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Research article

Optimization of the monitoring of landfill gas and leachate in closed methanogenic landfills

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ABSTRACT

Monitoring of the gas and leachate parameters in a closed landfill is a long-term activity defined by national legislative worldwide. Serbian Waste Disposal Law defines the monitoring of a landfill at least 30 years after its closing, but the definition of the monitoring extent (number and type of parameters) is incomplete. In order to define and clear all the uncertainties, this research focuses on process of monitoring optimization, using the closed landfill in Zrenjanin, Serbia, as the experimental model.

The aim of optimization was to find representative parameters which would define the physical, chemical and biological processes in the closed methanogenic landfill and to make this process less expensive. Research included development of the five monitoring models with different number of gas and leachate parameters and each model has been processed in open source software GeoGebra which is often used for solving optimization problems. The results of optimization process identified the most favorable monitoring model which fulfills all the defined criteria not only from the point of view of mathematical analyses, but also from the point of view of environment protection. The final outcome of this research - the minimal required parameters which should be included in the landfill monitoring are precisely defined.

1. Introduction

Although the landfilling is the most undesirable solution according to the waste management hierarchy, it is still practicing even in highly-developed countries, such as USA (USEPA, 2010), Australia (Productivity Commission, 2006), etc. Serbia, as a candidate for EU membership, is unfortunately in a very difficult situation with more than 2.3 million tons of waste disposed on landfill each year. The most dominant category is the garden waste (12,14%) and other kinds of biodegradable waste (37,62), the next category is plastics (10%), and its subclass-plastic bags (4–7%), while paper, glass and cardboard makes 2–10% of total waste amount. However, there are 160 local-municipal landfills, and about 4500 illegal landfill (dumps) in Serbia. Most of them are 20–50 years old, with evident complement of capacity. Most of the landfills are in areas in which they have direct impact on all surrounding resources, since they do not fulfill the minimum of technological and sanitary conditions (Vujić et al., 2012).

Since a landfill, represents a potential risk to a human health (Giusti, 2009) and the environment (Christensen and Kjeldsen, 1995), permanent monitoring of a landfill, as well as the waste flows in various stages of a landfill lifetime are the activities of great importance.

The type and number of parameters, as well as the number of gas well which will be the subject of monitoring of an active (landfill which is still in use) and passive (closed) phase of landfill is proposed by the national regulations in many countries (EC, 1999; Ministry for the Environment, New Zealand, 2001; Sizirici, 2009). These regulations particularly define long-term monitoring of a landfill passive phase within the 30 year's period of time. However, Barlaz et al. (2002) emphasized that althought most of the countries carry out monitoring of a passive landfill phase at least 30 years, crucial for determining the period of posclosure monitoring should be geotechnological and gas production stability, as well as uniform leachate composition. On the other side, Lee and Lee (1996), claims that process of the waste decomposition is a constant threat to the environment, and the most intensive in the period of 20–50 years after closure.

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Table 1
Landfill monitoring in Republic of Serbia (OGRS, 2010).

Group	Parameter	Active phase	Passive phase
Meteorology	Precipitation	Daily	Daily, added to a monthly value
	Temperature and atmospheric pressure	Daily	Monthly average
	Velocity and direction of air/wind flow	Daily	Not defined
	Evaporation	Daily	Daily, added to a monthly value
	Relative humidity	Daily	Monthly average
Leachate	Qualitative analysis	Monthly	I Phase: Every 6 months (for 5 years)
	Quantitative analysis	Monthly	II Phase: Yearly, until finalization of activities (chemical and biological) in the landfill body
Ground water	Level of ground water	Every 6 months	Every 6 months
	Quality of ground water	According to the terrain characteristics	According to the terrain characteristics
Gases (mandatory):	Methane (CH_4)	Monthly	I Phase: Every 6 months (for 10 years)
	Carbon–dioxide (CO_2)		II Phase: Every 2 years until finalization of activities (chemical and biological) in the landfill body
	Oxygen (O_2)		
Gases (not mandatory):	Hydrogen sulfide (H_2S)	Due to waste composition and the legal acts	Yearly, until finalization of activities (chemical and biological) in the landfill body
	Hydrogen (H_2)		
Structure and the cover slope stability of the landfill	Waste covering area stability	Yearly	Yearly
	Waste composition and volume		
	Waste disposal time of the landfill		
	Landfill subsidence monitoring		
Surface water	Quality analysis	I Phase: Monthly-1st year II Phase: Quarterly - after 1st year	I Phase: Every 6 months (during 5 years) II Phase: Yearly, until finalization of activities (chemical and biological) in the landfill body
Protection layers	Sensor monitoring system inputted in impermeable layer	Continual	According to license
Pedological and geological characteristics	Taking sample from shallow and deep drilling pit	Yearly	Once in 5 years
Precipitation quantity	Not defined	In accordance with Law of water protection	In accordance with Law of water protection

The obligatory monitoring of active and passive phase of a landfill in the Republic of Serbia is presented in Table 1. (OGRS, 2010).

According to Table 1, monitoring of a passive phase of the landfill shows that there are certain unidentified issues as well as impresicements about the parameters which should be monitored. Thus, act of landfilling (OGRS 92/2010), defines that leachate parameters which have to be analyzed, can vary, depending on waste components, and it is should be determined by the Waste disposal permit. But, in practice, these permits specify that landfill operator should provide the maintenance, protection, monitoring and control of the landfill passive phase with the lack of precise and detailed informations.

Since the leachate is complex and heterogenous composition of variable components, which includes organic, non-organic components and microorganisms (Kjeldsen et al., 2002), and since its monitoring proposed by Serbian national legislation is not precisely defined, for the purpose of this research, 23 parameters have been suggested according to previous experience and practice in the Republic of Serbia (Vujić and Brünner, 2009). The costs of the each parameter is presented in Table 2.

The research was implemented on closed landfill in Zrenjanin,

Table 2
The costs for 30 years long monitoring of landfill leachate and gases.

Parameter		Leachate	Gases
Price for 1 sample [a]		62 €	50 €
Price for measured number of samples		for 23 parameters [b] 2,8€ per parameter	for 5 parameters [c] 10€ per parameter
Number of samples per gas well during 30 years	I phase	10 (every 6 month during 5 years)	20 (every 6 month during 10 years)
	II phase	25 (every year during 25 years)	10 (every second year during 20 years)
Total number of samples per extraction well during 30 years		35	35
Total price of analisis extraction well during 30 years (€)		2.170	350
Total price of monitoring for 30 gas wells during 30 years (EUR)		**65.100** **75.600**	**10.500**

Notes:
[a] According to the Official pricelist of the accredited Laboratory for the landfill, waste water and air monitoring, Faculty of Technical Science Novi Sad, Department of Environmental Protection Engineering and Occupational Safety.
[b] Temperature, pH, Conductivity, Dissolved oxygen, Nitrates, Nitrites, Chlorides, Sulphates, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Suspended m Suspended matter, dissolved matter, Dry residue, Ammonia, Orthophosphates, Calcium, Potassium, Aluminum, Lead, Iron, Cadmium, Nickel, Zink.
[c] According to the act of landfilling (OGRS 92/2010).

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