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DEPENDENCE OF THE LEVEL OF BIOLOGICAL POLLUTION OF THE SOIL ON THE DISTANCE TO SOLID MUNICIPAL WASTE LANDFILL

In recent years the total area of solid municipal waste landfills and dump sites, including overloaded ones, which violate the norms of ecological safety and are the objects of the intensive ecological loading, threatening the pollution of the environment with microorganisms (colibacilli bacteria,streptococci, staphylococci and ascarids), causing bacteriological pollution of soils has considerably grown. Determination of the regression dependence of the level of bacteriological pollution of the soils on the distance to solid municipal landfill is an important scientific engineering problem. Aim of the research is to determine the regression dependence of bacteriological pollution level of the soils on the distance to the solid municipal waste landfill. In the process of the research the method of the regressive analysis of the results of single-factor experiments and other paired dependences with the selection of the best type of the function from sixteen most widely-spread variants by the criterion of the maximum value of the correlation factor is used. Regression was performed on the base of the linearized transformations, which enable to reduce the non-linear dependence to linear one. Determination of the regression equations coefficients 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 rights to the copyright object. Adequate regression hyperbolic dependence of bacteriological pollution level of the soil on the distance to the solid municipal waste landfill is obtained, the dependence is used for the determination of the safe distance for SMW landfill location from agricultural soil by the index of biological pollution level. Graphic interpretation of the dependence of biological pollution level of the soil on the distance to the solid municipal waste landfill is constructed, it enables to illustrate the given dependence and show the sufficient coincidence of the theoretical results with actual results on the level of 0.99535.

Key words: *landfill, dump site, solid municipal waste, bacteriological pollution, regression analysis.*

Introduction

Solid domestic waste (SDW) [1, 2] are very dangerous for human health and environment as their characteristic feature is that it is the mixture of the components, unlike the waste of the construction industry which is, as a rule, homogeneous and can be rather easily recycled [3, 4]. Annual volume of SDW formation on the territory of our country exceeds 54 mil. m^3, greater part of solid domestic waste is buried on 6107 landfills and dump sites, their total area is almost 7700 ha and only small portion of the waste is partially recycled or disposed at incinerating plants unlike the developed countries, widely introducing modern technologies of SDW recycling and disposal [5]. During the period of 1999 - 2014 the total area of the landfills and dumpsites increased three times in Ukraine. The area of the overloaded landfills and dumpsites increased almost two time and the area of the landfills and dumpsites where the norms of ecological safety are violated, threatening the pollution of the environment (atmosphere, hydrosphere and lithosphere), in particular, as a result of biological pollution of the soil with the microorganisms (collibacill bacteria, streptococci, staphylococci and ascaridis) which are pathogenic organisms and transmitters of diseases [6], on the adjacent plots of land [7], including agricultural soils, increased almost three times.

Locations of solid domestic waste burial, as a result of biological processes, taking place in the layers of waste are also the sources of the long-lasting negative impact on the environment by the landfill gas, which contains the green house gases, toxic substances [8] and high toxic filtrate [9 – 11], that is why, to decrease the rate of the landfill area increase and their negative impact on the environment, the technological operation of SDW compaction is carried out during the waste loading into the dust-cart [12, 13]. Dehydration of SDW will also reduce the rate of the landfills area increase [14].

Problem set up

According to the Resolution of the Cabinet of Ministers of Ukraine № 265 the organization of the control over the acting and closed SDW landfills to prevent the harmful impact on the environment and human health is among the priority directions of SDW management in Ukraine [15]. That is why, the determination of the regression dependences of the level or bacteriological pollution of the soil on the distance to the landfill, which can be used for the determination of the safe distance for SDW landfills location from the agricultural soil, by the index of the bacteriological pollution of the soil, is an important scientific-engineering problem.

Analysis of the latest research and publications

Mathematical models, forecasting the volumes of SDW formation and areas of the landfills and dumpsites in Ukraine, are presented in the paper [16], by means of these models it is established that the total area of the landfills and dumpsites as well as those ones which do not correspond to the norms of ecological safety increases approximately by the exponential law and the area of the overloaded landfills and dumpsites which correspond and those landfills and dumpsites which do not correspond to the norms of ecological safety increases annually almost linearly. To decrease the rate of the landfills areas growth the technological operation of SDW compaction during the loading in the dump cart is performed [12, 13]. High coefficient of SDW compaction provides more efficient usage of the landfills area [17, 18]. In the study [19], the data, concerning the concentration of saprophytic bacteria in 0 – 20 cm layer of the soddy-weak podzolis soil, adjacent to the SDW landfill are presented. In [20] the data regarding sanitary-bacteriological composition of SDW are presented. In the paper [21] opportunistic-pathogenic and pathogenic kinds of microorganisms are revealed in the deposit waste, qualitative and quantitative composition of the microorganisms, which decompose the organic substances in SDW at different stages of their life cycle is determined. Authors of the paper [22] present data, regarding the changes of sanitary-bacteriological composition of SDW during the composting. The research [7] reveals wider nomenclature of sanitary-bacteriological composition of SDW in spring (colibacilli bacteria, streptococci, staphylococci and ascarids) due to the presence of staphylococci and ascarids not present in SDW during summer composting. In SDW environment along with saprophytic bacteria, pathogenic bacteria are developed, they are index cases of such diseases as hepatitis, tuberculosis, dysonteria, ascaridosis, respiratory, allergic, skin and other diseases [23]. In [24] by means of multifactorial experiment planning of Box-Wilson the regression dependences of the activity of biological processes in SDW on the degree of the compaction is determined, by means of this dependence it was established that the activity of biological processes in SDW greatly depends on its density and least – on the time. In the article [25] the regressive power-law dependences of various diseases morbidity rate among the adult population of the communities, adjacent to SDW disposal on the distance to the landfill are determined, these dependences are used for the determination of the safe distance for SDW landfills location from the communities by the morbidity indices of the pathology of the respiratory organs and diseases of blood circulation systems. In [26] mathematical models of the dependence of saprophytic bacteria concentration in the soil on the distance to the SDW burial landfill are constructed, these dependences enabled to determine that with the approaching to the landfill the concentration of saprophytic aerobic bacteria, needed for biochemical reaction of the decomposition of the organic fraction of SDW in the locations of their burial and self-purification of the soil from the foreign organic substances, greatly decreases. In the paper [27] it is noted that conventionally urban environment solves the problem of waste accumulation at the expense of the rural territories, as a result the problem of rural soils pollution arises, namely, worsening of the quality of the soil, water, air, also it was found out that SDW landfill can be the source of worsening of water quality and sanitary-hygienic state of soil at the adjacent rural territories. However, the authors did not reveal definite mathematic dependences of the level of bacteriological pollution of the soils on the distance to SDW landfill as a result of the

analysis of the known publications.

Aim and task of the paper

Aim of the given study is construction by means of regression analysis regression dependence of the level of the bacteriological pollution of soils on the distance to the SDW landfill, this dependence can be used for the determination of the safe distance for the location of SDW landfills from the agricultural soils by the index of the level of bacteriological pollution of the soils.

Methods and materials

The following methods are used for the determination of the regression dependence of the level of bacteriological pollution of soils on the distance to SDW landfill: regression analysis of the results of the single-factor experiments and other paired dependences, computer simulation.

Results of the research

Table 1 shows the levels of bacteriological pollution, depending on the distance to Myronivka SDW landfill (town of Myronivka, Kyiv Region) [27]. Data are given for the total microbial count (TMC), determined by the number of colony-forming units (CFU) per 1 g of the dry matter of the studied material. On the base of the data of Table 1 paired regression dependence of the level of bacteriological pollution of soil on the distance to SDW landfill was planned to obtain.

Table 1

Levels of bacteriological pollution of soils on the distance to SDW landfill [27]

Distance from SDW landfill	0	50	200	500
TMC, $\times 10^6$ CFUg	3.1	2.5	1.9	0.28

Regression was carried out on the base of 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 the State Registration of the rights to the copyright object, the program is described in the work [28].

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

Results of the regression analysis are presented in Table 2, where the cell with maximum value of the correlation factor R is marked by the grey color.

Thus, by the results of the regression analysis on the base of the Table 2 data, as the most adequate, such regression dependence is finally accepted:

$$TMC = 3{,}034 - 0{,}01383 x^{0,85} \quad [\times 10^6 \text{ CFU/g}], \tag{1}$$

where TMC – is total microbial count, $\times 10^6$ CFU/g; x – is the distance to SDW landfill, m.

Table 2

Results of regression analysis of the dependence of the level of bacteriological pollution of soils on the distance to SDW landfill

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0,99362	9	$y = ax^b$	0,47037
2	$y = 1 / (a + bx)$	0,94449	10	$y = a + b \cdot \lg x$	0,63522
3	$y = a + b / x$	0,63464	11	$y = a + b \cdot \ln x$	0,63598
4	$y = x / (a + bx)$	0,94437	12	$y = a / (b + x)$	0,94449
5	$y = ab^x$	0,97760	13	$y = ax / (b + x)$	0,37242
6	$y = ae^{bx}$	0,97760	14	$y = ae^{b/x}$	0,46976
7	$y = a \cdot 10^{bx}$	0,97760	15	$y = a \cdot 10^{b/x}$	0,46976
8	$y = 1 / (a + be^{-x})$	0,37241	16	$y = a + bx^n$	0,99535

Fig. 1 shows actual and theoretical graphic dependence of the level of bacteriological pollution of soils on the distance to SDW landfill.
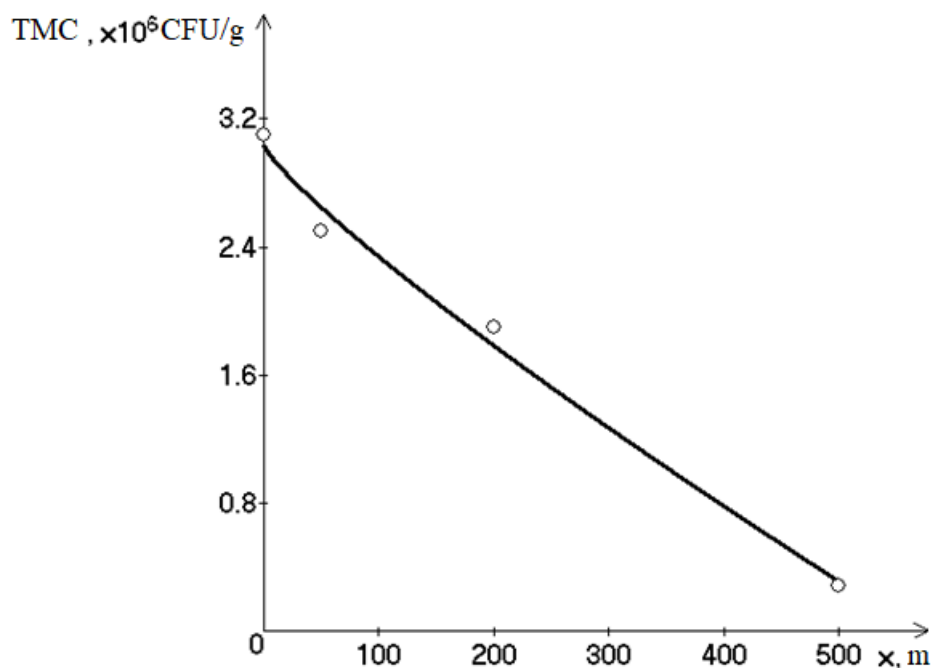

Fig. 1. Change of the level of bacteriological pollution of soils on the distance to SDW landfill

Comparison of actual and theoretical data showed that theoretical level of the bacteriological pollution of soils depending on the distance to SDW landfill, calculated by means of regression equation (1) does not differ greatly from the data, presented in the study [27], this proves sufficient accuracy of the dependence, obtained previously, determined previously on the level of 0.99535.

Having substituted the value of the background natural level of $TMC = 2.1 \cdot 10^5$ CFU/g [27] in the regression equation (1) the safe distance of SDW landfills location from the boundaries of the agricultural soils will be determined

$$x = \left(219{,}4 - 72{,}31 \cdot TMC\right)^{1/0{,}85} = \left(219{,}4 - 72{,}31 \cdot 0{,}21\right)^{1/0{,}85} \approx 522 \ (m).$$

Conclusions

1. Regression power dependence of the level of bacteriological pollution of the soils on the distance to solid domestic waste landfill is determined, this dependence is used for the determination of the safe distance for SDW landfills location from agricultural soils by the index of the level of

bacteriological pollution of the soils.

2. Graphic dependence of the level of bacteriological pollution of the soils on the distance to solid domestic waste landfills is constructed, this dependence enables to illustrate the given dependence and show sufficient coincidence of the theoretical results with actual ones on the level of 0,99535.

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