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A Study on Water Quality Ranking in Rajam

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***Abstract*— Prediction of water quality for drinking purpose is essential as water sources are becoming polluted rapidly. Conventional approaches for water quality prediction are (i) Assessment using Water Quality Index calculation, (ii) Assessment using Nemerow's Pollution Index. A third approach based on compliance of water quality parameters with respect to permissible values prescribed by IS 10500:2012 is also considered. Twenty five ground water samples, from Rajam town in Srikakulam district, are analyzed in laboratory for a specific set of parameters and are assessed for their suitability using the above three approaches. The water quality can be ranked as Poor using all the three approaches. Another set of twenty five treated drinking water samples are also analyzed and assessed using the above three models. The water quality in this case can be ranked as Excellent for drinking purpose indicating good treatment provided to the water.**

Keywords*— *Water quality, Water quality index, Nemerow's Pollution Index, Compliance study, Rajam

I. INTRODUCTION

The rapid growth of urban and semi urban areas affected the groundwater quality due to over exploitation of resources and improper waste disposal practices. The quality of water used for drinking should be of good standard to avoid undesired health impacts. Permissible values are available [4] to define suitability of water used for drinking purpose. However, due to fluctuation of water quality in different areas, a quality assessment approach is necessary. Several investigators [1, 3, 5, 6, 8, 12, 14, 15, 17-21] have studied on development of water quality indices (WQI) for assessing the water to be suitable for drinking or not. Fitting of actual field data to determine WQI of a locality is essential to take remedial measures for supplying potable water. Ramakrishna [11] used Multiple Regression models to assess the inter-relationship among the water quality parameters while Sirisha [16] and Ramakrishna [10] applied Artificial Neural Networks to predict the ground water quality.

The assessment of the water quality in Rajam, a small municipality in Srikakulam district, is considered in the present study. The sources that are considered are open wells and tube wells, which are the primary sources of drinking water to the local community. An educational Institute, GMRIT, is located in Rajam catering educational needs of young engineers, housing hundreds of students. The campus houses boys and girls hostels, staff quarters and hence there is a large demand for drinking water in the campus. They have a protected water treatment facility in the campus. Water quality of water supplied in the campus is also assessed for comparison.

II. SAMPLE COLLECTION AND LABORATORY TESTING

Representative water samples (25 each) were collected from Rajam town and GMRIT campus. They were given nomenclature as S1-S25 for Rajam town water samples while D1-D25 given to GMRIT campus drinking water samples. The sources of S1 to S25 were from wells and hand pumps of Rajam town, while the sources of D1 to D25 were from different student hostels, canteen, dining halls and administrative block of GMRIT campus. The samples were collected during February-March 2014. All the samples were analyzed for water quality parameters such as pH, Total Hardness, Chlorides, Total Dissolved Solids, Sulphates, Calcium, Magnesium, and Sodium for S1-S25. The drinking water samples D1-D25 are analyzed for pH, EC, TH, TDS and chlorides only. Titrimetric and instrumental methods were used to test the samples. All tests were done for ground water and after completing it drinking water samples were tested.

III. RESULTS AND DISCUSSION

The results of samples [13] S1-S25 are given in Table-1 while that of D1-D25 are given in Table-2. The impacts of these parameters beyond the prescribed limits are given in Table-3.

A. Assessment of suitability of water quality:

For assessing the suitability of water quality for specific purpose, the results are compared with the prescribed limits (Refer Table-1). The drinking water quality is compared with IS 10500:2012 [4]. The suitability of Rajam water for irrigation purposes is compared with the permissible value of Sodium Absorption ratio (SAR) available in literature [9]. It is determined using the following formula:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

Where, Na^{+}, Ca^{+2}, Mg^{+2} are in meq/L.

Water Quality Index based on Conventional WQI approach

The calculation of WQI for drinking purpose based on conventional approach [3, 5, 18, 20] depends on (i) assigning specific weights are assigned to the water quality parameters based on their relative importance (ii) calculation of quality index (Ci) of each parameter based on average value of the samples, standards and ideal values. The weights are assigned to each parameter such that, the most significant parameters have a weight of 5 and the least significant a weight of 1. The relative weight (Wi) of each parameter is calculated as a ratio of weight of individual parameter and total weights of all parameters.

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Table-2:Results of tests conducted on the drinking water samples in the campus

Sample No	pH	EC	TH	Cl	TDS
D1	7.56	0.187	7.7	26	100
D2	7.29	0.053	14	18	23
D3	7.61	0.061	9	18	27
D4	6.94	0.039	16	16	30
D5	7.01	0.02	5	12	26
D6	7.21	0.18	7	11	21
D7	7.09	0.185	0	12	22
D8	6.25	0.012	0	9	21
D9	7.1	0.059	14	14	34
D10	6.93	0.093	9	19	21
D11	6.32	0.015	7	9	23
D12	6.68	0.0461	9	12	27
D13	6.68	0.0537	7	11	29
D14	6.63	0.0701	20	12	38
D15	6.7	0.0545	7	11	30
D16	7.68	0.6	207	48	412
D17	7.97	0.608	216	42	422
D18	7.81	0.65	189	53	403
D19	7.88	0.702	207	57	455
D20	7.82	0.528	176	49	352
D21	7.83	0.654	185	65	410
D22	7.63	0.668	198	53	423
D23	7.35	0.114	27	16	68
D24	5.2	1.2	252	78	462
D25	7.44	0.849	252	81	455
Max	7.97	1.2	252	81	462
Min	5.2	0.012	0	9	21
Avg	7.14	0.31	84	29.6	173.4
Permissible	6.5-8.5	0.3	200	250	500

Table-3: Impacts of certain important water quality parameters

S.No	Parameter	Undesirable effect outside the desirable limit
1.	pH	Beyond this range the water will affect the mucous membrane and/or water supply system
2.	EC	Higher qualities of electrical conductivity indicates higher quantity of dissolved solids
3.	TDS	Beyond this palatability decreases and may cause gastro intestinal irritation
4.	Total Hardness (as $CaCO_3$ in mg/L)	Encrustation in water supply and adverse effect on domestic use
5.	Chlorides (as Cl in mg/L)	Beyond this taste/corrosion and palatability are affected
6.	Calcium (as Ca in mg/L)	Encrustation in water supply structure and adverse effect on domestic use
7.	Magnesium (as Mg in mg/L)	Encrustation in water supply structure and adverse effect on domestic use
8.	Sulphates	Diarrhea, Dehydration, Scaling and Corrosion in pipes, Stains, bad smell in water.

The formula for calculation of water quality index is given as follows:

Relative weight of each parameter, Wi = Σ (Wi/W)

Where, W = total weights of all parameters

Quality index of each parameter, Ci = [(Va-Vi)/(Vs-Vi)] x 100

Where, Va = Average value of the parameter

Vi = Ideal value of the parameter = (7 for pH and zero for other parameters)

Vs = Standard value of the parameter

The product of (Ci)(Wi) is calculated and is summed up for all the parameters under the study. The WQI of the water for drinking purpose is assessed based on the following rating scale [5]:

WQI Rating scale:

WQI: < 50: Excellent

WQI: 50-100: Good

WQI: 100-200: Poor

WQI: 200-300: Very poor water

WQI: >300: Unsuitable

The WQI value for the Rajam and GMRIT campus are calculated based on the above approach and are given in Tables-4 and -5. The ratings are also given based on the above classification.

Water Quality based on Nemerow's Pollution Index (NPI):

The ground water quality of the study can also be assessed using Nemerow's Pollution Index (NPI) using the average values of the water quality parameters. The NPI value, dimensionless, of each parameter indicates the relative pollution contributed by single parameter [19]. NPI value exceeding 1.0 indicate the presence of impurity in water and hence require some treatment prior to use. The NPI values for the two sets of water samples S1-S25 and D1-D25 are calculated and given in Tables -6 and -7 respectively.

Table-6: NPI values of ground water samples of Rajam

Item/Parameter	pH	TH	Cl	TDS	SO4	Ca	Mg
Max.	7.6	1515	789	4775	407	287	251
Min.	6.9	318	122	437	94	25	29
Avg	7.2	680	360	1758	233	110.2	99.2
Permissible	6.5-8.5	200	250	500	200	75	30
NPI	0.96	3.4	1.44	3.52	1.17	1.47	3.33

Table-7: NPI values of drinking water samples in GMRIT campus

Item/Parameter	pH	EC	TH	Cl	TDS
Max.	7.97	1.2	252	81	462
Min.	5.2	0.012	0	9	21
Avg	7.14	0.31	84	30	173
Permissible	6.5-8.5	0.3	200	250	500
NPI	0.95	1.03	0.42	0.12	0.35

From Table-6, it can be understood that, except for pH, the NPI values of all other parameters are >1 indicating that they are present in ground water beyond the permissible limits. The NPI values are ranging from 1.17 (117%) to 3.52 (352%) indicating a high increase. Particularly, the parameters TH, TDS and Mg show >300% increase indicating the water as very hard and presence of high salt content. The ground water quality may hence be ranked as **very poor** and unsuitable for drinking which is in acceptance of the observation that was derived from conventional WQI approach discussed earlier. On the other hand, the NPI values of drinking water of GMRIT campus indicate (Refer Table-7) that all the parameters are within the permissible limits. A few samples collected do not have RO treatment system [13] that reflected in a few high values of TH, EC and TDS values. This is noticeable in slightly high NPI values, which otherwise

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showed a pretty low (0.12-0.42) NPI values. The drinking water quality can hence be ranked as Excellent.

Water Quality Index based on compliance studies

The compliance status i.e., number of samples that are exceeding the limits, is noted for each parameter. The results are given in Table-8 for Rajam water samples. The total number of samples tested for each parameter is 25. The percentage compliance status with regard to each parameter is calculated. For example, the pH value of all the samples for drinking purpose is within the prescribed limits (< 7.5) and hence it becomes 100% (= 25/25) compliance. Whereas, only one sample is within the limits for magnesium and hence it becomes 4% (= 1/25) compliance. Though the permissible limits of pH are given as 6.5-8.5 an average value of 7.5 is considered in the present study where as the ideal value of pH is taken as 7.0 [3], which indicates neutral value. However, the pH of natural water is slightly alkaline in nature [7].

In order to assess the water quality ranking of the samples, a linear ranking approach [2] based on compliance studies is adopted. In this approach, the total weight of all the parameters is considered as 100 and it is assumed that all the parameters are of equal importance. Hence the weight contribution for each of the 7 parameters considered for drinking purpose equals to 14.28 (= 100/7). This weight is multiplied with the percentage compliance of each parameter to obtain the weighted score. The score is added to obtain the overall score of the water quality (Refer Table-4). The cumulative weighted score obtained is divided by 100, the total points considered, to obtain the water quality ranking index based on percentage compliance (WQIPC). The water quality can be ranked based on the following linear scale:

WQIPC value: < 20: Very Poor
20-40: Poor
40-60: Moderate
60-80: Good
>80: Excellent

Water Quality Index based on compliance studies = 2685/100 = 26.85 = Poor quality

It can be noted from the above data that, only pH is below the limits in all the samples whereas Total hardness (TH) and Magnesium are in excess for all the samples indicating the ground water as hard. Large numbers of samples (20-24) are also in excess of permissible limits of chlorides and TDS indicating the high salinity of the water. All these values indicate the poor quality of water for drinking purpose.

Similar analysis is conducted on drinking water samples of GMRIT campus (Refer Table-9). The values for Cl, and TDS values are within the permissible limits and showing 100% compliance each. EC and pH are showing 64% compliance while TH is showing 80% compliance. The WQIPC score obtained is 8160 and hence the index is 8160/100 = 81.6, which indicates excellent. The TDS and Chloride values of all the samples are below the limits indicating good efficiency of RO treatment system provided in the campus for salinity. Only nine samples are exceeding for EC and pH while only 4 samples exceeded the limit of 200 for TH. Since only 5 parameters are considered in this study, the weight of each parameter will be taken as 20 (=100/5).

It should be noted that, the pH value that is considered for compliance is only 7.5 where as the upper limit is 8.5. All the samples are well within the limits of the upper limit of pH. If the upper limit of 8.5 is considered for compliance, the water quality index value is 88.80, which is higher than 81.6 obtained, and can be rated as Excellent.

Similarly the TH values exceeded only marginally above 200 mg/L (maximum: 252 mg/L) that is considered as prescribed limit and hence the water quality can be considered Excellent without any specific doubts. Few samples collected in the study are untreated water samples and hence recorded high values that reflected in high value of water quality index.

All samples of Rajam (S1-S25) are suitable for irrigation purpose i.e. the SAR values of all samples are within the permissible limit and are classified as very good [9] with low SAR value (< 10) as evident from Table-1. Hence a 100% compliance is obtained for the samples.

B. Salient Observations

- A comparison of the three water quality models studied is given in Table-10. It can be noticed that, the water quality of Rajam using all the three approaches is same (Poor) while that of GMRIT campus is also same (Excellent). This shows that all the methods can be reasonably used with similar accuracy.

Table-10: Comparison of results of water quality models studied

S No	Ranking approach	Water quality ranking for drinking	
		Rajam town	GMRIT campus
1	WQI approach	Poor	Excellent
2	NPI approach	Very Poor	Excellent
3	Compliance studies approach	Poor	Excellent

- Compliance method is used when the sample sources are same or assumed to be same and a large amount of sample data is available. In Rajam, it is assumed that the samples collected are representative samples of the entire area representing entire Rajam town. Reasonably a large data (25) is available for the study.
- Ideally, the WQI should be done for each area [1, 3] so that WQI of each area will be understood for taking better decisions. However, average values are also being taken [5] for calculating WQI assuming uniform distribution of samples in the study area.
- The drawback in conventional method is assigning weights for each parameter with accuracy. No defined scale is available except the point that weight and magnitude of permissible values are inversely proportional. Different weights may be assigned by different investigators for the same parameter.
- The compliance method approach is developed based on compliance to prescribed standards but not on adverse impacts of pollutants if present in excess concentrations.
- It may be noted from Table-8 that, the percentage compliance of TDS, Chlorides, Total hardness, Calcium

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and Magnesium hardness is very low with regard to drinking water quality in the study zone.

- It may also be noted that the compliance studies approach and NPI approach are similar in principle of assessment. The results are also comparable.
- In Rajam, the TDS value ranges from 473-4775 mg/L (up to 9 times higher), Chlorides range from 122-788 mg/L (up to 4 times higher) while total hardness ranges from 317-1022 mg/L (up to 5 times higher). This shows that, the water in the study zone is hard to very hard and saline. This implies that the ground water is not fit for direct consumption and warrants for usage of water treatment systems for its usage.
- The high TDS in drinking water may cause gastro intestinal irritation, high hardness may cause encrustation in water supply and adverse effect on domestic use and excess chlorides may lead to taste/corrosion problems and palatability.
- Higher values of calcium and magnesium lead to encrustation in water supply structure and adverse effect on domestic use.
- The permissible values of the above parameters for drinking purpose in the absence of alternate source are given by IS 10500:2012 as 2000 mg/L (TDS), 1000 mg/L (Chlorides) and 600 mg/L (total hardness). Considering the relaxation given by the IS Code, it is noted that only 5 samples are exceeding TDS value of 2000 mg/L and 14 samples exceeding 600 mg/L of total hardness. It clearly shows that around 56% of the samples collected are showing high hardness even with relaxation. The chloride values of all the samples within the relaxation limit of 1000 mg/L.
- Hence, it is recommended that all the ground water users in this study zone should use only protected water for drinking purpose.

IV. SUMMARY AND CONCLUSIONS

The ground water quality assessment of Rajam is studied using three different approaches viz., conventional WQI approach, NPI approach, and compliance studies approach. The results indicated that ground water quality is Poor for drinking purposes. The drinking water quality of treated water is also assessed using similar approaches. The water quality is very good and can be ranked as Excellent using all the approaches.

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Table-1: Results of tests conducted on the ground water samples

Sample No	pH	TH	Cl	TDS	SO4	Ca	Mg	Na	SAR
S1	7.55	485	258	1243	152	35	71	220	4.88
S2	7.34	688	526	2214	407	44	139	229	3.79
S3	7.12	530	187	882	254	41	103	96	1.8
S4	7.6	493	328	1297	103	25	65	222	5.28
S5	7.18	490	222	943	94	44	91	111	2.18
S6	7.18	945	482	2553	243	94	170	230	3.25
S7	7.45	510	292	1169	357	51	92	115	2.21
S8	7.1	663	449	2100	167	99	100	174	2.94
S9	7.46	425	300	1228	101	51	71	143	3.07
S10	7.05	743	444	1664	131	82	129	139	2.21
S11	6.93	825	392	1991	43	191	83	102	1.53
S12	7.05	840	317	1696	267	141	117	119	1.78
S13	7	705	353	1802	273	122	96	176	2.87
S14	7.11	783	295	1534	237	86	136	152	2.36
S15	7.14	878	479	1916	83	118	140	136	2.0
S16	6.93	1515	789	4775	346	188	251	203	2.26
S17	7.5	318	122	437	204	79	29	82	1.99
S18	7.01	535	253	1791	230	128	52	118	2.22
S19	7.04	568	246	1861	381	138	34	129	2.53
S20	7.05	628	280	1272	203	181	42	104	1.8
S21	7.23	490	222	1016	126	77	71	100	1.96
S22	6.9	965	400	1833	217	262	74	88	1.22
S23	7.46	780	277	1220	207	87	135	56	0.86
S24	7.31	748	480	2156	319	105	116	163	2.95
S25	6.99	1023	610	3351	325	287	73	111	1.51
Max.	7.6	1515	789	4775	407	287	251	230	5.28
Min.	6.9	318	122	437	94	25	29	56	0.86
Avg	7.2	680.1	360.12	1758	233	110.2	99.2	140.7	2.45
Permissible	6.5-8.5	200	250	500	200	75	30	NA	< 10

Table-4: Water Quality Index of Rajam based on Conventional approach

S. No	Parameter	Permissible value, Vi	Average Value, Va	Quality index, Ci	Weights	Relative Weight, Wi	Water Quality Rating Score, Si = (Ci)(Wi)
1	pH	7.5	7.2	40	4	0.19	7.6
2	Total hardness	200	680	340	2	0.095	32.3
3	Chlorides	250	360.12	144	3	0.143	20.6
4	TDS	500	1758	351.6	4	0.19	66.8
5	Sulphates	200	233	116.5	4	0.19	22.14
6	Calcium	75	110.2	147	2	0.095	13.97
7	Magnesium	30	99.2	330.67	2	0.095	31.41
	Total				21	1.00	194.82

WQI rating: Poor water (100-200)

Table-5: Water Quality Index of Campus water based on Conventional approach

S. No	Parameter	Permissible value, Vi	Average Value, Va	Quality index, Ci	Weights	Relative Weight, Wi	Water Quality Rating Score, Si = (Ci)(Wi)
1	pH	7.5	7.5	6.67	4	0.24	1.6
2	Total hardness	200	84	42	2	0.12	5.1
3	Chlorides	250	29.6	11.84	3	0.18	2.13
4	TDS	500	173.4	34.68	4	0.24	8.32
5	EC	0.3	0.31	3.33	4	0.24	0.8
	Total				17	1.00	17.95

WQI rating: Excellent (<50)

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Table-8: Compliance status of Rajam water quality for drinking purpose

S. No	Parameter	Suitability	Total samples	Compliance	% Compliance, Ci	Weight, Wi #	Score, Si = (Ci)(Wi)
1	pH	All	25	20	100	14.28	1428
2	Total hardness	Nil	25	0	0	14.28	0
3	Chlorides	S3, S5, S17, S19, S21	25	5	20	14.28	285.6
4	TDS	Only S17	25	1	4	14.28	57.12
5	Sulphates	S1, S4, S5, S8-11, S15, S21	25	9	36	14.28	514.08
6	Calcium	S1-5, S7, S9	25	7	28	14.28	400
7	Magnesium	Nil	25	0	0	14.28	0
	Total						2685

100/7 = 14.28

Table-9: Compliance status of Drinking water quality in GMRIT campus

S. No	Parameter	Suitability	Total samples	Compliance	% Compliance, Ci	Weight, Wi #	Score, Si = (Ci)(Wi)
1	pH	Except D1, D3, D16-D22,	25	16	64	20	1280
2	EC	Except D16-D22, D24, D25	25	16	64	20	1280
3	TH	Except D16, D17, D19, D24, D25	25	20	80	20	1600
4	Cl	All	25	25	100	20	2000
5	TDS	All	25	25	100	20	2000
	Total					100	8160

100/5 = 20