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REGRESSION DEPENDENCE OF COPPER CONCENTRATION IN THE SOIL AT THE OFFSET FROM THE LANDFILL OF SOLID MUNICIPAL WASTE

In recent years the total area of the landfills of solid municipal waste and dumps, including overloaded, which violate the norms of ecological safety and are the objects of intensive ecological loading has considerably increased. This threatens with the pollution of the environment with chemical substances, causing chemical pollution of soil with heavy metals, in particular, copper. That is why, determination of the regression dependence of copper concentration in the soil on the distance to the landfills of solid municipal waste is a relevant scientific technical problem. The objective of the research is the determination of the regression dependence of copper concentration in the soils on the distance to the landfills of solid municipal waste. In the process of study the method of regression analysis of the results of single-factor experiments and other paired dependences with the selection of the rational type of function from sixteen most widely-spread variants by the criterion of the maximum value of the correlation coefficient was used. Regression was carried out on the base of the linearized transformations, which enable to reduce the 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", the program is protected by the Certificate of the State registration of the rights to the copyright object. Adequate regression power dependence of the copper concentration in the soil on the distance to the landfill of solid municipal waste has been obtained, the dependence can be used for the determination of the level of chemical pollution of the soil with the copper. Graphical interpretation of copper concentration dependence in the soil on the distance to the landfill of solid municipal waste has been constructed, it enables to illustrate the dependence and show the coincidence of the theoretical results with actual results on the level of 0.99798. It was established, that the distance from the landfill of solid municipal waste, where the soil pollution with copper does not exceed maximum permissible concentration, is 25.5 m.

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

Introduction

Solid municipal waste [1, 2] exercise long lasting negative impact on the environment and human health, solid municipal waste is heterogeneous, multicomponent mixture of the complex morphological composition, unlike the construction [3, 4] or industrial waste [5], which, as a rule is homogeneous and can be recycled rather easily. Annual volume of SMW formation on the territory of our country exceeds 54 mil. m^3. Main part of the waste is buried at 6107 landfills and dumps, their total area is almost 7700 ha and only minor potion is recycled or disposed at waste incineration plants, whereas in highly developed countries modern technologies of the recycling and disposal are widely used [6]. In the period of 1999 – 2014, total area of the landfills and dumps in Ukraine increased almost three times. The area of the overloaded landfills increased almost twice and the area of the landfills and dumps, where the norms of ecological safety are violated, threatening the pollution of the environment (air, water and soil) increased more than three times, in particular, chemical contamination of soil by heavy metals, for instance, copper, that causes the diseases of living organisms [7], pollution of the adjacent land plots [8]. That is why, to prevent the increase of the landfill areas and their negative impact on the environment, the dustcarts in the process of loading perform technological operation of SMW compaction [9, 10]. Dehydration of SMW also limits the increase of the landfill areas [11].

Problem set up

According to the text of the resolution of Cabinet of Ministers of Ukraine № 265 the realization of

control over the operating and closed SMW landfills to prevent negative impact on the environment and human health is referred to the priority directions of the policy of SMW management in Ukraine [12]. That is why, the determination of the regression dependence of copper concentration in the soil on the distance to the landfill of solid municipal waste, that can be used for the determination of the level of chemical contamination of the soil with cooper is a relevant scientific-technical task.

Analysis of the recent research and publications

In [13] mathematical models for the prediction of SMW volumes formation, landfills and dumps areas in Ukraine are suggested, these models enabled to determine that the total area of the landfills and dumps, including those, which do not correspond to the norms of ecological safety increase in time approximately by exponential law and the area of the overloaded landfills and dumps which correspond and do not correspond to the norms of ecological safety annually increases almost by the linear law. To decrease the rate of the landfill areas growth, technological operation of SMW compaction is performed during waste loading into dustcart [9, 10]. High coefficient of SMW compaction provides more efficient usage of the waste disposal site area [14, 15].

Studies [16 - 19] are devoted to the problem of soil pollution with heavy metals as a result of SMW disposal. Paper [20] contains the data, regarding the impact of heavy metals on microbiocenosis of soddy-weak podzolic soil.

The survey of the most widely spread methods of heavy metals remediation in soil is presented in the research [21]. Material of the paper [22] contains the data ,regarding specific cost of electric energy, needed for the reduction of heavy metals (cadmium, lead and zink) concentration in the soil of SMW landfills, applying the method of electrochemical remediation, based on the usage of electric current for the extraction of the corresponding polluting substances. Application of this method enables to remediate the soil directly on the surface, without using special vessels, this makes the process less energy consuming. The regression dependence of the specific energy consumption for the decontamination of SMW landfills soil as a result of the pollution with such heavy metals as cadmium, lead and zink on their actual and limiting admissible concentrations was determined in the study [23]. In the paper [24] the studies, aimed at improvement of the mathematical model of specific energy consumption for the decontamination of the SMW landfills soil as a result of their pollution with heavy metals on the concentration of cobalt, copper, chromium, vanadium, manganese nickel are performed, they enable to evaluate the energy cost for decontamination of the polluted soil from the harmful substances.

In the paper [25] the authors note that traditionally the urban communities solve the problem of waste disposal at the expense of the rural territories, as a result the problem of soil pollution due to the worsening of the soil, water, air quality emerges, also it is established that SMW landfill can be the cause of worsening the quality of the portable water and sanitary-hygienic state of the soil on the adjacent agricultural territories. In the materials of the study [26] the adequate regression dependence of petroleum products concentration in the soil on the distance to solid municipal waste landfill was determined, it is used for the determination of the safe distance for the location of solid municipal waste landfill from the agricultural soil according to the index of the soil pollution level with petroleum products.

Regularities of total and mobile forms of cooper distribution in genetic horizons of the soil profile of main types of soil of agrarian and forest ecosystems of Zhytomyr Polisia were determined, the assessment of the pollution level of the ground cover with the mobile forms of cooper was performed [27]. The usage of the method of remediation of the soil, polluted technogenically polyelementy mainly by Cd, Zn and Cu, where as a result of using as sorbent-ameliorant the compounds of ferrous sulfate (II) and phosphate fertilizers in certain ratio by the gradation of soil pollution the increase of the efficiency of their ecological rehabilitation and restoration of their natural buffer properties by means of impact on the processes of heavy metals migration of different hazard classed and trophic mode in the soils and plants performance with the improved indices of ecological safety was substantiated in [28].

Paper [29] contains the results of the study of chemical composition of the soils around the SMW

landfill in the village of Tishne, Mizhgirskyi district Zakarpatska region, in particular, concentration of copper pollution at different distances from the landfill. But the author did not find any specific mathematic dependences of copper concentration in the soil on the distance to the landfill of solid municipal waste.

Objective of the research

Objective of the research is the application of the method of regression analysis for determination of copper concentration in the soil on the distance to solid municipal waste landfill, that can be used for the determination of the level of chemical pollution of the soil with copper.

Methods and materials

For the determination of the regressive dependence of copper concentration in the soils on the distance to the landfill of SMW the following methods were used: analysis of literature sources, regression analysis of the results of single factor experiments and other paired dependences, computer modeling.

Results of the research

On the base of the data, presented in the study [29], it was planned to obtain paired regression dependence of copper concentration on the distance to SMW landfill.

Regression was performed on the base of linearized transformations, enabling to reduce non-linear dependence to linear. Determination of the coefficients of the regression equations was performed by the method of the least squares [30] by means of the developed computer program "RegAnaliz" [31], protected by the Certificate of the State Registration of the rights to the copyright object and is described in details in the work [32].

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

Results of the regression analysis are presented in Table 1, where grey color indicates the cell with maximum value of the correlation coefficient *R*, that corresponds to power function №16.

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

$$C_{Cu} = 3{,}897 - 0{,}4692x^{0,2} = 3{,}897 - 0{,}4692\sqrt[5]{x} \text{ [mg/kg]}, \quad (1)$$

where C_{Cu} – is copper concentration in the soil, mg/kg; x – is the distance to SMW landfill, m.

Fig. 1 shows actual and theoretical graphic dependence of copper concentration in the soils on the distance to SMW landfill.

Comparison of actual and theoretical data showed that theoretical concentrations of copper in the soils, calculated by means of the regression equation (1) do not differ substantially from the data, presented in the study [29], this proves the accuracy of the obtained dependence on the level of 0.99798.

Table 1

Results of regression analysis of the dependence of copper concentration in the soils on the distance to SMW landfill

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0.77577	9	$y = ax^b$	0.68266
2	$y = 1 / (a + bx)$	0.95121	10	$y = a + b \cdot \lg x$	0.80539
3	$y = a + b / x$	0.80453	11	$y = a + b \cdot \ln x$	0.80652
4	$y = x / (a + bx)$	0.98948	12	$y = a / (b + x)$	0.95121
5	$y = ab^x$	0.88203	13	$y = ax / (b + x)$	0.55063
6	$y = ae^{bx}$	0.88203	14	$y = ae^{b / x}$	0.68160
7	$y = a \cdot 10^{bx}$	0.88203	15	$y = a \cdot 10^{b / x}$	0.68160
8	$y = 1 / (a + be^{-x})$	0.55062	16	$y = a + bx^n$	0.99798

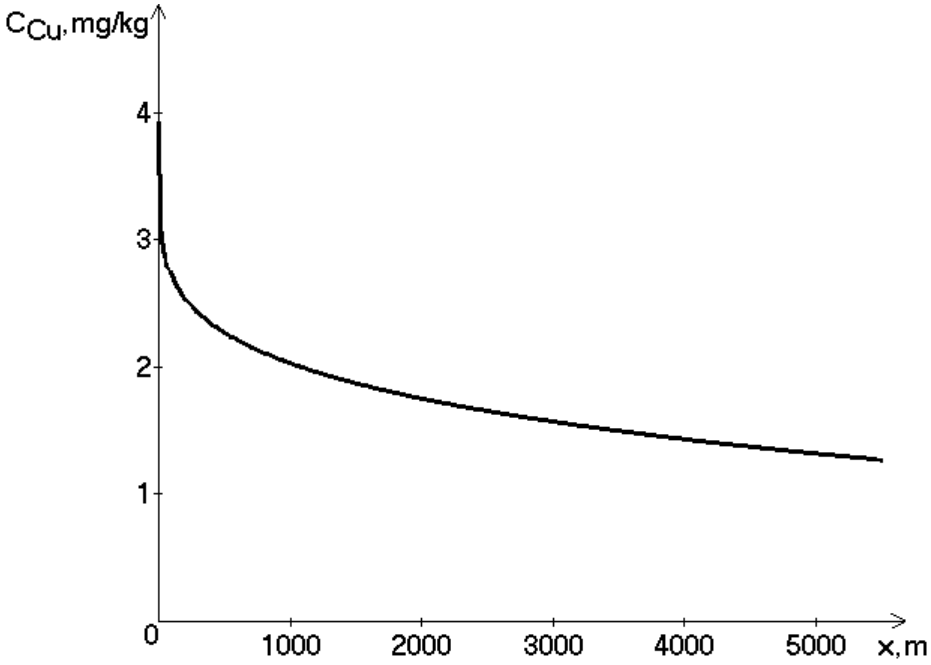

Fig. 1. Change of copper concentration in the soil on the distance to SMW landfill

As maximum permissible concentration (MPC) of copper in the soil is *MPC* = 3 mg/kg [29], then safe distance from SMW landfill, where soil pollution with copper does not exceed MPC is

$$x = \left(\frac{3{,}897 - C_{Cu}}{0{,}4692} \right)^5 = \left(\frac{3{,}897 - 3}{0{,}4692} \right)^5 \approx 25{,}5\ (m).$$

Conclusions

1. Method of regression analysis is used for the determination of copper concentration in the soils dependence on the distance to solid municipal waste landfill, it is used for determination of the level of soil chemical pollution with copper.

2. Graphic change of copper concentration in the soil on the distance to SMW landfill is constructed, it enables to illustrate the given regression dependence and show the coincidence of the theoretical results with actual on the level of 0.99798.

3. It has been established that copper concentration in the soil decreases with the increase of the distance to SMW landfill in accordance with power dependence.

4. It has been determined that the distance to SMW landfill, where the soil pollution with copper does not exceed maximum permissible concentration is 25.5 m.

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