MME SEE CONGRESS 2023

5th Metallurgical & Materials Engineering Congress of South-East Europe
Trebinje, Bosnia and Herzegovina
7-10th June 2023

CONGRESS PROCEEDINGS

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DIRECTIONS AND CHALLENGES OF THE CIRCULAR ECONOMY: MOVEMENT OF MUNICIPAL SOLID WASTE IN CITY OF PARAĆIN

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This paper aims to show a short economic analysis of the profitability of recycling management on the territory of Paraćin municipality. Consumption habits of modern society and socioeconomic conditions have made it difficult to implement sustainable waste management strategies. Industry, economics, sociocultural and political activities must work together to solve the multifaceted problem of waste management. The municipality of Paraćin is located in the central part of the Republic of Serbia, Pomoravlje region. Annually, this municipality generates about 18,000 t of waste, while the mass of recyclable waste is approximately 7,000 t. This small industrial city have been constantly facing with an insufficient number of available bins and containers for the disposal of Municipal Solid Waste (MSW). Moreover, this city has been challenging by an increasing number of illegal dumps along the roads. Together with surrounding municipalities, the local government was planning to create Regional Recycling Center and Landfill with all necessary operations. Sorting of the waste at the source of its origin, and adequately disposing it in containers intended for different types of waste, would provide precisely insight into the movement of recyclable waste. In addition, with these actions by the local community, it could produce a habit among citizens for proper deposition and disposal of household waste and reduce the negative impact on the environment. This article shows the categories of waste and their percentages, as well as the resulting amount of recyclable waste, which should be a starting point for establishing a recycling center with surrounding municipalities.

Keywords: Municipal Solid Waste (MSW); recyclable materials; recycling center; economy analysis

Introduction

Municipal Solid Waste (MSW) can induce a potential threat to the environmental and public health if it is not properly handled [1]. Waste management include several process phases, from the source separation, collecting/grouping, transfer to the right place and adequate treatment by following 3R rule *reuse-recycle-reduce*. The generated amount of MSW threatens to become more than 3.4 billion of tons by 2050 [2]. In the most developed countries (Central Europe, USA, Australia, Japan) lives one seventh of the total human population, that produce one third of the global MSW. The share of recycled and reused waste is about 80%, controlled disposal is about 50%, while uncontrolled disposal is slightly less than 5% [3].

Waste management represent one of the main problems faced by Republic of Serbia in the field of environmental protection. According to the data of the Environmental Protection Agency, there are only 11 sanitary and 2305 nonsanitary landfills in the Republic of Serbia [4]. An incineration plant in the Republic of Serbia has been built and is currently in the pilot phase. The planned operation start of this facility is June 2023. With this project, the deposited mass of MSW will be reduced by approximately 12% and the emphasis will be on the incineration of all waste that can be treated in this way [5].

The territory of the municipality of Paraćin is located in the central part of Pomoravlje on an area of 542 km². The total number of citizens in the territory of the municipality was 54,242 (year of 2011.) According to the official data from 2011. census, the number of households in the municipality of Paraćin was 16,381. The average number of household members is 3.31. Recent data shows that number of citizens of the municipality is 48,881 (year of 2022.). According to the 2022. census, the number of households in the municipality of Paraćin is 16,488. The average number of household members is 2.96.

Considering the numbers from 2016, the mass of MSW generated on the territory of the Republic of Serbia was 1.9 million tons, while the mass of MSW which could be used again - *recyclable* was 160,000 tons, which is slightly more than 8% [4]. During the same year, the mass of MSW generated in the city of Paraćin was 18,000 tons, of which 7,000 tons were recyclable waste, which is almost 40% [6]. Recent data from 2021. shows that the mass of MSW generated on the territory of the Republic of Serbia was 2.87 million tons, while the mass of recyclable waste was 390,320 tons which is approximately 16% [7]. In the same year, the mass of MSW generated in the city of Paraćin was 19,205 tons, of which 7,500 tons were recyclable waste, which is 40% [8]. According to the presented data, increasing of generated mass of MSW from 2016 to 2021 increased by 1650 tons on an annual basis despite the decrease in the number of citizens. Currently, in the territory of the municipality of Paraćin, all generated waste types are deposited at the "Buljanka" landfill near Paraćin (Figure 1.). This landfill did not receive the status of a sanitary landfill - in the coming period, a rehabilitation plan is expected to fulfill the existing conditions in order to receive the status of a sanitary landfill [6,8].

Figure 1 Landfill Buljanka during recultivation process [6]

Materials and methods

A comparative analysis of all available documents in the field of waste management in the territory of the municipality of Paraćin and the Republic of Serbia was carried out. Therefore, an analysis of documents and reports from the Environmental Protection Agency and local reports based on the "Plan and implementation of waste management in the territory of the municipality of Paraćin" was performed. The interpretation of results derived from this analysis, namely the movement of waste in this municipality, the progress of waste generation, a detailed analysis of the morphological composition, needs to sustain or not an idea of whether this municipality is suitable for a Recycling Center, as well as the economic aspects of the profitability of using this type of waste treatment.

Results and discussion

The initial data from which this research was started is based on the rate of generation of waste per inhabitant, the number of households that generate waste, the average number of inhabitants per household and the total mass of waste generated annually in kilograms are shown in equations below and results are presented in Table 1.

- Average number of habitants:
  $$\text{Avg. no. of habitants} = \frac{\text{Total number of population}}{\text{Total number of households}} \quad (1)$$
- Generation of waste per habitant and day [6,8]
- Number of households [6,8]
- Total mass of waste on an annual basis is obtained by multiplying these data above:

$$\text{Total mass of MSW per year, [kg]} = \text{Avg. no. of habitants x Generation of waste per habitant x No. of households x 365 days} \quad (2)$$

Table 1 Initial information of municipality by year

Year	Generation of waste per habitant, [kg per habitant and day]	Number of households	Average number of household habitants	Total MSW of waste per year, [kg]
2016	0.91	16,381	3.31	18,009,541.68
2021	0.97	16,488	2.96	17,279,226.14

Table 2 presents morphological composition of the MSW in municipality of Paraćin which is the main point of further presentation of recyclable waste. The table contains data of MSW classification according to the List of Waste Categories

Table 2 List of Waste Categories in municipality of Paraćin

Year	2016.		2021.	
Category	Percentage, [%]	Mass, [kg]	Percentage, [%]	Mass, [kg]
Biodegradable waste	40.56	7,282,601	47.51	9,124,593
Paper	7.90	1,418,455	7.0	1,344,393
Glass	4.74	851,073	5.26	1,010,216
Cardboard	6.12	1,098,854	4.87	935,314
Metal	1.38	247,780	1.52	291,926
Aluminium can	0.57	102,344	1.40	268,878
PET, Foil	12.19	2,188,731	17.10	3,284,162
Other plastic	5.77	1,036,011	3.39	651,070
Other	20.77	3,729,281	11.95	2,295,072

All MSW generated in the territory of the municipality of Paraćin is deposited without prior treatment. Also, recyclable waste are not treated before disposition. The following table (Table 3.) shows the amount of generated recyclable waste in 2016. and 2021. Reuse, recycling, transformation into another form of recyclable waste can relieve the current landfill, where all waste generated on the territory of the municipality is deposited. Currently, there are no operators to collect the recyclable waste that is generated.

Table 3 Generated mass of recyclable waste annually in municipality of Paraćin

Category/ Year	Mass of recyclable waste in 2016. [kg]	Mass of recyclable waste in 2021. [kg]
Paper	1,418,455	1,344,393
Cardboard	1,098,854	935,314
Aluminium can	102,344	268,878
Glass	851,073	1,010,216
PET, Foil	2,188,731	3,284,162

In the presented tables, it can be seen that although the number of citizens in the municipality of Paraćin decreased, the amount of waste generated in 2021. was higher than in 2016. The whole process of recycling requires the circular movement of the product, from its creation, use by the user, through the loss of use value (it becomes waste), to its return to reuse in the same or approximately similar form. A prerequisite for creating a sustainable recycling process is an organized way of separating and sorting waste [9,10]. The first in a series of operations related to recycling is the sorting of waste at the point of origin (e.g. in households), where the habitants disposes different types of waste in different containers. The idea of a Recycling Center in this municipality would extend the life of the landfill and the transformed waste could also be used as a starting point raw material in some process of manufacturing. The only recyclable material whose return is complete is glass. By using recycled glass during the production of glass packaging, the emission of gases during the combustion of the glass mass is reduced by up to 20% [9].

Figure 2 shows the material flow of waste as well as the mass of waste that would be recycled and the mass that would be deposited according to the List of Waste Categories.

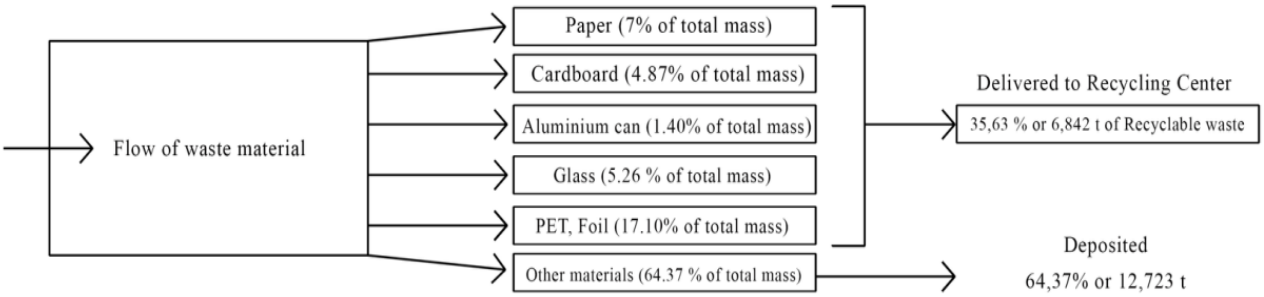

Figure 2 Material flow of MSW

The following table shows the basic economic profitability based on the sales price of recyclable waste generated on an annual basis. In recycling center these materials would be prepared as secondary raw material and sale to customers. Benefits for this are shown in table below.

Table 4 Economy analysis and profitability of Recycling center

Category/ Year	Mass of recyclable waste in 2021. [kg]	Price per kilogram of waste, [RSD] [11]	Profit, [RSD]
Paper	1,344,393	5.00	6,721,965
Cardboard	935,314	5.00	4,676,570
Aluminium can	268,878	85.00	22,854,630
Glass	1,010,216	2.00	2,020,432
PET, Foil	3,284,162	35.00	114,945,670
Σ			**151,219,267**

Conclusion

A significant amount of MSW is currently generated in the territory of the municipality of Paraćin, of which almost 40% is recyclable waste. This waste is deposited together with other waste at the municipal landfill, which still does not have the status of a sanitary landfill. In the future, the first step towards the reduction of landfilled waste would be separation at the source of waste generation, and then sorting into that which can be reused and other waste that should be deposited. The most ideal model would be a Recycling Center, which could also be a Regional one, where other surrounding municipalities could also process and recycle their waste, which would primarily increase awareness of recycling, reduce the number of illegal landfills, where the current landfill "Buljanka" would relieve a large part of the waste that is currently depositing.

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