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DEPENDENCE OF THE LEVEL OF MICROBIOLOGICAL POLLUTION WITH GENERAL COLI GROUP BACTERIA OF THE SURFACE WATER ON THE DISTANCE TO THE SOLID MUNICIPAL WASTE LANDFILL

In recent years the total area of solid municipal waste landfills and dump sites, including overloaded, which violate the norm of ecological safety and are the objects of the intensive ecological loading has considerably increased. This may cause the pollution of the environment by the microorganisms (colibacilli bacteria, streptococci, staphylococci and ascarids), causing bacteriological contamination of the soil and ground water. Determination of the regression dependence of the level of the microbiological pollution by general coli group bacteria of the ground water on the distance to the solid waste landfill is an urgent scientific-engineering problem.

Aim of the research is to determine the regression dependence of the level of microbiological pollution with the general coli group bacteria on the distance to the solid municipal waste landfill. In the process of the research the method of the regression analysis of the results of single-factor experiments and other paired dependences with the selection of the rational 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 the 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 rights to the copyright object. Adequate regression dependence of the level of microbiological pollution with the general coli group bacteria of the surface water on the distance to SMW landfills was obtained , the given dependence is used for the determination of the safe distance for the location of SMW landfills from the sources of the drinking water by the index of the level of microbiological pollution with the general coli group bacteria of the surface water. Graphic interpretation of the dependence of the level of microbiological pollution with the general coli group bacteria of the surface water on the distance to the solid waste landfill is constructed, it enables to illustrate this dependence and show the coincidence of the theoretical results with the actual results on the level of 0.99996.

Key words: *dump site, landfill, solid municipal waste, microbiological pollution, surface water, general coli group bacteria, regression analysis.*

Introduction

Safety of the environment and health is endangered by the impact of solid municipal waste [1, 2], which is a mixture of the components, unlike the construction waste which are mainly, homogeneous and are easily recycled [3, 4]. In Ukraine annual volume of SMW formation is more than 54 mil. m^3, main part of the waste is buried on 6107 landfills and dump sites, their total area is almost 7700 ha, only minor portion of the waste is partially recycled or disposed at incinerating plants unlike the developed countries, where modern technologies of recycling and disposing of SMW are widely used [5]. During the period of 1999 - 2014 the total area of the landfills and dumpsites in Ukraine increased three times. The area of the overloaded landfills and dump sites which violate the norms of the ecological safety, threatening the pollution of the environments (atmosphere, hydrosphere and lithosphere) increased almost two times. In particular, as a result of bacteriological pollution of the soil and surface water with microorganisms (colibacilli bacteria, streptococci, staphylococci and ascarids) which are pathogenic organisms and transmitters of the diseases [6 – 8], the adjacent plots

of land [9], surface water and sources of drinking water. As a result of biological processes, occurring in SMW, locations of the waste burial are also the sources of the long-lasting negative impact on the surrounding environment by the landfill gas, which contains the greenhouse gases, toxic substances [10] and high toxic filtrate [11 – 13]. That is why, to reduce the rate of the landfills area increase and their negative impact on the environment technological operation of SMW compaction is performed during waste loading into the dump cart [14, 15]. Dewatering of SMW will also reduce the rate of the landfills area growth [16].

Problem set-up

According to the Resolution of the Cabinet of Ministers of Ukraine № 265 the organization of the control over the operating and closed SMW landfills to prevent the harmful impact on the environment and human health is among the priority directions of SMW management in Ukraine [17]. That is why, the determination of the regressional dependence of the level of microbiological pollution with the general colibacilli bacteria of the surface water on the distance to solid municipal waste landfill, which can be used for the determination of the safe distance for SMW landfill locations from the sources of the drinking water by the index of microbiological pollution level with the general colibacilli bacteria of the surface water is an important scientific-engineering problem.

Analysis of the recent research and publications

Predicative mathematical models of the volumes of SMW formation, areas of the landfills and dump sites in Ukraine are presented in the paper [18]. By means of these models it is established that the total area of the landfills and dump sites, as well as those which do not correspond to the norms of ecological safety increases in time approximately exponentially and the area of the overloaded landfills and dump sites both which correspond and do not correspond to the norms of ecological safety increases annually almost linearly. To decrease the rate of the landfills area growth the technological operation of SMW compaction during waste loading in the dump cart is performed [14, 15]. High coefficient of SMW compaction provides more efficient usage of the landfill area [19, 20]. Paper [21] contains the data, regarding the concentration of saprophytic bacteria in 0 – 20 cm layer of the soddy-weak podzolic soil, adjacent to the landfills for SMW burial. In the study [22] the value of sanitary-bacteriological content of SMW is given. In the research [23] potentially-pathogenic and pathogenic types of microorganisms are revealed in the deposited waste, qualitative and quantitative composition of the microorganisms, which destroy the organic substances in SMW at different stages of their life cycle are determined . Authors of the paper [24] present data, regarding the change of the sanitary-bacteriological composition of SMW during the composting. Wider nomenclature of the sanitary-bacteriological composition of SMW in spring is detected in the materials of the paper [9] (colibacilli bacteria, staphylococci, streptococci and ascarids) as a result of the presence of staphylococci and ascarids, absent in SMW during summer composting. In SMW media along with the saprophytic bacteria pathogenic bacteria are developed, they are carriers of various diseases, such as hepatitis, tuberculosis, dysenteria, ascaris infection, respiratory, allergic, skin diseases and others [25]. In [26] by means of Box-Wilson method of multifactorial experiment planning the regressional dependence of the biological processes activity in SMW on the degree of the waste compaction with time, is determined, by means of this dependence it was established that the activity of the biological processes in SMW mostly depends on the waste density and least – on time. In the work [27] regression degree dependences of the diseases occurrence of different types among the adult population of the populated localities, adjacent to the waste treatment sites on the distance to the landfill are determined , these dependences are used for the determination of the safe distance for SMW landfills location from the populated areas by the indices of respiratory organs pathology and blood circulatory system diseases occurrence. In the paper [28] mathematical models of the dependence of the concentration only of saprophytic bacteria in the soil on the distance to the

landfill of SMW burial were constructed, these dependences enabled to determine that with the approaching of the landfill the concentration of the saprophytic aerobic bacteria, needed for biochemical reactions of SMW organic fraction degradation in the places of their burial considerably decreases and self purification of the soil from the foreign organic substances improves . In [29] it is noted that traditionally urban environment solves the problem of waste accumulation at the expense of the rural territories, as a result the problem of the pollution of these territories appears, namely worsening of soil quality, water, air also it is established that SMW landfill can be the reason of worsening the portable water quality and sanitary-hygienic state of the soil at the adjacent rural territories. However, as a result of the analysis of the known publications authors did not reveal specific mathematical dependences of the level of microbiological pollution with general coliforms of the surface water on the distance to SMW landfill.

Aim and task of the paper

Aim of the paper is the construction by means of the regressional analysis the regressional dependence of the level of microbiological pollution with general coliforms of the surface waters on the distance to solid municipal waste landfill, this dependence can be used for the determination of the safe distance to SMW landfill location from the sources of the portable water by the index of the level of microbiological pollution with general coliforms of the surface water.

Methods and materials

For the determination of the regressional dependence of the level of microbiological pollution with general coliforms of the surface waters on the distance to the SMW landfill the following methods are used: regressional analysis of the results of the single factor experiments and other paired dependences, computer simulation.

Results of the research

Table 1 presents the levels of pollution according to the microbiological index – general coliforms of the surface water, obtained in accordance with ДСТУ (State Standard of Ukraine) 5667-1-2003 [29], ДСТУ (State Standard of Ukraine) 5667-2-2003 [30], МВ 10.2.1.1-113-2005 [31], from the distance to Myroniv SMW landfill (town Myronivka, Obukhiv District, Kyiv Region), this type of soil refers to loam soil with the layers of the sandy clay and fine-grained sand with the intended use «disposal of solid municipal waste» [32]. Level of ground water occurrence to the final bottom of the landfill in its upper part is 10 m, in the middle part – 8.5 m, in lower part – 3.62 m. Supply of the water-bearing bed is performed as a result of the infiltration of the atmospheric precipitations. Data are given for general coliforms (GC), determined by the quantity of the colony-forming units (CFU) per 100 cm^3 of the dry mass of the studied material. On the base of the data of the Table 1 it was planned to obtain the paired regression dependence of the level of microbiological bacteriological pollution of the soil on the distance from the SMW landfill.

Table 1

Levels of microbiological pollution with general coliforms of the ground waters of the distance to SMW landfill [32]

Distance from the SMW landfill	700	800	1100	1500
GC, CFU/100 cm^3	291	258	50	0

Regression was carried out on the base of the linearized transformations, which enable to reduce the non-linear dependence to the linear dependence. 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 rights to the copyright object and is described in the work [33].

Program "RegAnaliz" allows to carry out the regression analysis of the results of the single-factor experiments and other paired dependences with the selection of the best type of 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 the Table 2, where the cell with the 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 data from Table 1 the following regression dependence is accepted as the most adequate:

$$\ln(GC) = 5,702 - 8,733 \cdot 10^{-22} x^7 \quad \text{[CFU/100 cm}^3\text{]}; \tag{1}$$

or

$$GC = e^{5,702 - 8,733 \cdot 10^{-22} x^7} \quad \text{[CFU/100 cm}^3\text{]}, \tag{2}$$

where *GC* – general coliforms, CFU/100 cm^3; *x* – distance to SMW landfill, m.

Table 2

Results of the regression analysis of the level of microbiological pollution with general coliforms of the ground water on the distance to SMW landfill

№	Type of regression	Correlation factor R	№	Type of regression	Correlation factor R
1	$y = a + bx$	0.92766	9	$y = ax^b$	0.88661
2	$y = 1 / (a + bx)$	0.75243	10	$y = a + b \cdot \lg x$	0.88661
3	$y = a + b / x$	0.83841	11	$y = a + b \cdot \ln x$	0.88661
4	$y = x / (a + bx)$	0.64041	12	$y = a / (b + x)$	0.75243
5	$y = ab^x$	0.92766	13	$y = ax / (b + x)$	0.61777
6	$y = ae^{bx}$	0.92766	14	$y = ae^{b / x}$	0.77559
7	$y = a \cdot 10^{bx}$	0.92766	15	$y = a \cdot 10^{b / x}$	0.77548
8	$y = 1 / (a + be^{-x})$	0.92766	16	$y = a + bx^n$	0.99996

Fig. 1 shows actual and theoretical graphic dependence of the level of microbiological pollution with general coliforms of the ground waters on the distance to SMW landfill.

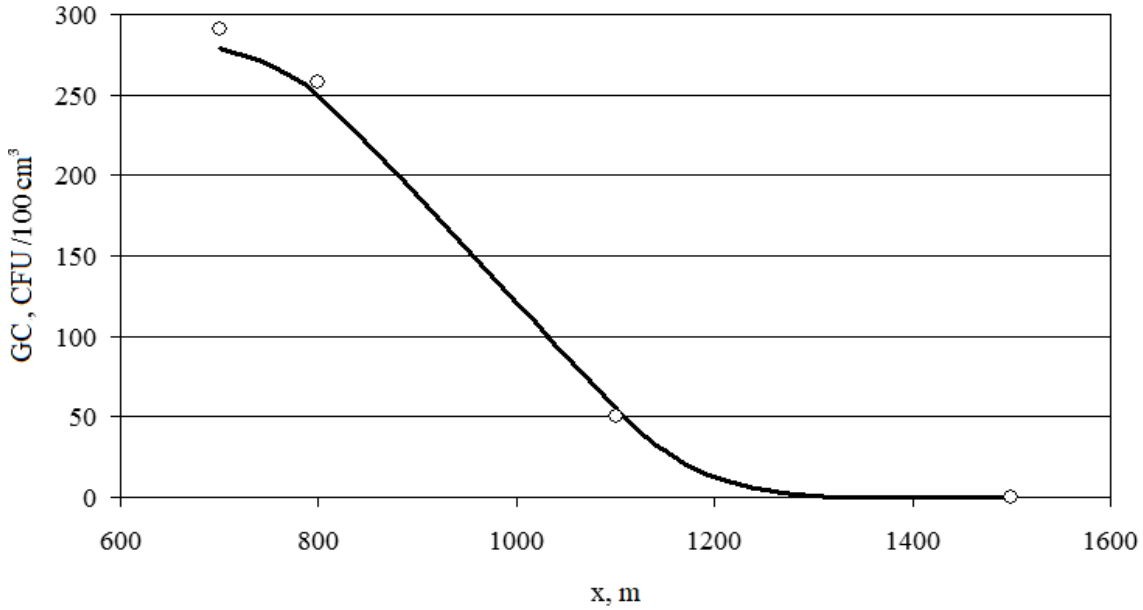

Fig. 1. Change of the level of microbiological pollution with general coliforms of the ground water on the distance to SMW landfill

Comparison of actual and theoretical data showed that theoretical level of the pollution with general coliforms of the ground water on the distance to SMW landfill calculated by means of regression equation (2), does not differ significantly from the data, presented in the study [32], that proves the accuracy determined before of the obtained dependence on the level of 0.99996.

Having substituted the normative value of GC = 1 CFU/100 cm^3 [32] in the regression equation (1), the safe distance for SMW landfill location from the sources of portable water will be determined:

$$x = \sqrt[7]{\frac{5,702 - \ln(GC)}{8,733 \cdot 10^{-22}}} = \sqrt[7]{\frac{5,702 - \ln(1)}{8,733 \cdot 10^{-22}}} \approx 1307\ (m).$$

Conclusions

1. Regression dependence of the level of microbiological pollution with general coliforms of the ground water on the distance to the landfill of solid municipal waste in the town of Myronivka, Obukhiv district, Kyiv Region is determined, it may differ for other landfills, the regression is used for the determination of the safe distance of SMW landfills location from the sources of portable water by the index of the level of microbiological pollution with general coliforms of the ground water.

2. Graphic interpretation of the dependence of the level of microbiological pollution with general coliforms of the ground water on the distance to the landfill of solid municipal waste is constructed, it enables to illustrate this dependence and show the coincidence of the theoretical results with the actual results on the level of 0.99996.

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Editorial office received the paper 10.09.2021.
The paper was reviewed 14.09.2021.

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