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WORLD TRENDS TOWARD INCREAING THE AMOUNT OF BIOGAS INSTALLATIONS ON THE SOLID MUNICIPAL WASTE (SMW) LANDFILLS

The area of the solid municipal waste landfills and dump sites is constantly growing in Ukraine, these landfills and dump sites are the sources of the landfill gas or biogas, this gas, without the available biogas installations for its collection can pollute the atmosphere. Determination of the regression dependences, which describe the dynamics of the growth of the number of biogas installations at the solid municipal waste landfills is an urgent scientific-engineering problem. The aim of the research is the determination of the regression dependences, which describe the dynamics of the number of biogas installations increase at the solid municipal waste landfills and can be used for the forecast of the number of such installations. In the process of the research the method of the regressive analysis of the results of single factor experiments ant other paired dependences with the selection of the best kind of function from the sixteen most widely spread variants by the criterion of the maximum value of the correlation factor was used. The regression was carried out on the base of the linearized transformations, which enable to reduce the nonlinear dependence to the linear one. Determination of the regression equations coefficients was performed by the method of the least squares, by means of the developed computer program "RegAnaliz", the program is protected by the Certificate of the State Registration of the Rights to the Copyright Object. Adequate regression dependences, describing the dynamics of the number of biogas installations increase at the solid municipal waste landfills are obtained, these dependences can be used for the forecast of the number of such installations. Graphic dependences, describing the dynamics of biogas installations increase at the solid municipal waste landfills are constructed, these graphic dependences allow to illustrate this dynamics and show the sufficient coincidence of the theoretical results with the actual data.

Key words: *landfill, dump site, solid municipal waste, biogas, biogas installation, dynamics, regression analysis.*

Introduction

Unlike solid industrial waste, which subject to recycling [1 – 5], solid municipal waste (SMW) are, mainly, buried at the landfills and dump sites [6], where, as a result of the anaerobic fermentation of the biomass the landfill gas or biogas is formed. According to the data [7] 481 biogas collecting units operate in the world. Total production of these systems is 5.15 bil. m^3/yr. But only approximately 25 - 50% of the collected biogas finds commercial application, the rest is flared. Global emission of biogas in the atmosphere is an important factor, influencing the climatic changes on the Earth. Main component of the biogas is the methane, its emission from the areas of SMW burial is 1.5 – 70 mil. t/yr. [8, 9]. In case of the methane utilization at all SMW landfills of the USA its amount will represent 5% of the overall consumption of the natural gas in the USA or 1% of the total consumption of the energy carriers [7]. By the degree of the environmental misconduct methane is considered to be the second after carbon dioxide, the most harmful green house gas and represents 18% of the total amount of the green house gases, emitted in the atmosphere of the Earth. Methane by the value of the global warming potential is almost 21 times more dangerous than the carbon dioxide. The necessity of the account of the total emission of methane is stipulated by the fact that this gas is the component of the national quota for substances, influencing the green house effect and the change of the ozone layer of the planet. At the same time the development of the biogas extraction in Ukraine will contribute to the considerable reduction of the natural gas usage and its partial replacement in the sphere of the thermal and electric energy supply.

Problem set up

In accordance with the Decree of the Cabinet of Ministers of Ukraine № 265 organization of the separate collection of some waste components, application of modern high efficient dust-carts, creation of up-to-date solid municipal waste landfills with the filtrate deactivation and biogas utilization is among prior directions of the program of SMW management in Ukraine [10]. That is why, the determination of the regression dependences, describing the dynamics of the growth of the amount of biogas units at SMW landfills and can be used in the process of the forecast of the quantity of such installation is an urgent scientific-engineering problem.

Analysis of the recent research and publications

Author of the paper [11] presents statistical data, regarding the potential of the biogas and the spreading of its utilization in different countries of the world. The research [7] contains the data about the volume of the biogas extraction in different countries. In the study [12] the modeling of biogas composition at anaerobic decomposition of solid municipal waste is carried out. The papers [13 – 15] contain the data, concerning the composition and physical-chemical properties of the biogas, formed in the locations of SMW burial. In the paper [16] regression analysis of the SMW landfill area for biogas extraction is performed. In [17] the biogas from the locations of SMW burial is considered as non-traditional source of energy. The study [18] presents the mathematical model of the forecast of the specific volume of the biogas extraction, mathematical model of the specific potential of the biogas is published in [19], the efficiency of the biogas extraction is studied in the research [20]. In [21] the impact of SMW characteristics on the volume, dynamics, formation, composition and the potential of the landfill biogas energy application is studied. The authors of the paper [22] performed the analysis of the methods of the extracted biogas utilization, and in [23] the mathematical model of these methods spreading is presented. However, the authors did not reveal the exact mathematical dependences, which describe the increase of the biogas installations quantity at SMW landfills as a result of the analysis of the known publications.

Aim and task of the research

Aim of the given research is the construction by means of the regression analysis the regression dependences, describing the dynamics of the increase of biogas installations quantity at SMW landfills and can be used in the process of the forecasting the quantity of such installations.

Methods and materials

For the determination of the regression dependences, which describe the dynamics of the increase of the number of biogas installations at SMW landfills such methods are used: regression analysis of the results of single factor experiments and other paired dependences, computer modelling.

Results of the research

Table 1 shows the dynamics of the increase of the number of biogas installations at the SMW landfills in Germany and in Ukraine [24]. On the base of the data, presented in Table it was planned to obtain paired regression dependences, which describe the dynamics of the increase of the number of biogas installations at the SMW landfills on the example of Germany and in Ukraine.

Table 1

Number of biogas installations at the SMW landfills in Germany and Ukraine, units, in different years [24]

Year	2015	2016	2017	2018	2019
Germany	9014	9209	9331	9444	9523
Ukraine	7	7	12	20	25

Regression was performed on the base of linearized transformations, which enable to reduce the non-linear dependence to linear one. Determination of the regression equations coefficients was performed, applying the method of the least squares by means of the developed computer program "RegAnaliz" [25], which is protected by the Certificate of the State Registration of the Rights to the Copyright Object and is described in details in [26, 27].

Program "RegAnaliz" enables to perform the regression analysis of the results of the single factor experiments and other paired dependences with the selection of the best type of function out of 16 the most wide-spread variants by the criterion of the maximum correlation factor, saving the results in MS Excel and Bitmap formats.

Results of the regression analysis are presented in Table 2, where the cell with maximum value of the correlation factor *R* is marked by the grey color.

Thus, by the results of regression analysis on the base of the data of the Table 1, as the most adequate the following regression dependences are finally accepted

$$n_{SWD.Ger.} = \frac{t-2014}{9,269\cdot10^{-6}+1,035\cdot10^{-4}\left(t-2014\right)} \text{ [un.]}; \quad (1)$$

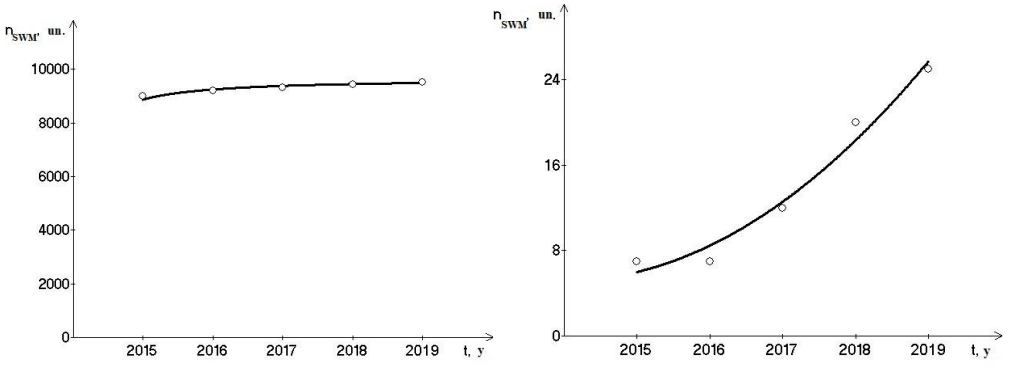
$$n_{SWD.Ua.} = 5,171+0,8209\left(t-2014\right)^2 \text{ [un.]}. \quad (2)$$

Table 2

Results of the regression analysis of the dynamics of the number of biogas installations increase at SMW landfills on the example of Germany and in Ukraine

№	Type of regression	Correlation factor R		№	Type of regression	Correlation factor R	
		Germany	Ukraine			Germany	Ukraine
1	y = a + bx	0,98623	0,96319	9	$y = ax^b$	0,99808	0,90986
2	y = 1 / (a + bx)	0,98343	0,95787	10	y = a + b·lg x	0,99756	0,88104
3	y = a + b / x	0,95975	0,75918	11	y = a + b·ln x	0,99756	0,88104
4	y = x / (a + bx)	0,99995	0,08290	12	y = a / (b + x)	0,98343	0,95787
5	$y = ab^x$	0,98486	0,96966	13	y = ax / (b + x)	0,96418	0,82774
6	$y = ae^{bx}$	0,98486	0,96966	14	$y = ae^{b/x}$	0,96200	0,80204
7	$y = a\cdot10^{bx}$	0,98486	0,96966	15	$y = a\cdot10^{b/x}$	0,96200	0,80204
8	$y = 1 / (a + be^{-x})$	0,95478	0,81817	16	$y = a + bx^n$	0,93658	0,98678

Fig. 1 presents actual and theoretical graphical dependences, which describe the dynamics of the number of biogas installations increase at the SMW landfills on the example of Germany and in Ukraine.



a) b)

Fig. 1. Dependences, which describe the dynamics of the number of biogas installations increase at SMW landfills on the example of Germany (a) and in Ukraine (b) during 2015 - 2019: actual ○, theoretic —

Comparison of actual and theoretical data showed that theoretical dynamics of the number of biogas installations increase at the SMW landfills calculated by means of regression equations (1, 2) does not differ greatly from the data, presented in the study [24], this confirms the sufficient accuracy of dependences, obtained before.

Using the dependences (1), it is possible to forecast, that the number of biogas installations at the SMW landfills in Germany in 2025 will reach 9584, and in 2030 – 9608. Taking into account the dependence (2) it can be forecast that the number of biogas installations at SMW landfills in Ukraine will reach 104 in 2025, and in 2030 – 215. Considerable lagging from the European leader of the biogas market proves the necessity of the introduction in Ukraine modern technologies of recycling and utilization of solid municipal waste.

Conclusions

1. Regression dependences, which describe the dynamics of the number of biogas installations increase at the SMW landfills and can be used for the forecast of the quantity of such installations are determined.

2. Graphic dependences, describing the dynamics of the number of biogas installations increase at SMW landfills, able to illustrate this dynamics and show the sufficient coincidence of the theoretical and actual results are constructed.

3. Results of the application of the suggested forecasting models of increasing the number of the biogas installations at the SMW landfills on the example of Germany and Ukraine prove the need of introduction in our country modern technologies of the recycling and utilization of solid municipal waste.

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