Analysis of Groundwater Quality using WQI and GIS Mapping in The Kurnool District of Andhra Pradesh, India

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Abstract— **The study of groundwater quality parameters is most important for irrigation and drinking water, and its quality is a serious problem around the study area. A systematic study has been carried out to access the water quality index of regions in Kurnool district in Andhra Pradesh, India. 140 water samples were collected from different villages and analysed for water quality parameters. A water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. Six most important parameters such as pH, total dissolved solids (TDS), total hardness, Chlorides, Sulphates, and Nitrates were taken for the calculation of WQI. It gives the public a general idea of the possible problems with water in a particular region. GIS is a powerful tool for representation and analysis of spatial information related to groundwater resources management. To attain this aim, the ground water quality parameters and WQI value integrated with GIS map. The indices and GIS map are among the most effective ways to communicate the information on water quality trends to the public or to the policy makers and water quality management for irrigation and drinking. WQI is a mathematical equation which was developed by Horton and modified by Tiwari and Mishra [7,8]As WQI is calculated from the physicochemical elements of water, this parameter is one of the most effective tools to obtain a general idea of water quality. [9]This parameter is a mathematical technique that transforms multiple water characterization data into a unique number that reflects overall water quality.It is simple and easy to understand for decision makers about quality and feasible use of any water body. [10]Water quality index (WQI) has been widely used to indicate a water quality class for drinking use. [11]GIS is a powerful tool to evaluate water quality to understand water availability and to understand and manage water resources which are present in the natural environment. [12]This study's objective is to evaluate the quality of groundwater in the Kurnool District for drinking purposes using the WQI and Geographic information system (GIS). The study mainly focused on the generation of the spatial distribution of water quality parameters using GIS, which helps the policymakers to evaluate and manage the available groundwater resources.**

Index Terms— **pH, TDS, Nitrate, Chloride, Sulphate, WQI, GIS**

I. INTRODUCTION

It is estimated that only 2.5% of the world's water is utilizable. 70% of this occurs in the form of glaciers and ice sheets in Antarctica, Greenland, and mountain ranges while the rest is stored as groundwater. Groundwater pollution is one of the most main environmental and ecological issues in the current world. [1]Groundwater resources are dynamic and affected by several factors such as irrigation activities, industrialization, urbanization. Hence, monitoring and conserving these critical resources is essential. [2,3] Water quality is a vital environmental issue globally, and it depends on a large number of physicochemical parameters. Regular monitoring of water quality parameters and identification of contaminant sources are essential for providing safe water. [4] Geological formations, seasonal variation, and inconsistency in monsoonal rainfall, the rapid growth of population, intensive agriculture, and other anthropogenic activities on the ground and overexploitation of water sources led to the deterioration of surface water quality.Also, contamination of groundwater creates adverse consequences on human beings, mainly where unplanned urbanization takes place.[5] Customary and intermittent observing of water bodies with the necessary number of attributes, just as the nature of water, not just prevents the flare-up of sickness and event of other sick medical issues yet additionally checks the water from further contamination and accordingly secures it.Water quality index (WQI) is one of the most effective, simple and easily understandable tools to assess water quality for its

II. METHODLOGY

A. Study Area

Kurnool is a city of Andhra Pradesh state in southern India, about 307 kilometers south of state capital Amravati. Kurnool is the gateway to Rayalaseema and the largest city in the area. The district is located in the west-central part of the state. It has a population of 4,053,463 of which 28.35% were urban as of the 2011 census. The district is the third largest by area and tenth largest by population in the state. Average annual rainfall of Kurnool district is about 600mm. The K.C. Canal (Kurnool-Kadapa) was built by the Dutch for transportation and later sold and converted to irrigation purpose.

B. Sample Collection

The quality assessment of water involves two important aspects one is sampling and other is analysis. The sample collection must assure correct weighting of individual sampling times and locations where averaging is appropriate where maxima or minima values exist, statistical methods must be applied to observed variation to determine an adequate number of samples to assess probability of exceeding those critical values. The 126 water sample collected around Kurnool city and tested various parameters in laboratory for assessment of water quality index.

C. Water Quality Index Estimation

Water Quality Index (WQI) is defined as a value that reflects the combined influence of different water quality characteristics on the overall quality of water. Horton (1965) was among the first to give an idea of the concept of indices to represent water quality. The WQI has been calculated to evaluate the groundwater quality of the study area for the purpose of drinking. The BIS code for drinking purposes is considered for the calculation of WQI.To calculate WQI, six

parameters such as: pH, TDS, turbidity, acidity, alkalinity, chlorides have been used.To calculate WQI the following four steps are to be adhered.

D. Methodology

The survey of observation bore wells was fixed using GPS instruments and Arc GIS 10.1 software. The groundwater quality monitoring for drinking purpose was assessed in terms of physical and chemical parameters based on Bureau of Indian Standards (BIS, 1991 table1) .The Kumool map was selected from the toposheet of India, then the map was Geo – referenced with coordinates. Geographical information system (GIS) method is used to spatially represent water quality index data for the purpose of generating maps and making spatial comparisons of data. Spatial analyst tools were the primary tool used to produce maps that aided analysis. The spatially integrated data and analytical results can be used for corresponding water quality status. The WQI results were compared with standard guideline values shown in table 2.

Table1: Assignment of significance weight to the water quality parameter [17]

SI. No.	**Parameter Weight**	**Factor Standards**	**(IS-10500) (1991)**
1	pH	1	6.5-8.5
2	Total Dissolved Solids (mg/l)	3	500-2000
3	Total Hardness (mg/l)	1	300-600
4	Fluoride (mg/l)	3	1.5-2.0
5	Chloride (mg/l)	1	250-1000
6	Sulphate (mg/l)	2	25-1000
7	Nitrate (mg/l)	3	10-100

Table 2**:** WQI and corresponding water quality status [18]

S.No	Classification	WQI Value	Status
1	Heavily polluted	0-24	Unsuitable for all purposes
2	Poor	25-49	Special Treatment
3	Fair	50-74	Needs Treatment (filtration and disinfection)
4	Good	75-94	Acceptable
5	Excellent	95-100	Pristine quality

III. RESULTS AND DISCUSSION

The results obtained from analysis of water samples of Kurnool district, WQI values are shown in Table 3 and integrated map shown in figure 1. The results indicate that the quality of water varies considerably from location to location. A summary of the findings is given below:

Table 3: The results of ground water quality analysis and WQI values of Kurnool District

S.No	**Village Name**	**pH**	**TDS ppm**	**So4 mg/l**	**No3 mg/l**	**Cl mg/l**	**TH mg/l**	**WQI Value**
1	Venkatapuramu	8.50	794.24	14.00	2.60	160.00	159.92	50.736
2	80-Bannur	8.20	544.00	65.00	3.80	140.00	139.84	47.361
3	Potalapaddu	8.00	549.76	53.00	1.20	110.00	178.19	46.225
4	Thudicherla	8.10	814.72	69.00	3.90	200.00	279.92	70.806
5	Kothapalli	7.80	468.48	26.00	3.90	140.00	218.19	49.353
6	Allur	8.30	569.60	46.00	10.30	160.00	201.07	55.514
7	Bijinivemula	7.40	670.08	48.00	6.50	190.00	319.34	69.305
8	Maddigatla	8.00	691.20	23.00	26.40	270.00	440.49	92.097
9	East Prathakota	8.10	589.44	67.00	1.50	150.00	219.34	55.748
10	Nehru Nagar	7.90	639.36	57.00	1.00	150.00	159.34	50.019
11	Bhanakacherla	7.40	381.44	3.00	4.40	70.00	161.15	34.040
12	Bhanumukkala	7.70	457.60	14.00	56.80	140.00	318.77	73.177
13	Jutur	8.30	784.00	66.00	22.20	140.00	220.49	64.784
14	Vempenta	8.20	716.80	46.00	0.08	140.00	118.19	45.680
15	Atmakur	7.90	372.48	11.00	22.90	80.00	178.77	43.024
16	Kurukunda	7.60	1958.40	49.00	57.60	910.00	819.67	219.365
17	B.Atmakur	7.80	1238.40	76.00	2.90	490.00	520.99	126.939
18	Gani	7.50	2521.60	75.00	50.80	800.00	939.59	230.749
19	Gadivemula	8.30	1344.00	71.00	16.60	430.00	219.34	99.983

20	Bannuru	7.50	517.76	31.00	3.40	70.00	378.19	58.552
21	J.Banglow	8.10	531.20	73.00	4.80	130.00	158.77	48.910
22	Gargeyapuramu	7.80	403.20	26.00	22.40	100.00	218.77	50.188
23	Talamudupi	7.80	615.68	62.00	23.50	170.00	201.73	62.473
24	Kazipetta	7.80	1939.20	134.00	89.20	440.00	340.41	150.144
25	Jalakanuru	7.90	702.72	164.00	4.20	190.00	480.49	94.700
26	Miduthuru	7.80	2483.20	146.00	98.20	850.00	699.09	233.733
27	Nandikotkuru	8.50	1420.80	70.00	2.50	370.00	278.68	97.077
28	Pagidiyala	7.60	2713.60	169.00	10.20	1260.00	1319.42	306.892
29	Mittakandala	8.10	373.76	26.00	23.20	70.00	199.34	45.584
30	Velgodu	8.00	294.40	14.00	20.60	40.00	179.34	37.657
31	Pangidigudem	7.90	432.64	36.00	0.09	140.00	121.15	39.695
32	Chinnatekur	8.10	343.04	36.00	1.02	90.00	240.49	44.773
33	Krishnagiri	8.10	965.76	56.00	37.60	400.00	641.48	133.633
34	Lakkasagaramu	8.10	756.48	31.00	51.80	220.00	400.41	93.579
35	Kothaburuju	8.50	833.28	48.00	7.60	160.00	158.77	55.947
36	Kalichetla	7.90	452.48	21.00	38.10	60.00	318.11	60.843
37	Racherrla	7.90	407.04	19.00	25.80	50.00	199.34	44.401
38	Yegnaramapuramu	8.10	971.52	75.00	46.10	350.00	741.40	142.579
39	Kothavheruvu	7.80	723.20	20.00	4.30	190.00	241.07	60.186
40	Malkapuramu	8.00	435.20	16.00	10.60	90.00	298.68	52.763
41	Dhone	8.30	1312.00	61.00	9.50	350.00	559.09	119.954
42	Veldurthhy	8.00	1152.00	46.00	9.70	270.00	562.06	108.557
43	Mugathi	7.70	600.96	42.00	3.35	100.00	179.92	45.874
44	Baichigerri	7.60	600.32	22.00	39.20	100.00	261.07	62.224
45	Kallubavi	7.70	2880.00	125.00	89.30	1170.00	1140.74	305.522
46	Ahobilamu	7.40	336.64	14.00	1.53	50.00	220.49	36.932
47	Aspari	7.80	737.28	28.00	24.00	150.00	320.49	70.723
48	Banaganapalle	8.10	405.12	31.00	0.62	80.00	199.92	40.728
49	Pathapadu	8.30	961.92	44.00	3.70	250.00	200.49	68.595
50	Nandavaramu	7.90	652.16	39.00	33.30	160.00	261.07	68.561
51	Cement nagar	7.90	1058.56	62.00	40.30	190.00	338.11	89.893
52	Polakal	8.20	1203.20	102.00	27.20	290.00	458.60	112.416
53	Kothakota	8.60	1497.60	129.00	15.80	350.00	159.34	95.260
54	Chagalamarri	8.00	781.44	27.00	55.40	220.00	420.99	96.571
55	Chipagiri	7.80	1286.40	92.00	9.30	230.00	238.11	81.853
56	Ramadurgamu	7.70	2592.00	98.00	50.60	810.00	1241.48	262.535
57	Devanakonda	8.40	480.00	24.00	31.70	60.00	400.41	67.462
58	Chakirajuvemula	8.30	479.36	42.00	3.00	130.00	121.73	41.358
59	B.Agraharamu	8.70	810.24	48.00	15.90	150.00	159.92	57.361
60	Gonegandla	8.20	753.28	44.00	53.10	200.00	359.34	89.606
61	H.Kairavada	8.30	1459.20	127.00	6.80	480.00	399.26	125.100
62	Gospadu	8.10	776.96	72.00	5.00	200.00	198.77	63.348
63	Guduru	8.60	2201.60	146.00	63.00	620.00	319.84	163.044
64	Halaharri	8.10	1619.20	139.00	6.40	500.00	540.41	143.508

65	Yellarthy	7.60	972.80	35.00	33.30	280.00	460.41	102.876
66	Kodumuru	7.70	1185.28	93.00	22.00	270.00	460.41	107.739
67	Pulakurthy	8.40	790.40	65.00	51.70	160.00	298.11	82.684
68	Yerradoddi	8.00	691.84	47.00	29.10	150.00	278.11	69.437
69	Koilakuntla	8.20	1230.72	63.00	7.80	380.00	379.84	104.513
70	Kolimiguntla	7.80	855.04	124.00	30.10	210.00	219.34	79.698
71	Abdullapuramu	8.00	590.72	130.00	10.64	140.00	160.58	57.956
72	Vandagallu	7.90	429.44	50.00	34.80	50.00	280.49	57.732
73	Panchalingala	7.60	1632.00	165.00	8.88	420.00	519.26	137.357
74	bukkapuramu	7.90	526.72	61.00	28.70	140.00	359.84	74.047
75	Gajullapalli	7.50	773.12	49.00	20.15	280.00	439.26	94.550
76	Malapalli	8.50	622.72	51.00	44.60	130.00	339.84	77.338
77	Suguru	7.80	2745.60	158.00	29.80	930.00	2239.42	366.171
78	Thungabadra	8.10	680.32	88.00	1.46	160.00	240.49	62.129
79	Hussenapuramu	8.00	1479.68	156.00	13.28	480.00	601.48	148.274
80	Owk	8.20	402.56	50.00	1.24	60.00	101.73	31.913
81	Panyam	7.90	371.84	23.00	2.58	80.00	101.73	30.942
82	Tamarajupali	8.30	359.04	19.00	10.84	60.00	238.11	43.671
83	Kowluru	7.70	1452.80	131.00	21.90	370.00	439.84	123.248
84	Pandikona	8.20	412.80	31.00	2.84	80.00	139.34	36.094
85	Allamuru	8.20	410.24	31.00	7.26	90.00	258.11	49.093
86	Rudravaramu	8.00	387.20	15.00	2.88	80.00	199.92	39.572
87	Yellavarthula	8.10	308.48	17.00	6.78	60.00	159.34	34.058
88	Yerragudidinne	8.30	1792.00	108.00	21.80	640.00	521.48	159.626
89	Perusomula	7.90	879.36	59.00	21.35	330.00	441.07	102.707
90	Sirivella	7.80	521.60	56.00	1.02	110.00	161.15	44.261
91	Pendekal	8.00	826.88	53.00	58.40	180.00	360.99	91.579
92	Pagidirayi	8.00	696.96	44.00	26.90	120.00	281.65	66.185
93	Thugalli	8.10	525.44	42.00	33.00	90.00	319.26	65.486
94	Uyyalawada	7.60	2208.00	131.00	38.40	640.00	398.02	162.663
95	banavasi	8.50	711.68	30.00	17.30	200.00	379.84	78.773
96	Gudikallu	8.10	661.12	31.00	7.80	180.00	158.77	52.908
97	Kurnool	7.80	1002.24	81.00	6.20	320.00	259.34	84.860
98	Kowthalamu	7.80	416.00	15.00	4.50	100.00	281.07	49.661
99	rallakothur	8.10	462.08	36.00	6.10	120.00	179.92	45.697
100	Nandyala	7.50	1401.60	99.00	6.70	480.00	438.11	124.524
101	Haligera	8.10	826.24	31.00	47.20	250.00	539.18	108.796
102	Bethamcherlla	7.70	999.68	57.00	37.80	350.00	498.60	116.625
103	kosigi	7.50	976.00	68.00	45.60	300.00	659.18	129.489
104	Maddikera	7.90	1574.40	127.00	17.10	370.00	679.26	145.528
105	nannuru	8.10	989.44	62.00	65.20	280.00	418.11	111.757
106	Chinnakambalanuru	8.40	716.80	55.00	10.90	90.00	100.58	43.752
107	Adoni	7.60	680.32	33.00	4.50	210.00	200.49	58.657
108	Muthyalapadu	7.40	433.92	24.00	4.70	80.00	300.49	50.571
109	Nandyala	8.10	1062.40	65.00	17.30	290.00	261.07	85.474

110	Maddur	7.80	2937.60	135.00	71.10	1190.00	880.91	280.220
111	Kotekal	7.70	856.32	35.00	24.80	170.00	278.11	71.670
112	Bathuluru	8.20	1162.24	85.00	24.70	330.00	241.07	93.229
113	Kondapuramu	8.30	625.28	56.00	1.14	190.00	161.73	53.811
114	W.Govindinne	8.30	1753.60	124.00	42.95	680.00	239.92	144.831
115	Yalluru	8.00	801.28	93.00	2.22	220.00	601.48	103.225
116	Ramata	8.10	1465.60	158.00	2.50	390.00	301.07	109.502
117	Chetnihalli	7.90	1785.60	157.00	11.46	590.00	500.99	154.179
118	Ayyaluru	7.80	449.92	36.00	0.48	90.00	199.34	42.630
119	Govindapalli	7.90	463.36	46.00	70.80	160.00	154.65	67.454
120	Uppalapadu	8.30	608.00	39.00	3.36	140.00	198.77	51.445
121	Muthyalapadu	7.80	472.32	30.00	12.94	100.00	261.07	52.788
122	Sulikera	8.60	774.40	22.00	15.10	80.00	81.73	40.570
123	Basapuram	7.60	2188.80	164.00	34.30	760.00	1238.44	251.381
124	Sathanur	8.00	1225.60	108.00	20.80	380.00	540.99	126.979
125	Nagalapuram	7.80	2912.00	160.00	48.10	1110.00	1101.89	287.875
126	Halvi	8.10	820.48	71.00	37.00	210.00	380.41	91.167

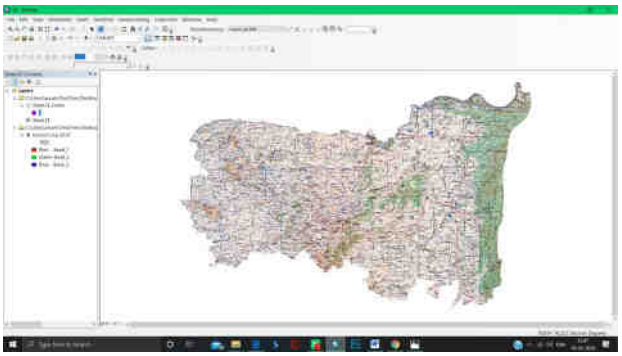

Figure 1: The WQI values integrated with GIS map

A. pH

pH is one of the important parameters of water and determines the acidic and alkaline nature water. The pH of the good quality water ranges from 6.5-8.5 as per BIS. The values of pH ranged from 7.4 to 8.7. Minimum value was observed in Bijivemula, Bhanakacherla, Ahobilam, Muthyalapadu villages and maximum value was observed in B.Agraharam village. The pH value of the samples was within limits as per standards.

B. Total dissolved solids

The concentration of dissolved solids in natural water is usually less than 500 mg/l, while water with more than 500 mg/l is undesirable for drinking and many industrial uses as per BIS stanadards. The minimum TDS (294.40 mg/l) was observed in Velugodu town, while maximum TDS (2937.60) was observed in Maddur village. This was mainly due to presence of cement grade limestone deposits in the nearby surroundings and also TDS concentration was high due to the presence of bicarbonates, carbonates, sulphates, chlorides and calcium. TDS can be removed by reverse osmosis, electro dialysis, exchange and solar distillation process.

C. Sulphates

Sulphates occur in natural water at concentrations up to 50 mg/l concentration. If 1000 mg/l may be found in water having contact with certain geological formation, rain water has quite high concentration of sulphate particularly in areas with high atmospheric pollution in humid regions. The observation of the SO4 value in the study area ranges between 3mg/l to169 mg/l. The sulphate values of the sample were within limits as per BIS standards.

D. Nitrate

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate can reach both surface water and groundwater as a consequence of agricultural activities like excess application of inorganic nitrogenous fertilizers and manures, from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. In the present studies the values varies from 0.08 mg/l to 98.2 mg/l .The study reveals that nitrogen levels are maximum in Midthuru, Sirivella and Kallubavi villages and minimum in most of the eastern villages of Kurnool district

E. Chloride

Chloride also occurs in bedrock cementing material. Chlorides in groundwater originate from various sources including the dissolution of halite and related minerals, marine water entrapped in sediments and anthropogenic sources. , chloride is a widely distributed element in all types of rocks in one or the other form. In case of high temperature and reduced rainfall conditions, the chloride concentration is found to be high. Soil porosity and permeability also shows their key role in building up chlorides concentration. Chloride containing water can be recognized as soil, discharge of effluents from chemical industries, all of this affected surface may result in local

contamination of both surface and groundwater. In this present study of the chloride higher value (1260 mg/l) is observed in Pagidyala village and lower value (40 mg/l) is reported in Velugodu village.

F. Total Hardness

The study in the Kurnool district revealed that higher values of Total Hardness are found in water which contain dissolved polyvalent metallic ions from sedimentary rocks, seepage and runoff from soils. Calcium and magnesium are the two principal ions, which are present in many sedimentary rocks, the most common being limestone which is largely found in many parts. And a minor contribution to the total hardness of water is also made by other polyvalent ions such as shale and iron. In this present study of the Total hardness values varies from 81.73 mg/l and 2239 mg/l. The higher value is observed in Suguru village and lower value is reported in Sulikera village.

G. Water Quality Index (WQI)

WQI is a single number which can be calculated easily and used for overall description of the quality of water bodies. In this present study the value of WQI varies from 30.942 and 366.71. The study reveals that 29 samples were poor quality which required special treatment, 36 samples were fair quality which required some degree of treatment, 17 samples were good quality which is acceptable for drinking and 37 samples were excellent quality of water for drinking purpose.

CONCLUSIONS

Application of Water Quality Index (WQI) in this study has been found useful in assessing the overall quality of water and to get rid of judgment on quality of the water. The computed WQI shows that 47.6% of water samples fall in the 'good' to 'excellent' water category. On the other hand 52.4% of water samples fall in the 'fair' to 'poor' category. The study benefits us to understand the quality of the groundwater resources to improve proper management in the area.

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