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Prediction of the Pollutants Concentration Using Artificial Neural Network (ANN)

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Abstract

Air pollution is one of the most important environmental issues that annual causes to mortality large number of people around the world. So, investigating, measuring, and predicting the concentrations of different pollutants in various areas play an important role in preventing the production of this pollutant sand planning to reduce them by people and relevant authorities. One of the new models that play an important role in measuring and predicting pollution is artificial neural network or regression methods. Therefore, this study is trying to predict air pollution in Yasouj by using artificial neural network in 2014. Because the evidences showed that Yasouj due to uncontrolled growth of industrial and urban transport is subject to various air pollutants such as carbon monoxide and particulate matter. Overall, the results of the assessment and prediction of concentration of pollutants of Yasouj by artificial neural network showed that sigmoid transfer function to the hyperbolic tangent function is more efficient in measuring the concentration of pollutants.

Keywords:air pollution, particulate matter, Yasouj city, artificial neural network, stepwise regression.

Introduction

Air pollution is one of the most important environmental issues that in recent decades, particularly with the development of the industrial revolution, the rise in urbanization coupled with population increase and indiscriminate use of fossil fuels human society is facing (Ziaee, et al., 2010). Air pollution is then trance of one or more of the contaminant to the open air or change in the natural ratio of its components, so that be harmful to humans or other living organisms, damage to monuments and textilesor threaten the comfort and safety of human life. This phenomenon which annually causes the deaths of a large number of people around the world is of great importance so that today, different laws and conventions on the control and prevention of this phenomenon have arisen around the world (Falahati, et al., 2013). One of the most terrible events that had occurred as a result of air pollution is the death of more than 4,000 people in London in 1952 caused by acidic smog (Afyuni, et al., 1999).Therefore, the effects of air pollution on human health have been consider by researchers and the public from the past. Thus in many industrial and developed countries in order to protect human health and prevent environmental degradation, air pollution control programs from the first decades of the twentieth century have been used (Alkasassbeh, et al., 2013). Air pollution is a major environmental issue that most of the major cities in the world, especially in third world countries are facing. Considering the importance of air pollution, predicting it in urban areas, because of its impact on human health, is one of the most important issues in environmental researches. Basically, the evidences show that pollutions with high concentrations lead to bad effects and premature death of sensitive and vulnerable groups of the society, including children, the elderly and those suffering from respiratory diseases and asthma (Tiittanen, et al., 1999).Yasouj is the center of Kohgiluyeh and Boyer-Ahmad province and is one of the important cities of Iran that due to geographical conditions and its natural position is subject to various air pollution caused by transportation of cars and factories and various constructions. Also, in recent decades with the arrival of dust phenomenon in the country, this city is not excluded of the harmful effects of this phenomenon, especially in summer and autumn.

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Therefore, check the status of air pollution in the city in terms of various pollutants and assess the impact of various factors, including climatic factors on the concentration of air pollutants can be very effective in comprehensive programming that is done now and in the future in order to control and reduce air pollution in this city. Basically, the evidences suggest that among the pollutants of Yasouj particulate matter, carbon monoxide and nitrogen oxides, for reasons such as the use of old cars, large transportation, various constructions and extensive use of fossil fuels, are more important. Therefore, according to what was said, predicting pollutant concentrations of Yasouj by using scientific methods available is important. Some of these methods are artificial intelligence or regression methods.

Today, forecasting and modeling air quality parametersisan important topicof human society. Because, this issue is directly related to the health and wolf are of human society. So, according to what was said, predicting air pollution by using new scientific models rather than traditional methods is necessary. Mean while, in recent years, artificial intelligence has replaced the previous scientific traditional methods and artificial neural network is one of the most popular ways of artificial intelligence so that uses mathematical models of the human brain as simple as a system.
These networks are typically trained with the training data. They are able to discover new connections, new functions, or new patterns and because of the above features have been widely used compared to traditional methods. Especially, the using of the multilayer perceptron network to predict the air quality in recent decades has been conducted by many studies on the basis of it (Bodaqpur, et al., 2011). Therefore, this study attempts to forecast air pollution of Yasouj by using artificial neural network. Researches show that so far, despite the various sources of pollution and pollution from particulate matter and ... a careful study on the pollution of this city has not been done. Therefore, according to the mentioned topics such research to evaluate air pollution in Yasouj and forecast it by using artificial neural networks is essential. It is hoped that this study may be a beginning for other future researches.

Material and Methods

In this study the relationship between various meteorological parameters such as temperature, rainfall, wind speed with air pollutants (particulate matter and carbon monoxide and nitrogen dioxide) are investigated. So, determining the meteorological parameters affecting the air pollution and measuring its effect can be important for estimating the pollution. One of the data-driven models which has recently attracted much attention is artificial neural networks, that in this study by using this model the concentration of particulate matter and nitrogen dioxide, and carbon monoxide in Yasouj is estimated. This model has its own advantages, including the ability to simulate nonlinear systems, high precision and less time to make the model and its calculation.

The Studied Area

Yasouj is a city in southwestern Iran and is the center of Kohgiluyeh and Boyer Ahmad which is located in northeast of the province. Yasouj is located in the geographical coordinates 30 degrees and 28 minutes north latitude and 51 degrees and 36 minutes Eastern longitude from Greenwich meridian and near the Beshar river at an altitude of 1870 meters above sea level. That, today this city due to its geographical location and the increasing development of urban is threatened by various pollutions caused by transportation and different factories.

Required Statistics and Information

In this study, in order to collect the required data, first all stations of measuring air pollution and meteorological stations in Yasouj were identified. Then, by going to the Department of Environment and Meteorological Agency of Yasouj Information on air pollutants and meteorological parameters in 1393, the needed data were collected.

Convert Amount of Data to Daily Average

Basically, given that the Meteorological Agency data for some parameters is as the 3 hours and for some other parameters is as the daily average and also since the data related to the Department of Environment for air pollutant concentrations is as one hour, so in this research in order to use data at the same time, they are converted to daily average.

Artificial Neural Network

Artificial neural network is a computational method that with the help of learning process and the use of simple processors called neurons by recognizing in herent relationships between the data tries to providea mapping between input space (the input layer) and optimal space (the output layer). In the artificial neural network try to design a structure similar to the biological structure of the human brain and body network that like it have the power of learning, generalization and decision-making. Hidden layer or layers, processes the data received from the input layer and provides to the output layer. Each network is trained by receiving examples. Education is a process that eventually leads to learning. Learning of network is done when communication weights between the layers change so that the differences between predicted and measured values are acceptable. By achieving this condition, the learning process has been realized. These weights express the memory and knowledge of the network. The trained neural networks can beused to predict outputs commensurate with the new set of data (Menhaj, 2004).

The conducted researches indicate that the Feed-forward multilayer perceptron network by Error Back-propagation Learning rule is the simplest and most widely used type of neural network that is appropriate for the estimation of unknown parameters. This type of network has an input layer, one or more hidden layers and an output layer. Input parameters are located inthe first layer and output parameters are located in the third layer. In feed-forward Back-propagation network first the weights of the output layer are adjusted, because for each of the neurons of outer layer there is desirable value that can adjust the weights. After calculating training error by network, its value is compared with the desired value and learning algorithm optimizes the amount of the related error. If the training errorbe less than the determined error, the learning process is ended. In the training phase first the calculations are done from network input to its output and then the calculated error values spread to the previous layer. First the output calculation is done layer by layer and output of each layer will be input of the next layer. The structure of an artificial neural network is characterized by determining the number of layers, the number of neurons in each layer, the driving function (controller of output of each neuron), training method, weight correction algorithm and the type of model (Aliyari, et al., 2009).

To run the neural network, first and before the training, data are standardized and then entered into the model. The importance of standardization is in the integration of units of data used inartificial neural network model. The following equation is used for standardization.

$$N_i = \left[\left(\frac{X_i - \mathrm{X_{min}}}{\mathrm{X_{max}} - \mathrm{X_{min}}}\right) \times 0.8\right] + 0.1$$

Here: N_i is normalized data; X_i is preliminary data, X_{max} the largest data and X_{min} the smallest data. Then the data were divided into three parts, so that 70 percent of data was used for training, 15% was used for Validation and 15% for the test (Wang, et al., 2009). Finally, data were entered into the artificial neural network. As noted above, the artificial neural network consists of three layers of input, hidden and output. Measurements features of meteorological variables that have been selected are entered to the network as input layer, the hidden layer is selected by trial and error until the output of the network which is the amount of air pollutants, be achieved and compared with the amount of observational pollutants.

The Training Phase

Training phase is to determine the patterns between dependent and independent variables, which is trained at this stage according to the desired algorithm of the network. The best training algorithm is Levenberg-Marqurte algorithm in which artificial neural networks were used for updating weights and is one of the most widely used algorithms. Because performs training of network very fast and minimizes the level oferror. In fact, this algorithm has been designed to speed up the learning of network that is based on the Hysn matrix. It is not able that in the study the differentiable nonlinear sigmoid function and asymmetric hyperbolic tangent function is used in the hidden layer and linear function is used in output layer.

Sigmoid transfer function is used in the back-propagation networks. The transfer function receives the input values in the range of extremely positive to extremely negative and produces an

output value between -1 and 1 based on the following formula.

$$f(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$$

Hyperbolic tangent transfer function is also used in the back-propagation networks. The transfer function receives the input values in the range of extremely positive to extremely negative and produces an output value between 0 and 1 based on the following formula. Figure 1 shows Schematic of the artificial neural network used in this study.

$$f(x) = \frac{1}{1 + e^{-x}}$$

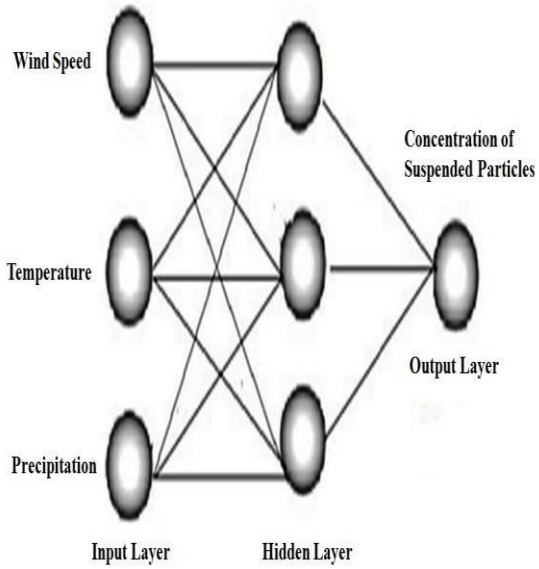

Figure 1: feed-forward network error back-propagation used in this study with architecture 3:3:1.

Evaluation of the Models

In order to compare the performance of artificial neural network with sigmoid transfer function with hyperbolic tangent transfer function the statistics of root mean square error (RMSE) and correlation coefficient (R) was used. The root mean square error (RMSE) is between zero and one, and whatever its value is closer to zero shows high accuracy of the model in estimating the concentration of pollutants. Also, in the correlation coefficient whatever is closer to one the model has more accuracy in estimating the concentration of pollutants.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(q_o(t) - q_p(t))^2}$$

$$R^2 = \frac{\sum_{i=1}^{n}(q_o(t) - \bar{q}_o(t))(q_p(t) - \bar{q}_p(t))}{(\sum_{i=1}^{n}(q_o(t) - \bar{q}_o(t))^2)^{0/5}(\sum_{i=1}^{n}(q_p(t) - \bar{q}_p(t))^2)^{0/5}}$$

In which $q_o(t)$ is the observed concentrations with the percentage of t, $q_p(t)$ is the estimated concentration with the percentage t, n is the number of observed data, $\bar{q}_o(t)$ is the average of observed concentration with the percentage of t, and $\bar{q}_p(t)$ is the average of estimated rate with the percentage of t. In this study, in all of the stations, 70 percent of data for training, 15 percent for the validation process and 15 percent of data for test, were randomly used.

Results and Discussion

The study results of the correlation between the concentrations of pollutants of Yasouj (PM, monoxide) in different seasons

The results of study, the correlation between the concentrations of carbon monoxidein different seasons in the studied area by using the Spearman test showed that there is a positive significant relation between the spring of 2014 and autumn of 2014, but there is no significant correlation between spring with summer and winter. The results showed that there is a significant positive correlation at the level of 5% between summer and autumn. In addition, there was no significant correlation between autumn andwinter (Table 1). In general, due to changes in the amount of sources of carbon monoxide in different seasons, the increase in the use of fossil fuels especially the use of heaters, and fire places in cold seasons and reduce their use in warm seasons can benoted asthe most important of these reasons. The results of study the correlation between the concentrations of particulate matter in different seasons showed that there is a positive significant correlation between the spring of 2014 with three other seasons but there was a significant negative correlation between summer and winter.

The results also showed that there is a positive and significant correlation between autumn and summer

Table 1: Correlation between the concentrations of carbon monoxide in different seasons of the year in the studied area.

Winter	Fall	Summer	Spring		
0.6	0.717	0.567	1	Correlation Coefficient	Spring-2014
0.088	0.03*	0.112	000	Sig. (2-tailed)	
9	9	9	9	N	
0.817	0.717	1	0.567	Correlation Coefficient	Summer-2014
0.007**	0.03	000	0.112	Sig. (2-tailed)	
9	9	9	9	N	
0.567	1	0.717	0.717	Correlation Coefficient	Fall-2014
0.112	000	0.03*	0.03*	Sig. (2-tailed)	
9	9	9	9	N	
1	0.567	0.817	0.6	Correlation Coefficient	Winter-2014
000	0.112	0.007	0.088	Sig. (2-tailed)	
9	9	9	9	N	

2011, autumn 2010 and spring 2011, autumn 2010 and autumn 2011, winter 2010 and autumn 2011

Table 2: Correlation between concentrations of

Winter	Fall	Summer	Spring		
0.26	0.516	0.367	1	Correlation Coefficient	Spring-2014
0.008	0.04	0.03	000	Sig. (2-tailed)	
9	9	9	9	N	
0.617-	0.417	1	0.367	Correlation Coefficient	Summer-2014
0.007	0.031	000	0.03	Sig. (2-tailed)	
9	9	9	9	N	
0.211	1	0.417	0.517	Correlation Coefficient	Fall-2014
0.002	000	0.031	0.04	Sig. (2-tailed)	
9	9	9	9	N	
1	0.211	0.617-	0.26	Correlation Coefficient	Winter-2014
000	0.002	0.007	0.008	Sig. (2-tailed)	
9	9	9	9	N	

The effect of rainfall, particularly in late autumn and winter, as well as the entry of dust phenomenon especially in the summer can be noted as the main reasons for this. The result of this study is consistent with the findings of Tavakoli, et al. (2013). As they stated between the concentration of particulate matter in different seasons in Tehran in two years, 2010 and 2011, at 5% level there is a positive and significant correlation between spring and winter 2010, spring and autumn 2010, summer and autumn 2010, winter 2010 and spring 2011, autumn and winter 2010, autumn and summer particulate matter in different seasons of the year inbut there was no significant relationship between summer and winter 2010, but this correlation was negative and significant for the year 2011.

The results of study the correlation between the concentrations of particulate matter, carbon monoxide in studied stations by using the Pearson test showed that there is a significant positive correlation between the concentrations of particulate matter with crane-monoxide (Table-3).

Table 3: Correlation between the concentrations of pollutants of Yasouj in the studied seasons.

CO	PM		
0.245	1	Correlation Coefficient	PM
0.006*	000	Sig. (2-tailed)	
365	365	N	
1	0.245	Correlation Coefficient	CO
000	0.006*	Sig. (2-tailed)	
365	365	N	

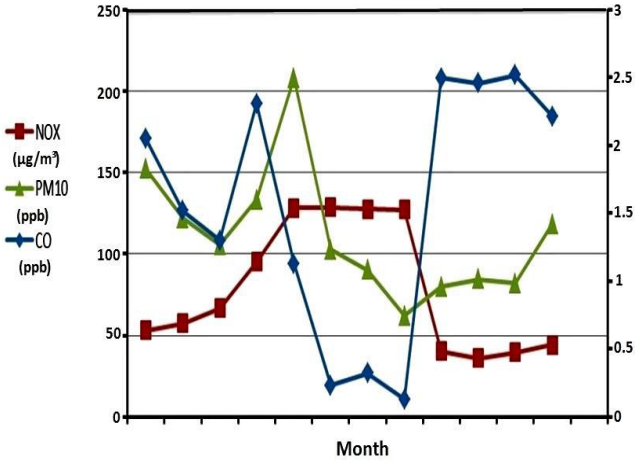

Figure 2: The study results of the monthly average concentration of pollutants of Yasouj.

The study results of the average concentration of PM and CO in different months

The results of study the monthly average concentration of air pollutants of Yasouj showed that for particulate matter August has the highest concentration to the amount of 208.3 micrograms per cubic meter, and then July is in the second place (133.23 micrograms per cubic meter). That, this is consistent with the results of Jamshidi, et al. (2006) that they stated that particulate matter concentrations respectively in summer and autumn in Gachsaran were in its highest amount of 266.3 and 111.6 micrograms per cubic meter. They expressed that the lowest amount of particulate matter in the winter is 85.7 micrograms per cubic meter, they also reported that there is a direct linear relationship between the particulate matter and the air temperature that the results of this study with their results is remarkable. In addition, in a study by Ehrampoush and Amini (1999) was conducted in Yazd, they linked the high level of particulate matter in air with the low rainfall and very low humidity in this city. Therefore, it can be said that the high level of particulate matter in summer can be partly due to these factors. The results also showed that for carbon monoxide has the highest concentration respectively in October, November, and December to the 2.6, 2.5 and 2.45 ppb. This is justifiable due to the extensive use of fossil fuels in this month.

The results of simulating the concentrations of PM and CO using Sigmoid function artificial neural network model and hyperbolic tangentIn this study, to estimate pollutant concentrations, Multilayer Perceptronnetwork with Sigmoid transfer function and hyperbolic tangent was used in the hidden layer and linear function was used in output layer.For Suitable generalization of the network, over-fitting training should be prevented. In the present study, Automated Regularization method was used to prevent over-fitting training in Multilayer Perceptron networks and for achieving this process the training algorithm Levenberg - Marqurtewas used. Coefficient of determination and root mean square was used to select the best network amongthe introduced networks. The results of artificial neural network are in Table 4. The results of the measured pollutants values including PM and CO with simulated data by ANN model in 2014 at Yasouj is shown in Figure 3.

The study results of the most important transfer function for estimating the concentration of pollutants of Yasouj, including Particulate matter and carbon monoxide show that in the studied area, sigmoid membership function for both pollutants with respect to the root mean square error (RMSE) (is between zero and one and whatever its amount be closer to zero, show the high accuracy of the model in estimating the concentration of pollutants) and correlation coefficient (whatever be closer to one) has more accuracy in estimating the concentration of pollutants. So that according to the findings the amount of RMSE and R^2 for particulate matter due to the low total squares error and the high correlation coefficient of Sigmoid

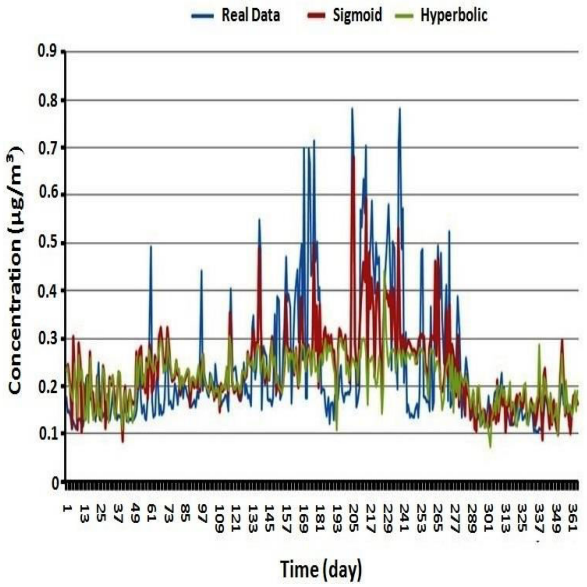

Figure 3: (a) Comparison between the measured and estimated particulate matter values in Yasouj

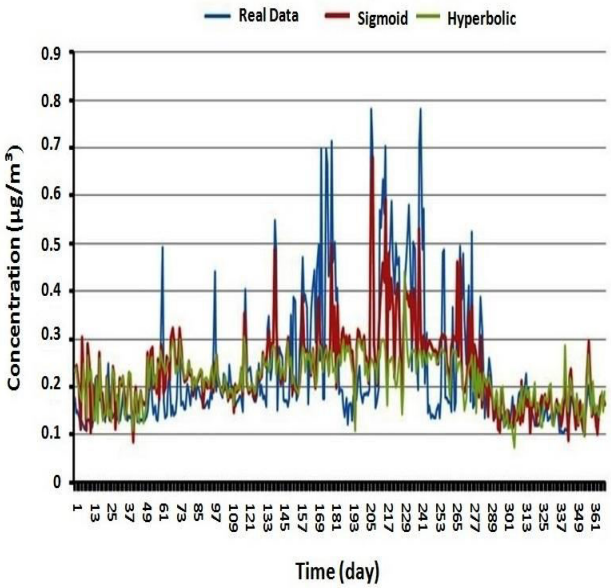

Figure 3: (b) Comparison between the measured and estimated carbon monoxide values in Yasouj

Table 4: The results of statistics of artificial neural network to estimate the concentration of studied pollutants in Yasouj.

Stages						Transfer function in the hidden layer	Network configuration	pollutant
Test		Validation		Training				
R^2	RMSE	R^2	RMSE	R^2	RMSE			
0.000	0.09	0.012	0.076	0.020	0.092	Sigmoid	3-9-1	CO
0.000	0.094	0.000	0.076	0.0225	0.091	tangenthyperbolic	3-6-1	
0.055	0.06	0.265	0.045	0.447	0.07	Sigmoid	3-2-1	PM
0.007	0.104	0.018	0.037	0.165	0.125	tangenthyperbolic	3-4-1	

transfer function, respectively, in the training phase (RMSE=0.098, R^2=0.457) in the validation phase (RMSE=0.082, R^2=0.604) and in the test phase (RMSE=0.042, R^2=0.388) is chosen as the best function. While these two factors i.e. total squares error and correlation coefficient for hyperbolic tangent transfer function, respectively, in the training phase (RMSE=0.111, R^2=0.379) in the validation phase (RMSE=0.094, R^2=0.000) and in the test phase (RMSE=0.056, R^2=0.003) and for carbon monoxide in the two stages of validation and test no significant difference was observed between the two functions, but in training stage the sigmoid function has better performance. So, it can

be said that the sigmoid transfer function in measuring and modeling the pollutants of Yasouj has better performance than hyperbolic tangent transfer function. Also, the results of sigmoid function and hyperbolic tangent in estimating the concentration of particulate matter and carbon monoxide and nitrogen oxides showed that the best performance in these functions for estimating the concentration of ozone and particulate matter is related to the sigmoid membership function, which in terms of both statistics R^2 and RMSE is better

than the hyperbolic tangent membership function. A study has shown that in the artificial neural network models used to estimate pollutant concentrations, sigmoid transfer function due to low RMSE has better performance than the other functions to predict the pollutants (McKendry, 2002). Also, Tavakoli, et al. (2013) in a study investigated and assessed the concentrations of pollutants such as ozone and particulate matter in different pollutant measuring stations in Tehran by using artificial neural networks and at the end showed that for ozone, sigmoid membership function in Imam Khomeini station with the amount of RMSE=0.016 in the test phase was selected as the best membership function for estimating this pollutant. And the results also showed that for particulate matter this function has better performance due to low RMSE in Golbarg station to the other stations and functions (Tavakoli, et al., 2013). Jafari, et al. (2013) in a study compared the performance of the two functions of sigmoid transfer hyperbolic tangent in predicting the storm's run off coefficient. That, according to their results the variables obtained from factor analysis answered well for network with sigmoid transfer function, but the variables for network with hyperbolic transfer function due to different performance of this function did not provide appropriate results. Hence, they stated that the sigmoid transfer function has better performance to the hyperbolic function (Jafari, et al., 2013).

Conclusions

Air pollution is one of the most important environmental issues that in recent decades, particularly with the development of the industrial revolution, the rise in urbanization coupled with population increase and in discriminate use of fossil fuels human society is facing. This phenomenon which annually causes the deaths of a large number of people around the world is of great importance so that today, different laws and conventions on the control and prevention of this phenomenon have arisen around the world. So, investigating, measuring, and predicting the concentrations of different pollutants, especially in urban areas play an important role in preventing the production of these pollutants and planning to reduce them by people and relevant authorities. One of the new models that play an important role in measuring and predicting pollution is artificial neural network or regression methods. So, according to what was said, forecasting air pollution by using new scientific precision models, instead of traditional methods is essential. Therefore, this study is trying to predict air pollution in Yasouj by using artificial neural network. Because the evidences show that Yasouj due to uncontrolled growth of industrial and urban transport is subject to various air pollutants such as carbon monoxide and particulate matter. Overall, the results of the assessment and prediction of concentration of pollutants of Yasouj by artificial neural network showed that sigmoid transfer function to the hyperbolic tangent function is more efficient in measuring the concentration of pollutants. And the results also showed that among the studied meteorological parameters the rainfall plays an important role in the estimation of particulate matter by the sigmoid function. In addition, for other pollutants, respectively, temperature and wind speed play an important role in the estimation of carbon monoxide by studied functions.

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