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IMPACT OF POPULATION INCOMES ON THE VOLUME OF MUNICIPAL SOLID WASTE FORMATION IN UKRAINE

Annual volume of municipal solid waste formation on the territory of Ukraine, according to statistical data, exceeds 54 mil. m^3, creating serious threat for the ecological safety. That is why, determination of the regression dependence, describing the impact of the population incomes on the volumes of municipal solid waste formation in Ukraine is an important scientific-technical task. Aim of the research is determination of the regression dependence, which describes the impact of the population incomes on the volume of municipal solid waste formation in Ukraine and can be used for the prediction of such volumes.

In the course of the research method of regression analysis of the results of single factor experiments and other paired dependences was used with the selection of the rational type of function from sixteen most widely spread variants by the criterion of maximum values of the correlation factor. Regression was performed on the base of linearized transformations, which allow 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 right to the copyright object.

Adequate regression dependence, describing the impact of the population incomes on the volumes of the municipal solid waste formation in Ukraine was obtained, it can be used for the prediction of these volumes. Graphical dependence, describing the impact of the population incomes on the volumes of municipal solid waste, being formed in Ukraine was constructed, it enables to illustrate this dependence and shows the sufficient coincidence of the theoretical results with the actual data. It has been established that the volumes of municipal solid waste formation in Ukraine grow with the increase of the incomes of the population in accordance with the hyperbolic dependence.

Key words: *impact, population income, volumes of formation, municipal solid waste, regression dependence.*

Introduction

As compared with solid industrial waste, which can be easily recycled [1 – 6], municipal solid waste (MSW) in Ukraine, as a result of its heterogeneity, are buried at the landfills and dumps, polluting the environment and creating serious threat for ecological safety [7 – 10]. Annual volume of MSW, formed on the territory of Ukraine, according to statistical data, exceeds 54 mil. $m^{3.}$ Greater part of this volume is buried on 6107 landfills and dumps, their total area is almost 7700 ha and only partially is recycled or disposed at waste incineration plants, in contrast with highly developed countries, where modern technologies of recycling and disposal of MSW are widely used [11]. During 1999 - 2014 the total area of the landfills and dumps increased three times in Ukraine. Area of the overloaded landfills and dumps increased almost two times and the area of the landfills and dumps which do not meet the requirements of ecological safety, threatening the pollution of the environment (atmosphere, hydrosphere and lithosphere), in particular, due to chemical contamination of the soil, causing the diseases of living organisms [12], pollution of the adjacent land plots [9], including agricultural lands increased more than three times.

Problem set up

Resolution of the Cabinet of Ministers of Ukraine № 265 [13] formulated the basis for the development of the National Strategy of MSW management in Ukraine. Among the tasks of the strategy, laid out in the law of Ukraine of February 28, 2019 № 2697-VIII “On basic fundamentals (strategy) of the state ecological policy of Ukraine for the period until 2030”, it is noted, in

particular, the return in the business circulation the resource valuable materials [14]. That is why, the determination of the regression dependence, describing the impact of population incomes on the volumes of MSW formation in Ukraine an can be used for the forecast of such volumes is the relevant scientific-technical problem.

Analysis of the research and publications

The paper [15] contains scientific-methodical support for the forecast of the volumes of MSW formation on the territory of Zhytomyr, the dependence of MSW accumulation on the impact of the basic social, ecological and economic factors which would provide the possibility to forecast their dynamics as the base for efficient managerial decisions in the sphere of regional ecological safety.

Author of the research [16] established that the efficiency of MSW management sphere greatly depends on the stability of the general economic and political situation in the country. Possibility of the prediction of the events development in the country by the economic entities and planning of their activity at least for the short-term prospects, reduction of social strain also are the important external factors regarding the contaminators of the environment.

In the paper [17], it was revealed that important factors, influencing the volume of MSW within the limits of such tourist destinations (physical space where the visitor spends at least one day) are the amount of the tourists and sightseers, exchange rate, number of the population. As a result of the regression analysis, carried out, of the dependence of the volume of the formed waste on the chosen factors, the close connection between them was determined, this is proved by high correlation factor. Besides, for further forecasting of the possible volume of waste within the limits of the tourist destinations, especially MSW, the corresponding linear economic-mathematic models, taking into account the above mentioned factors, were constructed.

Author of the paper [18] presents the statistical data regarding the MSW management expenses for the groups of the residents with law, average and high annual incomes. In the paper [19] the regression dependences of the MSW management expenses (collection, transport, burial, total expenses, interest cost from the incomes) on the level of the population incomes, on the base of which MSW management expenses in Ukraine are calculated.

According to the Resolution of the Cabinet of Ministers of Ukraine № 303 [20] Standard norms of the fees for waste disposal greatly depend on the class of hazard. In the study [21], the parameters, the fees for MSW deposition depends on, and exponential regression dependence of the fee value for their disposal on the basic parameters of the impact, are determined.

Regression dependence, describing the dynamics of the volumes of the scrap metal formation in Ukraine is determined in the paper [22].

The research [23] contained the suggested mathematical model of the short-term forecasting of the regional volumes of MSW formation. This mathematical model is constructed by means of the Solow function and takes into account the impact of the following five factors: number of the population, amount of residential stock, retail turnover (including public catering facilities, where greater part of MSW is formed), volume of the industrial output and total financial incomes of the population. In our opinion, mathematical model, suggested by the author is rather cumbersome and requires a great number of data for each settlement of the region for each of the five factors of influence, providing comparatively low accuracy, not taking into account possible effects of the factors interaction. In the paper [24] mathematical model of the prediction of the volumes of municipal solid waste formation in Ukraine is constructed in the form of the quadratic regression with the interaction effect of the first order, that takes into account the number of the population and gross domestic product (both in actual and comparative prices) of Ukraine, and can be used for the determination of the need in new dust carts.

The research [25] contains the statistical data regarding the incomes of the population and volume of MSW formation per person in different groups of regions of Ukraine according to

average annual income per capita. However as a result of the analysis of the known publications the authors did not reveal specific mathematical dependences, describing the impact of the incomes of the population on the volumes of MSW formation.

Aim and tasks of the research

The aim of the given paper is the construction by means of the regression analysis the dependence, describing the impact of the population incomes on the volumes of MSW formation in Ukraine, it can be used for the prediction of such volumes.

Methods and materials

For the determination of the regression dependence, describing the impact of the populations on the volumes of MSW formation in Ukraine the following methods are used: analysis of the literature sources, regression analysis of the results of the single-factor experiments and other paired dependences, computer simulation.

Results of the research

Table 1 contains the statistical data, regarding the incomes of the population and volumes of MSW formation per capita in different groups of regions of Ukraine by average annual income per capita [25]. On the base of the data, presented in Table 1 it was planned to obtained paired regression dependence, describing the impact of the incomes of the population on the volumes of MSW formation in Ukraine.

Table 1

Statistics of the incomes of the population and volumes of MSW formation per capita in Ukraine [25]

Group of regions by the average annual income per capita, hrs.	Average annual income, hrs.	Average annual volume of MSW, kg
I – from 27363 to 50244	34658	99.5
II – from 50245 to 73126	65213	119.5
III – from 73127 to 96008	96007	162.6

Regression was performed on the base of the linearized transformations, which enable to reduce the non-linear dependence to the linear one. Determination of the coefficients of the regression equations was carried out, applying the method of the least squares [26] by means of the developed computer program "RegAnaliz" [27], protected by the Certificate of the State registration of the rights to the copyright object, and is described in the works [20, 28].

Program "RegAnaliz" allows 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 maximum correlation factor, saving the results in MS Excel and Bitmap format.

The results of the regression analysis are presented in Table 2, where the cells with the rational type of regression and maximum value of the correlation factor *R* are marked with a grey color.

Thus, according to the results of the regression analysis on the base of the data from Table 1, the following regression dependence is finally taken as the most adequate

$$m_{MSW} = \frac{1}{0.01234 - 6.36 \cdot 10^{-5} Д} \text{ [kg/person·year]}, \quad (1)$$

where m_{MSW} – is the annual volume of MSW formation per person in Ukraine, kg/person·year; $Д$ – is average annual income per capita, ths. hrs.

Table 2

Results of the regression analysis of the population incomes impact on the volumes of MSW formation in Ukraine

№	Type of regression	Correlation factor R	№	Type of regression	Correlation factor R
1	$y = a + bx$	0.97885	9	$y = ax^b$	0.95999
2	$y = 1 / (a + bx)$	0.99704	10	$y = a + b \cdot \lg x$	0.94059
3	$y = a + b / x$	0.89095	11	$y = a + b \cdot \ln x$	0.94059
4	$y = x / (a + bx)$	0.93891	12	$y = a / (b + x)$	0.99704
5	$y = ab^x$	0.98973	13	$y = ax / (b + x)$	0.94200
6	$y = ae^{bx}$	0.98973	14	$y = ae^{b / x}$	0.91761
7	$y = a \cdot 10^{bx}$	0.98973	15	$y = a \cdot 10^{b / x}$	0.91761
8	$y = 1 / (a + be^{-x})$	0.90646	16	$y = a + bx^n$	0.99067

Fig. 1 shows actual and theoretical graphics dependences, describing the impact of the population incomes on the volumes of MSW formation in Ukraine.

Comparison of the actual and theoretical data showed that the theoretical volumes of MSW formation in Ukraine, calculated by means of the regression equation (1), do not differ greatly from the data, presented in the paper [25], this proves rather high accuracy of the dependence, obtained before.

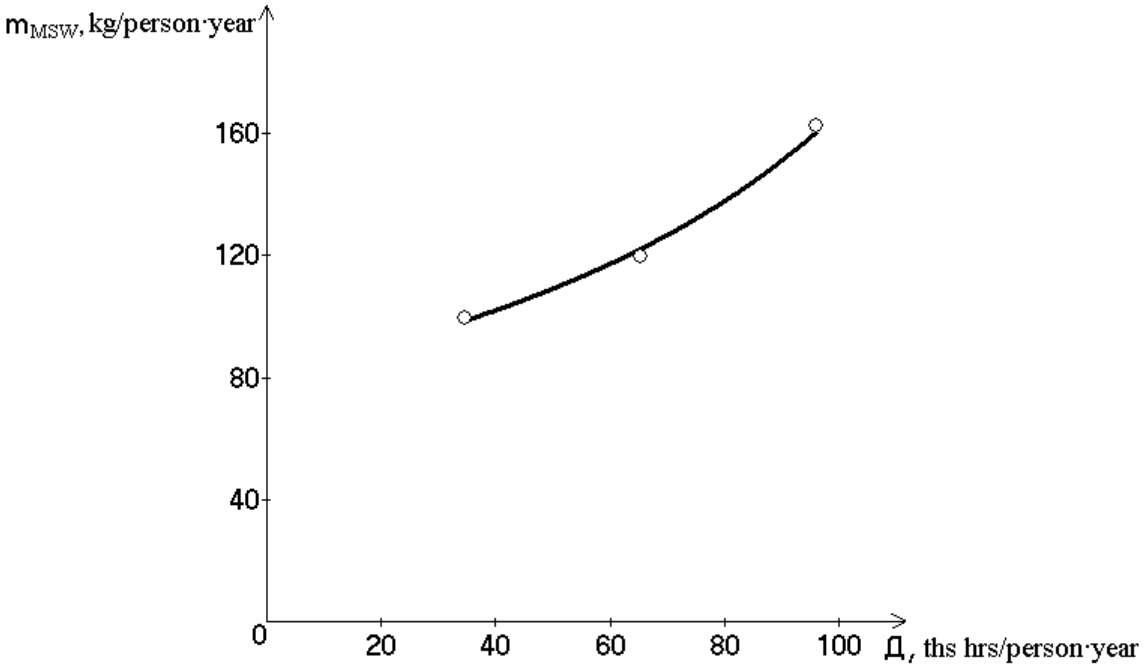

Fig. 1. Dependence, describing the impact of the population incomes on the volumes of MSW formation in Ukraine: actual ○, theoretical —

Conclusions

1. Regression dependence, describing the impact of the population incomes on the volumes of municipal solid waste formation in Ukraine and can be used for the prediction of such volumes, is determined.
2. Graphic dependence, describing the impact of the population incomes on the volumes of municipal solid waste formation in Ukraine and allows to illustrate this dependence and show the sufficient coincidence of the theoretical and actual results is constructed.
3. It is established that the volumes of municipal solid waste formation in Ukraine grow with the increase of the population incomes according to hyperbolic dependence.

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Editorial office received the paper 19.09.2022.
The paper was reviewed 23.09.2022.

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