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GIS backed parametric surface and groundwater quality indexing in the vicinity of a multi-utility system tank

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Parametric water quality indexing (WQI) helps integrate the interwoven effects of independent parameters which may enhance or impair the desirable physico-chemical and biological characteristics of both surface waters and groundwater reserves. Monsoon and post-monsoon status of the distribution of such parameters will give an insight on improvising the qualities of water for multiple usages in the vicinity of a tank and its influential area on groundwater contamination. A typical system tank in Coimbatore urban reach of the Noyyal river was studied by using GIS applications. The test values of all parameters considered were subjected to indexing for water quality grades inflicted by the presence of contaminants. On a 1 to 5 gradation, the study area was found to have a weighted mean water quality index of 2.34 and 2.35 for tank surface water during the monsoon and post-monsoon periods, respectively. In case of ground water sampling, the same was found to be 2.17 and 2.19 for the respective situations. The overall hazard rating was characterized under medium to high, warranting quarantine measures to safeguard the water quality standards for multiple uses in the study locality, pinning the eyes on dissolved oxygen improvements, turbidity control mechanisms, alkalinity amendments and moderations of hardness prevailing as high hazard indicators. The pre-monsoon season ratings were nearing the critical conditions at overall ratings ranging from 3.03 to 2.65 (high to severe) for surface and groundwater, respectively.

[**Keywords**: Water quality index; Surface water; Groundwater; Dissolved oxygen; Turbidity; Alkalinity and hardness; Monsoon]

Introduction

The knowledge and wisdom gained by our farming commu nity over decades with their long term trial and error experiences and experimentations hitherto have established Indian agriculture to be a 'Gamble with Monsoon' even as monsoons too have become unpredictable. Besides irrigation requirements, domestic and industrial sectors also compete on water for drinking, construction and processing needs. Surface water reserves and subterranean aquifers store the rainwater for multi-purpose usage in their vicinity in an impeccable way of distribution through canal and pipeline systems[1-4]. However, at the user end, the quality of water received gets impaired on account of point source and distributed contaminations from storm run-off, sewerage from domestic pockets, and effluents from industrial processing units. Water balancing and water budgeting to meet the multi-utility consumptions mostly result in significant water demand-supply gaps due to over-exploitation of surface and sub-surface water resources by way of unscrupulous pumping and wastages. Mostly, the conjunctive use of surface and subterranean water storage that is also responsible for water quality variations in accordance with the solute transport of salts and other contaminants governed by water table fluctuations and the concentrated influx of contaminants along streams and eventual depositions leads to eutrophication problems in stagnant water bodies such as tanks, ponds and lakes[5-9]. System tanks fed by stream or canal network or non-system tanks with their own independent catchments do contribute to the recharge of groundwater over a certain radius of influence from the water spread or the reservoir areal extent both on the downstream side and upstream side as can be observed from the water level variations in the wells of the tank command[10-13]. Hence, from the user end point of view, the corresponding quality criteria for the waters distributed from the surface storage or pumped from the wells should be assessed spatially and temporally, before water reaches its utility domains viz., drinking water supply storage, irrigation distribution, industrial process needs etc. Sustenance of the biosphere depends on the appropriate quality of water consumed by the flora and fauna that are in co-existence with human race that is consistently getting involved in developmental activities. Hence, water quality monitoring is a *sine quo non* to be accomplished in tandem with the lithosphere and hydrosphere barring the atmosphere as the primary contributory source of all our surface and subterranean water resources[14,19]. The scenario on the spatial variations of the key water quality parameters in the vicinity of a contamination-prone Ukkadam Periyakulam System Tank, lying at the downstream reach of the Noyyal River's axial passage through Coimbatore city, is presented.

Features of the study area

The Noyyalriver stretch proliferating and meandering through Coimbatore region encompasses 21 anaikuts and 31 tanks, of which 8 system tanks are located within Coimbatore city, viz.,, Narasampathi tank, Krisnampathi tank, Selvampathi tank, Kumarasamy tank, Selvasindhamani tank, Ukkadam periyakulam tank, Valankulam tank, and Singanallur tank. The study was however limited only to Ukkadam periyakulam tank only (Fig. 2.1) that is knitted to the downstream reach of the Noyyal River feeding where the concentrated dumping of pollutants and contaminants along the stream flows gushing into the tank water spread pose a severe threat on the surface water and groundwater qualities.

Methodology

The primary data collected includes the laboratory analysis results for the water samples collected along the stretch of the Ukkadam Periyakulam tank. Secondary data such as rainfall data, water quality data, ground water level data, lithology data, and aquifer parameters data were obtained from State Surface Water and Groundwater Board. The geo-referenced map of the study area was subjected to Arc/GIS analysis for spatial interpolations on water quality distributions (Fig. 2.2). By and large, the water quality indexing involves attachment of weights for specified quality ranges of the independent parameters that are going to result in an integrated change upon mutual interactions within the water body. For the present investigation, four sampling sites are selected randomly by considering the domestic, agricultural and industrial factions. The ground water and surface water of the pre- monsoon/summer (March-June), monsoon (July-November) and post–monsoon (December-February) seasons were analyzed for various physico-chemical parameters in line with NSF's parametric considerations for five samples per parameter. The results were compared with the drinking water standards/guidelines by Indian Standards (IS 10500:2012) and World Health Organization (WHO 2008). The water quality indexing was done based on the weights affixed to these parameters and the overall index taken as a weighted mean value of all the independent parametric water quality indices. The relative severity grading has been done on 1 to 5 grade scale in which <1 is hazard free or low, >1to 2 is medium, >2 to 3 is high, >3 to 4 is severe, and >4 to 5 is critical.

The flow chart best exemplifies the scrupulous methodology followed as regards the water quality indexing (Fig. 3.1).

Fig. 2.1 — Ukkadam Periykulam: Water sampling nodes

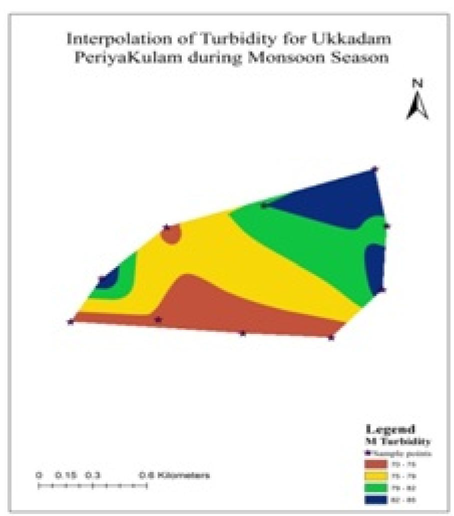

Fig. 2.2 — A sample GIS parametric output

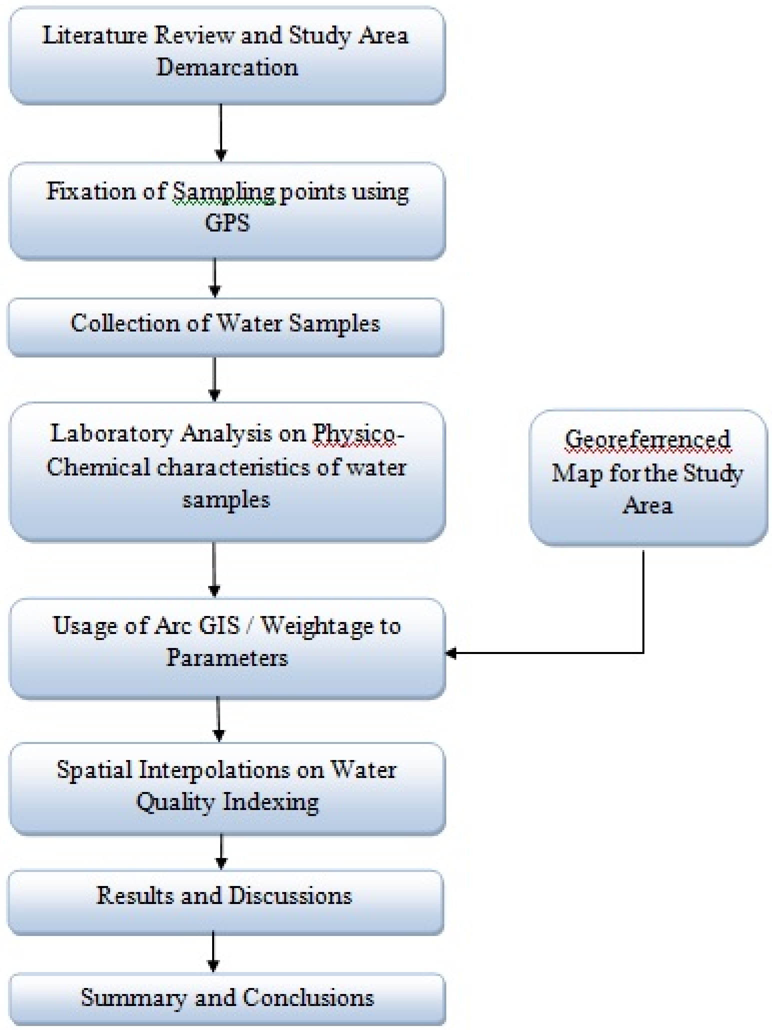

Fig. 3.1 — Flow chart for methodology

Results and Discussion

Lab assessment on water quality parameters

Five samples were collected from various nodal points randomly in and around the tank and the location by latitude and longitude of the sample collection points were noted down simultaneously. Table 4.1 furnishes the test result of mean parametric values for the 10 surface and groundwater water samples at a given nodal spot during monsoon season. Table 4.2. depicts the same for post-monsoon season in their customary units of measurement. The results were compared with the water utility guidelines of Indian Standard (IS 10500:2012).

The test values recorded as furnished in these tables indicate the distinctive effects on physico-chemical characteristic variations between the monsoon season contaminant dumps and the post-monsoon season residuals. As regards the colour and odour, both surface and groundwater samples exhibited satisfactory appearance from clear to slight grey waters and not much of odour diffusion in the vicinity during the monsoon season and the variations within the quality criteria were as agreeable by the IS or WHO guidelines. Hence the weights for these two parameters were reckoned as unity without much error.

Water quality indices

Barring the colour and odour, the remaining quantifiable parameters were assigned weights and the weighted mean values were used to get at the water quality indices for both surface water and the groundwater samples collected from the nodal points in the vicinity of the tank under study. The hazard rate

Table 4.1 — Water quality parameters: Ukkadam Periyakulam tank/pre-monsoon season

Physical/ chemical parameters	Water Quality Limits Prescribed by			Ground water and Surface water 5 Sample Mean values at (4 surface water + 8 groundwater) Nodal Points											
				Surface water				Ground water							
	IS 10500:2012		WHO	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
	From	To													
Colour	-	-	-	CL	G	CL	CL	SG	CL	CL	CL	CL	CL	CL	CL
Odour	Agreeable	Agreeable	-	O	O	E	O	O	M	O	O	O	O	O	O
Turbidity (NTU)	1	10	15	96	88	92	85	89	87	85	85	82	86	88	83
TDS(mg/L)	500	2000	-	159	147	132	140	149	137	139	141	132	138	144	133
EC	-	-	-	3.52	3.84	3.99	5.65	4.51	3.74	6.67	4.15	5.42	5.27	4.44	4.79
pH	6.5	6.5	6.5-8.5	8.81	8.61	8.9	8.58	8.64	8.48	9.36	9.67	8.85	9.5	9.58	8.92
TA(mg/L)	200	600	-	520	625	435	530	510	557	589	625	608	639	746	722
TH(mg/L)	200	600	150-500	552	675	695	855	765	409	667	805	722	879	475	859
Cl^-(mg/L)	250	1000	250	297	430	478	318	485	393	419	550	623	500	463	443
SO_4^{2}(mg/L)	200	400	500	377	334	409	415	356	264	262	423	356	467	337	359
DO(mg/L)	-	-	-	1.4	1.2	1.4	1.2	1.6	1.2	1.1	1.1	1.3	1.5	1.4	1.8
$(BOD)_5$,mg/l	-	-	-	237	416	301	286	292	294	277	267	293	295	271	217

grading for all these parameters was restricted to a uniform weightage factor range of 1 to 5 as to the relative severity of contaminant impact status.

Parametric water quality indexing (WQI) for turbidity

In accordance with IS 10500:2012 guidelines, the turbidity was measured in NTU units specified with the acceptable limits in the range of 1 to 10 and by the WHO standards at 15. However, the observed values of turbidity were found to be more than this limit range for all the samples collected and tested. A perusal onto the tabulated values for both monsoon and post-monsoon situations indicated a range of 60 to 90.

Hence, the weight ranges were stipulated as follows:

Turbidity (NTU)	50-60	60-70	70-80	80-90	90-100
Hazard rating	Low	medium	high	severe	critical
Weight	1	2	3	4	5

The weighted mean value of turbidity for pre-monsoon season stands at 91.50 NTU for surface water and at 85.65 NTU for ground water. The weighted mean value of turbidity for monsoon season stands at 81.4 NTU for surface water and at 77.48 NTU for the groundwater. By the same token, weighted mean values of turbidity for the post-monsoon season were reckoned to be 76.33 NTU and 74.30 NTU for the surface and groundwater sampling respectively.

However, the relative severity of the effect of turbidity in waters is given by the weighted mean value of the weights assigned in accordance with the actual turbidity values test verified, towards arriving at an integrated effect in terms of the overall parametric water quality index for the conditions stipulated and the parameters accounted for.

As to this rationale, Tables (4.1.1 to 4.3.1) summarize the weighted mean values of the parametric pre-monsoon $(WQI)_t$ values for the surface water at 4.07 and that for the groundwater at 3.11. The same form on soon quality rating were registered respectively at3.78 and 3.05. The corresponding values for the post-monsoon sampling were found to be 3.04 for surface water and 2.95 for groundwater.

Parametric water quality indexing $(WQI)_s$ for total dissolved solids

In accordance with IS 10500:2012 guidelines, the total dissolved solids (TDS) was measured in mg/l units specified with the acceptable limits in the range of 500 to 2000. However, the observed values of TDS were found to be far below the lower limit 500 for all the samples collected and tested. A perusal onto the tabulated values for both monsoon and post-monsoon situations indicated a range of 20 to 80 only. Hence, the parametric water quality indexing $(WQI)_s$ in the study area confined is taken as 1 irrespective of surface or ground water sampling and monsoon or post-monsoon. However, drastic deviations were found with the values during the pre-monsoon season even within the accepted range. The weighted mean

Table 4.1.1 — Summary of parametric water quality indices (Pre-monsoon)

S. No.	Parameter	Surface Water	Ground Water
1	Turbidity	4.07	3.11
2	Total Dissolved Salts	1.9	1.5
3	EC	2.1	1.95
4	pH	1.5	1.3
5	Total Alkalinity	4.25	3.91
6	Total Harness	3.96	3.24
7	Chlorides	2.67	2.42
8	Sulphates	1.8	1.4
9	Dissolved Oxygen	5.00	5.00
	Overall Index	3.03	2.65
	Overall Hazard Rating	High to severe	Medium to high

Table 4.2.1 — Summary of parametric water quality indices (Monsoon)

S.No.	Parameter	Surface Water	Ground water
1	Turbidity	3.78	3.05
2	Total Dissolved Salts	1	1
3	EC	1.25	1.15
4	pH	1	1
5	Total Alkalinity	3.44	3.45
6	Total Harness	3.72	3.40
7	Chlorides	1.57	1.51
8	Sulphates	1	1
9	Dissolved Oxygen	4.30	4.20
	Overall Index	2.34	2.19
	Overall Hazard Rating	Medium to High	Medium to High

values were 145 and 134 for surface water and groundwater sampling, respectively, resulting in corresponding parametric WQIs of 1.9 and 1.5.

Parametric water quality indexing (WQI) for electrical conductivity

By and large, the levels of contaminant concentration in domestic or irrigation or industrial waters are limited in the electrical conductivity (EC) range of 3 to 15 mg/l. However, the tested values of turbidity were found to fluctuate from 2 to 6 mg/l close range. Hence, the weight ranges were stipulated as follows:

EC, mg/l	< 3	3 - 6	6 - 9	9 - 12	12 - 15
Hazard rating	low	medium	high	severe	critical
Weight 1	2	3	4	5	

The weighted mean values of EC obtained from the water extracts during the pre-monsoon season were 4.56 mg/l for surface water and 4.44 mg/l for the ground water. The weighted mean value of EC for monsoon season stands at 3.39 mg/l for surface water and that for the ground water at 3.13 mg/l. In the same line, weighted mean values of EC for the post-monsoon season were reckoned to be 3.17 mg/l and 3.09 mg/l for the surface and groundwater sampling, respectively. The overall rating was found to be medium hazard only.

Parametric water quality indexing (WQI) for pH

A perusal of the pH values from the master tables suggests that the pH is well within the prescribed range of 6.5 to 8.5 as per IS or WHO guidelines in relation to the relative salinity/alkalinity/neutral levels. Hence, the parametric $(WQI)_{pH}$ is taken as 1 irrespective of the monsoon or post-monsoon seasons or the surface and ground water sampling. However, during the pre-monsoon season, this situation got turned down and the pH values for the surface water was at a weighted mean value of 8.56 and that for the ground water was at 9.23, showing relatively escalated salinity levels. By appropriate dilution techniques, the pH range can be toned down to the safe range of 6.2 to 8.5

Parametric water quality indexing $(WQI)_a$ for total alkalinity (TA)

Upon browsing through the tabulation, the level of contaminant concentration in surface and ground water sampling irrespective of the monsoon are contained well within the IS prescribed total alkalinity (TA) range of 200-600 mg/l. However, the tested values of TA were found to fluctuate widely even within this relatively wider range. Hence, the weight ranges were stipulated as follows:

TA, mg/l	<200	200 – 300	300 – 400	400 -500	> 500
Hazard rating	low	medium	high	severe	critical
Weight	1	2	3	4	5

The weighted mean values were at 550 mg/l for surface water and that for the ground water was found to be around 625 mg/l indicating critical conditions of alkalinity. The weighted mean value of TA for monsoon season stands at 378.46 mg/l for surface water and at 430.00 mg/l for the ground water. In the same line, weighted mean values of TA for the post-monsoon season were reckoned to be 359.15 mg/l and 308.13 mg/l for the surface and ground water sampling, respectively.

Table 4.2 — Water quality parameters: Ukkadam Periyakulam tank/monsoon season

Physical/ chemical parameters	Water Quality Limits Prescribed by			Ground water and Surface water 5 Sample Mean values at (4 surface water + 8 groundwater) Nodal Points											
				Surface water					Ground water						
	IS 10500:2012		WHO	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
	(A)	(B)													
Colour	-	-	-	CL	G	CL	CL	SG	CL	CL	CL	CL	CL	CL	CL
Odour	Agreeable	Agreeable	-	O	O	E	O	O	M	O	O	O	O	O	O
Turbidity (NTU)	1	10	15	87	81	84	71	73	74	72	85	74	82	80	75
TDS(mg/L)	500	2000	-	80	40	10	20	40	10	30	20	10	50	40	20
EC	-	-	-	2.59	2.87	1.59	4.95	2.11	0.077	5.07	2.15	4.4	3.2	1.94	2.77
pH	6.5	6.5	6.5-8.5	7.81	8.01	8.2	7.56	7.61	7.38	7.56	8.1	7.8	7.5	7.52	7.13
TA(mg/L)	200	600	-	440	425	235	330	310	250	520	325	400	530	340	525
TH(mg/L)	200	600	150-500	450	575	490	850	465	200	760	600	525	800	175	650
Cl^-(mg/L)	250	1000	250	197	133	217.8	215.8	385.8	193.9	219	150	123.3	200.1	163.9	143.93
SO_4^{2}(mg/L)	200	400	500	174	137	103	107.8	156	64	62	123.5	155.7	167.8	137.2	156
DO(mg/L)	-	-	-	2.4	1.8	2.1	1.8	2	2.2	2.1	1.6	1.9	2.5	3.1	2.1
$(BOD)_5$,mg/l	-	-	-	168	216	207	216	210	204	207	222	213	195	177	207

Table 4.3 — Water quality parameters: Ukkadam Periyakulam tank/post-monsoon season

Physical/ chemical parameters	Water Quality Limits Prescribed by			Ground water and Surface water 5 Sample Mean values at (4 surface water + 8 groundwater) Nodal Points											
				Surface water					Ground water						
	IS 10500:2012		WHO	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
	(A)	(B)													
Colour	-	-	-	CL	G	CL	CL	SG	CL	CL	CL	CL	CL	CL	CL
Odour	Agreeable	Agreeable	-	O	O	E	O	O	A	O	O	O	O	O	O
Turbidity (NTU)	1	10	15	82	79	69	71	68	64	71	67	83	70	72	85
TDS(mg/L)	500	2000	-	60	30	20	40	25	20	35	40	25	30	40	30
EC	-	-	-	2.2	2.72	1.33	4.79	2.12	0.039	4.98	1.4	2.8	2.5	3.2	4.4
pH	6.5	6.5	6.5-8.5	7.7	7.5	7.33	7.26	7.59	7.15	7.48	7.36	7.76	7.33	7.48	7.11
TA(mg/L)	200	600	-	420	400	210	323	305	205	290	330	410	310	415	390
TH(mg/L)	200	600	150-500	370	520	460	770	445	365	750	450	380	530	650	470
Cl^-(mg/L)	250	1000	250	166.2	121.6	212.4	213	365	171.3	206.9	130.5	225.6	325.3	212.5	275.3
SO_4^{2}(mg/L)	200	400	500	163.99	134.4	92.97	605	152	125	529.1	101.4	155.4	166.3	120.7	133.2
DO(mg/L)	-	-	-	0.9	1.1	1.6	1	1.2	1.7	1.4	1.2	1.5	1.3	1.4	1.7
$(BOD)_5$	-	-	-	243	237	222	240	234	219	228	234	225	231	228	219

Parametric water quality indexing $(WQI)_h$ for total hardness

Even as during the monsoon rains and catchment inflows, the surface and ground waters are getting softened, the receding water table during the post-monsoon dry spells may again impart hardness to the fluctuating waters. The total hardness (TH) indexing is slightly deviating from TA, with the same permissible range of 200-600 mg/l. The observed test values of the samples are also showing a trend of variations similar to that of TA, but some sample values exceeding up to 900 mg/l.

TA, mg/l	<200	200 – 400	400 – 600	600 -800	> 800
Hazard rating	low	medium	high	severe	critical
Weight	1	2	3	4	5

The weighted mean values were 627 mg/l and 726 mg/l for the surface and ground water respectively, during the pre-monsoon investigations, indicating the proximity to critical conditions. The weighted mean value of TH for monsoon season was at 628.21 mg/l for surface water and at 596.67 mg/l for the ground

Table 4.3.1 ─ Summary of parametric water quality indices (Post-monsoon)

S.No.	Parameter	Surface Water	Ground Water
1	Turbidity	3.04	2.05
2	Total Dissolved Salts	1	1
3	EC	1.23	1.38
4	pH	1	1
5	Total Alkalinity	4.05	3.12
6	Total Harness	3.19	3.16
7	Chlorides	1.60	1.84
8	Sulphates	1	1
9	Dissolved Oxygen	5.00	5.00
	Overall Index	2.35	2.17
	Overall Hazard Rating	Medium to High	Medium to High

water. In the same line, weighted mean values of TH for the post-monsoon season were reckoned to be 563.33 mg/l and 571.00 mg/l for the surface and ground water sampling, respectively.

Parametric water quality indexing $(WQI)_{cl}$ for chlorides

Even as WHO sticks onto a limiting value of 250, IS 10500:2012 prescribes the permissible range from 250 to 1000 in units of mg/l. Hence, the following weights were assigned to the classified sub-ranges:

Cl, mg/l	< 200	200 – 400	400 – 600	600 -800	> 800
Hazard rating	low	medium	high	severe	critical
Weight	1	2	3	4	5

The chloride (Cl) concentration was relatively heavy during the pre-monsoon season resulting in a critical stage value of around 237 mg/l for surface water and 376 mg/l for the ground water. The weighted mean value of Cl for monsoon season was reckoned as 199.53 mg/l for surface water and that for the ground water at 298.12 mg/l. Similarly, the corresponding weighted mean values of Cl for the post-monsoon season were interpreted to be 123.1 mg/ and 251.64 mg/l 1 for the surface and groundwater sampling, respectively.

The parametric water quality indices $(WQI)_{cl}$ worked out are available in Table 4.3.

Parametric water quality indexing $(WQI)_{sul}$ for sulphate

While WHO suggests a limiting value of 500, IS 10500:2012 prescribes the range from 200 to 400 mg/l. A perusal onto the tabulated values for both monsoon and post-monsoon situations indicated less than 200 mg/l only. Hence, the parametric water quality $(WQI)_{sul}$ in the study area confined is taken as 1 irrespective of surface or ground water sampling and monsoon or post-monsoon. However, the pre-monsoon readings deviated much for around 365 mg/l with surface water and 436 mg/l for ground water, requiring corrective measures like dilution during the pre-monsoon storages.

Parametric water quality indexing $(WQI)_{do}$ for dissolved oxygen

According to Thomann and Miller (1987), the saturated solubility of oxygen in water at 1 atm. pressure and an ambient temperature of 20 °C is 9.09 mg/l with zero chloride concentration. However, it is a bit red-signalling to observe that the contamination levels have impaired both surface and ground water qualities with DO alarmingly less than 3 mg/l only irrespective of whether monsoon and post-monsoon seasons. They have also prescribed optimum levels in the range of 5 mg/l to 8 mg/l for the survival base to fish and other water-borne entities. Hence, the following weight factor distribution in the reverse grade order was made:

DO, mg/l	< 2	2 – 4	4 – 6	6 - 8	> 8
Hazard rating	critical	severe	high	medium	low
Weight	5	4	3	2	1

The weighted mean value of DO for monsoon season was reckoned as 2.1 mg/l for surface water and 2.23s mg/l for the ground water. Similarly, the corresponding weighted mean values of DO for the post-monsoon season were interpreted to be 1.15 and 1.4 mg/l l for the surface and groundwater sampling, respectively. For pre-monsoon distribution, the value of DO was in the lowest range of 1.1 to 1.3 posing the criticality and indicating the need for re-aeration treatments.

Parametric water quality indexing $(WQI)_{bod}$ for 5-day bio-chemical oxygen demand

The values of 5-day bio-chemical oxygen demand had been calculated from the DO values only for a dilution fraction of (10/300) with reference to the saturated DO at 9.09 mg/l. Hence, this need not be included in arriving at the final WQI.

The independent parametric water quality indices obtained are summarized in Table and the overall water quality index for calculating the distribution uniformity within the uniform grading from 1 to 5, was reckoned.

Parametric water quality indexing $(WQI)_f$ for fluoride

Fluoride ions present in drinking water get absorbed in the bone structure of the body and the tooth enamel. Fluoride ions at extremely high levels may cause dislocation of teeth. Permissible limit of fluoride ions is 0.6-1.5 mg/l for ground water. All the collected samples exhibited values well below the desirable limits from 0.02 to 0.31 mg/l only. Due to the safest levels in and around the study area, fluoride was exempted from the quality index analysis.

Conclusion

Barring the colour and odour, the remaining quantifiable parameters were assigned weights and the weighted mean values were used to get at the water quality indices for both surface water and the ground water samples collected from the nodal points in the vicinity of the tank under study. The hazard rate grading for all these parameters was restricted to a uniform weightage factor range of 1 to 5 as to the relative severity of contaminant impact status.

The weighted mean value of turbidity for monsoon season stands at 81.4 NTU for surface water and at 77.48 NTU for the groundwater.

By the same token, weighted mean values of turbidity for the post-monsoon season were reckoned to be 76.33 NTU and 74.30 NTU for the surface and groundwater sampling, respectively.

The weighted mean value of TA for monsoon season stands at 378.46 mg/l for surface water and at 430.00 mg/l for the ground water. In the same line, weighted mean values of TA for the post-monsoon season were reckoned to be 359.15 mg/l and 308.13 mg/l for the surface and ground water sampling, respectively.

The weighted mean value of TH for monsoon season stands at 628.21 mg/l for surface water and at 596.67 mg/l for the ground water. In the same line, weighted mean values of TH for the post-monsoon season were reckoned to be 563.33 mg/l and 571.00 mg/l for the surface and groundwater sampling, respectively.

During the pre-monsoon season, with the criticality values for overall WQI parameters at 3.03 for surface and 2.65 for ground water, the potential hazard rating increased to severe to critical levels. Dissolved oxygen and the consequent bio-chemical oxygen demands are in the critical situation requiring immediate attention for dilution and re-aerations mechanism to avoid oxygen sag.

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