CALCULATION OF METHANE EMISSIONS FROM A LANDFILL WITH A VIEW TO OPTIMALLY SIZING THE COLLECTION, EVACUATION AND ELIMINATION SYSTEM AFTER CLOSURE AND CLEANUP

Alecsandru Valentin TOMUȘ[*], *Mircea GEORGESCU*[**]

Abstract

This paper displays a general procedure for calculating methane emissions emitted in a landfill, referring to the particular case of the deposit of Bârcea Mare waste investment, which is part of the centre for the integrated management of waste (CMID) in Hunedoara County.

Key words: *emissions of methane, mixed waste landfill*

1. Introduction

The implementation and functioning of ecological deposits in Romania is done according to the local strategy of each county," regarding the integration in the context of the new waste management policies at a local and national level".

The goal of these investments is to achieve beneficial correlations with forecasts of future developments in waste management resulting from the activity of the local economic units and of the inhabitants.

Investment opportunity consists in identifying the best technical closure solutions and greening of the organic deposits and in providing the legal framework for the financing of the required works.

In order to establish the optimum technical solutions for the collection and evacuation of deposit gas, it is necessary to previously calculate the quantities of gas to be emitted by the waste landfill.

2. Mixed waste landfill in Bârcea Mare [3]

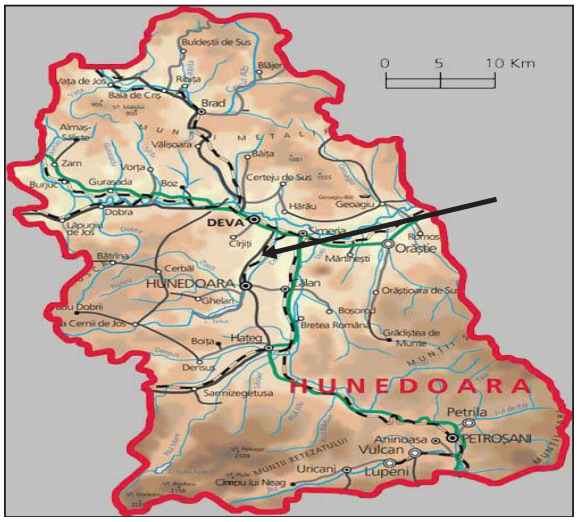

Fig.1. *Landfill location at Bârcea Mare*

The landfill is located approximately in the centre of Hunedoara County, at about 10 km from the municipalities of Deva and Hunedoara and at about 9 and 7 km from the towns of Călan and Simeria. (Fig.1).

The landfill extends over a total area of 26.2 ha. At present, only the first alveolus has been currently built, with a projected total capacity of 1,236,800 m3, of which a minimum capacity of 1,050,000 m3 representing the real storage capacity. The capacity of the 1st alveolus is estimated for a period of waste storage of about 7 years, at a waste height of approximately 23 m (considered from the level of the perimeter access road). The 1st alveolus has been built as pits whose basis surface represents 17,920 sqm, while the inner surface of the embankments represents 44,580 sqm. In order to avoid the infiltration of surface water to the body of the alveolus, it is surrounded by a perimeter embankment covering three sides (N, S, E) and an intercellular embankment built along the Western side. Channels for collecting pluvial water have been built in the perimeter afferent to the embankments. The inter-alveolar embankment is to be incorporated into the waste mass, when the 2nd alveolus is going to be operational (Fig.2).

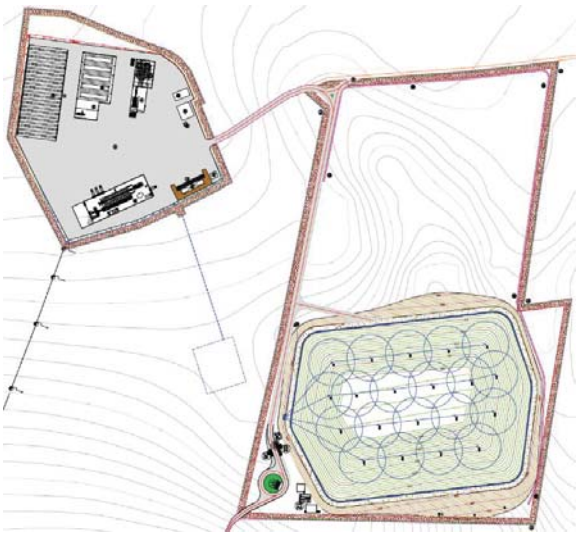

Fig.2. *Location of landfill at Bârcea Mare*

* *Eng.Ph.D University of Petroșani*
** *Prof.eng.Ph.D University of Petroșani*

3. Calculation of methane emissions from a waste landfill

The standard ecological is established for a total planned capacity (TPC) with a view to serve the inhabitants of a given area. The following types of waste are accepted at entrance:

- municipal mixed waste; code: 20.03.01;
- inert waste; code: 17.09.04;
- street waste; code: 20.03.03;
- mud from the treatment plant afferent to the projected landfill; code: 20.03.04.

The estimation of methane emissions from the eco-friendly landfill is done through the default method [1] (developed by Bingemer-Crutzen), using the formula:

$$Q_{CH4} = TDG \cdot FDG \cdot FCM \cdot FCOD \cdot FCOD_{CH4} \cdot F\left(\frac{16}{12} - R\right)(1 - OX)\ [t/yr]$$

where:

TDG - total quantity of waste, t/year;

$$TDG = 365 \cdot q \cdot n$$

q – average rate of urban waste:

0, 925kg/place/year

n – number of inhabitants

FDG– fraction of urban solid waste (t/year), which entered the landfill. It is considered that only about 91% of the waste produced are going to enter the landfill:

$$FDG = 0{,}91 \cdot TDG$$

FCM – methane correction factor that depends on the method of storage and landfill's depth

FCM = 0,6

FCOD - fraction of degradable organic carbon; depends on waste composition.

FCOD = 0,4A + 0,17B + 0,15C + 0,3

If A - paper, cardboard, textiles content, 8%

B - leaves, grass content, 6%

C - vegetables, fruit content, 16 %

D - wood content, 4%

then:

FCOD = 0,4 • 0,08 + 0,17 • 0,06 + 0,15 • 0,16 + 0,3 • 0,04 = 0,008

$FCOD_{CH4}$– degradable organic carbon fraction converted into biogas

$FCOD_{CH4}$ = 0,014t + 0,28

t – temperature in the anaerobic area of the waste layer. A constant temperature t = 35^0C should be considered, so that:

$FCOD_{CH4}$ = 0,014 • 35 + 0,28 = 0,77

F – fraction of methane in deposit gas: 0,6

R – retrieved methane fraction:1

OX – methane oxidation factor. It is considered that in the case of the upper layer of waste, where oxygen is present, methane oxidation occurs. Because this factor is not unanimously accepted, it is considered equal to 0.

4. The application of the calculation methodology for the landfill methane emissions at Bârcea Mare

For instance, one may calculate the estimated gas emissions from the 1st alveolus of the standardized waste landfill at Big Bârcea, an investment which is part of the centre for the integrated waste management (CMID) of Hunedoara County, which has a total of residents n=471,613, on 01.07.2015, according to the National Institute of Statistics. Consequently:

TDG =365·0,925 · 471.613 = 159.228.339 kg/year ≅ 159.228 t/year

FDG= 159.228 · 0,91= 144.897,48 ≅ 144.900 t/year

And $Q_{CH4} = 144.900 \cdot 0.6 \cdot 0{,}008 \cdot 0.77 \cdot 0.6\left(\frac{16}{12} - 1\right)(1 - 0) =$

107,11≅ 100 t/year = 0,275 t/day

The daily volume of methane emissions will be:

$$V_{CH4} = \frac{Q_{CH4}}{d_{CH4}} \quad [m^3]$$

where: d_{CH4} - relative density of methane: 0,424 kg/m^3 = 0,000424 t/m^3

so: $V_{CH4} = \frac{0{,}275}{0{,}000424} = 648{,}585$ m^3/day

This quantity will be evacuated by a series of vertical collecting tubes, located so that each of them covers a warehouse area with a radius of 22 m. Number of collecting tubes will be:

$$n = \frac{S_t}{S_{dfc}} \quad [piece]$$

where: S_t - total area of the 1st alveola: 62.500 m^2

S_{dfc} - the area afferent to one collecting tube:

$\pi \cdot r^2 = 3{,}14 \cdot 22^2 = 1520$ m^2

so: $n = \frac{62.500}{1.520} = 41{,}11 \cong 42$ pieces

Under these circumstances, the amount of methane evacuated by a collecting tube will be:

$$V_{tc} = \frac{V_{CH4}}{n} = \frac{648{,}585}{42} = 15{,}44\ m^3/day$$

Taking into account an average rate of methane emission in time k = 0.085 m3 · year-1, one may estimate the annual emissions of methane, considered from the moment the landfill enters into operation (2018) until the end of the 30-year monitoring period, after the year when waste would no longer be deposited (2046). Considering that the duration of waste depositing in the 1st alveolus is estimated at 7 years, the maximum emission of gas from the deposit will occur in the year following its closure, namely in the 8th year. Beginning with the 9th year, the emissions from the deposit will fall gradually, until exhaustion at the end of the monitoring period (Table 1).

Table 1. *Calculating the daily and annual quantities of methane emissions*

Year	Evacuation points / alveolus [piece]	ALVEOLUS 1				ALVEOLUS 2				ALVEOLUS 3				ALVEOLUS 4				TOTAL LANDFILL EMISSIONS [m³]			
		The amount of gas generated [m³]																			
		Daily		Anual		Daily		Anual		Daily		Anual		Daily		Anual		Daily		Anual	
		On 1 point	Total	On 1 point	Total	On 1 point	Total	On 1 point	Total	On 1 point	Total	On 1 point	Total	On 1 point	Total	On 1 point	Total	On 1 point	Total	On 1 point	Total
2018	42	8,29	348	3026	127.084	-	-	-	-	-	-	-	-	-	-	-	-	8,29	348	3.026	127.084
2019	42	9,06	380	3307	138.700	-	-	-	-	-	-	-	-	-	-	-	-	9,06	380	3.307	138.700
2020	42	9,90	416	3614	151.767	-	-	-	-	-	-	-	-	-	-	-	-	9,90	416	3.614	151.767
2021	42	10,82	455	3949	165.939	-	-	-	-	-	-	-	-	-	-	-	-	10,82	455	3.949	165.939
2022	42	11,83	497	4318	181.368	-	-	-	-	-	-	-	-	-	-	-	-	11,83	497	4.318	181.368
2023	42	12,93	543	4719	198.217	-	-	-	-	-	-	-	-	-	-	-	-	12,93	543	4.719	198.217
2024	42	14,13	593	5157	216.445	-	-	-	-	-	-	-	-	-	-	-	-	14,13	593	5.157	216.445
2025	42	15,44	648	5636	236.520	8,29	348	3026	127.084	-	-	-	-	-	-	-	-	23,73	996	8.662	363.781
2026	42	14,13	593	5157	216.445	9,06	380	3307	138.700	-	-	-	-	-	-	-	-	23,19	973	8.464	355.145
2027	42	12,93	543	4719	198.217	9,90	416	3614	151.767	-	-	-	-	-	-	-	-	22,83	959	8.333	349.984
2028	42	11,83	497	4318	181.368	10,82	455	3949	165.939	-	-	-	-	-	-	-	-	22,65	952	8.267	347.307
2029	42	10,82	455	3949	165.939	11,83	497	4318	181.368	-	-	-	-	-	-	-	-	22,65	952	8.267	347.307
2030	42	9,90	416	3614	151.767	12,93	543	4719	198.217	-	-	-	-	-	-	-	-	22,83	959	8.333	349.984
2031	42	9,06	380	3307	138.700	14,13	593	5157	216.445	-	-	-	-	-	-	-	-	23,19	973	8.464	355.145
2032	42	8,29	348	3026	127.084	15,44	648	5636	236.520	8,29	348	3026	127.084	-	-	-	-	32,63	1.344	11.688	490.688
2033	42	7,59	319	2770	116.284	14,13	593	5157	216.445	9,06	380	3307	138.700	-	-	-	-	30,78	1.293	11.235	471.857
2034	42	6,95	292	2537	106.465	12,93	543	4719	198.217	9,90	416	3614	151.767	-	-	-	-	29,78	1.251	10.870	456.527
2035	42	6,36	267	2321	97.487	11,83	497	4318	181.368	10,82	455	3949	165.939	-	-	-	-	29,01	1.218	10.589	444.723
2036	42	5,82	245	2124	89.211	10,82	455	3949	165.939	11,83	497	4318	181.368	-	-	-	-	28,47	1.196	10.392	436.451
2037	42	5,32	224	1942	81.637	9,90	416	3614	151.767	12,93	543	4719	198.217	-	-	-	-	28,15	1.182	10.275	431.539
2038	42	4,87	205	1778	74.623	9,06	380	3307	138.700	14,13	593	5157	216.445	-	-	-	-	28,06	1.179	10.242	430.160
2039	42	4,45	187	1624	68.255	8,29	348	3026	127.084	15,44	648	5636	236.520	8,29	348	3026	127.084	36,47	1.532	13.311	559.180
2040	42	4,07	171	1486	62.420	7,59	319	2770	116.284	14,13	593	5157	216.445	9,06	380	3307	138.700	34,85	1.463	12.720	534.250
2041	42	3,72	156	1358	57.090	6,95	292	2537	106.465	12,93	543	4719	198.217	9,90	416	3614	151.767	33,50	1.407	12.227	513.555
2042	42	3,40	143	1241	52.180	6,36	267	2321	97.487	11,83	497	4318	181.368	10,82	455	3949	165.939	32,41	1.361	11.830	496.845
2043	42	3,11	131	1135	47.692	5,82	245	2124	89.211	10,82	455	3949	165.939	11,83	497	4318	181.368	31,58	1.326	11.527	484.121
2044	42	2,84	120	1037	43.624	5,32	224	1942	81.637	9,90	416	3614	151.767	12,93	543	4719	198.217	30,99	1.302	11.311	475.077
2045	42	2,59	109	945	39.837	4,87	205	1778	74.623	9,06	380	3307	138.700	14,13	593	5157	216.445	30,65	1.287	11.187	469.865
2046	42	2,37	100	865	36.500	4,45	187	1624	68.255	8,29	348	3026	127.084	15,44	648	5636	236.520	30,55	1.283	11.151	468.332
2047	42	2,17	91	792	33.244	4,07	171	1486	62.420	7,59	319	2770	116.284	14,13	593	5157	216.445	27,96	1.174	10.205	428.627
2048	42	1,98	83	723	30.438	3,72	156	1358	57.090	6,95	292	2537	106.465	12,93	543	4719	198.217	25,58	1.074	9.337	392.141
2049	42	1,81	76	661	27.773	3,40	143	1241	52.180	6,36	267	2321	97.487	11,83	497	4318	181.368	23,40	983	8.541	358.795
2050	42	1,66	70	606	25.389	3,11	131	1135	47.692	5,82	245	2124	89.211	10,82	455	3949	165.939	21,41	899	7.815	328.215
2051	42	1,52	64	555	23.285	2,84	120	1037	43.624	5,32	224	1942	81.637	9,90	416	3614	151.767	19,58	822	7.147	300.161
2052	42	1,42	60	518	21.742	2,59	109	945	39.837	4,87	205	1778	74.623	9,06	380	3307	138.700	17,94	753	6.548	275.020
2053	42	1,30	55	475	19.918	2,37	100	865	36.500	4,45	187	1624	68.255	8,29	348	3026	127.084	16,41	689	5.990	251.565
2054	42	1,19	50	434	18.235	2,17	91	792	33.244	4,07	171	1486	62.420	7,59	319	2770	116.284	15,02	631	5.482	230.257
2055	42					1,98	83	723	30.438	3,72	156	1358	57.090	6,95	292	2537	106.465	12,65	531	4.617	195.925
2056	42					1,81	76	661	27.773	3,40	143	1241	52.180	6,36	267	2321	97.487	11,57	486	4.223	177.368
2057	42					1,66	70	606	25.389	3,11	131	1135	47.692	5,82	245	2124	89.211	10,59	445	3.865	162.345
2058	42					1,52	64	555	23.285	2,84	120	1037	43.624	5,32	224	1942	81.637	9,68	407	3.533	148.394
2059	42					1,42	60	518	21.742	2,59	109	945	39.837	4,87	205	1778	74.623	8,88	373	3.241	136.130
2060	42					1,30	55	475	19.918	2,37	100	865	36.500	4,45	187	1624	68.255	8,12	341	2.964	124.480
2061	42					1,19	50	434	18.235	2,17	91	792	33.244	4,07	171	1486	62.420	7,43	312	2.712	113.902
2062	42									1,98	83	723	30.438	3,72	156	1358	57.090	5,70	239	2.081	87.381
2063	42									1,81	76	661	27.773	3,40	143	1241	52.180	5,21	219	1.902	79.869
2064	42									1,66	70	606	25.389	3,11	131	1135	47.692	4,77	200	1.741	73.124
2065	42									1,52	64	555	23.285	2,84	120	1037	43.624	4,36	183	1.591	66.839
2066	42									1,42	60	518	21.742	2,59	109	945	39.837	4,01	168	1.464	61.473
2067	42									1,30	55	475	19.918	2,37	100	865	36.500	3,67	154	1.340	56.261
2068	42									1,19	50	434	18.235	2,17	91	792	33.244	3,36	141	1.226	51.509
2069	42													1,98	83	723	30.438	1,98	83	723	30.438
2070	42													1,81	76	661	27.773	1,81	76	661	27.773
2056	42													1,66	70	606	25.389	1,66	70	606	25.389
2057	42													1,52	64	555	23.285	1,52	64	555	23.285
2058	42													1,42	60	518	21.742	1,42	60	518	21.742
2059	42													1,30	55	475	19.918	1,30	55	475	19.918
2060	42													1,19	50	434	18.235	1,19	50	434	18.235

LEGEND

MAXIMUM EMISSION FROM ALVEOLAUS
MAXIMUM EMISSION FROM LANDFILL
EMISSION FROM ALVEOLUS DURING THE MONITORING PERIOD
EMISSION FROM ALVEOLUS AT THE END OF THE PERIOD OF MONITORING

NOTE:
- MAXIMUM EMISSION OF GAS FROM ALVEOLI, ONE YEAR AFTER THEIR CLOSURE;
- MAXIMUM EMISSION OF GAS FROM THE LANDFILL WILL OCCUR IN YEAR 2039, ONE YEAR AFTER THE OPENING OF THE 4TH ALVEOLUS.

5. Conclusions

The amount of methane produced by the 1st alveolus at Bârcea Mare solid waste landfill was calculated through the recommended IPCC default method. The estimation was made in accordance with the available data regarding the population and the rate of generation of the solid waste in Hunedoara County. As compared with the theoretical values resulting from calculations, the amounts of biogas that will come out from the 4 alveoli to be constructed on the landfill are sufficient enough in order to be retrieved, treated or used in controlled combustion processes. Meanwhile, the quantities emitted justify the drilling, within the waste mass, of biogas download wells, namely 42 pieces per each alveolus.

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