INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 2, Issue 1, January-March 2011: 45-54 www.ijcs.uaic.ro

EVALUATION OF GASEOUS EMISSIONS FROM THE RĂDĂUȚI MUNICIPAL LANDFILL

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Abstract

Our study presents the evaluation of gaseous emissions generated by a non-compliant municipal landfill after its closure (municipal landfill Rădăuți). To this end we measured and interpreted the characteristics of gaseous emissions captured in two monitoring boreholes made on the deposit surface (F1 and F2). The main components of landfill gas are CH_4 and CO_2, and in lower proportions O_2, N_2 and nitrogen oxides, and also traces of H_2S and CO. Their concentrations were measured using a portable gas analyzer GA type 2000Plus, which recorded simultaneously temperature and pressure data of the landfill gas. The high concentration of about 60% CH_4 and approximately 39% CO_2 in the landfill gas captured in two different areas (F1 and F2) shows the polluting character of those emissions with a direct impact on the environmental component "air", due to the greenhouse effect produced by those two components. Moreover, the characteristics of the measured gaseous emissions (a CH_4 content above 50%, a 2-3 l / h flow rate) indicates they have significant energy potential and represent a possible source of renewable energy.

Keywords: *municipal solid waste; landfill gas (LFG); LFG emission evaluation.*

Introduction

The continuous increase of human activities has economic, social and environmental implications. Among the environmental problems generated by human activities, the municipal waste management has gained a high priority for environmental protection in our days. The emissions from municipal landfills have a negative impact on all environmental components: “air", "water" and "soil"[1-5]. As for the environmental impact on "air", the storage of municipal solid waste in landfills leads to increasing greenhouse gas emissions [6]. The quantity and characteristics of emitted landfill gas (LFG) are determined by many factors, among which the most important are: climatic factors, the content of biodegradable organic solid waste materials, the quantity and composition of leachate [7]. The emission potential of greenhouse gases from municipal landfills is estimated in several ways, the most common method being developed by the Intergovernmental Panel on Climate Change - 1996 (Intergovernmental Panel on Climate Change method) [8, 9] and the LandGEM mathematical model (Landfill Gas Emission Model) [10].

The main components of landfill gas are CH_4 and CO_2, and in lower proportions O_2, N_2 and nitrogen oxides, and traces of H_2S and CO. The existence of a significant proportion of methane

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in the LFG composition makes it a potential source of energy. Potential LFG energy, defined by the term "exergy", is considered a significant indicator (among others) in assessing the impact on the environment of emissions from municipal landfills [11].

To reduce the impact of LFG on the environment, one thought of energy recovery by burning, in order to transform the exergy into thermal or electrical energy [12]. The issue of turning emissions into energy from municipal landfills is simultaneously addressed through the following three main areas: technological, economical (cost recovery) and environmental (impact and environmental policies). From the technological and economical point of view, the aim is to determine the feasibility of using solutions to increase the amount of CH_4 in landfill gasses, such as selective collection and disposal, according to the content of biodegradable organic matter [13, 14], or leachate collection and recirculation [15].

In Romania, issues relating to the operation, closing and monitoring of municipal waste landfills are regulated by GD 349/2005 regarding waste disposal, with its subsequent modifications. As a result of the environmental protection measures imposed by the Treaty of Accession, Romania must close 330 non-compliant landfills and build other 65 regional storage facilities, until 2016. General techniques of energy recovery from emission, developed in the European Union, cannot be applied directly to our country, because the composition of landfill in the non-compliant waste storage will be in constant change until 2016. Moreover, the introduction of selective collection of household waste and gradual reduction of the amount of biodegradable waste accepted at the final disposal unit, will lead to changes in the characteristics and composition of municipal waste collected by controlled disposal in landfills and thereby, in the quantity and characteristics of LFG, compared to the current situation, which is less controlled, both technically and economically.

Materials and methods

The Rădăuți municipal landfill is located on the right bank of the river Pozen. It is near the city's wastewater treatment plant and about 2.5 kilometers away from inhabited areas. The total area is 44300 m^2 and its projected capacity is of 250000 cubic meters. During our experiments, the technical characteristics of the deposits were: 772 m perimeter, an area of 33713 m^2 and an average height of 8m, which corresponds to a volume of waste stored of approx. 270000 cubic meters. The plant was established in 1984, it is owned by Rădăuți City Hall and it is in the category of the "non-compliant municipal landfills".

For the geographical positioning of the Rădăuți city landfill site and and the experimental points we used GPS satellites (Global Positioning System).

Our GPS receiver model was a GPSMAP 60CSx, made by Garmin, and a digital map of Romania (RO A.D. 2008). This equipment uses an advanced GPS positioning system, type WAAS (Wide Area Augmentation System) with a high precision tracking of ± 3 m. The GPS receiver has a communication port, so it can be connected to a PC via a USB port.

In order to assess the gaseous emissions from the storage, two drillings were made, to capture LFG (F1 and F2), with the following technical characteristic:

- geographical position: **F1**- N 47º 50,424' ; E 25º 57,593';
  F2- N 47º 50,443' ; E 25º 57,567'
- depth: 6 m for each drilling;
- outer diameter: 200 mm;

- tubing: polyethylene tube with an inner diameter of 110 mm, with 2 mm slits arranged on three sectors in circumference 10 cm apart, from the bottom up, over 3 m;
- a filtering material was set outside the tube: sorted river gravel, with a maximum grain size of 10 mm.

Prior to making the two boreholes, to determine their locations, gas emissions from another 38 points (from a depth of 60cm) were characterized, points located at equal distances apart. The gas components concentrations (CH_4, CO_2, O_2, H_2S, CO and N_2 + nitrogen oxides measured as „Bal"= Balance) were measured, with a portable gas analyzer GA2000Plus manufactured by Geotech Instruments Ltd from the UK. The analyzer allows simultaneous measurements of gas concentration; it simultaneously displays measurement values and includes values for pressure, temperature and gas flow (pressure sensor, temperature sensor and anemometer).

Results and Discussion

Fig. 1 represents a graphical design of the municipal landfill Rădăuți and the positioning of our measuring points.

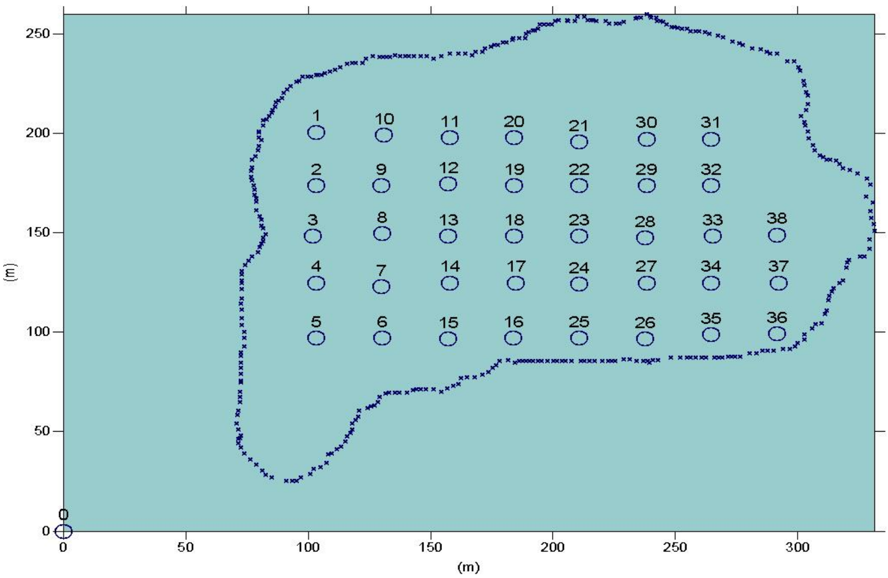

Fig. 1 Municipal landfill Rădăuți - design and the position of the measuring points

In Table 1 are the results of measurements for the composition of LFG with its gas components concentrations in the 38 selected points.

The results included in Table 1 show that the components of LFG, CH_4 and CO_2 are representative for the topic, because of their high concentration and the effect they have on the environmental component "air" (greenhouse gases). For these two gaseous components, using the data from Table 1, we drew maps with the distribution of their concentrations over the entire municipal landfill (Fig. 2 and Fig 3, respectively).

Table 1. Measurements values of the composition of LFG

No.	GPS coordinates		P_a (mbar)	P_r (mbar)	CH_4 (%)	CO_2 (%)	O_2 (%)	Bal. (%)	H_2S (ppm)	CO (ppm)
	NORTH (47º…)	EAST (25º…)								
1	50,486’	57,567’	967	0,75	89,3	2,5	0,2	8,0	2	2
2	50,472’	57,566’	967	0,89	81,4	16,4	2,2	0,0	>500*	38
3	50,458’	57,566’	967	1,15	52,8	44,2	1,5	1,5	>500	18
4	50,445’	57,567’	967	1,18	47,1	41,6	4,2	7,1	>500	132
5	50,430’	57,567’	967	1,18	35,2	52,6	3,8	8,4	>500	154
6	50,430’	57,587’	966	1,03	46,6	45,5	4,9	3,0	102	11
7	50,444’	57,587’	966	0,85	5,7	66,8	16,2	11,3	118	69
8	50,459’	57,587’	966	0,86	21	3,3	9,4	66,3	19	6
9	50,472’	57,587’	966	0,84	21	2,9	14,7	61,4	17	36
10	50,486’	57,587’	966	0,85	41,6	33	5,1	20,3	60	5
11	50,485’	57,607’	963	0,14	6,0	3,4	13,2	77,4	2	6
12	50,472’	57,607’	963	0,14	17,3	15,5	12,9	54,3	>500	14
13	50,458’	57,607’	963	0,12	48,9	39,4	2,6	9,1	52	10
14	50,445’	57,607’	963	0,18	52,7	36,3	2,4	8,6	232	2
15	50,430’	57,607’	963	0,16	8,9	0,3	19,1	71,7	5	2
16	50,430’	57,627’	975	0,22	40,0	15,8	9,5	34,7	13	6
17	50,445’	57,627’	975	0,22	38,2	16,4	10,1	35,3	16	3
18	50,458’	57,627’	975	0,28	21,8	1,6	9,2	67,4	9	19
19	50,472’	57,627’	975	0,26	34,6	18,2	12,1	35,1	16	12
20	50,485’	57,627’	975	0,25	54,3	45,6	0,1	0,0	>500	4
21	50,484’	57,647’	975	0,36	54,4	45,5	0,1	0,0	46	4
22	50,472’	57,647’	975	0,37	53,8	44,8	0,6	0,8	105	7
23	50,458’	57,647’	975	0,14	63,5	36,2	0,2	0,1	>500	21
24	50,445’	57,647’	975	0,21	69,8	28,4	1,1	0,7	395	11
25	50,430’	57,647’	975	0,19	71,6	25,8	2,1	0,5	286	21
26	50,430’	57,667’	975	0,24	82,3	6,7	2,5	8,5	311	14
27	50,445’	57,667’	975	0,34	86,9	4,3	2,1	6,7	269	8
28	50,458’	57,667’	975	0,26	64,3	32,7	1,9	1,1	52	4
29	50,472’	57,667’	975	0,14	33,5	19,6	11,7	35,2	194	11
30	50,485’	57,667’	975	0,31	54,9	44,9	0,1	0,1	461	4
31	50,485’	57,687’	975	0,29	46,8	40,3	6,1	6,8	396	18
32	50,472’	57,687’	975	0,11	19,6	1,4	10,6	68,4	25	4
33	50,458’	57,687’	975	0,28	84,3	3,6	4,9	7,2	41	11
34	50,445’	57,687’	975	0,31	89,2	2,4	1,4	7	18	2
35	50,431’	57,687’	975	0,17	78,6	12,9	2,1	6,4	29	4
36	50,431’	57,707’	975	0,21	61,9	32,6	3,7	1,8	104	18
37	50,445’	57,707’	975	0,29	71,4	26,3	2,1	0,2	91	3
38	50,458’	57,707’	975	0,18	60,2	30,4	5,1	4,3	118	14

Obs. (*): the maximum value recorded by the analyzer for the concentration of H_2S is 500 ppm.
P_a = atmospheric pressure; P_r = relative pressure; Bal. = N_2 + nitrogen oxides.

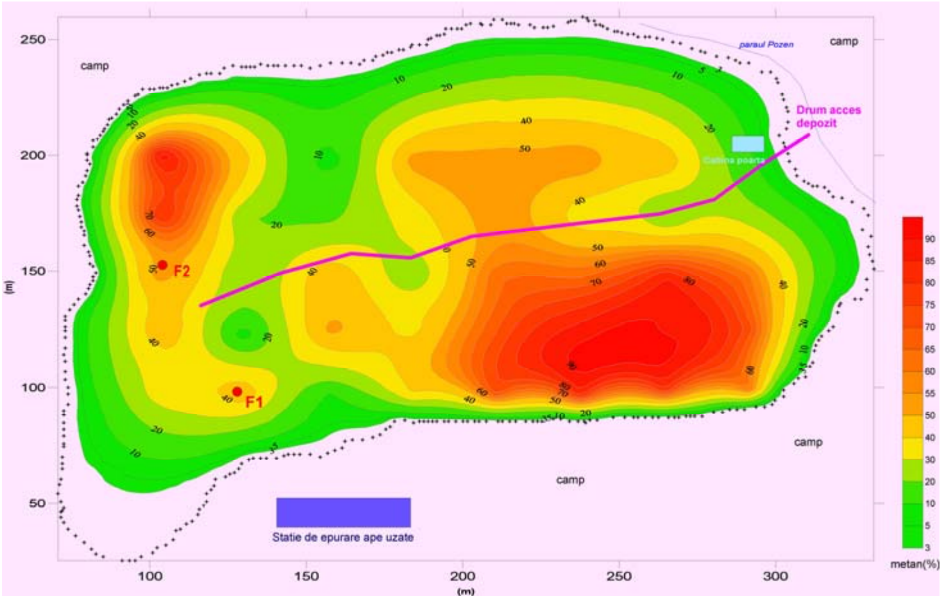

Fig. 2 Map of the distribution of CH_4 concentration (%) in the LFG released from the municipal landfill Rădăuți

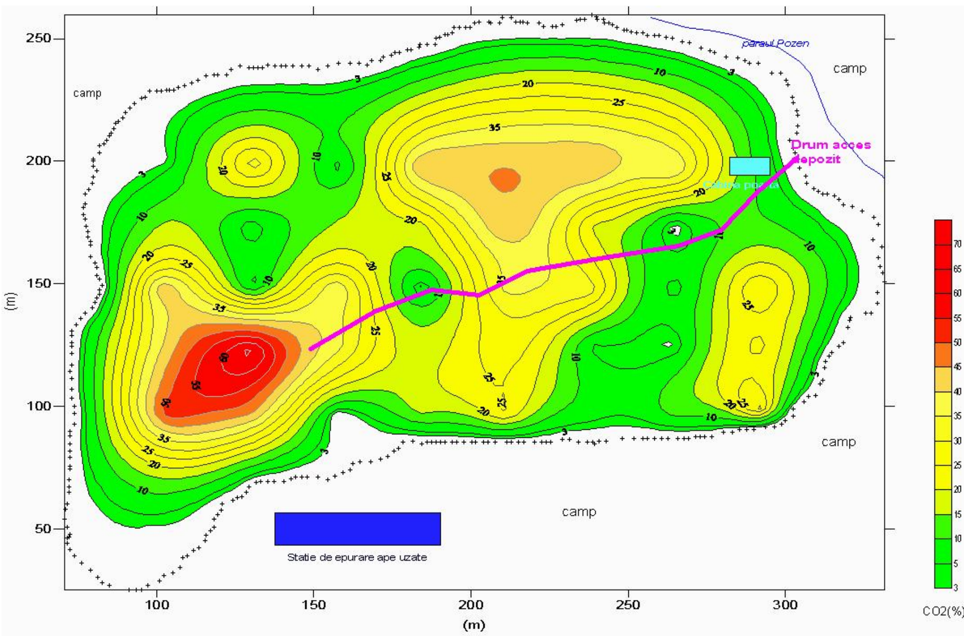

Fig. 3 Map of the distribution of CO_2 concentration (%) in the LFG released from the municipal landfill Rădăuți

From the results above, processed graphically for the CH_4 and CO_2 components, we established the positions for boreholes F1 and F2. The selection criteria were: concentration of CH_4> 50% and proper technical conditions necessary to preform drilling (the access into the area for drilling equipment).

Using the two boreholes F1 and F2, experiments were conducted to characterize the gaseous emissions, in terms of composition (CH_4, CO_2, O_2, H_2S, CO and N_2 + nitrogen oxides ="Bal"), flow (Q), pressure (P_a – atmospheric pressure, P_r-relative pressure) and temperature (T_a- air temperature, T_b- temperature of gas in borehole). Are presented instantaneous values and average values both (V_{med}) of measured characteristics. Experiments were carried out in a campaign during the summer only for borehole F1 (drilling for F2 was not done) and in four campaigns during the fall for each of the two boreholes. The results are included in Table 2 for the summer campaign corresponding to borehole F1, in Table 3 for the 4 campaigns in the corresponding period in autumn, for borehole F1 and in Table 4 for the 4 campaigns in autumn for borehole F2.

Table 2. Measurements data characterizing the gaseous emissions in the summer campaign for borehole F1

DATA: 03.08.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
Time	**Temperature (^{0}C)**		**Pressure (mbar)**		**Q (l/h)**	**CH_4 (%)**	**CO_2 (%)**	**O_2 (%)**	**Bal. (%)**	**H_2S (ppm)**	**CO (ppm)**
	T_a	**T_b**	**P_a**	**P_r**							
8^{00}	28	27	967	2,16	6,1	57,8	32,3	0,5	9,4	>500	2
10^{00}	29	28	968	1,14	5,8	58,6	32,4	0,4	8,6	>500	2
12^{00}	33	30	967	0,72	4,8	57,7	31,3	0,5	10,5	>500	3
14^{00}	34	31	966	1,03	3,3	58,1	30,8	0,5	10,6	>500	12
16^{00}	34	31	966	0,85	2,3	58,3	30,6	0,5	10,6	>500	2
18^{00}	31	30	966	0,82	2,4	58,4	30,5	0,4	10,7	>500	4
20^{00}	30	29	966	0,81	2,4	58,4	30,6	0,5	10,5	>500	2
V_{med}	***31,3***	***29,4***	***966,6***	***1,1***	***3,87***	***58,2***	***31,2***	***0,47***	***10,1***	**>500**	***3,9***

Table 3. Measurements data characterizing the gaseous emissions in the four campaign during autumn for borehole F1

DATA: 14.09.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
Time	**Temperature (^{0}C)**		**Pressure (mbar)**		**Q (l/h)**	**CH_4 (%)**	**CO_2 (%)**	**O_2 (%)**	**Bal. (%)**	**H_2S (ppm)**	**CO (ppm)**
	T_a	**T_b**	**P_a**	**P_r**							
8^{00}	18,3	21,4	975	0,05	3,9	59,1	40,9	0	0	>500	3
10^{00}	19,6	21,6	975	0,05	3,2	58,7	41,3	0	0	>500	1
12^{00}	22,3	21,8	975	0,74	3,1	58,6	41,2	0,2	0	>500	2
14^{00}	24,6	22,1	975	0,62	2,8	58,9	41,1	0	0	>500	3
16^{00}	25,2	22,1	975	0,76	2,6	59,2	40,7	0,1	0	>500	2
18^{00}	24,4	21,7	975	0,81	2,2	58,5	41,4	0,1	0	>500	1
V_{med}	***22,4***	***21,8***	***975***	***0,5***	***2,97***	***58,8***	***41,1***	***0,07***	***0***	***>500***	***2***
DATA: 15.09.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
8^{00}	17,2	18,8	971	0,22	3,8	58,5	41,2	0,3	0	>500	1
10^{00}	19,4	19,2	971	0,16	3,6	59,2	40,7	0,1	0	>500	2
12^{00}	23,4	20,1	971	0,28	3,1	59,4	40,5	0,1	0	>500	2
14^{00}	26,1	22,1	971	0,52	3,4	58,7	40,8	0,3	0,2	>500	1
16^{00}	26,5	22,3	971	0,64	2,9	58,5	41,1	0,4	0	>500	3
18^{00}	24,8	21,6	971	0,23	2,4	59,1	40,7	0,2	0	>500	2
V_{med}	***22,9***	***20,7***	***971***	***0,34***	***3,2***	***58,9***	***40,8***	***0,03***	***0***	***>500***	***1,8***

DATA: 12.10.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
8^{00}	4,8	15,1	972	0,81	3,3	59,3	40,6	0,1	0	334	1
10^{00}	7	15,3	972	0,04	2,8	59,1	40,8	0,1	0	266	0
12^{00}	9,7	15,5	972	0,12	2,7	59,6	39,9	0,1	0,4	312	1
14^{00}	13,5	15,8	973	0,35	2,4	59,7	40,1	0,1	0,1	218	0
16^{00}	13,3	15,4	973	0,16	2,5	59,2	40,7	0,1	0	245	2
18^{00}	12,6	15,2	973	0,07	2,3	58,9	40,9	0,1	0,1	193	0
V_{med}	***10,2***	***15,4***	***972,5***	***0,26***	***2,67***	***59,3***	***40,5***	***0,1***	***0,1***	***261,3***	***0,7***
DATA: 13.10.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
8^{00}	5,5	15,2	972	0,76	3,0	59,2	40,7	0,1	0	283	0
10^{00}	7,5	15,4	972	0,12	2,6	60,1	39,7	0,1	0,1	214	1
12^{00}	10,1	15,6	972	0,35	2,5	59,6	39,9	0,1	0,4	138	0
14^{00}	14,1	15,9	972	0,26	2,1	59,8	40,1	0,1	0	112	1
16^{00}	13,7	15,3	972	0,21	2,2	59,3	40,5	0,1	0,1	124	0
18^{00}	12,4	15,1	972	0,19	2,1	59,2	40,6	0,1	0,1	96	1
V_{med}	***10,6***	***15,4***	***972***	***0,31***	***2,42***	***59,5***	***40,3***	***0,1***	***0,1***	***161,2***	***0,5***

Table 4. Measurements data characterizing the gaseous emissions in the four campaigns during autumn for borehole F2

DATA: 14.09.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
Time	**Temperature (^{0}C)**		**Pressure (mbar)**		**Q (l/h)**	**CH_4 (%)**	**CO_2 (%)**	**O_2 (%)**	**Bal. (%)**	**H_2S (ppm)**	**CO (ppm)**
	T_a	**T_b**	**P_a**	**P_r**							
8^{30}	18,8	19,2	975	0,05	3,4	60,1	39,8	0,10	0	428	2
10^{30}	20,6	19,4	975	0,05	3,2	59,9	40,0	0,1	0	426	2
12^{30}	22,8	19,6	975	0,46	3,1	59,6	40,2	0,2	0	441	3
14^{30}	25,6	20,3	975	0,32	2,7	60,2	39,8	0	0	429	2
16^{30}	25,1	20,8	975	0,38	2,6	59,4	40,5	0,1	0	423	2
18^{30}	24,1	20,4	975	0,29	2,3	59,5	40,4	0,1	0	443	3
V_{med}	***22,8***	***20,0***	***975***	***0,26***	***2,88***	***59,8***	***40,1***	***0,1***	***0***	***431,7***	***2,3***
DATA: 15.09.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
8^{30}	17,5	18,5	971	0,22	3,5	61,0	38,9	0	0,1	402	1
10^{30}	19,9	19,1	971	0,06	3,2	60,4	39,4	0,1	0,1	429	2
12^{30}	24,2	20,1	971	0,26	3,1	59,5	40,3	0,1	0,1	448	2
14^{30}	26,9	21,6	971	0,31	2,8	59,6	40,2	0,1	0,1	396	2
16^{30}	26,1	21,8	971	0,29	2,7	59,3	40,5	0,1	0,1	421	3
18^{30}	24,4	21,7	971	0,14	2,4	59,1	40,6	0,2	0,1	416	2
V_{med}	***23,2***	***20,5***	***971***	***0,21***	***2,95***	***59,8***	***40,0***	***0,1***	***0,1***	***418,7***	***2***
DATA: 12.10.2010	**WEATHER CONDITIONS**: Clear sky, sunny, no wind, no rain										
8^{30}	5	15,0	972	0,06	2,1	61,7	38,2	0,1	0	245	0
10^{30}	7,3	15,2	972	0,26	1,8	60,6	38,4	0,4	0,6	216	1
12^{30}	9,9	15,3	972	0,14	1,9	60,9	38,6	0,3	0,2	119	2
14^{30}	13,6	15,6	973	0,18	2,2	61,5	37,9	0,3	0,3	58	0
16^{30}	13,2	15,8	973	0,10	2,3	61,3	38,4	0,2	0,1	94	1
18^{30}	11,8	15,4	973	0,11	2,1	60,8	39,1	0,1	0	208	2
V_{med}	***10,1***	***15,4***	***972,5***	***0,14***	***2,07***	***61,1***	***38,4***	***0,2***	***0,2***	***156,7***	***1***

DATA: 13.10.2010		WEATHER CONDITIONS: Clear sky, sunny, no wind, no rain									
8^{30}	5,8	14,7	972	0,14	2,4	61,4	38,6	0,1	0	186	1
10^{30}	8,1	15,1	972	0,22	2,2	61,6	38,0	0,1	0,3	429	2
12^{30}	10,5	15,6	972	0,06	1,9	62,4	37,3	0,1	0,4	361	1
14^{30}	14,6	15,7	972	0,12	2,1	62,2	37,6	0,1	0,1	372	1
16^{30}	13,4	15,9	972	0,21	1,8	61,8	38,1	0,1	0	265	0
18^{30}	11,8	15,6	972	0,16	1,8	61,2	38,6	0,1	0,1	214	1
V_{med}	***10,7***	***15,4***	***972***	***0,15***	***2,03***	***61,8***	***38,0***	***0,1***	***0,15***	***304,5***	***1***

The results obtained from the assessment of gaseous emissions from the municipal landfill Rădăuți, which are summarized in Tables 2-4, indicate that, regardless of weather conditions (air temperature, pressure, weather) and locations of boreholes, in the composition of LFG there are mainly two components, namely CH_4 and CO_2. During the summer, according to Table 2, the average LFG temperature was 1.9° C lower than air temperature. The small difference between ambient temperature and gas temperature recorded during the summer at borehole F1, demonstrates the existence of slow processes of anaerobic fermentation.

The same is true for the autumn period, for gaseous emissions from both boreholes F1 and F2. Thus, according to the data in Tables 3-4, only in September, which was characterized by high air temperatures, we recorded lower LFG temperature values than air temperature, as a result of the slow and steady way in which LFG is produced and released. As air temperature drops, LFG temperature decreases gradually. But the average LFG temperature is higher with approximately 5° C than air temperature, as seen from the results in Tables 3-4 for the two measurement campaigns in the month of October, for both boreholes.

The recorded temperature differences are the effect of an anaerobic fermentation process. It was found that, regardless of the season, the difference between the maximum and minimum air temperature is greater than the difference between the maximum and minimum temperature of LFG. That indicated a continuity of the LFG production. This continuing process, even if it is slow, was proven by the overpressure created in the boreholes, emphasized by the relative pressure P_r of the landfill. The gas flow rate was significant, given the condition of the municipal landfill (post closure). The value of this parameter decreases with the decrease of gaseous emissions temperature and air temperature.

The concentrations of CH_4 and CO_2 in the LFG emissions from both boreholes were approximately 60% CH_4 and 39% CO_2. We found that the recorded values were close to the emissions captured in the two boreholes, for all the periods of experimentation. In the F2 borehole the emissions captured had a 1% higher content of CH_4 and lower content of CO_2 than those captured in the F1 borehole.

The concentrations of the other two components highlighted in the gaseous emissions, namely CO and H_2S were low (hundreds of ppm for H_2S and order units of ppm for CO). We recorded concentration values higher than the limit H_2S measuring device (> 500 ppm) for emissions captured in the first three F1 borehole measurement campaigns.

Conclusions

Our study revealed the characteristics of gaseous emissions generated by a non-compliant municipal landfill after its closure. High concentrations of approximately 60% CH_4 and 39%

CO_2 of the LFG captured in two different areas (F1 and F2) revealed the polluting character of those emissions and that they directly affect the environmental component "air" - the greenhouse effect induced by those two components. Moreover, the characteristics measured for gaseous emissions (CH_4 content above 50%, flow rate 2-3 l / h) indicate that they have a significant energy potential, representing a potential source of renewable energy. The energy in the form of heat or electricity of the LFG has a direct impact on the environment by reducing the greenhouse effect of the methane produced.

To determine the feasibility of the LFG as an energy source, a further evaluation of the emissions, over a longer period of time is needed.

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Received: January 19, 2010
Accepted: February 18, 2011