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DETERMINATION ON THE DEPENDENCE OF LEAD CONCENTRATION IN THE SOIL ON THE DISTANCE FROM THE DISPOSAL SITE OF MUNICIPAL SOLID WASTE IN THE VILLAGE TISHNE, ZAKARPATSKA REGION

In recent years the total area of the landfills of municipal solid waste and dumps, including the overloaded, which violate the norms of ecological security and are the objects of the intensive ecological loading has greatly increased on the territory of Ukraine. This process may cause the pollution of the environment with chemical substances, causing chemical pollution of soil, in particular agricultural grounds, with lead. The objective of the research is the determination of the regressive dependence of lead concentration in soil on the distance to the landfill of municipal solid waste in the village Tishne, Zakarpatska region, that is relevant scientific engineering problem. In the process of the investigation method of regression analysis of the results of single-factor experiments and other paired dependences with the selection of rational type of function from sixteen most widely used variants by the criterion of maximum value of the correlation factor was used. Regression was carried out on the base of the linearized transformations, which enable to reduce non-linear dependence to linear one. Determination of the coefficients of the regression equations was performed, applying the method of the least squares by means of the developed computer program "RegAnaliz", protected by the Certificate of state registration of the right to the copyright object. Adequate regression power-logarithmic dependence of lead concentration in the soil on the distance to the landfill of municipal solid waste in the village Tishne, Zakarpatska region was obtained, it can be used for the determination of the level and area of the zone of chemical pollution of the soil with lead. Graphic interpretation of the dependence of lead concentration in the soil on the distance to the landfill of municipal solid waste is constructed, it enables to illustrate this dependence and show the coincidence of theoretical results with actual on the level of 0,98796. It was established that the distance from the landfill of municipal solid waste in the village Tishne, Zakarpatska region, at which the pollution of the soil with lead does not exceed the background level (boundary of the zone of weak pollution) is 135 m.

Key words: landfill, dump, municipal solid waste, chemical pollution, concentration, lead, soil, regression analysis.

Introduction

Municipal solid waste exercises negative long-lasting impact on human health and the environment [1, 2]. MSW is heterogenous, multicomponent mixture of complex morphological composition unlike construction [3, 4] or industrial waste, which are mainly homogenous and can rather easily be recycled. Annual volume of MSW formation on the territory of Ukraine is more than 54 mil. m³, greater part of the waste, as of the beginning of 2022, is buried on 5969 landfills and dumps, which occupy the territory of 8816 ha and only minor part of the waste is recycled or disposed at the incineration plants, unlike highly developed countries of European Union, where modern technologies of recycling and disposal of municipal solid waste are widely used [6]. Only in the period of 1999 – 2014 the total area of Ukrainian landfills and dumps increased almost two times and the area of the landfills where norms of ecological safety are violated, threatening the pollution of the environment (air, water and soil) increased three times, in particular chemical contamination of the soil with heavy metals, such as lead, causing the diseases of the living organisms [7 – 9], pollution of the adjacent land plots [10], including agricultural land. That is why, in order to prevent the growth of the landfills and dumps areas, limit their negative impact on the environment dust-carts in the process of loading perform technological operation of MSW compaction in its body [11, 12]. Grinding and dehydration [13] also decreases the rate of landfills areas growth.

Problem setting

According with the provisions of the resolution of the Cabinet of Ministers of Ukraine No. 265 the control over the operating and closed MSW landfills to prevent harmful impact on the environment and human health is among the priorities of municipal solid waste management in Ukraine [14]. That is why, the determination of the regression dependence of lead concentration in the soil on the distance to the landfill of municipal solid waste in the village Tishne, Zakarpattia region, which can be used for the determination of the level and dimensions of the area of chemical pollution of the soil with lead, is relevant scientific-engineering problem.

Analysis of the recent research and publications

Forecast of the volumes of MSW formation and landfills area in Ukraine by means of the constructed mathematical models was suggested in the paper [15], these models enabled to establish that the total area of landfills and dumps as well as those which do not correspond to the norms of ecological safety increases in time according to exponential pattern and the area of the overloaded landfills and dumps which correspond and those which do not correspond to the norms of ecological safety annually increases almost linearly. In order to decrease the rate of landfills areas growth technological operation of MSW compaction during loading in the dust cart is preformed [11, 12]. High compaction coefficient of MSW provides more efficient usage of the landfills areas [16, 17].

In the study [18] the impact of the heavy metals concentration increase on the decrease of the agricultural plants productivity due to the property of the heavy metals to slow down the development of vegetative and reproductive functions of the plants was established. In the study [19] accumulation of lead in various parts of the plant wheat, depending on the intensity of soil pollution was investigated. Heavy metals pollution of the soil as a result of MSW disposal is studied in the works [20 – 23]. In paper [24] data, regarding the impact of the heavy metals on microbiocenosis of soddy-weak podzolic soil are presented.

Paper [25] contains the survey of the most widely used methods of heavy metals remediation in the soil. Materials of the study [26] contain data regarding the specific expenditures of electric energy, needed for the reduction of the concentration of such heavy metals as cadmium, lead, and zink in the soil of the landfills, using the method of electric chemical remediation. This method is based on the usage of the electric current for the elimination of the corresponding pollutants. By means of this method it is possible to restore soils directly on the surface of the ground without collecting it into special containers, that makes the process less energy consuming. The research [27] determines regression dependence of the specific energy expenditures for cleaning the soils of MSW landfills due to pollution with such heavy metals as cadmium, lead and zinc on their actual and maximum permissible concentrations. In the paper [28] improved mathematical model of the specific energy expenditures is suggested for cleaning the soils of MSW landfills as a result of the pollution with heavy metals from the concentrations of cobalt, copper, nickel, chromium, vanadium, manganese enabling to evaluate energy expenditures for cleaning the polluted soil from the harmful substances.

In the paper [29] the attention is concentrated on the fact that conventionally urban community solve the problem of waste accumulation at the expense of rural territories, as a result there emerges the problem of rural soils pollution due to the soil, water, air quality worsening, it was also established that MSW landfill may be the reason of water quality and sanitary-hygienic state of soil worsening at the adjacent agricultural territories. In the materials of the research [30] adequate regression power dependence of petroleum products concentration in soils on the distance to the landfills of municipal solid waste is determines, the given dependence is used for the determination of the safe distance of MSW landfills location from the agricultural lands according to the indices of the chemical pollution level with petroleum products.

In the paper [31] it is noted that the lead pollution of the soil is the result of manufacturing of lead acid batteries, formation, accumulation and recycling of their waste as well as usage of the leaded

gasoline as an engine oil. It is stressed in the study [32] that greater part of water-soluble compounds of lead, entering the soil, are fixed and transfer into the insoluble state.

The materials of the paper [33] contain the results of the study of chemical composition of soil on landfill in the village Tishne, Mizhhiria district, Zakarpatska region, in particular, the level of lead pollution at different distances from landfill.

The research [34] contains chemical characteristics of the soils of MSW landfill in the village Sencha, Lohvytsia district, Poltava region, in particular lead pollution level at different distances from the landfill. On this base, power dependence of lead concentration in the soil on the distance to the landfill is suggested. Study of the lead content in the black soil ordinary, depending on the distance from the soil of pollution showed that lead actively migrates outside the limits of the pollution [36]. However, the authors did not reveal specific mathematic models of the redistribution of the lead content in the soil depending on the distance to the landfill of municipal solid waste in the village Tishne, Zakarpatska region as a result of the analysis of the known publications.

Objective and task of the paper

Objective of the given paper is determination of the regression dependence of lead concentration in the soil on the distance to the landfill of municipal solid waste in the village Tishne, Zakarpatska region, the dependence can be used for the determination of the level and area of chemical pollution of the soil with lead.

Methods and materials

In the process of determination of regression dependence of lead concentration in soil on the distance to MSW landfill the following methods were used: analysis of the literature sources regression analysis of the results of single factor experiments and other paired dependences, computer simulation.

Results of the research

Table 1 contains data regarding the concentrations of lead in the soil of MSW of the village Tishne, Mizhhiria district, Zakarpatska region obtained by means of atomic-absorption method [33]. On the base of the data of Table 1 it was planned to obtain paired regression dependence of lead concentration in the soil on the distance to this landfill of municipal solid waste (MSW). As the argument of the regression dependence is the distance to the landfill, that changes within the wide limits (0...5500 m), then, in order to improve the accuracy of the regression dependence decimal logarithm of the distance from the landfill $\lg(x)$ is suggested to use as the argument of function.

Regression was carried out on the base of the linearized transformations, which enable to reduce non-linear dependence to linear. Determination of the coefficients of the regression equations was performed, applying the method of the least squares [37] by means of the developed computer program "RegAnaliz" [38], protected by the Certificate of State registration of the right to the copyright object, the program is described in details in the work [39].

Table 1

Lead concentrations in the soil of MSW landfill, village Tishne, Zakarpatska region [33]

Distance from MSW landfill, m	0	100	200	500	5500
Lead concentration in the soil, mg/kg	2.3	1.4	1.2	1.1	1.0

Program "RegAnaliz" enables to perform regression analysis of the results of single-factor experiments and other paired dependences and select rational functions from sixteen most widely used variants by the criterion of maximum value of the correlation coefficients, saving the results in the format MS Excel and Bitmap.

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

Table 2

Results of regression analysis of lead concentration dependence in soil on the distance to MSW landfill, village Tishne, Zakarpatska region.

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0.96311	9	$y = ax^b$	0.94324
2	$y = 1 / (a + bx)$	0.98573	10	$y = a + b \cdot \lg x$	0.97160
3	$y = a + b / x$	0.95941	11	$y = a + b \cdot \ln x$	0.97160
4	$y = x / (a + bx)$	0.98365	12	$y = a / (b + x)$	0.98573
5	$y = ab^x$	0.97878	13	$y = ax / (b + x)$	0.87791
6	$y = ae^{bx}$	0.97878	14	$y = ae^{b/x}$	0.92613
7	$y = a \cdot 10^{bx}$	0.97878	15	$y = a \cdot 10^{b/x}$	0.92613
8	$y = 1 / (a + be^{-x})$	0.92095	16	$y = a + bx^n$	0.98796

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

$$C_{pb} = 2.268 - 0.5463 \lg^{0.7} x \text{ [mg/kg]}, \quad (1)$$

where C_{pb} – is lead concentration in the soil, mg/kg; x – is the distance to MSW landfill, m.

Fig. 1 shows the actual and theoretical graphic dependence of lead concentration in the soil on the distance to MSW landfill, village Tishne, Zakarpatska region.

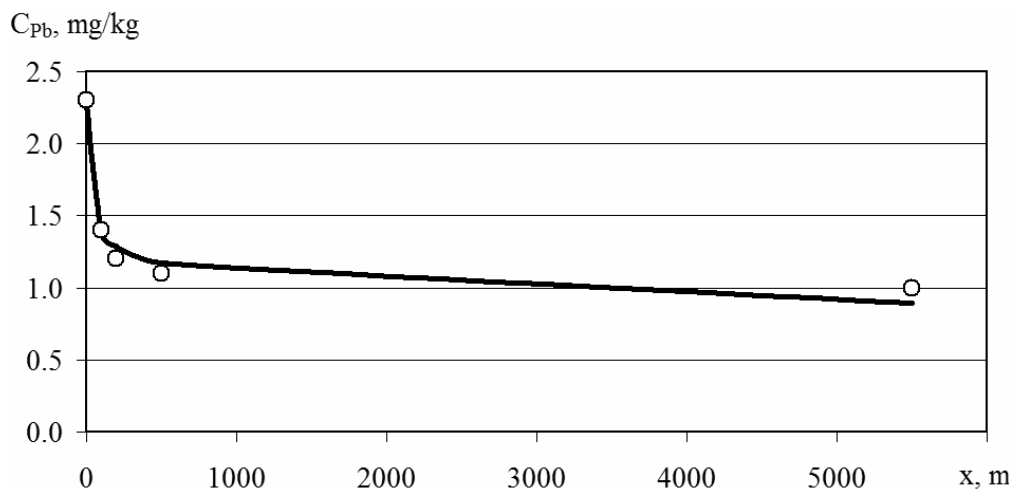


Fig. 1. Change of lead concentration in the soil depending on the distance to MSW landfill, village Tishne, Zakarpatska region

Comparison of actual and theoretical data showed that theoretical concentrations of lead in the soil, depending on the distance to MSW landfill, calculated by means of regression equation (1), do not differ greatly from the data, presented in the study [33], that proves the accuracy of the dependence, obtained previously on the level of 0.98796.

It is known that MAC of lead in the soil is $MAC = 32 \text{ mg/kg}$, this value is much higher than the values of pollution, determined in the study [33]. That is why, it is expedient to determine the boundary of the weak pollution zone, where lead concentration in the soil does not exceed MAC, but is higher than the natural background level. After substitution of the value of background concentration of lead in the soil of Zakarpatska region $C_{BG} = 1.34 \text{ mg/kg}$ [40] into the equation of regression (1), the distance from the MSW landfill in the village Tishne, where the soil pollution with lead does not exceed background level, i.e. the boundary of the weak pollution area will be determined

$$x = 10^{\left(\frac{2.268 - C_{pb}}{0.5463}\right)^{\frac{1}{0.7}}} = 10^{\left(\frac{2.268 - 1.34}{0.5463}\right)^{\frac{1}{0.7}}} \approx 135 \text{ (m)}.$$

Conclusions

1. Adequate regression dependence of lead concentration in the soil on the distance to municipal solid waste landfill in the village Tishne, Zakarpatska region is obtained, it is used for the determination of the level and area of chemical pollution of the soil with lead.
2. Graphic change of lead concentration in the soil on the distance to municipal solid waste landfill is constructed, it enables to illustrate the given regression dependence and show the coincidence of the theoretical results and the actual on the level of 0.98796.
3. It is established that lead concentration in the soil decreases by power-logarithmic dependence with the increase of the distance to the studied municipal solid municipal landfill.
4. It is determined that the distance from the MSW landfill in the village Tishne, Zakarpatska region, where lead pollution of the soil does not exceed background noise (boundary of the weak pollution zone) is 135 m.

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