Abstract: In order to create a successful model for waste management one of the major preconditions represents reliable information about amount and composition of generated waste. Including municipality of Novi Sad, currently in Serbia waste characteristic analysis was made only for 10 municipalities with different standpoint of development, population, belonging regions and other socio-economic indicators. Using artificial neural networks (ANN) it is possible to show existence of relation between waste characteristic and the aforementioned factors. In this paper obtained dependence is used to predict future waste quantity and composition in Novi Sad by 2020. Obtained information can be a good basis for waste managers in order to make appropriate future decisions and directions of waste management development in accordance with the specific conditions in Novi Sad.

Key Words: waste characteristic / artificial neural networks / forecasting

1. INTRODUCTION

In common with most developing countries, solid waste management in Serbia is underdeveloped and related data about waste quantities and composition are mostly unreliable and incomplete[1]. In order to comply with increasing international requirements for accurate and comparable regional data, study for determining quantity and morphological composition of waste in accordance with official national methodology was conducted in ten representative municipalities.

Knowing waste quantities and composition in the future will be very important to define optimal waste management options in accordance with achieving legislative obligations. In recognition of the importance of a reliable tool to predict the MSW characteristics, various researchers have attempted to construct models to predict these parameters[2],[3],[4]. The classical methods for forecasting include regression and state space methods. Modern methods include expert systems, fuzzy systems, evolutionary programming, artificial neural networks (ANN) and various combinations of these tools. Among the many existing tools, the ANN has received much attention because of its clear model, easy implementation and good performance[5].

Neural networks is a relatively new research field and is rapidly growing in popularity as evidenced by the proliferation of neural networks applications in virtually all fields of research[6]. Their flexible and adaptive nature enables them to model any non-linear function to any degree of accuracy.

By using artificial neural networks model it is possible to determine existence of relation between analysed waste and socio-economic indicators in representative municipalities, and modeled with acceptable error. In this research neural network model was used to predict waste characteristic in municipality of Novi Sad. In order to get more accurate information, mentioned dependence is observed also for 13 European countries, which were included in ANN model.

Selection of appropriate procedures and technologies in a field of solid waste management is one of the major challenges and significant factor that essentially determine further development of the company, municipality or entire country[2]. For waste managers in Novi Sad future waste characteristic will be a good basis for the future decisions and directions of waste management development, in accordance with the principles of environmental protection.

2. METHODOLOGY

As a starting point for using ANN for forecasting waste generation and composition for Novi Sad, were information about waste generation and composition in several different municipalities with diverse socioeconomic conditions. It is important that these measures are not based on empirical data. Measurements were made in ten municipalities in three different sectors according different housing conditions during 2008., as a part of the government project.
In order to obtain more accurate model, beside data for Serbian municipalities, data about waste characteristic for a certain number of European countries were also considered. Mostly selected were surrounding countries, which are from perspective of geographical, social and cultural characteristics very similar to Serbia, and which passed through economic transition like is now in Serbia. Other part of selected countries belong to group of developed European countries, where the waste management system is at a much higher level, which it can be assumed that Serbia and municipality of Novi Sad strive to achieve in the next 10 years.

ANN used in this paper had 3 inputs, 10 neurons in hidden layer and 6 outputs. Used inputs were:
- average income,
- level of employment,
- municipal sector for each municipality.

Analysis of waste composition was performed measuring 16 different waste fractions, and for applicability of the ANN, these fractions were grouped in 6 main categories, which are also represented outputs of the ANN model expressed in form kg/capita/day, including:
- organic waste,
- paper and cardboard,
- glass,
- metal,
- plastic,
- other waste.

Based on that, it is enabled that data of population projections in Novi Sad up to year 2020[7], easily can be exploited in order to obtain information about total waste fractions quantity that will be produced.

Architecture of ANN is shown in Figure 1. Activation function for hidden layer is Logarithmic sigmoid transfer function and for output layer is pure linear function.

3. RESULTS AND DISCUSSION

Training set consisted 39 values obtained by study of waste analysis in Serbia, and 13 values from literature data about quantity and composition of waste for different European countries [8],[9]. For testing purposes were used 14 values, and 8 for cross validation. ANN was trained after few dozens of epoch and error on training set was 4,7%. Error on verification set was less than 5 percents.

ANN model was recognized level of dependence between inputs and outputs data, with correlation factor $R^2=0.87$ on training set.

Based on the dynamics of GDP growth in Serbia projections of average incomes indicator, and employment rate for Novi Sad and other municipalities by 2020 were done[10]. Similarly, input data for European countries were obtained, only instead of municipal were used national average data[11].

Diverse housing conditions in Serbian municipalities yield to different quantity and composition of waste. For this reason, inputs based on housing conditions that significantly affects the quantity and composition of generated waste are also considered.

By using designed ANN model with new input values, share of main waste categories for Novi Sad in period 2010 - 2020 were determined (Table 1).

<table>
<thead>
<tr>
<th>Waste category</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>41.9</td>
<td>34.0</td>
</tr>
<tr>
<td>Paper&amp;cardboard</td>
<td>20.5</td>
<td>23.8</td>
</tr>
<tr>
<td>Plastic</td>
<td>16.4</td>
<td>15.4</td>
</tr>
<tr>
<td>Glass</td>
<td>6.2</td>
<td>5.8</td>
</tr>
<tr>
<td>Metal</td>
<td>1.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Other</td>
<td>13.5</td>
<td>17.2</td>
</tr>
</tbody>
</table>

Results based on the ANN model indicate that mass proportion of organic waste, expressed in percentage, over the next 5 years will not be significantly change, while decreasing comparing to other factions can be expected in period 2015-2020.

Similar situation can be expected for all plastics categories which mass share in 2020 will be 15.4% compared to 16.4% generated in 2010. Opposed to mentioned fractions, paper and metal represents MSW categories with increasing rate over next 10 years.

All differences in proportion of certain waste categories generated in the period 2010-2020 in Novi Sad is shown in Figure 2.

Total generated waste quantity in Novi Sad according obtained ANN model will be increase from 133,162 tons in 2010 up to 155,466 tons in 2020. Reflected in form kg/capita/day, it can be concluded that daily production...
of municipal waste by average resident of Novi Sad, which is currently 1.16 kg/capita/day will be increased by 0.14 kg in 2020. Total projected amount of generated municipal solid waste in Novi Sad and mass of each waste category is shown in Figure 3.

![Figure 3. Projected quantity of overall MSW in Novi Sad](image)

Quantity of waste that potentially can be recycled or reused, including paper, plastic, glass and metal will increase from about 59,000 tons in 2010 to over 75,000 tons in 2020.

Organic fraction of waste generated in Novi Sad will not be significantly changed, but according National Waste Management Strategy and specific targets that include reduction to 35% of the total quantities (by weight) that in 2020 will be allowed to ends up at landfills, means that over 39,600 tons will must be treated in different ways[12].

4. CONCLUSION

Information about composition and quantity of generated waste represent the basis for development a successful waste management system, especially in developing countries which are facing with lack of real data about waste characteristic, like in Serbia. Currently, precise data exist for ten municipalities, different from the standpoint of socio-economic indicators. Purpose of this paper was to use artificial neural networks model in order to show existence and accuracy of relation between analysed waste characteristic and aforementioned indicators, and based on that relation, to predict future characteristic of waste in municipality of Novi Sad. Obtained data about future quantities and composition of waste in next 10 years for municipality of Novi Sad, can be of great importance for decision makers in this field, and significantly contributing to choice of most appropriate treatment methods for all category of municipal waste and to implement most favourable option from aspect of environmental protection, economic possibilities and other specifics of municipality.

5. REFERENCES


