THE COMPARATIVE ANALYSIS OF SOME MODELS OF BIOGAS GENERATION PROCESSES

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1. INTRODUCTION

In present days the models which concern biogas generation processes are very actual. Models are designed as the instrument which provides forecasting, monitoring and management of solid waste behavior. Such models help to solve many ecological and economical problems. They are useful:

- for economical advisability appreciation of biogas utilization;
- to solve real problems for homebuilders who restore the closed landfills and turn them into useful residential and mixed-use communities;
- to forecast the soil and air pollution;
- to predict the possibility of fire risk at landfills.

2. SHORT DESCRIPTION OF LANDGEM MODEL

In the international practice for the forecasting of uncontrollable biogas emission from solid waste landfills the model LANDGEM [1] of the USEPA is used. This model allows the calculation of the total biogas emission (by components) at any moment of life cycle of landfill and is based on the following dependence:

$$G = WL_0(k+s)(1-e^{-s(t-t_0)})(ke^{-k(t-t_1)})/s$$

where G –total biogas generation at the landfill during time t (m^3 per year); W – refuse on the territory (tons); L_0– potential capacity of biogas generation (m^3 per ton); t – time from the beginning of waste disposal (years); t_1 – time between beginning of waste disposal and beginning of biogas generation (years); k – first order constant of decomposition rate ($year^{-1}$); s – first order phase constant of rate increasing ($year^{-1}$).

The model offers two options for execution:

CAA – to apply to landfills in most climates and,

AP-42 – applicable to most landfills in the United States.

These modes set by default parameters' values (see Table 1).

Additionally, the user has the option to enter other values of parameters. Before the beginning of calculations, it is necessary to set maximum design capacity of a landfill, the updating of a landfill by waste products by years, year of the beginning and the end of operation of a landfill.

Table 1
USEPA LANDGEM: Modes of Operation

parameters / **mode**	k ($year^{-1}$)	L_0 (m^3/t)	NMOC (ppmV)	
			codisposal	Non codisposal
CAA	0,05	100	4000	-
AP-42	0,04	170	2420	595

3. CHARACTERISTICS OF SOME OTHERS MODELS

In the multi-disciplinary model [2], developed in Biological Center of Walloon, Belgium, for modeling of organic matter degradation, the following equation, based on first order degradation kinetics is used:

$$C_t = C_0 e^{-kt},$$

where C_0 is the initial organic content, C_t is the organic content at time t, k is the inverse of the half-life constant.

The model of State Technical University of Perm [3] is based on the dependence:

$$Q(\tau) = L_0 \theta e^{-k\tau},$$

where $Q(\tau)$ is the methane emission (Nm3/year); k is the constant of biogas emission rate (1/year); θ is the average annual level of accepted refuse during operation of landfill (tons); τ is the landfill age since the beginning of biogas emission (year); L_0 is the methane potential (Nm3/year).

The methane potential is defined for each fraction of refuse, and then the total potential of mixed components is calculated taking into account average annual humidity of refuse and morphological composition of solid waste.

All these models take as the entrance parameters some average statistical characteristics, and their values are set to be constant through all the depth of the landfill.

4. SHORT DESCRIPTION OF SWOD_MM MODEL

In the Institute of Mathematics and Computer Science of Academy of Sciences (Moldova) a mathematical model SWOD_MM and a corresponding computer program [4, 5] which models process of organic chemistry decomposition and biogas generation have been created. One of the bases of the model is the fact that the organic decomposition is a process during which heat evolution occurs (significant amounts during the complete combustion associated with the aerobic and smaller amounts during the anaerobic stages of decomposition).

This approach results in the fact that even under adverse climatic conditions, in some cases, the local conditions in a body of a landfill eventually improve and become favorable to biogas generation. The landfill in depth is warmed up, and the process of biogas generation becomes more intensive. For modeling of heat generation initiation and the transfer through the body of a landfill, the equation of heat conductivity (modified parabolic Fourier Field Equation) taking into account the sources of heat in the body of the landfill is used:

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(\lambda(T) \frac{\partial T}{\partial z} \right) + Q(z),$$

where T, is temperature, t, is time, z, is depth, $\lambda(T)$, is the coefficient of temperature conductivity, $Q(z)$, the distributed sources of heat.

The coefficient of thermal conductivity is a function of humidity and humidity, generally, is a function of depth. The amount of heat produced as the result of organic decomposition depends on the rate of reaction and the rate mechanism. This in turn depends on humidity and temperature in the body of the waste. Consequently, a systems approach is required. In order to calculate the amount of organic matter degenerated, the following equation is used:

$$C_t = C_0 e^{-kt} g(W) f(T)$$

where C_0 is the initial organic content, C_t - the organic content at time t, k - the inverse of the half-life constant, $g(W)$ and $f(T)$ - functions which represent the dependencies of the organic degradation rate on humidity (W) and temperature (T) respectively.

The equation of heat conductivity is a parabolic. The solution can be obtained by the finite difference method. The initial conditions are set by temperature and humidity distribution on depth at initial time. Boundary conditions are set by temperature at the surface and the bottom of the landfill. Thus to set initial and boundary conditions for a concrete landfill, it is necessary to carry out biophysical and biochemical surveys of the landfill.

Key factors in the model are:

- The algorithm supposes that the landfill is broken on depth into small layers (Δh) – "levels". The calculation is conducted in each level in view of its characteristics and the influence of the adjacent levels, instead of with average values of characteristics on all depth of a landfill as a homogeneous body. The conditions at the bottom of the landfill are used as the boundary conditions.

- Seasonal changes of temperature (as boundary conditions) on a surface of a landfill (depending on time) are incorporated. In other models this factor is to some extent taken into account with the help of a coefficient k. The model achieves greater accuracy by accounting for both specific climatic conditions, and the general tendency of warming of climate.

Thus, having experimental data for a specific landfill, we can estimate biogas generation which is close to reality. If for any reasons it is impossible to get site-specific data, the model allows the user to set the initial data from the characteristics of a landfill which is similar to the investigated one. Alternatively, the model can be used for sensitivity studies (and as an educational tool) to study the impact of a specific parameter while holding the everything else constant.

5. COMPARISON OF MODELS OF BIOGAS GENERATION PROCESSES

SWLs represent objects with complex biochemical, mechanical, physical and other characteristics which complicate their modeling. Therefore the existing models make some assumptions to simplify process. Mathematical models existing today [1-3], are mainly built upon the assumption that all processes of organic decomposition have a first order rate (1):

$$M = M_0 \exp(-k * t), \qquad (1)$$

here M – is the mass of organic remained at the moment of time t, M_0 – is initial mass of organic, k – is the coefficient of proportionality.

The processes of decomposition have a complex nature, but equation (1) is taken due to its simplicity and, besides, uncertainties in assignment of parameters and constants are comparable with the precision of a model in complex models.

The model SWOD_MM takes into consideration additionally the following temperature effects: influence of seasonal change of temperature, exothermicity of the basic reactions in aerobic and anaerobic stages, various boundary conditions at the bottom of SWL. This is one of the main differences of this model from others. It allows:

- to model more precisely the process of biogas generation;
- to calculate not only the volume of biogas generated, but also the value of temperature at different depth of dump and at different moments of time.

Due to the last feature the model helps to predict the possibility of fire risk at landfills.

Another important difference of model SWOD_MM from other models is the fact that the influence of organic density, humidity, temperature conductivity, heat capacity and of some other factors is taken into account. All the models try to take these parameters into account. But, as a rule, only the combined influence of these parameters is reflected in those models. This combined influence is expressed by some coefficient. Moreover, it is supposed that this coefficient is constant through all the depth of the landfill. The model SWOD_MM allows to set the values for all parameters mentioned above and to change them through the depth of the landfill. The model provides means for experimental data input and getting their approximation.

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