Artificial Neural Network Based Water Quality Forecasting Model for Ganga River

Anil Kumar Bisht, Ravendra Singh, Rakesh Bhutiani, Ashutosh Bhatt

Abstract: ***Development of river water quality forecasting model (RWQFM) created using the concept of artificial neural network (ANN) for the river Ganga, India still has not been done as far as best awareness of the authors. In this research work an effort have been made for developing such model first time for the stream Ganga in the stretch from Devprayag to Roorkee, Uttarakhand, India by choosing five testing stations along this waterway. The month to month exploratory dataset for the time arrangement of 2001 to 2015 including four water quality parameters was taken. Using one of the proficient machine learning approach called ANN an optimal model is developed by conducting several experiments in Weka data mining tool. In advance the water quality is forecasted for next 12 months and the forecasting accuracy is determined using various performance measures. The computation of 12-steps ahead WQ indicated that the water comes out to be suitable for drinking throughout the year 2016 only at three stations: Devprayag, Rishikesh and Roorkee. At Haridwar station, the water is also comes out to be of best quality but only in nine months. In last quarter of 2016, a little degradation at Haridwar station while a crucial deterioration was noticed at Jwalapur site. The results showed that the proposed WQ model is more efficient in terms of the forecasting accuracy. At Rishikesh station the developed forecasting model achieved a noteworthy accuracy of 100%. Thus, the proposed ANN forecasting model is verified as an effective model and concluded that in overall the WQ of the Ganga River in this stretch is fine in 2016. Also, ANN has proven its significance as an efficient tool in the forecasting domain. Such models will definitely be helpful for the water management bodies in order to control the river pollution and consequently help the society as well.***

Keywords **: *Artificial Neural Network (ANN), Mean Square Error (MSE), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Water Quality (WQ).***

I. INTRODUCTION

Water is the most precious resource of any country. Because it is an essential component required to live for both the human being as well as the wild life all over the globe. But recently it has been noticed that the quality of water is deteriorating very hastily due to man-made problems like unorganized industrialization, enlarged population, heavy and unstructured urbanization etc. As we know rivers are the paramount source of water. In India, its national river i.e. the Ganga which has also got the prime status of living entity and is being adored by its inhabitants is also started declining with respect to its quality gradually. Therefore it's the demand of time to get aware of such alarming situation and to initiate technologically sound steps to restore the Ganga River to its pious state. Forecasting the quality of water in rivers is itself a very critical phenomenon and also a challenging task. Due to complex and nonlinear relationship among the parameters responsible for determining the water quality the development of such proficient forecasting models is very tedious work. Accurate prediction of water quality will absolutely leads to the development of comprehensive solutions and decisions by the water management bodies. However, development of such water quality (WQ) models for the river Ganga built on artificial neural network (ANN) still has now not been performed or reported in the literature as far as best knowledge of the authors. During the last few decades it has been a tremendous developments in the field of artificial intelligence (AI) specifically targeting the problem of pattern recognition. One of such growing area of AI is known as Artificial Neural Networks which has been applied successfully in the problems involving prediction or forecasting. Based on historical data, ANNs are capable of performing non-linear mapping among the given data set and its elements i.e. recognizing the trends and patterns in the given data generates the desired output. The remaining segments of the paper are systematized as shown in the following Fig. 1.

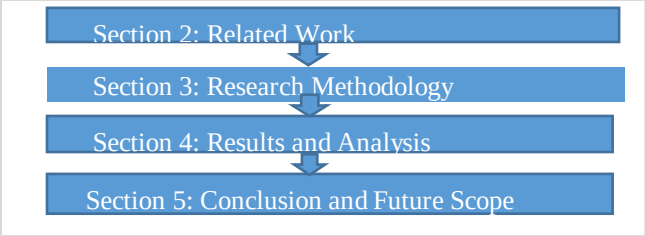

Fig. 1 Organization of the remaining Paper

II. RELATED WORK

ANN models has been applied successfully in diagnosing the diseases [1], [2], [3]. The models developed using ANN have been applied in variety of applications like prediction of flow of rivers [4], [5], [6], [7], rainfall prediction model [8], weather forecasting [9], prediction model for water quality Index [10], [11], [12], [13], [14], [15],
prediction of water quality

Revised Manuscript Received on August 25, 2019
* Correspondence Author
Anil Kumar Bisht*, Computer Science & Information Technology, Mahatma Jyotibha Phule Rohilkhand University, Bareilly, India.
Ravendra Singh, Computer Science & Information Technology, Mahatma Jyotibha Phule Rohilkhand University, Bareilly, India
Rakesh Bhutiani, Deptt. of Env. Sc., Gurukula Kangri University, Haridwar, Uttarakhand, India.
Ashutosh Bhatt, Deptt. of Computer Science and Engg., BIAS, Bhimtal, Uttarakhand, India.

parameters [16], [17], [18], [19], [20], [21], [22], prediction and forecasting with artificial neural networks: introduction, issues and applications [23], [24], time-series forecasting using ANNs [25], [26], role of ANNs in ecological modelling [27], predicting stock price index [28], modelling electricity demand [29], forecasting of water quality using ANN [30], Modelling water quality [31], [32], time series forecasting of WQ of the river Godavari [33]. All such research works leads to the conclusion that ANNs are currently being used in finding the solution for prediction or forecasting problems in a variety of domains specifically in the field of ecology. But a biggest research gap found by going through all these and other research literatures is that still there is no effort in the direction of modelling (predicting or forecasting) the water quality of the river Ganga using the concept of ANNs as far as to the best knowledge of the authors of the present work. In summary, the focus of this research is to develop a (RWQFM) river water quality forecasting model for the river Ganga consisting four WQ parameters for every one of the five testing sites along this river stretch by applying the technique of ANNs on the extensive time series experimental dataset (monthly) for the period of fifteen years from 2001 to 2015 using WEKA tool.

III. RESEARCH METHODOLOGY

A. Study Area and the Experimental Dataset Used

For the research purpose, the country wide holiest river of India Ganga has been selected. The Ganga river is generated as a result of joining of River Bhagirathi with river Alaknanda at Devprayag starting up from Garhwal Himalayas.The Ganga River basin in India is highlighted in Fig. 2. The monthly experimental data sets collection for the WQ of the River Ganga from 2001 to 2015 at five different stations named: Devprayag, Rishikesh, Haridwar, Jwalapur and Roorkee in Uttarakhand analyzed by Limnology & Ecological Modelling Laboratory, Gurukul Kangri Vishwavidhyalaya, Haridwar, Uttarakhand, India is being taken in this research. This data set comprised of four WQ parameters temperature, pH, dissolved oxygen (DO) and biochemical oxygen demand (BOD). The goal of the current research work is to develop a water quality forecasting model for the river Ganga for each and every sampling station along this river by applying the technique of ANNs on the experimental dataset taken over the period of fifteen years from 2001 to 2015 using WEKA tool [34]. WEKA tool provide support for different data mining problems involving classification, clustering and visualization.

Fig. 2 The Ganga River Basin (Source: Google Earth)

B. Model Development: Named "River Water Quality Forecasting Model" (RWQFM) using ANN in Weka

For development of the proposed model named here "RWQFM", the authors have used the results of their research done in [35] where the best prediction accuracy of 95.9% was obtained when the value of the best learning rate is determined as 0.04 following 50000 epochs after a set of various experiments. As the learning rate (the amount the weights are updated) and the number of epochs (the number of times the dataset presented to the network to train through) are the two main factors while performing training of the neural network. For each of the five stations authors have taken the WQ dataset of size 180 for fifteen years (2001-2015) from January to December. In order to decide the WQ classes the standards formulated by the Central Pollution Control Board (CPCB), India is followed where the quality of water is categorized into five different classes which is described as below:

1. Class 'A' : drinkable water
2. Class 'B': bathing water only
3. Class 'C': drinkable water but after traditional remedy.
4. Class 'D': best only for marine and wild life
5. Class 'E' : only for agriculture and industries

For experimental purpose the initial file containing the input data instances is prepared and stored in comma separated value (csv) file. Then for preprocessing purpose in weka this initial file is converted into another file format which is compatible with weka called attribute-relation file format (arff). A supervised machine learning approach called artificial neural network (ANN) is used for creating the forecasting model by setting its parameters in such a way that its output performance will be efficient one. This can be achieved by conducting various experiments to develop the models and checking their performance using four different metrics. The steps followed for development of 'RWQFM' are as below:

1. Create csv files of water quality dataset of the Ganga River for previous fifteen years for all five stations.
2. Convert all csv files containing dataset to arff format for suitable to run in Weka.
3. Import the data instances contained in arff file for particular station for preprocessing in Weka.
4. Build the structure of ANN based time series forecasting model in Weka using multilayer perceptron as a classifier function by choosing best configuration of the network.
5. Run the forecasting process for the structured forecasting model.
6. Save the run information and the evaluation results for the model identified as best model by comparing various forecaster outputs.
7. Save the developed forecasting model which comes out to be best w.r.t. its performance metric.

The output view of experiments performed in Weka is as shown in the Fig. 3.

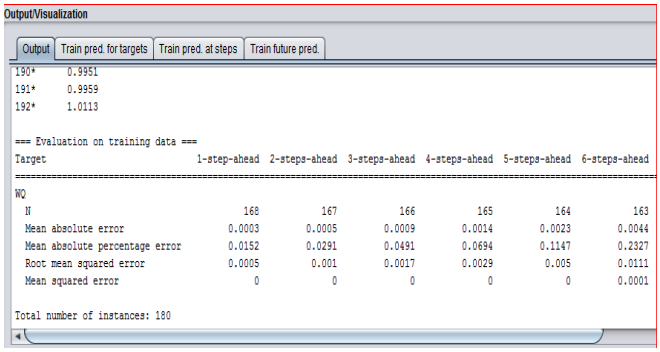

Fig. 3 Experimental View in Weka for output result screen in developing the RWQFM

IV. RESULTS AND ANALYSIS

For developing the proposed time series 'RWQFM', the authors have developed the ANN based model to generate predictions (forecasts) for future monthly values (classes) of WQ at each and every station on the basis of known past respective WQ values at corresponding station. Various experiments were conducted and their results have been analyzed by going through the steps mentioned above. We made monthly forecasts into the future for a one year period i.e. 12-steps ahead. The future forecasts/ predictions from end of training data is marked as '*' that indicates the future trends. Different metrics are used which perform relative measurement that compared the forecasted result to the last known target value i.e. class of WQ as the prediction which is always taken as relative to the step at which the forecast is to be done. These matric are defined mathematically as follows:

1. Mean Absolute Error (MAE): sum(abs(predicted - actual)) / N
2. Mean Squared Error (MSE): sum((predicted - actual)^2) / N
3. Root Mean Squared Error (RMSE): sqrt(sum((predicted - actual)^2) / N)
4. Mean Absolute Percentage Error (MAPE): sum(abs((predicted - actual) / actual)) / N

Where N denotes total number of instances.

Forecasting Model Development for First Station "Devprayag"

For the very first station Devprayag the authors have developed the proposed model i.e. RWQFM in Weka. From the analysis of the results it is found that at this site the forecast for the WQ of the river ganga for the next 12-months from the end of training data is displayed in the table I with '*' marked entries from January 2016 to December 2016. The resulting forecast of WQ at this station is shown in the Fig. 4 where the curve is showing that the water is remain in the class A throughout the year 2016.

Table-I: 12 months-ahead forecasted result of ANN model (RWQFM) for Devprayag station

Time Stamp	Instance No.	WQ
July-2015	175	1
Aug-2015	176	1
Sept-2015	177	1
Oct-2015	178	1
Nov-2015	179	1
Dec-2015	180	1
Jan-2016	181*	0.9967
Feb-2016	182*	0.9962
Mar-2016	183*	0.9983
Apr-2016	184*	1.0019
May-2016	185*	1.0052
June-2016	186*	1.009
July-2016	187*	1.0143
Aug-2016	188*	1.0223
Sept-2016	189*	1.0316
Oct-2016	190*	1.0405
Nov-2016	191*	1.0486
Dec-2016	192*	1.0561

Thus, it is concluded from these results that at this site with reference to the past fifteen years data the quality of Ganga water is extraordinary and is suitable for drinking purpose. The forecasting performance of developed model is computed using various measures which is presented in the table II which showed that the developed model attained a best accuracy of 99.52% as the minimum MSE is 0.0048 during forecasting the WQ one month-ahead as highlighted.

Table-II: The forecasting performance of ANN model for station "Devprayag"

Performance Metric / Target WQ	MAE	MAPE	RMSE	MSE
1 month-advance	0.0234	1.709	0.0694	**0.0048**
2 month-advance	0.0544	3.4571	0.1635	0.0267
3 month-advance	0.0771	5.1752	0.1629	0.0265
4 month-advance	0.1197	8.037	0.254	0.0645
5 month-advance	0.1804	12.3513	0.4899	0.24
6 month-advance	0.2473	17.0798	0.5958	0.3549
7 month-advance	0.3149	20.2091	0.7112	0.5058
8 month-advance	0.3694	24.0791	0.8526	0.727
9 month-advance	0.4679	30.6478	1.0289	1.0587
10month-advance	0.584	37.5198	1.1739	1.3781
11month-advance	0.6428	40.3489	1.2381	1.5329
12month-advance	0.6983	44.4507	1.2561	1.5779

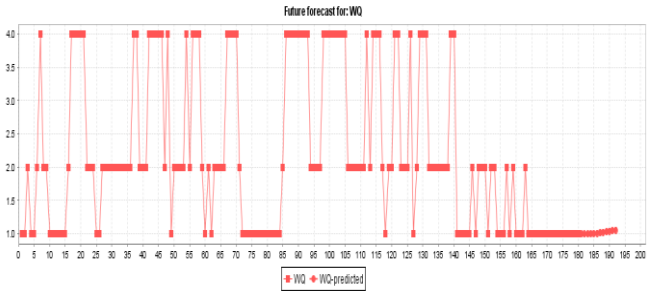

Fig. 4 Future Forecast for WQ (12-steps ahead) at Devprayag Station

Forecasting Model Development for Second Station "Rishikesh"

For the second station Rishikesh, the WQ at this station for next 12 months is displayed in the table III with '*' marked entries with the forecasting performance of developed model presented in the table 4. A graph for the resulting forecast of WQ at this station is shown in the Fig. 5. It is concluded from these results that at this station the quality of Ganga water will remain the same as in previous months i.e. no further deterioration will going to be noticed as the water quality curve is showing an almost constant values belonging to class A for the next 12 months in 2016. In totality, conclusion is that the Ganga River had a remarkable water quality at Rishikesh station in 2016. The developed model have a best accuracy of 100% when it forecasts the WQ 1,2,3,4 and 5 month-ahead as highlighted in table IV.

Table-III: 12 months-ahead forecasted result of ANN model (RWQFM) for Rishikesh station

Time Stamp	Instance No.	WQ
July-2015	175	1
Aug-2015	176	1
Sept-2015	177	1
Oct-2015	178	1
Nov-2015	179	1
Dec-2015	180	1
Jan-2016	181*	0.9938
Feb-2016	182*	0.9975
Mar-2016	183*	0.9971
Apr-2016	184*	0.9941
May-2016	185*	0.9941
June-2016	186*	1
July-2016	187*	0.9969
Aug-2016	188*	0.9941
Sept-2016	189*	1.0074
Oct-2016	190*	0.9951
Nov-2016	191*	0.9959
Dec-2016	192*	1.0113

Table-IV: The forecasting performance of ANN model for station "Rishikesh"

Performance Metric Target WQ	MAE	MAPE	RMSE	MSE
1 month-advance	**0.0003**	0.0152	0.0005	**0**
2 month-advance	0.0005	0.0291	0.001	**0**
3 month-advance	0.0009	0.0491	0.0017	**0**
4 month-advance	0.0014	0.0694	0.0029	**0**
5 month-advance	0.0023	0.1147	0.005	**0**
6 month-advance	0.0044	0.2327	0.0111	0.0001
7 month-advance	0.0069	0.409	0.0191	0.0004
8 month-advance	0.0128	0.8453	0.0427	0.0018
9 month-advance	0.0234	1.6366	0.068	0.0046
10month-advance	0.0426	3.256	0.143	0.0204
11month-advance	0.105	8.6365	0.4974	0.2474
12month-advance	0.1276	9.9148	0.519	0.2693

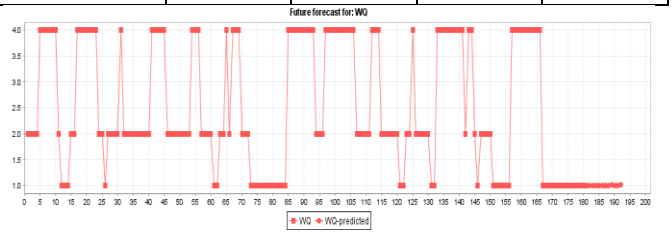

Fig. 5 Future Forecast for WQ (12-steps ahead) at Rishikesh Station

Forecasting Model Development for Third Station "Haridwar"

For the third station Haridwar the developed model resulted in the forecast for the WQ of the river Ganga for the next 12-months in advance as given in the table V with '*' marked entries. The resulting forecast of WQ at this station is indicated graphically in the Fig. 6. It is concluded from these results that at this station the water is belonging to the class A everywhere except showing a little swing from this class towards class C and class B in the month of October and November. Therefore it is concluded that in general the water quality at Haridwar site is found suitable for drinking but indicated a sign of little bit deterioration also particularly in two months. The developed model accomplished a best accuracy of 99.55% when forecasting the WQ in one step (month) advance as emphasized in table VI where the forecasting performance of developed model is presented.

Table-V: 12 months-ahead forecasted result of ANN model (RWQFM) for Haridwar station

Time Stamp	Instance No.	WQ
July-2015	175	2
Aug-2015	176	2
Sept-2015	177	2
Oct-2015	178	1
Nov-2015	179	1
Dec-2015	180	1

Jan-2016	181*	1.9023
Feb-2016	182*	0.6147
Mar-2016	183*	0.3812
Apr-2016	184*	1.582
May-2016	185*	0.6254
June-2016	186*	0.9188
July-2016	187*	1.0117
Aug-2016	188*	0.7937
Sept-2016	189*	0.103
Oct-2016	190*	3.5707
Nov-2016	191*	2.9232
Dec-2016	192*	-0.9287

Table-VI: The forecasting performance of ANN model for station "Haridwar"

Performance Metric **Target WQ**	**MAE**	**MAPE**	**RMSE**	**MSE**
1 month-advance	0.0214	1.4842	0.0667	**0.0045**
2 month-advance	0.0541	3.3325	0.1707	0.0291
3 month-advance	0.1093	7.4293	0.2855	0.0815
4 month-advance	0.193	13.2483	0.5137	0.2639
5 month-advance	0.3146	22.7623	0.7923	0.6277
6 month-advance	0.413	29.2842	0.943	0.8892
7 month-advance	0.5056	35.5322	1.057	1.1171
8 month-advance	0.6129	41.7054	1.1854	1.4052
9 month-advance	0.8308	52.1879	1.5423	2.3785
10 month-advance	0.9121	53.4328	1.5797	2.4955
11 month-advance	1.0178	56.7156	1.6452	2.7065
12 month-advance	1.2289	68.9053	1.9621	3.8498

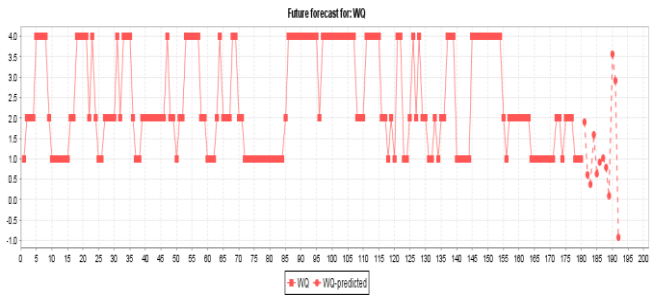

Fig. 6 Future Forecast for WQ (12-steps ahead) at Haridwar Station

Forecasting Model Development for Fourth Station "Jwalapur"

For the Jwalapur station the WQ of the river Ganga for the next 12 months (Jan 2016 to Dec 2016) in advance is presented in the table 7 with '*' marked entries and in finding this the forecasting performance of developed model is computed is mentioned in the table 8. The resulting forecast of WQ at this station is shown as a graph in the Fig. 7 where a high fluctuation in the quality of water was noticed. Initially there exist an uncertainty in the water quality and then in the last months the curve is showing that the WQ is going to worsen to a greater extent. Consequently, authors concluded that at this place over-all the water is degrading momentously. The developed model achieved a best accuracy of 92.55% when it forecasts the WQ one month-ahead as indicated in table 8.

Table-VII: 12 months-ahead forecasted result of ANN model (RWQFM) for Jwalapur station

Time Stamp	**Instance No.**	**WQ**
July-2015	175	4
Aug-2015	176	4
Sept-2015	177	4
Oct-2015	178	4
Nov-2015	179	4
Dec-2015	180	4
Jan-2016	181*	-1.258
Feb-2016	182*	1.1846
Mar-2016	183*	-2.4063
Apr-2016	184*	-1.794
May-2016	185*	-3.4866
June-2016	186*	-3.866
July-2016	187*	-2.6316
Aug-2016	188*	-1.2381
Sept-2016	189*	2.7471
Oct-2016	190*	5.8086
Nov-2016	191*	7.6206
Dec-2016	192*	-2.3123

Table-VIII: The forecasting performance of ANN model for station "Jwalapur"

Performance Metric **Target WQ**	**MAE**	**MAPE**	**RMSE**	**MSE**
1 month-advance	0.1101	5.0165	0.2729	**0.0745**
2 month-advance	0.2072	9.9251	0.4291	0.1841
3 month-advance	0.3764	17.3772	0.7097	0.5037
4 month-advance	0.6388	27.1995	1.1181	1.2501
5 month-advance	1.0292	44.199	1.7836	3.1811
6 month-advance	1.2967	53.4927	2.1733	4.7233
7 month-advance	1.6712	66.6589	2.7312	7.4596
8 month-advance	1.7452	76.9113	2.75	7.5626

9 month-advance	1.9583	88.0516	2.9789	8.8736
10 month-advance	2.2893	105.7638	3.2199	10.3677
11 month-advance	2.8557	137.3646	4.0213	16.1707
12month-advance	2.8427	142.906	4.0343	16.2755

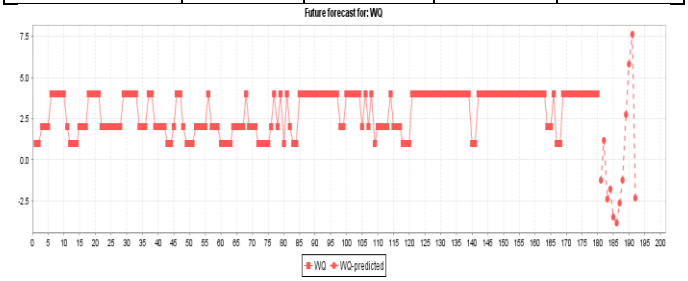

Fig. 7 Future Forecast for WQ (12-steps ahead) at Jwalapur Station

Forecasting Model Development for Fifth Station "Roorkee"

For the Roorkee station the proposed model indicated forecast for the WQ of the river ganga for the next 12-months from the end of training data in the table IX with '*' marked entries from January 2016 to December 2016 with the forecasting curve shown in Fig. 8. It is concluded from these results that the water quality at this station forecasted to be of class A. The developed model given a best accuracy of 99.35% when it forecasts the WQ one month-ahead as highlighted in table X.

Table-IX: 12 months-ahead forecasted result of ANN model (RWQFM) for Roorkee station

Time Stamp	Instance No.	WQ
July-2015	175	1
Aug-2015	176	1
Sept-2015	177	1
Oct-2015	178	1
Nov-2015	179	1
Dec-2015	180	1
Jan-2016	181*	0.9385
Feb-2016	182*	0.9514
Mar-2016	183*	0.9369
Apr-2016	184*	0.9366
May-2016	185*	0.9112
June-2016	186*	0.9215
July-2016	187*	0.9019
Aug-2016	188*	0.8909
Sept-2016	189*	0.893
Oct-2016	190*	0.8901
Nov-2016	191*	0.8855
Dec-2016	192*	0.8623

Table-X: The forecasting performance of ANN model for station "Roorkee"

Performance Metric / Target WQ	MAE	MAPE	RMSE	MSE
1 month-advance	0.0395	3.033	0.0807	**0.0065**
2 month-advance	0.0484	3.4705	0.0905	0.0082
3 month-advance	0.0588	4.039	0.105	0.011
4 month-advance	0.0769	5.0519	0.1396	0.0195
5 month-advance	0.1176	7.5158	0.244	0.0595
6 month-advance	0.1574	9.267	0.3467	0.1202
7 month-advance	0.2085	11.8011	0.4377	0.1916
8 month-advance	0.3377	18.4448	0.7829	0.6129
9 month-advance	0.3575	20.7527	0.7216	0.5206
10 month-advance	0.4477	28.8266	0.8396	0.7049
11 month-advance	0.5414	32.3212	0.9341	0.8725
12 month-advance	0.6055	35.8225	1.0207	1.0419

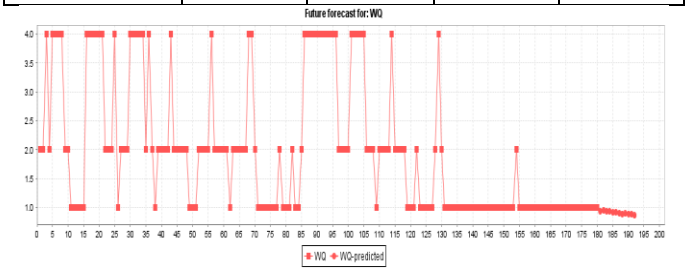

Fig. 8 Future Forecast for WQ (12-steps ahead) at Roorkee Station

V. CONCLUSION AND FUTURE SCOPE

In this paper, the authors attempted to develop machine learning based river water quality forecasting model (RWQFM) using one of the technique called artificial neural network (ANN) for the river Ganga first time in India as far true to their best knowledge. In order to carry out this objective five different stations along this river stretch from Devprayag to Roorkee, Uttarakhand have been selected and a time series based monthly experimental dataset from 2001 to 2015 encompassing four water quality characteristics have been taken. For each station water quality forecasting models were developed by conducting several experiments using Weka tool. Out of various models at every station that model is selected as optimal one which performs the best by determining their forecasting performance using several performance measures like MAE, MAPE, RMSE and MSE and on the basis of that selected model monthly WQ forecasting is done for the next 12 months at every station. Analyzing all these forecast results, authors concluded that at three stations Devprayag, Rishikesh and Roorkee the quality of the Ganga river is comes out as extraordinary as it was forecasted as class A throughout the 2016 year. Consequently, we can say that

the water at these sites is suitable for drinking purpose. However, at the Haridwar station in general, the water quality was also forecasted to be in class A i.e. suitable for drinking but only in nine months while in the last months of the year 2016 a minute degradation in quality was also noticed. It can be because of the heavy tourist load. Moreover, at the Jwalapur site the forecasting results indicated a lot of uncertainty as well as critical condition of water quality in the last quarter of the year i.e. WQ is degrading significantly. The reason may be heavy sewage dumping at this site.

These results are on the basis of the forecasting performance performed by the developed model with accuracies: 99.52% at Devprayag, 100% at Rishikesh, 99.55% at Haridwar, 92.55% at Jwalapur and 99.35% at Roorkee. At Rishikesh station the WQ of river is astonishing or i.e. it will remain in class A (suitable for drinking). Among five stations at the Rishikesh station the developed model attained a best forecasting accuracy of 100% having MSE=0 which means the developed model forecasts WQ effectively without any error. Finally, the forecasted results show that the developed RWQFM (River Water Quality Forecasting Model) based on ANN is more efficient in terms of the accuracy. Consequently, the ANN based technique is proved to be highly proficient in the forecasting applications. Also, in general the water of the Ganga river is found to be fine among the undertaken stations in the year 2016. Thus, the authors have got success in achieving their objective and provided a support to the water management bodies for handling the pollution issues related with the river water.

Still this research work have few shortcomings like the available dataset size of fifteen years which can be extended, the study area and its geographical constraints under consideration etc. As a future prospective firstly, the same model can be enhanced by considering another learning methods with extended data set and improved configuration of model parameters. Secondly, the forecasting can be done for other stations as well subject to the availability of historic quality data. In this way it is concluded that such models will be more proficient for solving the forecasting problems in various application domains. Our results can be used by water management bodies which are concerned with pollution in rivers. Therefore, this research work can really be fruitful for the society and for the entire nation as well.

REFERENCES

1. R. Dey, V. Bajpai, G. Gandhi and B. Dey, “Application of Artificial Neural Network (ANN) technique for Diagnosing Diabetes Mellitus”, IEEE Kharagpur Section &IEEE Sri Lanka Section Region 10 Colloquium and the Third ICIIS, Kharagpur, INDIA December 8-10, 2008.
2. S. Chattopadhyay, “A neuro-fuzzy approach for the diagnosis of depression”, Applied Computing and Informatics, article in press, Production and hosting by ELSEVIER, 2014.
3. C. Mahesh, V. G. Suresh, Manjula Babu, “Diagnosing Hepatitis B Using Artificial Neural Network Based Expert System”, International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 6, December 2013.
4. S. Riad & J. Mania (2004). Rainfall-Runoff Model Using an Artificial Neural Network Approach. Mathematical and Computer Modelling 40 (2004) pp. 839-846.
5. Abrahart, R.J. & See, L.M (2007). Neural network emulation of a rainfall-runoff model. The journal of Hydrology and Earth System Sciences 4, 287–326.
6. Reyes J.V. et al. (2016). Artificial Neural Networks applied to flow prediction: A use case for the Tomebamba river. In International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development. Procedia Engineering Vol. 162, pp. 153 – 161.
7. Krishna, B. et al. (2011). Time Series Modeling of River Flow Using Wavelet Neural Networks. Journal of Water Resource and Protection, Vol.3, pp. 50-59.
8. K. Abhishek, A. Kumar, R. Ranjan, S. Kumar, “A Rainfall Prediction Model using Artificial Neural Network”, Control and System Graduate Research Colloquium (ICSGRC), IEEE, 2012.
9. Imran Maqsood, Muhammad Riaz Khan, Ajith Abraham, “An ensemble of neural networks for weather forecasting”, Neural Comput & Applic, Springer-Verlag London Limited 4, 13: pp. 112–122, 2004.
10. Mohd. Fahmi Mohd. Nasir, H. Juahir, N.Roshan, I. Mohd. N.A. Shafie, N. Ramli, “Artificial Neural Networks Combined with Sensitivity Analysis as a Prediction Model for Water Quality Index in Juru River, Malaysia”, International Journal of Environmental Protection, IJEP Vol.1 No. 3 PP.1-8., 2011.
11. N. M. Gazzaz, MohdKamilYusoff, Ahmad ZaharinAris b, Hafizan Juahir, Mohammad FiruzRamli, “Artificial neural network Modelling of the water quality index for Kinta River (Malaysia) using water quality variables as predictors”, Marine Pollution Bulletin, ELSEVIER, 2012.
12. Sujana Prajith kumar, Shweta Verma, B V Mahajan, “Application of ANN model for the prediction of Water Quality Index ”, International Journal of Engineering Research and General Science Volume 3, Issue 1, ISSN 2091-2730, January-February, 2015.
13. Faris Gorashi, Alias Abdullah, “Prediction of Water Quality Index Using Back Propagation Network Algorithm. Case Study: Gombak River”, Journal of Engineering Science and Technology Vol. 7, No. 4 (2012) 447 – 461, 2012.
14. Hossein Banejad, Ehsan Olyaie, “Application of an Artificial Neural Network Model to Rivers Water Quality Indexes Prediction – A Case Study”, Journal of American Science, 7(1) 2011.
15. Sirilak Areerachakul, Siripun Sanguansintukul, “Water Quality Classification using Neural Networks: Case Study of Canals in Bangkok, Thailand”, Institute of Electrical and Electronics Engineers, 2009.
16. M. Heydari, E. Olyaie, H. Mohebzadeh and O. Kisi, “Development of a Neural Network Technique for Prediction of Water Quality Parameters in the Delaware River, Pennsylvania”,Middle-East Journal of Scientific Research 13 (10): pp.1367-1376, 2013.
17. Nibedita Guru, Ramakar Jha, “Simulation of BOD-DO Modelling in Mahanadi River System lying in Odisha using ANN, India”, IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) ISSN: 2319-2402, ISBN: 2319-2399. Volume 2, Issue 4, PP 52-57, Jan. - Feb. 2013.
18. Vesna Rankovi, Jasna Radulovic, Ivana Radojevic, AleksandarOstojic, Ljiljana Comic, “Neural network Modelling of dissolved oxygen in the Gruza reservoir, Serbia”, Ecological Modelling 221 (2010) 1239–1244, ELSEVIR, 2010.
19. Gholamreza Asadollahfrdi, Azadeh Hemati,Saber Moradinejad and Rashin Asadollahfardi, “Sodium Adsorption Ratio (SAR) Prediction of the Chalghazi River Using Artificial Neural Network (ANN) Iran”, Current World Environment Vol. 8(2), 169-178, 2013.
20. M. Niroobakhsh, S. H. Musavi-Jahromi, M. Manshouri, H. Sedghi, “Prediction of water quality parameter in Jajrood River basin: Application of multi-layer perceptron (MLP) perceptron and radial basis function networks of artificial neural networks (ANNs) ”, African Journal of Agricultural Research Vol. 7(29), pp. 4131-4139, 31 July, 2012.
21. Archana Sarkar, Prashant Pandey, “River Water Quality Modelling using Artificial Neural Network Technique”, International Conference on Water Resources And Ocean Engineering (ICWRCOE), ELSEVIER, 2015.
22. Anita Talib, Mawar Idati Amat, “Prediction of Chemical Oxygen Demand In Dondang River Using Artificial Neural Network”, International Journal of Information and Education Technology, Vol. 2, No. 3, June 2012.
23. G. Zhang, B. Eddy Patuwo, Michael Y. Hu, “Forecasting with artificial neural networks: The state of the art”, International Journal of Forecasting 14, ELSEVIER, pp. 35–62, 1998.
24. H. R. Maier, Graeme C. Dandy, “Neural networks for the prediction and forecasting of water resources variables: a review of modeling issues and applications”, Environmental Modeling & Software 15, ELSEVIER, pp. 101–124, 2000.

25. Yan, W. (2012). Toward Automatic Time-Series Forecasting Using Neural Networks. IEEE Transactions on Neural Networks and Learning Systems, VOL. 23(7).
26. M. Khashei , M. Bijari, "An artificial neural network (p,d,q) model for timeseries forecasting", Expert Systems with Applications 37,ELSEVIER, pp. 479–489, 2010.
27. Sovan Lek, J.F. Guegan, "Artificial neural networks as a tool in ecological modelling, an introduction", Ecological Modeling, ELSEVIER, 65–73, 1999.
28. Kara, Y., et al., (2011). Predicting direction of stock price index movement using artificial neural networks and support vector machines: The sample of the Istanbul Stock Exchange. Expert Systems with Applications 38 (2011), pp. 5311–5319.
29. A. Abraham, B. Nath, "A neuro-fuzzy approach for modeling electricity demand in Victoria", Applied Soft Computing 1, ELSEVIER, 127–138, 2001.
30. Sundarambal Palani, Shie-Yui Liong, Pavel Tkalich, "An ANN application for water quality forecasting", Marine Pollution Bulletin 56, 1586–1597, ELSEVIER, 2008.
31. Shrivastava Kriti, Joshi Smita "Artificial Neural Network Modeling of Shyamala Water Works, Bhopal MP, India: A Green Approach towards the Optimization of Water Treatment Process", Research Journal of Recent Sciences, ISSN 2277-2502, Vol. 2(ISC-2012), 26-28, 2013.
32. Bisht, A.K., et al. (2017). Water quality modelling of the River Ganga using artificial neural network with reference to the various training functions. Volume 18(1&2), 2017 Environment Conservation Journal [UGC Approved], PP: 41-48. ISSN 0972-3099 (Print) 2278-5124 (Online).
33. Mahesh Kumar Akkaraboyina, B.S.N.Raju, "Time Series Forecasting of WQ of the River Godavari", IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), ISSN: 2278-1684 Volume 1, Issue 3 (July-August 2012), PP 39-44.
34. http://www.cs.waikato.ac.nz/ml/weka.
35. Anil Kumar Bisht, Ravendra Singh, Rakesh Bhutiani, Ashutosh Bhatt, "Artificial Neural Network Based Prediction Model For Estimating the Water Quality Of the River Ganga", 3RD International Conference On Advances in Computing, Communication and automation, (ICACCA 2017), 15-16 September 2017, Dehradun, Uttarakhand, IEEE [Scopus] India.

AUTHORS PROFILE

Mr. Anil Kumar Bisht is currently a Ph.D. research scholar and Asstt. Professor in the department of CS & IT, FET, Mahatma Jyotibha Phule Rohilkhand University, Bareilly, U.P. India. He has a teaching experience of 15 years. He has done his M.Tech. in CSE from Uttarakhand Technical University, Dehradun, Uttarakhand, India. He has done his B.Tech in CSE from Uttar Pradesh Technical University, Lucknow, U.P., India. His research Areas are Artificial Intelligence, Machine Learning and Wireless Communications. He has completed online certificate course from Electronics and ICT Acedemy, IIT Kanpur on "Machine Learning". He has a total number of 18 reputed research publications. He is a life time member of Computer Society of India (CSI).

Dr. Ravendra Singh is a Professor in the department of CS & IT, FET, Mahatma Jyotibha Phule Rohilkhand University, Bareilly, U.P. India. He has a teaching experience of 21 years and 5 years experience in industry as Assistant Manager in Uptron India Ltd., Lucknow (U.P. Govt. Undertaking). His research Areas are at present, mainly engaged in Artificial Intelligence, Wired & Wireless networks, QoS based routing, ad hoc network, VANET, routing in under water and terrestrial sensor network, Admission control schemes for Real time communication and guided many scholars over the simulation and performance evaluation of wireless networks, Cost optimization & testing issues and Task allocation & scheduling in Distributed parallel computers. He is also working in the area related to big data, machine learning, association rules, cleaning & Integration of data in Data mining, & Data warehousing. He has a total number of more than 37 reputed publications. Also he had written 2 books with New Age International, N.Delhi and University Science Press, N.Delhi.

Dr. Rakesh Bhutiani is currently working as Assistant Professor in deptt. of environmental science, Gurukul Kangri University, Haridwar (UTTARAKHAND) INDIA. He has done his Ph.D. in Environmental Science. He has a total 17 years of teaching and research experience. He has more than 80 reputed publications in National and International Journals of repute and guided several scholars. Dr. Bhutiani is fellow of several academic societies and has several awards to his credit.

Dr. Ashutosh Bhatt is in Deptt. of CSE at Birla Institute of Applied Sciences, Bhimtal, Uttarakhand, India. He has done his Ph.D. in CSE in the field of Machine Learning. He is having a teaching experience of 21 years. He has a good number of reputed research publications. His Interest area are: Neural Networks, Web Applications. He has guided many research scholars. He is a member of different research societies.