J. Indian Chem. Soc.,
Vol. 94, April 2017, pp. 441-448

Assessment of water quality using WQI and prediction of WQI using ANN in some selected coastal villages of Vizianagaram district, Andhra Pradesh

G. V. S. R. Pavan Kumar*, T. V. N. Partha Sarathi and K. Srinivasa Rao

Department of Chemistry MV GR College of Engineering (A), Vijayaramnagar Campus, Chintalavalasa, Vizianagaram-535 005, Andhra Pradesh, India

E-mail : prs_ganti@yahoo.co.in, sarathitirumala@gmail.com, svr.kondrotu@gmail.com

Manuscript received online 05 October 2016, accepted 13 December 2016

Abstract : The present paper is aimed at the assessment of water quality of ground water using Water Quality Index (WQI) method. Seven coastal villages of Vizianagaram district of Andhra Pradesh were selected for the present study. Various physico-chemical parameters such as pH, EC, TDS, THW, Ca, Mg, Na, K, Cl, F, nitrite were analyzed for the samples collected. From such data WQI values were computed and it was concluded that the ground water of the villages under study was rated as "poor" in its quality. Artificial Neural networks tool in MATLAB was adopted and the feedback propagation and TRAINGLM program was used to predict the water quality of the ground water using WQI. The ANN predicted WQI values were found to be well in accordance with the experimentally computed values. A relative error of 0.15% between the predicted and experimentally computed values was observed. The regression coefficient values for testing and validation of the program was well within the prescribed limits.

Keywords : WQI, ANN, MATLAB, water quality assessment, coastal villages, ground water.

Introduction

Water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public. A single number cannot tell the whole quality of water; there are many other water quality parameters that are not included in the index. However, a water index based on some very important parameters can provide a simple indicator of water quality. It gives the public a general idea the possible problems with the water in the region.

Water quality index (WQI) is a dimensionless number that combines multiple water quality factors into a single number by normalizing values to subjective rating curves[1]. Conventionally it has been used for evaluating the quality of water for water resources such as rivers, streams and lakes, etc. Factors included in WQI vary depending upon the designated water uses of the water body and local preferences. Parameters in defining water quality can be grouped into three board categories : physical, chemical, and biological. *Physical factors* include temperature, sediment and bed material, suspended sediments, turbidity, color and odor. *Chemical factors* consist of the major and minor elements, and other chemical parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The major elements include agro-nutrients such as nitrogen and phosphorus; and minor elements include elements such as arsenic (As), lead (Pb) and mercury (Hg), etc. *Biological constituents* include Fecal Coli-form and *E. coli*. Conventionally water quality is expressed in terms of the measured value(s) of one or more of these parameters in relation to their accepted or implied limits. They are expressed in different units, and their magnitudes can vary significantly from one location to another and over time. For example, the temperature is expressed in degrees Celsius or degrees Fahrenheit, and coliforms in numbers, and most chemicals and nutrients in milligrams per liter (mg/L) or in parts per million (ppm).

Several organizations in the United States and around the world including United Nations have adopted the WQI concept for expressing the water quality[2–5] for their water resources. Several authors have worked on these concepts and presented examples with case scenarios[6–14].

The process of developing a WQI involves the following steps :

(1) Identify water quality parameters of interest and their ranges of acceptability for the intended uses of the water body.

(2) Compare the measured value with the subjective rating curve and arriving at a dimensionless sub-index value (0–1) for each parameter.

(3) Define the weighing factor and/or heuristics for each parameter to be considered while building an overall WQI.

(4) Select an algorithm and computing the WQI with the available data and assumptions.

A number of algorithms (models) for calculating WQI have been developed and reported in the literature. Some of these include :

(a) Weighted arithmetic mean : In this model, different water quality components are multiplied by a weighting factor and are then aggregated using simple arithmetic mean (eq. (1)).

$$\text{WQI} = \sum_{i=1}^{n} SIi \times Wi \qquad (1)$$

where WQI = water quality index, SIi = sub-index i, n = number of sub-indices, Wi = weight given to sub-index i.

(b) Weighted geometric mean : Similar to arithmetic weighted mean, each water quality component is weighted by a power factor, and then WQI is calculated using the geometric mean procedure (eq. (2)).

$$\text{WQI} = \prod_{i=1}^{n} SIi \times Wi \qquad (2)$$

where WQI = water quality index, SIi = sub-index i, n = number of sub-indices, Wi = weight given to sub-index i.

(c) Un-weighted harmonic square mean : This model is considered an improvement over the weighted arithmetic mean and the weighted geometric mean. This allows the most impaired variable to impart the greatest influence on the water quality index and acknowledges that different water quality variables will pose differing significance to overall water quality at different times and locations (eq. (3)).

$$\text{WQI} = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SIi^2}}} \qquad (3)$$

where WQI = water quality index, SIi = sub-index i, n = number of sub-indices, Wi = weight given to sub-index i.

Water quality index helps in assessing the potability of the water. Climatic changes, global warming, industrialization and urbanization led the decrease in the availability of fresh water resources. This also caused deterioration of the quality of the water. Most the fresh water aquifers available were becoming contaminated. And it was also found that most of the developing and developed countries also facing problems with usage of contaminated ground water. Indian being a developing country of the century is vulnerable to water scarcity. According to the statistics given by Ministry of Water Resources, Government of India, Indian sub-continent is endowed with diverse geological formations from oldest achaeans to recent alluviums and characterized by varying climatic conditions in different parts of the country. The natural chemical content of ground water is influenced by depth of the soils and sub-surface geological formations through which ground water remains in contact. In general, greater part of the country, ground water is of good quality and suitable for drinking, agricultural or industrial purposes. Ground water in shallow aquifers is generally suitable for use for different purposes and is mainly of calcium bicarbonate and mixed type. However, other types of water are also available including sodium-chloride water. The quality in deeper aquifers also varies from place to place and is generally found suitable for common uses. There is salinity problem in the coastal tracts and high incidence of fluoride, arsenic, iron and heavy metals etc. in isolated pockets have also been reported. The distributions of various constituents present in ground water in different parts of the country. Andhra Pradesh with thirteen districts and with a coastline of 900 km becomes a residual state after the reorganization of the state into two such as Telangana and residual Andhra Pradesh. Industrial, educational, medical and government organizations are stepping forward to establish all new assets in residual Andhra Pradesh. This may increase demand for fresh water for human consumption. It was also planned to develop coastal industrial belt in the state. In the light of these facts a study was carried out by the authors to assess the quality of ground water of seven chosen coastal villages of Vizianagaram district, Andhra Pradesh. In literature it was found that earlier researchers conducted experimentation to assess the water quality of ground water based on WQI method globally.

Experimental

Study area :

Vizianagaram district covers geographical area of 6539 sq. km. The district is a part of the Northern Coastal plains of Andhra Pradesh and lies in between 17.51–19.15N latitudes and 83.00–83.45E longitudes (Fig. 1). The normal annual rainfall of the district is 1131 mm. The district gets benefit from both the South West and North East monsoon. The district was found to be with semi-arid and hard rock structures. The district has rich sources of granite, mica and manganese ore deposits. The district has a coastline of 28 km; the two coastal mandals of the district are Bhogapuram and Pusapatirega. These two mandals have many villages and panchayats. Seven villages from the two mandals were selected for the present study based the population of the villages, as water quality has an important role to play with the health of the residents of the villages. In total 35 sampling stations were identified for the analysis of ground water from all the chosen villages.

Methodology :

Composite sampling procedures were adapted for the collection of ground water samples from the chosen villages. Analysis of the ground water samples from these sampling stations were carried out for twelve months. Standard methods prescribed by APHA[15] were followed for the analysis of water samples. Table gives details of the methods used for the analysis of various parameters.

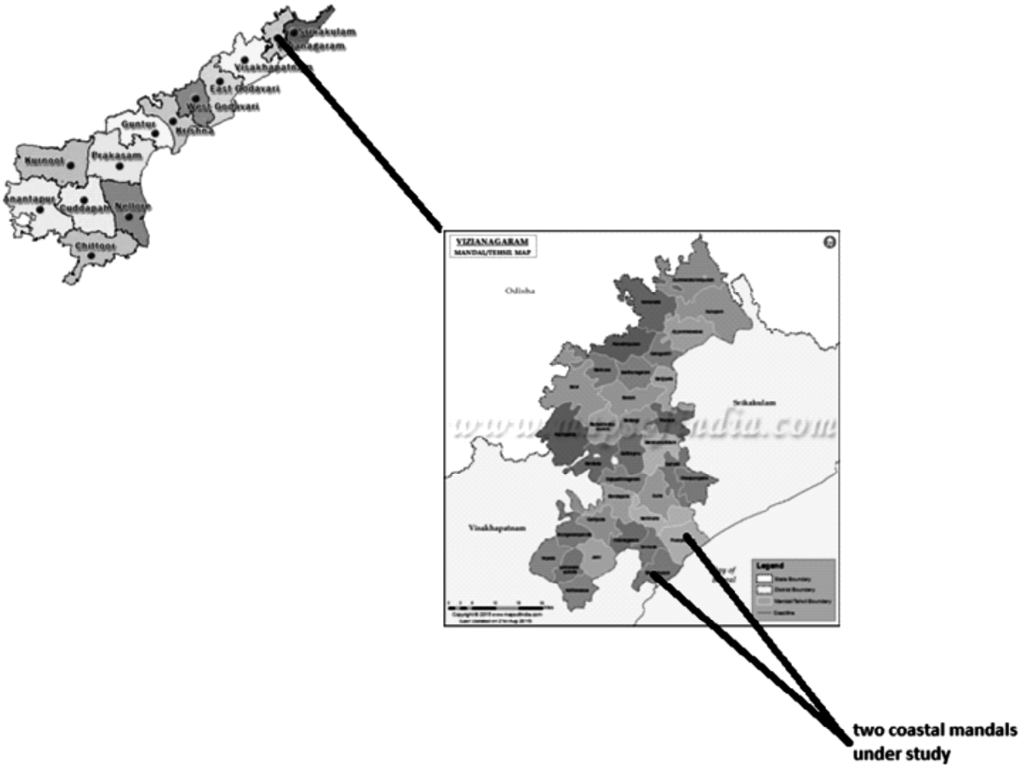

Fig. 1. Maps depicting the areas under study.

Sr. no.	Name of the parameter	Method adapted	Instrument/ equipment used
1.	pH	Instrumental	pH meter
2.	EC	Instrumental	Conductivity meter
3.	TDS	Instrumental	TDS meter
4.	Total hardness	Volumetric method	Glassware
5.	Calcium	Volumetric method	Glassware
6.	Magnesium	Volumetric method	Glassware
7.	Sodium	Instrumental	Microprocessor based flame photometer
8.	Potassium	Instrumental	Microprocessor based flame photometer
9.	Chloride	Volumetric method	Glassware
10.	Fluoride	Instrumental	Fluoride ion selective electrode
11.	Nitrite	Instrumental	Nitrite ion selective electrode
12.	Total alkalinity	Volumetric method	Glassware

Water quality index calculations were carried out by using weighted arithmetic mean method. Unit weight of each of the selected parameter was calculated. From these calculations WQI was calculated. Chatterji and Raziuddin[16] established standards to assess the quality of water based on WQI values. According to them if WQI value is in the range 0–25 they stated that the water is "Excellent" in quality, if the value is 25–50 the water quality is rated as "Good", if the value is 50–75 then the water is "Poor" in its quality, if the value is in the range 76–100 the quality of the water is "Very poor" and if WQI value is greater than 100 then the water is "Unsuitable for drinking".

WQI for the ground water of the chosen seven villages was calculated and compared with the standards as mentioned above.

Prediction of WQI using ANN :

In literature[17–19] it was found that Artificial neural networks (ANN) program was used to predict the water quality of the water samples analyzed. ANN tool box in MATLAB was used to compute the results obtained. The complete procedure for the same is as follows. Back propagation method was adopted for running the program ANN in MATLAB. The network created was trained by TRAINGLM model. For the network to run, physico-chemical parameters analyzed for ten months were given as inputs, Water quality index (WQI) computed for hr same ten months were taken as targets. Physico-chemical parameters of rest of the two months were given as samples to predict the WQI. WQI for the two months were also computed and checked with the predicted values by ANN model. The testing and validation regression analysis was computed by the ANN model. R^2 values for the same were found to be well within the prescribed limits.

Results and discussion

Water quality analysis was done for twelve seasons from June 2015 to May 2016. A complete WQI data is presented in Table 2.

Table 1. Comparison between the ANN predicted and experimented values of WQI

	01-04-2016		01-05-2016	
	Predicted	Expt.	Predicted	Expt.
V1	132.5	132.7	134.7	134.9
V2	137.5	137.8	140.4	140.6
V3	132.1	132.4	167.2	167.3
V4	133.1	133.3	134.7	134.9
V5	142.1	142.4	142.3	142.5
V6	132.2	132.4	134.7	134.9
V7	136.8	137	140.3	140.5

Table 2. WQI values of the ground water of all the seven villages under study in different seasons

	V1	V2	V3	V4	V5	V6	V7
S1	135.1	127.1	118.3	125.5	127.3	118.7	130.1
S2	134.7	135.03	132.3	124.5	134.8	132.3	130.1
S3	136.4	130.1	136.4	136.4	130.1	136.5	134.3
S4	129.4	133	126.8	129.4	133	126.8	129.6
S5	131.8	132.3	131.8	131.8	132.05	131.6	132.3
S6	131.8	131.8	132.4	131.8	131.9	132.3	134.6
S7	129.1	147.05	129.3	129.3	131.5	129.3	130.1
S8	134.6	136.1	131.7	134.6	133.9	131.9	130.1
S9	129.3	141.1	132.9	129.4	141	132.5	133.2
S10	134.4	136.1	134.8	134.5	135.9	134.8	137.7
S11	132.7	137.8	132.4	133.3	142.4	132.4	137
S12	134.9	140.6	167.3	134.9	142.5	134.9	140.5

pH of water samples was found to be alkaline in nature. pH of water samples was found to be in the range 7.6–9.2 for the water samples analyzed during all the twelve seasons under study. Electrical conductivity of the water samples under study were found to be in the range 1000–1585 µS/cm. These values were found to be higher and found to be beyond the acceptable limit of BIS. These values are may be due to the mixing of sea water into the fresh water aquifers of the villages under study. The distance between the sea coast and the villages under study was found to be less than 1.0 km. Hence every chance of mixing of salt water into the fresh water aquifers is feasible. In every season under study, total hardness of water, concentration levels of calcium, magnesium, chloride, sodium and potassium were also found to be beyond the permissible limits prescribed by BIS. Higher concentrations of all the parameters are due to unhygienic surroundings, contamination of ground water due to seepage and sewage fed into the fresh water aquifers in the villages. From all the values of physico-chemical characters, it was found that all parameters were found to be beyond the permissible limits prescribed. From these data it is concluded that the water is unsuitable for human consumption either for drinking or for industrial, agricultural purposes.

From the WQI calculations it was found that the ground water of the chosen villages was unsuitable for drinking as the WQI value was found to be greater than 100 in all the villages in every season under study. In the villages Chintapalli and Pallanki the highest value of WQI was found during August 2015. The highest value of WQI as 147.05 was observed during December 2015 for the village Chepalakancheru. During May 2016, highest values of WQI were found in the villages of Dallipeta, Mukkam and Pathivada. In the village Konada the highest value of WQI was found during January 2016. A comparative study on the seasonal variation in WQI in each of the villages under study was presented in Figs. 2–8. Fig. 9 gives a complete comparison between the WQI values of all the villages under study during all the seasons. Sudhakar Gummadi *et al.*[20] presented in their research paper that, a WQI value of 121.87 for all the ground water samples analyzed from Bapatla mandal of Prakasam district, Andhra Pradesh. Whereas the east coast of Krishna district was found to have WQI values lies in the range of 17.89–134.49 for the ground waters of Bapulapadu mandal. The authors of the paper concluded that the water under study was found to be poor in its quality and unfit for human consumption[21]. Packilakshmi *et al.*, presented in their research article that the ground water of Sholingur area of Kanchipuram district of Tamilnadu was found to unfit for

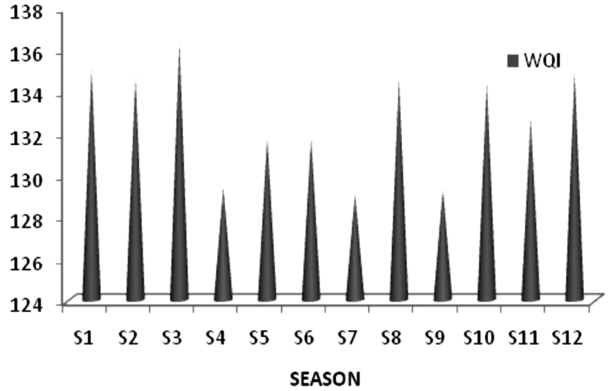

Fig. 2. Seasonal variation in WQI for the village Chintapalli.

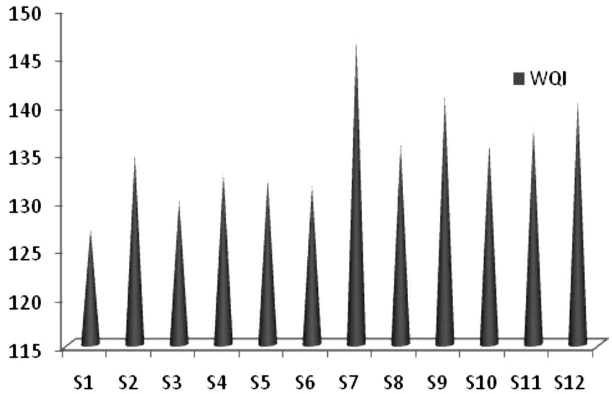

Fig. 3. Seasonal variation in WQI for the village Chepalakancheru.

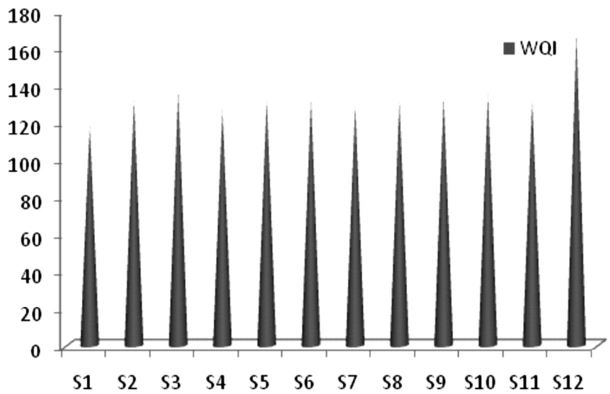

Fig. 4. Seasonal variation in WQI for the village Dallipeta.

human consumption based on the WQI value, and the WQI values were found to be beyond 110.8[22]. The ground water quality of Kakinada, costal area of East Godavari district was assessed and found to be in the range 49.52–123.54, the authors concluded that the ground water of the study area is unsuitable for human consumption due to

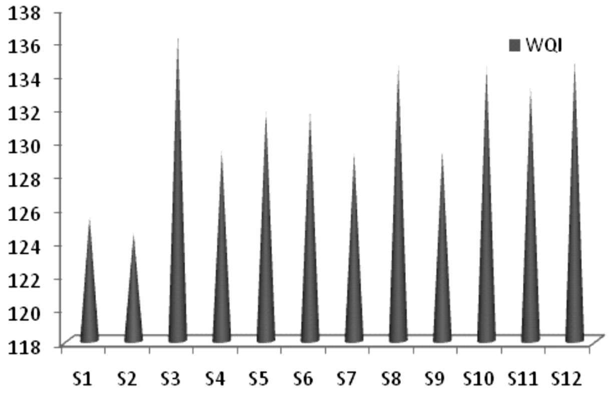

Fig. 5. Seasonal variation in WQI for the village Konada.

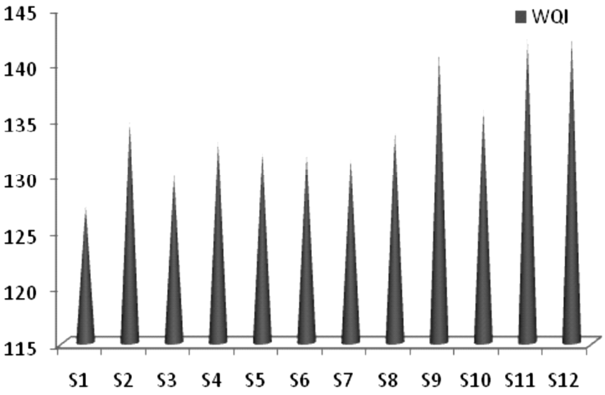

Fig. 6. Seasonal variation in WQI for the village Mukkam.

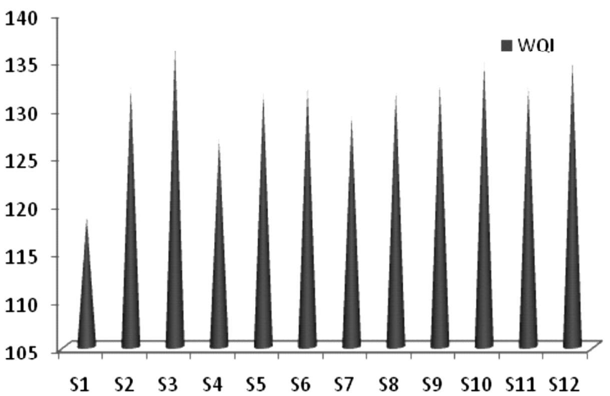

Fig. 7. Seasonal variation in WQI for the village Palanki.

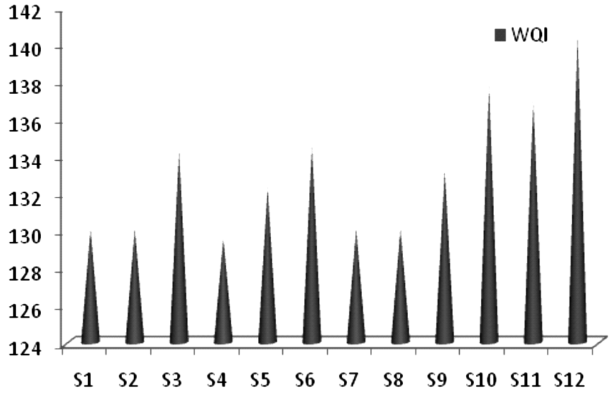

Fig. 8. Seasonal variation in WQI for the village Pativada.

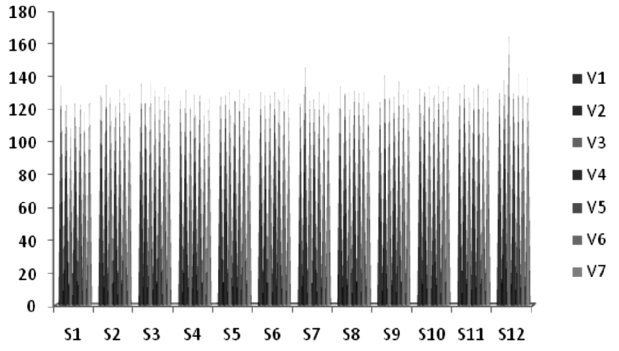

Fig. 9. Comparative study on the seasonal variation in WQI for all the villages.

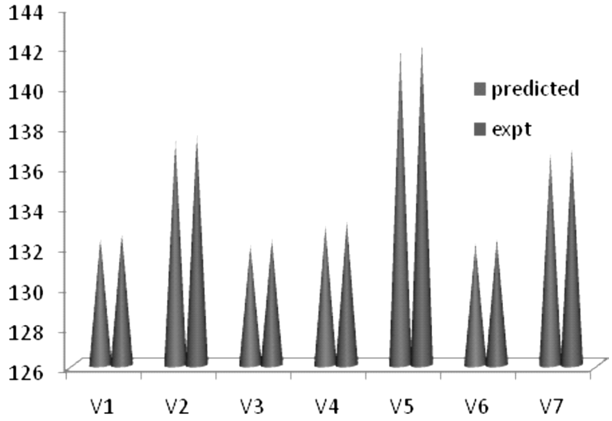

Fig. 10. Comparative representation of ANN predicted and experimented WQI values during April 2016.

its poor quality[23]. In a study carried out by Vishnupriya Sowjanya I., to assess the ground water quality of selected coastal villages of Visakhapatnam district of Andhra Pradesh, found to have WQI values greater than 75 and it was concluded that the ground water of the villages is unfit for human consumption[24]. Rammohan H. *et al.*, presented the ground water quality status of coastal areas of Srikakulam district of Andhra Pradesh. They observed that WQI values of the ground water were found to be in the range 52.47–201.87, concluding that the water is poor in its quality[25]. From all these literature cited data, the

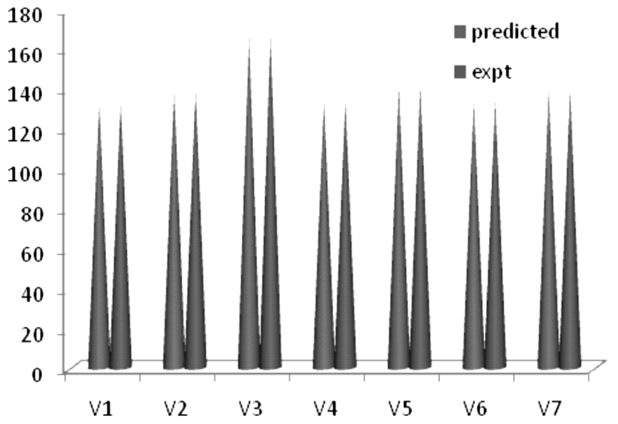

Fig. 11. Comparative representation of ANN predicted and experimented WQI values during May 2016.

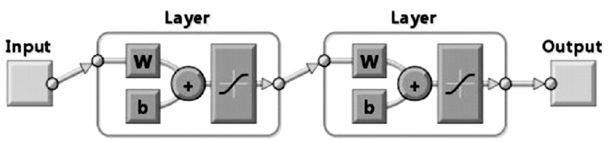

Fig. 12. ANN feed forward backdrop TRAINGM network.

ground water quality of the coastal villages of various coastal districts of Andhra Pradesh was found to be poor, based on WQI values computed. In the present study of the authors a strong resemblance with the reported WQI values and status of water quality of the ground water was noticed.

Back propagation method and TRAINGLM was followed for all the seven villages under study. The network created by the ANN tool for the model under study was represented in Fig. 12, Fig. 10 and Fig. 11 gives a comparison between the WQI predicted by ANN and the experimentally computed values, in two months April 2016 and May 2016 respectively. Testing and validation regression analysis plots were presented in Fig. 13. Table 1 gives a comparative analysis for the WQI predicted by ANN and experimentally computed values.

Conclusions

Water quality index (WQI) values for the ground water of the seven coastal villages chosen were computed.

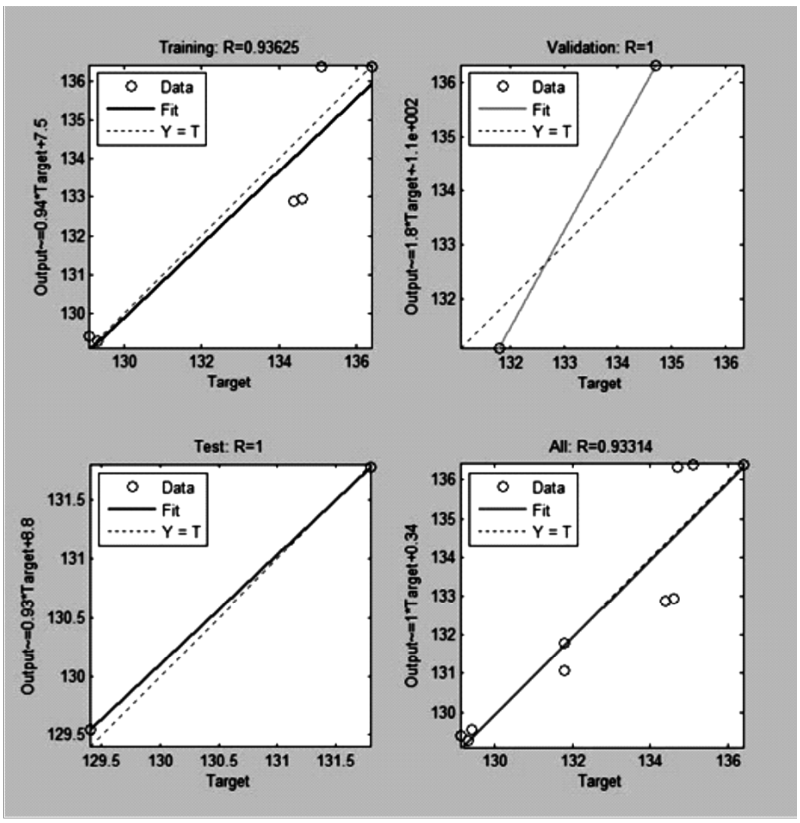

Fig. 13. Regression equation for different parameters by ANN.

And the same was predicted by using ANN tool in MATLAB. The WQI values for the ground water in all the twelve months was found to be greater than 100, from this data it is concluded that the water is "poor" in its quality and "unfit" for human consumption. An average error of 0.15% was observed on comparison with the ANN predicted and experimentally computed WQI values in all villages under study in the two months April 2016 and May 2016. R^2 value for the validation and testing was found to be 0.98 and 0.99 respectively. This concludes that the ANN model used for prediction was found to be apt.

Acknowledgement

The authors are thankful to University Grants Commission, New Delhi, Government of India for the financial support provided under Minor Research Project (UGC MRP 6311-15/SERO). The authors are also thankful to the management and the Principal MV GR College of Engineering (A), Vizianagaram, for their constant support and encouragement.

References

1. W. W. Miller, H. M. Joung, C. N. Mahannam and J. R. Garret, *J. Environmental Quality*, 1986, **15**, 265.
2. Oregon water quality data summary, June 2009.
3. Oregon water quality data summary, June 2008a.
4. D. Hallock, "Results of the 1990 water quality index analysis", Washington, USA, 1990.
5. CCME, Canadian Environmental quality guidelines technical report 1.0, 2001.
6. P. W. Bolton, *Water Pollution Control*, 1978, 271.
7. D. S. Bhargava, *Environmental Pollution (B)*, 1983, **6**, 51.
8. M. A. House, *Journal of the Institute of Water and Environment Management*, 1989, **3**, 336.
9. M. K. Mitechll and W. B. Stapp, "Field management for water quality monitoring", Thomson Shore Inc, Dexter, Michigan, 1996, 277.
10. S. F. Pesce and P. A. Wunderland, *Water Research*, 2000, **34**, 2915.
11. C. Cude, *Journal of the American Water Resources Association*, 2001, **37**, 125.
12. S. Liou and S. Wang, *Environmental Monitoring and Assessment*, 2004, **96**, 35.
13. A. Said, D. Stevens and G. Selke, *Environmental Management*, 2004, **34**, 406.
14. F. Nasiri, I. Maqsood, G. Hang and N. Fuller, *Journal of Water Resources Planning and Management*, 2007, **133**, 95.
15. APHA, "Standard methods for the examination of water and waste water", American Public Health Association, Washington DC, 1999.
16. C. Chatterjee and M. Raziuddin, *Nature, Environment and Pollution Technology*, 2002, **1**, 49, 181.
17. Sujana Prajith Kumar, Swetha Verma and B. V. Mahajan, *International Journal of Engineering Research and General Science*, 2015, **3**, 652.
18. M. J. Diamantopoulu, V. Z. Antonopoluos and D. M. Papamichali, *European Water*, 2005, **11/12**, 55.
19. Pallavi D. ALte and Parag A. Sadgir, *Interntional Journal of Advances Foundation and Reserch in Science and Engineering*, 2015, **1**, 278.
20. Gummadi Sudhakar, G. Swarnalatha, G. Venkataramanamma and Z. Vishnuvardhan, *International Journal of Environmental Science*, 2014, **5**, 1.
21. K. Sundara Kumar, Ch. Satish Kumar, K. Hari Prasad and B. Rajesh, *International Journal of Innovative Research in Advances in Engineering*, 2015, **3**, 103.
22. S. Packilakshmi, Meheli Deb and Hrituparna Chakraborty, *Indian Journal of Science and Technology*, 2015, **8**, 1.
23. J. Srinivs, A. V. Purushotham and K. V. Murali Krishna, *International Research Journal of Environmental Sciences*, 2013, **2**, 37.
24. Vishnupriya Sowjany I., B. V. Param and P. S. Rajasekhar, *International Journal of Innovative Research in Science Engineering and Technology*, 2015, **4**, 12
25. H. Ammohan, I. Sudhakar, P. Suresh Patnaik and A. Udayasree, *International Journal of Environmental Sciences*, 2016, **6**, 5.