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ESTIMATION OF ROW MATERIAL POTENTIAL IN LANDFILL MINING

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Abstract: Nowadays landfilling is still an integral part of any waste management system, regardless of the fact that different technologies are used for the treatment of waste. Even today, most economically developed countries, still rely on landfilling as an integral part of solid waste management system, while in developing countries this is very often, the most commonly or solely used waste treatment. Accordingly, a large amount of recyclable materials, as well as materials for energy recovery, are deposed at landfills. In this paper the mathematical model for estimation the quantities of recyclable material and material for energy recovery obtained in landfill mining was presented. Based on the data from the field of quantities and composition of landfilled waste and age of existing landfills, a preliminary estimation of the raw material potential of landfill could be done, and obtained results could be used in order to help the decision makers in Republic of Srpska to choose the sustainable material and energy resource recovery.
Keywords: Landfill mining, waste, raw material potential, mathematical model

1. INTRODUCTION

Old non-sanitary landfills, not in service in the long period, are a source of environmental risk, mainly due to the presence of micro-pollutants, such as heavy metals and similar materials. These locations can cause contamination of underground and surface water due to leachate as well as soil contamination and degradation. One way to solve this problem is the landfill mining process. Landfill mining technique involves the extraction and processing of materials landfilled in a closed landfill in order to use energy and materials with respect environmental and social criteria such as reuse a land for new purposes, removal of potential sources of pollution, mitigation of site contamination, reduction of management costs and rebuilding the site, etc. Traditionally, landfill mining involves the extraction, treatment, treatment and/or recycling of deposited materials.

The question arises: what can be used in the landfilled waste: the organic part of waste, deposited metals, plastic, glass or mixture that is suitable for energy recovery. In order to answer this answer, one must observe what is landfilled and what happened to the organic and inorganic waste over time. The population habits, the life style, the economic and technological development and other socio-economic factors certainly influence the composition of landfilled waste after a certain number of years. Also, factors such as the age of the landfill, the type of landfill, region in which the landfill is located may have an impact on the type of landfilled material and their potential for valorization.

In this paper the mathematical model for estimation the quantities of recyclable material and material for energy recovery obtained in landfill mining was presented. Based on the data from the field of quantities and composition of landfilled waste and age of existing landfill Ramići near Banja Luka, a preliminary estimation of the raw material potential of landfill could be done, and obtained results could be used in order to help the decision makers in Republic of Srpska to choose the sustainable material and energy resource recovery.

2. MATERIALS AND METHODS

Mathematical model presented by Wolfsberger et. al. [1] was used for a preliminary estimate of the raw material potential of landfill.

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The model is based on three step calculation: (1) Calculation of the degree of degradation of the deposited waste; (2) Survey of the biodegradable proportion of selected waste fractions; and (3) Calculation of the theoretical raw material potential.

— Calculation of the degree of degradation of the deposited waste

Owing to organic components, conversion processes take place in landfills that can reduce the raw material potential. Therefore, the degradation degree of the waste should be considered. This degradation degree depends on the storage duration and composition of the waste, as well as the prevailing environmental conditions within the landfill.

After waste is landfilled, the organic components start to undergo biochemical reactions. The principal reaction in landfills is anaerobic digestion that takes place in three stages. The emissions released during this conversion process are discharged mainly in the form of landfill gas. For this reason, gas forecast models are used for the calculation of the degree of degradation in the course of the presented method. For this calculation, mathematical model developed by Tabasaran and Rettenberger [2], which allows the calculation of the gas amount formed if the biodegradable organic carbon content is known, is applied. The formula takes into account the influence of the landfill body temperature as well as the temporal course of landfill gas formation:

$$G_t = M_A \cdot 1.868 \cdot C_{org} \cdot (0.014 \cdot T + 0.28) \cdot (1 - 10^{-k \cdot t}) \quad (1)$$

where Gt is the landfill gas quantity for the period t (m^3), C_{org} is the introduced biodegradable carbon content (C kg/t), MA is the deposited waste quantity (t), T is the temperature (°C), k is the degradation constant (1/y) and t is time (y).

The model simulates ideal environmental conditions inside a landfill body, and factors like actual water or nutrient content as well as its distribution in the landfill are not included.

If it is assumed that 1.868 L of landfill gas is formed per gram of carbon, the portion of degraded carbon (equation (2)) can then be concluded and the degree of degradation (equation (3)) estimated:

$$C_{org,de} = \frac{G_t}{1.868} \quad (2)$$

$$D = \frac{C_{org,de}}{C_{org,tot}} \cdot 100 \quad (3)$$

where $C_{org,de}$ is the degraded carbon content (kg C), $C_{org,tot}$ is the total introduced biodegradable carbon in time t (kg C) and D is the degree of degradation (%).

— SURVEY OF THE BIODEGRADABLE PROPORTION OF SELECTED WASTE FRACTIONS

As already mentioned, even biodegradable substances do not usually consist of 100% biodegradable proportions. To take this into consideration, the biodegradable proportion of selected waste was surveyed. For this study, analyses [1,3], which had already been carried out in the past and found in literature, were used.

— CALCULATION OF THE THEORETICAL RAW MATERIAL POTENTIAL

For the calculation of the theoretical raw material potential, the initial value of waste quantity in each waste category is needed. The amount of each waste fraction has been multiplied by the calculated degree of degradation as well as the respective average of the biodegradable proportion, allowing the already-degraded proportion of the respective waste fraction to be estimated (4):

$$DW = I \cdot D \cdot b \quad (4)$$

where DW is the degraded waste (t), I is the initial value (t), D is the degree of degradation (%) and b is the biodegradable proportion (%).

The waste quantity deposited in the landfill was then calculated by subtracting the degraded waste DW from the corresponding initial value I. The sum of the amounts of glass, metal, paper and cardboard, and plastics obtained using this formula gives the secondary raw material potential of the landfill site.

3. EXPERIMENTAL RESEARCH

A mathematical model for estimating the quantities of recyclable materials and materials for energy recovery obtained in landfill mining was applied to the case study of the city of Banja Luka as the largest city in the Republic of Srpska. In the vicinity of the City of Banja Luka there is a regional landfill Ramići, where generated waste is landfilled.

According to the data found in literature around 705,141 t of waste was landfilled at the landfill Ramići in period 2010–2017 [4]. As mentioned above that only waste of an organic nature (M_A)

i.e. food and yard waste, paper and cardboard, textile and animal waste was considered for the calculation, those quantities are also presented in Table 1.

Table 1. The quantity of waste generated annually in the city of Banja Luka in period 2010-2017 [4].

Waste quantity (t/y)	Landfilled amount of waste per year (t)								
	2010	2011	2012	2013	2014	2015	2016	2017	Total
MSW	85,000*	86,000*	87,000*	92,896	88,954	81,548	89,246	94,497	705,141
M_A	46,070	46,612	47,154	50,349	48,213	44,199	48,371	51,217	382,186

* estimated quantities

In Table 2 composition of waste (mean values) generated in the city of Banja Luka, landfilled quantities in landfill Ramići in period 2010-2017, and its biodegradable proportion is presented.

Table 2. Composition of waste (mean values) generated in the city of Banja Luka, landfilled quantities in period 2010-2017, and its biodegradable proportion [1,3,4].

Fractions	Percentage (mean values) (%)	Waste quantity (t)	Biodegradable proportion (%)
Food and yard waste	38.3	270,069	60
Animal waste	3.8	26,795	70
Paper and cardboard	10.8	76,155	65
Textile	1.3	9,166	40
Plastics	12.9	90,963	0
Foil	9.4	66,283	10
Glass	4.9	34,552	0
Metals	6.7	47,244	0
Rubber	0.9	6,346	5
Other	11.0	77,565	40
Total	100	705,141	

Based on the presented mathematical model, using the equations (1-4), as well as on the basis of the quantity and composition of the deposited waste, the degree of degradation of the deposited waste can be calculated. As indicated parameters in equations were used: 2010 was set as the starting value, and the 2017 was chosen as the endpoint of the consideration period; the temperature T for the landfill is set to the average of the two temperatures (32.5 °C) for the entire period considered; the k value with the average of the two specifications (0.040 1/y) is used; biodegradable carbon content is adopted from the literature as 185 kg C/t [5]; for the survey of the parameter M_A, the quantities presented in Table 2 was adopted as initial values.

4. RESULTS AND DISCUSSION

Using quantity of landfilled waste and the indicated parameters t, T, k, and C_{org}, the theoretical landfill gas quantity (G_t) formed in landfill Ramići within a period 2010 – 2017 is calculated. Further, based on that the degree of degradation is calculated also. Obtained results show that, in the period 2010 – 2017, amount of 118,354,588 m³ of landfill gas is generated in landfill Ramići. That amount of generated landfill gas corresponds to amount of degraded C_{org} of 63,358,987 kg. As mention above, only waste of an organic nature (food and yard waste, animal waste, paper and cardboard, and textile) was considered for the calculation of the introduced biodegradable C_{org}. Based on that and using the adopted value of introduced biodegradable carbon content of 185 kg C/t of waste, the total introduced biodegradable $C_{org,tot}$ in period of 2010 – 2017 of 74,034,225 kg is calculated. If degraded C_{org} is viewed in relation to the introduced biodegradable C_{org}, the degree of degradation can be estimated at approximately 85.58%.

Table 3. The amount of undegraded waste, and the theoretical raw material potential.

Fractions	Quantity (t)	Quantity (%)
Food and yardwaste	92,451	24.94
Animal waste	6,879	1.86
Paper and cardboard	22,811	6.15
Textile	4,707	1.27
Plastics	77,847	21.00
Foil	51,053	13.77
Glass	29,570	7.98
Metals	40,432	10.91
Rubber	5,159	1.39
Other	39,828	10.74
Total	370,737	100
Theoretical raw material potential	170,659	50.19

Further, for the calculation of degraded waste (DW), as mention above, biodegradable proportion

(b) of waste fractions is adopted from the literature [1] and also presented in Table 2. Based on calculated degree of degradation (D), adopted biodegradable proportion (b), and using equation (4) the amount of undegraded waste, and according to that the theoretical raw material potential is calculated and presented in Table 3.

According to the results presented in Table 3, the calculated amount of undegraded waste is 370,737 t that is 54.20% compared to the total amount of landfilled waste in the period 2010 – 2017. From this amount, theoretical raw material potential of landfill Ramići is 50.19%. In calculation of the theoretical raw material potential, undegraded quantities of paper and cardboard, plastics, glass and metals were taken into account. If it is assumed that mainly glass and metals obtained in landfill mining are suitable for material recycling, it means that about 18.88% could be supplied for material recovery. Based on their high calorific value, the fractions paper and cardboard, and plastics, seem to be suitable for energy recovery. Therefore, 27.15% of the theoretical raw material potential could thus be used for waste-to-energy treatment.

5. CONCLUSION

Based on the data from the field of quantities and composition of landfilled waste and age of existing landfill, a mathematical model for estimation the quantities of recyclable material and material for energy recovery obtained in landfill mining was applied in order to help the decision makers to choose the sustainable material and energy resource recovery before the application of the excavations and waste sampling, the expensive, time consuming and technically complex procedures.

The presented methodology was applied in the case study landfill Ramići near the city of Banja Luka. The obtained results show that 18.88% of the landfilled waste, i.e. glass and metals could be used for material recovery, while 27.15% of the landfilled waste, i.e. paper, cardboard, and plastics can be used for energy recovery, due its high calorific value.

Also, it should be notes, that the presented methodology allows no statement on the quality and the subsequent suitability of potential secondary raw materials for an actual recovery, but represents a tool for the estimation of raw material potential of landfilled waste.

Note:

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