964
Na	125.5	100.5	92.5	98.5	87.5	100.9	200	50.45	0.000704	0.035517
K	21.2	21.3	21.4	21.5	17.5	20.58	12	171.5	0.011733	2.012255
Fe	0.1	0.1	0.1	0.009	0.008	0.094	0.3	31.33333	0.469331	14.70569
Cl	54.5	156	75.5	75.5	58.5	84	250	33.6	0.000565	0.018923
PO4	3.1	3.2	3.2	3.2	2.5	3.04	2	152	0.0704	10.70074
No2	0.1	0.2	0.1	0.1	0.3	0.16	0.5	32	0.281598	9.011148
F	0.4	0.4	0.6	0.4	0.6	0.48	1	48	0.140799	6.758361
TA	382.9	382.9	255.2	351	287.2	331.84	200	165.92	0.00704	0.116807
										WQI = 46.12398

Table 4.2.4 Water quality index (WQI) calculation

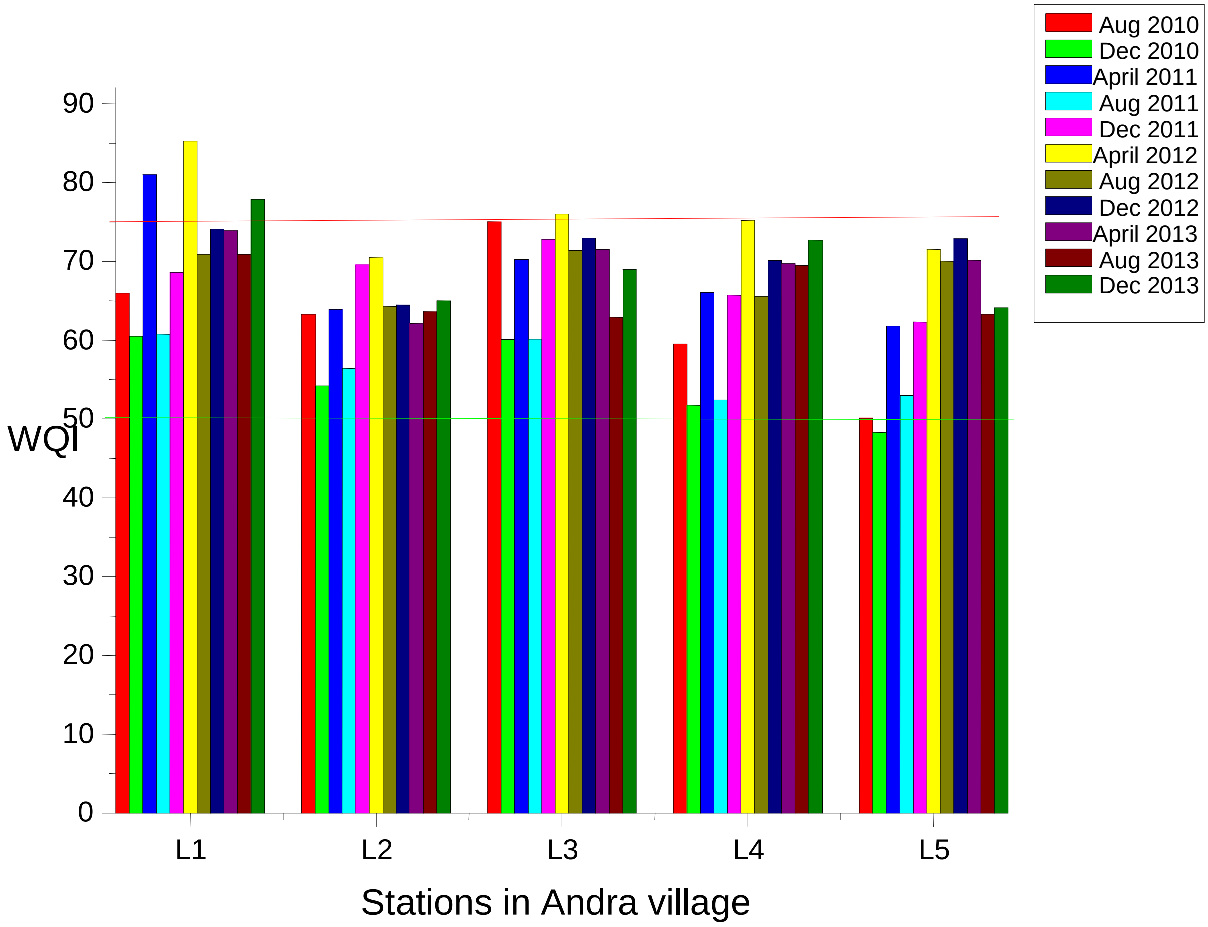


Fig. 4.2.1 WQI for Village 1 Andra

L1: location 1; L2 Location 2; L3 location 3; L4 location 4; L5 location 5 (sampling station= location)

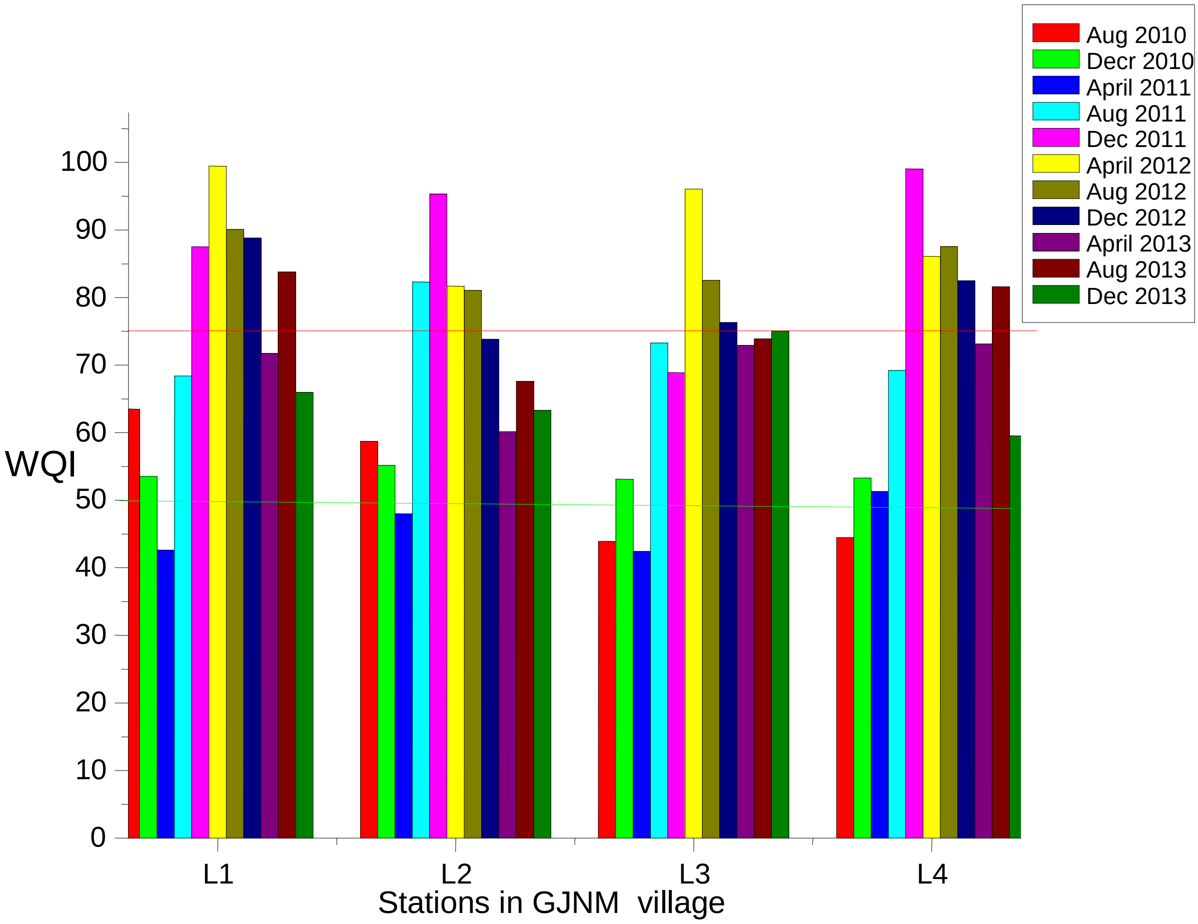


Fig.4.2.2 WQI in village 4 Gajapathinagaram

L1 location 1; L2 Location 2; L3 location 3; L4 location 4; (sampling station= location)

WATER QUALITY INDEX VALUES FOR TE VILLAGES UNDER STUDYING DIFFERENT SEASONS										
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
S1	62.8	73.37	46.12	52.15	46.86	65.81	59.53	61.19	79	87.1
S2	55.9	61.89	50.25	53.81	49.26	57.56	44.84	56.3	71.27	74.08
S3	68.4	85.67	46.37	46.12	54.46	59.76	49.82	53.3	97.19	93.65
S4	56.56	86.56	80.3	73.36	52.39	84.08	100.21	65.96	92.47	88.36
S5	67.8	88.78	101.41	87.72	74.01	90.71	93.16	64.55	92.08	88.8
S6	75.7	101.12	103.46	90.81	74.35	85.8	92.11	64.41	91.44	89.12
S7	68.43	99.41	77.14	85.54	87.62	82.8	94.42	63.58	88.55	88.82
S8	70.89	99.41	78.23	80.3	83.73	82	93.22	65.06	87.27	89.94
S9	69.49	98.28	64.62	97.63	81.71	79.19	93.4	67.67	81.8	83.27
S10	66.09	93.04	67.22	105.62	74.64	79.56	93.28	68.03	85.85	86.19
S11	69.66	98.36	68.98	108.62	79.4	81.35	95.51	69.19	82.3	87.5

Table 4.2.5 Seasonal variation in the water quality index (WQI) of the villages

V1: Andra; V2 Aaguru; V3 Mentada; V4 Gajapathinagaram; V5 Seetaramapuram; V6 Nellimarla; V7 Saripalli; V8 A T Agraharam; V9 Nadipalli; V10 Konada; AR; Andra reservoir; DA; Denkada anicut

WQI of Reservoirs		
Season	Andra	Denkada
S1	24.9	39.6
S2	23.5	31.8
S3	36.4	32.4
S4	29.1	32.4
S5	32.1	26.9
S6	35.1	32.5
S7	35.1	32.4
S8	35.6	32.4
S9	38.5	32.5
S10	38.7	32.4
S11	36.7	30.2

Table 4.2.6 WQI for the two reservoirs under study in various seasons

S1- August 2010; S2- December 2010; S3- April 2011; S4- August 2011; S5 – December 2011; S6 – April 2012; S7 – August 2012; S8 – December 2012; S9- April 2013; S10 – August 2013; S11- December 2013

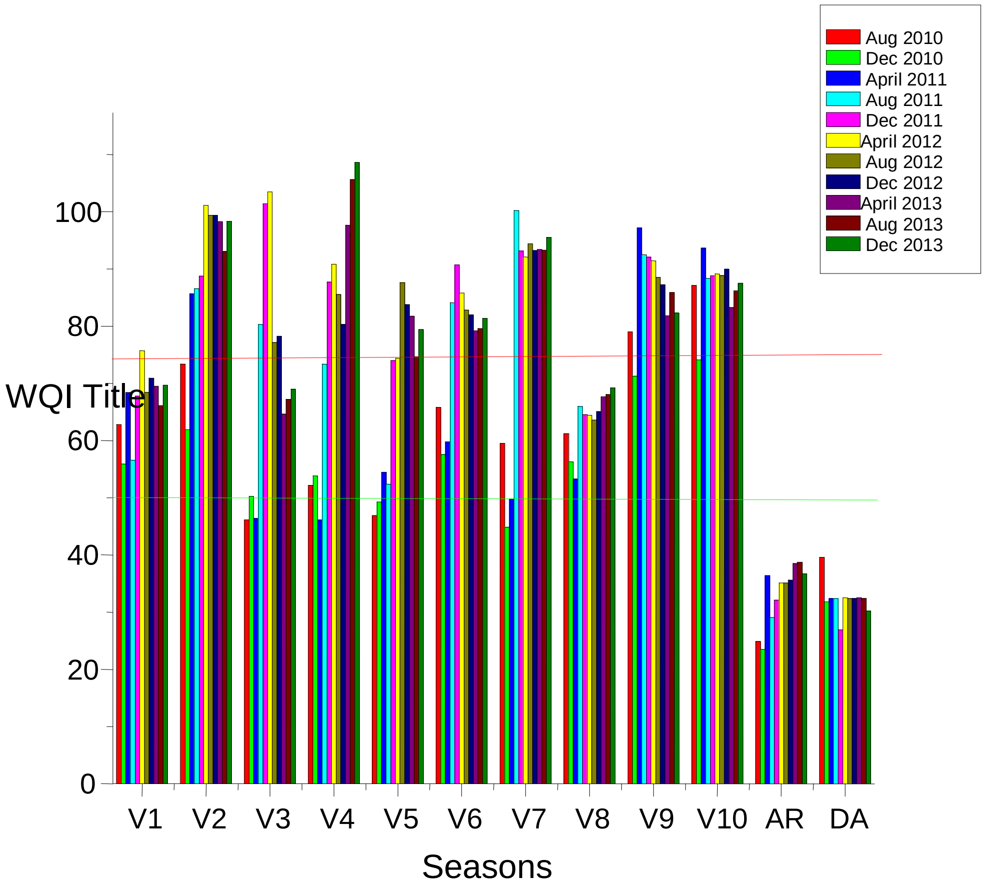


Fig. 4.2.3 Water quality index (WQI) of all the villages reservoirs

V1: Andra; V2 Aaguru; V3 Mentada; V4 Gajapathinagaram; V5 Seetaramapuram; V6 Nellimarla; V7 Saripalli; V8 A T Agraharam; V9 Nadipalli; V10 Konada; AR; Andra reservoir; DA; Denkada anicut

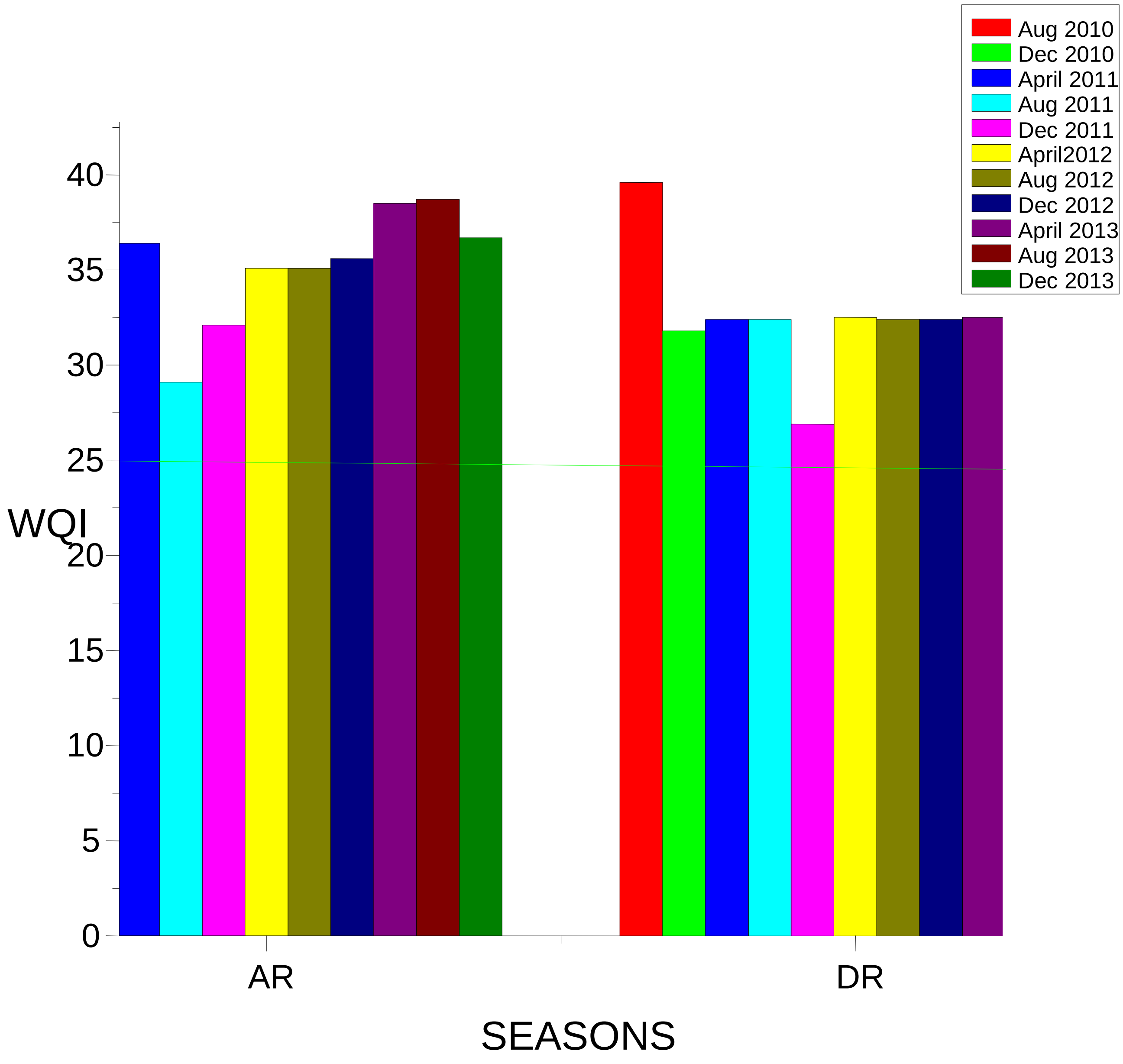


Fig. 4.2.4 Seasonal Variation in WQI for the two reservoirs

4.3 Irrigation water quality data of the reservoirs:

Additional water quality indices of the reservoirs viz. sodium absorption ratio (SAR), residual sodium carbonate (RSC), % Na and magnesium hazard were calculated. A perusal of Fig.4.3.1-4.3.4 and table 4.3 indicate that all the parameters are within the standard limits (IS: 2296-1992) [166] inferring that water of these reservoirs is suitable for irrigation.

Season	SAR		RSC		%Na		Mg-hazard	
	Andra	Denkada	Andra	Denkada	Andra	Denkada	Andra	Denkada
S1	1.537	1.31	-5	-3.8	27.9	24.3	46.4	46.4
S2	1.308	1.3	-1.5	-0.3	31.3	30.8	49.5	49.6
S3	0.376	0.79	-1.2	-1.07	9.71	18.9	32.9	49.2
S4	1.374	0.9	-0.03	-1.41	29.25	20.6	39.8	47.4
S5	1.632	0.97	-2.9	-1.63	27.75	21.3	37.2	45.7
S6	1.922	0.95	-3.5	-1.86	30.1	20.8	36.45	45.5
S7	1.922	0.87	-3.5	-1.4	30.1	19.5	36.45	46.8
S8	1.827	0.9	-2.9	-1.1	30	20.5	37.43	47.4
S9	1.759	0.92	-3.5	-1.8	28.5	19.9	28.6	49.5
S10	1.841	0.97	-3.8	-1.12	36.15	21.9	36.31	47.4
S11	1.93	1.15	-4.41	-1.29	29.2	25.1	38.1	43.1

SAR- sodium absorption ratio; RSC - Residual sodium carbonate

Table. 4.3 Irrigation water quality parameters of the two reservoirs

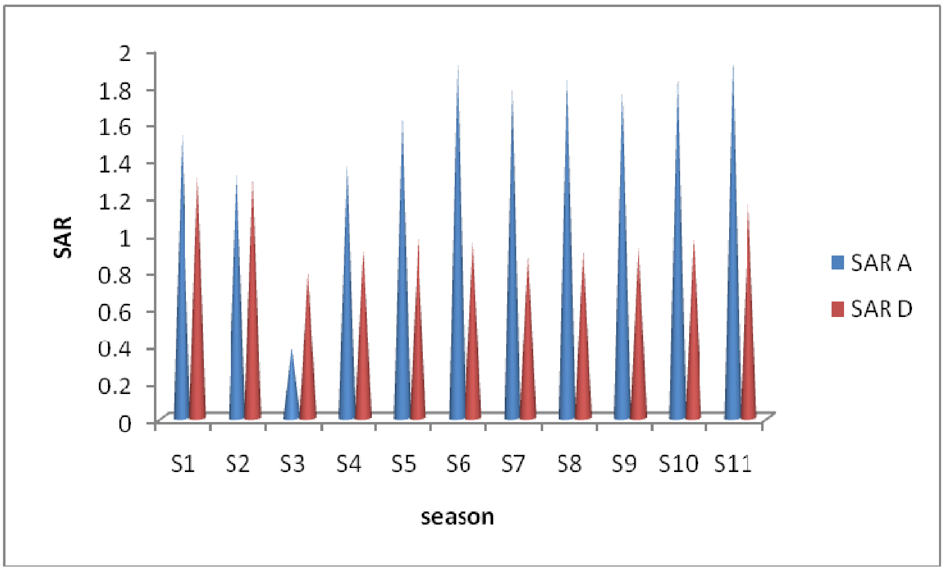


Fig.4.3.1 Seasonal variation of sodium absorption ratio (SAR)

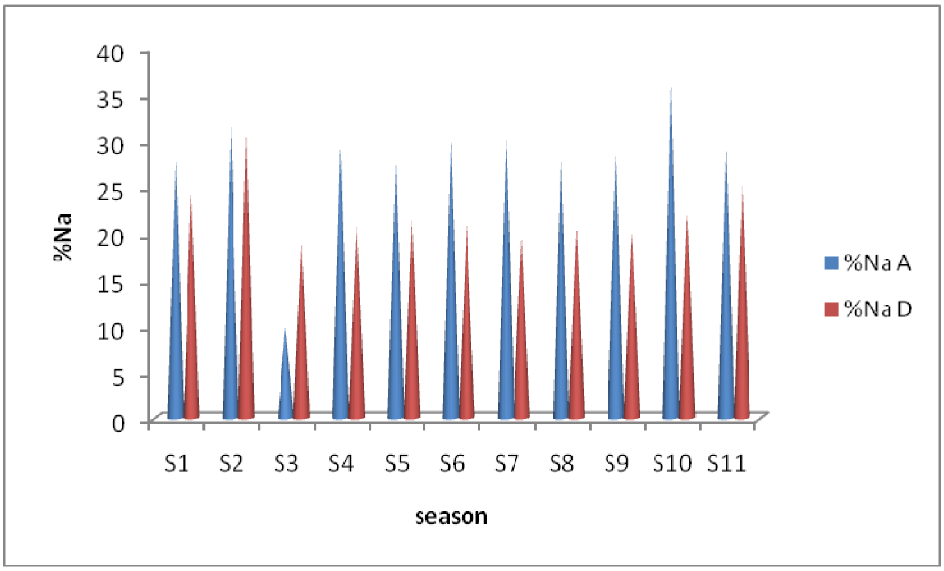


Fig.4.3.2 Seasonal variation of percentage sodium (%Na)

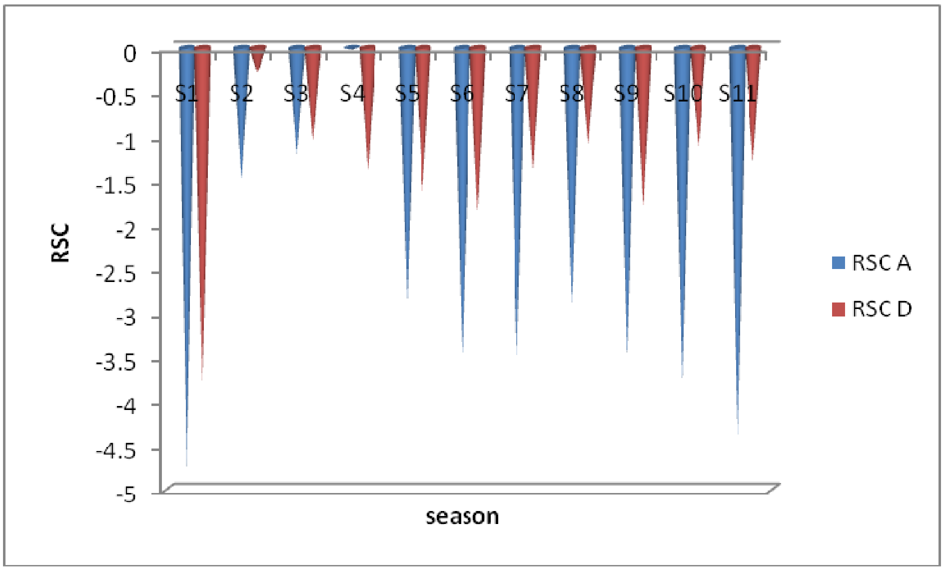


Fig.4.3.3 Seasonal variation of Residual Sodium carbonates (RSC)

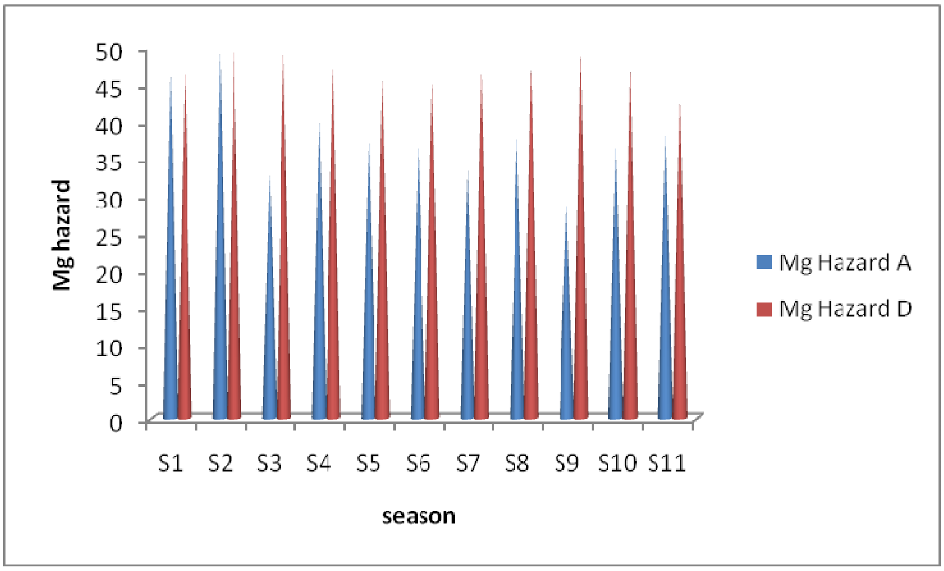


Fig.4.3.4Seasonal variation in Mg-hazard

4.4 HEAVY METAL ANALYSIS

Heavy metal contamination of water is hazardous to terrestrial, aquatic or marine life. Further, it not only affects agricultural/ dairy products, but also detrimental pediatric/adult/geriatric health.

The concentrations of Al (III), Si (IV), Cr (VI), Cd (II), Mn (II), Ba(II), Tl (III), V (V), Hg(II), As(III), Pb(II) and Sr (II) are estimated by ICP- MS for the water samples from bore wells and reservoirs. The concentrations of all heavy metals except Silicon are below limit of detection (LOD).

S.No	Name of the village/ reservoir	Concentration of Silicon in mg/L		
		April 2013	August 2013	December 2013
1	Andra	24.9	25.34	25.5
2	Aaguru	19.9	20.63	20.7
3	Mentada	19.01	19.4	19.5
4	Gajapathinagaram	20.17	20.17	20.01
5	Sitaramapuram	19.42	19.48	19.45
6	Nellimarla	25.01	25.51	25.5
7	Saripalli	28.98	29.25	29.35
8	A Tt Agraharam	27.98	28.92	28.62
9	Nadipalle	22.29	22.3	22.5
10	Konada	22.29	22.3	22.5
11	Andra reservoir	8.8	8.2	8.2
12	Denkada anicut	6.5	7.5	7.5

Table. 4.4 Seasonal variation of silicon

Fig.4.1a. Waste from houses and agriculture runoff fed into the river

Fig.4.1b Solid waste getting dumped into the river

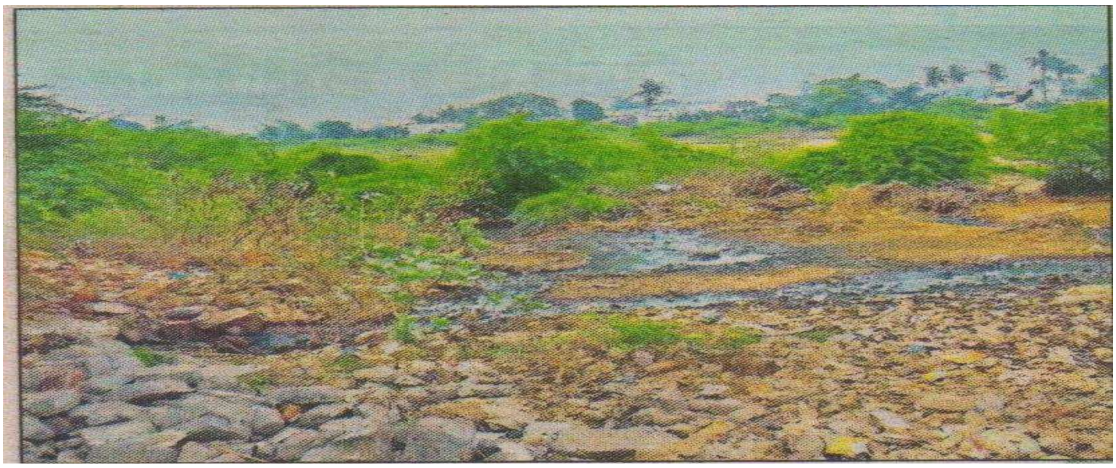


Fig.4.1c Household seepage and agricultural runoff fed into river