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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ТЕМПЕРАТУРЫ И ПРОЦЕССА ВЫДЕЛЕНИЯ СВАЛОЧНОГО ГАЗА С ПОЛИГОНОВ ТБО

Анотація. У статті розглядається моделювання виходу біогазу з полігонів ТПВ. Були побудовані залежності обсягу біогазу від часу на кількох полігонах України. У статті також наводиться порівняння виміряної і розрахованої, в результаті моделювання, температури в тілі полігону.

Ключові слова: біогаз, полігон ТПВ, викиди, температура, відходи.

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МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ ТЕМПЕРАТУРИ ТА ПРОЦЕСУ ВИДІЛЕННЯ ЗВАЛИЩНОГО ГАЗУ З ПОЛІГОНІВ ТПВ

Аннотация. В статье рассматривается моделирования выхода биогаза с полигонов ТБО. Были построены зависимости объема биогаза от времени на нескольких полигонах Украины. В статье также приводится сравнение измеренной и рассчитанной, в результате моделирования, температуры в теле полигона.

Ключевые слова: биогаз, полигон ТБО, выбросы, температура, отходы.

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MATHEMATICAL SIMULATION OF TEMPERATURE AND GASE EMISSION PROCESSES FROM LANDFILLS

Abstract. The article considers modeling of biogas yield from the landfills. The dependence of biogas from time were built at several landfills in Ukraine. The article also provides a comparison of the measured temperature and the simulated temperature in the landfill.

Key words: biogas, landfill, emission, temperature, methanogenesis,waste.

Landfill is a source of biogas. More than 10 million tons of waste are generated annually in Ukraine. As a result of anaerobic fermentation each ton of waste can allocate 120 ... 200 m^3 of biogas, and total outlet of biogas from all landfills of Ukraine is up to 400 million m^3. The main component of biogas is methane. It has 21 times more greenhouse effect than carbon dioxide. Biogas can be used as fuel for cars and for cogeneration units that produce both electricity and heat.

The process of decomposition of organic compounds in waste in mesophilic anaerobic conditions, leads to the formation of biogas, significantly affecting the "greenhouse effect." 40-50% of the total amount of methane is produced by human activities, with more than 20% is formed in landfills. Biogas can migrate outside the landfill into the ground and the atmosphere under the influence of overpressure, which causes a negative impact on the environment.

Recent researches show that carrying out a large number of measurements is very difficult in practice. It requires high financial and time costs as well as high accuracy and integrity of research. So there is need for modeling of temperature in the body of the landfill and the prediction of biogas volume.

The purpose of of research - prediction of temperature and output of landfill gas from the landfill.

Setting the research - mathematical simulation of temperature in the body of landfill and landfill gas output, and comparing the results with the experimental ones.

Mathematical simulation is the most convenient and low-cost method of gas generation volume prediction. Usually mathematical model of the first-order decay is used for this simulation. It includes first order decay rate constant k, total methane potential L_o, the annual burial rate M_i.

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$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0,1}^{1} kL_0 \left(\frac{M_i}{10} \right) \cdot e^{-kt_{ij}} \quad (1)$$

Total methane potential L_o and first order decay rate constant k depend on the number and fractional composition of waste, landfill conditions (humidity, temperature, pH, the presence of inhibitory substances, etc.), operating conditions (the presence of pre-sorting, landfill shape, compaction degree of waste, the presence of the upper gas-tight layer and other). L_o is in the range 0 ... 312 m3 / t of waste, and k - 0,001 ... 0,4 year-1. For the calculation of biogas program was used LandGEM - Landfill Gas Emissions Model, Version 3.02, developed by US Environmental Protection Agency. The simulations were carried out for the Mariupol, Chernigov and Boryspil polygons.

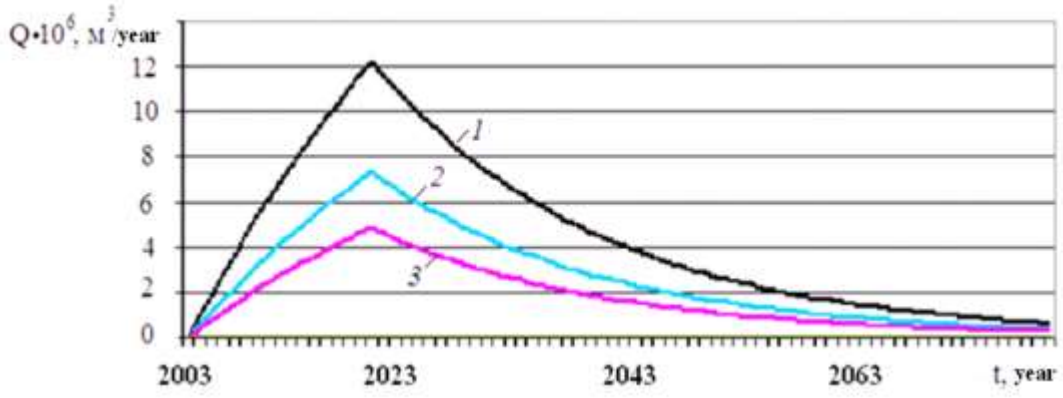

Fig.1. The dependence of biogas from time on the Boryspil landfill: 1 - the total output of biogas, 2 - output of methane, 3 - output CO2.

The figure shows the dependence of biogas emissions from time in Boryspil landfill. The figure shows that at first there is a growth of biogas emissions within the time, and the maximum generation of biogas accounts for 2019, which corresponds to the stage of active methanogenesis and it is possible to receive 7,3 • 10^6 m3 of methane per year. Further a decrease of volume of biogas was observed, which corresponds to the stage of stable methanogenesis. Predicted volumes of methane, calculated by 2143, are 2,1 • 10^8 m3.

Chernihiv landfill is working since 1961. It should be noted that the landfill hasn't special protection of the environment. According to the scheme of sanitation of the city the landfill should have operated only up to 1997. But because of the absence of alternative waste disposal, it is still functioning. Currently, the area under the waste at the landfill is almost exhausted, while approximately 185 thousand tons of waste are placed there every year.

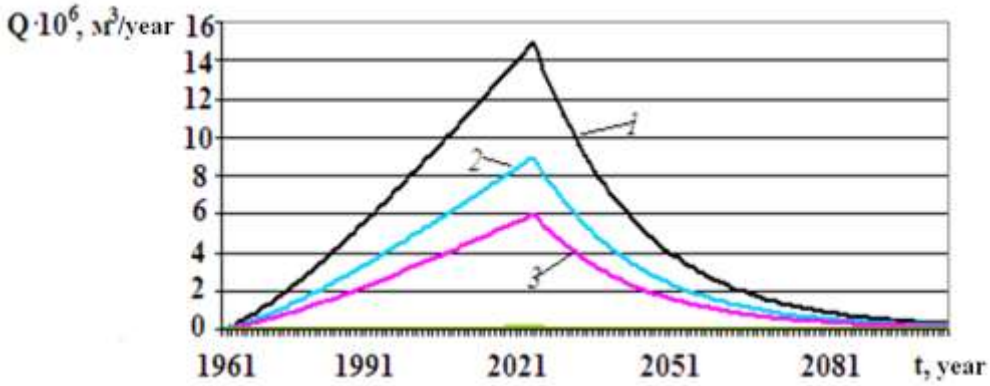

Fig.2. The dependence of biogas from time on the Chernihiv landfill: 1 - the total output of biogas, 2 - output of methane, 3 - output CO2.

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It is planned to drill 60 wells for the production of biogas and construction of a 5-km-long pipeline to transport gas from the landfill to the boiler. Implementation of the project will ensure the reduction of gase emission. Moreover, it will allow to use the gas produced in the landfill for heating of one of the districts of Chernihiv with 12 thousand inhabitants. The project can be partially financed from the budget for projects realized under the Kyoto Protocol.

For modeling of temperature in the body of the landfill the heat conduction equation was used. The initial conditions are given in the form of the temperature distribution in the initial period of time. Boundary conditions describe the behavior of the heat flux at the boundaries. The integration of the initial-boundary value problem is solved numerically using an implicit finite difference scheme. Simulation of the temperature in the body of the landfill can be provided using the heat equation of parabolic type, which includes *λ(T)* and *Q(z)* which are the functional dependence on temperature *T* and humidity

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(\lambda(\mathrm{T})\frac{\partial T}{\partial z}\right) + \mathrm{Q(z)} \qquad (2)$$

The initial conditions of the problem can be defined as the temperature distribution in the initial period $t = 0$:

$$T(z,0) = T_0(z), \qquad (3)$$

or in the form of humidity distribution:

$$W(z,0) = W_0(z). \qquad (4)$$

For the boundary conditions conditions of the 2nd kind are accepted, as they describe the behavior of the heat flux at the boundaries

$$\frac{\partial T}{\partial z} = h_1(T - T_c), \qquad \text{z=0},$$
$$\frac{\partial T}{\partial z} = h_2(T - T_z), \qquad \text{z=l}, \qquad (5)$$

T_c і T_z – ambient temperature for a given layer.

The researches on the existing landfill, located in Boryspil, Kyiv region were conducted. The experimental system for the collection of landfill gas consists of one vertical gas collection well. During the selection process composition, degree of decomposition of solid waste and humidity was estimated. In the drilled pit along the wall temperature sensors HTF 250 were mounted at a depth of about 1, 3, 6 and 8 m. The figure shows the experimental and simulated results of temperature changes in the Boryspil landfill.

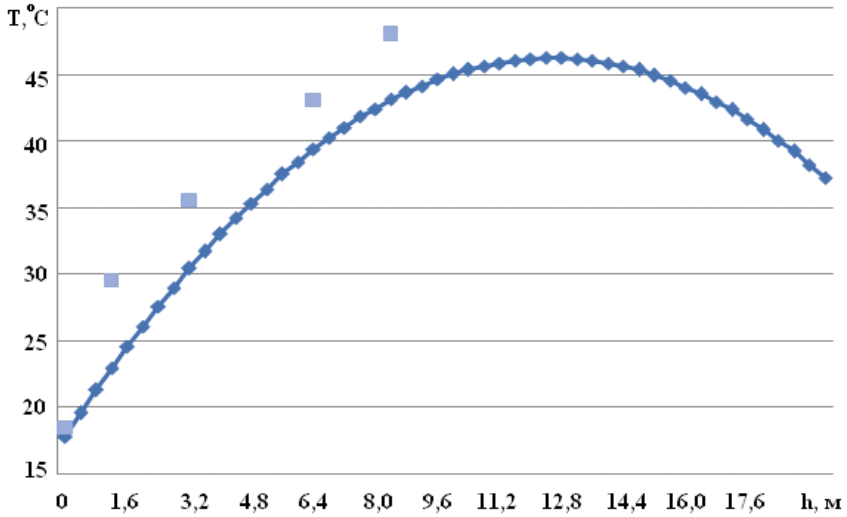

Fig.3.Simulation and experimental results of temperature changes in Boryspil landfill :

— simulation results

— experimental results.

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Speaking about current situation, dumping of solid waste in landfills and polygons remains the main method of waste disposal in Ukraine. Biogas is released during the decomposition of household waste from landfills. Biogas is a valuable hydrocarbon fuel. The most effective way to reduce methane yield from landfills into the atmosphere, is to collect and use it. Since the measurement is an expensive process, there is a need for modeling of processes on landfills. We developed a method for calculating the temperature in the body of the landfill and biogas emissions from landfills. Comparing the results of experiments and mathematical modeling, we can conclude that they are practically the same.

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