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DYNAMICS OF SOLID MUNICIPAL WASTE MASS REDUCTION AS A RESULT OF BIODEGRADATION

In recent years the total area of the solid domestic waste dump sites and landfills, including overloaded ones, which violate the norms of ecological safety and are the objects of the intensive ecological loading has grown. This may cause the pollution of the environment with harmful substances, heavy metals, microorganisms (colibacilli bacteria, streptococci, staphylococci and ascarids), high toxic filtrate, landfill gas, etc.), giving rise to diseases. Determination of the regression dependence of the residual part of solid domestic waste (SDW) per 1 kg on the duration of the biodegradation is an urgent scientific engineering problem. The aim of the research is the determination of the regression dependence of the residual part of SDW per 1 kg on the duration of the biodegradation. During the research the method of the regression analysis of the results of single-factor experiments and other paired dependences with the selection of the best type of the function from sixteen most widely - spread variants by the criterion of the maximum value of the correlation factor is used. Regression was performed on the base of the linearized transformations, which enable to reduce the non-linear dependence to linear one. Determination of the coefficients of the regression equations was carried out, applying the method of the least squares by means of the developed computer program "RegAnaliz", protected by the Certificate of the State Registration of the rights to the copyright object. Adequate regression hyperbolic dependence of the residual part of SDW per 1 kg on the duration of biodegradation, which is used for the forecast of SDW biodegradation duration to certain residual mass has been obtained, it can be used for the determination of the rational periodicity of the landfill site recultivation. Graphic interpretation of the dynamics of the residual part of SDW per 1 kg on the duration of biodegradation, is constructed, it enables to illustrate this dependence and show the sufficient coincidence of the theoretical results with actual results.

Key words: *dump site, landfill, solid domestic waste, biodegradation, dynamics, mass reduction, regression analysis.*

Introduction

Solid domestic waste (SDW) [1] produce great danger for human health and environment safety, as the characteristic feature of SDW is that it is the mixture of the components, unlike the waste of the construction industry, which are mainly homogeneous and can be rather easily recycled [2, 3]. Annual volume of SDW formation on the territory of Ukraine is more than 54 mil. m^3, greater part of solid domestic waste is buried on 6107 landfills and dump sites, their total area is 7700 ha, the waste is only partially recycled or disposed at incinerating plants unlike the developed countries, widely introducing modern technologies of recycling and disposing of SDW [4]. During the period of 1999 - 2014 the total area of the landfills and dump sites increased three times. The area of the overloaded landfills and dump sites increased almost two times, and the area of the landfills and dump sites which violate the norms of the ecological safety, threatening the pollution of the environment with harmful substances, in particular, polluting soils with heavy metals, which along with the filtrate can penetrate the underground waters, polluting them, that is a threat for the safety of life, health and human activity. Landfills are the objects of the intensive ecological loading on the environment and may create the danger of the pollution with microorganisms (colibacilli bacteria, streptococci, staphylococci and ascarids) of the adjacent plots of land [5], which are pathogenic organisms and transmitters of diseases [6]. Locations of solid domestic waste burial as a result of biological processes, taking place in the layers of waste are also sources of the long-lasting negative impact on the environment by the landfill gas, which contains the green house gases, toxic substances [7] and high toxic filtrates [8, 9]. That is why, in order to reduce the rate of the landfills area increase and their negative impact on the environment the technological operation of SDW

compaction is performed during waste loading into dump cart [10, 11]. In solid domestic waste medium along with the pathogenic bacteria – carriers of various diseases, also saprophytic aerobic bacteria are present, due to these bacteria biochemical reactions of the organic fraction of SDW degradation occur in the locations of the waste burial and self-purification of the soil from non-indigenous substances takes place, as a result the volume and mass of the buried SDW constantly decreases [12 – 14].

Problem set-up

According to the Resolution of the Cabinet of Ministers of Ukraine № 265 the organization of the control over the operating and closed SDW landfills to prevent the harmful impact on the environment and human health is among the priority directions of SDW disposal in Ukraine [15]. That is why, the determination of the regression dependence of the mass of SDW residual portion per 1 kg on the duration of biodegradation, which can be used for the identification of the rational periodicity of the recultivation measures on the landfill of the waste burial, is actual scientific-engineering problem.

Analysis of the latest research and publications

Forecasting mathematical models of the volume of SDW formation and areas of the landfills and dump sites in Ukraine are presented in the paper [16], by means of these models it is established that the total area of the landfills and dump sites, as well as those which do not correspond to the norms of ecological safety increases in time approximately by the exponential law. Area of the overloaded landfills and dump sites both which correspond and do not correspond to the norms of ecological safety increases annually almost linearly. To decrease the rate of the landfills area growth the technological operation of SDW compaction during loading in the dump cart is performed [10, 11]. Due to high coefficient of SDW compaction more efficient usage of landfill area is provided [17, 18]. In the research [13] the data, concerning the concentration of saprophytic bacteria in 0 – 20 cm layer of the soddy-weak podzolic soil, adjacent to the landfills for SDW burial, it was also established that the increase of the amount and concentration of the heavy metals in the soil during its polycomponent pollution causes the decrease of the total amount of microorganisms and biological activity of the soil. Authors of the paper [19] present data regarding the change of the sanitary-biological composition of SDW during the composting. In [5] the wider nomenclature of sanitary-biological composition of SDW is revealed in spring (colibacilli bacteria, staphylococci, streptococci and ascarids) due to the available staphylococci and ascarids, not available in SDW during summer composting. In the research [20] considerable pollution with heavy metals of the soil as a result of SDW burial is stated. Modeling of the specific energy expenditures for clearing the soil of SDW landfills from heavy metals pollution is performed in the paper [21], as a results of the studies logarithmic regression dependences of the specific energy expenditures of the soil of SDW landfills due to heavy metals pollution on the decrease of cadmium, lead and zinc concentration are suggested, they are used for the construction of mathematical model of the specific energy expenditures for the landfills soil cleaning from heavy metals pollution. In [22] by means of the method of multifactorial experiment planning of Box-Wilson the regression dependence of biological processes activity in SDW on the degree of the compaction is determined, by means of this dependence it was established that the activity of biological processes in SDW greatly depends on the density, and least – on time. In the paper [23] the mathematical model in the form of the logarithmic dependence of polluting substances concentration in the filtrate of SDW landfills was improved. In the paper [24] mathematical models of the dependence of saprophytic bacteria concentration in the soil on the distance to the SDW landfill were constructed, these models enabled to determine that with the approaching to the landfill the concentration of the saprophytic aerobic bacteria, needed for the biochemical reactions of the SDW organic fraction degradation in the places

of the burial and self-purification of the soil from non–indigenous organic substances greatly decreases. In [25] it was established that the negative impact of dump sites on the environment influences the living conditions of the population, including health indices, experimental data, regarding the change of the SDW residual part mass per 1 kg during biodegradation are given. However, the authors did not reveal specific mathematical dependences of the SDW residual part mass per 1 kg on the duration of the biodegradation.

Aim and task of the paper

Aim of the paper is the construction by means of the regression analysis the regression dependence of the mass of the residual part of SDW per 1 kg on the duration of the biodegradation, which can be used for the determination of the rational periodicity of recultivation measures on the landfill, where the waste is buried.

Methods and materials

For the determination of the regression dependence of the mass of the residual part of SDW per 1 kg on the duration of the biodegradation the following methods were used: regression analysis of the results of the single-factor experiments and other paired dependences, computer simulation.

Results of the research

Table 1 shows the change of the mass of the SDW residual part per 1 kg during biodegradation [25]. On the base of the data of Table 1, it was planned to obtain the paired regression dependence of the mass of the residual part of SDW per 1 kg on the duration of biodegradation.

Table 1

Change of the mass of the residual part of SDW per 1 kg during biodegradation [25]

Duration of biodegradation, days	1	7	14	21	28	35	42	49	56	63
Mass of the residual part of SDW per 1 kg, g	1000	1000	937	893	869	863	784	779	751	730

Regression was carried out on the base of the linearized transformations, which enable to reduce the nonlinear dependence to the linear dependence. Determination of the coefficients of the regression equations was carried out, applying the method of the least squares by means of the developed computer program "RegAnaliz", protected by the Certificate of the State Registration of the rights to the copyright object and is described in the work [26].

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 from 16 most widely-spread variants by the criterion of the maximum correlation coefficient, saving the results in the format MS Excel and Bitmap.

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 the regression analysis on the base of the data from Table 1, such regression dependence is accepted as the most adequate:

$$m_{SWD} = \frac{1}{9,769 \cdot 10^{-4} + 6,293 \cdot 10^{-6} t} \text{ [g]}, \quad (1)$$

where m_{SDW} – is the mass of the residual part of SDW per 1 kg, g; t – is the duration of biodegradation, days.

Table 2

Results of the regression analysis of the change of the residual part of SDW mass per1 kg on the duration of biodegradation

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0,98620	9	$y = ax^b$	0,85913
2	$y = 1 / (a + bx)$	0,98902	10	$y = a + b \cdot \lg x$	0,87327
3	$y = a + b / x$	0,58936	11	$y = a + b \cdot \ln x$	0,87327
4	$y = x / (a + bx)$	0,99667	12	$y = a / (b + x)$	0,98901
5	$y = ab^x$	0,98854	13	$y = ax / (b + x)$	0,55135
6	$y = ae^{bx}$	0,98854	14	$y = ae^{b / x}$	0,57063
7	$y = a \cdot 10^{bx}$	0,98854	15	$y = a \cdot 10^{b / x}$	0,57063
8	$y = 1 / (a + be^{-x})$	0,46267	16	$y = a + bx^n$	0,93269

Fig. 1 shows actual and theoretical graphic dependence of the mass of SDW residual part per 1 kg on the duration of biodegradation.

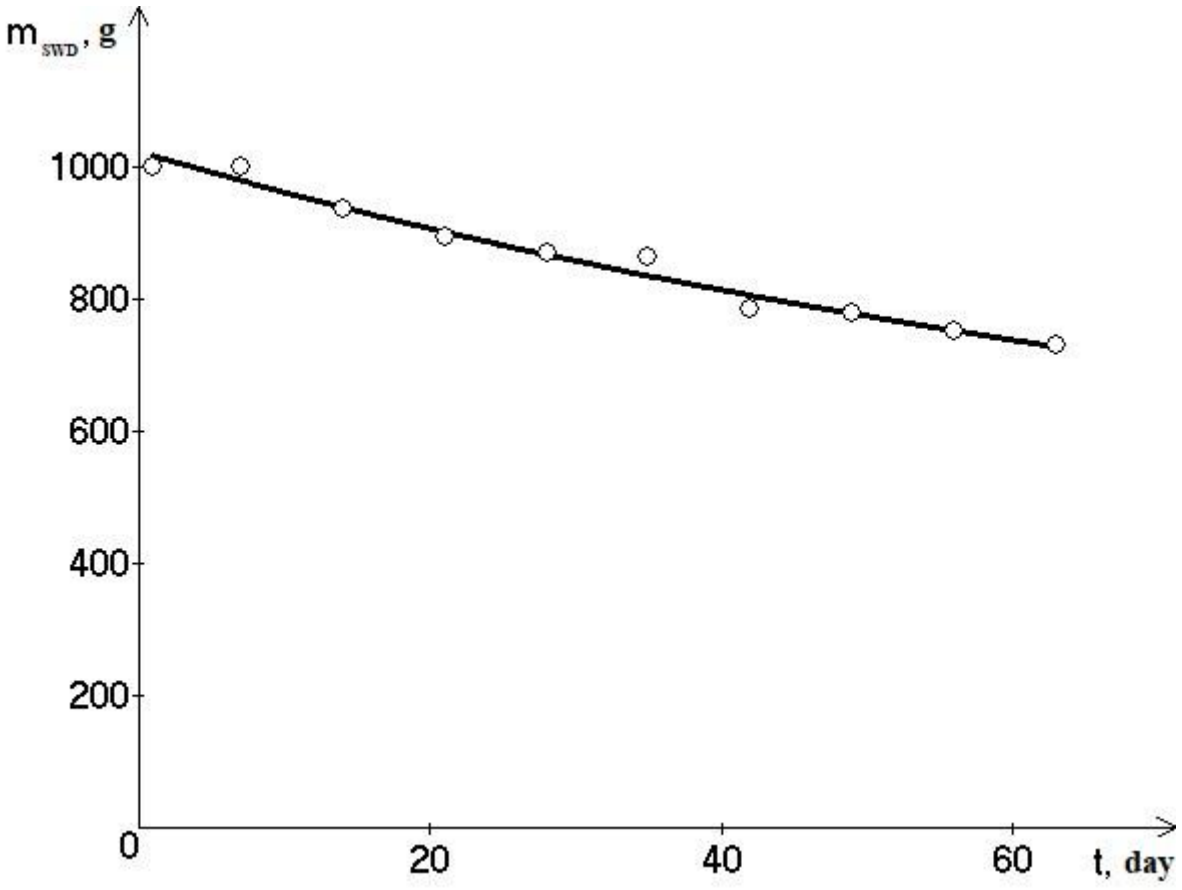

Fig. 1. Change of the mass of residual part of SDW per 1 kg during biodegradation

The comparison of the actual and theoretical data showed that the theoretical dependence of the mass of residual part of SDW per 1 kg on the duration of biodegradation, calculated by means of the regression equation (1), does not differ greatly from the data, given in the study [25], that proves the sufficient accuracy of the dependence, obtained before.

From the regression equation (1) the duration of biodegradation may be forecast, for instance, to the reduction of the SDW mass two times (to 500 g per 1 kg)

$$t = \frac{158907}{m_{SWD}} - 155,2 = \frac{158907}{500} - 155,2 \approx 163\,(days).$$

Conclusions

1. Regressive hyperbolic dependence of the mass of residual part of solid domestic waste per 1 kg on the duration of biodegradation is determined, it is used for the forecast of the duration of SDW biodegradation to certain residual mass and which can be used for the determination of the rational periodicity of the recultivation measures at the landfill of waste burial.

2. Graphic interpretation of the dynamics of the residual part of the solid domestic waste per 1 kg on the duration of biodegradation is constructed, it enables to illustrate this dependence and show the sufficient coincidence of the theoretical results with actual results.

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