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REGRESSIVE DEPENDENCE OF THE BIOLOGICAL PROCESSES ACTIVITY IN SOLID HOUSEHOLD WASTE ON THE DEGREE OF ITS COMPACTION IN THE COURSE OF TIME

In recent years the total area of solid waste landfills and landfill sites, including overloaded sites has increased, this violates the ecological norms, besides the overloaded landfills are the objects of intensive ecological loading, threatening the pollution of the environment with harmful substances: heavy metals, microorganisms (colibacilli, streptococci, staphylococci and ascarids, high toxic filtrates, landfill gas, etc). The paper contains the results of determination of the regressive dependence of the biologic processes activity in the solid household waste on the degree of the compaction with the course of time by means of planning of multifactorial experiment applying Box-Wilson method. Adequate regressive dependence of the biologic processes activity in solid household waste on the degree of the compaction in the course of time in the form of the quadratic regression with the effects of interaction of the first order is obtained. The adequacy of the regression model was verified by means of Fischer test and the significance of the regression coefficients – by Student's test. The suggested mathematical model proves the need of the waste compaction before burying to minimize the negative impact on the environment and can be used for the design of the mechanisms of waste compaction in the dust-carts. By Student's test it was determined that among the studied factors of the impact the activity of biological processes in solid household waste depends greatly on the density and to a lesser extent – on time. The response surface of the efficiency function – dehydrogenase activity of the solid household waste and its 2D cross-section in the plane of the impact parameters is constructed, which allows to represent the obtained dependence and the character of the simultaneous impact of several factors on the efficiency function.

Key words: *dust-cart, landfill, compaction, solid household waste, activity of biological processes, experiment planning.*

Introduction

Annual volume of the solid household waste (SHW), formed in the residential areas of Ukraine and is of great danger for the health of the population and safety of the environment [1], exceeds 54 mil. m³. The characteristic feature of solid household waste (SHW) is that they are mixed, i. e., it is a mixture of the components, unlike the construction waste, mainly homogeneous, such waste can rather easily be processed [2, 3]. The Resolution of the Cabinet of Ministers № 265 [4] became the base for the development of National strategy of the solid household waste management on the territory of Ukraine. Greater part of the domestic solid household waste is buried at 6107 landfill sites, their total area is almost 7700 ha and only partially is processed or recovered at waste incineration plants, unlike highly developed countries, where modern technologies of solid waste processing and recovery have been introduced [5]. During 1999-2014 the total area of the landfill sites increased 3 times. The area of the overloaded landfills increased 2 times and the number of landfills which do not meet the norms of ecological safety increased 3.1 times, these landfills pose a threat of the pollution of the environment with harmful substances, in particular, as a result of soil pollution by heavy metals, which along with the filtrate can penetrate into the underground waters and are very dangerous for life safety and human activity. Landfills are also the objects of the intensive ecological loading on the environment and can be the source of the pollution with microorganisms (colibacilli, streptococci, staphylococci, and ascarids) of the adjacent land plots [6], including agricultural land. As a result of biological processes, taking place in solid household waste column, the landfill sites are the source of lasting negative impact on the environment by high toxic filtrate [7, 8] and landfill gas, that contains greenhouse gases and toxic substances [9, 10]. That is why, to reduce the rate of landfills area growth and their negative impact on the environment the

technological operation of solid household waste compaction during the loading in the dust-cart is performed [11, 12]. High compaction factor of solid household waste gives a boost to the efficient usage of the landfill area [13]. Transportation of the solid household waste by the dust-carts to the site of the utilization at the minimal distance of 30 km., that corresponds to the dimensions of the sanitary zone in Ukraine, is connected with considerable financial expenditures, as the municipal services spend more than 45 ths. tons of fuel per year [14]. Wear of the dust-carts fleet of the Ukrainian municipal enterprises reaches approximately 70% [15], that makes necessary manufacturing of new dust-carts.

Problem set-up

According to the Resolution of the Cabinet of Ministers of Ukraine № 265 provision of the usage of modern high efficient dust-carts is among the priority directions of the solid household waste management in Ukraine [4], that is why, the definition of the regressive dependence of the biological processes activity in the solid household waste on the degree of the compaction in the course of time, that can be used in the process of the design of the mechanism for the solid waste compaction in the dust-carts is an important scientific-engineering problem.

Analysis of the recent research and publications

In [6] wider nomenclature of the sanitary-bacteriologic composition of the SHW is determined in spring (colibacilli, streptococci, staphylococci, and ascarids) due to the presence of the staphylococci and ascarids, absent in the SHW during summer composting. The comparison of the dynamics of the SHW sanitary-bacteriologic composition during the composting in different seasons of the year is contained in [16]. In [17] it was determined that in non-compacted, unrecovered part of the SHW after sorting high dehydrogenase activity is observed, this proves the intensive biological processes, taking place in the SHW; experimental data, regarding the dehydrogenase activity of the unrecovered part of the SHW for various values of their density after compaction in the course of time are given, also it was determined that the deep compaction of the SHW greatly decreases the activity of biological processes, taking place in the solid waste due to the decrease of oxygen access in the process of oxidation of the organic substances, able to biodeterioration and reducing the humidity indices. The research [18] presents: the results of the experimental study of the SHW dehydration processes by means of the worm press, regression models of the dehydration indices on the main parameters of the impact, parametric optimization of the efficiency function – energy intensity of the SHW dehydration, that enabled to obtain the optimal values of the dehydration process parameters. In [19] mathematical models of saprophytic bacteria concentration in the soil dependence on the distance to the site of the SHW burying, these models helped to define that the concentration of the saprophytic aerobic bacteria, necessary for biomedical reaction of the decomposition of the organic fraction of the SHW in the locations of the burying and self-cleaning of the soil from foreign organic substances substantially decreases with the reduction of the distance to the landfill. However, the authors did not identify the specific mathematical dependences of the biological processes activity in the SHW on the degree of the compaction in the course of time.

Aim and tasks of the study

The aim of the study is the construction by means of planning the multifactorial experiment of the regressive dependence of the biological processes activity in SHW on the degree of the compaction in the course of time, that can be used for the design of the waste compaction mechanisms of the dust-carts.

Models and materials

For the determination of the regressive dependence of the biological processes activity in SHW on

the degree of the compaction in the course of time the following methods were used: planning of the multifactorial experiment of Box-Wilson, computer simulation.

Results of the study

Table 1 contains the experimental data regarding the dehydrogenase activity of the unrecovered part of SHW for different values of their density after pressing in the course of time [17].

Table 1

Dehydrogenase activity of the unrecovered part of SHW for different values of the density after pressing in the course of time [17]

Density of SHW, kg/m ³	Dehydrogenase activity, un. of optimal density in the course of time, days			
	1	30	60	90
350	5.19	4.09	3.18	1.89
1000	2.97	2.8	1.96	1.48
1300	2.49	2.18	1.77	1.17

According to the data of the Table 1, applying the experiment planning by means of central composite rotatable design of the second order, using the developed software, protected by the Certificate of the state registration of the rights to the copyright objects [20] and described in the [21], the regression equation of biological processes activity in SHW on the degree of the compaction in the course of time is obtained

$$DHA = 6,138 - 0,003277\rho - 0,03598t + 2,183 \cdot 10^{-5} \rho t + 3,286 \cdot 10^{-7} \rho^2 - 6,682 \cdot 10^{-5} t^2, \quad (1)$$

where ρ – is the density of SHW, kg/m³; t – time, days.

In Fig. 1 the response surface of the efficiency function – dehydrogenase activity of the SHW and its 2D cross- section in the plane of the impact parameters is shown, it enables to represent the dependence (1) and the character of the simultaneous impact of several factors on the efficiency function.

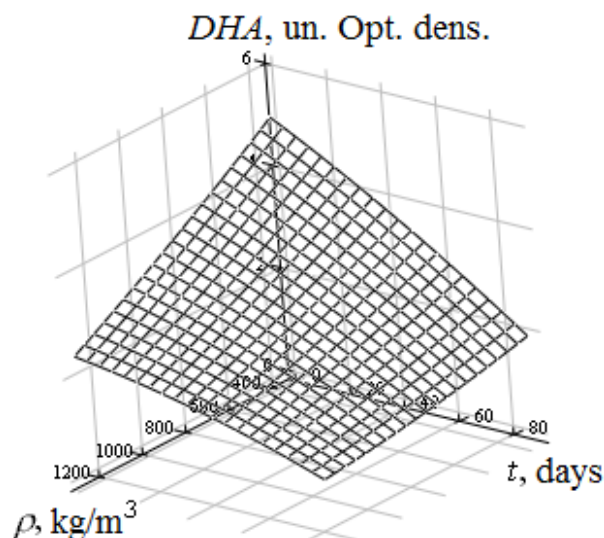


Fig. 1. Response surface of the efficiency function – dehydrogenase activity of the SHW and its 2D cross-section in the plane of the impact parameters

The character of the graphic dependence, shown in Fig. 1 proves the necessity of the SHW compaction prior the burying in order to minimize the negative impact on the environment and the dependence (1) can be used in the process of the design of the mechanisms for the waste compaction in the dust-carts.

According to the Student's test it was determined that the activity of the biological processes in the SHW depends at most on their density and at least – on time.

It was determined, that according to Fischer criterion the hypothesis concerning the adequacy of the regressive model (1) may be considered to be correct with 95% of certainty. Correlation factor was 0.99561 that shows the reliability of the results obtained.

Conclusions

1. The adequate mathematical dependence of the biological processes activity in the SHW on the degree of the compaction with the course of time in the form of the quadratic regression with the effects of the interaction of the first order is suggested, it proves the necessity of the compaction of the solid household waste prior its burying in order to minimize the negative impact on the environment and can be used for the design of the mechanisms of waste compaction in the dust-carts.

2. It is determined that the activity of biological processes in the SHW depends mostly on its density, at least – on time.

3. The response surface of the efficiency function – dehydrogenase activity of the SHW and its 2D cross-section in the plane of the impact parameters that allows to represent the obtained dependence and character of the simultaneous impact of several factors on the efficiency function is constructed.

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