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"WATER QUALITY MODELING OF PURNA RIVER USING ANFIS"

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Abstract* — River Purna being polluted from the effluents discharged from the nearby industries, towns and villages located near the banks. The presence of pollutant makes water most unsuitable for human use. The fertilizers used for agricultural purpose affect the pH and nitrate content of water. Assessment of Water Quality Index (WQI) of water is extremely important at the gauging stations located near the industries to prepare remedial measures. To the end, the present study proposes an efficient methodology such as adaptive Neuro fuzzy inference system (ANFIS) for the prediction of water quality in Purna River. The model performed quite satisfactory with actual and predicted data on water quality. It can be concluded that if the present conditions can be considered to remain the future years could have most likely similar trend as from the trend observed during 2011 to 2016.

Keywords- W.Q.I, ANFIS, Purna River, Water quality

I. INTRODUCTION

Water is very important for human beings and to the health of their system. Thus, quality of water is most important factor. Water Quality is very sensitive issue and is a great environmental concern in world. Surface water pollution by chemical, physical, microbial and biological contaminants can cause major problems, all over the world. Fish survival / growth and other biodiversity, conservation activities, recreational activities like swimming and boating, industrial and municipal water supply, agricultural use such as irrigation and livestock watering, waste disposal and all other water uses are affected by the physical, chemical, microbial and biological conditions are exist in the water courses and in subsurface aquifers too. The surface water systems are naturally open to the atmosphere, such as lakes, rivers, estuaries, reservoirs and coastal waters. A natural process such as changes in erosion, precipitation, weathering of crustal material as well as any anthropogenic influences such as urban, industrial and agricultural activities, increasing rate of consumption of water resources, degrade in the quality and quantity of surface water and make it unsuitable for domestic uses. Industrial wastewater, runoff over the agricultural lands and municipal sewage disposal are the most vulnerable for water pollution. Since man strode the earth Water resources have been the most exploited natural system, as a result of increasing, civilization, urbanization, industrialization and other developmental activities, our natural water system is being polluted by different sources. Pollutants coming as a waste to the water bodies are likely to create nuisance by way of physical appearance, odor, taste, quality and render the water harmful for utility. This has resulted in the decrease in the quality of drinking water available.

Water quality modeling is one of the important elements in water resource management. The development of water quality models depend on the various objectives & purposes, and based on a number of different modeling techniques. The uses for which river models have been developed include, environmental impact assessment (climate, river use or land use change (long-term) and combined sewer overflows or accidental spills (short-term); flood forecasting; planning and consent setting; and operational (on-line) management.

There are mainly three models namely Adaptive Neuro Fuzzy Inference System (ANFIS), Artificial Neural Network (ANN) and Monte Carlo Simulations (MCS) are used to describe the input and output relationships of the water quality data. In these studies, for each step, some important points related to model reliability are answered by discussing and applying the method and tools to analyze the behavior of the model and to prepare actions that are to be taken to reduce error in outputs. New techniques such as fuzzy logic (FL) and adaptive neuro fuzzy inference system (ANFIS) have been recently used as efficient alternative tools for modeling of complex water resources systems and widely used for forecasting. FL is a rule based system consisting of three conceptual components, including (1) a rule-base, containing a selection of fuzzy if-then rules; (2) a data-base, defining the membership functions used in the fuzzy rules; (3) an inference system, performing the inference procedure upon the rules to derive an output. FL models focus on the use of heuristics in the system description.

II. STUDY AREA AND DATA COLLECTION

Purna river originates from Saputara hills and meets in Arabian sea. Its length is 180 km. and having a catchment area of 2431 sq.km. Zankhri is main tributary of Purna river. Purna River is an important west flowing river with its catchment lying in Ahwaa, Valsad and Navsari districts of Gujarat and in Nasik district of Maharashtra. The Purna basin can be divided into three prominent physiographic regions, i.e. i) eastern parts, (ii) the middle reaches and (iii) the coastal zones. The eastern parts of the basin cover a chain of rugged mountain ranges of the Western Ghats running at an elevation of above 1300 m and descending to an elevation of about 100 m at the edges of uplands of the Surat district. The middle reaches of the basin area are marked by high relief zone with ridges and valleys. The hilly zone then merges into the plains through an undulating piedmont coastal zone running parallel to the sea.

TABLE 1.Catchment Area Detail

Name of State	Catchment area (sq km)	% Total area
Maharashtra	58	2.39
Gujarat	2373	97.61
Total	2431	100

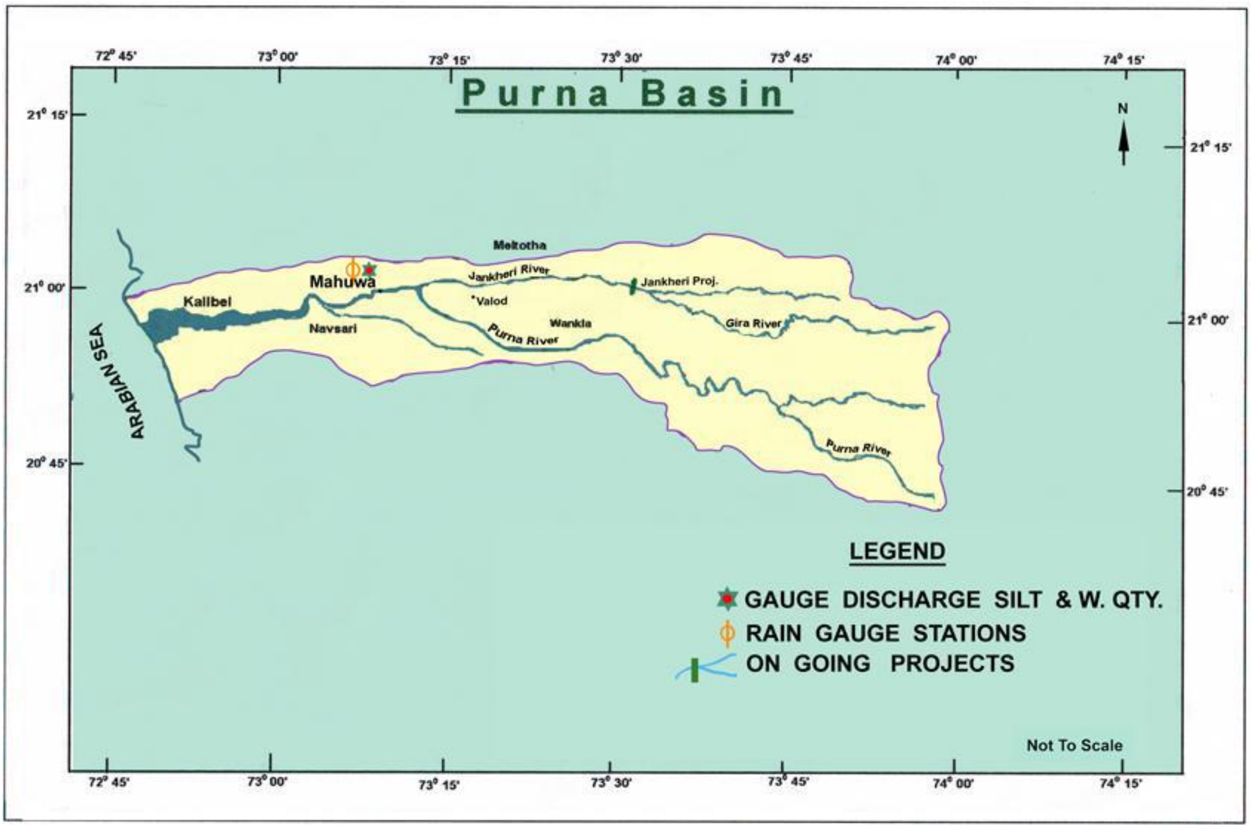

Figure 1. Purna River Basin

The river Purna rises in the Saputara hills of the Western Ghats near the village Chinchi in Maharashtra. The length of the river from its source to outflow in the Arabian Sea is about 180 km. The important tributaries of the Purna River are Dhodar nala, Bardanala, Nagihpar nala, Girna River, Zankari River and Dumas khadi. The catchment area of the Purna basin is 2431 Sq. km. The basin lies between 72° 45’ to 74° 00’ East longitude and 20° 41’ to 21° 05’ North latitude. There is only one H.O station of CWC near the mouth of the river at Mahuwa in Surat district of Gujarat state. State wise distribution of drainage area is shown in Table:1

Field data were collected from GPCB (Gujarat pollution control board) for years 2011-2016.

III. METHODOLOGY

3.1 Water Quality Index

Water quality index is one of the most effective tools to monitor the surface as well as ground water pollution and can be used efficiently in the implementation of water quality upgrading programs. It is one of the aggregate indices that have been accepted as a rating that reflects the composite influence on the overall quality of numbers of precise water quality characteristics.

For computing WQI three steps are followed. 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 (Table-2). The maximum weight of 12 has been assigned to the parameter pH due to its major importance in water quality assessment. COD and Total, which is given the minimum weight of two by itself, may not be harmful. In the second step, the relative weight (Wi) is computed from the following equation: 1

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad (1)$$

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters. Calculated relative weight (Wi) values of each parameter are also given in Table-2.

TABLE 2. Relative Weight (Wi) Values Of Each Parameters

Parameters	Indian Standards (Sn)	Weight (wi)	Relative weight (Wi)
pH	8.5	8	0.16
DO	5	12	0.24
BOD	5	4	0.08
CONDUCTIVITY	300	3	0.06
NITRATE	45	2	0.04
TC	5000	7	0.14
FC	5000	7	0.14
COD	15	2	0.04
ALKALINITY	120	3	0.06
T.H.	300	2	0.04

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result multiplied by 100.

$$qi = \left(\frac{Ci}{Si}\right) * 100 \quad (2)$$

Where, qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, Si is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS.

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation.

$$SI = Wi * qi \quad (3)$$

$$WQI = \sum_{i=1}^{n} SIi \quad (4)$$

Where, SIi is the sub index of i_{th} parameter, qi is the rating based on concentration of i_{th} parameter, n is the number of parameters. The computed WQI values are classified into five types, “excellent water” to “water, unsuitable for drinking”.

TABLE 3. Water Quality Classification Based On WQI Value

WQI Value	Water Quality
<25	Excellent Water
25-50	Good Water
50-75	Average Water
75-100	Poor Water
>100	Unstable for Drinking

3.2 Adaptive Neuro Fuzzy Inference System (ANFIS)

Adaptive neuro-fuzzy inference system (ANFIS) is result of combination between artificial neural networks (ANN) and fuzzy inference system (FIS) in MATLAB. A neural network and fuzzy logic are related and complementary technology to each other. The data and feedback can be learned by neural network, however understanding the knowledge or trend of data can be difficult. However, fuzzy logic models and toolboxes are easy to execute because of the linguistic terms like IF-THEN rules. An Adaptive Neuro-Fuzzy Inference System consists of five important functional building parts of the fuzzy logic toolbox, those are (i) rule base, (ii) data base, (iii) decision making unit, (iv)fuzzification interface and (v) defuzzification interface. Figure 2 shows typical architecture of ANFIS.

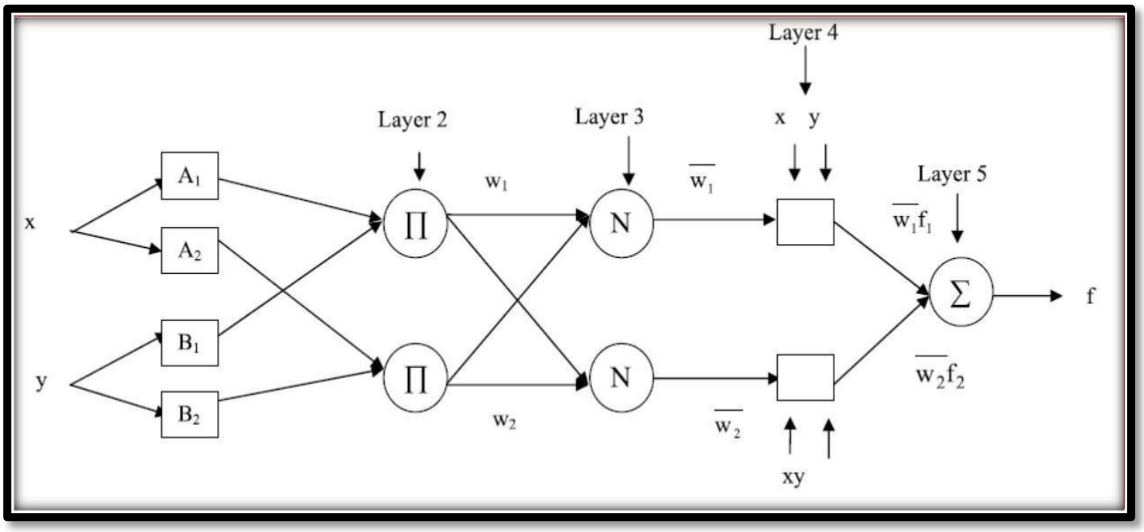

Figure 2: ANFIS Architecture

3.2.1 Development of WQI Prediction Model in ANFIS

In ANFIS, the datasets divided into training and validation data, and loaded in ANFIS editor as training and testing data keeping 10 water Quality parameters (pH ,DO ,BOD, CONDUCTIVITY, NITRATE, TC, FC, COD, ALKALINITY, T.H.) as input and Water Quality Index as output of model. The ANFIS editor GUI, MATLAB is shown in figure 3 with loaded data.

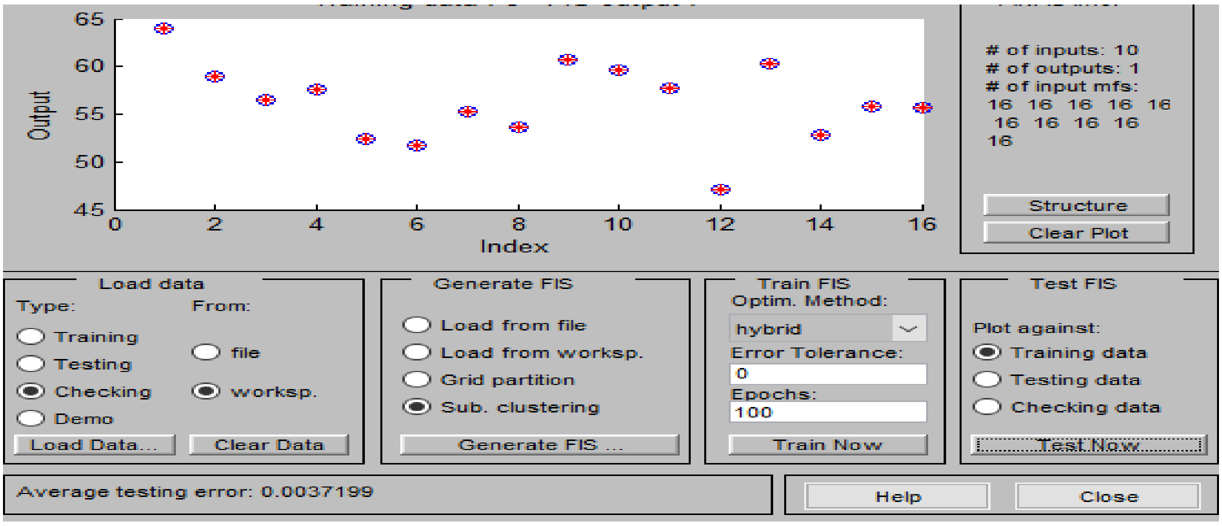

Figure 3: ANFIS Editor GUI

The FIS generated for Subtractive Clustering function, which produces accurate outputs values by using a large number of membership function. The FIS is then train for 100-epoch and 0-error tolerance in order to generate output as Water Quality Index Value.

IV. RESULTS AND ANALYSIS

4.1 Water Quality Index

After Analysis and Calculation of WQI, the following result is conducted for Vankla Station and S.H (Navsari) Station of Purna River.

TABLE 4: Water Quality Classification based on WQI Value – Station Vankla

WQI Value	Water Quality	Percentage of Water Samples		
		Pre Monsoon	Post Monsoon	Overall
<25	Excellent Water	0%	0%	0%
25-50	Good Water	8%	4%	6%
50-75	Average Water	88%	90%	89%
75-100	Poor Water	4%	6%	5%
>100	Unsuitable for Drinking	0%	0%	0%

As shown in Table 4, the WQI for Purna River water samples at Vankla station ranges from 29.05 to 92 only 6 percent of the samples range between 25-50, good limit for drinking water. About 89 percent of water samples are average in quality and 5 percent of water samples are of poor quality and should not use directly for drinking purpose. As per the classification based on water quality index, no sample is in range of excellent quality of river water.

Table 5 Water Quality Classification based on WQI Value – S.H NAVSARI

WQI Value	Water Quality	Percentage of Water Samples		
		Pre Monsoon	Post Monsoon	Overall
<25	Excellent Water	0%	0%	0%
25-50	Good Water	0%	0%	0%
50-75	Average Water	45%	42%	43%
75-100	Poor Water	35%	33%	34%
>100	Unstable for Drinking	20%	25%	22.5%

As shown in Table 5, the WQI for water samples of purna river ranges from 56 to 112, almost 22.5 percent of the samples exceeded 100, the upper limit for drinking water quality and should not use directly for drinking purpose. About 43 percent of water samples are average in quality and 34 percent of water samples are of poor. As per the classification based on water quality index 43 percent water samples shows average quality of water.

4.2 Adaptive Neuro Fuzzy Inference System (ANFIS)

Two models are developed to predict water Quality of Purna River at two different stations using ANFIS.

1. **ANFIS Model-1: 70%-30%**
2. **ANFIS Model-2: 80%-20%**

After developing the best Water quality index prediction Model using ANFIS for each station with the training & validation datasets with two combination, comparison is carried out to conclude the best ANFIS model for both Vankla and S.H navsari among all models.

TABLE 6: Best ANFIS Model Developed for post monsoon season

Station	Phase	ANFIS Model-1 (70%-30%)		ANFIS Model-2 (80%-20%)	
		RMSE	r	RMSE	r
Vankla	Training	0.341	0.991	0.970	0.940
	Validation	0.886	0.908	1.713	0.829
Navsari (S.H)	Training	0.196	0.999	0.525	0.954
	Validation	0.861	0.976	1.434	0.904

From the above Table-6
It is clear that the **ANFIS Model-1(Vankla)** having RMSE and R-value of 0.341 and 0.991 respectively during training and RMSE and R-value of 0.886 and 0.908 during Validation. Hence, **ANFIS Model-1** is the better model for Vankla station for Water Quality Index Prediction. While ANFIS models having RMSE and r value of 0.196 and 0.999 respectively during training and RMSE and r value of 0.861 and 0.976 during Validation, Hence **ANFIS Model-1** provides best result for Station **S.H (navsari)** for water Quality Index Prediction.

So we conclude that MODEL-1 is Better model comparing to MODEL-2 and The value of Coefficient of correlation (R) is very close to 1 for MODEL -1 for training values but compare to checking values for this station training values give more accurate result And from the values it can be concluded that observed WQI is very near to predicted WQI.

Graphs given below shows correlation between Predicted WQI vs. Observed WQI of ANFIS Model-1 during training and validation for Vankla station and ANFIS Model-2 during training and validation for Navsari station. It has observed that during training and validation, Predicted WQI and Observed WQI values are highly correlated at Vankla station and Navsari station.

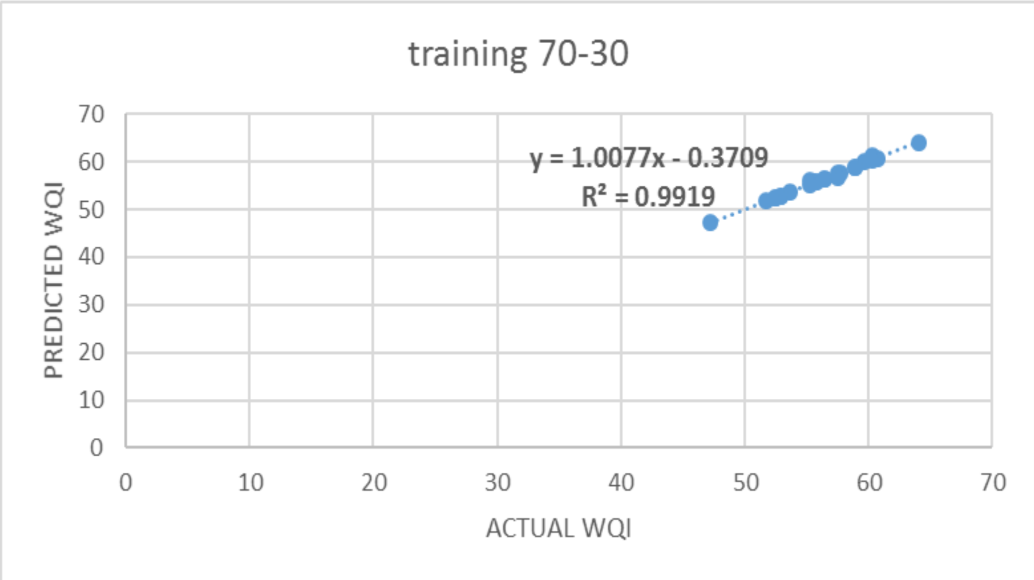

Figure 3. Correlation between Predicted WQI vs. Actual WQI of ANFIS for VANKLA

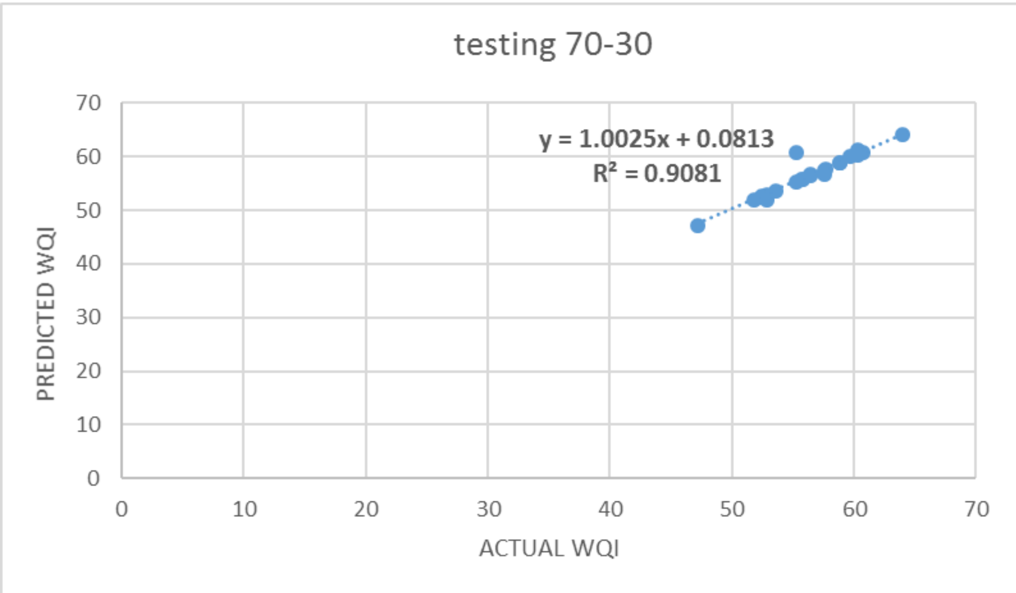

Figure 4. Correlation between Predicted WQI vs. Actual WQI of ANFIS for VANKLA

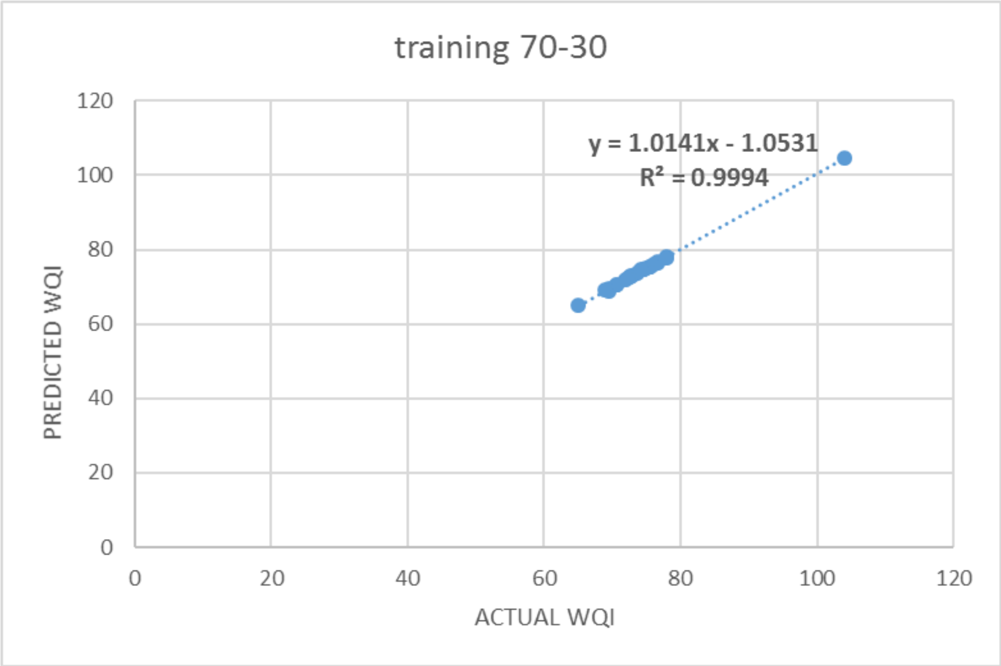

Figure 5. Correlation between Predicted WQI vs. Actual WQI of ANFIS for Navsari

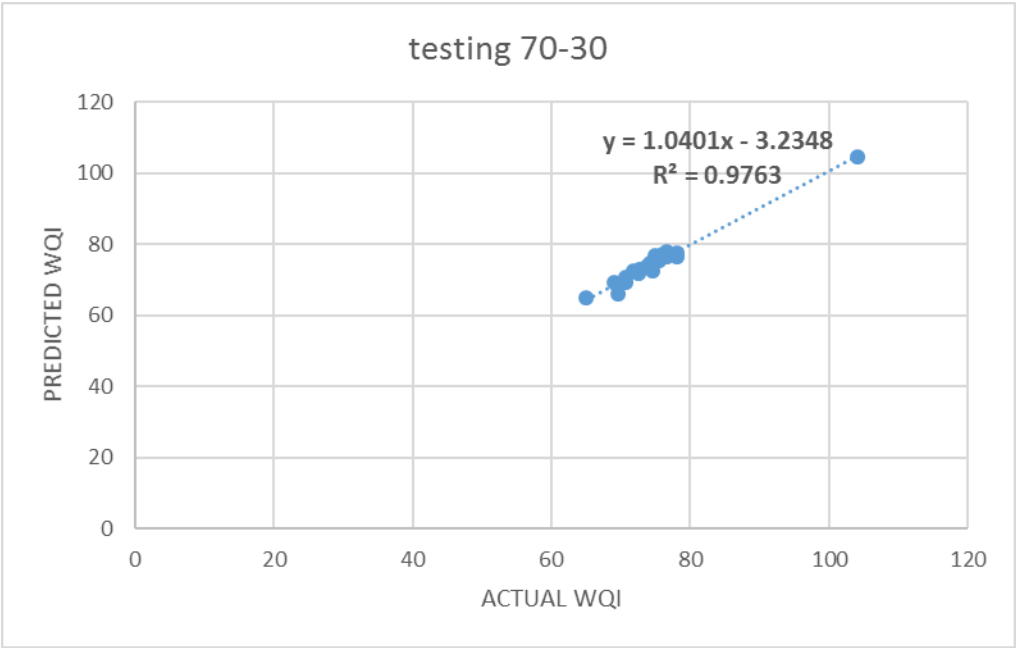

Figure 6. Correlation between Predicted WQI vs. Actual WQI of ANFIS for Navsari

V. CONCLUSIONS

- From the result one can conclude that most of water quality in pre-monsoon season lies between good to average water, while in post-monsoon season most of water quality lies between average to poor water and sometimes not suitable for drinking.

- Water quality index values slightly improves in the pre-monsoon season comparatively to the post-monsoon season.

- It is clear that the ANFIS Model-1(Vankla) having RMSE and R-value of 0.341 and 0.991 respectively during training and RMSE and R-value of 0.886 and 0.908 during Validation. Hence, ANFIS Model-1 is the best model for Vankla station for Water Quality Index Prediction. While ANFIS models having RMSE and r value of 0.196 and 0.999 respectively during training and RMSE and r value of 0.861 and 0.976 during Validation, Hence ANFIS Model-1 provides best result for Station S.H (navsari) for water Quality Index Prediction.

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