

CCME-WQI Application to Groundwater Quality assessment for drinking in Western part of Vizianagaram District, Andhra Pradesh, India

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ABSTRACT: The Water Quality Index (WQI) developed by the Canadian council of ministers of the Environment (CCME) was applied to the assessment of groundwater quality for drinking in Western part (Saluru region) of Vizianagaram district. The groundwater samples were collected from bore wells of 50 selected sampling locations at regular monthly intervals (from November 2018 to October 2019) in the study area. Various parameters such as pH, EC, TDS, TH, TA, Ca²⁺, Mg²⁺, Na⁺, CO₃²⁻, HCO₃⁻, Cl⁻, SO₄²⁻, NO₃⁻, F⁻ of samples were analyzed using standard laboratory procedures. Range and Mean were also calculated for measured parameter values of each sample. The overall quality was assessed using Canadian Council of Ministry of Environment Water Quality Index (CCME-WQI) Method. It is observed that quality of about 2% of the water samples is good, about 84% is fair and remaining 14% is marginal for drinking purpose in the study area.

KEY WORDS: Alkalinity, Canadian Water Quality Index, Chloride, Fluoride, Nitrate, Sulphate,

I. INTRODUCTION

Water is an essential component for human life and industrial development. For many rural and small-scale communities, groundwater is the only source of drinking water. Groundwater is the accumulation of water below the ground surface, caused by rainfall and its subsequent percolation through pores and crevices. The groundwater occurs under water table and controlled by land form, structure and lithology. The groundwater table fluctuates due to changes in groundwater storage and draft in response to rainfall incidence, applied irrigation, influent and effluent seepages and draft from groundwater.

Groundwater quality is very essential in a sense of practical utility for domestic, agricultural and industrial purposes. Hence, present utility and future development programs are depending on the physical, chemical and bacterial character of the water. The quality of groundwater varies due to a change in chemical composition of the underlying sediments and aquifer. However, in the recent past groundwater quality is getting deteriorated due to various reasons and making it unsuitable for drinking purposes threatening the human health. Therefore, the groundwater quality assessment for drinking has become a necessary and important task for the present and future groundwater quality management.

Groundwater, in general, is less susceptible to bacterial pollution when compared with the surface water. But it contains several chemical elements like Ca²⁺, Mg²⁺, Na⁺, K⁺, HCO₃⁻, Cl⁻ and SO₄²⁻ which play an important role in the classification and assessment of quality of groundwater. Keeping this in view, the present study aims at the assessment of the quality of groundwater at different locations of the study area using Canadian water quality index method by analyzing groundwater samples month wisely over a period of one year.

Several studies have been conducted to assess the quality of surface water for aquatic life [1-4], for irrigation [5] and for drinking [6-7] using CCME-WQI method. The groundwater quality assessment also was done by some researchers in Cauvery deltaic region for drinking [8] and in Kadava River basin for both drinking [9] and irrigation [10] using the same method. The studies related to assessment of water quality using Canadian water quality index in Vizianagaram district were not conducted earlier. Therefore, the

present study aimed to apply CCME Water Quality Index to study groundwater quality in the study area for drinking.

Study Area

Vizianagaram District is one of the north coastal districts of Andhra Pradesh comprising of 1582 Villages and occupying an area of 6,539 square

kilometers. The study area considered for this work is Western part of Vizianagaram district. It lies between 18⁰-20' and 18⁰-45' of the northern latitudes and 83⁰-05' and 83⁰-20' of the eastern longitudes (FIG.1) and occupies an area of around 1230 sq.km and comprises of 264 villages.

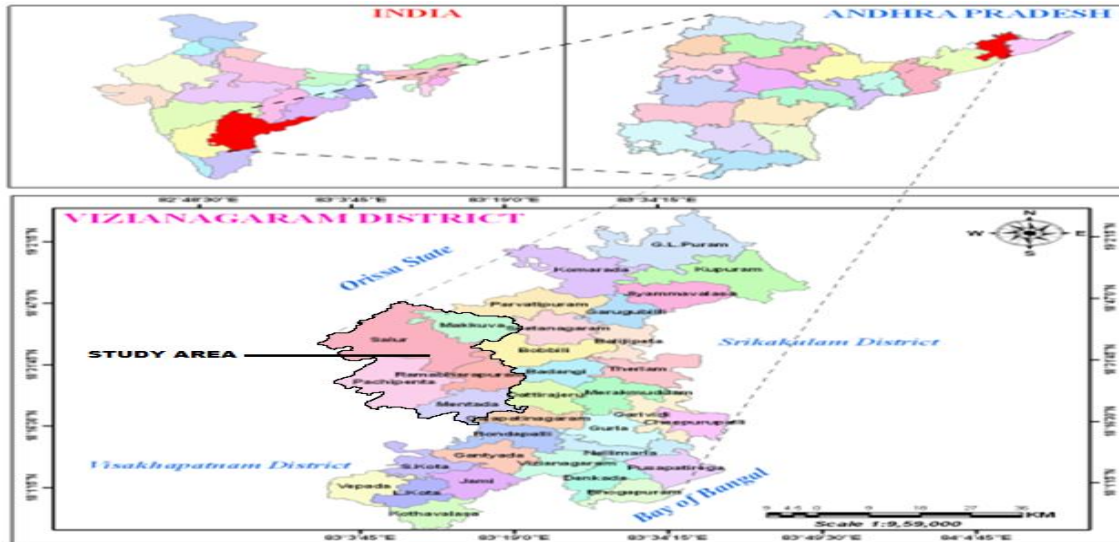


Fig 1: Location map of study area

TABLE 1: Coordinates of Sampling Locations in the Study area

S No	Sample Id	Sampling Station	Mandal	Latitude	Longitude
1	SS1	Duggeru	Makkuva	18 ⁰ 43'59"	83 ⁰ 11'21"
2	SS2	Kannampeta	Makkuva	18 ⁰ 38'00"	83 ⁰ 18'19"
3	SS3	Kona	Makkuva	18 ⁰ 41'49"	83 ⁰ 16'30"
4	SS4	Makkuva	Makkuva	18 ⁰ 39'37"	83 ⁰ 16'06"
5	SS5	Markondaputti	Makkuva	18 ⁰ 41'30"	83 ⁰ 13'36"
6	SS6	Mukavalasa	Makkuva	18 ⁰ 38'02"	83 ⁰ 15'34"
7	SS7	Papayyavalasa	Makkuva	18 ⁰ 39'37"	83 ⁰ 17'44"
8	SS8	Butchirajupeta	Mentada	18 ⁰ 23'04"	83 ⁰ 16'08"
9	SS9	Challapeta	Mentada	18 ⁰ 20'45"	83 ⁰ 16'15"
10	SS10	Ippalavalasa	Mentada	18 ⁰ 21'41"	83 ⁰ 14'51"
11	SS11	Kuneru	Mentada	18 ⁰ 23'04"	83 ⁰ 14'23"
12	SS12	Lothugedda	Mentada	18 ⁰ 20'39"	83 ⁰ 12'16"
13	SS13	Poramlova	Mentada	18 ⁰ 24'45"	83 ⁰ 15'21"
14	SS14	Aluru	Pachipenta	18 ⁰ 26'02"	83 ⁰ 05'57"
15	SS15	Borramamidi	Pachipenta	18 ⁰ 29'05"	83 ⁰ 10'32"
16	SS16	Cherukupalli	Pachipenta	18 ⁰ 31'48"	83 ⁰ 09'31"
17	SS17	Gurivinaidupeta	Pachipenta	18 ⁰ 27'54"	83 ⁰ 10'05"
18	SS18	Kankanapalli	Pachipenta	18 ⁰ 31'45"	83 ⁰ 06'05"

19	SS19	Mathumuru	Pachipenta	18°27'17"	83°09'21"
20	SS20	Mirthivalasa	Pachipenta	18°28'54"	83°07'24"
21	SS21	Mosuru	Pachipenta	18°29'12"	83°11'16"
22	SS22	Nanda	Pachipenta	18°25'54"	83°11'18"
23	SS23	P. Konavalasa	Pachipenta	18°31'33"	83°08'29"
24	SS24	Pachipenta	Pachipenta	18°28'59"	83°06'58"
25	SS25	Padmapuram	Pachipenta	18°28'59"	83°05'43"
26	SS26	Panchali	Pachipenta	18°28'55"	83°10'02"
27	SS27	Panukuvalasa	Pachipenta	18°31'52"	83°09'52"
28	SS28	Peddavalasa	Pachipenta	18°29'27"	83°05'42"
29	SS29	Taduru	Pachipenta	18°25'57"	83°09'13"
30	SS30	Viswanadhapuram	Pachipenta	18°30'38"	83°09'29"
31	SS31	Kondakenguva	Ramabhadrapuram	18°27'32"	83°15'40."
32	SS32	Kottakki	Ramabhadrapuram	18°30'50"	83°14'14"
33	SS33	Mamidivalasa	Ramabhadrapuram	18°28'33"	83°16'56"
34	SS34	Mutcherlavalasa	Ramabhadrapuram	18°28'32"	83°17'29"
35	SS35	Patharega	Ramabhadrapuram	18°25'54"	83°18'06"
36	SS36	Ramabhadrapuram	Ramabhadrapuram	18°29'27"	83°16'56"
37	SS37	Rompilli	Ramabhadrapuram	18°32'42"	83°15'54"
38	SS38	Annamarajuvalasa	Salur	18°37'46"	83°11'04"
39	SS39	Borabanda	Salur	18°33'35"	83°14'31"
40	SS40	Chinavootagedda	Salur	18°42'05"	83°11'43"
41	SS41	Jilleduvalasa	Salur	18°43'16"	83°08'07"
42	SS42	Kandulapadam	Salur	18°38'40"	83°09'22"
43	SS43	Karasuvalasa	Salur	18°34'34"	83°10'05"
44	SS44	Kurukutti	Salur	18°35'20"	83°05'35"
45	SS45	Maripalle	Salur	18°37'54"	83°09'07"
46	SS46	Mirtivalasa	Salur	18°36'04"	83°13'44"
47	SS47	Neliparti	Salur	18°30'16"	83°10'57"
48	SS48	Parannavalasa	Salur	18°32'22"	83°15'11"
49	SS49	Puroithunivalasa	Salur	18°34'08"	83°14'33"
50	SS50	Sivampuram	Salur	18°32'11"	83°14'36"

II. MATERIALS AND METHODS

A total number of 600 groundwater samples are collected from different selected sampling locations (vide **TABLE 1**) of the study area from November 2018 to October 2019. Samples are collected in polythene bottles, pre-cleaned by washing with non-ionic detergents, rinsed with water, 1:1 hydrochloric acid and finally with de-ionized water. Before sampling, the bottles were rinsed three times with sample water. Tube wells are operated at least five minutes before collection of the water samples. The water quality

parameter estimation was done using standard methods and techniques [11]. pH and EC are measured using digital pH meter (Elico LI-120) and conductometer (Elico CL-351) respectively. TDS is determined by gravimetric method whereas parameters like Total Hardness (TH), Total Alkalinity (TA), Calcium, Magnesium, Chloride, Carbonates and Bicarbonates are determined by titrimetric method. Nitrate (NO₃⁻) ion is determined using UV-visible spectrophotometer (Elico SL-177) with 1cm quartz cell, using Phenol Disulphonic Acid (PDA) method whereas Fluoride

(F⁻ ion) is determined by SPADNS method and other parameters such as Sulphate is determined by turbidimetry using standard barium chloride solution. Sodium ion is measured by flame photometry (Elico CL-361).

Water Quality Index:

Several WQIs have been proposed by Researchers [12-13] and used appropriately by Governmental agencies and researchers. They are Canadian Council of Ministers of Environment Water Quality Index (CCMEWQI), National Sanitation Foundation Water Quality Index (NSFWQI) and Oregon Water Quality Index (OWQI) and Weighted Arithmetic Water Quality Index Method (WAIWQI).

CCME Water quality Index:

Canadian water quality index is the water quality index developed by the Canadian Council of Ministers of the Environment (CCME 2001) and is used among the researchers in developing countries for simplifying the reporting of water

quality data and delivers a broad overview of water quality data. It requires Water Quality Objectives (WQOs) and this model essentially consists of three measures of variance from selected WQOs (scope, frequency and amplitude) that combine to produce a value between 0 and 100 that represent the overall water quality. Scope represents the number of variables not meeting water quality objectives; frequency considers the number of times these objectives are not met; and amplitude is the measure of the amount by which the objectives are not met. In the CCME-WQI a value of 100 (excellent) is the best possible index score and a value of 0 (poor) is the worst possible. This index categorizes the quality of water for the overall use as well as for drinking, aquatic, recreation, irrigation and livestock rearing. Fourteen parameters are considered for calculating the water quality index. Based on CCME-WQI values, ranking of water is classified [14], as shown in the TABLE 2.

TABLE 2: Classification of water quality based on CCME-WQI values

WQI range	Ranking of water quality	Remarks
95-100	Excellent	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
80-94	Good	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
65-79	Fair	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
45-64	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
0-44	Poor	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

III. RESULTS AND DISCUSSIONS:

The test results of varied parameters are showing some fluctuations based on range. The Range and mean values of the analyzed parameters and permissible values are as per WHO/ BIS presented in **TABLE 3**.

TABLE 3: Analysis of Groundwater samples: Range and mean of Physical and Chemical parameters values

Sample ID	SS1			SS2			SS3			SS4			SS5			le values (\$i)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.20	7.70	7.44	7.40	7.80	7.62	6.70	7.30	6.95	7.40	7.90	7.67	7.41	8.00	7.74	8.50
EC	1585.00	1634.00	1610.00	1079.00	1120.00	1094.33	1259.00	1290.00	1272.92	2001.00	2063.00	2032.08	1782.00	1829.00	1810.17	1000.00
TDS	1035.00	1065.00	1049.33	710.00	736.00	719.83	825.00	845.00	835.00	1300.00	1340.00	1320.00	1160.00	1190.00	1178.33	600.00
NO3	20.00	24.00	22.00	2.90	7.00	4.58	14.00	18.00	16.00	20.00	25.00	22.67	30.00	35.00	32.67	50.00
TH	445.00	460.00	454.08	290.00	310.00	303.33	500.00	540.00	520.00	630.00	645.00	634.92	400.00	430.00	415.00	500.00
Ca	40.00	44.00	42.00	49.00	53.00	51.17	59.00	63.00	60.83	57.00	62.00	59.33	44.00	48.00	45.67	200.00
Mg	83.00	87.00	85.17	40.00	44.00	42.00	87.00	91.00	89.17	116.00	120.00	118.00	94.00	97.00	95.67	150.00
Na	25.00	30.00	26.92	58.00	62.00	60.50	43.00	49.00	46.67	56.00	62.00	59.50	157.00	164.00	161.25	200.00
Cl	35.00	45.00	41.08	89.00	93.00	91.18	69.00	73.00	71.00	85.00	93.00	90.00	240.00	255.00	247.08	250.00
SO4	55.00	60.00	57.50	30.00	34.00	31.67	9.00	14.00	11.08	105.00	109.00	107.00	67.00	71.00	69.00	250.00
CO3	54.00	60.00	57.17	10.00	16.00	12.74	58.00	66.00	61.83	71.00	78.00	73.67	38.00	49.00	43.58	30.00
HCO3	310.00	350.00	326.83	270.00	310.00	283.33	350.00	390.00	364.17	390.00	430.00	409.83	340.00	390.00	361.67	500.00
F	0.41	0.59	0.49	0.45	0.64	0.53	0.30	0.42	0.36	0.18	0.36	0.26	0.74	0.85	0.79	1.20
TA	330.00	370.00	346.83	290.00	330.00	303.33	370.00	410.00	384.17	410.00	450.00	429.83	360.00	410.00	381.67	200.00

Sample ID	SS6			SS7			SS8			SS9			SS10			le values (\$i)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.30	7.80	7.55	7.24	7.70	7.44	7.10	7.63	7.33	7.00	7.50	7.27	7.50	8.00	7.76	8.50
EC	1266.00	1313.00	1285.17	1610.00	1666.00	1645.92	923.00	991.00	955.58	1384.00	1454.00	1422.33	1479.00	1510.00	1492.17	1000.00
TDS	830.00	860.00	841.67	1048.00	1086.00	1072.33	610.00	654.00	631.00	905.00	950.00	929.75	966.00	990.00	974.83	600.00
NO3	22.00	29.00	25.74	10.00	15.00	12.37	18.00	23.00	20.08	11.00	17.00	13.83	18.00	23.00	20.58	50.00
TH	340.00	355.00	347.00	375.00	400.00	386.50	250.00	270.00	258.00	380.00	410.00	391.08	408.00	430.00	416.92	500.00
Ca	28.00	32.00	30.25	25.00	29.00	26.83	26.00	31.00	28.00	42.00	49.00	45.08	37.00	41.00	38.83	200.00
Mg	62.00	67.00	64.83	76.00	80.00	78.00	43.00	47.00	45.25	65.00	69.00	67.33	72.00	77.00	74.50	150.00
Na	21.00	26.00	22.92	41.00	45.00	42.58	19.00	22.00	20.08	25.00	31.00	28.00	28.00	33.00	30.50	200.00
Cl	33.00	38.00	34.92	64.00	67.00	65.25	29.00	32.00	30.42	42.00	45.00	42.92	40.00	50.00	46.50	250.00
SO4	10.00	15.00	11.50	19.00	23.00	21.00	11.00	17.00	13.67	2.00	10.00	6.33	27.00	31.00	29.00	250.00
CO3	53.00	62.00	57.08	55.00	64.00	59.33	40.00	45.00	42.33	53.00	61.00	56.33	45.00	53.00	48.17	30.00
HCO3	240.00	270.00	253.00	270.00	320.00	293.33	174.00	210.00	187.83	300.00	350.00	324.00	300.00	340.00	318.83	500.00
F	0.23	0.37	0.30	0.35	0.53	0.43	0.47	0.66	0.55	0.58	0.73	0.65	0.26	0.39	0.32	1.20
TA	260.00	290.00	273.00	290.00	340.00	313.33	194.00	230.00	207.83	320.00	370.00	344.00	320.00	360.00	338.83	200.00

Sample ID	SS11			SS12			SS13			SS14			SS15			le values (\$i)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.40	8.00	7.67	7.20	8.00	7.44	7.20	7.80	7.40	7.10	7.70	7.38	7.30	7.90	7.64	8.50
EC	1345.00	1430.00	1391.17	1829.00	1901.00	1861.17	1657.00	1704.00	1678.50	1446.00	1485.00	1464.50	1602.00	1666.00	1634.33	1000.00
TDS	880.00	935.00	907.92	1190.00	1236.00	1210.67	1080.00	1110.00	1093.00	945.00	970.00	956.58	1045.00	1086.00	1065.50	600.00
NO3	17.00	23.00	19.83	32.00	37.00	34.36	11.00	16.00	13.50	7.00	12.00	9.21	31.00	36.00	32.79	50.00
TH	392.00	420.00	401.92	420.00	450.00	434.75	420.00	450.00	433.83	456.00	475.00	466.25	480.00	496.00	489.58	500.00
Ca	37.00	41.00	38.83	52.00	58.00	54.67	47.00	52.00	49.08	100.00	104.00	102.00	43.00	47.00	45.00	200.00
Mg	70.00	73.00	71.17	69.00	73.00	71.17	71.00	76.00	73.67	47.00	51.00	49.00	90.00	93.00	91.50	150.00
Na	26.00	31.00	27.75	40.00	44.00	42.17	37.00	42.00	40.00	50.00	53.00	51.42	33.00	38.00	35.50	200.00
Cl	38.00	46.00	41.92	60.00	70.00	66.33	58.00	63.00	61.08	76.00	79.00	77.42	50.00	60.00	54.50	250.00
SO4	11.00	17.00	14.00	44.00	48.00	46.08	2.00	7.00	4.92	43.00	48.00	45.92	32.00	39.00	35.17	250.00
CO3	90.00	98.00	93.92	41.00	48.00	43.67	74.00	80.00	76.42	60.00	70.00	63.83	75.00	82.00	78.33	30.00
HCO3	210.00	260.00	230.83	300.00	340.00	320.00	296.00	330.00	313.83	310.00	360.00	335.00	320.00	350.00	339.50	500.00
F	0.28	0.39	0.32	0.26	0.41	0.32	0.38	0.55	0.45	0.37	0.55	0.45	0.30	0.46	0.38	1.20
TA	230.00	280.00	250.83	320.00	360.00	340.00	316.00	350.00	333.83	330.00	380.00	355.00	340.00	370.00	359.50	200.00

TABLE 3: Analysis of Groundwater samples: Range and mean of Physical and Chemical parameters values

Sample ID	SS16			SS17			SS18			SS19			SS20			le values (Si)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.24	7.67	7.44	7.40	7.90	7.61	7.50	8.00	7.70	7.20	7.70	7.50	7.30	7.80	7.46	8.50
EC	720.00	759.00	736.08	1759.00	1798.00	1778.08	1516.00	1563.00	1535.58	1548.00	1610.00	1578.08	1438.00	1475.00	1459.92	1000.00
TDS	480.00	505.00	490.42	1145.00	1170.00	1157.92	990.00	1020.00	1002.33	1010.00	1050.00	1029.17	940.00	965.00	954.00	600.00
NO3	30.00	34.00	32.04	21.00	25.00	23.08	29.60	34.00	32.02	22.00	27.00	24.50	28.00	33.00	31.01	50.00
TH	270.00	290.00	280.00	425.00	440.00	433.50	405.00	420.00	411.75	450.00	465.00	456.17	358.00	384.00	369.67	500.00
Ca	43.00	49.00	45.75	65.00	70.00	67.33	41.00	46.00	43.25	38.00	43.00	40.33	41.00	46.00	43.42	200.00
Mg	38.00	42.00	40.25	61.00	65.00	63.17	72.00	76.00	73.92	85.00	88.00	86.83	60.00	64.00	62.00	150.00
Na	26.00	31.00	28.75	50.00	54.00	52.17	36.00	41.00	38.67	25.00	30.00	28.17	32.00	37.00	34.67	200.00
Cl	42.00	46.00	43.47	77.00	81.00	78.92	57.00	61.00	59.25	41.00	45.00	42.92	51.00	55.00	53.00	250.00
SO4	10.00	14.00	12.00	51.00	56.00	53.50	41.00	45.00	43.00	30.00	34.00	32.33	18.00	22.00	20.00	250.00
CO3	10.40	17.39	13.96	24.00	30.00	27.25	41.00	48.00	44.67	69.00	76.00	71.92	73.00	81.00	76.83	30.00
HCO3	260.00	300.00	275.83	330.00	380.00	355.00	296.00	340.00	315.50	320.00	360.00	335.00	200.00	250.00	225.83	500.00
F	0.15	0.26	0.20	0.12	0.24	0.17	0.23	0.33	0.28	0.33	0.44	0.38	0.53	0.64	0.58	1.20
TA	280.00	320.00	295.83	350.00	400.00	375.00	316.00	360.00	335.50	340.00	380.00	355.00	220.00	270.00	245.83	200.00

Sample ID	SS21			SS22			SS23			SS24			SS25			le values (Si)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.10	7.62	7.34	7.20	7.70	7.45	7.11	7.60	7.33	7.50	8.00	7.73	7.00	7.70	7.42	8.50
EC	1845.00	1907.00	1880.92	1001.00	1062.00	1020.92	1751.00	1798.00	1771.33	1410.00	1470.00	1438.67	1416.00	1462.00	1445.92	1000.00
TDS	1200.00	1240.00	1222.67	660.00	700.00	673.17	1140.00	1170.00	1153.67	922.00	960.00	940.58	926.00	955.00	944.83	600.00
NO3	29.00	34.00	31.80	27.00	31.00	29.23	15.00	19.00	17.00	6.00	11.00	8.67	5.00	10.00	7.67	50.00
TH	515.00	535.00	523.83	275.00	295.00	284.67	350.00	365.00	355.00	425.00	445.00	434.75	385.00	405.00	394.58	500.00
Ca	46.00	50.00	48.25	28.00	32.00	30.00	52.00	56.00	54.00	41.00	45.00	43.00	36.00	40.00	38.00	200.00
Mg	96.00	99.00	97.83	50.00	53.00	51.42	50.00	54.00	52.00	77.00	81.00	79.00	71.00	75.00	73.00	150.00
Na	35.00	40.00	37.67	18.00	23.00	20.83	62.00	67.00	64.50	30.00	33.00	31.50	25.00	29.00	26.83	200.00
Cl	55.00	59.00	56.83	30.00	35.00	32.00	92.00	101.00	97.44	46.00	49.00	47.33	39.00	44.00	41.00	250.00
SO4	37.00	40.00	38.67	15.00	20.00	17.67	73.00	77.00	75.00	4.00	9.00	6.67	6.00	10.00	8.00	250.00
CO3	84.00	92.00	87.50	30.00	34.00	31.58	10.00	14.00	11.50	73.00	79.00	75.83	65.00	72.00	67.67	30.00
HCO3	340.00	380.00	364.00	220.00	260.00	237.33	270.00	310.00	290.00	300.00	340.00	320.83	270.00	320.00	294.67	500.00
F	0.28	0.41	0.34	0.36	0.49	0.43	0.27	0.39	0.33	0.21	0.36	0.28	0.41	0.56	0.48	1.20
TA	360.00	400.00	384.00	240.00	280.00	257.33	290.00	330.00	310.00	320.00	360.00	340.83	290.00	340.00	314.67	200.00

Sample ID	SS26			SS27			SS28			SS29			SS30			le values (Si)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.30	7.80	7.53	7.50	8.10	7.73	7.10	7.90	7.65	7.50	7.90	7.72	7.20	7.89	7.56	8.50
EC	1265.00	1329.00	1297.00	1985.00	2032.00	2007.33	1930.00	1962.00	1946.00	1630.00	1980.00	1922.25	1538.00	1610.00	1574.50	1000.00
TDS	829.00	870.00	849.67	1290.00	1320.00	1304.25	1255.00	1275.00	1265.00	1061.00	1288.00	1250.08	1004.00	1050.00	1027.33	600.00
NO3	15.00	20.00	17.68	32.00	36.00	34.00	9.00	13.00	11.06	18.00	23.00	20.28	20.00	24.00	22.08	50.00
TH	312.00	330.00	320.33	615.00	635.00	625.00	450.00	470.00	460.00	450.00	465.00	457.50	365.00	385.00	373.33	500.00
Ca	31.00	35.00	32.83	52.00	56.00	53.83	54.00	58.00	56.00	43.00	47.00	45.00	47.00	51.00	49.00	200.00
Mg	54.00	59.00	56.83	116.00	120.00	118.17	77.00	81.00	78.83	82.00	86.00	83.83	48.00	52.00	49.83	150.00
Na	32.00	36.00	34.00	67.00	71.00	69.50	119.00	125.00	122.58	38.00	42.00	39.83	73.00	78.00	75.67	200.00
Cl	38.00	44.00	40.33	102.00	110.00	104.33	182.00	188.00	185.00	58.00	64.00	60.67	113.00	116.00	114.83	250.00
SO4	5.00	9.00	7.00	55.00	60.00	57.33	17.00	21.00	19.00	24.00	29.00	26.50	38.00	42.00	40.00	250.00
CO3	10.91	22.60	16.34	104.00	112.00	107.17	81.00	87.00	83.58	51.00	58.00	53.92	12.31	18.00	14.98	30.00
HCO3	320.00	360.00	337.50	370.00	420.00	395.00	300.00	340.00	319.67	340.00	380.00	365.50	290.00	320.00	305.00	500.00
F	0.41	0.63	0.52	0.66	0.82	0.73	0.33	0.45	0.39	0.32	0.47	0.39	0.62	0.73	0.67	1.20
TA	340.00	380.00	357.50	390.00	440.00	415.00	320.00	360.00	339.67	360.00	400.00	385.50	310.00	340.00	325.00	200.00

TABLE 3: Analysis of Groundwater samples: Range and mean of Physical and Chemical parameters values

Sample ID	SS31			SS32			SS33			SS34			SS35			le values (Si)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.00	7.60	7.32	7.30	8.00	7.55	7.00	7.50	7.26	7.40	7.90	7.62	7.20	7.60	7.38	8.50
EC	2110.00	2148.00	2124.75	1782.00	1860.00	1828.17	1407.00	1485.00	1442.17	3745.00	3832.00	3798.92	2276.00	2329.00	2301.50	1000.00
TDS	1370.00	1394.00	1379.33	1160.00	1210.00	1189.58	920.00	970.00	942.50	2416.00	2472.00	2450.83	1476.00	1510.00	1492.50	600.00
NO3	17.00	23.00	19.83	15.00	20.00	17.50	7.00	13.00	10.00	11.00	16.00	13.00	11.00	16.00	13.50	50.00
TH	395.00	420.00	407.50	395.00	420.00	406.75	315.00	345.00	328.75	630.00	650.00	640.83	430.00	455.00	443.33	500.00
Ca	71.00	75.00	73.17	34.00	39.00	36.50	48.00	53.00	50.33	109.00	113.00	110.58	80.00	86.00	82.92	200.00
Mg	41.00	47.00	44.25	74.00	79.00	76.67	43.00	49.00	46.58	73.00	76.00	74.25	54.00	59.00	56.92	150.00
Na	116.00	123.00	119.08	84.00	88.00	85.58	26.00	31.00	29.17	180.00	192.00	185.67	80.00	87.00	84.50	200.00
Cl	179.00	182.00	180.42	130.00	134.00	132.08	42.00	46.00	44.58	279.00	311.00	284.17	125.00	130.00	127.92	250.00
SO4	7.00	13.00	10.00	6.00	10.00	7.83	2.00	8.00	4.25	99.00	103.00	100.25	75.00	79.00	77.00	250.00
CO3	10.00	20.00	14.12	43.00	51.00	46.33	46.00	57.00	51.67	59.00	66.00	62.25	10.00	16.00	13.50	30.00
HCO3	370.00	410.00	390.00	310.00	350.00	330.00	230.00	270.00	250.00	340.00	370.00	355.00	390.00	420.00	404.17	500.00
F	0.64	0.82	0.74	1.02	1.19	1.13	0.31	0.50	0.40	0.60	0.75	0.67	0.29	0.42	0.35	1.20
TA	390.00	430.00	410.00	330.00	370.00	350.00	250.00	290.00	270.00	360.00	390.00	375.00	410.00	440.00	424.17	200.00

Sample ID	SS36			SS37			SS38			SS39			SS40			le values (Si)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.10	8.00	7.43	7.30	7.90	7.53	7.10	7.90	7.61	7.10	7.50	7.30	7.40	7.90	7.57	8.50
EC	1735.00	1829.00	1764.42	1313.00	1360.00	1342.58	1259.00	1305.00	1278.00	1120.00	1187.00	1148.75	1509.00	1688.00	1598.42	1000.00
TDS	1130.00	1190.00	1148.67	860.00	890.00	878.83	825.00	855.00	837.75	736.00	780.00	755.00	985.00	1100.00	1042.58	600.00
NO3	31.00	35.00	33.17	13.00	17.00	15.00	16.00	20.00	18.00	20.00	24.00	22.00	31.10	35.00	33.38	50.00
TH	390.00	420.00	404.17	230.00	250.00	238.33	370.00	385.00	378.67	360.00	380.00	369.08	364.00	375.00	370.67	500.00
Ca	61.00	66.00	63.67	35.00	39.00	37.00	34.00	39.00	35.67	39.00	46.00	42.42	32.00	37.00	34.42	200.00
Mg	55.00	60.00	57.75	33.00	37.00	35.08	70.00	73.00	71.83	83.00	88.00	85.92	65.00	71.00	68.08	150.00
Na	78.00	82.00	80.50	35.00	40.00	37.50	21.00	27.00	24.33	22.00	26.00	24.17	43.00	47.00	45.17	200.00
Cl	120.00	123.00	121.17	55.00	59.00	57.00	35.00	39.00	36.75	35.00	39.00	36.58	64.00	72.00	69.24	250.00
SO4	47.00	52.00	49.67	5.00	9.00	6.58	21.00	26.00	23.25	32.00	39.00	34.83	55.00	60.00	57.67	250.00
CO3	10.00	13.00	11.33	12.00	18.00	14.00	54.00	59.00	55.58	89.00	99.00	93.75	9.00	16.00	12.17	30.00
HCO3	370.00	410.00	390.17	220.00	240.00	230.00	260.00	310.00	290.33	270.00	300.00	282.50	300.00	350.00	325.00	500.00
F	0.76	0.99	0.87	1.18	1.29	1.22	0.30	0.54	0.41	0.34	0.56	0.45	0.35	0.48	0.41	1.20
TA	390.00	430.00	410.17	240.00	260.00	250.00	280.00	330.00	310.33	290.00	320.00	302.50	320.00	370.00	345.00	200.00

Sample ID	SS41			SS42			SS43			SS44			SS45			le values (Si)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		
pH	7.10	7.50	7.30	7.10	7.90	7.54	7.50	8.00	7.74	7.40	8.00	7.65	7.20	7.62	7.41	8.50
EC	1178.00	1226.00	1201.42	1345.00	1454.00	1424.25	1802.00	1852.00	1829.25	1337.00	1368.00	1350.67	1032.00	1070.00	1048.50	1000.00
TDS	774.00	804.00	788.58	922.00	950.00	938.00	1173.00	1205.00	1190.42	875.00	895.00	883.75	680.00	705.00	690.92	600.00
NO3	27.00	31.00	29.00	29.00	33.00	31.30	27.00	31.00	28.50	5.00	9.00	7.00	16.00	20.00	18.00	50.00
TH	340.00	365.00	353.83	290.00	315.00	305.00	465.00	485.00	473.67	355.00	375.00	363.75	300.00	315.00	309.33	500.00
Ca	32.00	35.00	33.50	37.00	41.00	38.75	52.00	56.00	54.00	36.00	40.00	37.92	27.00	31.00	28.83	200.00
Mg	64.00	68.00	65.67	45.00	51.00	48.58	80.00	83.00	82.00	63.00	65.00	64.00	53.00	58.00	55.42	150.00
Na	20.00	25.00	22.75	54.00	58.00	56.50	34.00	38.00	36.42	27.00	31.00	29.17	20.00	23.00	21.08	200.00
Cl	33.00	36.00	34.50	83.00	88.00	85.46	53.00	58.00	55.92	43.00	47.00	44.83	30.00	33.00	31.58	250.00
SO4	11.00	15.00	12.92	41.00	45.00	43.00	43.00	47.00	45.58	34.00	38.00	36.00	26.00	34.00	31.17	250.00
CO3	47.00	53.00	49.58	7.00	12.00	9.42	62.00	70.00	66.00	21.00	29.00	24.50	40.00	48.00	44.67	30.00
HCO3	270.00	300.00	286.17	260.00	290.00	270.00	330.00	370.00	349.17	300.00	320.00	310.00	200.00	240.00	214.83	500.00
F	0.32	0.44	0.38	0.40	0.63	0.51	0.34	0.45	0.39	0.40	0.54	0.47	0.25	0.37	0.31	1.20
TA	290.00	320.00	306.17	280.00	310.00	290.00	350.00	390.00	369.17	320.00	340.00	330.00	220.00	260.00	234.83	200.00

TABLE 3: Analysis of Groundwater samples: Range and mean of Physical and Chemical parameters values

Sample ID	SS46			SS47			SS48			SS49			SS50			le values (Si)
	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	RANGE		MEAN	
Parameters	MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN	MAX		MIN
pH	7.60	8.10	7.82	7.20	7.70	7.43	7.00	7.50	7.27	7.40	7.90	7.62	7.40	8.00	7.78	8.50
EC	1438.00	1475.00	1459.42	1980.00	2032.00	2000.17	1402.00	1454.00	1428.58	2250.00	2305.00	2281.00	1630.00	1998.00	1947.50	1000.00
TDS	940.00	965.00	953.67	1285.00	1320.00	1299.42	917.00	950.00	933.83	1460.00	1495.00	1479.67	1061.00	1298.00	1266.25	600.00
NO3	15.00	20.00	17.67	26.00	31.00	28.17	17.00	21.00	19.01	18.00	22.00	20.02	17.00	22.00	19.67	50.00
TH	370.00	400.00	386.25	400.00	420.00	411.08	420.00	435.00	427.33	600.00	640.00	620.17	420.00	435.00	428.83	500.00
Ca	60.00	65.00	62.67	58.00	63.00	60.50	39.00	44.00	41.50	65.00	68.00	66.17	41.00	48.00	44.00	200.00
Mg	52.00	56.00	54.33	60.00	64.00	62.08	75.00	80.00	77.58	112.00	116.00	114.00	74.00	81.00	77.75	150.00
Na	39.00	43.00	41.50	40.00	45.00	42.75	30.00	33.00	30.92	48.00	53.00	50.92	26.00	29.00	27.75	200.00
Cl	60.00	65.00	63.15	60.00	67.00	64.58	46.00	49.00	47.58	76.00	80.00	78.08	41.00	44.00	42.50	250.00
SO4	35.00	39.00	37.00	15.00	19.00	17.00	83.00	87.00	85.00	10.00	15.00	12.00	24.00	29.00	26.50	250.00
CO3	42.00	49.00	45.08	65.00	71.00	68.00	34.00	39.00	35.58	119.00	125.00	121.17	59.00	66.00	62.00	30.00
HCO3	270.00	310.00	286.67	270.00	320.00	291.67	300.00	340.00	313.67	420.00	460.00	438.33	310.00	350.00	328.83	500.00
F	0.61	0.74	0.67	0.18	0.32	0.24	0.70	0.91	0.81	0.52	0.73	0.62	0.31	0.46	0.37	1.20
TA	290.00	330.00	306.67	290.00	340.00	311.67	320.00	360.00	333.67	440.00	480.00	458.33	330.00	370.00	348.83	200.00

All units are in mg/l except pH (no units) and EC (micro Siemens/cm). EC= Electrical Conductivity; TDS= Total dissolved solids; TH= Total Hardness; TA= Total alkalinity.

TABLE 4: Calculated values of WQI of analyzed samples in the study area

SAMPLE ID→	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	SS11	SS12	SS13	SS14	SS15	SS16	SS17
TERM OF CCME INDEX↓																	
F1 (SCOPE)	28.571	21.429	35.71429	35.7142857	35.7142857	28.571	28.571	21.429	28.571	28.571	28.571	28.571	28.571	28.571	28.5714286	7.1429	21.428571
F2 (FREQUENCY)	28.571	21.429	35.11905	35.7142857	29.1666667	28.571	28.571	17.857	28.571	28.571	28.571	28.571	28.571	28.571	28.5714286	7.1429	21.428571
NSE (NORMALISED SUM OF EXCURSIONS)	0.2142	0.0579	0.191895	0.36475992	0.22405952	0.1397	0.2127	0.036	0.1835	0.1726	0.2349	0.2168	0.2655	0.2115	0.27276984	0.0342	0.184496
F3 (AMPLITUDE)	17.64	5.4739	16.09998	26.7270393	18.3046265	12.257	17.538	3.4779	15.508	14.721	19.024	17.814	20.978	17.461	21.4311993	3.3094	15.57591
CCMEWQI	66.499	76.601	60.02262	56.5798559	62.3031418	67.916	66.53	78.641	67.114	67.324	66.065	66.446	65.406	66.554	65.2462526	91.923	74.109661
RANKING	FAIR	FAIR	MARGINAL	MARGINAL	MARGINAL	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	GOOD	FAIR

SAMPLE ID→	SS18	SS19	SS20	SS21	SS22	SS23	SS24	SS25	SS26	SS27	SS28	SS29	SS30	SS31	SS32	SS33	SS34
TERM OF CCME INDEX↓																	
F1 (SCOPE)	28.571	28.571	28.57143	35.7142857	28.5714286	21.429	28.571	28.571	21.429	35.714	28.571	28.571	21.429	21.429	28.5714286	28.571	42.857143
F2 (FREQUENCY)	28.571	28.571	28.57143	35.7142857	27.3809524	21.429	28.571	28.571	21.429	35.714	28.571	28.571	21.429	21.429	28.5714286	28.571	42.857143
NSE (NORMALISED SUM OF EXCURSIONS)	0.1695	0.2475	0.202871	0.34307341	0.0344504	0.1603	0.2313	0.2035	0.1072	0.4342	0.3242	0.2665	0.1366	0.2481	0.22180357	0.1489	0.5894266
F3 (AMPLITUDE)	14.491	19.842	16.86557	25.5439062	3.33030921	13.815	18.785	16.912	9.681	30.273	24.483	21.04	12.015	19.879	18.1537832	12.964	37.084228
CCMEWQI	67.383	65.795	66.73033	56.9929946	69.8240911	74.693	66.142	66.717	75.827	55.256	64.101	65.385	75.229	72.461	66.3411619	67.756	46.009638
RANKING	FAIR	FAIR	FAIR	MARGINAL	FAIR	FAIR	FAIR	FAIR	FAIR	MARGINAL	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	MARGINAL

SAMPLE ID→	SS35	SS36	SS37	SS38	SS39	SS40	SS41	SS42	SS43	SS44	SS45	SS46	SS47	SS48	SS49	SS50
TERM OF CCME INDEX↓																
F1 (SCOPE)	21.429	21.429	28.57143	28.5714286	28.5714286	21.429	28.571	21.429	28.571	21.429	28.571	28.571	28.571	28.571	35.7142857	28.571
F2 (FREQUENCY)	21.429	21.429	24.40476	28.5714286	28.5714286	21.429	28.571	21.429	28.571	21.429	28.571	28.571	28.571	28.571	35.7142857	28.571
NSE (NORMALISED SUM OF EXCURSIONS)	0.2793	0.195	0.07706	0.14847817	0.21747024	0.1472	0.1214	0.1027	0.2757	0.1053	0.0616	0.1489	0.2851	0.1314	0.52271429	0.2763
F3 (AMPLITUDE)	21.831	16.316	7.154621	12.9282539	17.8624685	12.833	10.824	9.3122	21.609	9.5232	5.8069	12.962	22.183	11.613	34.3277981	21.651
CCMEWQI	71.621	73.848	70.93541	67.7642846	66.4312704	74.994	68.215	75.911	65.183	75.863	68.982	67.756	64.975	68.055	53.5969427	65.168
RANKING	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	MARGINAL	FAIR

IV. CONCLUSIONS

1. The results indicated that the water samples at 7 sampling stations out of 50 of the study area do not meet the required standards for drinking purpose based on CCME-WQI analysis.
2. The sampling stations where the ranking of groundwater quality as marginal is noticed in the respective revenue mandals are as follows.
 - a) Kona (SS3), Makkuva (SS4) and Markondaputti (SS5) in Makkuva Mandal
 - b) Mosuru (SS21) and Panukuvalasa (SS27) in Pachipenta Mandal
 - c) Mutcheralavalasa (SS34) in Ramabhadrapuram Mandal and
 - d) Purohithunivalasa (SS49) in Salur Mandal.
3. The water samples at 42 sampling stations (about 84%) were ranked as Fair. It is proposed that appropriate treatment and measures are to be taken before the consumption of water collected from these stations.

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