ESTIMATION OF RISKS INDUCED BY GASEOUS EMISSIONS FROM SOIL / SUBSOIL IN AREAS LOCATED NEAR THE LANDFILLS

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Abstract

Estimating risks induced by gaseous emissions from soil/subsoil dangerous nature (methane) in areas close to municipal landfills is of particular importance in the context of future developments, some of these lands may have residential destinations.

The methodology for assessing these risks starts with a documentary phase (office): gathering relevant information on the landfill site, its history, as well us geomorphology and lithology data area. Continue to identify potential sources and then the migration paths of gaseous emissions from soil / subsoil to the receptors.

This paper presents the methods of investigation of emissions from soil/subsoil area situated in the neighborhood of two municipal waste landfills chosen as case studies; running several campaigns of investigation on which the intrusive methods have been applied, i.e. achievement of boreholes and measuring collection gas concentration with portable gas analyzer (O_2, CO_2, CH_4, CO, and H_2S). For spatio-temporal evolution of the gaseous emissions were added for the correlation, data on weather conditions and lithology of the areas analyzed.

From the methodological point of view, risk estimation is based on the identification and expression of two categories of factors, i.e. the probability of appearance and the effects on receptors that highlight levels of risk arising on a scale with five levels of risk, at a very low risk to a very high level of risk.

Another methodological approach allows the quantification of risk gaseous emissions from soil/subsoil by introducing indicator "Gas Screening Value - GSV" product of high gas concentrations measured in borehole (CH_4 and CO_2) and measured flow (liters per hour). According to the values of this indicator of risk may evolve at a very low (GSV<0,07) up to one very large (GSV >70) on a scale of 6 levels of risk.

Applying the methodology for locations chosen as case studies allowed the identification and risk assessment of gaseous emissions from soil / subsoil in areas near potential sources and develop protective measures must be taken in case the area would in future residential destination.

INTRODUCTION

The potential sources of gaseous emissions in the ground / underground may heave anthropogenic or natural origins. Between anthropogenic sources, a particular importance are landfills where organic matter contained in the waste deposited is subject to biodegradation processes of the gaseous emissions resulting mainly consisting of: methane, carbon dioxide, carbon monoxide, hydrogen sulphide, volatile organic compounds.

Of these emissions, the methane has a special importance. Studies show that since 1750, atmospheric concentration of methane increased by 151% and is still increasing (IPCC report). The gas molecules have a high capacity to absorb heat, which means that weaker concentrations have an important contribution in terms of the greenhouse effect.
A particular importance is the gaseous emissions that may migrate into the soil /underground at different distances from the source and especially that can accumulate in the pores of rocks and can cause risks in these areas.
Therefore, the risk assessment of the gaseous emissions caused by the soil / underground is very important to achieve as well defined methodological criteria by which to emphasize all the factors to influence.

EXPERIMENTAL PART

The methodology applied to risk assessments induced by gas emissions in to soil/subsoil is focused in 5 directions:

1. Defining the initial scope of the study;
2. Determine the best practices for defining the regime of the underground gases (soil/underground);
3. Identify "best practices" in risk assessment induced by underground gas;
4. Deviation from compliance measures for assessing the risk;
5. Inclusion of all the above mentioned in a practical guide.

All focal points define the risk management conceptual model induced by gaseous emissions from soil / subsoil with a structure conducted on three directions in succession:

- site characterization;
- risk assessment;
- establishment / validation of the corrective measures.

The risk assessment methodology is based on the documentary study (the office phase) that involves tracking the following aspects:

1. The history of location: work at this stage that collect the relevant information about the site and its surroundings.
   In particular, to identify the areas where there may be potentially dangerous gases: e.g. quarries, docks, swamps, buried tanks etc. Typical sources of the information can be: of the different public Authorities records, aerial photographs, local libraries, etc.

2. The geological and hydrogeological conditions: to indentify lithology and hydrogeological conditions of the analyzed area (including the surrounding areas). Is accentuated on identifying potential gas migration and accumulation (permeable layers, cracks).
   Typical information sources include: geological and hydrogeological maps, existing studies for areas analyzed.

3. The current land use: provides information on gas storage potential.
   The easiest form of information is to walk on the location, interviews with people who know well the area and the way it was and is the current land use.

4. Knowledge of the pollution incidents or accidents: they must be accurately on site map. Source of information: the competent Authorities in environmental protection.

To obtain information about possibility of gas migration in soil/underground in vicinity of potential sources is necessary to apply the investigation techniques. These are grouped in two main categories:

- Non invasive
- Invasive

In first category are mentioned: infrared photography, aerial thermography, satellite imagery/aerial photography. The advantages of these techniques consist in possibility to investigate large areas in short periods of time, but the investigations must be completed with other investigations based on invasive techniques.

In second category are mentioned: borehole and trial pits realised with manual or mechanical equipment. These investigations permit to identify the local lithology and measure the gas concentrations with proper gas analyser equipment.

The invasive investigation methodology was applied on two areas (landfills) chosen as case studies (located in west side of Bucharest and Suceava county), respectively the characterization of landfill gases accumulated in boreholes in the vicinity of landfills. The measurements was performed with GA2000Plus analyser, in multiple campaigns in order to obtain results in different weather conditions (temperature, pressure, precipitations) to establish a temporal evolution of these emissions. Gas analyser permitted to measure 5 gases and simultaneous display of all gasses: CH_4, CO_2, O_2, CO (with hydrogen compensation) and H_2S.

Lithological conditions was analyzed and permeability tests were carried out soil probes. The result of identified lithology and permeability tests put in bold line follow aspects:

- predominant lithology were represented by sedimentary layers;
- a low permeability specific of mixture of clay, sand and silt (specific for sedimentary rocks);
- presented differences in permeability from a borehole from another, the greatest value of hydraulic conductivity was identify in location situated in West of Bucharest. In this location water penetrate rapidly underlying layers.

The gas measurements performed in period August 2009 – July 2010 have highlighted the presence of methane in one borehole (F2) situated in the vicinity of waste disposal located in West of Bucharest, where concentrations in all period of investigations stayed in the range 41.5 – 60.5 % (v/v) methane. The F2 borehole is located at 80 meters from the mass of deposit (figure 1), but the local conditions not preclude the other wastes to be buried in this area. Areas are made more recent uncontrolled waste and it is not clear if the methane source is local or comes from migration of landfill vicinity. The weather conditions at the moment of measurements were characterized by: clear and partly cloudy days with thermal regime between 6 and 32^{0}C, and atmospheric pressure in the range 992- 1012 mbar.

Figure 1 – *F2 borehole location (West side of Bucharest) (source: GoogleEarth 2011)*

Risk assessment methodology to gaseous emissions induced in soil / underground for a landfill is based on the relationship source – transmission path – receiver.

In table no.1 is defines hazards and the probability for the pollutants CH_4 and CO_2.

Table no 1.

Receivers	Pathways by receptors	Hazard (gravity)	Probabilities	Level of risk
0	***1***	***2***	***3***	***4***
Future users of the area, construc-tion workers	infiltration and accumulation	Harm to human health (Severe)	For example, marshy area or pond filled with waste since 1970. Dead vegetation in the vicinity of the location.Potential exposure of workers in excavation operations. Potential gas penetration in buildings around the site.	High
Buildings and structures	infiltration and accumulation	Degrada-tion of buildings (Mild)	For example, marshy area or pond filled with waste since 1970. Dead vegetation in the vicinity of the location. Potential exposure of workers in excavation operations. Potential gas penetration in buildings in the site and vicinity.	Moderate

0	*1*	*2*	*3*	*4*
Residents „off – site"	infiltration and accumulation	Affected of the human health (Severe)	Low probability: marshy area filled with wastes. The vegetation in the are was disappeared. Residential properties located at 20 m, but the migration of the gases was stopped by geological structure.	Moderate
Buildings situated „off-site"	Infiltration, migration and accumulation	Degradation buildings (Mild)	Low probability: marshy area filled with wastes. The vegetation in the are was disappeared. Residential properties located at 20 m, but the migration of the gases was stopped by geological structure.	Moderate/ Low

Classification of the probabilty can have 4 stages (table no. 2)

Table no .2

Classification	Definition
Highest likelyhood	There is a pollution linkage and an event that either appears very likely in the short-term and almost inevitable overthe long-term, or there is evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage and all the elements are present and in the right place, witch means that it is probable that an event will occur. Circumstance are such that an event is not inevitable, but possible in the short-term and likely over the long-term.
Lowest probabilty	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such event would take place, and is less likely in the short-term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long-term.

Definitions for classification of consequence is shown in table no. 3

Table no. 3

Classification	Definition
Severe	Short-term (acute risk to human health likely to result in significant harm. Short-term risk of pollution of sensitive water resource. Catastrofic damage to buildings / property. A short-term risk to a particular ecosystem, or organization forming part of such ecosystem.

Medium	Chronic damage to human health (significant harm). Pollution of sensitive water resources. A significat change in a particular ecosystem, or organism forming part of such ecosystem.
Mild	Pollution of non-sensitive water reources. Significant damage to crops, buildings, structures and services (significat harm). Damage to sensitive buildings/stuctures/services or the environment.
Minor	Harm, although not necessarily significat harm, wich may result in a financial loss

Risk assessment is the result from combination of consequence with probability (table no.4)

Table no. 4 Risk matrix

		Consequence			
		Severe	Medium	Mild	Minor
Probability	High likelihood	Very high risk	High risk	Moderate risk	Moderate/low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

Another approach to risk assessment is given by calculating an index called the GSV (Gas Screening Value) that the product of CH_4 or CO_2 concentrations and flow measured in borehole (expressed in liters per hour).

The results of calculation for determining GSV, 6 risk classification is described in table no.5.

Table no. 5

	Risk classification	**Gas screening value (GSV) (CH_4 or CO_2) (l/hr)**	**Additional factors**	**Typical source of generation**
0	*1*	*2*	*3*	*4*
1	Very low risk	<0,07	Typically methane 1% and/or carbon dioxide 5%. Otherwise consider increase to Situation 2.	Natural soil with low organic content.

0	1	2	3	4
2	Low risk	<0,7	Borehole air flow rate not to exceed 70 l/hr. Otherwise consider increase to characteristic Situation 3.	Natural soils with high organic content
3	Moderate risk	<3,5	-	Old lanfills, inert waste, mineworking flooded
4	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures.	Mineworking-susceptible to fooding, completed landfill.
5	High risk	<70	-	Mineworking unflooded inactive with shallow working near surface.
6	Very high risk	>70	-	Recent landfill site.

Note: GSV (Gas Screening Value) (litres of gas / hour) is calculated by multiplying the maximum gas concentration (%) by the maximum measured borehole flow rate (l/hr). If thre is no detectable flow, use the limit of detection of the instrument.

RESULTS AND DISCUSSION

Risk assessment methodology was applied to the locations chosen as case studies. The results of investigations made, that measurement of accumulated gas in boreholes and analysis in correlation with other key factors (weather, anthropogenic and lithologic) led to the following conclusions:

- for the landfill located in west side of the Bucharest, with work completed over 20 years, that there were concentrations of methane over 50% in 6 of the 11 measurements taken and analyzed throughout the period (duration of about 11months) have not produced a decrease in methane concentration (maximum value was recorded on 1 July, 2010, at the end of the observation period) there is a migration strengthen gas from storage.

Migration paths are the most different being influenced mainly by the anthropogenic factors (excavations, cracks, making excavation, placement of pipeline routes). The area was heavily anthropic modified , without having to provide the information about how waste disposal, if there was a compact and, especially, how the deposit remained stable after the cessation of activity.

Anthropogenic factors may induce manifestation through the action on the pores to increase gas permeability that gives the possibility to migrate and to accumulate.

Lithology of the area, sedimentary, is a permeable, favorable to the gas migration in soil / underground.

- for the landfill situated in Suceava county, low concentrations of methane up to 0,4% can not definitevily exclude the possibility of landfill gas migration in the vecinity. Lithology identified in the boreholes is mainly sand facilitates the migration of gas. Peculiarities of the deposit, that short period after cessation of activity and covering only small part of waste land filled cause most of the gaseous emissions to release directly in to the atmosphere.

Applying risk assessment methodology for F2 borehole from the landfill situated in West side of Bucharest, respectively the methane concentrations reached a maximum of 60.5% calculation of GSV (Gas Screening Value) (60.5 / 100) x

0.3 l / hr = 0,18 l / hr, lead to circumstances of LOW RISK, but require some protective measures in case the area will be a residential development.

CONCLUSIONS

Estimating risks induced by the presence of the gases in the soil / subsoil in the vicinity of landfills involves to go through the following several steps: it starts from a careful and laborious documentation, Identify the sources of gaseous emissions, receptors and pathways to them by identifying hazards and estimation of the probability of occurrence.

The methodology defines several stages of probability (from a high probability up to a less probable). Also the effects can be classified from severe to minor status. Risk assessment results from the manifestation of the two categories of factors, respectively the risk matrix (different stages of the risk assessment from very low to very high risk)

Estimating risks induced by dangerous gaseous emissions in the soil/ subsoil is made more easily by calculating the GSV (Gas Screening Value) by multiplying the maximum gas concentration (%) measured in the borehole with the maximum flow rate (l / hr) . In this approach are detectable six stages of risk, the highest risk is attributed to recent landfills.

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