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Estimation of Methane Emissions from Mirash Municipal Solid Waste Sanitary Landfill, Differences between IPPC 2006 and LandGEM Method

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ABSTRACT

This paper deals with the estimation of methane emissions from the Mirash municipal solid waste sanitary landfill. The methane emission was calculated according to two different methodologies, namely, IPCC 2006 and LandGEM. Within the framework of the research, the following parameters were evaluated: the amount of landfilled waste, landfill characteristics, and composition of landfilled waste as well as the climate conditions prevailing in the region. According to the IPCC methodology, the total amount of methane emitted from the Mirash landfill during the period 2006–2017 was 30.57 Giga grams (Gg), while according to the LandGEM methodology, the total amount of methane emitted from the Mirash landfill in the period 2006–2017 was 26.32 Giga grams (Gg). The total mass of CH_4 in the Mirash regional landfill for the years 2018–2025 is projected to be 53.74 Gg according to the IPCC method, while according to LandGEM method, the projection points to 50.74 Gg. This study was carried out for the sanitary landfill for solid waste management in Mirash, Prishtina Region, in the Republic of Kosovo, during the year of 2018.

Keywords: emissions, methane, municipal solid waste (MSW), sanitary landfill, Mirash.

INTRODUCTION

Urbanization and changes in the life style of the urban population have given rise to the generation of solid waste (Darban Astane, *et. al.,* 2017). Municipal waste generation in Kosovo increases, following the GDP growth and is similar to that in other Western Balkan countries. Waste generation has nearly followed the region's upward trend in GDP, which is attributed to the constant economic growth accompanying liberal markets and return of stability (ZOI Net, 2012). This trend is different from that in the EU member countries where the municipal waste generation is decreased. In total, 60% of the Kosovo population use the refuse collection service. In Kosovo, there is no developed infrastructure for collection, landfilling and separation of municipal waste all over the country's territory. This has resulted in a high number of illegal landfills. In addition, there is the problem of dumps, especially in the rural areas where there is no waste collection system organized by the competent authorities (Milenkovic, *et al.,* 2017; Morina, *et al.,* 2017). Before 2000, most of the solid waste collected from the urban areas in Kosovo was deposited in unmanaged landfills or waste dump sites. During the past decade (2006–2016), there was an improvement of waste disposal infrastructure from open dumping and unmanaged landfills to managed sanitary landfills. Such improvement of waste management increased the amount of disposed waste. At present, about 60% of the solid waste is disposed of in sanitary landfills (Veselaj, *et al.,* 2014). One of the major impacts of waste disposal in sanitary landfills or illegal dump sites is the emission of greenhouse gases, mainly methane, to the atmosphere (Berisha, *et al.,* 2018). These greenhouse gases are produced from the biodegradation of waste under anaerobic conditions through microbial activities. These waste disposal sites are considered as one of the most common anthropogenic sources of greenhouse gases (Scheutz, *et al.,* 2009; Powell, *et al.*, 2015). The methane gas emitted from the waste disposal sites has a global warming potential that is 25 times greater than that of carbon dioxide (IPCC, 2006). The bio-degradation of these deposited wastes leads to the production of landfill gases with a high risk of explosion (Huseyin, *et al.,* 2018). The emissions of greenhouse gases (GHG)from the managed waste in Kosovo represent around 3–4% of the total national GHG emissions. The methane emissions from the sanitary municipal solid waste landfills are the major source of GHG emissions from the waste sector in Kosovo (Berisha, *et al.,* 2015; KEPA, 2015; UNDP Kosovo, 2012). There are 6 municipal and regional waste landfills in the territory of Kosovo that are considered as potential hotspots. These landfills bear a potential risk regarding the impact on air, water, soil and public health (Veselaj, *et al.,* 2013). The largest sanitary landfill for solid waste management in Kosovo is Mirash, located in the Prishtina region, in the Republic of Kosovo.

MATERIAL AND METHODS

Study area

The observed landfill represents a sanitary landfill for solid waste management in the Prishtina region, situated in the Mirash location (Fig. 1). This landfill serves for depositing of waste collected from the following municipalities: Prishtina, Gracanica, Obiliq, Lipjan, Fushe Kosove, and Gllogovc. The information presented in table 1 shows that the population covered by the refuse collection service in the region represents 61.2% (or 238.810 inhabitants) of the population of the region (MLGA, 2017).

The landfill was established in 2006. An excavated coal mine with bordering walls was prepared and coated with a polyethylene foil sealing layer. The waste landfilling process in the sanitary solid waste landfill started in 2006. The total surface of the landfill is about 40 ha. The waste landfilling area has a size of about 8 ha. The waste landfilling is to continue until the year of 2025. At present, the average waste layer height is about 13 m (KEPA, 2015; GIZ, 2015). In the Mirash landfill, a number of passive degassing wells are installed in different zones of the covered and non-covered landfill body. There is no adequate equipment for active degassing of the landfill (table 2).

Mirash landfill is located in the Prishtina region, which is characterized by a prevailing continental climate with 640 mm/yr of rainfalls and

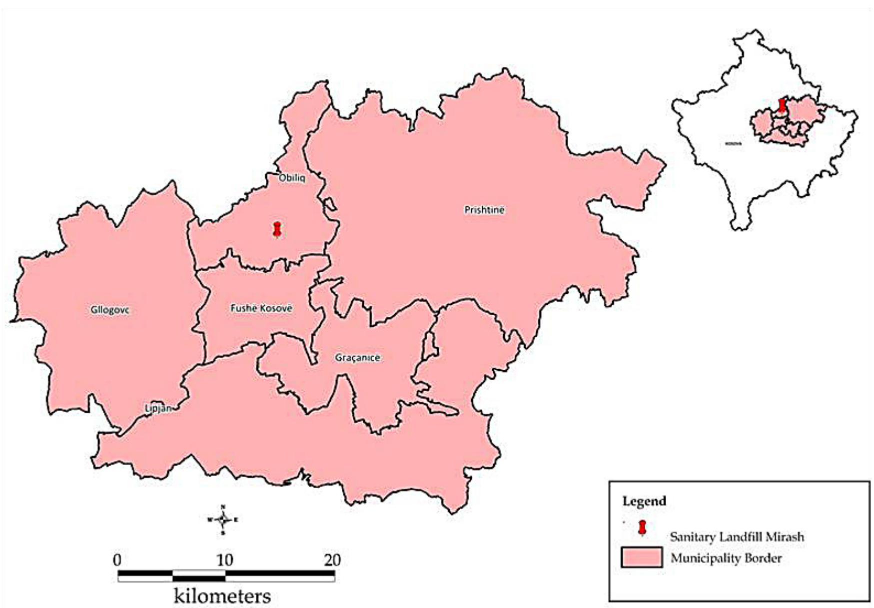

Fig. 1. Geographic location of the studied area

Table 1. Population covered by the refuse collection service in the Prishtina region

Name of the regional sanitary landfill	Municipalities	Area covered by the municipality km^2	Nr. of population	% of population covered by the refuse collection service	Nr. of population covered by the refuse collection service
Sanitary landfill in Mirash	Prishtina	523	204721	65 %	133069
	Gllogovc	276	60175	56 %	33898
	Obiliq	105	19165	70 %	13416
	Fushe Kosovo	84	37048	97 %	35936
	Lipjan	338	56643	25 %	14161
	Gracanica	122	11900	70 %	8330
Total		1448	389652	61.2 %	238810

Table 2. Characteristics of the Mirash sanitary landfill

Starting year of operation	Type of a landfill	Landfill status	Landfill area	Waste deposition area	Maximal height of waste	Total deposited waste in tons until 2016	Waste deposition is planned up to the year
2006	Managed semi-aerobic	Currently in use	40 ha	8 ha	13 m	985,207	2025

with an average yearly air temperature of about 11.4° Celsius (KHMI, 2017). Figure 2 shows the climate conditions in the Prishtina Region for the years 2006–2017.

The yearly amount of deposited waste in the sanitary landfill in Mirash amounted to about 121.785 tons in 2017. Cumulatively, about 1.106.992 tons of waste was deposited in the period 2006–2017 (Berisha, *et al.,* 2015; KAS, 2017). More detailed information is presented in Table 3.

The composition of fractions of the municipal solid waste is one of the main parameters that affect the GHG emission from the landfill (Sandhya, *et al.,* 2011). According to the analysis of the waste composition performed for the Prishtina region, it is characterized by a higher content of organic waste fractions. The main fractions of waste composition are food waste accounting for 36% while paper and cardboard account for 13% (Veselaj, *et al.,* 2014; MESP, 2017). The solid waste composition in the Prishtina region is presented in Figure 3.

Quantification of CH_4 emission

The calculation of CH_4 emission from the landfill in Mirash was based on the data on the landfilled waste for the period 2006–2017. In order to perform emission calculations over the years 2006–2017, annual data on waste disposal and data on the fractions of waste deposited into the sanitary landfills were collected from the Kosovo Environmental Protection Agency and the Statistical Agency of Kosovo and then entered

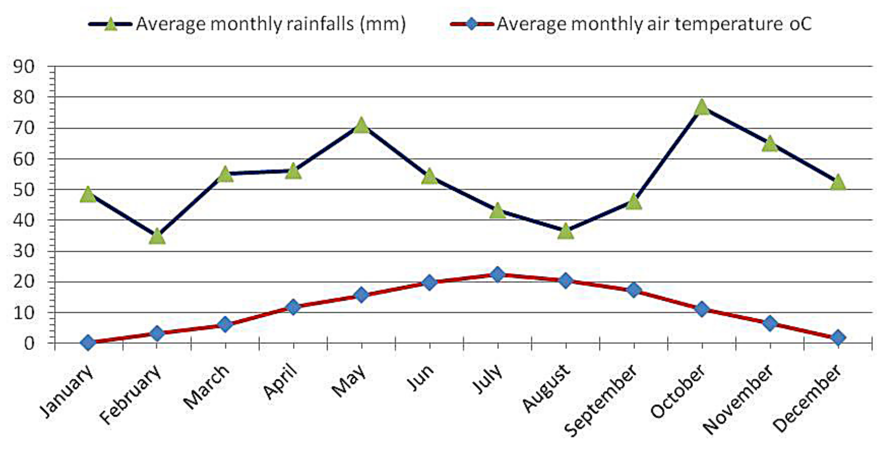

Fig. 2. Climate conditions in the Prishtina region in the period 2006–2017 (KHMI, 2017)

into the IPCC 2006 model spreadsheet as well as the Landfill Gas Emission Model (LandGEM), an automated estimation tool.

Method 1 IPCC 2006: The calculations of the CH_4 emission from the landfill were performed in Microsoft Excel 2007 spreadsheets according to the IPCC guidelines (IPCC, 2006). The IPCC default method for estimation of methane emission from waste disposal sites is based on the following equation:

$$\text{Methane emissions} = (MSWT*MSWF*MCF*DOC*DOCF*F*16/12-R)*(1-OX)$$

where: $MSWT$ = Total amount of generated waste (Gg/year)
$MSWF$ = Fraction of disposed waste
MCF = Correction factor of the waste fraction that generates methane gas from the sanitary landfill
DOC = Fraction of biodegradable organic carbon
$DOCF$ = Fraction of biodegradable organic carbon that is readily available for degradation
F = Fraction of methane in biogas
OX = Fraction of methane gas that is oxidized into carbon dioxide
R = Recovered CH_4 (Gg/yr)

The specific parameters and values applied for estimation of the CH_4 emissions from the Mirash landfills according to the IPCC method are presented in Table 4.

Method 2 LandGEM: The Landfill Gas Emission Model (LandGEM) is an automated estimation tool with a Microsoft Excel interface that can be used to estimate the emission rates for all landfill gases including methane. LandGEM can use either site-specific data or default parameters to estimate emissions if no site-specific data are available (Alexander, *et al.,* 2005; Kumar *et al.,* 2014). LandGEM is one of the most commonly used and most flexible models (Sadeghi, *et al.,* 2015). The model is presented to estimate annual emissions over a time period based on user specification (Kalantarifard, *et al.,* 2012; Rodrigue, *et al.,* 2018). The model contains two sets of default parameters, CAA defaults and inventory defaults. The CAA defaults are based on the USA federal regulations for MSW landfills laid out by the Clean Air Act (CAA). The inventory defaults are based on the emission factors in EPA's Compilation of Air Pollutant Emission Factors (AP-42). LandGEM uses the following first-order decomposition rate equation to estimate annual emissions over a specified time period.

Table 3. Waste disposal in the Mirash sanitary landfill 2006–2017 (Berisha, et al., 2015; KSA, 2017).

No.	Year	Waste disposal per year/tons	Accumulated disposed waste (tons)
1.	2006	77.000	77.000
2.	2007	77.250	154.250
3.	2008	79.568	233.818
4.	2009	81.955	315.773
5.	2010	84.413	400.186
6.	2011	86.946	487.132
7.	2012	89.554	576.686
8.	2013	92.241	668.927
9.	2014	95.008	763.935
10.	2015	104.743	868.678
11.	2016	116.529	985.207
12.	2017	121.785	1.106.992

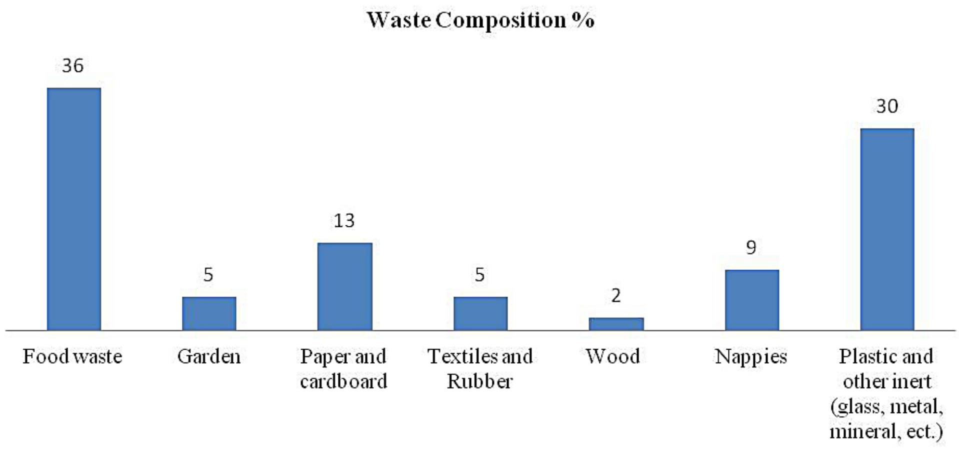

Fig. 3. Waste composition in the Prishtina region (mass %) (Veselaj, et al., 2014; MESP, 2017)

Table 4. Parameters used for the sanitary landfills according to the IPCC 2006 default value (IPCC, 2006)

Parameters		Value
DOC (Degradable organic carbon) (weight fraction, wet basis) Waste by composition	Food waste	0.15
	Garden	0.2
	Paper	0.4
	Wood and straw	0.43
	Textiles	0.24
	Disposable nappies	0.24
DOCf (fraction of DOC dissimilated)		0.5
Methane generation rate constant (k) (years^{-1})	Food waste	0.185
	Garden	0.1
	Paper	0.06
	Wood and straw	0.03
	Textiles	0.06
	Disposable nappies	0.1
Delay time (months)		6
Fraction of methane (F) in developed gas		0.5
Conversion factor, C to CH_4		1.33
Oxidation factor (OX)		0
Methane Correction Factor (MCF) for managed semi-anaerobic landfills		0.5

Table 5. LandGem inventory default values used for the calculation (Alexander, *et al.,* 2005).

Methane Generation Rate, k (*year^{-1}*)	0.05
Potential Methane Generation Capacity, L_o *(m^3/Mg)*	170
Methane Content (*% by volume*)	50

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

where: $QCH4$ = annual methane generation in the year of the calculation (m^3/year)
i = 1 year time increment n = (year of the calculation) – (initial year of waste acceptance)
j = 0.1 year time increment
k = methane generation rate (year-1)
Lo = potential methane generation capacity (m^3/Mg)
Mi = mass of waste accepted in the ith year (Mg)

tij = age of the jth section of waste mass Mi accepted in the ith year (decimal years, e.g., 3.2 years)

Used in this research were the inventory CAA default values for landfills presented in Table 3.

RESULTS AND DISCUSSION

The calculations of the CH_4 emissions from waste landfilled in the Mirash sanitary landfill in the period 2006–2016 are presented in Table 6, showing that the total mass of CH_4 generated in the Mirash landfill during 2006–2017 amounted to 30.57 Gg according to the IPCC method and 26.32 Gg according to the LandGEM method.

The calculations of the projections of CH_4 emissions from the landfilled waste for the years 2018–2025 in Mirash sanitary landfill are presented in Figure 4. The total mass of CH_4 from the Mirash sanitary landfill for the time period 2017–2025 was projected to 53.74 Gg according to the IPCC method, while the total mass of CH_4 projected according to the LandGEM method was 50.74 Gg.

As CH_4 is produced by bacterial decomposition of organic fractions within landfills, the amount of organic waste within a landfill dictates the amount of produced gas, whereat higher concentrations of organic matter yield higher concentrations of methane (Kumar, *et al.,* 2004; Mutasem El-Fadel, *et al.,* 2002). Several physical conditions and interactions influence methane emission from landfills. Waste composition, air temperature, topography, pressure, pH and microbial interactions are some of the factors

Table 6: Calculated CH_4 emissions from the waste deposited in the Mirash sanitary landfills, 2006–2017 (Gg/yr)

	Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CH_4 emissions (Gg/yr)	IPCC 2006 method	0	0.55	1.06	1.54	1.99	2.43	2.85	3.25	3.63	3.99	4.41	4.87
	LandGEM Method	0	0.42	0.83	1.23	1.63	2.01	2.40	2.78	3.16	3.53	3.94	4.39

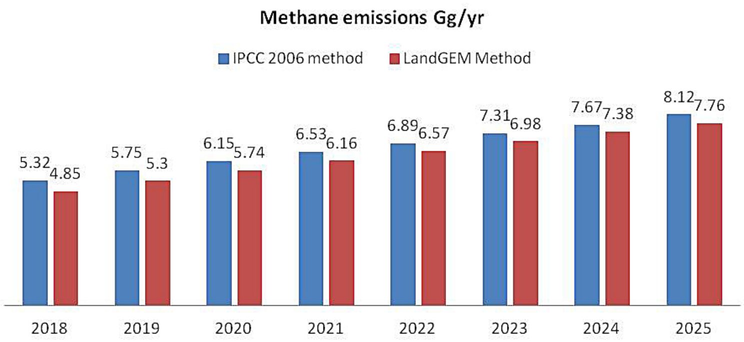

Fig. 4: Projections of CH_4 emissions from the Mirash sanitary landfill 2018–2025

considered important for methane generation and emission levels (EPA, 2001; Zawieja, *et al.,* 2011). The ambient temperature and rainfall exhibit strong correlations with landfill gas components (Yang, *et al.,* 2015; Delkash, *et al* 2015). The landfills without gas collection systems are predisposed to emit substantial amount of CH_4 to the atmosphere, with expectation of a large spatial and seasonal variability (Bogner, *et al.,* 2011). The research results show that there is a small difference in the total methane calculated by the two methods used. There is also a progressive increase in the amount of methane emitted from year to year according to both methods. The LandGem method is easier to use since it requires less information to calculate the emissions from sanitary landfills.

CONCLUSIONS

Methane monitoring and reporting in waste landfilling is of significant importance as landfilling is still the most common waste disposal method worldwide. The calculations of CH_4 emissions from the waste landfilled during 2006–2017 in the Mirash sanitary landfill were based on the amount of waste disposal and the use of the IPCC method and the LandGEM method, showing small differences in the total amount of calculated emissions. Additional specific information on the region (waste composition, climate conditions and landfill characteristics) was also considered. The results of the study provide important information which can be used for development of the country specific emission factor for the estimation of the methane emissions in the waste disposal category.

This paper could serve as a source of scientific information for the improvement of decision making on the sustainability waste management projects in Kosovo. The mitigation of the GHG emissions from the sanitary landfill in the Prishtina region is proposed to be addressed in the context of integrated waste management. Implementation of standards that encourage the landfill CH_4 recovery and reduction of the quantity of landfilled biodegradable waste is important and will bring environmental and economic benefits. Implementation of control measures and installation of a positive displacement fan ventilation system in the landfill is recommended.

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