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RESEARCH ARTICLE

PREDICTION OF MUNICIPAL SOLID WASTE GENERATION OF KHULNA CITY USING ARTIFICIAL NEURAL NETWORK: A CASE STUDY

ROY, S.*, RAFIZUL, I.M., DIDARUL, M., ASMA, U.H., SHOHEL, M.R. AND HASIBUL, M.H
Department of Civil Engineering, Khulna University of Engineering & Technology (KUET)
Khulna, Bangladesh

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SUMON ROY

Author for Correspondence:
E-mail:
sumonce08@yahoo.com

ABSTRACT

Accurate prediction of solid waste generation plays a crucial role in the municipal solid waste generation system. But the prediction of the amount of generated waste is an arduous task because various parameters affect it and its fluctuation is high. In this research with application of feed forward artificial neural network, an appropriate model for predicting the weight of waste generation in Khulna city, was proposed. A time series of Khulna's generated waste which have been arranged weekly, from 2005 to 2012, was used for this purpose. Also, for recognizing the effect of each input data on the waste generation best validation performance analysis was conducted. Finally, different structures of artificial network were investigated and then the best model for the prediction of Khulna's waste generation was chosen based on mean absolute error (MAE) and comparing regression (R) values (training, test, validation and all). After performing of the mentioned model, mean absolute error (MAE) in neural network have been achieved equal to 63.1219 and regression values for training, test, validation and all have been achieved equal to 0.95902, 0.94262, 0.83875 and 0.92478 respectively**.** Results indicate that artificial neural network model has more advantages in comparison with traditional methods in predicting the municipal solid waste generation.

Keywords: Waste Generation; Artificial Neural Network; Validation Performance Analysis; Khulna.

INTRODUCTION

Solid waste (SW) is the result of human activities. If an appropriate management system isn't used for this problem, it may lead to environmental pollution and jeopardize the mankind's health. But it is too difficult to design such system because the nature of waste is quite complicated and heterogeneous. Recognizing the quantity of generated waste is one of the most important factors for operating the solid waste management system (SWMS), correctly. Being aware of generation quantity can be very effective for estimating the amount of investigation in the field of machinery, onsite storage containers, transition stations, disposal capacity and proper organization. There are different ways to estimate the waste generation (WG) rates, which the most prominent of them are load-count analysis, weight-volume analysis and materials-balance analysis. However, these are the basic methods for estimating the measure of generated waste, but they have some disadvantages. For example load-count analysis method determines the rate of collection, not the rate of production. Materials balance analysis method also suffers from many errors if the source of WG were in a giant size (like a city). On the other part, traditional methods for estimating the amount of generated solid waste are established, mostly, on the basis of some elements such as population and social-economic factors of one society and they are computed according to generation coefficient per person. Since these coefficients change during the time, so they are useless devices for one dynamic SWMS as demonstrated [1].

Khulna, the third largest city is situated at the south-western part of Bangladesh near the world largest mangrove forest, Sundarbans. Beside in touristy cities like Khulna, where fluctuation of population and as its result, fluctuation of WG is significant, it is difficult to predict the amount of generated waste, accurately. For these reasons, employing new methods and advanced techniques can be useful for computing by means of this dynamic and non-linear system. These methods mostly consist of some models, classic statistics methods and many new techniques like time series methods and artificial neural networks [1].

In this study, Artificial Neural Network (ANN) was trained and tested to model weekly waste generation (WWG) in Khulna city of Bangladesh. Input data consist of WWG observation was obtained from Conservancy Department (CD) of Khulna City Corporation (KCC). The ANN models are basically based on the perceived work of the human brain. The artificial model of the brain is known as ANN [2]. ANNs were first introduced in the 1940s [3]. Interest grew in these tools until the 1960s when Minsky and Papert showed that networks of any practical size could not be trained effectively [4]. It was no until the mid 1980s that ANNs once again became popular with the research community when Rumelhart and McClelland rediscovered a calibration algorithm that could be used to train networks of sufficient sizes and complexities to be of practical benefit [5]. Since that time research into ANNs has expanded and a number of different network types, training algorithms and tools have evolved. Given sufficient data and complexity, ANNs can be trained to model any relationship between a series of independent and dependent variables (inputs and outputs to the network respectively). For this reason, ANNs have been usefully applied to a wide variety of problems that are difficult to understand, define, and quantify; for example, in finance, medicine, engineering, etc. Recently, use of ANNs in management of MSW like a proposed model based on ANN to predict rate of leachate flow rate in place of disposal solid wastes in Istanbul, Turkey [6], prediction for energy content of Taiwan MSW using multilayer perceptron neural networks [7]. HCl emission characteristics and back propagation neural networks prediction in MSW/coal co-fired fluidized beds [8], recycling strategy and a recyclability assessment model based on an ANN [9] and prediction of heat production from urban solid waste by ANN and multivariable linear regression in the city of Nanjing, China [10], have been become in current.

MATERIALS AND METHODS

Case Study and Data: According to final received reports of KCC, the city has a population of 1.5 million. In latest years, the rapid growth rate of population increasing to this city has been caused in expanding the WG and as a result making a problem for the SWMS. According to the CD report, the current actual collected waste per day is 31% only whereas WG rate is 0.40 Kg per capita per day. In the other hand, the rapid population growth rate and urbanization cause the significant fluctuations of WG in this city which consequently results many problems for SWMS. According to Existed reports the amount of generated waste in Khulna is 520 tons per day, thus offering an appropriate model for estimating the quantity of generated waste and its fluctuation can be useful for true programming and deciding which is made by related organizations

.**Table 1** Amount of waste generation in Khulna City

Year	Solid Wastes (Tons)											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2012	16300	14800	16320	16300	17500	16400	16940	16630	16100	16400	15950	16180
2011	15700	14100	15350	15410	16630	16100	16300	16000	15500	15860	15350	15700
2010	15340	13820	15150	14650	15630	15670	15700	15550	15050	15450	14900	15340
2009	15030	13540	15000	14265	15510	15470	15500	15390	14850	15340	14700	15200
2008	14780	13400	14825	14650	15290	15150	15290	15140	14650	15080	14590	14980
2007	14410	13120	14350	14220	14990	14440	14920	14830	14350	14420	13900	14310
2006	14050	12840	13980	14430	14530	14150	14560	14500	13950	14270	13750	14050
2005	13890	12560	13700	13550	14270	14000	14250	14000	13500	13950	13400	13850

Table 2 Characteristics of wastes in Khulna City

Year	Population	Solid Wastes (Tons/Day)	
		Generation	Collection
2012	1500000	520	312
2011	1461000	510	306
2010	1422000	500	300
2009	1385028	490	294
2008	1348056	480	288
2007	1313007	470	182
2006	1277957	460	276
2005	1244730	450	270

Factors affects the amount of generated wastes are: geographical situation, seasonal fluctuation, collection system, onsite process, people's food habits, economic condition, recovery and reuse boundaries, existed law and people's cultural conditions. Since having seasonal patterns of generated waste can have an effective role for estimating the generated waste and its fluctuation in one city (especially in touristy city like Khulna), so a time series model of WG has been made for predicting the amount of generated waste in Khulna. In this model weight of waste in t+1 week (Wt+1), is a function of waste quantity in (Wt), t-1 (Wt-1), …, t-10 (Wt-10) weeks. According to the CD report, the monthly WG in Khulna is shown in Table 1 and characteristics of SW are presented in Table 2. However, the weekly fluctuation in waste generation of Khulna city is shown in Figure 1.

Artificial Neural Network Model: The neural models are basically based on the perceived work of the human brain. The artificial model of the brain is known as Artificial Neural Network (ANN) or simply Neural Networks (NN). Neural Networks have many applications. Generally, however, the ANNs are a cellular information processing system designed and developed on the basis of the perceived notion of the human brain and its neural system. Rapid, efficient propagation of electrical and chemical impulses is the distinctive characteristic of neurons and the nervous system in general. The neurons operate collectively and simultaneously on most for all data and inputs, which performs as summing and nonlinear mapping junctions. In some cases they can be considered as threshold units that fire when total input exceeds certain bias level. Neurons usually operate in parallel and are configured in regular architectures. They are often organized in layers, and feedback connections both within the layer and toward adjacent layers are allowed. Strength of each connection is expressed by a numerical value called a weight that can be updated. Also they are characterized by their time domain behavior, which is often referred as dynamics. In general, the neuron could be modeled as a nonlinear activated function of which the total potential inputs into synaptic weights are applied. It is assumed that synapses can impose excitation or inhibition but not both on the receptive neuron.

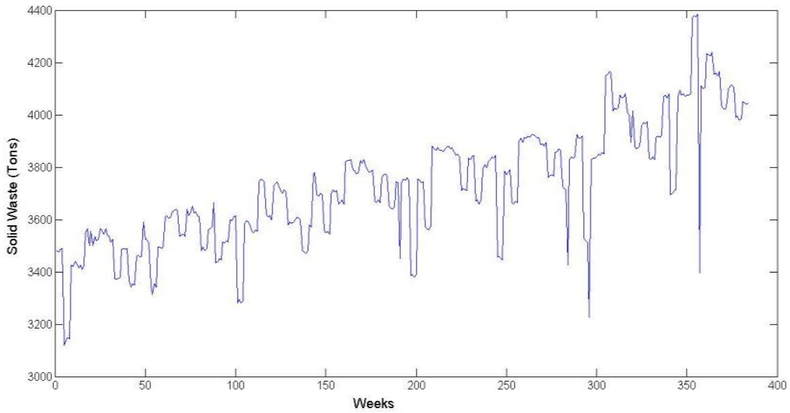

Figure 1 Weekly fluctuation of waste generation in Khulna City

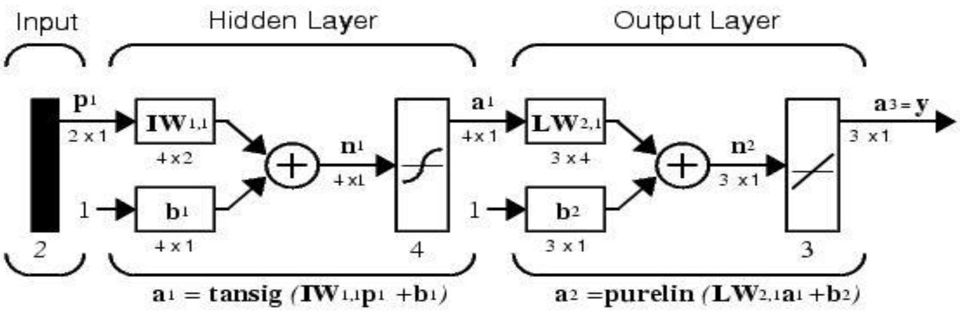

Figure 2 Single-layer feed forward network

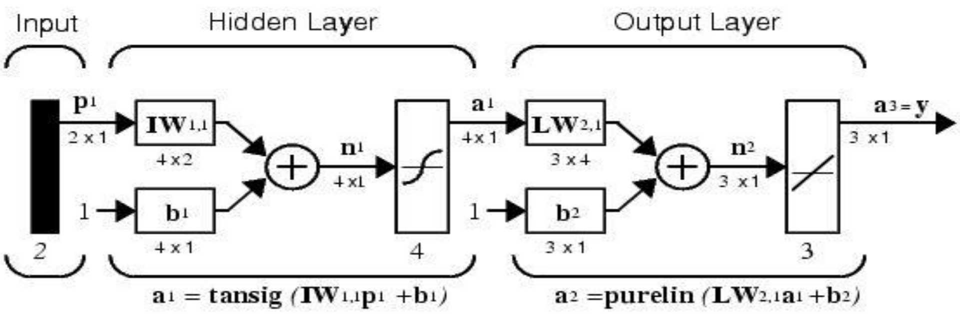

Figure 3 Multy-layer feed forward network

Feed Forward Network: A single-layer network of *S* Log-sigmoid transfer function neurons having *R* inputs is shown in Figure 2

Feed forward networks often have one or more hidden layers of sigmoid neurons followed by an output layer of linear neurons. Multiple layers of neurons with nonlinear transfer functions allow the network to learn nonlinear and linear relationships between input and output vectors. The linear output layer lets the network produce values outside the range -1 to +1. On the other hand, if the outputs of a network is needed to constrain (such as between 0 and 1), then the output layer should use a sigmoid transfer function (such as Log-sigmoid transfer function).

For multiple-layer networks the number of layers determines the superscript on the weight matrices provided in Figure 3. The appropriate notation is used in the two-layer Hyperbolic tangent sigmoid transfer function/Linear transfer function network shown next. This network can be used as a general function approximator. It can approximate any function with a finite number of discontinuities arbitrarily well, given sufficient neurons in the hidden layer.

In order to evaluate the performance of the ANN model the indices are used: the Mean Absolute Error (MAE), Regression values (R) (training, test, validation and all) that are the determining factor for the model output predictions and finally Best Validation performance analysis was performed to recognize the effect of each input data on the waste generation.

RESULT AND DISCUSSIONS

The summary of Prediction Performance Statistics Analysis of waste, during the weeks between "2005-2012", is given in Table 3. Based on the MAE and values of R, the best neural network is selected; it is observed that values of R for training and validation come out to be satisfactorily. To achieve the best ANN structure for estimating generated waste, various structures of feed forward ANN with three layers and different number of neurons in hidden layer was investigated. Finally, with consideration on MAE and R appropriate model was selected. The results of training, testing validation of ANN are given in Table 3. According to Table 3, the best results were obtained of (13-10-1) structures. These results are shown in Figures 4 to 6.

The best values of MAE in neural network have been achieved equal to 63.1219 and regression values for training, test, validation and all, have been achieved equal to 0.95902, 0.94262, 0.83875 and 0.92478 respectively. All the figures are generated by MATLAB 7.2.

TABLE 3 RESULTS OF TRAINING, TESTING VALIDATION OF ANN

ANN Model Structure	MAE	Regression (R) Training	Test	Validation	All
10-4-1	93.9339	0.94553	0.6981	0.6882	0.83547
10-6-1	55.0138	0.94548	0.85024	0.85601	0.90662
10-8-1	54.3128	0.96969	0.83991	0.83842	0.91455
10-10-1	62.0930	0.9522	0.91211	0.63591	0.8663
10-12-1	63.1219	0.95902	0.94262	0.83875	0.92478
10-14-1	61.2544	0.96282	0.90048	0.83862	0.91393
10-16-1	64.0032	0.96261	0.86873	0.88708	0.92876
10-18-1	58.5117	0.97085	0.88152	0.7746	0.90975
10-20-1	61.5351	0.98488	0.79792	0.81388	0.91092
10-22-1	56.6921	0.97677	0.69201	0.847	0.86507
10-24-1	61.6697	0.97926	0.88225	0.81214	0.91229
10-26-1	71.1592	0.97134	0.74596	0.56184	0.81888

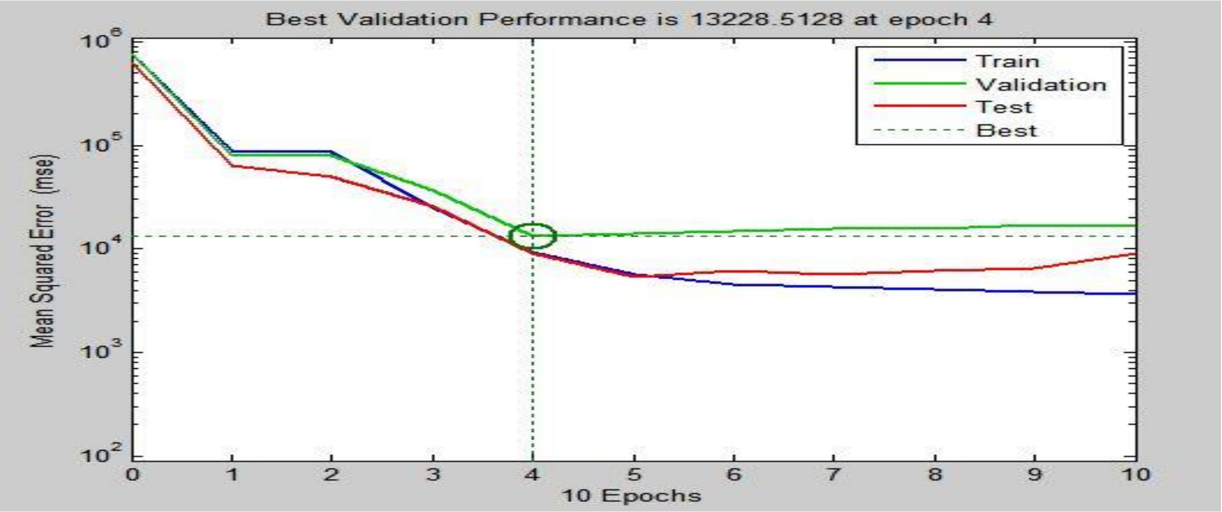

Figure 4 Performance Plot of Best Neural Network for prediction of waste generation (10-12-1)

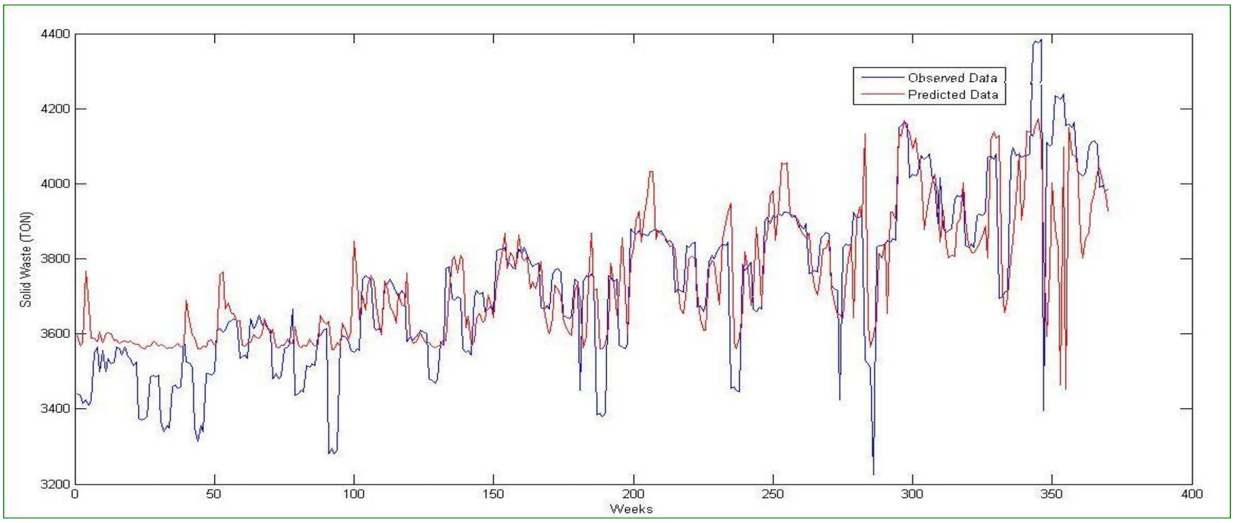

Figure 5 Observed and predicted solid waste from ANN Model with structure (10-12-1)

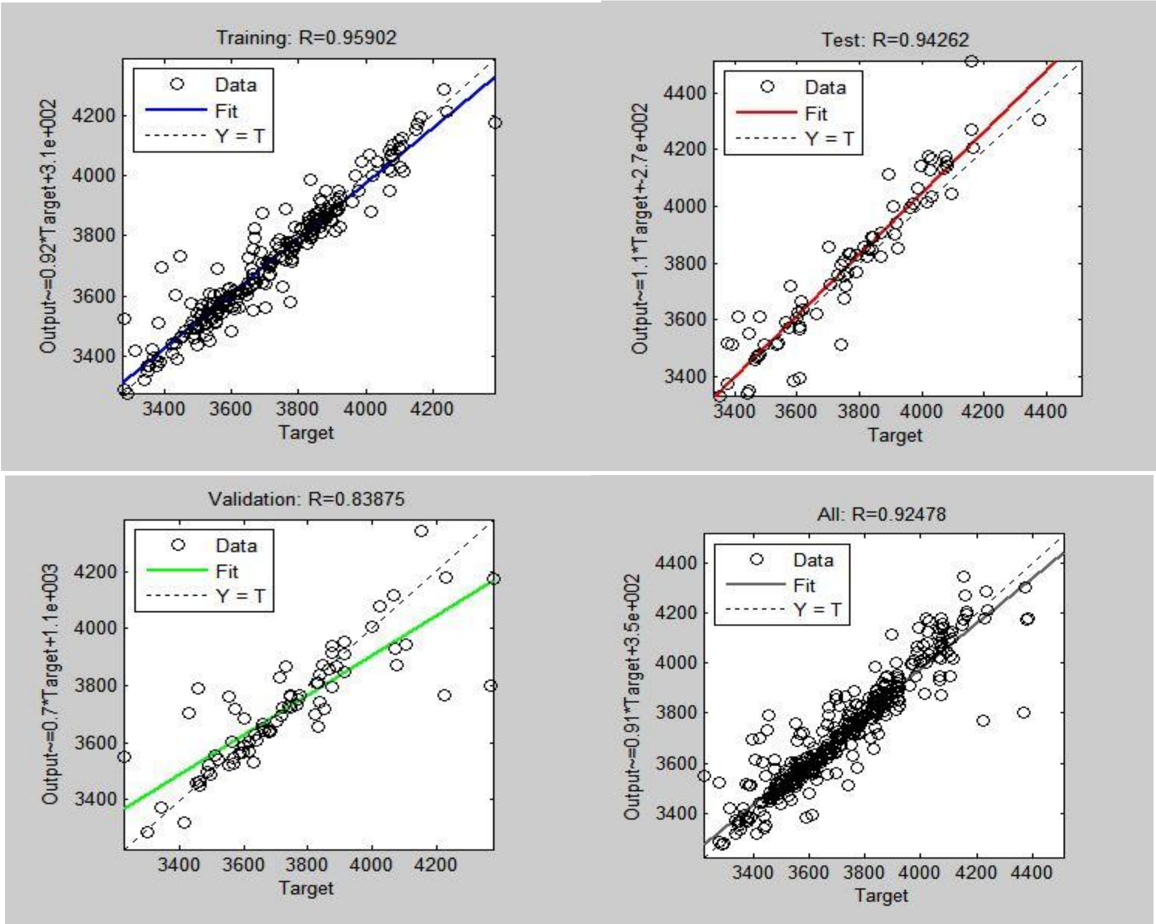

Figure 6 Regression between target vs. training, validation, test and all (10-12-1)

CONCLUSIONS

Exact prediction of WG plays an important role in the MSWMS. Therefore, the goal of this research is offering a suitable model for predicting this quantity accurately. In this paper, the feed forward artificial neural network was used for the prediction of weekly waste generation of Khulna city. At the first, by using of ANN with the one hidden layer and changing the number of neurons of the layer, different models were created and tested. Finally according to applied index in this paper MAE and R values (training, test, validation and all), structure with 12 neurons in the hidden layer was selected as the suitable model.

REFERENCES

[1] Jalili, G. Z. M. and Noori, R. Prediction of municipal solid waste generation by use of artificial neural network: a case study of Mashdad. Int.J. Environ. Res. 2008, 2(1): 13-22.

[2] Sahin, U., Ucan, O. N., Bayat, C. and Oztorun, N. Modeling of SO2 distribution in Istanbul using artificial neural networks. Environ. Model. Assess., 2005, 10: 135-142.

[3] McCulloch, W. S. and Pitts, W. A logical calculus of the ideas imminent in nervous activity. Bull. Math. Biophys., 1943, 5: 115-133.

[4] Minsky, M. L. and Papert, S. A. Perceptrons, 1969. MIT Press, Cambridge, MA.

[5] Rumelhart, D. E. and McClelland, J. L. Parallel Distributed Processing: Explorations in the Microstructures of Cognition, 1986. Vol. 1, MIT Press, Cambridge.

[6] Karaca, F. and Özkaya, B. NN-LEAP: A neural network-based model for controlling leachate flow-rate in a municipal solid waste landfill site. Environ. Model. Software, 2006, 21: 1190-1197.

[7] Shu, H. Y., Lu, H. C., Fan, H. J., et al. Prediction for energy content of Taiwan municipal solid waste using multilayer perceptron neural networks. J. Air and Waste Manag. Assoc., 2006, 56: 852–858.

[8] Chi, Y., Wen, J. M., Zhang, D. P., et al. HCl emission characteristics and BP neural networks prediction in MSW/coal co-fired fluidized beds. J. Environ. Sci.(China), 2005, 17: 699-704.

[9] Liu, Z. F., Liu, X. P., Wang, S. W., et al. Recycling strategy and a recyclability assessment model based on an artificial neural network. J. Mater. Proces. Tech., 2002, 129: 500-506.

[10] Dong, C., Jin, B. and Li, D. Predicting the heating value of MSW with a feed forward neural network. Waste Manag., 2003, 23(2): 103-106.