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INFLUENCE OF MORPHOLOGICAL COMPOSITION OF WASTE TO ENVIRONMENTAL PERFORMANCE OF MUNICIPAL SOLID WASTE MANAGEMENT TECHNOLOGIES

Abstract: *Inadequate waste management is one of greatest environmental problem of the modern world. Waste generation is directly correlated with national economy, but the achieved level of waste management system is highly dependent on the level of economic development. In addition, economic development significantly affects the morphological composition of solid waste. In the last few decades, particularly in high-income countries, great attention is paid and significant funds are invested in order to improve waste management practices. Determination of the composition and quantity of generated municipal waste is an essential part of any modern waste management system and is the basis for making strategic decisions.*
In this paper, based on the Life cycle assessment (LCA) method, the impact of morphological composition of waste to the environmental performance of four solid waste management scenarios in the city of Kragujevac was analysed. Through the application of the software package EASETECH, the life cycle inventory analysis (LCIA) was realized and the levels of eight standard categories of influence were determined. For each of these scenarios the comparative simulations for three typical composition of waste were made. The impact of the share of organic components in the overall composition of the waste was especially examined and discussed.
Keywords: *Environmental impact categories, Life Cycle Assessment, Solid waste management, Waste composition*

1. INTRODUCTION

By the end of the eighties, a growing need for more detailed data on municipal waste appeared, particularly in terms of planning of waste collection, waste treatment and identification of hazardous and harmful waste components. Determination of morphological composition of waste represents a key to successful management of municipal waste. Knowing the municipal solid waste composition is necessary for municipal and industrial stakeholders that are involved in the process of waste management at the municipal (city) level in order to develop successful strategies for the municipal waste sustainable management.

Solid waste morphological composition represents content of one component of waste in relation to the total mass of waste. Results greatly depend on the applied methodology of determining the waste composition. In publications that study this problem there can be noticed a significant number of different approaches to, first of all, the definition and the division of waste to certain constituent components [1]. This somewhat complicates the comparability of results as well as making the appropriate relevant conclusions [2].

A numerous different factors have influence to the waste composition and many of these factors are interconnected in certain way. The economic development of the country (or region, town, municipality) is one of the dominant influencing factors. On the other hand, the composition of the waste is significantly affected by the socio-cultural characteristics of a particular community, as well as the climatic and geographical conditions of the observed areas, energy resources etc. Waste collection frequency, as well as local approach and strategy in the whole process of waste management, to final disposal, are also important factors that determine the waste composition.

The quantity of generated municipal and industrial waste exceeds the ability of the environment to absorb them through natural processes, to decompose and recycle. The rapid global population growth and economic development inconsistent with adaptive capabilities of ecosphere are causing changes in the Earth that can have serious and long lasting consequences.

Inadequate waste management is recognized as one of the key environmental issues, while at the same time, waste is a major threat to public health. Sustainable waste management therefore becomes one of the primary goals but also the most complex problem in the entire environmental management system.

Christensen et al. [2] conducted a research focused on climate change and greenhouse gas emissions. For the purpose of implementation authors introduced terms “Northern European” MSW and “Southern European” MSW composition that differ primarily in the percentage of paper and organic fraction representation (Table 1).

Table 1. *Waste composition in Europe*

Waste category	Middle European	Northern European	Southern European
Organic	35	30	47
Paper	22	33	20
Textile	3	4	3
Plastics	10	9	9
Glass	6	4	5
Metal	4	4	5
Other	20	16	11

Calabrò [3] studied the role and influence of separate waste collection in greenhouse gas emissions. The author concluded that separate waste collection and recycling have a positive effect in terms of reducing GHG emissions and that the reductions are bigger with the increase of the percentage of separate collection and recycling.

The research [4], considered the impact on the environment during the process of depositing of fractions of municipal waste, using empirical model [5] and software package Easewaste [6]. Although the modeling of the environmental impact of waste fractions was based on many assumptions and had some uncertainties, this type of analysis can provide important information for improving the process of municipal solid waste management.

Swedish researchers Bernstad and Jansen [7], used the LCA approach to consider several options for household food waste management. The study examined three alternative treatments of households organic waste - incineration, composting and anaerobic digestion, which are used to design several different management scenarios for this component of municipal solid waste.

2. MODELING OF ALTERNATIVE SOLUTIONS

In order to compare selected treatment technologies in terms of their impact to the environment, four scenarios of municipal solid waste management in the city of Kragujevac were created:

- Scenario1: MSW system consists of waste collection, transport and final disposal of the complete municipal waste (56,158 tons) on the landfill. The landfill, provided for this scenario, has installed system for the collection of landfill gas and its utilization for energy purposes.
- Scenario 2: Recycables waste are collected separately, mainly packaging waste (glass, paper, Al), and diverted to recycling processes (21%, 11,707 tons), while the rest of waste (77%, 44,391 tonnes) is landfilled the same way as in the scenario 1.
- Scenario 3: Comparing to previous scenario, in addition to recycling of packaging waste (21%, 11,707 tons) the share of the organic waste is directed towards a composting plant (15%, 8,468 tons). The rest of the waste is disposed of

in landfill (64%, 35,983 tons), which also has installed system for landfill gas collection and utilization.

- Scenario 4: This scenario consits of recycling of packaging waste (21%, 11,707 tons), anaerobic digestion (15%, 8,468 tons) of one share of organic waste and landfilling of rest of waste (64 %, 35.983 tons) with landfill gas collection and utilization.

Influencing factors will be investigated through the usage of a software package EASETECH [6] which is based on LCA methods. Table 2 shows the amount of waste by type of treatment for each of the four selected scenarios, in share and absolute terms [8].

Table 2. *Waste quantities for different waste treatment*

Scenario	Waste treatment								Landfill gas collection system
	Recycle		Biological treatment				Landfilling		
			Composting		Anaerobic digestion				
	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	
Scenario 1	0	0	0	0	0	0	100	56.158	Yes
Scenario 2	21	11.707	0	0	0	0	79	44.391	Yes
Scenario 3	21	11.707	15	8.468	0	0	64	35.983	Yes
Scenario 4	21	11.707	0	0	15	8.468	64	35.983	Yes

3. RESULTS AND DISSCUSION

This section presents the results of the life cycle inventory analysis (LCIA), designed for four scenarios. The analysis includes the following four parameters - impact categories:

- Global Warming Potential, GWP
- Abiotic Depletion Potential, ADP
- Ozone Depletion Potential, ODP
- Acidification Potential, AP

Each of the analysis of the selected impact categories included the examination of the changes in these indicators, in particular in accordance with the variation in waste composition. Valuation of the performance of the proposed scenarios was carried out for the following three characteristic waste compositions:

- Composition 1 - Local „KG“ composition (Figure 1), which has a very similar morphological structure as the „Southern European“ type of waste
- Composition 2 - „Middle European“ waste composition and
- Composition 3 – „Northern European“ waste composition

Figure 1 shows the morphological composition of municipal waste for the city of Kragujevac [9].

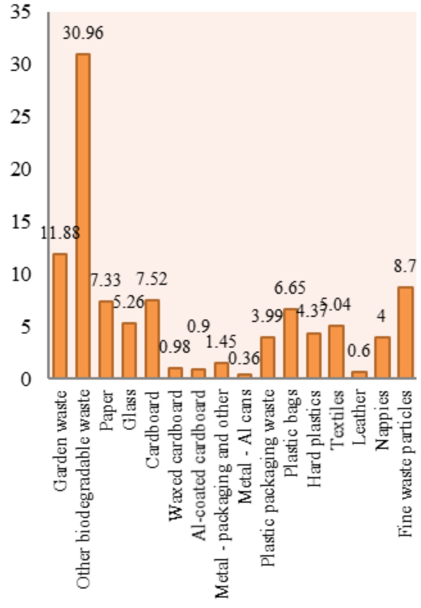

Figure 1 *- Composition of MSW in Kragujevac*

Figure 2 shows a comparation of the values of global warming potential for four selected scenarios and three types of waste. It is interesting to note that the scenario 4 is the only one where can be registered savings of greenhouse gas emissions (negative values of GWP). The reason for this lies in the production and utilization of biogas. This waste management option includes anaerobic digestion of organic components and gives better results with a reduction of share of organic - food waste. The highest level of avoiding harmful emissions can be seen with the simulation of this scenario for so-called "Northern European" waste composition. This composition is characterized less organic, primarily food waste component, which has the greatest greenhouse gas emissions potential.

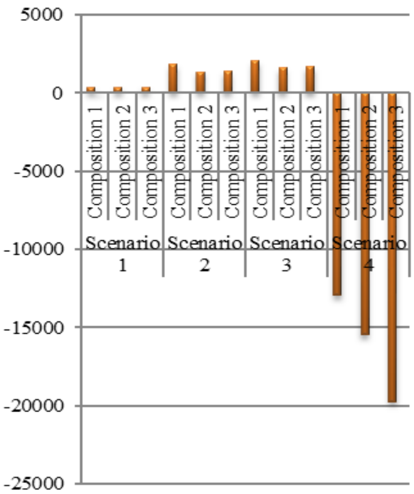

Figure 2 *- Global Warming Potential*

According to scenario 4, the difference of GWP for "KG - Southern European" and "Northern European" waste composition is over 30%. Among other three scenarios next most favorable in terms of the smallest impact on climate change, is scenario 1. Significant savings in emissions in this scenario, compared to scenario 2 and scenario 3, appear due to the absence of a broader process of waste sorting and transport.

Comparative consumption of renewable and non-renewable abiotic resources is presented in Figure 3. Looking at the value of this parameter, it can be seen that scenario 4 has the greatest savings in above mentioned categories of resources. The savings increased with decrease the share of the food waste, depending on the type of waste. Scenario 1 has the worst ADP value because of the complete absence of the recycling of packaging waste treatment and treatment of organic waste, which is intended to create the possibility of applying the substitution of certain natural resources.

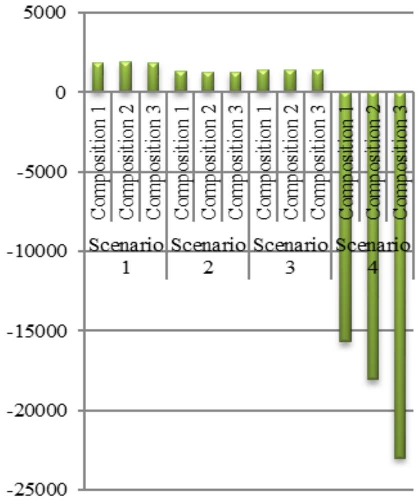

Figure 3 *- Abiotic Depletion Potential*

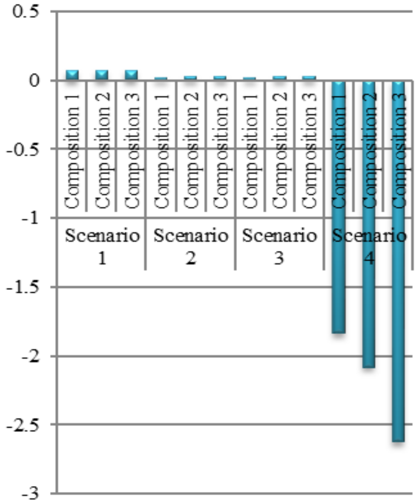

Figure 4 *- Ozone Depletion Potential*

The values of the ozone depletion potential (ODP), for all scenarios are shown in Figure 4. Scenario 4 is again characterized with the lowest level of impact to this atmospheric gas. The other three scenarios have relatively uniform impact values to ozone.

The values of acidification potential (AP) of soil and water resources are shown in Figure 5. The most favorable scenario in terms of the influence of this factor is scenario 1, while the other three scenarios gave fairly consistent values, with a bit higher values for "KG – Southern European" waste composition.

Scenario 1 provides a complete disposal of municipal waste on a sanitary landfill, which has installed systems for the collection of landfill gas and leachate. This kind of waste management should has localized and relatively small impact on the surrounding land and water resources.

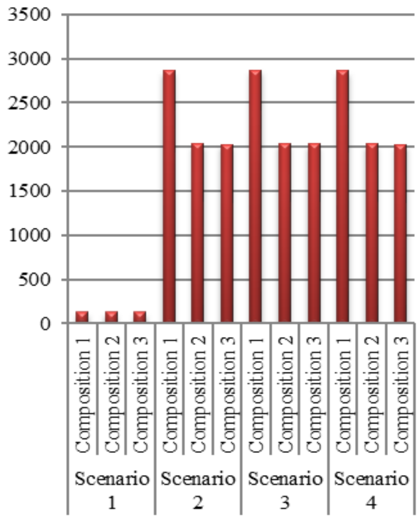

Figure 5 *- Acidification Potential*

4. CONCLUSIONS

Based on the previous analysis it can be seen that the scenario 4 is the scenario with registered savings of greenhouse gas emissions (negative values GWP). The explanation for this fact can be found in the production and utilization of biogas. This waste management option includes anaerobic digestion of organic components and has better values with a reduction in the share of organic - food waste. The highest level of avoided emissions is registered in the simulation of scenarios for so-called "Northern European" waste composition. This composition is characterized by a smaller share of organic, primarily food waste component, which carries the greatest greenhouse gas emissions potential.

Waste composition has also a significant influence to the other three indicators. This primarily refers to the share of the organic fraction of municipal solid waste. Similar to GWP parameters ADP, ODP and AP are sensitive to waste composition in the scenario 4.

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