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Landfill gas–landfill degassing system and methods of using landfill gas at Sarajevo landfill

Dzevad Imamovic* and Amra Serdarevic

Faculty of Civil Engineering, University of Sarajevo, Patriotske lige 30, Bosnia and Herzegovina

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Abstract. Municipal solid waste landfills are unpredictable bioreactors which in cases of mishandling and bad supervision presents numerous risks. The key to municipal waste landfills is to approach them from the point of prevention of the possible consequences, which means using methods of organized waste disposal, and also utilizing landfill gas, as an unavoidable consequence with disposal of municipal solid waste with a high share of biodegradable organic matter. This paper presents an overview about problems of solid municipal waste management, type and composition of waste, and an overview of waste management condition. Further, the problem of landfill and landfill gasses is described with the calculation models of landfill production, as well as the use of the SWM GHG Calculator and LandGEM software on a specific example of gas production for the central zone at Sarajevo landfill "Smiljevici". Main focus of this thesis is the analysis of potentials of greenhouse gas emission reduction measures from the waste management. Overview of the best available techniques in waste management is presented as well as the methodology used for calculations. Scenarios of greenhouse gas emission reduction in waste management were defined so that emissions were calculated using the appropriate model. In the final section of the paper, its description of the problem of collection and utilization the landfill gas at the sanitary landfill "Smiljevici", and implementation of the system for landfill gas collection and solution suggestion for the gasification and exploitation of gas. Energy, environmental and economic benefits can be accomplished by utilizing municipal solid waste as fuel in industry and energy and moreover by utilizing energy generation from landfill gas, which this thesis emphasizes.

Keywords: benefits; costs; Landfill; landfill gas; landfill gas collection; landfill gas energy projects; waste greenhouse gas emissions

1. Introduction

The term sanitary landfill means a building that serves for the reception and permanent disposal of waste that can no longer be used according to any option of the waste management hierarchy and it is permanently disposed of on the surface or under the land surface, with the application of technical measures to prevent soil, water and air pollution (Serdarević 2016).

The objective of sanitary landfill design is to provide for safe disposal of waste while protecting human health and the environment. Sanitary landfills should be designed and managed

*Corresponding author, Ph.D. Student, E-mail: dzevad4imamovic@gmail.com

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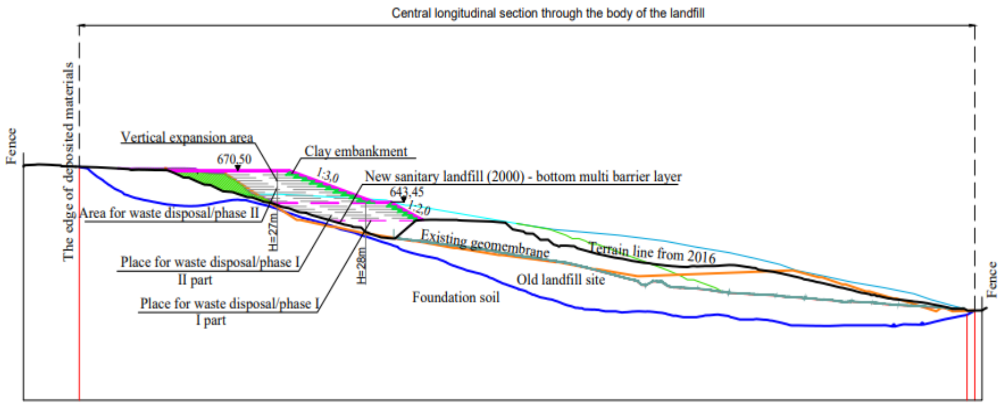

Fig. 1 Central longitudinal profile through the body of the sanitary landfill (IPZ Uniprojekt l.t.d)

to protect soil, ground water, surface water and air. Other important objectives of sanitary landfill design are to maximize the waste disposal quantity in the available space given site conditions, geometry, consideration of slope stability and future potential uses. Additionally, a well-designed and operated sanitary landfill will provide cost savings over the life of the site as preventive measures are often less costly than mitigation efforts associated with poorly designed and operated sites (USEPA 2012).

The basis of any landfill gas energy project involves the design, construction and operation of landfill gas collection and control system. The purpose of a system is to extract landfill gas from the waste mass and convey it to a combustion device for flaring or energy use. A typical system includes the following primary components: extraction wells; a system of lateral and header (manifold) piping to convey the collected landfill gas; a condensate management system; a blower and flare system; monitoring devices; and system controls (USEPA 2012).

Landfill gas is a natural byproduct of the decomposition of organic material in landfills and it is composed of roughly 50 percent methane (the primary component of natural gas), 50 percent carbon dioxide (CO_2) and a small amount of non-methane organic compounds (Mulaomerović *et al.* 2010). Also, methane is a potent greenhouse gas 30 to 36 times more effective than CO_2 at trapping heat in the atmosphere over a 100-year period.

Sarajevo landfill "Smiljevici" was established in 1962 year and reconstructed into sanitary landfill in 2000 year. The standard filling elevation varies from 25 m to 40 m. The expansion of this landfill is a part of transformation of the sanitary landfill and their facilities into the Regional Centre for Waste Management of Canton Sarajevo. According to the main landfill design, options for landfill vertical elevation and conditions of the disposed waste, the landfill is divided into several characteristics parts, (see Fig. 1).

In order to define the potential of the Sarajevo landfill for the production of landfill gas, and the profitability of the investment in the landfill gas utilization project, it was necessary to evaluate the amount and degree of landfill gas production. The assessment was made based on the composition and age of solid waste that was deposited at the Sarajevo landfill in the past.

2. Landfill gas production and greenhouse gas emissions at Sarajevo landfill "Smiljevici"

In the central zone of the landfill, in 2018, works began on drilling wells with the aim of installing a vertical degassing system and on that occasion 30 PEHD probes with perforated pipes DN 110 mm were installed. A protective plug made of hard plastic is buried in the field to a depth of max. 1 m, and thanks to it, the gas remains trapped in the probes until it is used, while a clay cover was built around the plug to ensure better impermeability. The depth of waste in the central part of the sanitary landfill ranges from 15 to 25 m on average, and in the lower part up to 10 m.

The share of methane at the "Smiljevici" landfill ranges from 50 to 55% on average, which is desirable from the aspect of its utilization. The amount of gas that will be generated at the landfill depends on the composition of the waste, the proportion of organic matter in the waste, as well as the type of landfill. The software used for the calculation of landfill gas production is LandGEM and it uses the following first-order decomposition rate equation to estimate annual emissions over a time period that you specify. LandGEM is an automated tool for estimating emission rates for total landfill gas, methane, carbon dioxide, nonmethane organic compounds (NMOCs), and individual air pollutants from MSW landfills.

First-order decomposition rate equation is defined as (Serdarević 2016)

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_0 \left(\frac{M_i}{10}\right) e^{-kt_{ij}} \quad (1)$$

Q_{CH_4} = annual methane generation in the year of the calculation (m^3/year),
i = 1-year time increment,
n = (year of calculation) – (initial year of waste acceptance),
j = 0.1 – year time increment,
k = methane generation rate ($year^{-1}$),
L_0 = potential methane generation capacity (m^3/Mg),
Mi = mass of waste accepted in the i^{th} year (Mg),
t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i_{th} year.

Two variants were considered:

- variant I – assessment of landfill gas production with and without the inclusion of old waste (disposed) in the calculation (central and foot zone),

- variant II – assessment of landfill gas production with and without the inclusion of old waste in the calculation with waste recycling (central and foot zone).

The following gas composition was used for the calculations, namely the share of CH_4 of 55%,

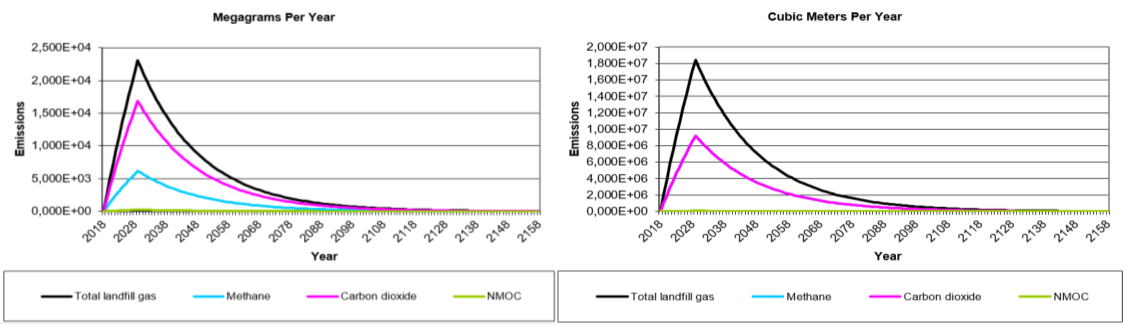

Fig. 2 Graphic representation of landfill gas production without old waste and recycling through LandGEM for the period from 2018 to 2068

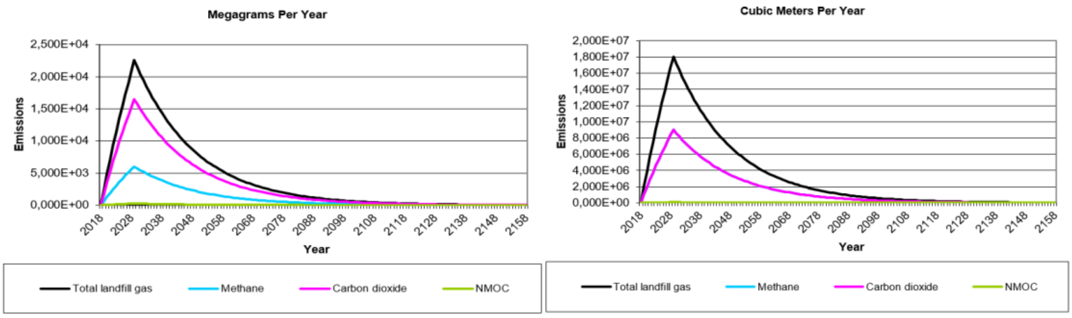

Fig. 3 Graphic representation of landfill gas production without old waste with recycling through LandGEM for the period from 2018 to 2068

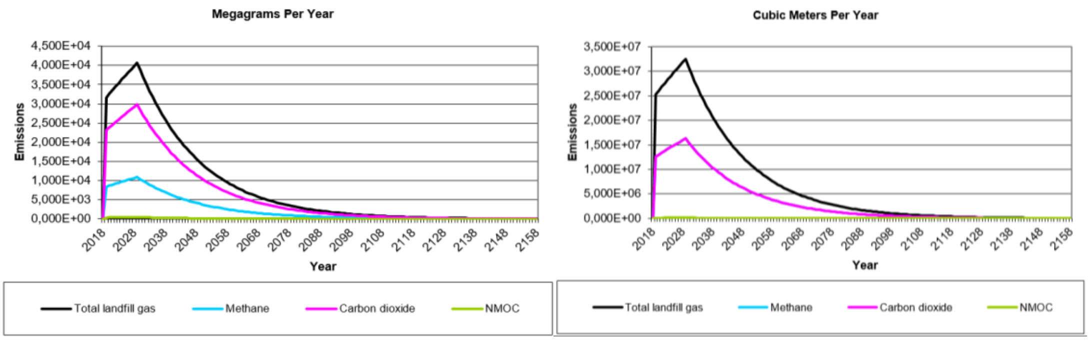

Fig. 4 Graphic representation of landfill gas production with old waste without recycling through LandGEM for the period from 2018 to 2068

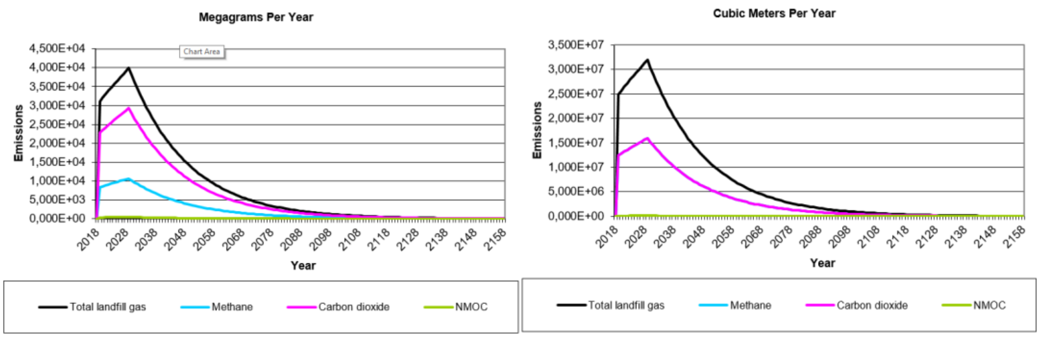

Fig. 5 Graphic representation of landfill gas production with old waste and recycling for the period from 2018 to 2068

the share of CO_2 of 44% and other pollutants 1%. Below (Figs. 2, 3, 4 and 5) are the estimated amounts of CH_4 and CO_2 production and their summary values for the period from 2018 to 2068 through the use of the LandGEM software, with the remaining trace pollutants.

From previous analyses, using the LandGEM software and Excel for calculation through the Weber model, it is noticeable that the largest gas production is caused by old waste, while the waste that will be produced in a period of 10 years does not have a significant impact primarily due to smaller quantities. As mentioned, two variants were considered, with the variant that takes

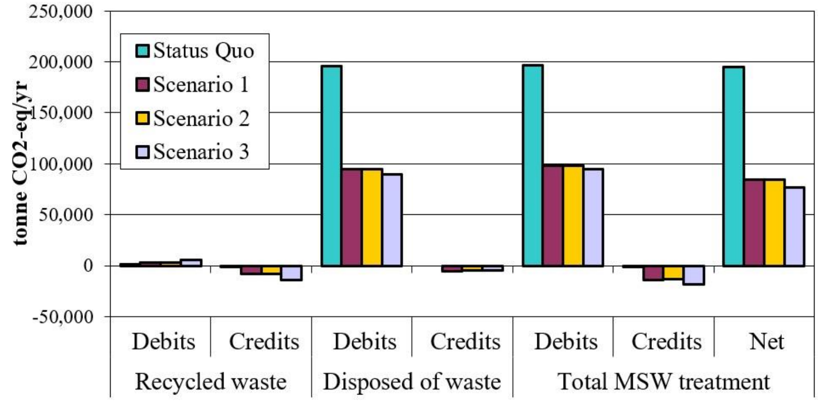

Fig. 6 Presentation of greenhouse gas emissions at the subject landfill, variant I

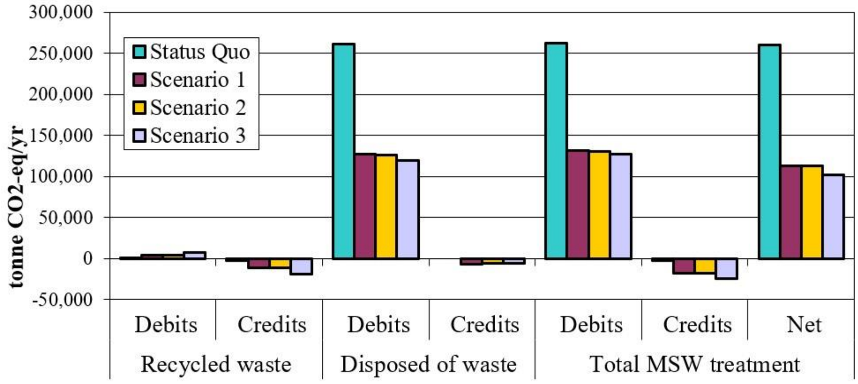

Fig. 7 Presentation of greenhouse gas emissions at the subject landfill, variant II

old waste into account, but without recycling, produces the largest amount of landfill gas. However, the current situation is such that recyclable materials are separated at the landfill in question in a very small percentage (1 to 2%), so this fact should also be taken into account when evaluating the amount of landfill gas, because in the near future, recycling will be covered larger amounts of waste.

Based on the results of the calculation, after the closure of the landfill - cessation of waste disposal (in 2028), the amount of landfill gas amounts to close to 11.5 million Nm^3/year, and its exploitation will be possible in the following period of 30 to 40 years.

The following shows the greenhouse gas emissions of the landfill in question for a period of one year through the use of the SWM GHG Calculator software. The program tool requires the definition of input data such as the amount of waste that is disposed of during the year (two variants were made, namely variant I of 150,000 t/year and variant II of 200,000 t/year), the number of inhabitants (according to the last population census from 275,524 inhabitants live in Canton Sarajevo in 2013), waste composition, waste humidity and specific greenhouse gas emission factor in terms of electricity generation (478 g CO2-eq/kWh).

Furthermore, the rates of recycling of recyclable material are defined for all scenarios of waste management, as well as the share of waste that goes to digestion or composting. Then, the methods of waste treatment at the landfill in question were defined with regard to the associated scenarios, and the proposed cost prices of various waste treatment activities. Each subsequent scenario represents an improved version of integrated solid waste management (Stepanov 2018).

Figs. 6. and 7. also shows the results of the comparison of the four scenarios, but using a different structure and with more details. The first part is about recycling results. The first four blocks represent debits from recycling in the four scenarios, and the second four credits from recycling in all four scenarios. The next section shows similar results, but for disposed waste. In the final part, debits, credits and net results for the total treatment of municipal solid waste for all four scenarios are presented.

Before drawing a conclusion, it is necessary to define the adopted scenarios. Currently, a very small percentage of recyclable materials are separated at the landfill in question. The recycling rate has been increased from scenario to scenario taking into account the real progress of our country. Calculation shows a realistic selection of waste treatment and disposal options, taking into account biological stabilization as the cheapest option while reducing the amount of waste that is disposed of.

According to the above, it can be concluded that scenario 3 is the best in terms of reducing greenhouse gas emissions, while the current situation is such that the emission of greenhouse gases into the atmosphere is twice as high. This also indicates that the Sarajevo landfill is a place of production of large quantities of methane and other landfill gases (200,000 to 250,000 t CO2-eq/year), so it is inevitable to exploit it for energy, that is, to use it for the production of electricity and heat.

3. Benefits of landfill gas energy projects

There are several empirical and mathematical methods for calculating the specific annual amount of landfill gas generated per ton of municipal waste. According to Earlson's empirical method, a ton of waste produces an average of 11 m^3 of landfill gas per year, so if we are talking about an annual amount of approx. 200000 tons of municipal waste, we are talking about an average of 2200000 m^3 of landfill gas.

According to the European Directive on waste disposal (1999/31/EC, 1882/2003, 1137/2008), it is considered necessary to degas every municipal waste disposal site with more than 10,000 m^3 of waste per year. From 1 ton of waste, 150 to 300 m^3 of gas can be generated in 15 to 25 years of the landfill's existence. On average, it is calculated with 10 to 25 m^3 of gas per ton of waste for one year.

Today in the world there is a whole series of examples of energy utilization of landfill gas that confirm its significant economic profitability. Analyzing the experience from the USA and the countries of the European Union, the possibilities of energy utilization of landfill gas can be divided into three basic groups like direct burning of landfill gas in steam generators and boilers, electricity production and cogeneration, and other possibilities of using landfill gas.

Larger amounts of gas are formed in the first years after waste disposal, while later they decrease. In conclusion, it can be said that the measured gas flow at the Sarajevo landfill shows the justification for the construction of a mini power plant. Gas production at the sanitary area was sufficient for exploitation, both in terms of quantity and percentage of methane in the gas mixture.

4. Conclusions

Based on the analyzes carried out both by applying the software LandGEM and SWM GHG Calculator, as well as by using Excel for the calculation of landfill gas production via the Weber model, it is noticeable that the greatest gas production will be caused by old waste at a height of 15 to 25 m in the central part of the landfill. Taking into account the favorable composition of the gas (an average of more than 50% CH_4 on all installed probes) as well as the satisfactory yield of the probes, enviable results can be expected in terms of the utilization of landfill gas at the Smiljevici landfill, and thus the reduction of greenhouse gas emissions that for "Current situation-Status Quo" amount to 200000 to 250000 CO_2-eq/year of disposed waste, depending on the observed variant, total amount of waste on an annual basis. Through other scenarios that include increasing the rate of recycling and utilization of waste, it is possible to reduce greenhouse gas emissions twice.

Therefore, as it was said, biogas is suitable for use in plants, because it is obtained from organic material that we have in large quantities in the environment. Bosnia and Herzegovina has great potential in biogas and landfill gas, which should be properly utilized. By investing in biogas and landfill gas, our country would be less dependent on expensive imported gas, and at the same time it would support the domestic economy, and only then would the principle that "our waste is our wealth" be fully realized.

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