To develop ground water quality index using Fuzzy AHP at Tamsa watershed

Abstract

The ecological sustainability of rivers is in question due to severe pollution and lack of stringent regulations. For trend analysis 14 parameters were used such pH, EC (µS/cm at 25°C), TDS (mg/l), Total Hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Sodium (mg/l), Potassium (mg/l), Carbonate (mg/l), Bicarbonate (mg/l), Sulphate (mg/l), Chloride (mg/l), Fluoride (mg/l) and Nitrate (mg/l). The value of water physical, chemical biological and parameters of temporal resolution indicate that value of pH, EC (µS/cm at 25°C), TDS (mg/l), Total Hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Sodium (mg/l), Potassium (mg/l), Carbonate (mg/l), Bicarbonate (mg/l), Sulphate (mg/l), Chloride (mg/l), Fluoride (mg/l) and Nitrate (mg/l) were observed very high compared to recommended value of Bureau of Indian Standards (BIS) and World Health Organization (WHO). The average water quality index value was observed as 381.244 hence, it is concluded that ground water was not suitable for drinking and irrigation purposes.

Key words: drinking water, waterquality, quality index, ground water

Introduction

"One of the most important aspects affecting human health is the quality of drinking water. However, the quality of the drinking water in many nations, particularly those that are developing, are not ideal, and numerous waters borne diseases have been linked to poor drinking water quality" (Sivaranjani *et al.*,2015). The situation is far from ideal, especially in rural regions, and this marginally better condition can potentially be harmed by the rising water demand and decreased water supply brought on by population growth and economic development (Grey and Sadoff, 2007). As a result, there is still a long way to go before there is harmony between people, resources, and the environment. Fortunately, a lot of academics are diligently researching drinking water. In this editorial, the drinking water quality assessment methods, drinking water quality parameters, and its governance policies are briefly discussed (Li and Wu, 2019).

“The WQI measures the scope, frequency, and amplitude of water quality exceedances and then combines the three measures into one score” (Dao*et al.*, 2020). This calculation produces a score between 0 and 100. The low score shows the better quality of water. The scores are then ranked into one of the six categories described below: Can shown in the tabular form

➢ Excellent: (WQI Value 0-25) - Water quality is protected with a virtual absence of impairment; conditions are very close to pristine levels. These index values can only be obtained if all measurements meet recommended guidelines virtually all of the time.

➢ Very Good: (WQI Value 26-50) - Water quality is protected with a slight presence of impairment; conditions are close to pristine levels. Water quality is protected with only a minor degree of impairment; conditions rarely depart from desirable levels.

➢ Poor: (WQI Value 51-75) - Water quality is usually protected but occasionally impaired; conditions sometimes depart from desirable levels.

➢ Very poor: (WQI Value 75-100) - Water quality is frequently impaired; conditions often depart from desirable levels.

➢ Unsuitable for drinking purpose: (WQI Value above 100) –“Water quality impaired conditions usually depart from desirable levels. The appraisal of WQI was done by allocating weights to each water quality parameters” (Amiri*et al.*, 2014).“The value of weight was utilized by utilizing pairwise correlation with one another and this appointed weighted worth assumed a significant part in the estimation of the WQI. In the present investigation, the weight value was assigned based on past research studies and expert knowledge. This was applied to estimate fuzzified triangular comparison matrix weight and normalized weight. After calculating normalized weight, water quality rating was found based on weight of each parameter”. [12] The (Fuzzy AHP) FAHP technique were used to find the appropriate weight of water quality index table 1 represents the various physiochemical parameters for the further analysis.

Table:1 Total Number of Parameter:

Parameter	Parameter
pH	Total Hardness (mg/l)
EC (µS/cm at 25°C)	Calcium (mg/l)
TDS (mg/l)	Magnesium (mg/l)
Potassium (mg/l)	Sodium (mg/l)
Bicarbonate (mg/l)	Carbonate (mg/l)
Chloride (mg/l)	Sulphate (mg/l)
Nitrate (mg/l)	Fluoride (mg/l)

MATERIALS AND METHODS:

The present study was used to conduct the quality of ground water at Tamsa watershed. (Kindly mention the method of standard water quality analysis with reference.

Description of Study Area:

Tamsa River flows through Ayodhya, Ambedkar Nagar, Azamgarh, Mau, and Ballia districts of Uttar Pradesh before joining the Ganga near Salahabad hamlet in the Ballia district. This river is significant mythologically since the Valmiki Ramayana refers to it as a seasonal stream. It begins close to the village of Lakhnipur in the Tehsil of Rudauli, and the Ramayana claims that it runs through the Ayodhya district to Darban Lake in the Tanda Tehsil of Ambedkar Nagar. two significant river basins of the Ganga, are the Ganga and Gomti, this river flows towards leftand travel through Azamgarh district via the Majauli tributary, which runs along the Sultanpur district's north-eastern border. The Tamsa River travels along the whole length of the Azamgarh district, entering at Ahiraula in the west and exiting near Chorhar in the east. After passing through Mau district, the Ganga River eventually meets it in the Ballia district. The total length of the river Tamsa are roughly 577 km. It passes through the districts of Ayodhya, Ambedkar Nagar, Azamgarh, Mau, and Ballia throughout its length. The map of Tamsa watershed shows in Fig:1.

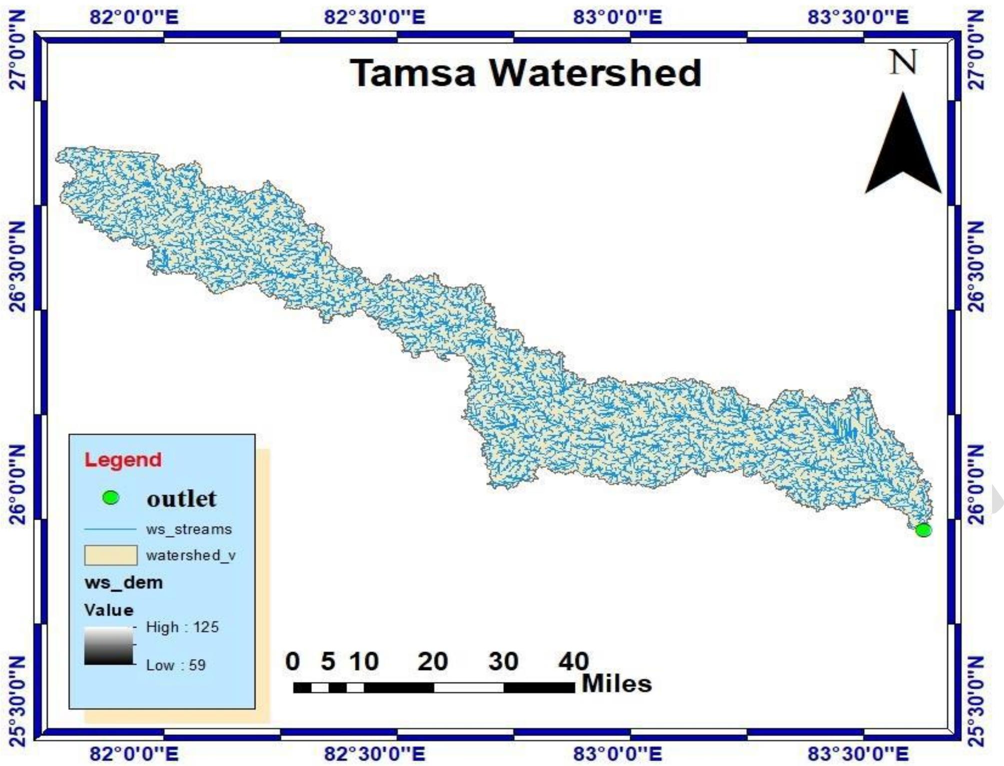

Fig:1 Tamsa Watershed

Water Quality Index:

The overall usageof water includes drinking, swimming, fishing, and aquatic life support is expressed numerically as the WQI. It offers a practical means of condensing intricate data on water quality into a single figure, which facilitates the understanding and interpretation of water quality data by scientists, policymakers, and the general public.

Analytic hierarchy process based on fuzzy sets (FAHP):

In the standard AHP, two astute assessments for each level regarding the goal of the best elective option are guided using a nine-point scale. In this fashion, the application of Saaty's AHP has the following shortcomings:

1) The AHP technique is frequently used in nearly new selection applications;
2) The AHP strategy makes and manages an extremely uneven size of judgment;
3) The AHP strategy doesn't take into account the vulnerability associated with the planning of one's judgment to a number;
4) The ranking of the AHP strategy is fairly loose;

5) The expressive judgment, determination, and inclination of leaders have a significant impact on the AHP results.

The fuzzy AHP approach can be viewed as a novel scientific method developed from the standard AHP. Generally speaking, it can be challenging to reflect the decision-uncertainty inclinations through new attributes (Mallick, 2021). Accordingly, Fuzzy AHP is suggested as a way to reduce the uncertainty of the AHP strategy, which makes use of fuzzy correlation proportions. (Gaya *et al.*,2020) offers a different approach for dealing with the pair-wise examination scale that is based on triangular (three-sided) fuzzy numbers and is handled by using a degree investigation technique for engineered degree estimation of the pairwise correlation.

In the first stage of this procedure, three-sided fuzzy numbers are used for pair wise correlation using FAHP scale methods, and in the second stage, degree investigation strategy is used to determine the loads using manufactured degree esteems (Singh*et al.*, 2021).

Step-1: Development of analytical hierarchy:

"Developed a hierarchy arrangement based on different levels. At first level, determined quantification of the prospective of water resources. The second level, analyzed potential of water quality parameters. In third level, developed a pairwise comparison matrix based on AHP scale and transform into a fuzzy triangular".[12]

Step- 2: Develop matrix:

"First, pairwise fuzzy comparison matrix has been developed based on total twenty-two water quality parameter viz. dissolved oxygen (DO), temperature, pH, electrical conductivity (EC), total dissolved solid (TDS), ammonia (NH3), Nitrate (NO3), Silicon dioxide (SiO2), biological oxygen demand (BOD), chemical oxygen demand (COD), total hardness (TH) due to (MgCaCO3), total alkalinity (TA) due to (MgCaCO3), Hardness (CaCO3), fluoride (F), boron (B), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), sulphate (SO4) and bicarbonate (HCO3). The pairwise fuzzy matrix was developed based on crisp numeric values. Therefore, developed fuzzy matrix based on the following matrix".[12]

$$FSM = \begin{matrix} WN_1 \\ WN_1 \\ WN_x \\ WP_z \end{matrix} \left\{ \begin{matrix} (1,1,1) & (\tau_{12}\delta_{12}\partial_{12}) & (\tau_{1w}\delta_{1w}\partial_{1w}) & (\tau_{1y}\delta_{1y}\partial_{1y}) \\ (\tau_{21}\delta_{21}\partial_{21}) & (1,1,1) & (\tau_{2w}\delta_{2w}\partial_{2w}) & (\tau_{2y}\delta_{2y}\partial_{2y}) \\ (\tau_{x1}\delta_{x1}\partial_{x1}) & (\tau_{x2}\delta_{x2}\partial_{x3}) & (1,1,1) & (\tau_{xy}\delta_{xy}\partial_{xy}) \\ (\tau_{z1}\delta_{z1}\partial_{z1}) & (\tau_{t2}\delta_{t2}\partial_{t2}) & (\tau_{zw}\delta_{tw}\partial_{zw}) & (1,1,1) \end{matrix} \right\} \ldots 1$$

Step- 3: Involve the calculation of the fuzzy geometric mean:

$$\text{FSM}=\begin{bmatrix} V_{1\tau} & V_{1\delta} & V_{1\partial} \\ V_{2\tau} & V_{2\delta} & V_{2\partial} \\ V_{x\tau} & V_{x\delta} & V_{x\partial} \\ V_{z\tau} & V_{z\delta} & V_{z\partial} \end{bmatrix}; \text{ where, } V_{\tau,\delta,\partial} = \begin{cases} V_\tau = (\sum_{x=1}^{y} \tau_{zy})\,^\wedge\, {}^{1}/_{y} \\ V_\delta = (\sum_{x=1}^{y} \delta_{zy})^\wedge\, {}^{1}/_{y} \\ V_\partial = (\sum_{x=1}^{y} \partial_{zy})^\wedge\, {}^{1}/_{y} \end{cases} \quad \ldots 2$$

V_τ is lower fuzzy geometric mean, V_δ is medial fuzzy geometric mean, V_∂ is upper fuzzy geometric mean.

Step- 4: Calculation step of fuzzy weight by formulas:

$$T_w = \left(\frac{\sum_{x=1}^{y} V_\tau}{\sum_{x=1}^{z}\sum_{w=1}^{y} V_{z\tau}}, \frac{\sum_{x=1}^{y} V_\delta}{\sum_{x=1}^{z}\sum_{w=1}^{y} V_{z\delta}}, \frac{\sum_{x=1}^{y} V_\partial}{\sum_{x=1}^{z}\sum_{w=1}^{y} V_{z\partial}} \right) = (T_\tau, T_\delta, T_\partial) \ldots 3$$

T_w is fuzzy weight, T_τ , T_δ and T_∂ are lower, medial and upper fuzzy weight respectively.

Step- 5: Calculate weightage of parameter:

$$\text{Ww} = \frac{(\boldsymbol{T_\tau + T_\delta + T_\partial})}{\mathbf{3}} \ldots 4$$

W_w = is weight of parameter.

Step- 6: Calculate normalized weight of water quality parameters:

$$W_n = \frac{W_w}{\sum_{w=1}^{y}(W_w)}; \quad w = 1,2 \qquad \ldots 5$$

W_n= Normalized weightage

RESULTS AND DISCUSSION:

Results of the trend analysis of water quality parameter of Tamsa watershed were described in this chapter. The water quality index for the 191 locations were analysed and discussed here-

Water Quality Index Using Fuzzy – AHP

Water quality data analysed at 191 locations of the Tamsa river. The 14physiochemical parameter of water quality namely, EC (μS/cm at 25°C, Mg, Cl, Chloride, TDS (mg/l), Total Hardness (mg/l), Sodium (mg/l), Potassium (mg/l), Carbonate (mg/l), Bicarbonate (mg/l), Sulphate (mg/l), Fluoride (mg/l), Nitrate (mg/l) were observed.

"The untreated wastes water from sugar, lather, fertilizer, plastic, automobiles industries, agricultural fields and urban sewage have also appeared in most of the basin that may be the main source of surface water pollution" (Tripathi & Hussain, 2021)."Consequently, physio-chemical parameters have an important role in controlling water pollution. The Tamsa River water quality was assessed and results showed the strong relations between physical and chemical parameters" (Siraj*et al.*, 2023)."River water quality assessment is one of the most important aspects to enhance water resources management plans. WQI, is one of the most frequently used evaluation tools, were usedfor comprehensively analyse of water quality in the Tamsa River" (Ajmal & Jamal, 2023). The average water quality index value 381.244 and it is also not suitable for drinking, irrigation purposes.The lowest value of WQI is location in no.1 as 145.0842 and highest value is location no.30 as 696.4566.

Table:2 Weightage of Parameter

Parameter	**Weightage**
pH	0.070202
EC (μS/cm at 25°C)	0.07053
TDS (mg/l)	0.07034
Total Hardness (mg/l)	0.070663
Calcium (mg/l)	0.071527
Magnesium (mg/l)	0.070986
Sodium (mg/l)	0.071138
Potassium (mg/l)	0.073265
Carbonate (mg/l)	0.073824
Bicarbonate (mg/l)	0.070531
Sulphate (mg/l)	0.072131

Chloride (mg/l)	0.071942
Fluoride (mg/l)	0.070837
Nitrate (mg/l)	0.072081

Table:2, Weightage of all parameters and these Weightage values were used for the determination of fuzzy AHP, WQI.In this table the Maximum and Minimum value of the weightage are Carbonate 0.073824 and pH 0.070202, respectively. pH values satisfy the weighting of the criteria and itsweightage is determined by the parameters' minimum frequency.

Table:3 Water quality index value using FAHP

Location	**WQI**	**Location**	**WQI**	**Location**	**WQI**
Location 1	145.0	Location 65	342.1	Location 129	260.9
Location 2	314.7	Location 66	226.8	Location 130	358.4
Location 3	379.9	Location 67	266.4	Location 131	295.2
Location 4	486.2	Location 68	279.5	Location 132	364.0
Location 5	259.0	Location 69	235.6	Location 133	373.4
Location 6	213.6	Location 70	454.2	Location 134	249.2
Location 7	316.1	Location 71	286.9	Location 135	296.0
Location 8	348.0	Location 72	274.1	Location 136	278.3
Location 9	337.0	Location 73	255.9	Location 137	308.3
Location 10	302.7	Location 74	207.3	Location 138	238.9
Location 11	316.4	Location 75	470.2	Location 139	341.7
Location 12	197.5	Location 76	367.0	Location 140	608.2
Location 13	250.5	Location 77	303.2	Location 141	492.0
Location 14	322.1	Location 78	194.7	Location 142	297.9
Location 15	348.7	Location 79	427.5	Location 143	481.5
Location 16	362.3	Location 80	256.4	Location 144	438.5
Location 17	1123.2	Location 81	273.1	Location 145	399.7
Location 18	409.4	Location 82	233.4	Location 146	373.6
Location 19	224.6	Location 83	239.7	Location 147	447.2
Location 20	300.6	Location 84	595.7	Location 148	401.4
Location 21	257.1	Location 85	354.1	Location 149	400.4
Location 22	323.3	Location 86	255.2	Location 150	487.9
Location 23	273.3	Location 87	491.3	Location 151	395.6
Location 24	368.3	Location 88	521.9	Location 152	440.4
Location 25	264.4	Location 89	289.0	Location 153	453.7
Location 26	234.6	Location 90	270.2	Location 154	467.7
Location 27	409.9	Location 91	316.1	Location 155	466.8
Location 28	417.4	Location 92	275.7	Location 156	365.5
Location 29	652.5	Location 93	306.4	Location 157	507.7

Location 30	696.4	Location 94	218.6	Location 158	424.0
Location 31	289.3	Location 95	307.9	Location 159	468.2
Location 32	367.5	Location 96	287.9	Location 160	489.3
Location 33	274.9	Location 97	272.4	Location 161	464.3
Location 34	416.3	Location 98	334.2	Location 162	477.0
Location 35	355.6	Location 99	344.2	Location 163	586.3
Location 36	434.9	Location 100	333.5	Location 164	442.2
Location 37	501.3	Location 101	305.5	Location 165	524.2
Location 38	508.2	Location 102	469.8	Location 166	550.3
Location 39	292.3	Location 103	484.0	Location 167	470.7
Location 40	483.8	Location 104	447.4	Location 168	355.7
Location 41	616.9	Location 105	363.5	Location 169	282.3
Location 42	487.7	Location 106	401.8	Location 170	415.6
Location 43	529.8	Location 107	426.4	Location 171	450.3
Location 44	677.8	Location 108	581.9	Location 172	474.6
Location 45	230.0	Location 109	438.6	Location 173	368.6
Location 46	234.4	Location 110	362.3	Location 174	401.0
Location 47	453.9	Location 111	497.0	Location 175	527.9
Location 48	303.3	Location 112	410.9	Location 176	391.5
Location 49	267.7	Location 113	476.7	Location 177	478.7
Location 50	276.9	Location 114	349.9	Location 178	549.1
Location 51	263.3	Location 115	334.3	Location 179	490.5
Location 52	403.6	Location 116	536.2	Location 180	424.2
Location 53	237.6	Location 117	500.4	Location 181	474.4
Location 54	605.9	Location 118	485.3	Location 182	556.2
Location 55	201.3	Location 119	414.8	Location 183	515.8
Location 56	336.7	Location 120	411.0	Location 184	481.5
Location 57	515.8	Location 121	275.9	Location 185	388.1
Location 58	288.6	Location 122	378.1	Location 186	363.3
Location 59	306.0	Location 123	422.3	Location 187	403.9
Location 60	177.3	Location 124	324.5	Location 188	445.6
Location 61	286.4	Location 125	316.6	Location 189	338.1
Location 62	229.7	Location 126	349.1	Location 190	460.4
Location 63	304.0	Location 127	349.6	Location 191	444.6
Location 64	350.2	Location 128	294.0		

The average water quality index value 381.244 and it is also not suitable for drinking, and irrigation purposes.The lowest value of WQI is location no.1 in 145.0842 and highest value of water quality index is location no.17 in 1123.2, represented in Table: 3.

Conclusions

The WQI measures the scope, frequency, and amplitude of water quality exceedances and then combines the three measures into one score. This calculation produces a score between 0 and 100. The low score shows the better quality of water. The average water quality index value wereobserved as 381.24 hence, it can be concluded that the investigated ground water quality was not suitable for drinking and irrigation purposes. Water quality was significantly negative correlated with agriculture land, rural residential land and urban land.

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