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REGRESSION ANALYSIS OF PETROLEUM PRODUCTS CONCENTRATION IN THE SOILS OF MUNICIPAL SOLID WASTE LANDFILLS

In recent years the total area of the municipal solid waste landfills and waste dumps, including overloaded, which violate the norms of ecological safety and are the objects of the intensive ecological loading, that pollute the environment with chemical substances, causing chemical pollution of the soils, in particular, with the petroleum products, has greatly increased. Determination of the regression dependence of the petroleum products concentration in the soils on the distance to the landfills of municipal solid waste is the relevant scientific-technical problem.

Objective of the study is determination of the regression dependence of the petroleum products concentration in the soils on the distance to the municipal solid waste landfills. Regression was performed on the base of the linearized transformations, which enable to reduce the nonlinear dependence to linear one. Determination of the regression equations coefficients was performed by the method of the least squares with the help of the elaborated computer program "RegAnaliz", protected by the Certificate of the State registration of the rights to the copyright object.

Adequate regression power dependence of the petroleum product concentration in the soils on the distance to the landfills of municipal solid waste was obtained, the dependence was used for the determination of the safe distance for the solid municipal landfills location from the agricultural lands by the index of the level of chemical pollution of the soil with petroleum products. Graphic interpretation of the dependence of the petroleum products concentration in the soil on the distance to the landfill of municipal solid waste is constructed, this interpretation enables to illustrate this dependence and show the coincidence of the theoretical results with the actual results on the level of 0.9999996. It was established that the safe distance for the location of the landfills of municipal solid waste from the agricultural lands by the index of the level of chemical pollution of the soil with petroleum products is 66 m.

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

Introduction

Municipal solid waste (MSW) [1, 2], being a mixture of the components, which unlike the building [3, 4] or industrial waste [5] that are mainly uniform and can easily be recycled, are dangerous for the environment and human health. Annual volume of MSW, formed in Ukraine exceeds 54 mil. m^3, greater part of the waste is buried on 6107 landfills and waste dumps, total area of which is almost 7700 ha, and only minor part is partially 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 [6]. During 1999 – 2014 total area of the landfills and waste dumps in Ukraine increased three times. The total area of the overloaded landfills and dumps increased almost two times and the area of the landfills and dump sites, where the norms of ecological safety are violated, threatening with the pollution of the environment (atmosphere, hydrosphere and lithosphere), in particular, due to chemical contamination of the soil, causing the spread of the diseases of living organisms [7], pollution of the adjacent land plots [8], including agricultural land, increased three times. That is why, to reduce the growth rate of the landfills, waste dumps and their adverse impact of the environment technological operation of MSW compaction during waste loading into the dust-cart is performed [9, 10]. Dehydration of MSW will also help to reduce the growth rate of the landfills area [11].

Problem set-up

In accordance with the Resolution of the Cabinet of Ministers of Ukraine № 265 provision of the control over the operating and closed landfills of MSW to avoid the adverse impact on the environment and human health is among the priority directions of MSW management in Ukraine [12]. That is why, the determination of the regression dependence of the petroleum products concentration in soil on the distance to the landfill of MSW, which can be used for the determination of the safe distance for the MSW landfills location from the agricultural soils by the index of the chemical pollution level of soils with petroleum products is an important scientific and technical task.

Analysis of the recent studies and publications

The paper [13] suggested the mathematical models for the forecasting the volumes of MSW formed and areas of the landfills and dumps in Ukraine, by means of these models it is established that the total area of the landfills and waste dumps as well as the area of the landfills and dumps that do not correspond to the norms of ecological safety increases in time approximately by the exponential law and dumps which correspond and do not correspond to the norms of ecological safety annually increases almost linearly. In order to decrease the growth rate of the landfills technological operation of MSW compaction during the loading in the dust-cart is carried out [9, 10]. High compaction coefficient of MSW provides more efficient usage of the landfills area [14, 15].

The papers [16 – 19] note the significant contamination of the soils with heavy metals as a result of MSW burial. Paper [20] contains data, regarding the impact of heavy metals on microbiota of soddy-weak podzolic soil.

The research [21] contains the survey of the most widely-spread methods of heavy metals remediation in the soil. The paper [22] contains data, regarding the specific consumption of electric energy for the reduction of the concentration, applying the method chemical remediation of such heavy metals in the soil of the landfills as cadmium, lead and zinc. This method is based on the usage of the electric current for separation of the corresponding polluting substances. Applying the method of electrochemical remediation the soil can be renovated directly on the surface without taking into a special tanks, that makes the process less energy consuming. In the study [23] the regression dependence of the specific energy consumption, needed for cleaning the soils of the landfills of MSW as a result of their contamination with heavy metals (cadmium, lead and zink) on their concentrations and MAC. In the paper [24] the improved mathematical model in the form of dependence of the specific energy consumption, needed for cleaning of the soils of MSW landfills as a result of heavy metals pollution on the concentration of cobalt, copper, nickel, chrome, vanadium, manganese is published, the model enables to evaluate the energy consumption, needed for cleaning the polluted soils from these substances.

It is noted in the study [25] that traditionally urban community solve the problem of waste accumulation at the expense of rural territories, as a result, there appears the problem of the pollution of these territories. Namely, quality of soils, water, air worsens, also it is established that MSW landfill can be the cause of worsening the quality of the tap water and sanitary-hygienic state of soils on the adjacent rural territories. In the research [26] the regression dependence of the benzopyrene concentration in the soil of MSW landfills the dependence is used for the determination of the dangerous depth of chemical contamination of soils. In the paper [27] it is noted that in the process of MSW landfill operation, there appears the danger of soils contamination with the waste and petroleum products, stipulated by the impact of transport, functioning at the landfill. Authors of the publication [28] not that the danger of contamination of soil with petroleum product lies in their migration in the profile of the soil and emerging of the danger of the secondary pollution of the surface and ground waters. Paper [29] contains chemical characteristics of the soils of the MSW landfill in the village of Sencha Lokhvytskyi District, Poltava Region, in particular the level of petroleum products

contamination at different distances to the landfill. However, the author did not reveal any specific mathematical dependences of petroleum products concentration in the soil on the distance to municipal solid waste (MSW) landfill as a result of analysis of the known publications.

Aim and tasks of the study

Aim of the given study is the usage of the method of regressive analysis in the process of determination of the petroleum products concentration in soil depending on the distance to the MSW landfill, that can be used for the determination of the safe distance for the location of MSW landfills from the agricultural soils by the index of the level of chemical contamination of the soil with petroleum products.

Methods and materials

For the determination of the regression dependence of the concentration of petroleum products in the soil on the distance to MSW landfill the following methods are used: regression analysis of the results of single-factor experiments and other pair dependences, computer simulation.

Results of the research

Table 1 contains the concentrations of the petroleum products in the soil of MSW landfill, located in the village of Sencha, Lokhvytskyi District, Poltava Region [29], obtained by means of the method of liquid chromatography. On the base of the data from Table 1 it was planned to obtain pair regression dependence of petroleum products concentration in the soil on the distance to MSW landfills.

Table 1

Petroleum products concentrations in the soil of MSW landfill [29]

Distance from MSW landfill	0	50	100	200
Petroleum products concentration in soil, mg/kg	1500	1100	798	264

Regression was performed on the base of linearized transformations, that enable to reduce non-linear dependence to linear one. Determination of the coefficients of the regression equations was carried out, applying the method of the least squares [30], using the developed computer program "RegAnaliz" [31], protected by the certificate of state registration of the right to the copyright object, the program is described in details in [32].

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

The results of the regression analysis are presented in Table 2, where the cell with maximum value of correlation factor *R*, is marked in grey color, that corresponds to power function №16.

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

$$C_{PP} = 1500 - 16.47x^{0.815} \text{ [mg/kg]}, \quad (1)$$

where C_{PP} – is the concentration of petroleum products in the soil, mg/kg; x – is the distance to MSW landfill, m.

Fig. 1 shows actual and theoretical graphic dependences of petroleum products concentration in soil on the distance to MSW landfill.

Comparison of the actual and theoretical data showed that theoretical concentrations of petroleum products in 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 paper [29], this fact

proves the accuracy of the dependence, obtained earlier, on the level of 0.9999996.

Table 2

Results of regression analysis of the dependence of petroleum products concentration in the soil on the distance to MSW landfill

№	Type of regression	Correlation factor R	№	Type of regression	Correlation factor R
1	$y = a + bx$	0.9954280	9	$y = ax^b$	0.5901348
2	$y = 1 / (a + bx)$	0.9453512	10	$y = a + b \cdot \lg x$	0.7484184
3	$y = a + b / x$	0.7481048	11	$y = a + b \cdot \ln x$	0.7488349
4	$y = x / (a + bx)$	0.9379301	12	$y = a / (b + x)$	0.9453512
5	$y = ab^x$	0.9885910	13	$y = ax / (b + x)$	0.4563523
6	$y = ae^{bx}$	0.9885910	14	$y = ae^{b / x}$	0.5897661
7	$y = a \cdot 10^{bx}$	0.9885910	15	$y = a \cdot 10^{b / x}$	0.5897661
8	$y = 1 / (a + be^{-x})$	0.4563431	16	$y = a + bx^n$	0.9999996

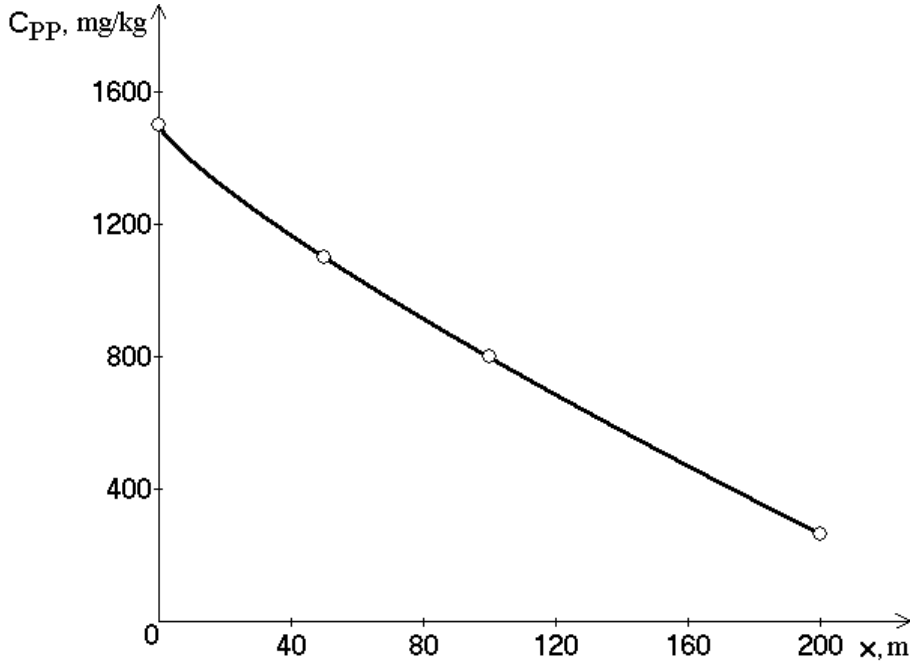

Fig. 1. Variation of petroleum products concentration in soil on the distance to MSW landfill

Having substituted the value of maximum admissible concentration of petroleum products in the soil, MAC = 1000 mg/kg [29] in the regression equation (1), the safe distance for the MSW landfill location from the agricultural land by the index of the level of chemical contamination of soil with petroleum substances will be determined

$$x = \left(\frac{1500 - C_{PP}}{16.47}\right)^{\frac{1}{0.815}} = \left(\frac{1500 - 1000}{16.47}\right)^{\frac{1}{0.815}} \approx 66 \text{ (m)}.$$

Conclusions

1. Method of regressive analysis is used in the process of determination of the petroleum products concentration in the soil on the distance to the landfill of municipal solid waste, used for the determination of the safe distance for the location of MSW landfills from the agricultural land by the index of the level chemical contamination of the soil with petroleum products.

2. Graphic change of petroleum products concentration in the soil on the distance to MSW

landfill is constructed, this dependence allows to illustrate the regression dependence and show the coincidence of the theoretical results with actual ones on the level of 0.9999996.

3. It is established that the safe distance for the location of MSW landfills from the agricultural lands by the index of the level of chemical contamination of the soil with petroleum products is 66 m.

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