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Predicting the Quality of Treated Water from an Activated Carbon Based Water Purifier Using Artificial Neural Network

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Abstract: Automated water purifier is a convenient and widely used device for obtaining purified water. However, performance of a system may vary over time and therefore monitoring of the treated water is essential for ensuring the quality control. In this study, a number of input and output samples of an activated carbon based water purifying system were monitored to check its efficiency. Overall quality of the inflow and outflow of the purifying system were assessed by Weighted Arithmetic Water Quality Index with ideal permissible limits of the water quality parameters as per Indian Council of Medical Research guidelines. Results indicate that the quality of the water enhanced significantly after purification. A model was developed from the water quality data with Artificial Neural Network to predict the quality of the water, treated by the purifier. The model was tested with more water quality data and found to be successful in prediction of the overall quality of the treated water fairly accurately.

Key words: Water quality, water purification, water quality index, activated carbon, artificial neural network.

Introduction

As natural water is not always fit for domestic purposes, purification of the source water is necessary to make it suitable for use. Activated carbon is the most popular purifying substance used in water purifiers due its high efficiency, low cost (Amirault et al., 2003) and ease of use (Lemley et al., 1995). However, as activated carbon purifies water by adsorption, its surface gets saturated on prolong use (Lemley et al., 1995). Also, it cannot remove microbes from water. For availing drinking water, therefore, a sterilizing system (e.g. UV filter, chlorine filter etc.) must be used in combination with activated carbon filter. Activated carbon purifiers can safely be used for purification of most natural surface water or groundwater.

Water Quality Index (WQI) is a useful tool to express the overall quality of water in concise and lucid manner (Roy et al., 2017). WQI is calculated from the concentrations of different water quality parameters (WQP) of the sample water. There are different methods of calculating WQI (e.g. National Sanitation Foundation WQI (NSFWQI), Oregon WQI, Weighted Arithmetic WQI (WAWQI), CCME WQI etc.) for different purposes. Being a numerical expression, WQI is easy to conceive, convey and interpret (Roy et al., 2017).

Artificial Neural Network (ANN) is a mathematical model, inspired by biological neural network in brain. Such models enable a system to be trained automatically by a set of input and output data (McClelland et al., 1986). A relation between input and output is developed by iteration modelling by putting adaptive weights in the multiple neural layers (Agatonovic-Kustrin and Beresford, 2000). ANN develops a relation between a given set of input and output through regression analysis (Specht, 1991). ANN has been used for forecasting of water quality (Goyal et al., 2015), prediction of some WQP from some other WQP (Khandelwal and Singh, 2005; Swathi and Lokeshappa 2015; Roy and Majumder, 2018b) and prediction of hardness (Sirisha et al., 2008; Roy and Majumder, 2018a).

In the present study, water qualities of a number of samples were assessed by WAWQI before and after purification to check the efficiency of the purification system. An ANN model was then developed from the water quality data to predict the quality of the purified water.

Methodology

Assessment of Water Quality

Water quality data of a number of samples were assessed by sensor-based multiparameter water quality monitoring devices before and after purification of water by an activated carbon based water purifier. The overall qualities of both sets of samples were determined by WAWQI (Tyagi et al., 2013) using the equations, given below:

$$WAWQI = \frac{\Sigma_{i=1}^{n} W_i Q_i}{\Sigma_{i=1}^{n} W_i} \quad (1)$$

$$Q_i = \frac{(V_i - Vo)}{(S_i - V_o)} \times 100$$

$$W_\mathrm{i} = \frac{K}{S_i}$$

$$K = \frac{1}{\Sigma(1/S_\mathrm{i})}$$

where Q_i = Quality rating for i^{th} WQP, W_i = Weight associated with i^{th} WQP, n = Total number of WQP considered, V_i = Concentration of i^{th} WQP, V_o = Ideal concentration of i^{th} WQP in pure water, S_i = Recommended standard concentration of i^{th} WQP, and K = Proportionality constant.

Four WQP, viz. pH, electrical conductivity (EC), turbidity (Turb) and total dissolved solids (TDS), were used to determine the overall quality of water in this study. The recommended concentrations of the WQP were taken as per the Indian Council for Medical Research (ICMR) guidelines (Yogendra and Puttaiah, 2008).

Development of Prediction Model

Different ANN models were developed with the water quality data before and after purification, using different ANN methods like Combinatorial (COM), Stepwise Forward Selection (SFS), Stepwise Mixed Selection (SMS) and GMDH Neural Network (GNN).

COM method utilizes the polynomial functions of linear parameters (Anastasakis and Mort, 2001) for prediction. In SFS method, however, suitable variables are being included till the model is optimized (Lancashirea et al., 2008). SMS functions similarly as SFS, but variables are both included and excluded in this method (Anastasakis and Mort, 2001). GNN is another regression analysis method where layers of neurone connections are formed. Those layers are then optimized by COM algorithm (Anastasakis and Mort, 2001).

Models were developed to predict the concentrations of WQP in the purified water from those in the supply water, using different ANN methods. WQI of different samples were predicted in two ways:

(i) WQI of the purified water were predicted directly from the WQI of the supply water by ANN models.
(ii) WQP values of the purified water were predicted by ANN and WQI were then calculated from those predicted values of WQP.

Suitability of Models

The predicted values from all the models were compared with the respective actual values to check the accuracy of the models. Correlation coefficient between each set of actual and predicted values were determined to assess how close they are. The closer the predictions to the actual are, the better the model is.

Results and Discussion

Purification Efficiency

200 samples were monitored for determining the concentrations of the WQP for assessment of the quality of water. The average quality of supply water was found to be excellent and that of purified water was even better (Table 1). On average, the purifier was able to improve pH by 0.85% and EC by 5.02% and to remove 5.32% TDS (Table 1). The purifier also completely removed the turbidity of the supply water (Table 1).

Table 1: Comparison of the average values of WQP of the supply and purified water

Source	*pH*	*EC*	*Turb*	*TDS*	*WAWQI*
Supply	6.4216	0.0602	10.84	0.03912	14
Purified	6.476	0.05718	0	0.03704	12
%Diff	0.85	5.02	100.00	5.32	14.29

Units: EC – mS/cm, Turbidity – NTU, TDS – g/lit

Thus, the purifier improved the overall quality of water by 14.29% (Table 1) on average. The purifier was, therefore, fairly efficient in purification of water.

Prediction of WQP

Different models were then developed to predict the WQP values of purified water from those of supply water. As the purification system removes turbidity completely, no model was developed to predict the turbidity of the purified water. As the predicted values of the WQP were very close (i.e. highly correlated) to the actual values (Table 2), the prediction models can be considered to be successful in prediction of WQP values of the purified water.

Table 2: Accuracy of prediction of WQP by different ANN models

ANN method	*Correlation of model fit with actual values*			*Mean correlation*
	pH	*EC*	*TDS*	
COM	0.893775	0.831001	0.767938	0.830905
SFS	0.893794	0.831001	0.767938	0.830911
SMS	0.893747	0.831001	0.767938	0.830895
GNN	0.647995	0.830931	0.767938	0.748954

Among all the ANN methods used, SFS was found to be best in prediction of WQP (Table 2)

Direct Prediction of WQI

The WQI of both supply and purified water were determined by WAWQI. Different ANN methods were then used to predict the WQI of the purified water directly from that of the supply water (WQI Direct) (Table 3). The actual WQI of the purified water were used as the training data set for the ANN models.

Low correlation between the actual and predicted dataset (Table 3) indicates that direct prediction of WQI is not very suitable using any of the ANN methods used.

Prediction of WQI from Modelled WQP

The WQI of the purified water were also calculated from the WQP values, predicted by different ANN methods (WQI Parameter). The WQI calculated from the predicted WQP were found closer to the actual values than the WQI predicted directly (Table 3). However, the correlation between actual and predicted WQI were found to be low for both the methods (Table 3).

Among all the ANN methods used, SFS was again found to be the best in prediction (Table 3).

Table 3: Prediction of WQI of purified water by different methods

ANN method	*Correlation of model fit with actual values*		*Mean correlation*
	WQI direct	*WQI parameter*	
COM	0.0526	-0.1631	-0.0555
SFS	0.0526	-0.1636	-0.0556
SMS	0.0526	-0.1638	-0.0553
GNN	0.0526	-0.0604	-0.0039

So, calculation of WQI from the predicted WQP is preferable over predicting it directly from the WQI of supply water. Such prediction can be obtained best by SFS ANN method.

Conclusion

It was found from the study that activated carbon is successful in complete removal of turbidity and improving the overall quality of water. Among the ANN methods used to predict the WQP and WQI, the SFS method was found to be best. The ANN methods were successful in prediction of individual WQP fairly accurately, but not much successful in prediction of overall quality of water. Thus, it is better to calculate the WQI from the predicted WQP than to predict the WQI directly by ANN methods.

However, different quality of input water, another indexing method or larger sample volume might have produced different results.

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