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"WATER QUALITY MODELING OF RIVER WATER BY USING ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM"

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Abstract: *COD and DO is a parameter frequently used to evaluate the water quality of different rivers. The aim of the present study is to investigate applicability of artificial intelligence techniques such as ANFIS (Adaptive Neuro-Fuzzy Inference System) in water quality COD and DO prediction for the case study, TAPI river basin of MAHARASHTRA, India. The proposed technique combines the learning ability of neural network with the transparent linguistic representation of fuzzy system. ANFIS models with various input structures and membership functions are constructed, trained and tested to evaluate efficiency of the models. For DO and COD we use past data of 5 years and various parameters uses are Ph, Temperature, Electrical Conductivity, Suspended solids Statistical indices such as Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of Determination (R2) and Discrepancy Ratio (D) are used to evaluate performance of the ANFIS models in predicting COD and DO. ANFIS model is used for the estimation of COD and DO concentration.*

Key words: *Water quality, Adaptive neuro-fuzzy inference system, Chemical oxygen demand, Dissolved oxygen, Tapi River*

I. INTRODUCTION

Water resources have been the most exploited natural system, since man strode the earth. As a result of increasing, civilization, urbanization, industrialization and other developmental activities, our natural water system is being polluted by different sources. The pollutants coming as a waste to the water bodies are likely to create nuisance by way of physical appearance, odour, taste, quality and render the water harmful for utility. This has resulted in the decrease in the quality of drinking water available.Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource; for example, high salinity is a frequent problem in arid and coastal areas.

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.

Water quality modeling is the development of abstractions of phenomena of river systems. The main objective of river water quality modeling is to describe and to predict the observed effects of a change in the river system. The usual application of a water quality model is for forecasting changes in water quality parameters resulting from changes in the quality, discharge or location of the point or non-point input sources (Crabtree et al., 1986). Water quality models can be used to predict the characteristics of water quality conditions in aquatic systems in order to ensure the water quality objectives will be maintained under a wide variety of conditions. Models provide the ability to develop a credible and defensible water quality management program. They are continually being developed and improved to optimize the demands of environmental regulations and protection. There are a large number of available in the literature and the Internet, which can be used for water quality and waste load allocation predictions.

Generally there are two types of water quality models; stochastic and deterministic models. Deterministic models attempt to simulate the natural processes of self-purification in a river system with each process modeled mathematically using derived parameters and rate constants. A deterministic model will predict a unique result from a specified set of input conditions without any consideration of the true relationship between the inputs and the predicted results. Meanwhile, stochastic or probabilistic models attempt to randomize error.

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.

The models can be seen as logical models that use if-then rules to establish qualitative and quantitative relationships among variables. Their rule-based nature allows the use of information expressed in the form of natural language statements, making the model transparent for interpretation (Vernieuwe et al., 2005). However, the main problem with FL is that there is no systematic procedure to define the membership function parameters, which must be predetermined by expert knowledge about the modeled system. The construction of the fuzzy rule necessitates the definition of premises and consequences as fuzzy sets. At the same time, ANN has the ability to learn from input and output pairs and adapt to it in an interactive manner. In order to overcome the problems, the ANFIS method, which integrates ANN and FL was proposed by Jang (1993)

II. STUDY AREA AND DATA COLLECTION

Tapi river is one of the longest river of western India. The history of this river is closely associated with the Anglo Portuguese history. The upper reaches of the river are now deserted, owing to silting at the outflow of the river. Water of tapi river is mostly usefull for irrigation and storage purpose for dam. Tapti river is one of the major rivers in India and flows in the central part of India. The river originates from the Betul district of Madhya Pradesh in the Satpura range at an approximate height of about 752 meter above the sea level.

It rises in Betul district of Madhya Pradesh and flows between two spurs of the Satpura Hills, across the plateau of Khandesh, and thence through the plain of Surat to the sea. It has a total length of around 724 km. And drains an area of 30,000 sq. M. The Tapti River flows through the Indian states of Maharashtra, Gujrat and Madhya Pradesh. Apart from the Narmada River, Tapi is the only river, which flows in the westward direction and empties into the Arabian Sea. The Tapi basin extends to the total area of 65, 145 sq km that is approximately 2.0% of the total geographical area of India. The main tributaries of the Tapi River are Purna, ,The Panjhara ,The Vaghur,The Girna, The Bori and The aner

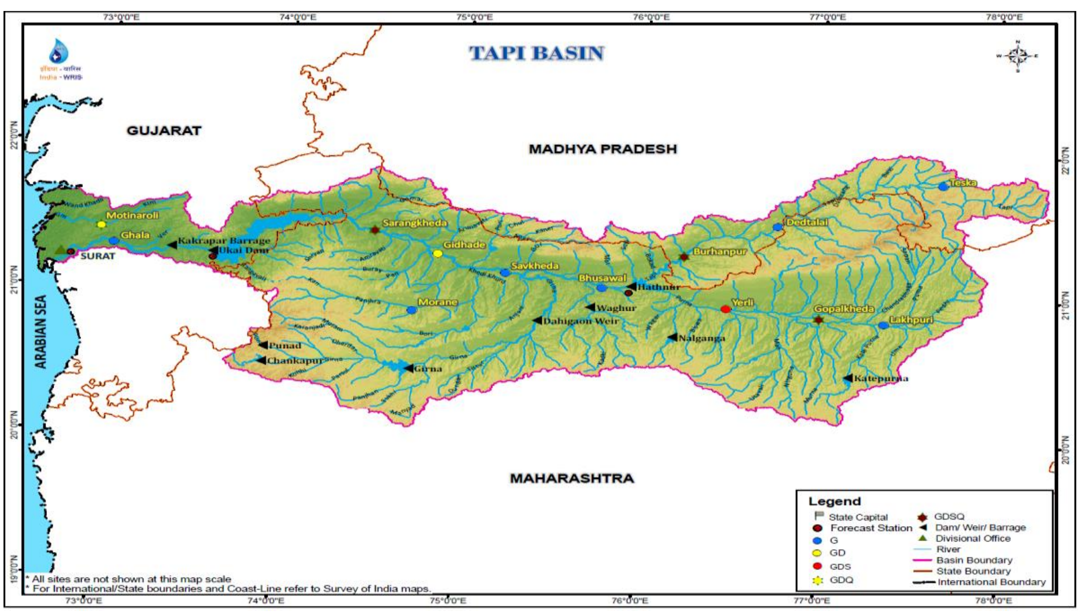

Figure1. Tapi river basin area

Figure2. Water Quality Stations In Maharashtra

Field data were collected from GPCB (Gujarat pollution control board) and MPCB (Maharashtra pollution control board) for years 2010-2015, three main stations of Maharashtra choose as part of study are Nandurbar , Bhusaval, Ajanad village

III. METHODOLOGY

Adaptive Network-Based-Fuzzy Inferences System (ANFIS) approach was employed in this study. The ANFIS architecture consists of 5 layers such as input layer, fuzzification layer, inferences process, defuzzification layer, and summation as final output layer. Typical architecture of ANFIS is shown by Figure 3

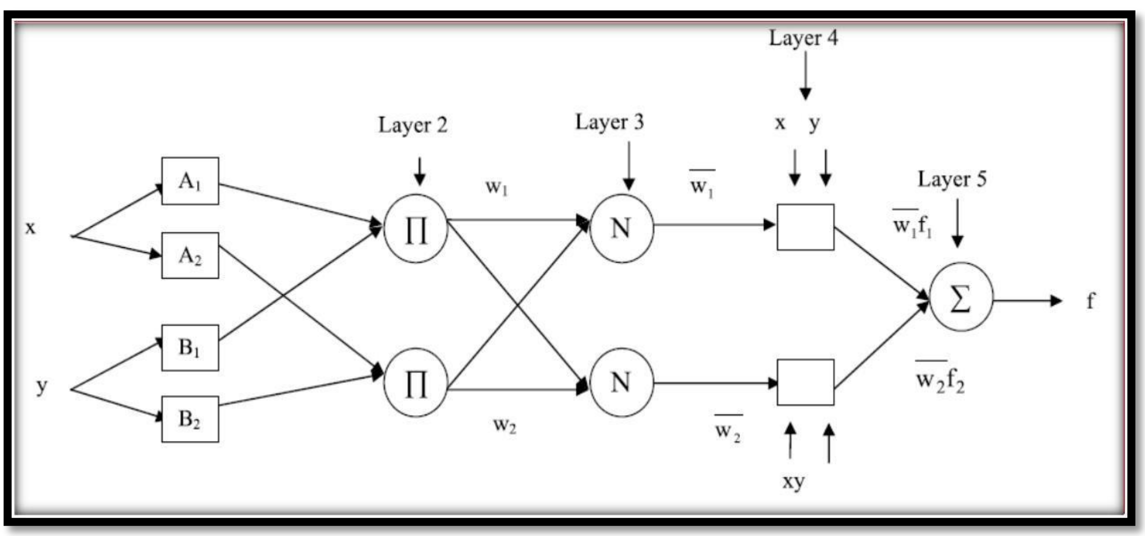

Figure3. ANFIS architecture

In above architecture the process flows from layer 1 to layer 5. It is started by giving a number of sets of crisp values as input to be fuzzyfied in layer 1, passing through inference process in layer 2 and 3 where rules applied, calculating output for each corresponding rules in layer 4 and then in layer 5 all outputs from layer 4 are summed up to get one final output.

The main objective of the ANFIS is to determine the optimum values of the equivalent fuzzy inference system parameters by applying a learning algorithm using input-output data sets. The parameter optimization is done in such a way during training session that the error between the target and the actual output is minimized. Parameters are optimized by hybrid algorithm which combination of least square estimate and gradient descent method. The parameters to be optimized in ANFIS are the premise parameters which describe the shape of the membership functions, and the consequent parameters which describe the overall output of the system. The optimum parameters obtained are then used in testing session to calculate the prediction.

The objectives for the study are,

a. Development of river stage-DO & COD concentration ANFIS model.
b. Validation of the formulated model.
c. Performance evaluation of the formulated model for the Mahi river system.

In this study, basic model is constructed by 2 inputs and 1 output. The inputs for DO are pH, EC, temperature and DO while for the output is predicted DO. For COD, inputs are temperature, pH, suspended solids, COD while for the output is predicted COD.In this ANFIS model 70% data is used for Training and 30% data is used for Validation. After load the data in ANFIS Editor the Fuzzy Inference System (FIS) is generated with taking 5 number of linear triangular membership function.

The model is validated on the remaining 30% of the data by evaluating the following statistic performance indicators: Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of determination (*R*2) and Discrepancy Ratio (D) which is given below:

Root mean square error (RMSE):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X(i) - \hat{X}(i))^2}{n}}$$

Correlation coefficient:

$$R = \frac{\sum_{i=1}^{n}(X(i) - \bar{X})(\hat{X}(i) - \bar{\hat{X}})}{\sqrt{\sum_{i=1}^{n}(X(i) - \bar{X})^2 \sum_{i=1}^{n}(\hat{X}(i) - \bar{\hat{X}})^2}}$$

Coefficient of determination:

$$R^2 = \frac{\left(\sum_{i=1}^{n}(X(i) - \bar{X})(\hat{X}(i) - \bar{\hat{X}})\right)^2}{\sum_{i=1}^{n}(X(i) - \bar{X})^2 \sum_{i=1}^{n}(\hat{X}(i) - \bar{\hat{X}})^2}$$

Discrepancy Ratio (D):

$$D = \frac{\sum_{i=1}^{n} X(i)}{\sum_{i=1}^{n} \hat{X}(i)}$$

Figure 4. statistical equations

Where (i) is the n estimated value, X(i) is the n observed value, is the mean of the observed values, and is the mean of the estimated values.

IV. DATA ANALYSIS AND RESULTS

60% data is used for Training and 40% data is used for Validation. The results obtained from ANFIS are shown below:

4.1 From observed and predict DO at AJNAD village, various plots for training and checking are shown below:

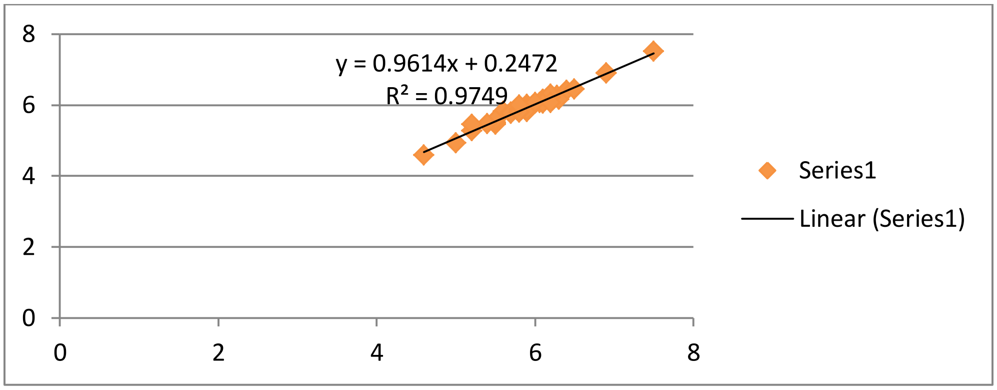

Fig 4: Scatter Plot for Observed Vs Predicted DO for Training for AJNAD village

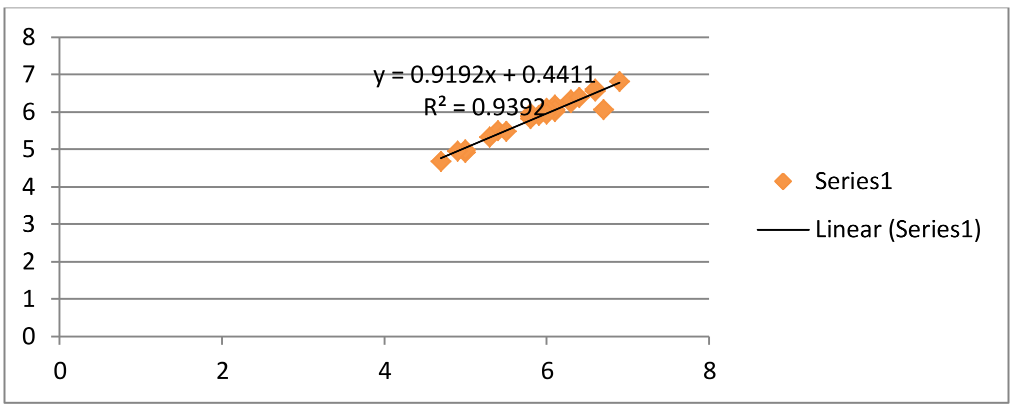

Fig 5: Scatter Plot for Observed Vs Predicted DO for Checking for AJNAD village

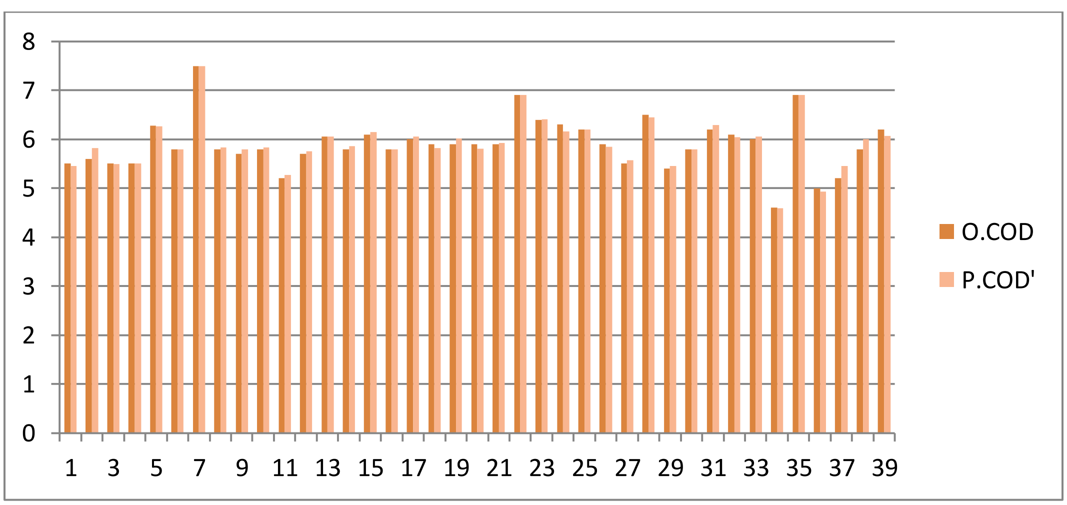

Fig 6: Bar chart for Comparison between Observed Vs Predicted DO for Training for AJNAD village

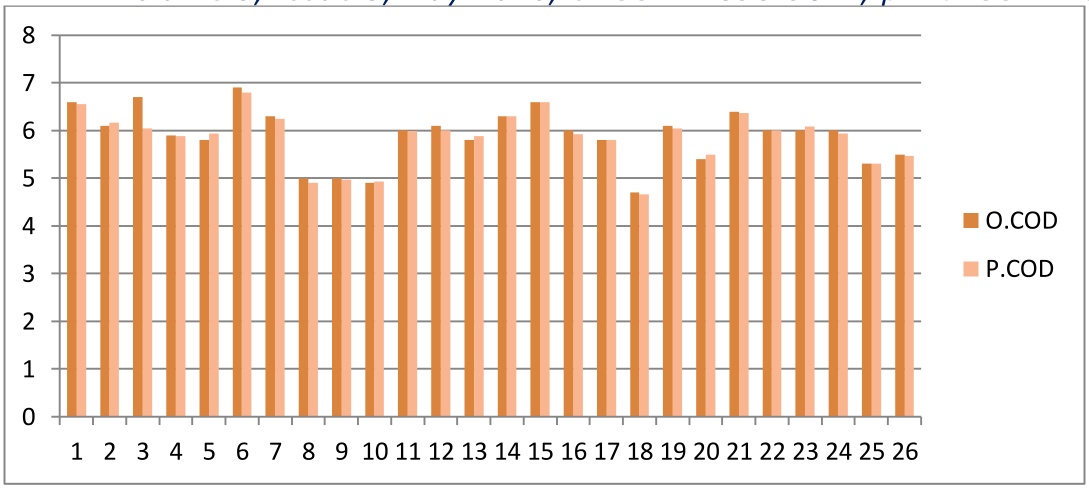

Fig 7: Bar chart for Comparison between Observed Vs Predicted DO for Checking for AJNAD village

4.2 From observed and predict COD at AJNAD village, various plots for training and checking are shown below:

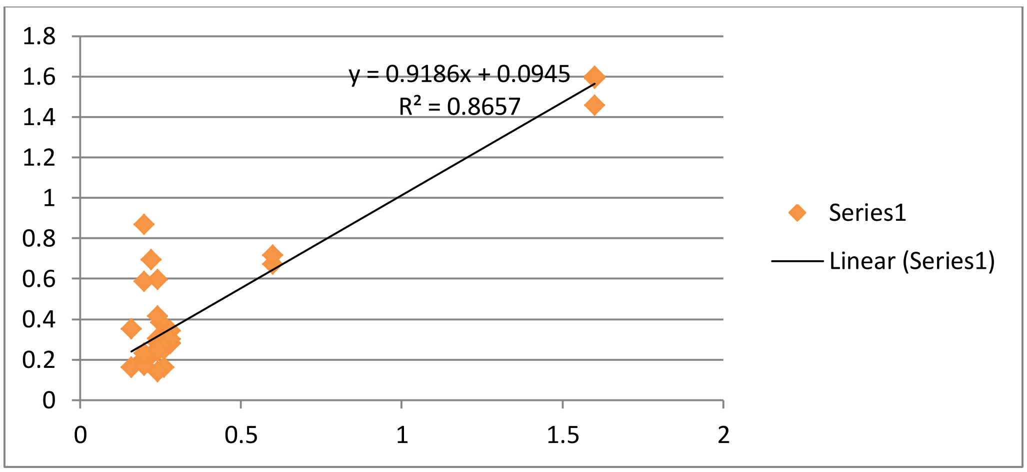

Fig 8: Scatter Plot for Observed Vs Predicted COD for Training for AJNAD village

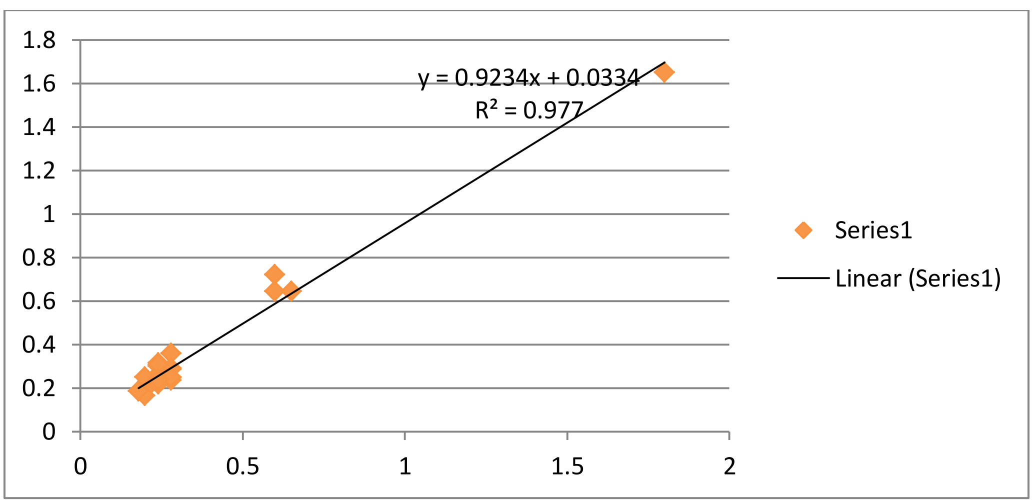

Fig 9: Scatter Plot for Observed Vs Predicted COD for Checking for AJNAD village

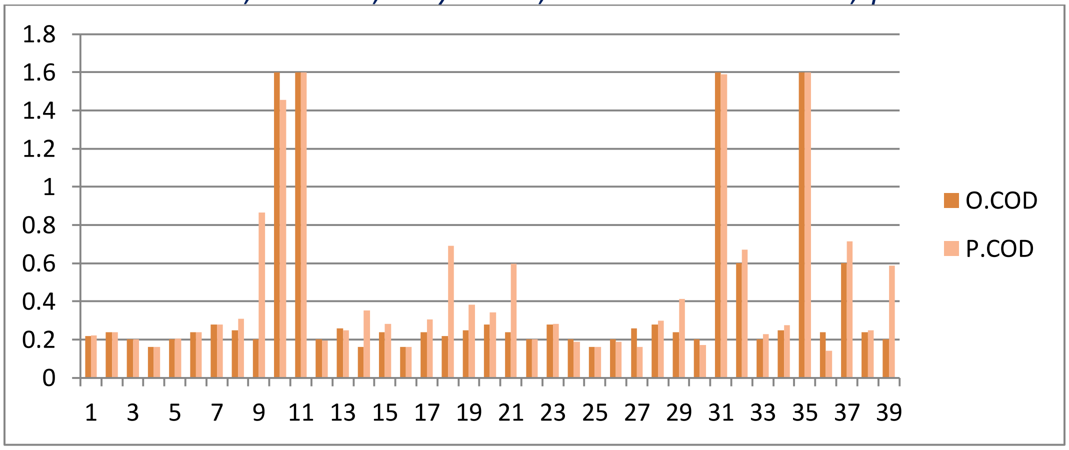

Fig 10: Bar chart for Comparison between Observed Vs Predicted COD for Training at AJNAD village

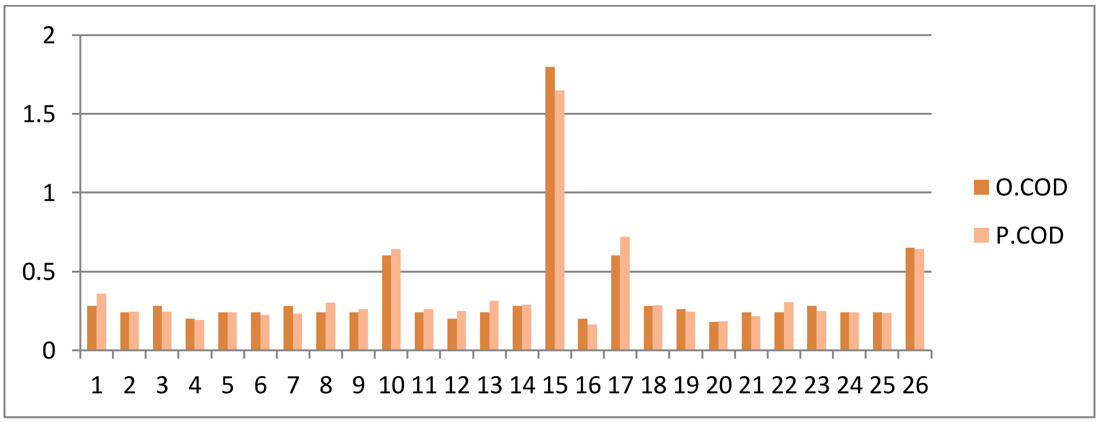

Fig11: Bar chart for Comparison between Observed Vs Predicted COD for Checking at AJNAD village

In this primary stage of study ANFIS model was tested and the results were compared by means of correlation co-efficient and RMSE(root mean square error).we were use 60% monthly data for training and 40% monthly data were use checking (validation) for ANFIS model

Here, for ANFIS, model structure identification was done by grid partition with a constant membership function.

TABLE A: Performance evalution of model on training and checking period for ANFIS model (DO) at AJNAD village (Dist, JALGAON)

		RATIO 60-40%			
STATION	**PHASE**	**RMSE**	**CORRELATION (R)**	**R^2**	**DISCREPANCY RATIO**
AJNAD	TRAINING	0.465205	0.9873	0.974761	0.958504
	CHECKING	0.665545	0.9691	0.939155	0.989121

TABLE B: Performance evalution of model on training and checking period for ANFIS model (COD) at AJNAD village (Dist, JALGAON)

		RATIO 60-40%			
STATION	PHASE	RMSE	CORRELATION (R)	R^2	DISCREPANCY RATIO
AJNAD	TRAINING	0.219435	0.976823	0.9541	1.148378
	CHECKING	0.088591	0.9959	0.99181	1.0365

V. CONCLUSION:

Adaptive neuro-fuzzy inference system(anfis) is use in our study to predict water quality of of tapi river and maharasta basin taken as our study area Dissolved oxygen (DO) & chemical oxygen demand (COD) concentration has traditionally been used as a variable of water quality and for water systems. Therefore, modeling of water quality parameters is a very important aspect. The chemical, physical, and biological components of aquatic ecosystems are very complex and nonlinear. In recent years, computational-intelligence techniques such as neural networks, fuzzy logic, genetic algorithm, and combined neuro-fuzzy systems have become very effective tools to identification and modeling nonlinear systems.

From the table A and B we can see the values of RMSE, Coefficient of correlation (R), Coefficient of determination (R2) and Discrepancy ratio (D) for training phase as well as for checking phase, The value of Coefficient of correlation (R) is very close to 1for DO AND COD so, it can be concluded that observed DO is very near to predicted DO and observed COD is very near to predicted COD.

The ability of ANFIS model in estimation of DO & COD water quality parameter has been investigated in this study.and From the results, it can be concluded that the ANFIS can be used for predict DO and COD for this study area

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