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Computation of Groundwater Quality of Baramati with the help of Fuzzy Water Quality Index (FWQI)

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Abstract: One of the natural resources having the latent for home, agrarian, and engineering use is surface and groundwater. Due to humanoid and certain natural reasons, the eminence of the groundwater serving Baramati City and Tehsil has deteriorated. Agriculture is using more pesticides and fertilizer, therefore this supply is being affected. Municipal water pollution can be caused by "septic boilers", "bathe sewage", "polluted aquatic", "improper discarded management", "public excretion", "improper waste structure", "public sewage discharges", and "unorganized solid waste disposal". The current study will improve the accuracy of the water quality index for areas in Baramati Tehsil that are affected by industry and drinking water supplies. The groundwater zones were created using a weighted index overlay analysis, which assigned weights based on several classes of individual water quality metrics and drinking water standards. Based on few observations, fuzzy logic offers an effective and practical tool for categorizing drinking water quality. This study's objective is to provide a fuzzy logic-based water quality indicator for basin-wide reservoirs. For a weight-based fuzzy quality index, a minimum of 6 physico-chemicals are needed.

Keywords: Fuzzy Water Quality Index (FWQI), Fuzzy Logic, Groundwater, Water Treatment.

1. Introduction

Groundwater is often used by people for drinking, farming, and industrial uses [1]. It is essential that we have a full understanding of the geochemical procedures that govern the organic configuration of groundwater. It is helpful to understand the hydro-chemical schemes in many parts of the world [2]. Such knowledge can help with groundwater supply organization and consumption by prominence the influences among groundwater excellences, aquatic, and renew type [3]. Surface and ground water are traditionally treated like independent units in water resource management strategies. In the recent developments in this area, both systems show a qualitative and quantitative influence on one another [4]. However, the capacity of groundwater supplies is reduced or their usage is restricted by groundwater contamination brought on by humanoid or the natural factual configuration of aquifers [5]. The use of fertilizers and pesticides in agriculture may also have an influence on groundwater quality as it is one of the physical and chemical characteristics that are affected by human and geological activities [6]. This is true despite the fact that various biological and human activities can potentially affect the quality of groundwater [7]. The conventional approach is used for evaluating groundwater quality frequently makes extensive use of mathematical modeling techniques like time series analysis, probability statistics, etc. The overall quality of these models is frequently subpar because these approaches presuppose a linear relationship between the dependent and independent variables [8]. New computational methods to this issue are needed given the ongoing difficulties in simulating groundwater quality [9]. During the past 10 years, the development of AI models in the hydrological and environmental sectors has drawn a lot of attention [10]. This is why several research have concentrated on developing computer-based methods for simulating groundwater quality. An artificial neural network (ANN) model, for instance, was developed by Yesilnacar *et al.* to anticipate the level of nitrate in groundwater in Turkey's Harran Plain [11]. According to the study, the proposed approach was successful in creating a groundwater resource management that was both efficient and affordable. The ANN approach also succeeded in resolving the complex nonlinear connections between the assessment component and the grade of the water quality. Additionally, model attained a great scale of forecast precision, supplied operative, satisfactory recital as evaluation technique. Yesilnacar and Sahinkaya developed an ANN model to forecast groundwater sulphate (SO4) and sodium adsorption ratio (SAR) concentrations [12]. According to the study's findings, managing groundwater resources might be made simpler and cheaper by using the proposed technique. The experimental analysis shows that the statistical analysis-based ANN modeling technique may be utilized to estimate the water content of soils under a variety of meteorological conditions.

The selected 6 physico-chemical parameter are playing vital role in determination of water quality index. In every Water quality index, above parameter are used with some additional parameter to calculate the WQI. In FWQI model, on the basis of the above said parameter, the water quality is calculated with precision result without considering other parameter so experimental cost is reduced.

2. Data and Materials

2.1 Study Area

Baramati Tehsil is situated in Pune Division's western region of Maharashtra. It is 240 kilometres (km) from Mumbai, the state capital, and 100 kilometres (km) from Pune, the district administrative centre. The tehsil is located between latitudes 18°04 and 18°32 in the north and 74°26 and 74°69 in the east. At 550 metres above mean sea level, it is situated. The Baramati tehsil has a 1382 sq. km. area. In the tehsil area, there are more than these sub-villages and 116 major villages. 3,75,185 people make up the entire study area, of which 1,93,451 are men and 1,81,734 are women. 3,55,841 people—94.84 percent—live in the tehsil's rural areas. Phaltan Tehsil to the south, Daund Tehsil to the north, Malshiras Tehsil to the east, Indapur Tehsil to the east, and Purandar Tehsil to the west side border Baramati Tehsil.

In this study, 30 different groundwater samples from different tehsil districts around Baramati are utilised to evaluate the water quality index.

The samples are taken in the pre-monsoon season of 2023 (April–May) and the monsoon season of 2023 (June–July). Each sample was collected in a high-quality, one-liter polyethylene bottle.

2.2 Water Quality Index (WQI)

The WQI converts water eminence factor phases interested in a numerical mark using logical tools, illuminating the typical condition of water physiques. It is examined from the standpoint of how humanoids will be used. Based on physical, chemical, and biological factors, WQI may be evaluated. The purpose of the idea of water is to categorise water according to the degree of concentration [13].

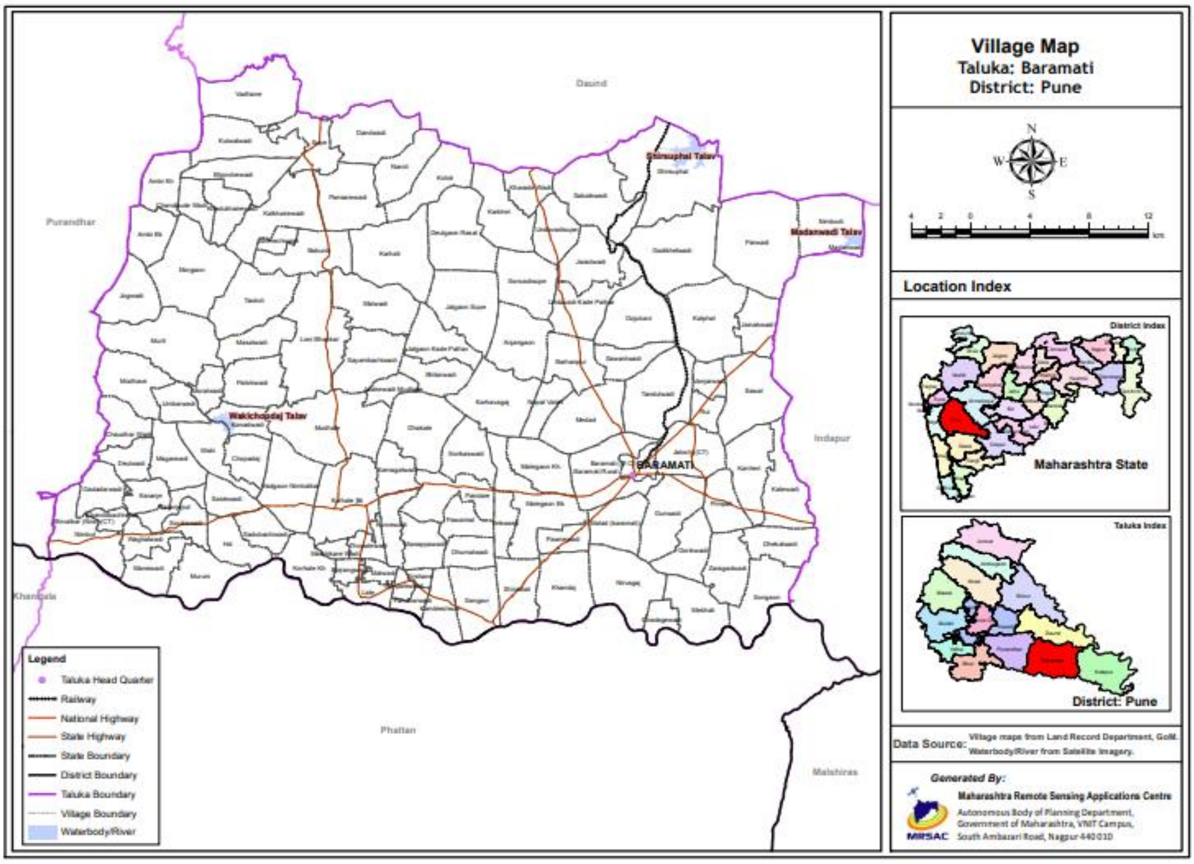

Figure 1. Study Area: Baramati Tehsil

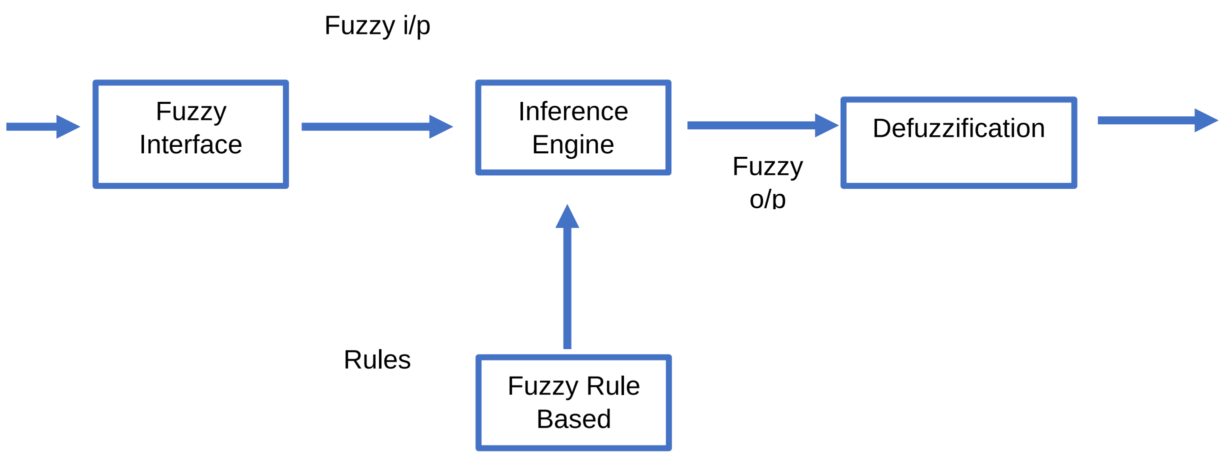

Figure 2. Fuzzy Logic System Architecture

The process of scoring that provides the total strength of each individual water excellence component over water excellence is discussed. The WQI is calculated to evaluate the survey region's groundwater's suitability for drinking purposes. Indian Standards' recommended measurements for drinking: 10500. The weighting for several water quality parameters in this method is anticipated to differ from the suggested measurements for the resulting factors. [14]. Thus, the following approach is used to calculate the value of the i^{th} factor:

$$W_i = k/s_i \quad (1)$$

Where, W_i=unit weight, s_i=the recommended standard, i=ranges 1 to 16, k= bias.

The assessment contains following steps:

- Calculation of eminence value for distinct water merit aspects
- Average of all sub-parameters

The eminence value is obtainable:

$$Q_i = 100 * V_i/S_i \quad (2)$$

Where, v_i= precise cost, s_i =allowable threshold.

$$WQI = \sum(Q_i W_i)/\sum W_i \quad (3)$$

2.3 Research Contribution

Artificial intelligence (AI)-based computing techniques, such as computerized mechanism that enable specialist to practice approximate perceptive with partial and imprecise information. The subject-matter professionals are increasingly being used to address the essential doubts, prejudice, and engineering experiments in environmental complications [15]. This study describes the creation of a novel fuzzy logic-based WQI known as the "fuzzy water quality index" (FWQI) in order to evaluate the usefulness of this instrument. Comparing the new FWQI to the previous two reference indices, satisfactory correlations and findings were offered. Finally, the Baramati Tehsil's water management might involve using the FWQI as a decision-maker.

- In FWQI, the parameters are used minimum 6 parameter to assessment of groundwater quality like Tubidity, DO, BOD, Ph, NO-3, TDS
- In WQI, only 5 categories of assessment of water index are available and In FWQI, 10 categories are available for water quality index.
- FWQI is extending and improving the water quality index as compared to WQI
- Experimental cost is minimized because FWQI can work on less numbers water quality parameter.
- Identification of potential drinking water zones

3. Fuzzy Water Quality Index (FWQI)

A professional technique with a focus on rules is the fuzzy expert approach. Fuzzy logic is used as a tool to demonstrate several types of intelligence on the conundrum. The measurement of drinking water quality uses fuzzy logic [16]. Data on physical, chemical, and biological aspects may be recycled to calculate the water excellence of any given area or resource. The excessive quantities of the aforementioned components are dangerous to a person's physical health. It provides a more exact assessment of general quality [17]. FWQI is worked with six response variables. Giving the best intake water, which is distributed to four further sorts, is one of the plan's outcomes [18]. The association functions planning the semantic variables define the intelligence ground illuminating the system's performance [19]. Hence, for the proposed system's behavior, 7 semantic variables are identified. Out of these 6, six is input variables namely- turbidity (T), dissolved oxygen (DO), biochemical oxygen demand (BOC), pH value (pH), Nitrate(NO_3) and Total Dissolved Solid (TDS) and one is output variable drinking water quality [20]. Each point in input space is justified in its evolution through the application of triangle and trapezoidal association functions, which are connected to association cost among 0 to 1 [21]. This professional organism goes through three stages: fuzzification, evaluation of the inference rules, and defuzzification of the output findings. If-then rules are used to construct inferences. The if-part of an if-then rule is referred to as the antecedent, and the then-part is referred to as the consequent [22]. The fuzzified input variables are used as input for the fuzzy operator, which accepts two or more association values [23]. Each of the seven input factors is divided into a number of groups in the research.

The fuzzy set is being modified by the crisp collection. It only permits full association or none at all, whereas fuzzy sets only provide partial connection. [24]. In a crisp collection, association or non-association of element x in set A is described by a characteristic function μA(x), where μA(x)=1 if x∈A and μA(x)=0 if x∉A. Fuzzy set theory extends this concept by defining partial association. A fuzzy set A on a universe of discourse U is characterized by an association function μA(x) that takes values in the interval {0, 1}. Commonsense language terms like slow, quick, tiny, huge, heavy, low, middle, high, and tall are represented by fuzzy sets [25]. At any given time, an element can be a part of several fuzzy sets. In essence, an association function is a curve that specifies how each point in the input space is translated to an association value (or degree of association) ranging from 0 to 1. Depending on the model option, the number scale and association function outline are chosen. The level of accuracy needed in the output amount [26]. The formula to choose the association function is as follows.

$$f(m;p,q,r)=\begin{cases}0 for & m<p\\ \frac{m-p}{q-p} for & p\le m<q\\ \frac{r-m}{r-q} for & q\le m\le r\\ 0 for & m>r\end{cases} \tag{4}$$

Trapezoidal arcs vary according to 4 factors p, q, r, and s.

$$f(m;p,q,r,s)=\begin{cases}0 for & m<p\\ \frac{m-p}{q-p} for & p\le m<q\\ 1 for & q\le m<r\\ \frac{s-m}{s-r} for & r\le m<s\\ 0 for & s\le m\end{cases} \tag{5}$$

The most elementary crisp set operations are union, intersection, and complement, which essentially correspond to OR, AND, and NOT operators, respectively. Let P and Q be two subsets of M. The union of P and Q, denoted P∪Q. That is, μP∪Q(x)=1 if x∈ P or x ∈ Q. The intersection of P and Q, denoted P∩Q, contains all the elements that are simultaneously in P and Q; that is, μP∩Q(x)=1 if x∈P or x∈Q. The complement of P is denoted and it contains all elements that are not in P; that is μP(x)=1 if x ∉P, and μP(x)= 0 if x∈P. In FL, the truth of any statement is a matter of degree. To define FL operators, AND, OR, and NOT operators are to be used. The answer is min, max, and complements operations. These operators are defined by Equation (6), (7) and (8) respectively.

$$\mu_{P\cup Q}(x)=max[\mu_P(x),\mu_Q(x)] \tag{6}$$

$$\mu_{P\cap Q}(x)=max[\mu_P(x),\mu_Q(x)] \tag{7}$$

$$\mu_P(x)=1-\mu_P(x) \tag{8}$$

If-then rules that define a connection between the input and output fuzzy sets make up fuzzy inference systems [27]. Fuzzy relations show a degree of linkage or interaction between the components of two or more sets, either present or absent. The average of the various centroids, weighted by their heights, is then determined as U_o, according to Equation (9).

$$U_o=\frac{\sum_{i=1}^{N}u_i u(u_i)}{\sum_{i=1}^{N}u(u_i)} \tag{9}$$

Table 1. Fuzzy Water Quality Index Values Range

Water Excellence	FWQI Values
More than Excellent	1
Excellent	0.9
Very Good	0.8
Good	0.7
Fair	0.6
Average	0.5
Bad	0.4
Poor	0.3
Very Poor	0.2
Not Used	0.1

4. Experimental Analysis

4.1 Performance of FWQI

In this research study, the 30 water samples are taken from various locations from Baramati taluka. The 6 physico-chemical parameters are used to determine the water quality index using FWQUI. In WQI, 13 parameters are required to determine the water quality index of samples. Table 1. Show the result category of water sample using the FWQI.

Table 2. List of Groundwater Sample Stations of Baramati Tehsil

Sample Station Number	Location	Latitude	Longitude
SMP-1	Baramati Water Plant-1	18.1569	74.6004
SMP-2	Baramati Water Plant-2	18.1663	74.5745
SMP-3	Amrai Post office	18.1492	74.5784
SMP-4	Shardanagar	18.1354	74.5368
SMP-5	Desai Estate	18.1517	74.5856
SMP-6	Bobade Hospital	18.1457	74.5822
SMP-7	Jalochi	18.1537	74.6005
SMP-8	Kasaba	18.1428	74.5704
SMP-9	Mukti Village	18.1458	74.5640
SMP-10	Surynagari	18.1696	74.6070
SMP-11	Baramati MIDC	18.1891	74.6179
SMP-12	Tahasil Office	18.1455	74.5789
SMP-13	Vivid Lahari	18.1505	74.5712
SMP-14	Water Tank, Malegao Khu	18.14008	74.5111
SMP-15	Sugar Fact. Malegao	18.1100	74.5130
SMP-16	Malad Water Tank	18.1341	74.5733
SMP-17	Wadujkar Estate	18.1633	74.5925
SMP-18	Medical College Baramati Lake	18.1774	74.5969
SMP-19	Canal Road	18.1590	74.5738
SMP-20	Khandoba nagar	18.1600	74.5586
SMP-21	Tandulwa di wes	18.1877	74.5967
SMP-22	Pandare	18.13824	74.4585
SMP-23	Gunwadi Lake	18.8772	74.8016
SMP-24	Medad	18.1788	74.5452
SMP-25	Rui MIDC Aread	18.1830	74.6139
SMP-26	Pimpali	18.1304	74.6202
SMP-27	Katfal	18.2331	74.5963
SMP-28	Katewadi	18.1259	74.6559
SMP-29	Zargadwadi	18.0894	74.6231
SMP-30	Korhale Khurd	18.0853	74.3681

Table 2 shows the samples location detail with latitude and longitude.

Table 3. Weights and Criteria as per WHO Drinking Water Standard for Water Quality Parameter used in FWQI

Sr. No	Water Quality Index	Criteria as per Drinking Water	Weight
1	pH	<6.5	1
		6.5-7.5	4
		7.5-8.5	3
		>8.5	1

2	TDS	500-1000	4
		1000-1500	3
		1500-2000	2
		>2000	1
3	Total Hardness	150-300	3
		300-600	2
		>600	1
		<100	4
4	TA	200-400	3
		400-600	2
		>600	1
		<75	4
5	CL	<250	4
		250-500	3
		750-1000	2
		>1000	1
7	SO_4	<200	4
		200-300	3
		300-400	2
		>400	1
8	Ca	<75	4
		75-150	3
		150-200	2
		>200	1
9	Mg	<30	4
		30-50	3
		50-100	2
		>100	1
10	DO(mg/l)	<1	4
		2-5	3
		6-9	2
		>10	1
11	NO_3	<5	4
		5-25	3
		25-45	2
		>45	1
12	BOD(mg/l)	<3	4
		2-5	3
		6-10	1
13	Turbidity	0-4	4
		5-7	3
		8-10	2

As per the WHO, ISI and ICMR standard, the every parameter is having the acceptable range of value. The said value is categories into 4 type that is “Not Acceptable”, “Acceptable with Major Changes”, “Acceptable with Minor Changes”, “Acceptable”. According to said categories, in FWQI, the weights are assigned to the respective category like 1, 2, 3, 4. The said weights are employed in FWQI to calculate the water quality.

Table 4. Weights and Criteria as per WHO Drinking Water Standard for Water Quality Parameter

Sample Id	pH	EC	TDS	TH	TA	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	CL^{-}	SO_4^{2-}	DO	BOD	NO_3^{-}	Turbidit y	Fe^{-}
SMP-1	7.9	943	989	225	115	85	15.6	21.4	1.5	40	440	157	90	7	2	46	1	0.345
SMP-2	8.3	889	1279	550	185	35	21.4	13.8	2	37	530	198	35	4	3	23.28	8	0.757
SMP-3	7.7	1056	534	250	105	36	14.7	14.1	6	56	250	253	60	3	3	32.54	1	0.927
SMP-4	8.4	1179	746	180	80	64	14.2	18.5	2.5	90	180	354	49	3	1	58	0.5	0.93
SMP-5	8.1	971	1221	150	100	72	18.4	15.7	1	10	150	292	34	2	2	45.8	9	0.268
SMP-6	7.9	1265	1642	160	130	80	20.3	18.2	1.5	42	200	285	42	4	6	40.22	7	0.889
SMP-7	8.2	1126	1497	290	95	31	13.3	16.9	2	28	290	260	90	2	7	36	8	0.725
SMP-8	9.6	1575	598	220	120	28	17.6	22.1	2.5	36	220	406	124	8	3	56	2	0.83
SMP-9	8.9	1108	826	430	55	33	20.3	14.8	1	16	430	255	40	4	1	35.4	1	0.43
SMP-10	7.5	1389	1439	145	135	106	16.7	24.5	1.5	47	145	349	58	3	5	43.49	0.5	0.125
SMP-11	8.2	826	1027	210	180	19	21.4	21.4	3	36	210	90	36	2	2	40.5	5	0.49
SMP-12	7.3	675	931	90	100	71	13.8	14.7	6	25	90	57	132	2	1	57	2	0.43
SMP-13	8.4	826	998	180	65	50	14.1	14.2	4	90	180	376	90	5	1	22.94	3	0.62
SMP-14	7.9	1340	1824	270	85	120	18.5	18.4	3	35	270	98	38	2	6	22.12	9	0.34
SMP-15	7.4	971	1356	330	100	84	15.7	20.3	2	60	330	279	46	2	3	13.88	8	0.53
SMP-16	7.6	2272	729	160	130	16	18.2	15.7	8	49	160	49	42	8	9	5.8	3	0.63
SMP-17	7.7	971	1342	190	90	36	16.9	21.4	4	34	190	263	122	4	1	104.59	9	0.86
SMP-18	7.8	1127	693	240	60	76	22.1	13.8	2.5	16	240	42	56	2	2	83.92	2	0.55
SMP-19	8.2	989	1178	290	125	136	14.8	14.1	2	28	290	110	38	5	1	110.45	6	0.84
SMP-20	7.3	769	1060	160	70	127	24.5	18.5	6	56	160	108	44	3	2	12.67	4	0.93
SMP-21	8.2	745	1425	175	85	54	16.7	17.2	3	10	175	374	50	4	1	42	9	1.21
SMP-22	8.1	985	956	90	75	23	21.4	28.4	5	29	90	114	64	3	1	43	3	0.98
SMP-23	7.4	1180	1249	195	135	12	13.8	16.9	1.5	33	195	149	132	6	4	6	5	0.725
SMP-24	7.2	885	974	85	80	25	14.1	22.1	4	42	85	62	68	1.5	3	9	2	0.93
SMP-25	7.5	1839	1053	215	180	132	18.5	14.8	2	26	215	104	38	5	6	3	1	0.889
SMP-26	7.9	1265	1273	95	95	50	17.2	24.5	5	32	95	88	42	7	8	3	3	0.52
SMP-27	8.2	899	854	100	70	66	26.4	16.7	2.5	42	100	68	20	6	2	2	1	0.83
SMP-28	8.4	769	773	160	105	62	13.2	17.9	9	10	160	75	67	3	2	3	1.5	0.49
SMP-29	7.9	1089	583	290	185	90	23.4	19.8	1.5	29	290	35	44	6	4	2	2	0.125
SMP-30	8.2	1678	1439	225	100	205	18.9	26.4	4	38	225	286	34	7	6	9	9	0.48

In the above Table-4, the detail experimental result with values of various physio-chemical parameters is mentioned. The total 18 parameters are used for this experiment. In the Table-2, The detail sample locations are mentioned with latitude and longitude. In this experimental work, total 30 groundwater samples are used. In the Table-3, 13 samples are used with assigned weights. These weights are assigned on the basis of limit of BIS standard for water quality index. These assigned weights are used in Fuzzy Quality.

Table 5. FWQI Index for Assessment of Water Quality Index of Baramati Tehsil

Sample Id	TUB	Wt	DO	WDO	BOD	WBOD	pH	WpH	NO_3^-	$W_{NO\text{-}3}$	TDS	WTDS	∑µweights	FWQI
SMP-1	1	4	7	2	2	4	7.9	3	10	3	989	4	20	0.8
SMP-2	8	2	4	3	3	3	8.3	3	0.8	4	1279	3	18	0.8
SMP-3	1	4	3	3	3	3	7.7	3	6	3	534	4	20	0.8
SMP-4	0.5	4	3	3	1	4	8.4	3	4	4	746	4	22	0.9
SMP-5	9	2	2	3	2	4	8.1	3	4	4	1221	3	19	0.8
SMP-6	7	2	4	3	6	1	7.9	3	3	4	1642	2	15	0.6
SMP-7	8	2	2	3	7	1	8.2	3	12	3	1497	3	15	0.6
SMP-8	2	4	8	2	3	3	9.6	1	9	3	598	4	17	0.7
SMP-9	1	4	4	3	1	4	8.9	1	7	3	826	4	19	0.8
SMP-10	0.5	4	3	3	5	1	7.5	3	17	3	1439	3	17	0.7
SMP-11	5	3	2	3	2	4	8.2	3	14	3	1027	3	19	0.8
SMP-12	2	4	2	3	1	4	7.3	4	12	3	931	4	22	0.9
SMP-13	3	4	5	2	1	4	8.4	3	8	3	998	4	20	0.8
SMP-14	9	2	2	3	6	1	7.9	3	0.7	4	1824	2	15	0.6
SMP-15	8	2	2	3	3	3	7.4	4	4	4	1356	3	19	0.8
SMP-16	3	4	8	2	9	1	7.6	3	2	4	729	4	18	0.8
SMP-17	9	2	4	3	1	4	7.7	3	0.9	4	1342	3	19	0.8
SMP-18	2	4	2	3	2	4	7.8	3	0.4	4	693	4	22	0.9

SMP-19	6	**3**	5	**2**	1	4	8.2	**3**	2	4	1178	3	**19**	**0.8**
SMP-20	4	**3**	3	**3**	2	4	7.3	**4**	8	3	1060	3	**20**	**0.8**
SMP-21	9	**2**	4	**3**	1	4	8.2	**3**	0.6	4	1425	3	**19**	**0.8**
SMP-22	3	**4**	3	**3**	1	4	8.1	**3**	6	3	956	4	**21**	**0.9**
SMP-23	5	**3**	6	**2**	4	3	7.4	**4**	6	3	1249	3	**18**	**0.8**
SMP-24	2	**4**	1.5	**4**	3	3	7.2	**4**	9	3	974	4	**22**	**0.9**
SMP-25	1	**4**	5	**2**	6	1	7.5	**3**	0.5	4	1053	3	**17**	**0.7**
SMP-26	3	**4**	7	**2**	8	1	7.9	**3**	0.8	4	1273	3	**17**	**0.7**
SMP-27	1	**4**	6	**2**	2	4	8.2	**3**	2	4	854	4	**21**	**0.9**
SMP-28	1.5	**4**	3	**3**	2	4	8.4	**3**	3	4	773	4	**22**	**0.9**
SMP-29	2	**4**	6	**2**	4	3	7.9	**3**	2	4	583	4	**20**	**0.8**
SMP-30	9	**2**	7	**2**	6	1	8.2	**3**	9	3	1439	3	**14**	**0.6**

In the above Table-5, the detail working principal of FWQI is explaining. In this water quality index only 6 parameters are used for assessment of groundwater quality.

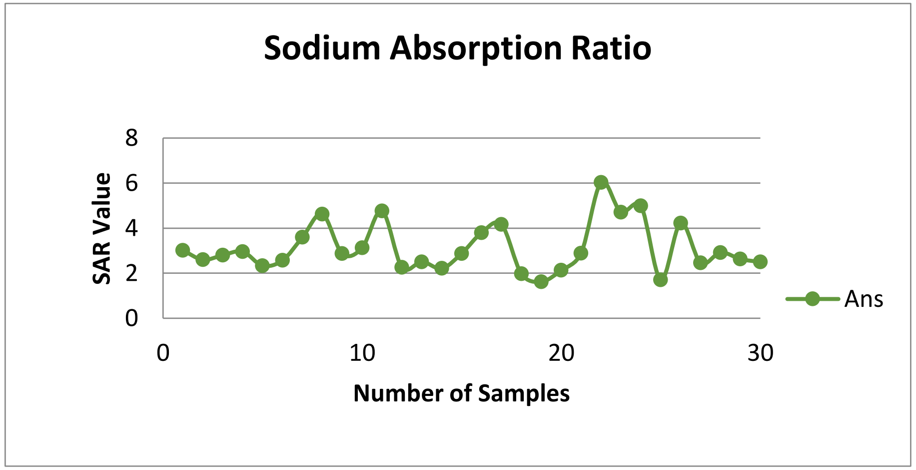

Figure 3. Sodium Absorption Ratio

Table 6. Assessment of Groundwater using Fuzzy Water Quality Index (FWQI) for Baramati Tehsil

Sample Station Number	FWQI	Result of Sample for Drinking Water
SMP-1	0.8	Very Good
SMP-2	0.8	Very Good
SMP-3	0.8	Very Good
SMP-4	0.9	Excellent
SMP-5	0.8	Very Good
SMP-6	0.6	Average/Bad
SMP-7	0.6	Average/Bad
SMP-8	0.7	Good
SMP-9	0.8	Very Good
SMP-10	0.7	Good
SMP-11	0.8	Very Good
SMP-12	0.9	Excellent
SMP-13	0.8	Very Good
SMP-14	0.6	Average/Bad
SMP-15	0.8	Very Good
SMP-16	0.8	Very Good
SMP-17	0.8	Very Good
SMP-18	0.9	Excellent
SMP-19	0.8	Very Good
SMP-20	0.8	Very Good
SMP-21	0.8	Very Good
SMP-22	0.9	Excellent
SMP-23	0.8	Very Good
SMP-24	0.9	Excellent
SMP-25	0.7	Good
SMP-26	0.7	Good
SMP-27	0.9	Excellent
SMP-28	0.9	Excellent
SMP-29	0.8	Very Good
SMP-30	0.6	Average/Bad

Table 7. Assessment of Groundwater using water Quality Index (WGI) For Baramati Tehsil

Sample Name	Tubidity			DO			BOD			pH			NO3			TDS			∑μweights	WQI
	Value	Q Value	3 0.115	Value	Q Value	3 0.115	Value	Q Value	5 0.192	Value	Q Value	5 0.192	Value	Q Value	5 0.192	Value	Q Value	5 0.192	26	
SMP-1	1	25	2.88	7	700	80.77	2	66.67	12.82	7.9	105.33	20.26	10	200	38.46	989	98.9	19.02	21.9	Very Bad
SMP-2	8	25	2.88	4	400	46.15	3	100	19.23	8.3	110.67	21.28	0.8	16	3.08	1279	127.9	24.6	27.48	Bad
SMP-3	1	25	2.88	3	300	34.62	3	100	19.23	7.7	102.67	19.74	6	120	23.08	534	53.4	10.27	13.15	Very Bad
SMP-4	0.5	25	2.88	3	300	34.62	1	33.33	6.41	8.4	112	21.54	4	80	15.38	746	74.6	14.35	17.23	Very Bad
SMP-5	9	25	2.88	2	200	23.08	2	66.67	12.82	8.1	108	20.77	4	80	15.38	1221	122.1	23.48	26.37	Bad
SMP-6	7	25	2.88	4	400	46.15	6	200	38.46	7.9	105.33	20.26	3	60	11.54	1642	164.2	31.58	34.46	Bad
SMP-7	8	25	2.88	2	200	23.08	7	233.33	44.87	8.2	109.33	21.03	12	240	46.15	1497	149.7	28.79	31.67	Bad
SMP-8	2	25	2.88	8	800	92.31	3	100	19.23	9.6	128	24.62	9	180	34.62	598	59.8	11.5	14.38	Very Bad
SMP-9	1	25	2.88	4	400	46.15	1	33.33	6.41	8.9	118.67	22.82	7	140	26.92	826	82.6	15.88	18.77	Very Bad
SMP-10	0.5	25	2.88	3	300	34.62	5	166.67	32.05	7.5	100	19.23	17	340	65.38	1439	143.9	27.67	30.56	Bad
SMP-11	5	25	2.88	2	200	23.08	2	66.67	12.82	8.2	109.33	21.03	14	280	53.85	1027	102.7	19.75	22.63	Very Bad
SMP-12	2	25	2.88	2	200	23.08	1	33.33	6.41	7.3	97.33	18.72	12	240	46.15	931	93.1	17.9	20.79	Very Bad
SMP-13	3	25	2.88	5	500	57.69	1	33.33	6.41	8.4	112	21.54	8	160	30.77	998	99.8	19.19	22.08	Very Bad
SMP-14	9	25	2.88	2	200	23.08	6	200	38.46	7.9	105.33	20.26	0.7	14	2.69	1824	182.4	35.08	37.96	Bad
SMP-15	8	25	2.88	2	200	23.08	3	100	19.23	7.4	98.67	18.97	4	80	15.38	1356	135.6	26.08	28.96	Bad
SMP-16	3	25	2.88	8	800	92.31	9	300	57.69	7.6	101.33	19.49	2	40	7.69	729	72.9	14.02	16.9	Very Bad
SMP-17	9	25	2.88	4	400	46.15	1	33.33	6.41	7.7	102.67	19.74	0.9	18	3.46	1342	134.2	25.81	28.69	Bad
SMP-18	2	25	2.88	2	200	23.08	2	66.67	12.82	7.8	104	20	0.4	8	1.54	693	69.3	13.33	16.21	Very Bad
SMP-19	6	25	2.88	5	500	57.69	1	33.33	6.41	8.2	109.33	21.03	2	40	7.69	1178	117.8	22.65	25.54	Bad
SMP-20	4	25	2.88	3	300	34.62	2	66.67	12.82	7.3	97.33	18.72	8	160	30.77	1060	106	20.38	23.27	Very Bad

SMP-21	9	25	2.88	4	400	46.15	1	33.33	6.41	8.2	109.33	21.03	0.6	12	2.31	1425	142.5	27.4	30.29	Bad
SMP-22	3	25	2.88	3	300	34.62	1	33.33	6.41	8.1	108	20.77	6	120	23.08	956	95.6	18.38	21.27	Very Bad
SMP-23	5	25	2.88	6	600	69.23	4	133.33	25.64	7.4	98.67	18.97	6	120	23.08	1249	124.9	24.02	26.9	Bad
SMP-24	2	25	2.88	2	150	17.31	3	100	19.23	7.2	96	18.46	9	180	34.62	974	97.4	18.73	21.62	Very Bad
SMP-25	1	25	2.88	5	500	57.69	6	200	38.46	7.5	100	19.23	0.5	10	1.92	1053	105.3	20.25	23.13	Very Bad
SMP-26	3	25	2.88	7	700	80.77	8	266.67	51.28	7.9	105.33	20.26	0.8	16	3.08	1273	127.3	24.48	27.37	BAD
SMP-27	1	25	2.88	6	600	69.23	2	66.67	12.82	8.2	109.33	21.03	2	40	7.69	854	85.4	16.42	19.31	Very Bad
SMP-28	1.5	25	2.88	3	300	34.62	2	66.67	12.82	8.4	112	21.54	3	60	11.54	773	77.3	14.87	17.75	Very Bad
SMP-29	2	25	2.88	6	600	69.23	4	133.33	25.64	7.9	105.33	20.26	2	40	7.69	583	58.3	11.21	14.1	Very Bad
SMP-30	9	25	2.88	7	700	80.77	6	200	38.46	8.2	109.33	21.03	9	180	34.62	1439	143.9	27.67	30.56	BAD

Table 8. Comparison of Groundwater using Fuzzy Water Quality Index (FWQI), Water Quality Index and National Sanitation Foundation Water Quality Index (NSF WQI) for Baramati Tehsil

Sample Station Number	FWQI	WQI
SMP-1	Very Good	Very Bad
SMP-2	Very Good	BAD
SMP-3	Very Good	Very Bad
SMP-4	Excellent	Very Bad
SMP-5	Very Good	BAD
SMP-6	Average/Bad	BAD
SMP-7	Average/Bad	BAD
SMP-8	Good	Very Bad
SMP-9	Very Good	Very Bad
SMP-10	Good	BAD
SMP-11	Very Good	Very Bad
SMP-12	Excellent	Very Bad
SMP-13	Very Good	Very Bad

SMP-14	Average/Bad	BAD
SMP-15	Very Good	BAD
SMP-16	Very Good	Very Bad
SMP-17	Very Good	BAD
SMP-18	Excellent	Very Bad
SMP-19	Very Good	BAD
SMP-20	Very Good	Very Bad
SMP-21	Very Good	BAD
SMP-22	Excellent	Very Bad
SMP-23	Very Good	BAD
SMP-24	Excellent	Very Bad
SMP-25	Good	Very Bad
SMP-26	Good	BAD
SMP-27	Excellent	Very Bad
SMP-28	Excellent	Very Bad
SMP-29	Very Good	Very Bad
SMP-30	Average/Bad	BAD

From Above table 8, the FWQI is perfroming water quality index with the help of only 6 physico-chemical parameter but WQI fail to detect the water quality on the basis of 6 physico-chemical. WQI index will provide precise results of assessment of water quality using 13 parameters only so WQI is more costly as compares to FWQI.

In Baramati city and in Tehsil many agro base and allied as well as number of Chemical, Automobile, Plastic, Heavy industries etc. are in operation for different final product. They use huge quantity of surface as well as groundwater for product processing. However, due to limited and partial water treatment for effluent and domestic wastewater form big town along with Baramati city raise the question of water quality for surface and groundwater in the area. Therefore, assessment of water quality and hence the index is essential in Baramati Tehsil. Reliable and future prediction of water quality changes is a prerequisite for early water pollution control and is vital in environmental monitoring, ecosystem sustainability, and human health. The assessment and prediction of groundwater quality is an essential for planning and management of water resources; for early forecasting there is need of consistent, precise and resilient predictive model.

5. Conclusion

When deciding whether groundwater is fit for consumption, a number of biophysical water features' effects on the human biological system are taken into account. With the use of subject-matter expertise, inference techniques, the FWQI Index integrates distinct physico-chemical and biotic characteristics to reveal actual level of groundwater quality. This index may also be used to keep an eye on aquatic bodies.

To establish the water quality index, which serves as the foundation for assigning water quality rankings, fuzzy logic is applied. The unit-less number ranging from 1 to 10 represents the Water Quality Index that is displayed here. Better water quality is indicated by a higher number. It is further noted that, with the exception of Total Hardness, Calcium, and Magnesium, all parameters are within the permitted ranges established by WHO, ISI, and ICMR. The drinking water quality indicators were compared to those established by the Indian Standards Institute (ISI), the World Health Organization (WHO), and the Indian Council of Medical Research (ICMR).

The computation complexity is major limitation of FWQI. The fuzzy logic expert professional can handle this complexity smoothly as compare to normal end user.

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