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DYNAMICS OF SOLID MUNICIPAL WASTE COMPOSTING SPEADING IN UKRAINE

Composting is the technology of solid municipal waste processing, it is based on the principle of natural biodecomposition, its end product is compost, used in urban management and agriculture. Determination of the regressive dependence that describes the rate of spreading the process of solid municipal waste composting is Ukraine an important scientific engineering problem. Aim of the study is to determine the regressive dependence, describing the rate of solid municipal waste composting spread in Ukraine and can be used for the forecasting the spreading the solid municipal waste management methods. During the research process the method of regressive analysis of the results of single factoral experiments and other paired dependences was used with the selection of the rational type of the function from sixteen most widely-spread variants by the criterion of the maximum value of the correlation factor. Regression was performed on the base of the linearized transformations, which enable to reduce the non-linear dependence to linear one. Determination of the regression equations coefficients 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 dependence is obtained, it describes the rate of spreading the process of solid municipal waste composting in Ukraine and can be used for the forecasting the spreading of the solid municipal waste management methods. Graphic dependence, describing the rate of spreading solid municipal waste management methods in Ukraine and allows to illustrate this rate, show sufficient coincidence of the theoretic results with actual data is constructed. Using the obtained dependence, it is forecast that in Ukraine the level of composting solid municipal waste, comparable with the level of the EU countries at present rate of growth can be achieved by 2035.

Key words: *solid municipal waste, methods of disposal, composting, rate, regression analysis.*

Introduction

Unlike solid industrial waste, which are to be recycled [1 – 5], solid municipal waste (SMW) in Ukraine mainly are disposed at the landfills and dump sites, polluting the environment and only small portion is recycled and reused [6]. In such highly developed countries as Denmark and Netherlands the spread of composting reaches the third part of the total amount of solid municipal waste [7, 8]. Composting is the technology of SMW processing, based on the natural biodegradation, the end product of this process is the compost, widely used in the municipal sphere and agriculture. In Ukrainian one-family houses and at garden plots the compost pits are often used for composting. At the same time the composting process can be centralized and it can be carried out at a special site areas.

Problem set-up

According to the Resolution of the Cabinet of Ministers of Ukraine № 265 organization of separate waste collection, usage of the modern high efficient dust carts, creation of the modern landfills and dump sites for the solid municipal waste with the filtrate treatment and biogas disposal is among priority directions of SMW management in Ukraine [9]. In the Law of Ukraine of 28 February 2019 № 2697-VIII "On the Basic Fundamentals (Strategy) of the State Ecological Policy of Ukraine for the period to 2030" among the tasks of the strategy the following problems were indicated: return to the economic turnover recoverable materials, also it is planned for the period to 2030 the share of the buried waste to decrease to 35% of the total volume of the accumulated waste [10]. Such reduction of SMW disposal can be achieved, in particular, as a result of the increase of SMW composting. That is why, the determination of the regression dependence that describes the

dynamics of solid municipal waste composting process in Ukraine and can be used for the forecasting of SMW management methods spreading is urgent scientific-engineering task.

Analysis of the recent studies and publications

The works [7, 8] by T. A. Orlova and A. Yu. Maslennikov contain statistic data, regarding the methods of SMW management in different countries, in particular, composting. In the paper [11] the conclusion is made regarding the expediency of plants waste composting with microbiological additive both in case of thermophilous and mesophilous composting. Also it is shown that the bacterial complex accelerates the composting process of the organic component of SMW 3.3 times in case of thermophilous mode and 2.1 times in case of mesophilous conditions of composting. This indicates the efficiency of its usage in the processes of solid municipal waste recycling to increase the general level of ecological safety. In the research [12] the composting of food component of SMW of the eating establishments is studied. In the paper [13] by means of regression analysis the regression dependence of the area, required for the equipment for SMW composting on its performance is determined. In the studies [14 – 16] the dynamics of sanitary bacteriological composition of SMW during composting is investigated. It is established, that unlike summer composting the duration of spring composting is by an order of magnitude longer (242 days vs 21 day) due to the difference of natural indices of these seasons. Wider nomenclature of the sanitary-biological composition of SMW is revealed in spring due to the presence of staphylococci and ascarids, absent in SMW during summer composting. In the research [17] the experience of different countries in the sphere of SMW composting is compared. The results of sanitary-bacteriologic studies [18] indicate considerable infestation of SMW with microflora which are hepatitis, tuberculosis, dysentery, ascaris infection, respiratory, allergic, skin diseases agents. Thus, provision of sanitary-epidemiological welfare for the population, living close to the sites of SMW composting is one of great unsolved ecological and social problems. In the paper [19, 20] the possibility of using fertilizers, obtained by SMW composting is considered. Stephen Varro patented one of the technologies of SMW composting, this technology got the name of Varro-Converse and is characterized by a considerable intensification of the process [21]. Paper [22] contains mathematical models of spreading only of such methods of SMW management as burial and burning, using energy. In the research [23] the parameters (density of the population of the country, value of GDP per capita, Human Development Index (HDI), average geographic latitude and share of the rural population), which the occurrence of the composting as a method of SMW management in different countries depends on, are revealed, mathematical model of SMW composting occurrence is developed. However, as a result of the analysis of the known publications the authors did not find the specific mathematical dependences, describing the dynamics of SMW composting occurrence in Ukraine.

Aim and tasks of the paper

Aim of the given paper is the construction by means of regression analysis the regression dependence, describing the dynamics of solid municipal waste composting occurrence in Ukraine and can be used during the forecasting of the occurrence of SMW management methods.

Methods and materials

The following methods are used for the determination of the regression dependence that describes the dynamics of solid municipal waste composting occurrence in Ukraine: regression analysis of the results of single-factor experiments and other paired dependences, computer modeling.

Results of the research

Table 1 shows the dynamics of SMW composting occurrence in Ukraine [24] in the period of 2016 - 2020. On the base of the data of the Table 1 the paired regression dependence, describing the dynamics of SMW composting in Ukraine was planned to obtain.

Table 1

Dynamics of SMW composting occurrence in Ukraine [24]

Year	2016	2017	2018	2019	2020
Volume of the collected SMW, m^3	49573034.55	52048874.87	53788662.12	52920120.57	54119219.54
Volume of the composted SMW, m^3	2032	3750.2	13216	10261	37873
Occurrence of SMW composting in Ukraine, %	0.004099	0.007205	0.02457	0.01939	0.06998

Regression was performed on the base of the linearized transformations, they enable to reduce nonlinear dependence to linear dependence. Determination of the coefficients of the regression equations was realized by means of the least squares method [25], applying the developed computer program "RegAnaliz" [26], protected by the certificate of the State Registration of the rights to the copyright object and is described in the works [27, 28]. 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 rational 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 the Table 2, where the cell with the 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, the following regression dependence is accepted as the most adequate:

$$\Pi_{comp.} = 0,007141 + 4,318 \cdot 10^{-5} (t - 2015)^{4,5} \ [\%], \tag{1}$$

where $\Pi_{comp.}$ – is the occurrence of SMW composting in Ukraine, %; t – year.

Fig. 1 shows the actual and theoretical graphic dependences, describing the dynamics of SMW composting occurrence in Ukraine.

Table 2

Results of the regression analysis of the dynamics of SMW composting occurrence in Ukraine

№	Type of regression	Correlation factor R	№	Type of regression	Correlation factor R
1	y = a + bx	0.85896	9	y = ax^b	0.93222
2	y = 1 / (a + bx)	0.91843	10	y = a + b·lg x	0.76570
3	y = a + b / x	0.65327	11	y = a + b·ln x	0.76570
4	y = x / (a + bx)	0.76846	12	y = a / (b + x)	0.91843
5	y = ab^x	0.95323	13	y = ax / (b + x)	0.94651
6	y = ae^{bx}	0.95323	14	y = ae$^{b/x}$	0.86854
7	y = a ·10^{bx}	0.95323	15	y = a ·10$^{b/x}$	0.86854
8	y = 1 / (a + be^{-x})	0.94644	16	y = a + bx^n	0.95574

Comparison of the actual and theoretical data showed that the theoretical dynamics of SMW composting occurrence in Ukraine, calculated by means of the regression equation (1), does not differ greatly from the data, presented in the works [21 – 24] that confirms the accuracy of the obtained dependence, determined before.
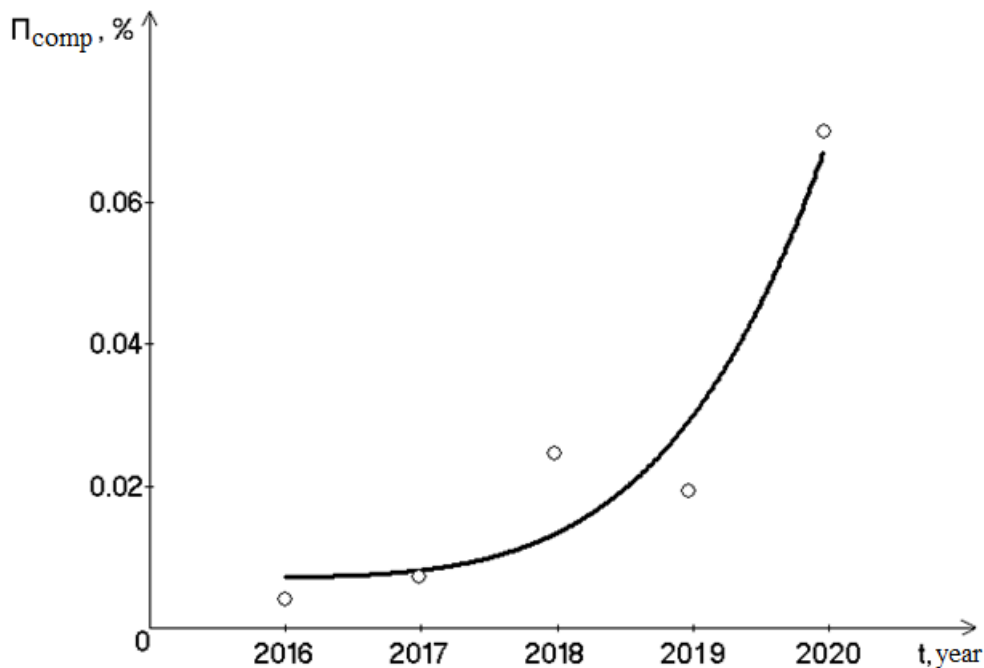
Fig. 1. Dependence, describing the dynamics of SMW composting occurrence in Ukraine for the period of 2016 - 2020: actual ○, theoretical —

Among the EU countries the greatest occurrence of SMW composting is observed in Netherlands, it reaches 33% [7, 8]. By means of the dependence (1) it can be forecast that such occurrence of SMW composting in Ukraine at present rate of increase can be achieved by 2035:

$$t = \left(\frac{\Pi_{comp.} - 0,007141}{4,318 \cdot 10^{-5}} \right)^{1/4,5} + 2015 = \left(\frac{33 - 0,007141}{4,318 \cdot 10^{-5}} \right)^{1/4,5} + 2015 \approx 2035 \ [year].$$

Conclusions

1. Regression dependence, describing the dynamics of solid municipal waste occurrence in Ukraine is determined, it can be used in the process of the forecasting of SMW management methods occurrence in Ukraine.

2. Graphic dependence, describing the dynamics of solid municipal waste composting occurrence in Ukraine and allows to illustrate this dynamics, show the sufficient coincidence of the theoretical results with actual results, is constructed.

3. It is established that in Ukraine during 2016 – 2020 the occurrence of solid municipal waste composting increased by the power dependence.

4. It is forecast, that in Ukraine the achievement of the level of solid municipal waste composting occurrence as in the developed countries of EU at the present rate of increase will be achieved by 2035.

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