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WATER QUALITY INDEX USING GIS AND SUITABILITY FOR DRINKING PURPOSE IN AND AROUND BADVEL TALUKA OF KADAPA DISTRICT, ANDHRA PRADESH, INDIA

D. Janardhana Rao[1], Swami A.V.V.S.[1], Raghu Babu K.[2] and B. Hari Babu[3,*]
[1]Department of Environmental Sciences, Acharya Nagarjuna University, Guntur-522510, (Andhra Pradesh) India
[2]Department of Geology, Yogi Vemana University, Kadapa-516003, (Andhra Pradesh) India
[3]Department of Chemistry, Acharya Nagarjuna University, Guntur-522510, (Andhra Pradesh) India
*E-mail:dr.b.haribabu@gmail.com

ABSTRACT

The present study is aimed to analyze the ground water quality at Badvel Taluka of Kadapa district, Andhra Pradesh. In the present study, the Bureau of Indian Standard (BIS) values have been adopted. Water Quality Index (WQI) was used to determine the suitability of groundwater for drinking purpose. In this study 60 station ground water samples were collected during pre-monsoon (July 2014) and post monsoon (December 2014) seasons and analyzed for 9 physico chemical parameters for pre- and post-monsoon seasons (2014). WQI values varied 48.85 to 84.68 during pre-monsoon, 40-78 during post monsoon. pH range in pre-monsoon varies 7.11 to 8.58 during post-monsoon 7.02 to 8.60. Total Hardness ranges 394 to 607(mg/L) in pre-monsoon and 295 to 575 (mg/L) during post monsoon. Total alkalinity, nitrate and calcium are within the BIS (1998) permissible limits. The groundwater quality in the study area is mixed Ca^{2+}, type but few samples showing mixed $Ca^{2+}$$Cl^-$ type in both the pre monsoon and post monsoon season. The North east part of the study area is poor category for drinking in pre monsoon and post monsoon this category is reduced according to WQI.

Keywords: Ground water, water quality index, Total hardness, Total Alkalinity, Badvel.

INTRODUCTION

Water is an universal solvent and it dissolves the minerals from rocks in which it is stored and thus the chemical and physical attributes of ground water depend on geology of that area, Groundwater though contributes only 0.6% of the total water resources on earth, it accounts for nearly 80% of the rural domestic water needs and 50% of the urban water needs in the developing countries like India. Groundwater represents an important source of safe drinking water because surface water does not possess certain properties, but currently its quality is threatened by a combination of over-extraction, chemical contamination. In India more than 80 percent of the rural population depends on untreated groundwater for potable water supplies. Water Quality Index is an important factor to judge environment changes, which are strongly associated with social and economic development.

This index allows a general analysis of water quality on many levels that affect a stream's ability to host life. This was derived by weightage arithmetic method. It is one of the most effective ways to communicate information on water quality trends to policy makers to shape strong public policy and implement the water quality programs. WQI is defined as a rating that reflects the composite influence of different water quality parameters.

The objectives behind the study were to develop an overall picture of the groundwater quality using WQI, assessment of seasonal variation in the ground water quality, suitability of ground water for different purposes and contamination.

EXPERMENTAL

Study Area

The Badvel Taluka of Kadapa District of Andhra Pradesh, India occupies an area of 626 km² and has a population of 11, 59,450 of which 11.21% are rural. It is the largest in area among the agriculture Taluka of rayalaseema districts. The coordinates of the Badvel Taluka from Reddypalle to Moddur 78^0 52' 40"E 15^0 01' 14" N and 79^0 08' 24" E 14^0 31'48" N (Figure-1); the average elevation (above msl) is10 m (30ft). It is bounded on the north by Prakasam and Kurnool Districts, on the south by Chittoor and Ananthapur Districts, on the east by Nellore and on the west by Kurnool Districts. The district headquarters is located at K adapa.

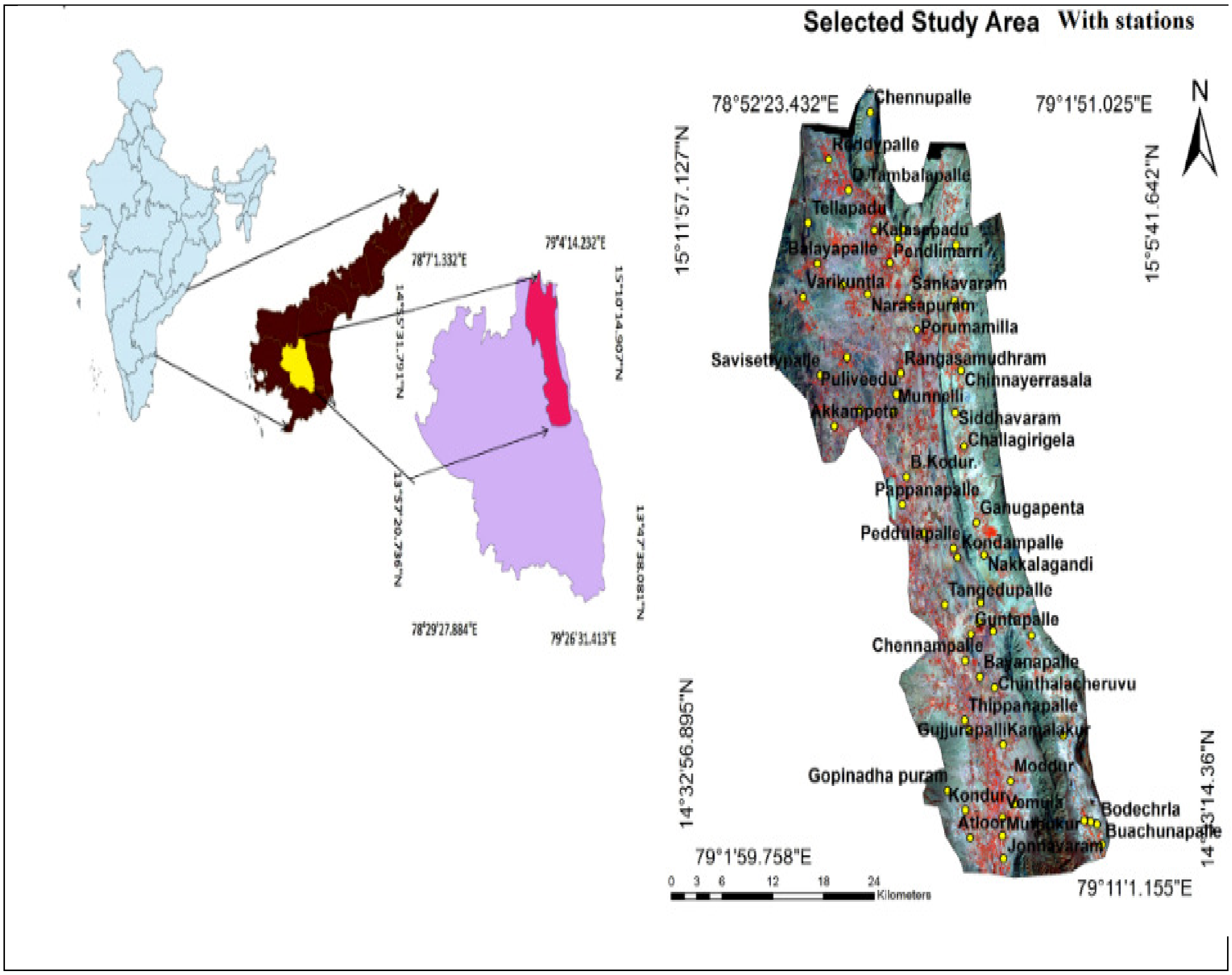


Fig.-1: Selected study area with sampling stations

Materials

The current study was designed to investigate the conditions of groundwater contamination in the study areas. The hydro geochemistry study was undertaken by randomly collected 60 groundwater samples from bore wells covering entire Badvel Taluka during June and December 2014. Samples were drawn with a 2 L pre cleaned plastic polyethylene bottle for a period of 6 months from June 2014 to December 2014. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the groundwater. Water quality parameters such as pH and electrical conductivity (EC) were analyzed immediately. Other parameters were later analyzed in the laboratories of Yogi Vemana University, Kadapa. Total dissolved solids (TDS) were computed by multiplying the electrical conductivity (EC) by a factor (0.64), of ground water collected at sixty different stations within the Badvel Taluka.

Methodology

Two times (pre and post monsoons) continuous monitoring involved comprehensive physicochemical analyses encompassing estimation of major cations (Ca^{2+} and Mg^{2+}), anions (Cl^-, NO_3^-, F^-) besides general parameters (pH, TDS, Total alkalinity, Total hardness). In situ parameters like pH, TDS, etc. has measured immediately in the field immediately after sampling. The standard analytical procedures as recommended by the (American Public Health Association (2005) was employed in the present study (Table-1). The suitability of the ground water from these two seasons for drinking, and domestic purposes was evaluated by comparing the values of different water quality parameters with those of the Bureau of Indian standards (BIS 1998 and revised, 2003) (Table:1) guideline values for drinking water.

GIS-modelling

For creating the spatial distribution maps, GIS has emerged as a powerful tool. GIS can be used for storing, displaying, and analysing spatial data. By using this data, we can make decisions in several areas including environmental and engineering field. The spatial distribution maps were prepared to show the variation in concentrations of the various chemical parameters using inverse distance weighted (IDW) raster interpolation technique of the spatial analyst module in ArcGIS® 9.1. The general formula used in the IDW interpolation method was -

$$\hat{Z}(S_O) = \sum {}^{N}_{i=I} \lambda i \, Z(S_i)$$

Where, Z (SO) is the value we are trying to predict for S_0, N is the number of measured sample points surrounding the prediction location that will be used in the prediction, and *ki* is the weights assigned to each measured point that we are used here. These weights will decrease with distance; Z (Si) is the observed value at the location Si. When we compare several interpolation techniques, IDW with a squared distance term gives the more consistent results in this study, spatial distribution maps were generated for the selected water quality parameters, namely pH, TDS, TH, Total Alkalinity, Chloride, Nitrates, Fluoride, Ca^{2+}, Mg^{2+}, and WQI.(Fig.2,3,4,5,6,7,8,9,10,11).

Table-1: Analytical methods adopted along with the BIS desirable and permissible limits

S. No	Category of parameters	Characteristics .	Analytical method	Unit	BIS limits (1998 and revised, 2003)	
					Desirable	Permissible
1	General	pH	Electrode	–	6.5–8.5	6.5–8.5
2		Total dissolved solids	Conductivity-TDS meter	mg/L	500	1500
3		Total Alkalinity	Titrimetric	mg/L	200	600
4		Total hardness as a $CaCo_3$	EDTA titrimetric	mg/L	300	600
5	Major Cations	Calcium as Ca^{2+}	EDTA titrimetric	mg/L	75	200
6		Magnesium as a Mg^{2+}	EDTA titrimetric	mg/L	30	100
7	Major anions	Chlorides	Argent metric titration	mg/L	250	1000
8		Nitrates (as NO_3)	Ion selective electrode (ISE)	mg/L	45	45
9		Fluoride(as F^-)	Ion selective electrode (ISE)	mg/L	1	1.5

Water Quality Index

The WQI provides a comprehensive picture of the quality of ground water for most drinking uses. WQI is defined as a rating that reflects the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption. Hence, for calculating the WQI in the present study, 9 parameters namely, pH, Total Dissolved Solids, Total Hardness, Total alkalinity, chloride, nitrate, fluorides, Calcium and Magnesium, have been considered (Table-2).

There were three steps for computing WQI of a water sample.

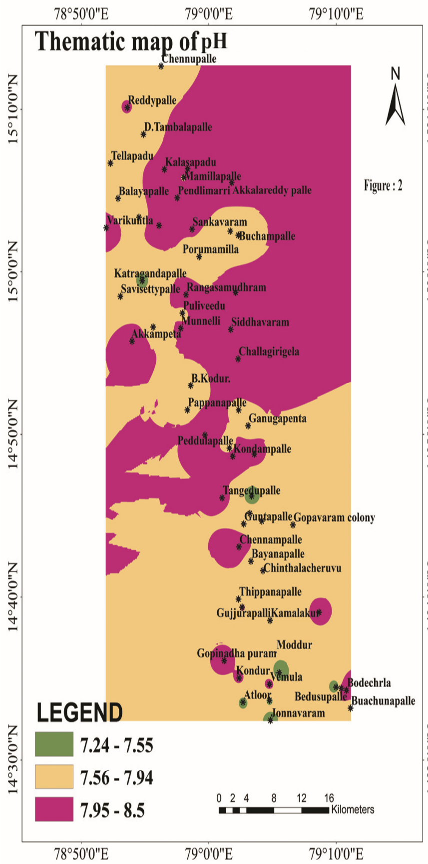
1. Each of the chemical parameters was assigned a weight (w_i) based on their perceived effects on primary health/ their relative importance in the overall quality of water for drinking purposes (Table-2). The highest weight of 5 was assigned to parameters which have the major effects on water quality and their importance in quality (viz., NO_3^-, and TDS) and a minimum of 2 was assigned to parameters which are considered as not harmful (Ca^{2+}, Mg^{2+}).
2. Computing the relative weight (Wi) of each parameter using Eq.-1. (Table-2) present the weight (Wi) and calculated relative weight (Wi) values for each parameter C. A quality rating scale (qi) for each parameter is computed by dividing its concentration in each water sample by its respective standard according to the guidelines laid down by BIS (1998) and then, the result was multiplied by 100 using Eq.-2.
   $$Wi = [w_i / \sum_{n=1}^{n} wi] \quad (1)$$
   Where, W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters.
   $$qi = [C_i / S_i] X\ 100 \quad (2)$$
   Where, q_i= quality rating, C_i=concentration of each chemical parameter in each water sample in mg/L, S_i = Indian drinking water standard (BIS 1998) for each chemical parameter in mg/L except for pH.
3. Finally, for com-putting the WQI, the water quality sub-index (SI_i) for each chemical parameter is first determined, which is then used to determine the WQI as per the Eqs.-3and 4.
   $$SI = W_i q_i \quad (3)$$
   $$WQI = \sum_{i-I}^{n} SI_i \quad (4)$$
   Where, SI_i is the sub-index of *i* th parameter; q_i is the rating based on concentration of i^{th} parameter and n is the number of parameters.

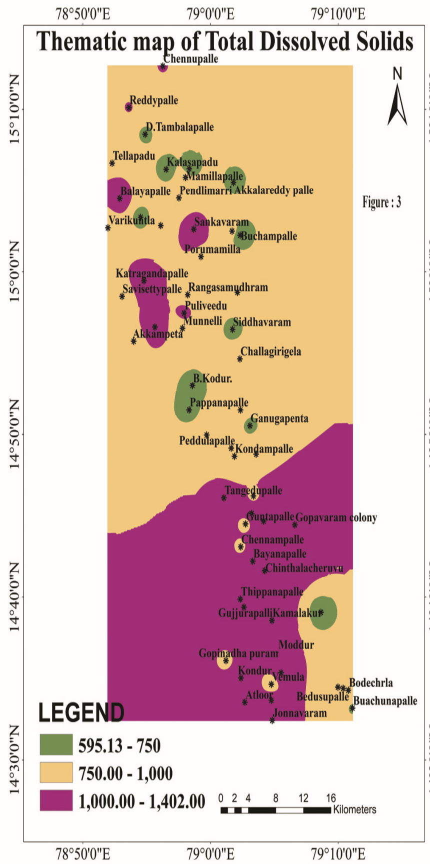
RESULTS AND DISCUSSION

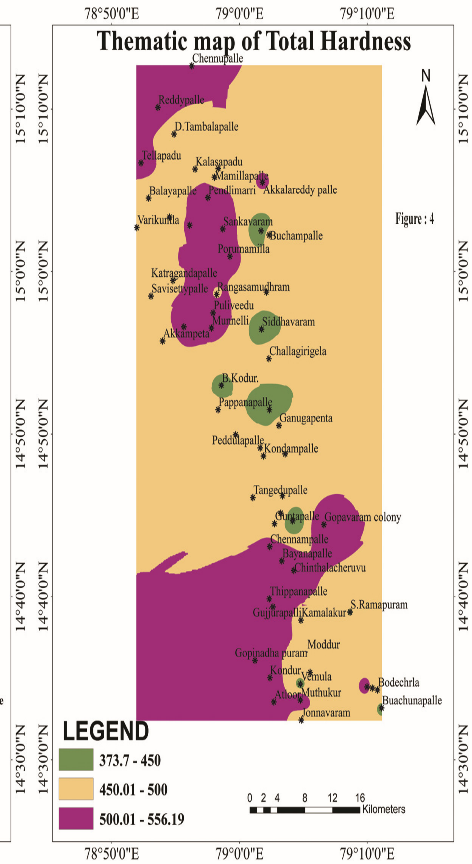
The results obtained were evaluated in accordance with the standards prescribed by Bureau of Indian Standards (1998) under Indian standard drinking water specification IS: 10500:2012.

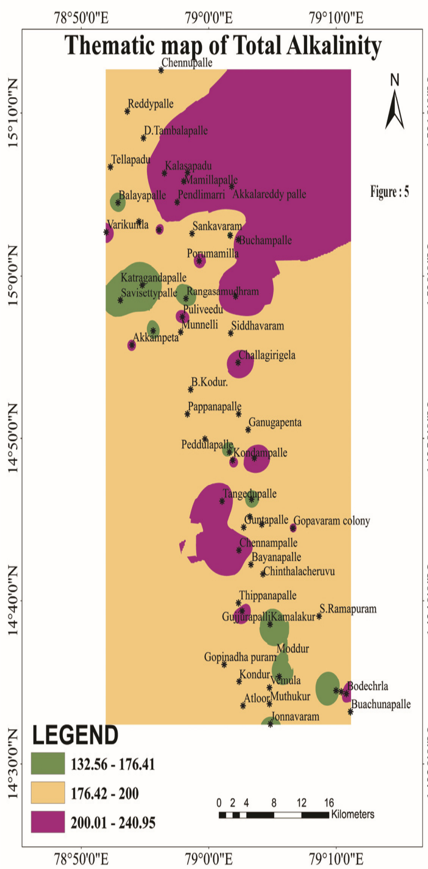
Concentration of hydrogen (pH) is a numerical expression that indicates the degree to which water is acidic or alkaline, with the lower pH value tends to make water corrosive and higher pH provides taste complaint and negative impact on skin and eyes. pH values ranged from 7.10 to 8.58 during pre-monsoon period and 7.02 to 8.60 during post monsoon period.

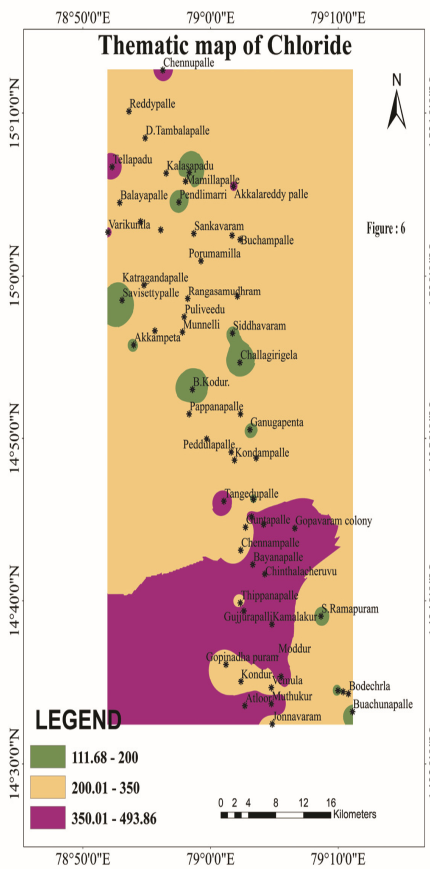
Total dissolved solids (TDS) are used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants. The TDS values in the present study vary from 561 to 1432 (mg/L) during pre-monsoon and 521 to 1395 (mg/L) in post-monsoon period. All station samples of pre and post monsoons were below the permissible limit (1500 mg/l) prescribed by BIS (1998). Most of the stations TDS values in the study area were beyond the permissible limits of BIS.

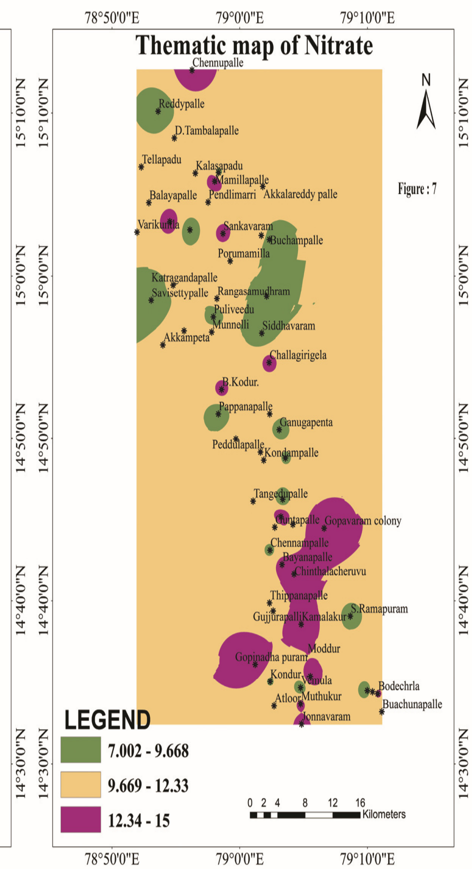

Thematic map of pH
Figure : 2
LEGEND
7.24 - 7.55
7.56 - 7.94
7.95 - 8.5
Kilometers


Thematic map of Total Dissolved Solids
Figure : 3
LEGEND
595.13 - 750
750.00 - 1,000
1,000.00 - 1,402.00
Kilometers


Thematic map of Total Hardness
Figure : 4
LEGEND
373.7 - 450
450.01 - 500
500.01 - 556.19
Kilometers


Thematic map of Total Alkalinity
Figure : 5
LEGEND
132.56 - 176.41
176.42 - 200
200.01 - 240.95
Kilometers


Thematic map of Chloride
Figure : 6
LEGEND
111.68 - 200
200.01 - 350
350.01 - 493.86
Kilometers


Thematic map of Nitrate
Figure : 7
LEGEND
7.002 - 9.668
9.669 - 12.33
12.34 - 15
Kilometers

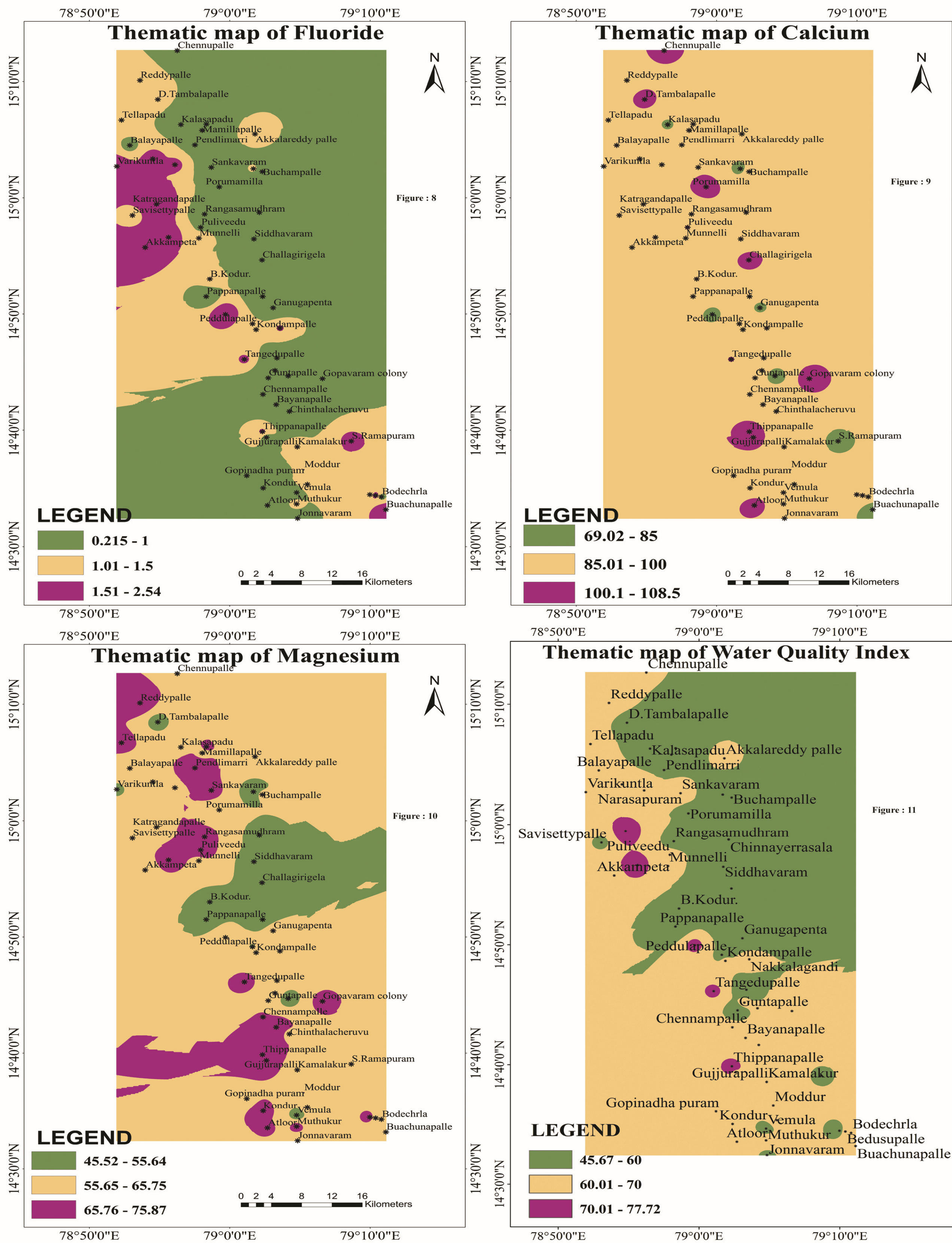


Fig-2: Thematic maps for average of Pre monsoon and Post monsoon seasons

Total hardness is a measure of the capacity of water to the concentration of calcium and magnesium in water and is usually expressed as the mg/l of $CaCo_3$ concentration. In the present study, the total hardness of the water samples ranges from 378 to 607 (mg/L) during pre-monsoon and 295 to 575 (mg/L) during post monsoon. 99% of samples within the permissible and only one station sample was exceeded the permissible limits in pre monsoon, and but all the stations in post monsoon were recoded within the permissible standard limit (600 mg/L) prescribed by BIS.

Total Alkalinity is a measure of the ability of water to neutralize acids. The alkalinity varies from 110 to 260 (mg/L) in pre-monsoon and 132 to 258 (mg/L) during post monsoon period. All samples were recorded below the standard limit (600 mg/L) as prescribed by BIS in pre monsoon and post monsoon. Large amount of alkalinity imparts a bitter taste, harmful for irrigation as it damages soil and hence reduces crop yields.

The higher concentrations of chloride in the groundwater may be because of the percolation of domestic sewage and irrigated land water. In the present study, chlorides content of underground water varied from 112 to 490 (mg/L) in pre-monsoon and 100 to 560 (mg/L) during post monsoon period. All samples were in pre-post monsoon below the standard limit (1000 mg/l) prescribed by BIS. Increase of chlorine level in water is injurious to people suffering from heart and kidney disease.

Nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of agricultural runoff, refuge dump runoffs, or contamination with human or animal wastes (Nas and Berktay, 2006). The value of Nitrate, in the present study lies between is 6 to 20 (mg/L) during pre-monsoon and 4 to 18 (mg/L) during post- monsoon period. All the samples in pre monsoon and post monsoon were recorded below the permissible limits of BIS Standards limit 45 (mg/L).

Fluoride is beneficial for human beings as a trace element, this protects tooth decay and enhances bone development, in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects. The fluoride values in the study area ranges from 0.27 to 2.83 (mg/L) in pre-monsoon and 0.21 to 2.28 (mg/L) (Table-3) during pre-monsoon period. 51.66% of samples were above the standard limit in post -monsoon and 31.66% samples were above the standard limit in post monsoon the standard limit BIS (1998) standard limit 1.5 (mg/L). The high concentration of fluoride in the worth west position of the study area poses a sign of water quality problem. Skeletal fluorosis is an important disease caused due to presence of high fluoride content in groundwater.

Calcium may dissolve readily from carbonate rocks and lime stones or be leached from soils. The Calcium concentrations are varied from 61 to 115 (mg/L) during pre-monsoon season where as in the post-monsoon season it ranges between 49 to112 (mg/L). Most of the samples were recorded below the standard limit in pre monsoon and post monsoons as measuring by BIS (1998) (200 mg/L).
The magnesium concentrations are varied from 43 to 84 (mg/L) during pre-monsoon season where as in the post-monsoon season it ranges from 40 to 77 (mg/L). All samples were below the standard limit in pre monsoon and post monsoon the standard limit being (100 mg/L as prescribed by BIS.

Water Quality index values are classified in to Five categories namely, excellent water WQI-25, good water WQI-50, Poor water WQI-75, Very poor water WQI-100, unfit for Drinking water. In the present study, Water Quality Index is calculated to determine the suitability of water for drinking purpose. The computed WQI values in Badvel Taluka water were 48.85 to 84.69 during pre- monsoon, 40.17 to 77.51 during post monsoon of samples are 1.66% under good, 85% are under poor, 13.34% under very poor which cannot be used for domestic purpose therefore cannot be used for human consumption during pre-monsoon. 30% under good, 68.33% under poor, 1.67% under very poor, and station (46) unfit for drinking purpose therefore cannot be used for human consumption during post- monsoon.

Table-2: The weight and relative weight of each of the parameters used For WQI determination.

S. No	Parameters	BIS1998 and revised-2003 (Permissible limits)	Weight (*wi*)	Relative Weight (Wi)
1	pH	6.5-8.5(7.0)	3	0.103448276
2	TDS	1000	5	0.172413793
3	T. H	600	4	0.137931034
4	T. Alkalinity	600	2	0.068965517
5	Cl^-	1000	3	0.103448276
6	NO_3^-	45	5	0.172413793
7	F	1	3	0.103448276
8	Ca^{2+}	200	2	0.068965517
9	Mg^{2+}	100	2	0.068965517

Table-3: Average Characteristics of Physico-Chemical parameters for Groundwater - 2014)

S. No.	pH	TDS mg/L	TH mg/L	T.A mg/L	Cl mg/L	N mg/L	F mg/L	Ca mg/L	Mg mg/L	WQI mg/L
GWS-1	7.92	936	412	185	350	10.1	0.48	88.7	46.5	52.75
GWS-2	7.50	1092	478	168	325	12.8	0.695	91	61	57.96
GWS-3	7.53	1253	531	201	400	12.7	1.105	98.5	69.5	68.37
GWS-4	7.52	1139	538	177	390	11.2	0.855	106	67	63.03
GWS-5	7.98	1234	515	182	310	9.4	0.65	91	70	63.45
GWS-6	8.06	761	433	196	315	8.05	0.8	92	49.5	53.84
GWS-7	7.39	1315	478	166	365	14	1.25	97	57.5	67.61
GWS-8	8.06	933	505	182	340	15	0.815	98.5	63	62.53
GWS-9	7.57	1147	489	162	465	14	1.095	94	62	65.80
GWS-10	7.29	1013	446	163	335	10	2.39	85	57	70.45
GWS-11	8.00	595	449	192	180	9	1.63	80.5	60.5	58.81
GWS-12	8.45	946	497	238	370	13	0.725	94.5	63.5	64.41
GWS-13	7.69	726	439	175	140	10.1	2.1	69	65	63.27
GWS-14	8.06	887	482	197	190	11.2	1.83	97	58.5	68.52
GWS-15	7.23	734	515	132	180	8	1.105	91	70	51.92
GWS-16	7.82	1310	556	201	402	14.8	0.73	109	69.5	69.19
GWS-17	7.34	929	483	166	175	8	0.615	96.5	59	49.97
GWS-18	7.96	1325	542	214	408	12	0.785	102	70	69.67
GWS-19	7.76	1202	535	188	326	10.8	1.605	104	67	72.74
GWS-20	7.70	1402	554	189	437	13	0.485	97	76	67.02
GWS-21	7.66	1292	504	177	393	13.6	0.385	96.5	64	61.41
GWS-22	7.62	1393	492	175	386.5	15	0.43	91	64.5	63.40
GWS-23	8.50	924	515	241	300	9	0.545	96	67	61.00
GWS-24	7.83	857	465	196	265	10	0.58	92.5	57	53.09
GWS-25	7.78	1352	374	188	495.5	12	0.555	74	46	60.62
GWS-26	8.01	963	478	221	210	9.42	1.565	99.5	56	66.32
GWS-27	8.03	1160	487	219	395.5	10	1.61	101	71.5	73.74
GWS-28	8.44	751	466	210	202	12	1.06	86.5	61	60.82
GWS-29	7.74	915	467	159	270	12	1.01	96.5	55	58.37
GWS-30	8.06	948	453	189	258	10.8	2.38	81	61	74.64
GWS-31	7.91	686	454	194	224	8.1	0.455	96.5	52	47.82
GWS-32	7.76	652	441	185	149.5	13	1.275	96	49	55.15
GWS-33	7.95	841	502	177	200	10	1.25	96	64	61.19
GWS-34	7.86	669	460	179	170	9	0.315	82.5	62	45.66
GWS-35	8.24	909	478	210	177	13	0.215	105	52.5	53.89
GWS-36	8.32	692	419	182	195	8	0.39	88	48.5	48.24

GWS-37	8.03	834	456	221	235	9	0.49	99.5	50.5	52.36
GWS-38	7.92	1066	544	216	290	9.1	0.93	101	71.5	64.20
GWS-39	8.12	890	497	159	255	10	0.29	85	69.5	53.48
GWS-40	7.60	935	516	203	275	10.2	0.575	108	60	54.96
GWS-41	7.90	666	485	215	209.5	7	0.51	98	58.5	48.84
GWS-42	7.71	794	382	173	355	12	1.095	78	45.5	54.73
GWS-43	8.12	723	503	210	355.5	11	1.35	98	63	63.75
GWS-44	8.11	871	469	202	195	9.9	1.985	89	60	69.28
GWS-45	7.89	1197	520	173	290	12	2.07	91.5	71	77.74
GWS-46	7.48	1172	496	156	313.5	9.95	2.54	95	63	77.66
GWS-47	8.16	840	502	201	220	8	1.675	95	64.5	66.72
GWS-48	7.71	877	490	170	111.5	7	1.25	96	61	57.49
GWS-49	7.83	641	481	181	283.5	14	1.815	93	60.5	64.36
GWS-50	8.12	758	464	206	355	10	2.035	97	54	69.42
GWS-51	7.67	1269	481	169	305	11	0.805	95.5	59	62.52
GWS-52	7.97	1353	537	178	345	13.2	0.625	100	70	67.72
GWS-53	8.37	757	547	214	160	10	0.715	94	76	58.90
GWS-54	8.27	677	494	214	115	9	0.505	88.5	66.5	51.71
GWS-55	7.90	834	484	238	225	15	0.71	88.5	64	57.32
GWS-56	7.94	684	470	203	245	10	0.5	83	64	50.23
GWS-57	7.84	983	517	189	386.5	10	1.105	91	70.5	64.01
GWS-58	719	468	198	295	10	1.17	105	50	56.96	56.96
GWS-59	1010	542	184	245	8.2	1.39	93	75.5	66.97	66.97
GWS-60	1007	512	183	365	14	0.61	103	62	60.20	60.20

CONCLUSION

The ground water in the study area is better for drinking purposes except a few samples, which are not crossing the standards limits prescribed by BIS (1998). Total Dissolved Solids, Total Hardness, Total Alkalinity, Chloride, Calcium and Magnesium, which are not exceeded the permissible limits (BIS1998 and revised, 2003). Fluoride was dominating in several stations of the study area. Even though the majority of samples are within the permissible limits, few are very near to permissible units and some are very close to the allowable limits which indicate that there may be a deterioration of water quality in near future. This was because of the interaction of the ground water with sewage and intensive agricultural practices. Water quality Index of the present study area is established from important various physicochemical parameters in pre-post monsoons. The water quality index obtained from the water bore wells in Pre-monsoon and post monsoon season based on the WQI classification, in whiles most of the samples are preferably not suitable for drinking purpose. Total Dissolved solids and medium concentration of the chemical constituents such as Calcium, Magnesium, Chlorides and Bicarbonates present in the groundwater may be due to dissolution of mineral phases and may be under the influence of anthropogenic activities such as interaction with sewage from urban and industrial waste, massive usage of fertilizers, and intense agricultural practices. From the GIS analysed spatial maps, we can see that the lower region of the study area has highly affected on groundwater quality when compared with the other areas. The spatial maps derived are helpful for the public to get knowledge about groundwater pollution. The rainwater harvesting structures such as percolation ponds, check dams, recharge pits, and farm ponds can be constructed for the sustainability of quality of groundwater resources.

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