International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 6, Issue 3, March 2017 **ISSN 2319 - 4847**

Hydro-Chemical Classification and Microbiological Analysis of Groundwater in parts of Western Delta, West Godavari District, A.P, India

G.Suri Babu[1], E.U.B.Reddi[2], P.A.R.K.Raju[3], V.Vanisree[4], M.S.R.Reddy[4]

[1]Assistant Professor, WET Centre, Dept of Civil Engineering, S.R.K.R.Engineering College, Bhimavaram. W.G.Dist. A.P, India.

[2]Professor, Dept. of Environmental Sciences, Andhra University, Visakhapatnam, A.P, India.

[3]Dean, R&D, SRKR Engineering College, Bhimavaram, W.G.Dist, A.P, India.

[4]Professor, Dept. of Civil Engineering, SRKR Engineering College, Bhimavaram, W.G.Dist. A.P, India.vanisree.

ABSTRACT

Godavari river is the third largest river in India. The Godavari river flows in five different states and enters into state of Andhra Pradesh and then to Bay of Bengal. Most of the people in this Godavari delta region depends on agriculture and West Godavari district stood in state first place in paddy production. The water flows are shared among the six states of the Godavari basin. In recent years, due to declining nature of rainfall and surface water flow, farmers are forced depend on groundwater for their agriculture, drinking and basic needs. The overexploitation of groundwater leads to depletion of shallow aquifer and it is big threat to water crisis. In the present study groundwater quality was carried out in Kakaraparru-Bank canal region. About 27 groundwater samples were collected from 13 different villages from the study area to compare the seasonal variations and to monitor the water chemistry of physico-chemical and microbiological studies in summer and rainy seasons. The results were compared with WHO and BIS standards.

Keywords: Drinking water quality, Groundwater, Microbiological analysis, Seasonal variation, Brackish water.

1. INTRODUCTION

Groundwater utility has been rapidly increased due to unavailability of the surface water and failure of the seasonal monsoons. If water is suitable for drinking then it is suitable for every purpose. Determination of groundwater composition is of utmost importance from the point of view its suitability for various uses like drinking, irrigation and industries etc. an attempt has been made to understand the geochemical evolution of groundwater and assess its suitability for drinking and irrigation. Chemical classification also throws light on the concentration of various predominant cat ions, anion and their interrelationships. A number of techniques and methods have been developed to interpret the chemical data. Present study related to the chemistry and quality of groundwater has been carried out in Kakaraparru bank canal region in Godavari western delta, West Godavari district, Andhra Pradesh.

2. STUDY AREA

The study area covers Godavari Western Delta, which is situated in the Southern part of West Godavari District, Andhra Pradesh state. It is bounded in the East by the Godavari River, North by Eluru canal, West by Upputeru River and Kolleru Lake and South by Bay of Bengal. The study area lies between16°19'05.02" to 16°56'08.37" N latitudes and 80°58'16.10" to 81°51'26.10"E longitudes.

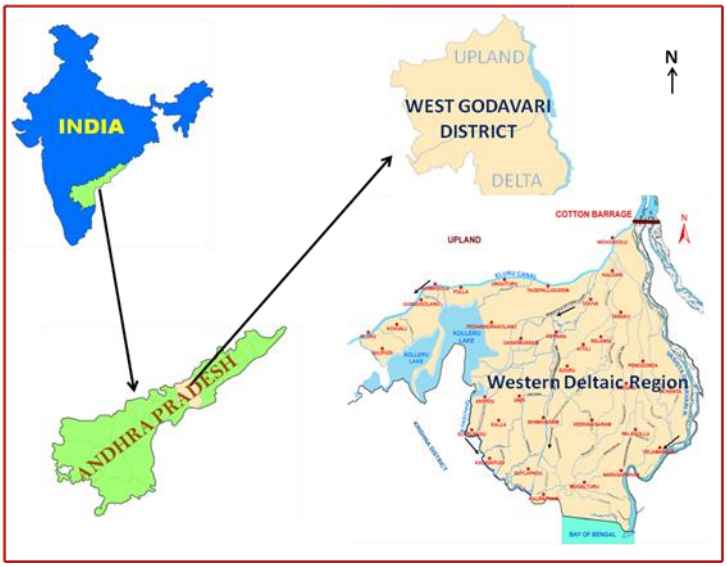

Fig.1. Stuidy area

Table:1 Sample location places, their codes along with Latitude and Longitude values

Sl. No	Sample Code	Place	Latitude	Longitude
1	A1	Kaldhari	16° 50' 14.582" N	81° 40' 39.198" E
2	A2	Vadluru	16° 47' 2.8381" N	81° 39' 10.1556" E
3	A3	Pydiparru	16° 44' 21.4048" N	81° 39' 54.522" E
4	A4	Gummampadu	16° 43' 1.2144" N	81° 38' 13.8228" E
5	A5	Attili	16° 41' 18.528" N	81° 36' 31.3812" E
6	E1	Nidadavolu	16° 54' 5.76" N	81° 39' 49.68" E
7	E2	Nandamuru	16° 50' 45.7692" N	81° 38' 47.9724" E
8	E3	Badampudi	16° 49' 33.1608" N	81° 28' 26.5656" E
9	E4	Chebrolu	16° 49' 44.202" N	81° 23' 31.8408" E
10	G1	Undrajavaram	16° 47' 21.588" N	81° 41' 55.0572" E
11	G2	Achanta	16° 36' 7.3282" N	81° 48' 27.7175" E
12	G3	Iragavaram	16° 41' 28.356" N	81° 42' 22.356" E
13	G4	Veeravasaram	16° 32' 11.9364" N	81° 37' 39.6804" E
14	G5	Palakoderu	16° 35' 10.1616" N	81° 32' 52.7532" E
15	G6	Bhimavaram	16° 33' 4.1623" N	81° 32' 23.1133" E
16	K1	Settipeta	16° 52' 16.1976" N	81° 40' 14.2392" E
17	K2	Tadiparru	16° 47' 15.7416" N	81° 43' 23.9268" E
18	K3	Khandavalli	16° 43' 14.4192" N	81° 46' 9.714" E
19	K4	Siddantham	16° 40' 19.0272" N	81° 48' 36.4968" E
20	K5	Nadipudi	16° 38' 55.5576" N	81° 50' 2.5728" E
21	K6	Burugupalli	16° 31' 29.64" N	81° 50' 36.96" E
22	N1	Peravali	16° 45' 4.0968" N	81° 44' 30.4116" E
23	N2	Ayitampudi	16° 40' 49.4508" N	81° 44' 24.36" E
24	N3	Maruteru	16° 37' 36.7644" N	81° 41' 20.364" E
25	N4	Vedangi	16° 49' 33.1608" N	81° 28' 26.5656" E
26	N5	Jinnuru	16° 32' 44.52" N	81° 43' 21.36" E

27	N6	Kavitam	16° 35' 48.4152" N	81° 43' 16.5396" E

3. METHODOLOGY

In order to assess the groundwater quality, a total of 15 water samples were collected from 15 villages. To observe the seasonal variation, ground water sampling was done in two seasons, summer and rainy season respectively. Samples were collected in acid washed sterile polyethylene bottles (1ltr), transported to the lab on ice, and analyzed. The samples were analyzed for most water quality influencing 12 Physico-chemical parameters such as P^H, TDS, EC, Total Hardness, Total Alkalinity, Chlorides, Ammonia, Nitrite, Nitrate, Sodium and Potassium; Microbiological parameters such as Most Probable Number and Total Faecal Coliform count. The parameters were determined by using the standard methods mentioned in the Table.1 for the examination of water. The feature of this report is to analyze the parameters and present the seasonal variation between these parameters.

Table.2: Methods for the analysis of water samples.

Sl No	Parameter	Units	Analytical Reference
1	P^H	---	P^H meter
2	TDS	ppm	TDS meter
3	EC	µS/cm	EC meter
4	Turbidity	NTU	Nephlometer
5	Total Alkalinity	ppm	Titrimetry
6	Total Hardness	ppm	Complexometric titration
7	Chlorides	ppm	Mohr's Method by Titrimetry
8	Ammonia	ppm	UV-VIS Spectrophotometer
9	Nitrate	ppm	UV-VIS Spectrophotometer
10	Sodium	ppm	Flame Photometer
11	Potassium	ppm	Flame Photometer

4. RESULTS AND DISCUSSION

4.1. Turbidity: Turbidity is the cloudiness of water caused by a variety of particles and is another key parameter in drinking water analysis. It is also related to the content of diseases causing organisms in water which may come from soil runoff. The values vary from 0.2NTU to 3.8NTU with an average of 1.3NTU during winter season, 0.1NTU to 4.7NTU with an average of 2.1NTU during summer season and 1.8NTU to 9.6NTU with an average of 4.5NTU during rainy season.

4.2. P^H: The P^H value is a measure of the intensity of the alkaline or acid condition of water. It is a way of expressing hydrogen ion concentration. Water containing a great deal of organic pollution will normally tend to be somewhat acidic. During the present study the values vary from 6.6 to 8.3 in winter season, 7.1 to 8.9 in summer season and 6.8 to 8.4 during rainy season.

4.3. Total Alkalinity (T.A): Alkalinity is the capacity of water neutralizing an acid solution. It provides an idea of natural salts present in water. If the alkalinity is high in water, taste becomes unpleasant. In the present study, alkalinity values vary from 96ppm to 520ppm with an average of 277ppm during winter season, 150ppm to 700ppm with an average of 382ppm during summer season, 50ppm to 500ppm with an average value of 258ppm in rainy season.

4.4. Ammonia: Measurement of ammonia is an index of water pollution. In the present study, ammonia values vary from 0.0ppm to 0.10ppm during both the winter and rainy seasons. Maximum value was observed during summer season at 0.78ppm.

4.5. Nitrates: Nitrates are a measure of the oxidized form of nitrogen and are essential macronutrient in aquatic environments. Most of the nitrates are from organic and inorganic sources, the former includes waste discharges and the later comprising chiefly artificial fertilizers. In the present study area, the nitrates from fertilizers are leached through soil into the subsurface aquifer system leading to groundwater pollution. The values range from 0.00ppm to 59ppm with an

average of 10.68ppm during winter season ,2.8ppm to 68.60ppm with an average of 31.60ppm during summer, 0ppm to 67.3ppm with an average of 18.41ppm during rainy season.

4.6. Sodium: presence of sodium in fresh water is an index of sea water intrusion. High levels of sodium impair the taste of drinking water. In the present study the sodium values vary from 28ppm to 162ppm with an average of 94ppm during winter season, 21ppm to 740ppm with an average of 193ppm during summer season and 14ppm to 170ppm with an average of 97.8ppm during rainy season.

Table.3: Chemical Analysis of Groundwater samples during Winter season

Sample Code	P^H	TDS (ppm)	EC (µS/cm)	Turb (NTU)	T-Alk (ppm)	T-Hard (ppm)	NH_3 (ppm)	NO_3 (ppm)	Na^+ (ppm)	K^+ (ppm)	Cl^- (ppm)
A1	7.7	1190	1690	1.0	510	328	0.00	23.50	108	159	187.8
A2	8.0	140	220	0.9	96	84	0.00	7.40	28	2	31.2
A3	8.2	870	1240	1.1	372	308	0.00	19.70	110	1	172.9
A4	7.9	780	1130	0.9	300	328	0.01	2.10	100	49	127.6
A5	8.0	760	1090	1.5	405	224	0.01	3.64	110	14	92.2
E1	7.4	510	740	3.8	325	290	0.00	6.07	83	2	56.7
E2	6.9	410	590	0.6	140	175	0.00	12.80	63	2	127.6
E3	7.0	1600	2260	0.5	190	490	0.01	4.70	146	41	514.0
E4	6.6	720	1000	0.2	135	320	0.01	10.60	85	29	187.8
G1	7.8	270	400	1.3	105	135	0.00	2.73	38	1	35.5
G2	7.2	330	480	2.5	220	130	0.02	3.52	88	20	49.6
G3	7.6	840	1180	0.5	350	180	0.00	4.40	133	33	148.8
G4	7.9	740	1060	1.0	110	320	0.10	3.03	106	2	205.6
G5	8.1	300	440	0.3	105	140	0.02	0.01	44	3	46.0
G6	7.9	180	270	0.8	105	130	0.10	3.90	37	1	35.5
K1	7.0	880	1240	2.8	355	430	0.01	12.27	104	5	198.5
K2	7.3	1010	1430	2.9	430	260	0.01	32.30	112	14	202.0
K3	7.9	800	1170	3.8	390	280	0.00	25.60	64	3	120.5
K4	7.5	700	1000	3.1	250	420	0.04	59.00	68	3	99.2
K5	8.0	500	720	2.5	420	325	0.10	7.40	93	9	99.2
K6	8.3	470	680	2.1	190	250	0.01	13.90	65	2	127.6
N1	8.1	820	1160	0.6	260	280	0.00	6.70	142	12	170.2
N2	8.2	530	770	0.2	410	170	0.00	0.00	119	7	35.5
N3	8.2	540	780	0.4	190	280	0.01	3.30	87	7	81.5
N4	7.7	540	800	0.4	200	135	0.00	7.30	109	8	63.8
N5	8.1	1130	1600	0.4	520	325	0.10	9.60	145	51	255.4
N6	8.2	940	1310	0.2	385	210	0.00	2.78	162	7	78.0

Table.4: Chemical Analysis of Groundwater samples during Summer season

Sample Code	P^H	TDS (ppm)	EC (µS/cm)	Turb (NTU)	T-Alk (ppm)	T-Hard (ppm)	NH_3 (ppm)	NO_3 (ppm)	Na^+ (ppm)	K^+ (ppm)	Cl^- (ppm)
A1	8.0	1160	1640	2.2	620	410	0.01	66.60	167	95	219.7
A2	8.2	1800	2540	1.2	325	630	0.01	46.50	197	34	496.3
A3	8.0	910	1300	1.2	385	470	0.01	29.10	130	5	206.6
A4	8.0	810	1160	1.6	368	370	0.01	43.90	112	41	205.6
A5	8.3	1700	2400	1.1	504	370	0.78	18.70	740	0	416.9
E1	7.9	560	800	1.6	320	360	0.03	6.07	119	7	134.7
E2	7.6	420	620	4.6	170	230	0.02	22.30	96	3	113.4

E3	7.3	1700	2400	4.7	210	620	0.02	65.80	175	70	588.5
E4	7.1	750	1050	4.0	150	345	0.06	67.80	103	44	262.3
G1	8.1	600	860	2.3	290	180	0.00	2.80	90	3	209.1
G2	8.7	1800	2540	2.1	700	520	0.00	11.70	650	105	496.3
G3	8.0	1160	1640	2.3	460	250	0.01	12.90	171	59	234.0
G4	8.3	910	1300	1.2	380	320	0.00	6.70	141	5	336.7
G5	8.2	710	1020	1.6	320	170	0.01	10.50	150	30	141.8
G6	8.1	1370	1940	2.1	470	600	0.01	68.60	123	1	400.5
K1	7.5	920	1290	3.5	370	440	0.04	20.10	158	5	397.0
K2	8.0	1130	1600	4.0	540	500	0.78	53.50	410	9	269.4
K3	8.5	850	1210	2.5	410	350	0.00	65.60	156	18	209.1
K4	8.5	730	1050	3.2	295	425	0.54	63.90	92	1	145.3
K5	8.5	530	780	2.6	470	340	0.01	24.57	149	14	109.8
K6	8.5	480	690	3.5	230	340	0.02	19.30	95	5	226.8
N1	7.8	840	1200	0.4	385	340	0.01	11.80	160	13	262.3
N2	8.3	500	730	0.5	340	170	0.00	25.80	127	16	53.9
N3	8.5	840	1240	0.1	350	230	0.18	11.90	21	3	134.7
N4	8.2	1020	1450	2.3	410	250	0	55.00	200	180	319.1
N5	8.9	1190	1690	0.4	400	460	0.10	10.80	148	58	390.0
N6	8.2	940	1350	0.4	440	250	0.01	11.07	330	130	226.8

Table.5: Chemical Analysis of Groundwater samples during Rainy season

Sample Code	P^H	TDS (ppm)	EC (μS/cm)	Turb (NTU)	T-Alk (ppm)	T-Hard (ppm)	NH_3 (ppm)	NO_3 (ppm)	Na^+ (ppm)	K^+ (ppm)	Cl^- (ppm)
A1	7.6	1190	1680	3.2	170	320	0.00	65.50	112	108	191.4
A2	8.1	1600	2260	3.0	220	570	0.00	39.40	140	31	218.3
A3	8.4	560	800	3.0	290	360	0.00	19.10	130	3	191.4
A4	7.7	760	1140	3.0	300	270	0.00	35.10	86	43	177.6
A5	7.7	900	1280	3.3	250	310	0.01	5.49	157	7	205.6
E1	7.1	540	780	3.6	315	230	0.01	5.32	87	0	78.0
E2	7.4	380	560	5.4	110	210	0.01	19.27	75	0	42.5
E3	7.2	1600	2260	6.6	180	560	0.03	63.60	45	22	581.50
E4	6.8	740	1040	9.6	110	320	0.1	65.3	141	9	205.60
G1	7.9	570	820	4.8	260	170	0.01	1.82	14	0	99.3
G2	8.3	1500	2100	4.2	500	190	0.01	8.22	120	10	354.5
G3	7.8	1040	1480	4.0	390	180	0.01	8.95	120	20	117.2
G4	8.2	670	960	3.7	350	280	0.01	6.53	113	2	163.1
G5	8.2	540	760	4.6	200	270	0.01	4.14	140	1	191.4
G6	7.9	1290	1840	3.2	450	480	0.03	67.30	170	10	226.9
K1	7.4	880	1240	5.2	310	360	0.00	11.06	91	0	191.4
K2	7.4	970	1380	5.4	400	460	0.00	18.70	78	0	191.4
K3	8.0	170	250	4.8	50	170	0.00	15.90	41	0	113.4
K4	7.6	650	930	5.6	250	300	0.02	18.70	40	0	63.8
K5	8.1	500	720	5.0	420	280	0.09	2.78	62	2	42.5
K6	8.0	450	650	6.1	170	280	0.06	3.57	40	0	56.7
N1	8.0	500	720	5.2	135	210	0.00	4.12	143	7	163.1
N2	8.1	460	660	5.1	220	160	0.00	1.10	30	8	28.4
N3	7.5	410	610	4.0	210	175	0.01	1.06	140	2	127.6
N4	7.5	260	380	1.8	170	120	0.00	0.00	47	8	56.8

N5	8.2	540	780	2.8	190	140	0.00	2.98	108	24	106.3
N6	8.3	800	1140	4.0	335	190	0.01	2.10	170	0	205.6

Table.6: Summary Findings of Groundwater Quality Analysis

Parameter	Standard Deviation			Median Value			Mean Value		
	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy
P^H	0.5	0.4	0.4	7.9	8.2	7.9	7.7	8.1	7.8
TDS (ppm)	332	405	393	720	910	650	685	975	758
EC (µS/cm)	463	565	549	1000	1290	930	980	1389	1082
Turbidity (NTU)	1.1	1.3	1.5	0.9	2.1	4.2	1.3	2.1	4.5
Total-Alk. (ppm)	133	125	112	260	380	250	277	382	258
Total-H (ppm)	102	132	122	280	350	270	257	368	280
NH_3 (ppm)	0.03	0.22	0.03	0.01	0.01	0.01	0.02	0.10	0.02
NO_3 (ppm)	12.59	23.39	22.27	6.70	22.30	8.22	10.68	31.60	18.41
Na^+ (ppm)	36	163	46	100	149	108	94	193	97.8
K^+ (ppm)	32	46	22	7	14	3	18	35	12
Cl^-(ppm)	99.5	134.2	112.4	120.5	226.8	163.1	131.5	266.9	162.6

Parameter	Maximum Value			Minimum Value		
	Winter	Summer	Rainy	Winter	Summer	Rainy
P^H	8.3	8.9	8.4	6.6	7.1	6.8
TDS (ppm)	1600	1800	1600	140	420	170
EC (µS/cm)	2260	2540	2260	220	620	250
Turbidity (NTU)	3.8	4.7	9.6	0.2	0.1	1.8
Total-Alk. (ppm)	520	700	500	96	150	50
Total-H (ppm)	490	630	570	84	170	120
NH_3 (ppm)	0.10	0.78	0.10	0.00	0.00	0.00
NO_3 (ppm)	59.00	68.60	6730.00	0.00	2.80	0.00
Na^+ (ppm)	162	740	170	28	21	14
K^+ (ppm)	159	180	108	1	0	0
Cl^-(ppm)	514	588.5	581.5	31.2	53.9	28.4

Table.7: Comparison of Groundwater quality with Drinking water quality standards WHO, BIS.

Parameter	WHO (1984)	BIS (2012)	Groundwater samples exceeding the safe limit					
			Winter		Summer		Rainy	
			No.of Samples	% of Samples	No.of Samples	% of Samples	No.of Samples	% of Samples
P^H	7-8.5	6.5-8.5	0	0%	2	7%	0	0%
TDS (ppm)	500	500	19	70%	24	89%	19	70%
Turbidity (NTU)	10	10	0	0%	0	0%	0	0%

Total-Alk. (ppm)	200	200	16	59%	25	93%	17	63%
Total-H (ppm)	100	300	10	37%	19	70%	9	33%
Cl^-(ppm)	200	250	2	7%	12	44%	2	7%
NH_3 (ppm)	0.1	0.1	0	0%	11	41%	0	0%
NO_3 (ppm)	45	45	1	4%	9	33%	4	15%

4.7. Microbiological quality of Groundwater: The presence of Total Coliform bacteria in water is measured in the form of MPN index, i.e. Most Probable Number in 100 ml water sample. Coliform bacteria naturally present in the gastro intestinal tract of humans and animals. The presence of Coliform bacteria in water indicates that, water has been contaminated with fecal matter of human or any other animal. The presence of faecal contamination is an indicator and potential health risk exists for individuals exposed to the water.

Presence of *E.coli* in water indicated recent fecal contamination and may indicate the possible presence of disease causing pathogenic microorganisms such as bacteria, virus and other parasites. MPN index and *E.coli* in drinking water are used as indicators to measure the degree of pollution and sanitary quality of drinking water.

In the present study, 7 villages (25% of samples) are found to be suitable for potable water out of 27 villages during winter and summer seasons and only 5 villages (18.5% of samples) are found to be suitable for potable water out of 27 villages during rainy season based on MPN Values. Badampudi (E3) and Maruteru (N3) villages were found to be no contamination in all the three seasons.

Table.8: Seasonal variations of Microbiological Analysis of Groundwater samples

Sample Code	Winter		Summer		Rainy	
	MPN/100ml	TFC/100ml	MPN/100ml	TFC/100ml	MPN/100ml	TFC/100ml
A1	150	93	43	0	75	75
A2	≥2400	1100	0	0	≥2400	240
A3	0	0	≥2400	≥2400	≥2400	1600
A4	93	43	≥2400	≥2400	43	15
A5	230	23	≥2400	120	320	93
E1	460	43	0	0	0	0
E2	0	0	15	3	64	11
E3	0	0	0	0	0	0
E4	240	0	0	0	≥2400	≥2400
G1	240	23	23	0	≥2400	≥2400
G2	460	23	0	0	93	0
G3	93	43	≥2400	23	≥2400	≥2400
G4	23	0	≥2400	150	≥2400	460
G5	240	9	19	14	23	3
G6	0	0	43	3	15	0
K1	≥2400	1100	0	0	39	9
K2	93	23	240	36	3	0
K3	4	0	240	9	0	0
K4	75	23	93	23	240	15
K5	75	9	93	23	9	0
K6	43	3	≥2400	150	7	0
N1	9	0	240	93	0	0

N2	0	0	≥2400	43	43	0
N3	0	0	0	0	0	0
N4	≥2400	240	≥2400	9	23	0
N5	≥2400	460	460	43	93	23
N6	0	0	43	9	150	15

5. CONCLUSION

Chemical classification also throws light on the concentration of various predominant cat ions, anion and their interrelationships. A number of techniques and methods have been developed to interpret the chemical data. Zaporozee (1972) has summarized various modes of data representation and discussed their possible uses.

5.1. Classification based on total dissolved solids (TDS):

There is a great geological variability in chemical composition of groundwater. Such variability is a function of geological substrate in which groundwater is found, the residence time of water in the subsurface and groundwater interactions (Loaiciga 2000). Groundwater chemistry alters when the water flows through the surface geological environment which increases the dissolved solids and major ions (Suresh et al. 2009).

Groundwater can be classified on the basis of total dissolved solids (Freeze & Cherry 1979) as given in the Table.9. It is the important governing factor that determines suitability of water for various uses (Nanjunndasamy et al.2007).

Based on the above classification, the data generated during the period of study show that 29% of water belongs to freshwater type and 70% belongs to brackish water category in both winter and rainy seasons. 11.11% of water belongs to freshwater type and 88.88% belongs to brackish water category in summer season.

Table.9 Classification of water based on TDS

TDS Range (ppm)	Classification	Winter	Summer	Rainy
<500	Fresh water	29.62%	11.11%	29.62%
500-30000	Brackish water	70.37%	88.88%	70.37%
30000-50000	Saline water	0.0%	0.0%	0.0%
>50000	Brine water	0.0%	0.0%	0.0%

5.2. Classification based on Electrical Conductivity (EC): Groundwater can also be classified into five categories on the basis of electrical conductivity Table.10 In the present study, the data reveal that 7.40% belong to excellent category, 11% belongs to good, 33.33% samples were permissible limit, 37.% of samples are brackish type, 11.11% belongs to saline category in winter season. 22.22% samples were permissible limit, 44.4% of samples are brackish type, and 33.3% belongs to saline category in summer season. 3.7% belong to excellent category, 3.7% belongs to good, 48.1% samples were permissible limit, 25.9% of samples are brackish type, 18.5% belongs to saline category during rainy season.

Table.10: Classification of water based on EC

EC Range (μS/cm)	Classification	Winter	Summer	Rainy
0-333	Excellent	7.4%	0.0%	3.7%
333-500	Good	11.1%	0.0%	3.7%
500-1000	Permissible	33.3%	22.2%	48.1 %
1000-1500	Brackish	37.0%	44.4%	25.9

				%
1500-10000	Saline	11.1%	33.3%	18.5 %

5.3. Classification based on Total Hardness (T-H): Hardness in water is caused by divalent cat ions. Hardness is classified as temporary and permanent hardness. Temporary hardness is mainly due to carbonate and bicarbonate of calcium and magnesium. Permanent hardness is due to sulphates and chlorides of calcium and magnesium. Hardness is used as an equivalent concentration of calcium carbonate. It is also used as an indicator of the rate of scale formation in hot water heaters and low pressure boilers. Majority of the water samples of the study area belongs to hard and very hard type, Table.11.

Table.11: Classification of water based on Total Hardness

Total Hardness Range (ppm)	Classification	Winter	Summer	Rainy
0-75	Soft	0.0%	0.0%	0.0%
75-150	Moderately Hard	22.2%	0.0%	7.4%
150-300	Hard	40.7%	29.6%	59.2 %
>300	Very Hard	37.0%	70.3%	33.3 %

5.4. Classification based on chlorides/ Stuyfzand's Classification:
The hydro-chemistry of groundwater of different environments could be assessed using the scheme proposed by Stuyfzand's (1989). This scheme combines special features of other existing classifications with a new type of assessing criteria for sub-divisions. This has been successfully used to interpret hydro geological groundwater of an aquifer (Subramanian 1994, Sathish & Puttaiah 2006). The main type of Stuyfzand's classification is determined by chloride concentration, Table.12.

As per Stuyfzand's classification, 44.4% of total groundwater samples with respect to all the three seasons belong to fresh category, 39.4% fresh brackish and 14.8% of samples belong to brackish category.

Table.12: Classification of water based on Chlorides

Chloride Range (ppm)	Classification	Winter	Summer	Rainy
<5	Oligohaline	0.0%	0.0%	3.7%
30-150	Fresh	66.6%	25.9%	40.7%
150-300	Fresh-brackish	29.6%	40.7%	48.14 %
>300	Brackish	3.7%	33.3%	7.4%

ACKNOWLEDGEMENT
This is a part of the work under the project No. DST/TM/WTI/2K14/183, sponsored by Technology mission cell: Water and Solar Energy, Department of Science and Technology, New Delhi. The authors expressed their sincere gratitude to Dr. D.R.PrasadRaju, Former Scientist-G/Advisor & Head (TMC), Dr.SanjayBajpai, Associative Head, Scientist-F & Dr. Neelima Alam, Scientist-D, Technology Mission Cell: Water and Clean Energy, Department of Science and Technology and Government of India, New Delhi for their encouragement and guidance. We are also acknowledging Dr.M.Jagapathi Raju, Principal Investigator, Head, Civil Engineering Department, WET Centre Staff, beloved Principal sri.G.P.Saradhi Varma & Management of S.R.K.R. Engineering College, Bhimavaram for their support in our research work.

REFERENCES

[1] APHA (2005), Standard methods for the examination of water and waste water. 21st
[2] Banerjea S. M., (1967), Water quality and soil condition of fishponds in states of India in relation to fish production, Indian journal of Fisheries, 14(1&2), pp 115-144.
[3] BIS (2012) Drinking water specifications. Bureau of Indian Standards IS 10500.
[4] Chisty. N., (2002), Studies on Biodiversity of Freshwater Zooplankton in Relation to Toxicity of selected Heavy Metals. Ph. D. Thesis submitted to M.L Sukhadia Univeristy Udaipur.
[5] Damotharan P, Permal NV, Perumal P., (2010), Seasonal variation of physico-chemical characteristics of Point Calimere coastal waters (South east coast of India). Middle-East Journal of scientific research, 6(4), pp 333-339.
[6] Devaraju TM, Venkatesha MG. Singh S., (2005), Studies on physic-chemical parameters of Muddur Lake with reference to suitability for aquaculture. Nat. Environment and pollution technology, 4, pp 287-290.Edn., Washington, D. C.
[7] Freeze, R.A. and Cherry, J.A. 1979. Groundwater. Prentice Hall, Inc., 604 p. Englewood Cliff. New Jersey.
[8] Garg RK, Saksena DN, Rao RJ. (2006b). Assessment of physic-chemical water quality of Harsi Reservoir, district Gwalior, Madhya Pradesh, Journal of Ecophysiology and Occupational Health, 6, pp 33-40.
[9] Handa, B.K. 1965. Modified Hill piper diagram for presentation of water analysis data. Curr. Sci., 34: 131-134.
[10] Hujare, M.S., (2008), Seasonal variation of physico-chemical parameters in the perennial tank of Talsande, Maharashtra, Ecotoxicology and Environmental Monitoring, 18(3), pp 233-242.
[11] Jayaraman PR, Ganga DT, Vasudevan NT., (2003), Water Quality Studies on Karamana River, Thiruvananthapuram District, South Kerala, India, Pollution research, 22(1), pp 89-100.
[12] Kadam, M. S. Pampatwar D. V. and Mali R.P., (2007), Seasonal variations in different physico-chemical characteristics in Mosoli reservoir of Parbhani district, Maharashtra, Journal of aquatic biology, 22(1), pp 110-112.
[13] Kirubavathy AK, Binukumari S, Mariamma N, Rajammal T., (2005), Assessment of water quality of Orthupalayam reservoir, Erode District, Tamil Nadu, Journal of Ecophysiology and Occupational Health, 5, pp 53-54.
[14] Kodarkar, M. S., A.D. Diwan, N.Murugan, K.M. Kulkarni and Anuradha Remesh., (1998), Methodological water analysis (physico-chemical, biological and microbiological) I.A. A. B. Publication, Hyderabad.
[15] Laoiciga, H.A., Maidment, D.R. and Yaldes, J.B. 2000. Climate-change impacts in a regional karst aquifer Texas, USA. Journal of Hydrology, 227: 173-194.
[16] Prasanna M, Ranjan P C., (2010). Physico-chemical properties of water collected from Dhamra estuary, International Journal of Environmental Science, 1(3), pp 334-342.
[17] M.S.V.K.V.Prasad, G.Siva Praveena, Ch.Durga Prasad and P.V.V.Prasad Rao, "Assessment of Ground water quality in and around Narsapur-Mogalthur mandals of West Godavari district in Andhra Pradesh, India", International Research Journal of Environmental Sciences, 4(8), 8-12, August (2015).
[18] Sathish, N.S and Puttaiah, E.T. 2006. Nitrate and fluoride level in groundwater of Chikmangalur city. World Conference on Environmental Hazards, Kalpataru Institute of Technology, Tiptur, India.
[19] Sawyer, C.N. and Mc Carthy, D.L. 1967. Chemistry of Sanitary Engineers, 2nd MC Graw Hill, New York, pp.518.
[20] Stuyzand, P.J. 1989. A New hydro chemical classification of water type with examples application. IAHS, 184: 89-98.
[21] Suresh, T., Kottureshwara, N.M and Revanna Siddappa, R. 2009.Assessment of Groundwater quality in and around Bellary city of Karnataka. Nature Environment and Pollution Technology.
[22] Tirrey Vijaya Prasadini, "Physico-Chemical Characteristics Variation in Pre-Monsoon and Post-Monsoon of Ground WQuality at Bhimavaram Industrial Area, West Godavari, India", International journal of Pharmaceutical and Chemical Sciences, Vol.4(3), Jul-Sep 2015
[23] Todd, D.K (1980) Ground water Hydrology. Wiley, New York.
[24] Venkateswara Rao.B, "Physicochemical analysis of selected groundwater samples of Vijayawada rural and urban in Krishna district, AP, India" International Journal of Environmental Sciences, 2(2), 2011
[25] WHO, (1984). Guidelines for drinking water quality. World Health Organization, Geneva.
[26] Zaporozee, A. 1972. Graphical interpretation of water quality data Groundwater, 10(2): 32-34.