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RATE OF THE QUANTITY OF MATERIAL RECOVERY FACILITIES INCREASE IN UKRAINE

Sorting of the solid municipal waste promotes the extension and reuse of the waste. Sorting and preparation for further recycling, disinfection and disposal of non-toxic solid municipal waste, collected by indiscriminative method, is performed by material recovery facilities. Determination of the regressive dependence, that describes the rate of material recovery facilities increase in Ukraine is urgent scientific-engineering problem. The aim of the study is determination of the regressive dependence, describing the rate of these facilities growth and can be used for the prediction of the quantity of such facilities. In the process of the study the method of regressive analysis of the results of single-factor experiments and other pair dependences with the selection of the rational type of function from the sixteen most widespread variants by the criterion of the maximum value of the correlation coefficient has been used. Regression was carried out on the base of the linearized transforms, which enable to reduce non-linear dependence to linear one. Determination of the beta coefficients was carried out applying the least square method, by means of the elaborated computer program "RegAnaliz", protected by the Certificate of the State Rregistration of the rights to the copyright object. Adequate regression exponential function, describing the rate of the material recovery facilities increase in Ukraine and can be used for the prediction of the number of such facilities has been obtained. Graphic dependence, that describes the rate of the number of material recovery facilities increase in Ukraine and allows to illustrate this dynamics, show sufficient reproducibility of the theoretical results with factual data has been constructed. Using the obtained dependence it is estimated that for the sorting of the annual volume of SMW in Ukraine the necessary quantity of material recovery facilities at the present rate of increase can be provided by 2040.

Key words: *solid municipal waste, sorting, material recovery facility, dynamics, regression analysis.*

Introduction

Unlike solid industrial waste that are subject to recycling [1 – 5], solid municipal waste in Ukraine are mainly buried at landfills and dump-sites, polluting the environment, and only minor part of the waste is subject to recycling and reuse [6]. Sorting of SMW improves the quality of recycling and reuse [7], it enables to extract certain components: scrap paper, glass, ferrous and non-ferrous metals, polymers. Technological process of SMW sorting is a sequence of technological operations, carried out by main technological and auxiliary technological equipment according to the stages of the sorting process that allows to separate the total mass of SMW into the recyclable components and residues that cannot be recycled. Sorting technology can be introduced as the pre-treatment of the raw material before using one of the methods of waste treatment. This would enable to reduce considerably the negative impact on the environment and make a profit as a result of realization of the processed raw materials [8]. Material recovery facilities are designed for sorting and preparation for further recycling, treatment and disposal of nontoxic SMW, collected using indiscriminative method [9]. Process of SMW sorting takes place as follows [10]: SMW from the dustcart is charged into the storage bin, further the conveyor transports the waste into cylindrical screen drum, where fine fraction and organic substances are separated. Then SMW is supplied into the trash room for manual or mechanical sorting. Sorted out waste is directed to the press to reduce its volume and is baled. Waste sorting is carried out into such fractions: metal, glass, plastics, polyethylene, paper. Sorted out waste is sent to recycling and unrecyclable residues are buried in a SMW landfill.

Problem statement

According to the Resolution of the Cabinet of Ministers of Ukraine № 265 organization of the separate waste collection, employment of modern high efficient dust carts, construction of modern

landfills with the filtrate deactivation and biogas disposal is among the priority areas of waste management in Ukraine [11]. In the Low of Ukraine of 28 February 2019 № 2697-VIII "On the fundamental principles (strategy) of State ecological policy of Ukraine for the period until 2030" valuable resources recovery is indicated among the tasks of the strategy for the period until 2030, the share of the buried waste is planned to decrease to 35% from the total volume of the generated waste [12]. That is why, determination of the regression dependence that describes the rate of the number of the material recovery facilities in Ukraine and can be used for the prediction of the quantity of such facilities is important scientific engineering problem.

Overview of the research works and publications

Scheme of the improved device for sorting SMW has been patented [13], the device enables not only to sort out the elastic from non-elastic components but also to arrange the elastic components by fractions into multisectional container. The paper [14] contains the analytical dependences of the basic kinematic and geometric parameters of the device for sorting the elastic components of SMW into multisectional container, rational values of basic kinematic and geometric parameters of the device for sorting the elastic components of SMW using multisectional container are obtained. In the papers
[15, 16], the parameters, influencing the percentage shares of separately collected SMW in different countries are determined, by means of planning multifactoral experiment of the second order mathematical model of the percentage shares of separately collected SMW prediction was constructed. Improved forecasting model of separate collection of SMW spreading in different countries, including Ukraine is presented in the paper [17]. Study [18] is devoted to the determination of the regression dependence, describing the dynamics of the involvement of the communities of Vinnytsia Region in the process of separate collection of SMW and enables to predict the number of communities, involved in the process of separate collection of SMW.

Studying the operation of the material recovery facility in the paper [9] the efficiency of the processed raw material extraction, conditions of the profitable operation and composition of SMW, forwarded to landfill after sorting was evaluated. As a result of sorting the volume of SMW, forwarded to the landfill, substantially decreased. Due to this fact the term of the landfill operation can be increased, that will lead to the efficient usage of the land resources. As a result of the waste composition change (organic components became the basic element) loading of the environment decreased. Consequently, the pollution of the soil, water, underground water-bearing horizons and atmospheric air with harmful substances also reduced.

Variety of technical means, designed for SMW sorting is shown in [19].

Application of the image processing during the development of the efficient automated mechanical system for mixed SMW sorting is studied in the paper [20]. First in priority stage of the processing is distribution of the plastic and paper waste. Intelligent system is developed by means of computer-optic parts recognition on the sorting line (conveyer). System operates without any human interference and the efficiency of the correct classification is at least 80%. In the process of the experiment paper and plastic objects of various shapes and sizes were used. The suggested algorithm was experimentally verified by means of the manufactured prototype of the paper-plastic system.

Study [21] contains statistical data regarding the dynamics of introduction the modern methods and technologies in the sphere of waste management in Ukraine, in particular, increase of the quantity of the material recovery facilities in the period of 2015 – 2019. However, the authors did not find, as a result of the analysis of the known publications, the specific mathematical dependences, describing the dynamics of the increasing the quantity of the material recovery facilities in Ukraine.

Aim and task of the paper

Aim of the given research is to construct by means of regression analysis the regression

dependence, describing the dynamics of the growth of material recovery facilities quantity in Ukraine and can be used for the prediction of the number of such facilities.

Methods and materials

For the determination of the regression dependence, that describes the dynamics of the increase of the material recovery facilities in Ukraine the following methods are used: regression analysis of the results of single-factor experiments and other paired dependences, computer simulation.

Results of the research

Table 1 shows the dynamics of the number of material recovery facilities increase in Ukraine [21 – 24] in 2013 - 2020. Analysis of the literature sources showed the lack of the statistical data regarding the quantity of the material recovery facilities in Ukraine for the previous years. On the base of the data from the Table 1 it was planned to obtain the paired regressive dependence, describing the change rate of the increase of the material recovery facilities quantity in Ukraine.

Table 1

Quantity of material recovery facilities in Ukraine, units in different years [21 – 24]

Year	2013	2014	2015	2016	2017	2018	2019	2020
Quantity of material recovery facilities in Ukraine, units	21	21	20	22	25	26	34	35

Regression was performed on the base of linearized transformations, which allow to reduce the non-linear dependence to linear one. Determination of the beta coefficient was carried out by means of the least square method, with the help of the developed computer program "RegAnaliz" [25], protected by the Certificate of the State Registration of the rights to the copyright object and described in the works [26, 27].

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

Results of the regression analysis are presented in Table 2, grey color marks the cell with maximum value of the correlation coefficient R.

Hence, by the results of the regression analysis on the base of the data of the Table 1, the following regression dependence is finally taken as the most adequate:

$$n_{MRF} = 20{,}15 + 0{,}05381(t - 2012)^{2,74} \text{ [units]}, \quad (1)$$

where n_{MRF} – is the quantity of material recovery facilities in Ukraine, units; t – year.

Fig. 1 shows actual and theoretical graphic dependence, describing the change rate of the increase of the quantity of material recovery facilities in Ukraine.

Table 2

Results of the regression analysis of the change rate of the quantity of material recovery facilities increase in Ukraine

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0.90510	9	$y = ax^b$	0.78490
2	$y = 1 / (a + bx)$	0.92681	10	$y = a + b \cdot \lg x$	0.76648
3	$y = a + b / x$	0.58023	11	$y = a + b \cdot \ln x$	0.76648
4	$y = x / (a + bx)$	0.92106	12	$y = a / (b + x)$	0.92681
5	$y = ab^x$	0.91810	13	$y = ax / (b + x)$	0.61389
6	$y = ae^{bx}$	0.91810	14	$y = ae^{b / x}$	0.59855
7	$y = a \cdot 10^{bx}$	0.91810	15	$y = a \cdot 10^{b / x}$	0.59855
8	$y = 1 / (a + be^{-x})$	0.52363	16	$y = a + bx^n$	0.97150

Comparison of the actual and theoretical data showed that theoretical change rate of the increase of the quantity of material recovery facilities in Ukraine, calculated by means of regression equation (1) does not differ greatly from the data, presented in the studies [21 – 24], this proves the sufficient accuracy of the obtained dependence.

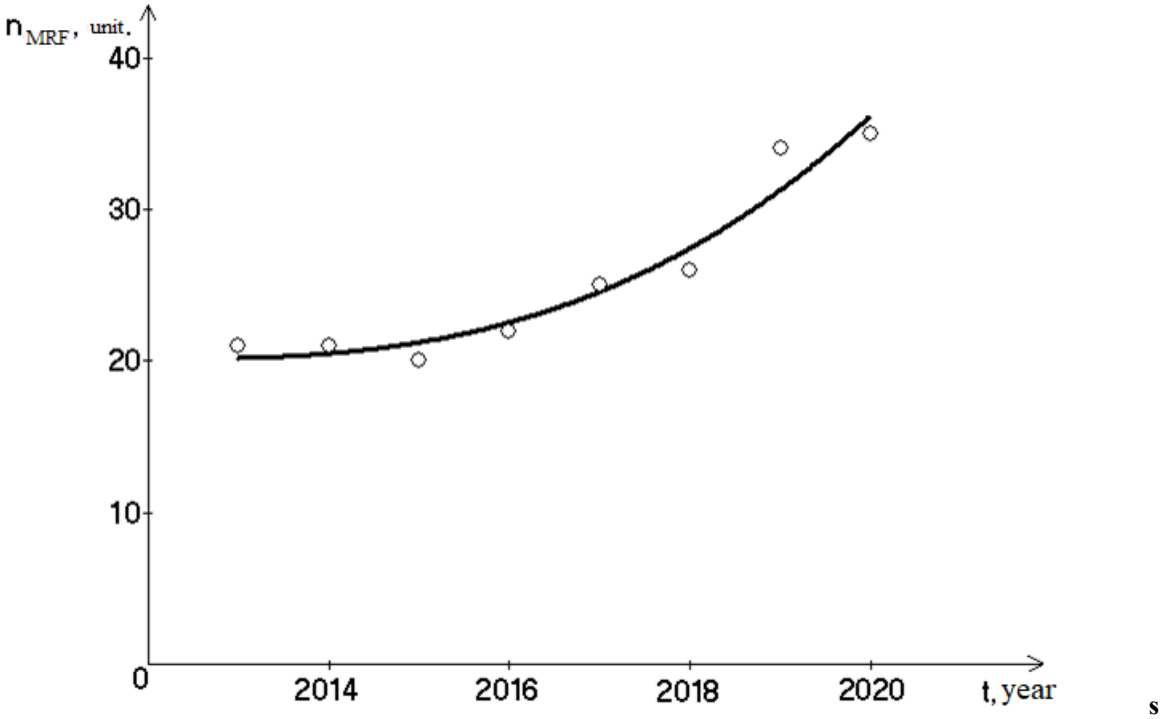

Fig. 1. Dependence, describing the change rate of the quantity of the material recovery facilities increase in Ukraine during the period of 2013 - 2020: actual ○, theoretical —

Using the dependence (1) it can be predicted that the quantity of the material recovery facilities in Ukraine in 2025 will reach 81 and in 2030 – 168 units.

Having assumed average performance of one facility as 50 000 tons per year [10] or for the average density of SMW 210 kg/m^3 and compaction factor in the dust cart 2.2 [6] in terms of the volume – 108 thousand m^3 per year, it can be calculated that for sorting the annual volume of SMW of 54 mil. m^3 in Ukraine, 500 material recovery facilities are needed. By means of dependence (1) it can be predicted that such quantity of material recovery facilities in Ukraine at present rate of growth can be provided by 2040.

Conclusions

1. Regression dependence, describing the change rate of the quantity of the material recovery facilities increase in Ukraine is determined, it can be used for the prediction of the quantity of such facilities.

2. Graphic dependence, describing the change rate of material recovery facilities increase in Ukraine is constructed, this dependence allows to illustrate the change rate and show the sufficient convergence of the theoretical results with actual ones.

3. It is established that in Ukraine in the period of 2013 – 2020 the quantity of material recovery facilities increased in exponential function.

4. It is predicted that for sorting the total annual volume of SMW, generated in Ukraine the needed quantity of material recovery facilities at present rate of growth can be provided by 2040.

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