GIS MAPPING AND ASSESSMENT OF WATER QUALITY INDEX BASED ON FUZZY LOGIC APPLIED TO GROUNDWATER IN JAFRABAD REGION

Sarita Jibhau Wagh[1],Pradip M. Paithane[2],Dr.S.N.Patil[3],Dr.S.T.Ingale[4]

M. Tech Student[1],

Assistant Professor[2],

Professor[3],

Director and Professor[4]

School of Environment Science, North .Maharashtra. University., Jalgao,India[1,3,4],
VP Kamalnayan Bajaj Institute of Technology and Engineering,Baramati,Pune,India[2]

Abstract:

Due to growing urbanization and industrialization, the environment is suffering from pollution of rivers, degradation of soils and deteriorated air quality. Quality indices appear to be useful to evaluate the conditions of these media. The present work is aimed at assessing the water quality index (WQI) for the groundwater of Jafrabad taluka, Dist Jalna. Jafrabad taluka is surrounded by Purna River. At Takarkheda Bhagile village,Tq. Deogaoraja,Dist.Buldhana, Khadakpurna dam is sited over Purna River and backwater of this dam up-to 30 km from the dam location which cover south-east location of Jafrabad taluka. Agriculture Water, Drinking Water, Industry Water, Daily Need Water is supplied from this backwater. Green algae are major problem of this backwater. In agriculture field, used of fertilizer and pesticide is more so this source is affected. Major sources of groundwater contamination in the city were open discharges of domestic sewage, in-adequate sewerage system, open defecation, septic tanks, soak pits, contaminated water pools and unorganized solid waste dumping. The objective of the study was to assess the impact of anthropogenic activities on groundwater quality and to identify the groundwater potential zones for drinking water production using GIS.

This has been determined by collecting groundwater samples and subjecting the samples to a comprehensive physicochemical analysis. The high value of WQI has been found to be mainly from the higher values of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate and manganese in the groundwater. The results of analyses have been used to suggest models for predicting water quality.

Fuzzy expert system makes it possible to combine the certainty levels for the acceptability of water based on an approved parameter. Fuzzy logic provides an efficient and useful device for classifying drinking water quality based on limited observations.

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Keywords: **Fuzzy Water Quality Index (FWQI), Water Quality Index (WQI), Geographical information System (GIS).**

1. INTRODUCTION

Groundwater quality has become one of the most important aspects in our living environment and that chemistry of groundwater has a bearing on our health and livestock [1]. The water is being a worldwide solvent utilized from mankind era. The total amount of large scale water, only 2.4% is circulated on the main land, of which only a small portion can be utilized as fresh water. The accessible clean water to man is only just 0.3-0.5% of the total water available on the earth and therefore, its sensible use is essential.

Groundwater studies are gaining more importance all purposes such as household, industrial and agricultural activities in various parts of the world [2]. The fresh water is a predetermined and partial resource. The consumption of water from ages has led to its overuse together with the increasing population along with enhanced standard of living as an effect of scientific innovations. This pollution of groundwater is not away from the harms of improvement. Thus, eminence of groundwater is failing at an earlier speed suitable to contamination vary from septic tanks, land fill leachates, domestic sewage agricultural runoff/ agricultural fields and industrial wastes. Contamination of groundwater also depends on the geology of the region and it is fast in hard rock areas mainly in lime stone regions where wide cavern systems are lower the water table. This is an aspect common, not only in urbanized countries but also in developing countries like India. The changes in excellence of groundwater reply to difference in physical, chemical and biological environments throughout which it passes.
The inherent uncertainties, subjectivity, and engineering challenges in environmental problems are increasingly being worked upon computing methods based on artificial intelligence (AI), including computerized tools that allow an analyst to use approximate reasoning with incomplete and inaccurate information and with the support of an expert in the field [3]. In order to evaluate the applicability of this tool, this paper presents the development of a new water quality index based on fuzzy logic called the “fuzzy water quality index” (FWQI). The new FWQI provided reasonable correlations and results in comparison to the other two reference indexes [4]. Finally, the FWQI could be used as a decision maker in the water management of Purna River

2. Material

2.1 Study Area

Jafrabad is city and tehsil in Jalna subdivision of Jalna district in the Maharashtra state, India. Jafrabad is a small city residing at over the bank of Purna River, with an Eye soothing Natural surrounding & High yielding Farmlands. Its geographical coordinates are 20° 12' 0" North, 76° 0' 0" East. East-South Jafrabad Taluka is surrounded by Purna basin. Khadakpurna project dam situated on Purna river near Takarkhed Bhagile village,Tq. Deogaoraja, Dist. Buldhana. Green algae problem is occur in backwater of Purna Basin. Rameshwar Sugar factory is located at Sipora Ambora village which 25 km long from Jafrabad headquarter. Dal Mill, cotton-company, small scale oil mill, excess use of fertilizer, pesticides in agriculture field due to all groundwater is affected. The Purna river rises from near Mehun about 8 km NE of Satmala hills and at a height of about 725 mamsl. Its tributaries are the Charna, the Khelna, the Jui, the Dhamna, the Anjan, the Girja, the Jivrakha and the Dudhna.

2.2 Geomorphology

The northwestern part of the Jalna district is comprised of the eastern slopes of the Ajanta Plateau. The satmala hill ranges (943m) throws an offshoot in south-eastern direction through Jafrabad taluka which forms the western edge of the Buldhana plateau. Eastern offshoot of the Ajanta or Satmala hill ranges comprising flat topped hills form divides between Purna and Girija rivers and between Girja and Dudhna rivers. Apart from these, hilly regions are occurring in northern and western parts of Jafrabad, Bhokardan and Ambad taluka. Elevations of the hilly regions are range from 600 to 900 m above (mamsl) and of the plains from 450 to 600 mamsl.

2.3 Climate and Rainfall

Agriculture in the area depends mainly on the rainfall from south-west monsoon. The area experiences the sub-tropical to tropical temperate monsoon climate. It was observed that the distribution of rainfall is more or less uniform over the area. The rains usually start in the second week of June and last till the end of September. The intensity of rainfall is the highest in July. On the basis of rain fall analysis it is observed that:

- The normal annual rainfall of Jafrabad taluka is 636.6 mm.
- The coefficient of variation in rainfall is observed as 31%.
- Normal rainfall has been received for 60 % of years at Jafrabad taluka of the total years, whereas excess rainfall has been received for 22% of years.
- The taluka have suffered moderate drought conditions in 8 % of years. Whereas, severe drought in 10% of the years.

The long term trend of rainfall was calculated and it is observed that there is a falling trend in Jafrabad taluka @ 1.803 mm/year.

Temperature during rainy season ranges from 210 to 300 C. In winter season temperature fall appreciably and range from 10 to 250C. In nights temperature range is 20 to 250C with privilege of cool breeze.

2.4 Land Area

The area can be broadly divided into four physiographic units i.e., the Ajanta Hill range, undulating plateau, Denudation slope and older flood plain. The altitude in Jafrabad taluka range between 534to 710mamsl.The major older flood plain is observed along Purna River. It has been observed that the major parts of the area are covered by agricultural land. Forest covers very little area in the northern-east part. Soil plays a very important role in the agricultural activities and forest growth of the area. The fertility of the soil from agricultural point of view depends upon the texture and structure which controls the retaining and transmitting capacity of moisture and various nutrients such as nitrogen, phosphorous and potassium present in the soil. The formation of the soil in the area is influenced by the climate, geology, vegetation and
Topography

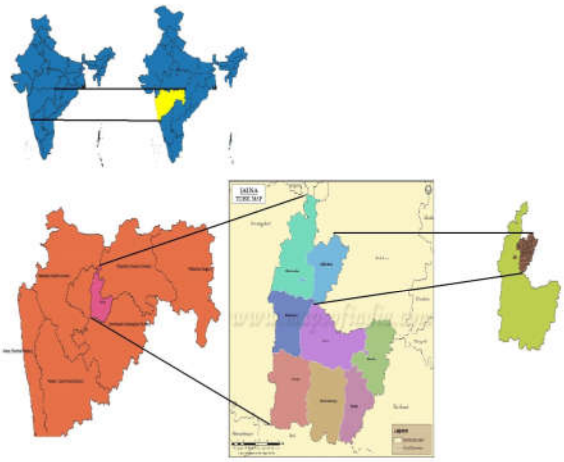

Figure 1. Jalna District Map

2.5 Selection and Collection of Sample

Samples are collected from Jafrabad taluka of Jalna District. Samples are collected from groundwater of Purna river Basin and tubwell resources. The water samples were full in pre-cleaned polyethylene bottles; after collection the samples was directly placed in mysterious boxes and processed within 24 hr of collection. The collected samples were analyzed by using physical and chemical water quality parameters like pH, EC, TDS, TA, chloride, Total hardness, dissolved oxygen, Biochemical Oxygen Dissolved, Sulphates, calcium, magnesium, nitrate and turbidity as per BIS standard [5]. Samples are collected from 30 different villages from Jafrabad taluka.

Table 1. Sample Collection from Different Village from Jafrabad Taluka

Sample Id	Sample Detail				
	Location	Latitude	Longitude	Depth (m)	Source
PGW-1	Kumbharzari 1	20.148631	76.086604	13	Dug well
PGW-2	Kumbharzari 2	20.155722	76.090434	14.50	Hand Pump
PGW-3	Savargao Mhske	20.146742	76.046298	15	Tubwell
PGW-4	Brahmapuri	20.156680	76.095344	10	Dug well
PGW-5	Khamkheda	20.177861	76.028670	18	Tubwell
PGW-6	Nalvihira	20.170313	76.044167	22	Tubwell
PGW-7	Jafrabad 1	20.185596	76.044734	15	Dug Well
PGW-8	Jafrabad 2	20.186766	76.010041	13	Hand Pump
PGW-9	Jafrabad 3	20.186982	76.008754	16	Tubwell
PGW-10	Jafrabad 4	20.196846	76.010412	14	Tubwell
PGW-11	Jafrabad 5	20.199305	76.012987	15	Tubwell
PGW-12	Davargao Devi	20.168582	75.964604	10	Tubwell
PGW-13	Tembruni	20.164797	75.978422	18	Tubwell
PGW-14	Garkheda	20.172778	75.971001	12	Tubwell
PGW-15	Aland	20.173360	76.083486	11	Dug Well
PGW-16	Savarkheda Gondhan	20.223367	76.101223	12	Dug Well
PGW-17	Takali	20.188056	75.988982	13	Hand Pump
PGW-18	Borkhedi Chinch	20.184497	76.064097	20	Hand Pump
PGW-19	Dolkheda Kh.	20.100785	76.070879	21	Tubwell
PGW-20	Khaparkheda	20.275509	76.084197	13	Hand Pump
PGW-21	Hanumant Kheda	20.182876	76.98157	10	Tubwell
PGW-22	Pimpal khuta	20.203508	76.026911	14	Hand Pump
PGW-23	Deoulgao Ugale	20.205836	76.045921	12	Tubwell
PGW-24	Sipora	20.211	76.095504	17	Hand Pump

Sample Id	Sample Detail				
	Location	Latitude	Longitude	Depth (m)	Source
	Ambhora	134			
PGW-25	Sawangi	20.159927	75.998734	18	Tubwell
PGW-26	Merakhed	20.271380	76.075391	19	Hand Pump
PGW-27	Janefal	20.260222	75.987952	15	Tubwell
PGW-28	Asai	20.147600	75.889134	15	Tubwell
PGW-29	Konad	20.246099	76.152572	16	Hand Pump
PGW-30	Varud Budruk	20.253374	76.121045	16	Dug Pump

3. METHODOLOGY

Groundwater is used for domestic and industrial water supply and irrigation all over the world. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions [6]. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas.

3.1 Water Quality Index (WQI)

A Water Quality Index (WQI) describes the general situation of water bodies by changing water quality parameters levels into a numerical score using mathematical tools 16- 18. It is calculated from the view of human consumption. WQI can be evaluated on the basis of physical, chemical and biological parameters. The concept of water quality to categorize water according to its degree of purity or pollution dates back to 1848 in Germany [7]. WQI is defined as a method of ranking that provides the composite power of individual water quality parameter on the overall quality of water. The WQI has been calculated to assess the suitability of groundwater quality of the study area for drinking purposes.

The standards for drinking purposes as recommended by Indian Standards: 10500, have been considered for the calculation of WQI. In this method, the weightage for various water quality parameters is assumed to be inversely proportional to the recommended standards for the corresponding parameters [8].
Accordingly, the weightage of ith parameter is calculated by following formula:

$$Wi=k/si \qquad (1)$$

Where, Wi is the unit weight for the i^{th} parameter, si the recommended standard for the i^{th} parameter and i=1,2,3,…16; and k the constant of proportionality.
The calculation involves the following steps:
(a) First, the calculation of the quality rating for each of the water quality parameters
(b) Second, a summation of these sub-indices in the overall index
The individual quality rating is given by the expression:

$$Qi=100*vi/si \qquad (2)$$

Where, vi is the measured value of the ith parameter in groundwater sample under consideration and si the standard or permissible limit for the ith parameter
The WQI is then calculated as Follows:

$$WQI=\sum(QiWi)/\sum Wi \qquad (3)$$

The computed WQI values are classified into five types

Table 2. Category of WQI Value

Water Quality	WQI Values
Excellent water	<50
Good water	50-100
Poor water	100-200
Very poor water	200-300
Unfit for use	>300

3.2 Fuzzy Expert System

Fuzzy Expert System is a rule based expert system where fuzzy logic is used as a tool for representing different form of knowledge about the problem.

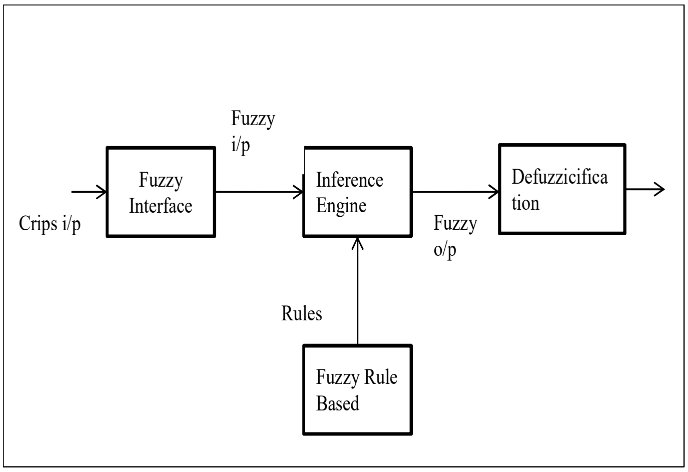

Figure 2. Fuzzy Expert System

In this study, the fuzzy logic has been used to assessment of drinking water quality by developing a Fuzzy Expert System for drinking water quality index based on fuzzy logic [9]. Fuzzy expert system makes it possible to combine the certainty levels for the acceptability of water based on an approved parameter. Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are unsafe for human health if they occurred more than defined limits.

New approach to water quality evaluation uses fuzzy logic to combine different problems and provide a more precise indicator of overall quality [10].

Fuzzy logic provides a structure to model ambiguity. Fuzzy logic was first introduced by Zadeh 1965 [11]. The fuzzy index has been shown to be efficient in avoiding the loss or non-detection of information critical for classification of water quality. The proposed system consists of 6 input, 1 output and 10 rules and actual flow diagram for fuzzy expert system is shown in Fig. 3. The present system is used for developing a drinking water quality index.

FWQI based on six input parameter. System output is actually giving the drinking water quality which is divided into four types. The knowledge base describing the system's behavior is represented by the membership functions designing the linguistic variables [12]. Hence, for the proposed system's behavior, 7 linguistic variables are defined. Out of these 6, six is input variables namely- turbidity (T), dissolved oxygen (DO), biochemical oxygen demand (BOC), pH value (pH), Nitrate(NO3) and Total Dissolved Solid (TDS) and one is output variable drinking water quality. In this study, use triangle and trapezoidal membership function that explain process of each point in the input space is correlate to a membership cost between 0 and 1[13]. Steps of this expert system are fuzzification, assessment of inference rules, and defuzzification of fuzzy output results.

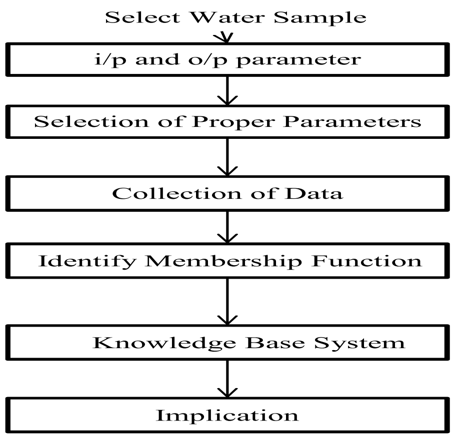

Figure 3. Flow Diagram of Fuzzy Expert System

Conception of inference rule is an if–then rule has the form: "If x is A then z is C", the if–part is called the antecedent, while the then–part is called the consequent. The antecedent and the consequent of a rule can have multiple parts. Fuzzification is process to define inputs and outputs as well as their individual membership function that convert the numerical value of a variable into a membership grade to a fuzzy set [14]. After the inputs are fuzzified, the degree to which each part of the antecedent is fulfilled for each regulation. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number is then applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables [15]. The output is an only truth value. The input for the inference process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule. In this research, each of the seven input parameter has been divided into different categories and defined by triangular and trapezoidal membership function.

3.3 Fuzzy Set and Membership Functions

A crisp set is modifies which called fuzzy set. It allows only full membership or no membership at all and fuzzy sets allow partial membership [16]. In a crisp set, membership or non-membership of element x in set A is described by a characteristic function $\mu_A(x)$, where $\mu_A(x)=1$ if $x \in A$ and $\mu_A(x)=0$ if $x \notin A$. Fuzzy set theory extends this concept by defining partial membership. A fuzzy set A on a universe of discourse *U* is characterized by a membership function $\mu_A(x)$ that takes values in the interval [0, 1]. Fuzzy sets represent commonsense linguistic labels like *slow, fast, small, large, heavy, low, medium, high, tall, etc* [17]. A given element can be a member of more than one fuzzy set at a time. A membership function is essentially a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1 [18]. Various types of membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions [19]. The choice of number range and shape of membership function

depends upon the design choice and the accuracy desired in the resultant value. Following points should be kept in mind while selecting the membership value.
(i) Symmetrically distribute the fuzzy set across the defined universe of discourse.
(ii) Use an odd number of fuzzy set for each value; this ensures that some fuzzy set will be in the middle. 3, 5 and so on fuzzy sets for each system variable are fairly typical.

(iii) Ensure that all crisp value falls to any set by overlapping adjacent fuzzy sets and to help in ensuring that more than one rule is involved in determining the output.

(iv)Use triangular or trapezoidal membership functions, as these require less computation time than other types. System variable with three to five fuzzy sets with 15% to 25% overlap of adjacent fuzzy sets tend to work fairly well. Triangular curves depend on three parameters a, b, and c and are given by below Equation.

$$f(x;a,b,c) = \begin{cases} 0 \ for \quad x < a \\ \dfrac{x-a}{b-a} \ for \quad a \le x < b \\ \dfrac{c-x}{c-b} \ for \quad b \le x \le c \\ 0 \ for \quad x > c \end{cases} \tag{4}$$

Trapezoidal curves depend on four parameters a, b, c and d and are given by below Equation

$$f(x;a,b,c,d) = \begin{cases} 0 \ for \quad x < a \\ \dfrac{x-a}{b-a} \ for \quad a \le x < b \\ 1 \ for \quad b \le x < c \\ \dfrac{d-x}{d-c} \ for \quad c \le x < d \\ 0 \ for \quad d \le x \end{cases} \tag{5}$$

The most elementary crisp set operations are union, intersection, and complement, which essentially correspond to OR, AND, and NOT operators, respectively. Let A and B be two subsets of U. The union of A and B, denoted $A \cup B$, contains all elements in either A or B; that is, $\mu_{A\cup B}(x)=1$ if $x\in A$ or $x \in B$. The intersection of A and B, denoted $A\cap B$, contains all the elements that are simultaneously in A and B; that is, $\mu_{A\cap B}(x)=1$ if $x\in A$ or $x\in B$. The complement of A is denoted by $\bar{A}$, and it contains all elements that are not in A; that is $\mu_A(x)=1$ if $x \notin A$, and $\mu_A(x)= 0$ if $x\in A$. In FL, the truth of any statement is a matter of degree. In order 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.

$$\mu_{A\cup B}(x)=\max[\mu_A(x), \mu_B(x)] \tag{6}$$

$$\mu_{A\cap B}(x)= \min [\mu_A(x), \mu_B(x)] \tag{7}$$

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

Fuzzy inference systems consist of if–then rules that specify a relationship between the input and output fuzzy sets. Fuzzy relations present a degree of presence or absence of association or interaction between the elements of two or more sets. Fuzzy relations play an important role in fuzzy inference systems. FL uses notions from crisp logic. Concepts in crisp logic can be extended to FL by replacing 0 or 1 values with fuzzy membership values. A singleton fuzzy rule assumes the form “if x is A, then y is B,” where $x\in U$ and $y\in V$. The if part of the rule, “x is A,” is called the antecedent or premise, while the then

part of the rule, "y is B," is called the consequent or conclusion. Interpreting an if–then rule involves two distinct steps. The first step is to evaluate the antecedent, which involves fuzzifying the input and applying any necessary fuzzy operators. The second step is implication, or applying the result of the antecedent to the consequent, which essentially evaluates the membership function. It can be seen that in crisp logic a rule is fired if the premise is exactly the same as the antecedent of the rule, and the result of such rule firing is the rule's actual consequent. In fuzzy logic, a rule is fired so long as there is a nonzero degree of similarity between the premise and the antecedent of the rule.
The most popular defuzzification method is the centroid, which calculates and returns the center of gravity of the aggregated fuzzy set [20]. In this method, the centroid of each membership function for each rule is firstly evaluated. The final output, Uo, is then calculated as the average of the individual centroids, weighted by their heights as given by Equation(9)

$$U_0 = \frac{\sum_{i=1}^{n} u_i \mu(u_i)}{\sum_{i=1}^{n} \mu(u_i)} \quad (9)$$

4. Result and Discussion

4.1 Water Quality for Domestic Drinking Purpose

pH of groundwater from analyzed samples, ranged from 7.2-9.6 with an average value of 7.9. The pH values for all groundwater samples were found within the permissible limits compared with the BIS (2012) standards established for drinking water. Electrical conductivity is a function of total dissolved solids (TDS) known as ions concentration, which determines the quality of water. The EC values for all groundwater samples were found with-in the permissible limits according to BIS drinking water standards and can be used for irrigation purpose as well. The total dissolved salts in the groundwater ranged from 534 – 1824 mg/L with an average value of 1082.93 mg/L. It was observed that the TDS in groundwater of all the samples were within the permissible limits compared with the BIS.
The concentration of calcium in groundwater ranged from 12 -205 ppm with an average value of 67.46 ppm. The results showed that the level of calcium in 2 (10 %) groundwater samples was observed exceeds permissible limits compared with BIS. The concentration of sodium in groundwater ranged from 13.8 – 28.4 ppm with an average value of 18.57 ppm. The results showed that the level of sodium in all groundwater samples was observed within permissible limits compared with BIS.
The concentration of potassium in groundwater ranged from 1 -9 ppm with an average value of 3.32 ppm. The results showed that the level of potassium in 5 (23%) groundwater samples was observed exceeds permissible limits compared with BIS.
The concentration of chloride in groundwater ranged from 35 - 406 ppm with an average value of 187.87 ppm. The results showed that the level of chlorides in all samples of groundwater was within permissible limits compared with BIS.

The concentration of Sulphates in groundwater ranged from 20 - 132 ppm with an average value of 60.84 ppm

4.2 Water Quality for Irrigations

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment.

- Irrigation Water Salinity

The main problem related to irrigation water quality is water salinity—which refers to the total amount of salts dissolved in the water, but it does not indicate which salts are present. High levels of salts in irrigation water reduce water availability to the crop (because of osmotic pressure) and cause yield reduction. Above a certain threshold, reduction in crop yield is proportional to the increase in salinity level. Different crops vary in their tolerance to salinity and, therefore, have different thresholds and yield reduction rates. The most common parameters used for determining irrigation water quality in relation to its salinity are EC and TDS. If irrigation water salinity exceeds the threshold for the crop, yield reduction will occur.

- SPECIFIC ION TOXICITY

Certain ions (sodium, chloride, or boron) from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields.

- Alkalinity and pH

Alkalinity is the sum of the amounts of bicarbonates (HCO3-), carbonates (CO32-) and hydroxide (OH-) in water. It is expressed as mg/l or meq/l CaCO3. Alkalinity buffers the water against sudden changes in pH. If the alkalinity is too low, any addition of acidic fertilizers will immediately lower the pH. In container plants and hydroponics, ions released by plant roots may also rapidly change the pH if alkalinity is low.

- Residual Sodium Carbonate (RSC)

Lloyd and Heathcote have classified irrigation water based on RSC as Suitable (< 1.25), marginal (1.25 to 2.5) and not suitable (> 2.5). The values for RSC is calculated as per Eaton,
RSC = (CO32- + HCO3-) - (Ca + Mg)
All ionic values are in meq/l
Accordingly the all groundwater is suitable for irrigation except one sample because its RSC value is > 2.5.

- Sodium Absorption Ratio

Classification of water with reference to the SAR values less than 10 it is indicates excellent for irrigation. The SAR of municipal groundwater ranged from 1.5-4.9 with an average value of 3.0. The results showed that the groundwater under S1class

$$SAR = \frac{Na}{\sqrt{(Ca + mg)/2}} \tag{10}$$

- Kelley's Ration (KR)

Kelley and Paiwal introduced a parameter for calculating irrigation water quality based on the level of Na+ measured against Ca2+ and Mg2+. If the concentration of Na+ exceeds the concentration of Ca2+ and Mg2+ then the water is unsuitable.

$$KR = \frac{Na^{+}}{(Ca^{2+} + Mg^{2+})} \tag{11}$$

Water with Kelley′s Ratio < 1 is suitable for irrigation and Kelley′s Ratio >1 is unsuitable. 53% of the samples record KR<1 indicating that the good quality of water for irrigation purposes

Piper-Trilinear diagram: The piper trilinear diagram consisting of three distinct fields, two triangular fields and one diamond shaped fields. The piper trilinear diagram has been used for variation and differences in chemical composition of water samples. The chemical composition of water samples from area under study were plotted in piper trilinear diagram. The diagram shows that the water belongs to Ca-Cl-HCO3 facies. The piper plot shows that water is dominant of calcium bicarbonate. Ca, HCO3 indicate temporary hardness and overall hydrogeochemistry of the area under study is dominated by Ca,Mg, Cl and HCO3.

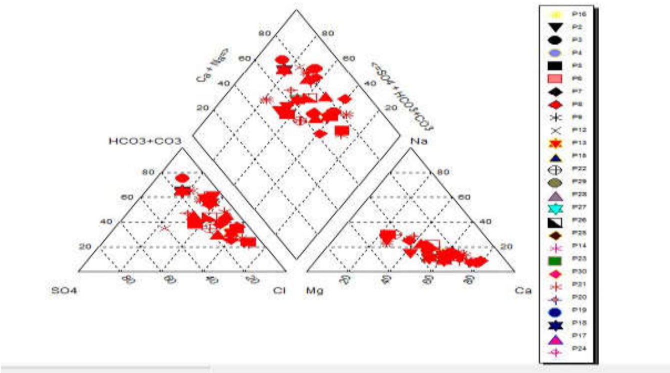

Figure 4. Piper Trilinear Diagram

Durov Diagram: The expanded Durov diagram provides a distinct classification of dominant cations and anions. From the graphical representation of the study area shows dominance of calcium bicarbonate

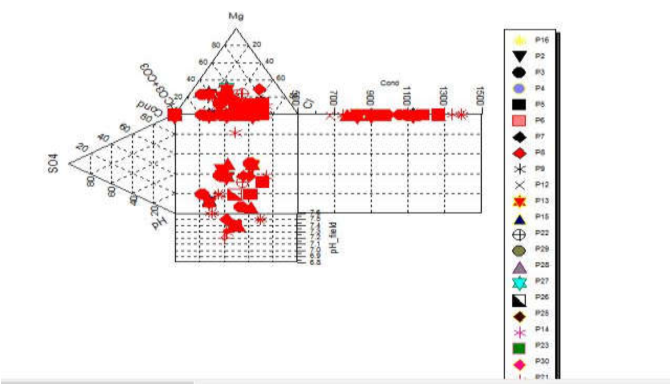

Figure 5. Durov Diagram

Correlation Coefficient: Relationship of physico-chemical parameters from water and their coefficient correlation is a normally use for measurement of recognized the correlation between two variables. The correlation matrices for 14 variables were prepared and presented in figure 5.4. EC and TDS, EC and Cl show strong positive correlation. TDS and Cl also exhibit high positive correlation with SO4 and Cl-ions. F- and B, SO4 2-and TDS, SO4 2- and TDS are also exhibits the good positive correlation pairs.

Total Number of Samples: 30

Correlation coefficient

		pH_field	Ca	Cl	SO4	Meas_Hardness	NO3	CO3	HCO3	Meas_Alk	Na	Mg	TDS	Cond	DO
pH_field		1.0	-0.164	0.443	-1.6E-2	0.307	0.183	-8.6E-2	0.274	-8.1E-2	3.4E-3	8.0E-2	-0.218	3.3E-2	0.301
Ca	mg/l		1.0	-1.6E-2	-0.379	2.7E-2	4.4E-2	2.4E-3	6.2E-2	3.8E-2	0.108	0.159	0.319	0.182	7.4E-2
Cl	mg/l			1.0	0.171	0.155	0.183	0.323	0.139	-0.163	7.8E-2	-0.303	0.24	2.7E-2	3.0E-2
SO4	mg/l				1.0	-0.198	0.224	1.5E-2	-0.126	-9.8E-2	4.3E-2	-0.538	-0.105	-0.15	7.2E-2
Meas_Hardness	mg/L					1.0	9.2E-2	-6.6E-2	0.927	0.306	-0.369	0.111	7.5E-2	3.6E-3	-1.5E-2
NO3	mg/l						1.0	-0.117	0.114	-0.133	-0.139	-0.175	2.9E-2	-0.203	-0.172
CO3	mg/l							1.0	-5.0E-2	-0.119	4.3E-2	-0.148	-9.9E-2	6.9E-2	7.0E-2
HCO3	mg/l								1.0	0.298	-0.293	6.3E-2	6.9E-2	-2.2E-2	8.6E-2
Meas_Alk	mg/L									1.0	-2.8E-2	9.2E-2	1.9E-2	0.268	0.232
Na	mg/l										1.0	7.9E-2	0.194	0.114	0.147
Mg	mg/l											1.0	-0.103	4.0E-2	0.117
TDS	mg/l												1.0	2.9E-3	-0.202
Cond	uS/cm													1.0	0.529
DO	mg/l														1.0

Figure 6. Correlation Coefficient Diagram

US Salinity Hazard Wilcox Diagram: This diagram indicates type of salinity hazards. It is marked that, majority of water samples fall under category C3S1 which is indicates groundwater of study area high salinity hazards. 1 sample shows C4S1 category which indicates very high salinity hazards. One sample is fall under category C2S1 moderate salinity hazards and low sodium content. Sodium Adsorption Ratio is the most commonly used method to evaluate the effects of exchangeable sodium on the physical condition of the soil. The excess sodium in water reacts with soil which changes the soil structure and reducing the soil permeability. Then the soil becomes compact and impervious. Low alkali and moderate salinity hazard water can be used for irrigation on all soil. High sodium hazard water generates exchangeable sodium in a harmful level, so it needs regular leaching and special soil management for salinity control.

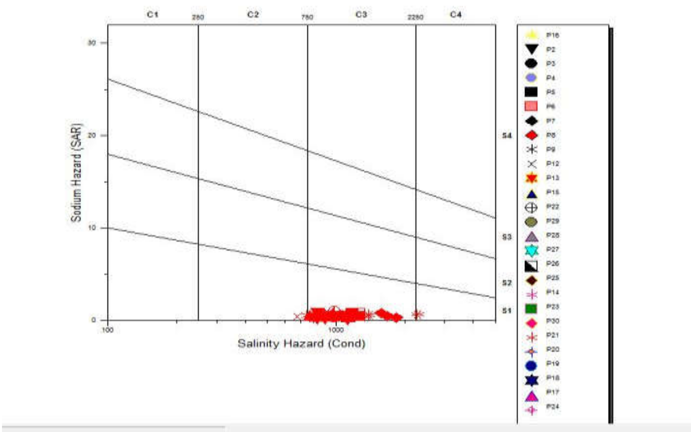

Figure7. Salinity Hazard Wilcox Diagram

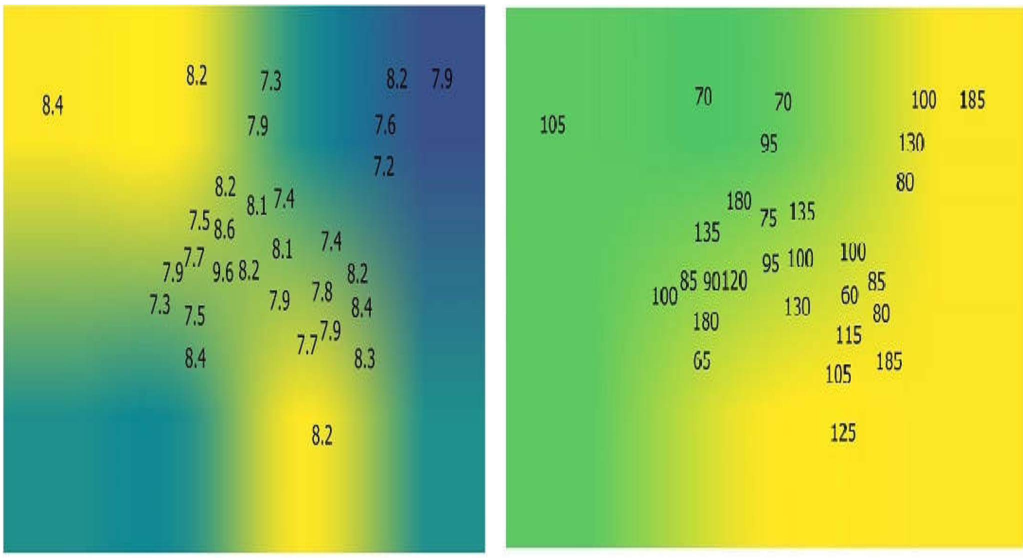

Figure 8. Spatial Distribution of pH and TA

The spatial distribution of pH shows most of the samples are within permissible range according to BIS standard. Permissible range of pH is 6.5-8.5 according to BIS standard. Sample PGW 8 and PGW 9 value more than 8.5 permissible range. Groundwater quality zones indicated poor water quality in the city area due to dense habitation and anthropogenic activities.

Table 3. Result with FWQI

Sr.No	Sample Id	Location	FWQI	Result of Sample for Drinking Water
1	**PGW-1**	Kumbharzari 1	0.8	Very Good
2	**PGW-2**	Kumbharzari 2	0.8	Very Good
3	**PGW-3**	Savargao Mhske	0.8	Very Good
4	**PGW-4**	Brahmapuri	0.9	Excellent
5	**PGW-5**	Khamkheda	0.8	Very Good
6	**PGW-6**	Nalvihira	0.6	Average/Bad
7	**PGW-7**	Jafrabad 1	0.6	Average/Bad
8	**PGW-8**	Jafrabad 2	0.7	Good

9	**PGW-9**	Jafrabad 3	0.8	Very Good
10	**PGW-10**	Jafrabad 4	0.7	Good
11	**PGW-11**	Jafrabad 5	0.8	Very Good
12	**PGW-12**	Davargao Devi	0.9	Excellent
13	**PGW-13**	Tembruni	0.8	Very Good
14	**PGW-14**	Garkheda	0.6	Average/Bad
15	**PGW-15**	Aland	0.8	Very Good
16	**PGW-16**	Savarkheda Gondhan	0.8	Very Good
17	**PGW-17**	Takali	0.8	Very Good
18	**PGW-18**	Borkhedi Chinch	0.9	Excellent
19	**PGW-19**	Dolkheda Kh.	0.8	Very Good
20	**PGW-20**	Khaparkheda	0.8	Very Good
21	**PGW-21**	Hanumant Kheda	0.8	Very Good
22	**PGW-22**	Pimpal khuta	0.9	Excellent
23	**PGW-23**	Deoulgao Ugale	0.8	Very Good
24	**PGW-24**	Sipora Ambhora	0.9	Excellent
25	**PGW-25**	Sawangi	0.7	Good
26	**PGW-26**	Merakhed	0.7	Good
27	**PGW-27**	Janefal	0.9	Excellent
28	**PGW-28**	Asai	0.9	Excellent

29	**PGW-29**	Konad	0.8	Very Good
30	**PGW-30**	Varud Budruk	0.6	Average/Bad

5. Conclusion

The suitability of ground water for drinking purpose is determined keeping in view the effects of various physicochemical parameters of water on the biological system of human being. The FWQI Index combines individual physico-chemical and biological variables, with the help of expert knowledge and rules of inference, to provide information about the real status of river water quality. Additionally, this index can be implemented to monitor water bodies.

The fuzzy logic is used for the deciding the water quality index on the basis of which, water quality rankings are given to determine the quality of water. The Water Quality Index presented here is a unit less number ranging from 1 to 10. A higher number is indicative of better water quality. It is also observed that all the parameters fall within the permissible limits laid by WHO, ISI, and ICMR, except Total Hardness, Calcium and Magnesium. The quality parameters were compared with standards laid by the World Health Organization (WHO), Indian Standards Institute (ISI) and Indian Council of Medical Research (ICMR) for drinking water quality. Result shows 7 sample, 4 sample are excellent and average/bad respectively.

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