# GROUNDWATER QUALITY INDEX OF NAVSARI TALUKA USING ANFIS AND STATISTICAL ANALYSIS

**[1]Paresh H. Saratanpara, [2]Dr. S. S. Singh**
[1]P.G.Student, [2]Associate Professor
Water resources engineering,
Dr. S. & S. S. Gandhy GEC Surat, Gujarat, India.

***Abstract: - Groundwater is used for drinking as well as irrigation purposes. Nowadays, due to human and industrial activities the groundwater quality has been deteriorated. For proper natural groundwater eco system, groundwater quality should be maintained is necessary. In this study, groundwater quality of Navsari district is predicted by Groundwater Quality Index. In Navsari; groundwater sources are open well and dug well which are used for drinking purpose. Total dissolved solid, nitrate, hardness, chloride, magnesium, electrical conductivity, sulphate are various important indicators of groundwater quality. The main aim of this study is prediction of groundwater quality by water quality index for pre-monsoon and post monsoon of navsari taluka using an adaptive neuro-fuzzy inference system (ANFIS) in MATLAB R2017b and statistical analysis. For water quality index, 31 groundwater well samples are collected of last 3 year of 2014 to 2016. For WQI various input parameters like chloride, sulphate, calcium, magnesium, hardness, alkalinity, pH, TDS are used. For the best model 80-20 of RMSE is 1.7702 comes as per statistical analysis.***

***Keyword :- Groundwater, Groundwater quality index, MATLAB R2017b, Statistical analysis***

## 1 INTRODUCTION

Groundwater can simply define as water that occurs below the surface of the earth. Water is stored in permeable and impermeable rock. There are two types of aquifer (1) confined aquifer and (2) unconfined aquifer.
An aquifer is sandwiched between two impermeable layers it's called confined aquifer. An aquifer where water table is the upper surface limit and extends below till the impermeable rock strata is called unconfined aquifer.

**Groundwater quality**: -Groundwater contains mineral ions which slowly dissolve from soil particles, sediments, and rocks as water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. It's contain physical, chemical and biological qualities of groundwater. Hence groundwater quality index is becomes necessary for its quality. For this various parameters are taken for its present quality of groundwater. Parameters like calcium, ph, TDS, chloride, Magnesium, total hardness, Alkalinity, are consider for modelling of pre monsoon and post monsoon of groundwater quality index by using adaptive neuro fuzzy inference system and statistical analysis.
MrutyunjayaSahu (2011) studied on prediction of water quality index using anfis. In this study he carried out WQI using anfis for wells, which are between 9 and 47. Most of wells water is permissible for human consumption.
Mangukiya et al. (2012) is calculate WQI using 13 parameters of groundwater quality. The calculation of Water Quality Index (WQI) was done by using the Weighted Arithmetic Index method. The statistical analysis in terms of mean, standard deviation (SD), correlation and regression of obtained data were carried out using Microsoft Office Excel 2007
Mrs.P.Lilly et al.(2012) is collect the 15 sample from different groundwater wells Gangavalli Taluk in Salem District during the Pre-Monsoon (PM1) period (June –July 2010) and Post-Monsoon (PM2) period (December 2010 - January 2011) were analyzed for their physio-chemical characteristics. The multivariate statistical tools such as Correlation Coefficient Analysis (CCA), Factor Analysis (of water quality data and its spatial variations.
Aslan, M(2007) in his study he use ANN and ANFIS in matlab and compare the result of both tool of modelling. From this study ANN modelling effect on DO is successfully described and result shows that ANFIS give better result compare to ANN.
From so many studies conclude that ANFIS is a capable to carry out water quality index for groundwater.

## 2 OBJECTIVE

- To identify various water quality parameters in groundwater of navsari region for drinking purpose.
- Evaluation of ground water quality index of navsari region using statistical analysis.
- To develop an appropriate model for WQI
- Prediction of GWQI for future year using ANFIS tool in MATLAB R2017b software.

## 3 STUDY AREA AND DATA COLLECTION

Navsari district:-
Navsari is located at 20.95°N 72.93°E. and located in southern Gujarat. The district covers an area of 2,211 square kilometers, and had a population of 13,30,711 in 2011. Various panchayat and wells sample if shown in the following table 1.

Table 1 name of punchayat and sample ID

| Panchayat | Sample id | Panchayat | Sample id | Panchayat | Sample id |
|---|---|---|---|---|---|
| Adada | PU003150253 | Kabilpore | PU003129649 | Mahudi | PU002837837 |

| | | | | | |
|---|---|---|---|---|---|
| Amadpor | PU002791072 | Kachhol | PU002795577 | Nagdhara | PU002817082 |
| Astagam | PU002811021 | Kachhol | PU003450669 | Padgha | PU002768765 |
| Boriach | PU002813181 | Kaliyawadi | PU003150581 | Pardi | PU002814217 |
| Boriach | PU003150386 | Kanbad | PU003150144 | Pinsad | PU002768871 |
| Boriach | PU002813279 | Kadipor | PU003150576 | Satem | PU003169412 |
| Chandravasan | PU002840784 | Khadsupa | PU002795617 | Telada | PU003149781 |
| Dharagiri | PU002791450 | Khergam | PU002774823 | Tighra | PU002795456 |
| Dharagiri | PU002795155 | Khumbharfaliyu | PU002840718 | Ugat | PU002840819 |
| Italva | PU002791524 | Kurel | PU003150118 | Jamalpore | PU002791502 |
| Italva | PU002795546 | Mahudi | PU002814493 | | |

## 4 LOCATION OF STUDY AREA

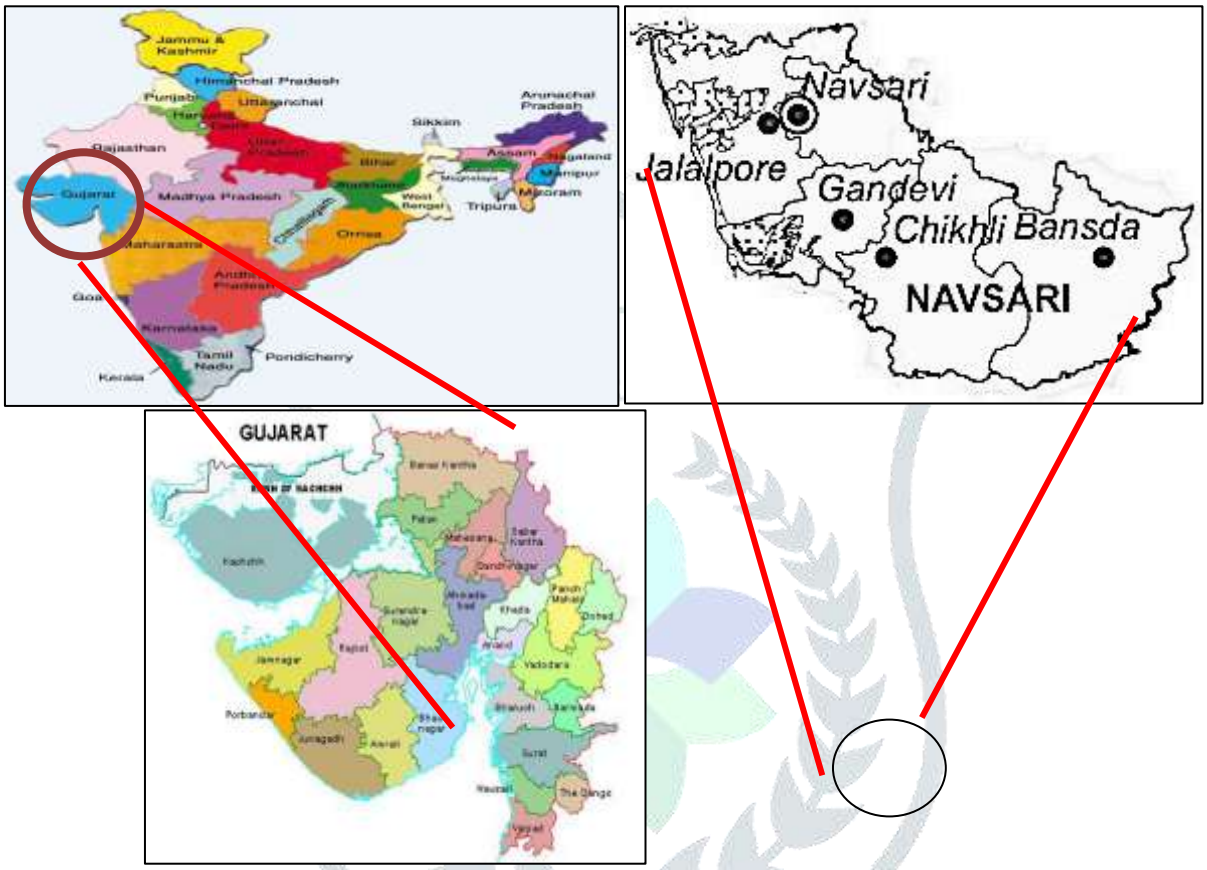


**Figure 1. Location of navsari**

Data of ground water quality parameters of pre monsoon season & post monsoon season for 3 years (2015 to 2017) were obtained from NRDWP report.

Water Parameters such as pH, total hardness TH(mg/L), fluoride FLU (mg/L), total dissolved solids TDS (mg/L),calcium CL(mg/l), chloride CHL (mg/l),Nitrate-N (mg/L), magnesium MG (mg/L), ALK (mg/L), were analyzed.

## 4 WATER QUALITY MODELLING

### 4.1 water quality index

In the first step, each of the all parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. See the table 2

Table 2 relative weight of parameter

| Water Quality Factor | Weightage | Relative weight |
|---|---|---|
| pH (mg/L) | 4 | 0.2105 |
| Total dissolved solids - TDS (mg/L) | 4 | 0.2105 |
| Total alkalinity - TA as CaCO3 (mg/L | 2 | 0.1053 |
| Sulphate | 3 | 0.1578 |
| Magnesium - MAG (mg/L) | 2 | 0.1053 |
| Chloride - CHL (mg/L) | 2 | 0.1053 |
| Calcium - CAL (mg/L) | 2 | 0.1053 |

$Wi = w_i / \sum w_i = 1$ i=1,2,…
Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters.
Quality rating index $q_n = \mathbf{100} * \left(\frac{Vi}{Si}\right)$
Where $V_i = V_n - V_{io}$ and $S_i = S_n - S_{io}$
$V_n$= estimated value of the $n^{th}$ parameter at a given sampling station.
$S_n$ = standard permissible value of the $n^{th}$ parameter.
$V_{io}$= ideal value of the $n^{th}$ parameter in pure water.

**4.2 Anfis (Adaptive Neuro Fuzzy Inference System)**
In past years, Takagi and Sugeno first used ANFIS model symmetrically at 1985 and they found numerous applications in the field of prediction and inference (Sugeno 1985; Predrycz 1989). In this five important function are (i) Rule base, (ii) Data base, (iii) Decision making unit, (iv)Fuzzification interface and (v) Defuzzification interface.

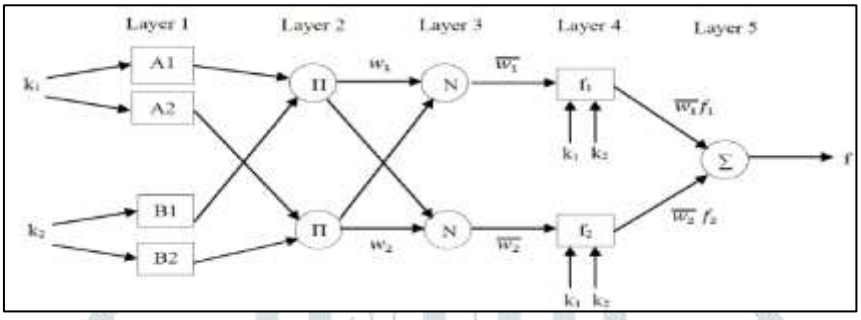

Figure 2 ANFIS Structure

**Layer1**: Every node in this layer adapts to a function parameter. The output from each node is a degree of membership value that is given by the input of the membership functions.
$O_{1,I} = \mu_{ai\,(Xi)}$ i = 1,2
$O_{1,i} = \mu_{B1\text{-}2(X2)}$ I = 3, 4
Where,
x1 and x2 are the inputs to node i (i = 1, 2 for x1 and i = 3, 4 for x2) and
x1 (or x2) is the input to the ith node and Ai (or Bi-2) is a fuzzy label.

**Layer 2**:All nodes are fixed in this layer.Each node in this layer represents the firing strength for each rule.In the second layer, the T-norm operator with general performance, such as the AND, is applied to obtain the output.

$O_{2,i} = Wi = \mu A_i(x) * \mu B_i(y)$, i=1,2

**Layer 3:**All node in layer is fixed or nonadaptive and the circle node is labeled as N. Each node is a calculation of the ratio between the i-th rules firing strength and the sum of all rules firing strengths.

$O_{3,i} = w_i = \frac{Wi}{W1+W2}$, i =1,2

**Layer 4:** Every node in this layer is an adaptive node to an output, with a node function defined as

$O_{4,1} = W_i f_i = W_i(p_x + q_i + r_i)$

where _wi is the normalized firing strength from the previous layer (third layer) and $(_{Px+Qx+Ri})$ is a parameter in the node.

**Layer 5**:The single node in this layer is a fixed or nonadaptive node that computes the overall output as the summation of all incoming signals from the previous node. In this layer, a circle node is labeled as Σ
$O_{5,1} = \sum_i^n wifi = \frac{\sum_i^n wifi}{\sum_i^n wi}$
The structure identification phase involves finding a suitable number of fuzzy rules and fuzzy sets and a proper partition feature space.

Follow the steps in ANFIS R2017b to calculate the water quality index.
- Start the neurofuzzy designer.
- Create the training(input) workspace.
- Create the testing (output) workspace.
- To start the anfis editor GUI, type the following command at the MATLAB prompt: anfisedit
- Load training (input) data from workspace.
- Load testing (output) data from workspace.
- Select the sub clustering and generate fuzzy inference system (fis)
- Set the number of training epochs to 100, under the Epochs listing on the GUI (the default value is 3).
- Select train now
- Select test now.

- Now click on view and select surface rules.Now the paste only input parameters weighted value and press enter, output gives the water quality index.

**4.3 Statistical Analysis for Model**

Root Mean Squared Error (RMSE):- Root Mean Squared Error or Root Mean Squared Deviation was a measure of the differences between values predicted by model or an estimator and the actually observed values.

$$RMSErrors = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}}$$

**5 RESULT**

- **For model 80-20 pre monsoon and post monsoon graph of training and testing:**


Fig.3 Correlation between Predicted WQI vs. Actual WQI for pre monsoon of ANFIS Model-80-20 during Training

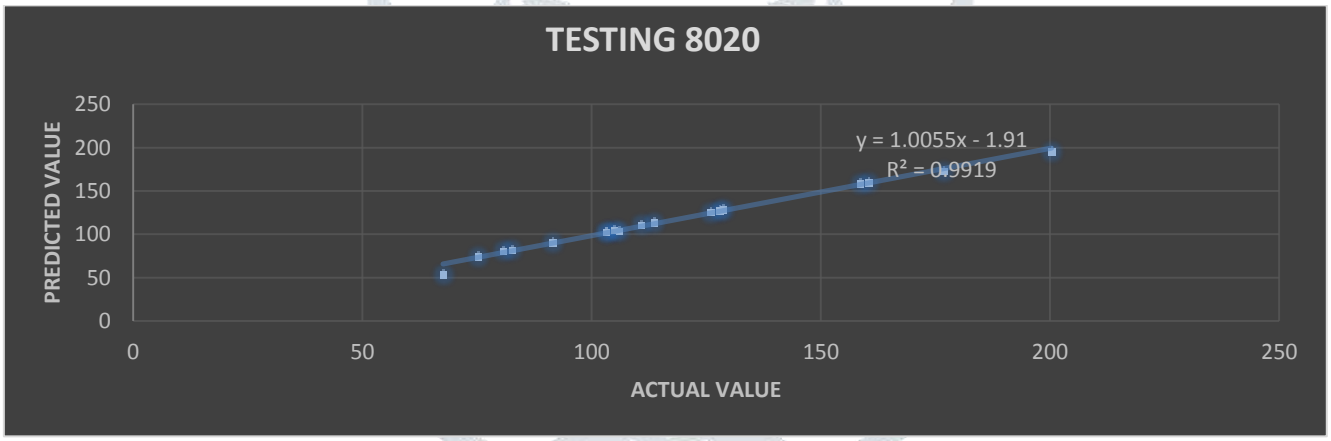


Fig.4 Correlation between Predicted WQI vs. Actual WQI for pre monsoon of ANFIS Model-80-20 during Testing


Fig. 5 Correlation between Predicted WQI vs. Actual WQI for post monsoon of ANFIS Model-80-20 during Training

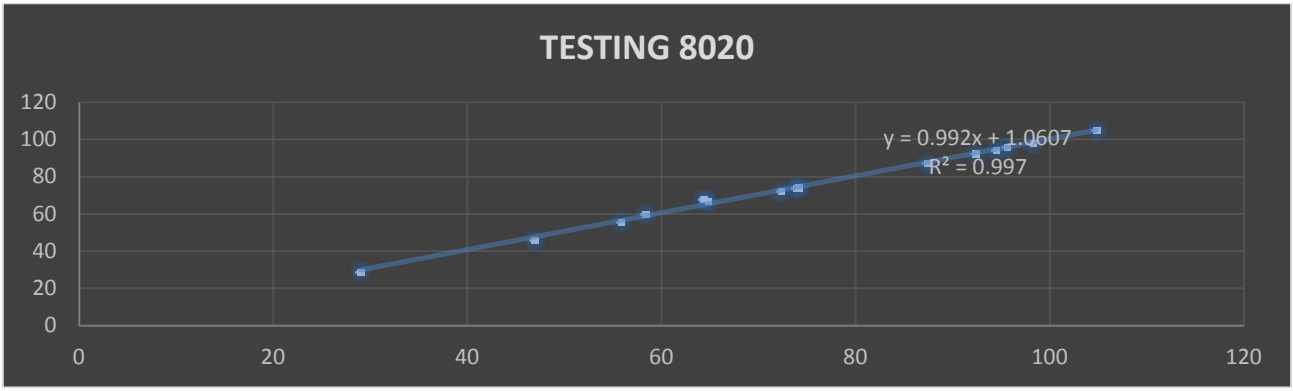


Fig.6 Correlation between Predicted WQI vs. Actual WQI for post monsoon of ANFIS Model-80-20 during Testing

- **For model 70-30 pre monsoon and post monsoon graph of training and testing**
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Fig.7 Correlation between Predicted WQI vs. Actual WQI for pre monsoon of ANFIS Model-70-30 during Training

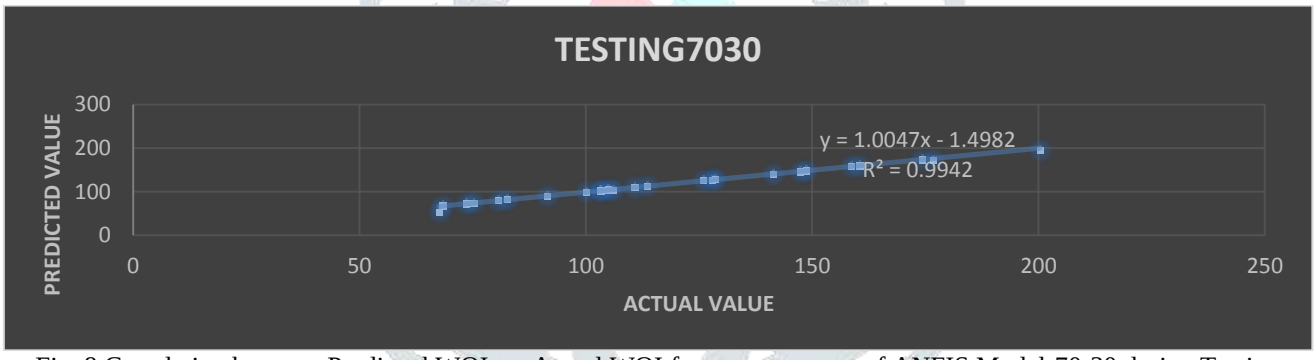


Fig. 8 Correlation between Predicted WQI vs. Actual WQI for post monsoon of ANFIS Model-70-30 during Testing

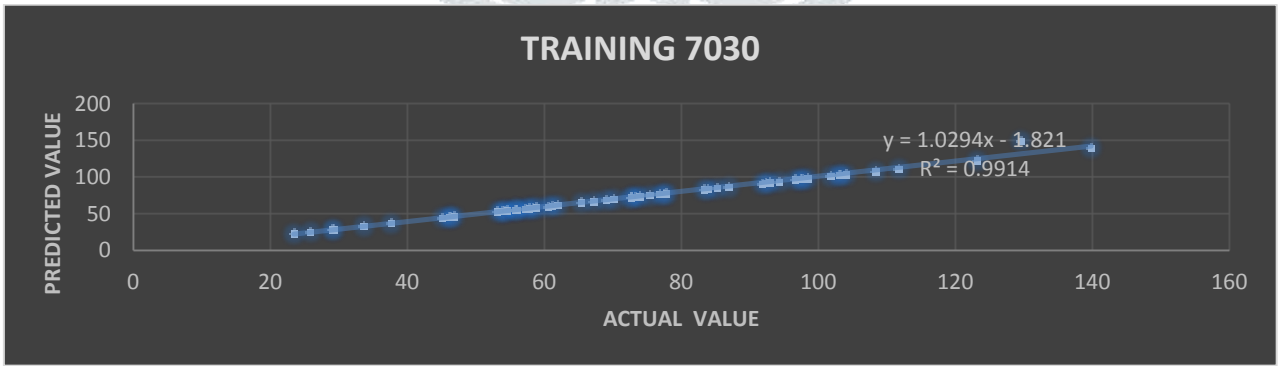


Fig.9 Correlation between Predicted WQI vs. Actual WQI for post monsoon of ANFIS Model-70-30 during Training

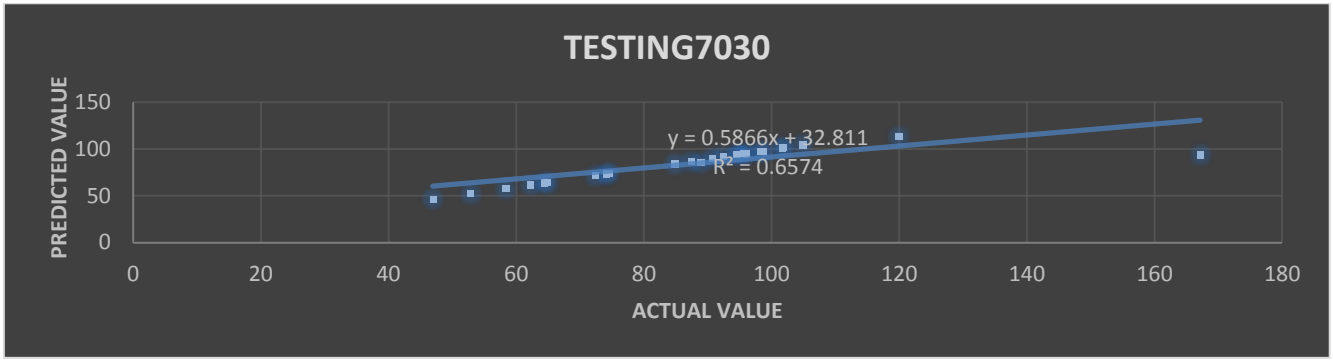


Fig.10 Correlation between Predicted WQI vs. Actual WQI for post monsoon of ANFIS Model-70-30 during Testing

## 6 CONCLUSION

| Model | Pre monsoon | | Post monsoon | |
|---|---|---|---|---|
| | Training | Testing | Training | Testing |
| Model 70-30 | 0.9992 | 0.9942 | 0.9914 | 0.6574 |
| Model 80-20 | 0.9904 | 0.9919 | 0.8904 | 0.9904 |

| Model | RMSE |
|---|---|
| Model 80-20 | 1.7702 |
| Model 70-30 | 2.1227 |

As per the above tables and graph shows that the best model is 80-20 is fit for water quality index using anfis in matlab R2017b.

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