SECTION 1. BIOLOGY

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1.1 The levels study of microbiological contamination of groundwater around the landfill of municipal solid waste

Environmental safety and health protection are threatened by municipal solid waste (MSW) [1-3], which is a mixture of components, in contrast to construction waste, which is mostly homogeneous and relatively easily processed [4, 5]. In Ukraine, the annual volume of municipal solid waste generation exceeds 54 million m^3, the main part of which is buried in 6,107 landfills with an area of almost 7,700 hectares and is only partially processed or disposed of at waste incineration plants, in contrast to highly developed countries in which modern technologies have been widely adopted processing and disposal of MSW [6]. During the period 1999-2014, the total area of landfills in Ukraine tripled. The area of overloaded landfills that violate environmental safety standards has almost doubled and more than tripled, threatening environmental pollution (atmosphere, hydrosphere, and lithosphere), in particular due to bacteriological contamination of soils [7] and groundwater with microorganisms (Escherichia coli bacteria, streptococci, staphylococci and roundworms), which are causative agents and carriers of diseases [8-12], adjacent land plots [13], groundwater and sources of drinking water. Due to the passage of biological processes in the layer of MSW, their burial sites are also sources of long-term negative impact on the environment by landfill gas, which contains greenhouse gases and toxic substances [14-20] and highly toxic leachate [21-23], therefore, to reduce the rate of growth of areas landfills and their negative impact on the environment perform the technological operation of MSW compaction during loading into a garbage truck [24, 25]. Dewatering of municipal solid waste will also contribute to the decrease in the rate of growth of landfill areas [26].

According to the Resolution of the Cabinet of Ministers of Ukraine No. 265, the list of priority directions for municipal solid waste management in Ukraine includes ensuring the organization of control over active and closed MSW landfills to prevent harmful effects on the environment and human health [27].

Prognostic mathematical models of the volumes of municipal solid waste generation and the areas of landfills in Ukraine are given in the article [28], with the help of which it was established that the total area of landfills, as well as those that do not meet eco-safety standards, increases over time approximately according to an exponential law, and the area of overloaded landfills, both those that meet and those that do not meet eco-safety standards, grows almost linearly every year. To reduce the rate of growth of landfill areas, a technological operation of municipal solid waste compaction is performed during loading into a garbage truck [24, 25]. More efficient use of the landfill area provides a high municipal solid waste compaction factor [29, 30].

The article [31] provides data on the concentrations of saprophytic bacteria in the 0-20 cm layer of sod-slightly podzolic soil adjacent to municipal solid waste disposal sites. In work [32], the value of the sanitary and bacteriological composition of MSW is given. In the article [33], opportunistic and pathogenic types of microorganisms in deposited waste were identified, the qualitative and quantitative composition of microorganisms that decompose organic substances in MSW at different stages of their life cycle was determined.

Work [34] is devoted to cost modeling of anaerobic decomposition of municipal solid waste. The article [35] considers the possibility of using fertilizers obtained by composting municipal solid waste, the prevalence of which is studied in [36]. The authors of the work [37] provide data on changes in the sanitary and bacteriological composition of MSW during composting. In the materials of the article [13], a wider nomenclature of the sanitary and bacteriological composition of municipal solid waste in spring (Escherichia coli bacteria, streptococci, staphylococci, and roundworms) was revealed due to the presence of staphylococci and ascaris, which were absent in MSW during summer composting. Pathogenic bacteria that are carriers of various diseases, such as hepatitis, tuberculosis, dysentery, ascariasis, respiratory, allergic, skin and other diseases, develop in the MSW environment alongside saprophytic ones [38]. In the article [39], using the Box-Wilson multifactorial experiment planning method, the regression dependence of the activity of biological processes in MSW on the degree of their compaction over time was determined, with the help of which it was established that the activity of biological processes in municipal solid waste depends most on their density, least on time.

In work [40], the regression degree dependences of the prevalence of different classes of diseases in the adult population of settlements adjacent to the place of municipal solid waste removal from the distance to the landfill were determined, which were used to determine the safe distance of placement of MSW landfills from settlements based on the prevalence of respiratory diseases and system diseases blood circulation In the article [41], mathematical models of the dependence of the concentrations of only saprophytic bacteria in the soil on the distance to the MSW disposal site were built, which made it possible to establish that as the landfill approaches, the concentration of saprophytic aerobic bacteria, necessary for the biochemical reactions of the decomposition of the organic fraction of MSW in the places of their disposal, significantly decreases and self-cleaning of the soil from foreign organic substances. In work [42] it is stated that traditionally the urban environment solves the problem of waste accumulation at the expense of rural areas, as a result of which the problem of pollution of the latter arises, namely the deterioration of the quality of soil, water, air, and it is also established that the MSW landfill can be the cause of the deterioration of the quality of drinking water and sanitary-hygienic condition of soils in the surrounding rural areas.

In the table 1 shows the levels of pollution according to the microbiological indicator of total coliforms of groundwater, obtained according to DSTU 5667-1-2003, DSTU 5667-2-2003, MV 10.2.1.1-113-2005, from the distance to the Myronivsky MSW landfill (Myronivka, Obukhivsky District, Kyiv region), the soil type of which refers to loams with layers of sandy loam and fine-grained sands with the purpose of "disposal of municipal solid waste" [42]. The level of groundwater to the design bottom of the landfill reaches 10 m in its upper part, 8.5 m in the middle part, and 3.62 m in the lower part. The aquifer is fed by infiltration of atmospheric precipitation. The data are given for total coliforms (TC), as well as for the total microbial count (TMC), which is an indirect indicator of bacterial water pollution, as it characterizes the total content of microorganisms in water without their qualitative characteristics and is determined by the number of colony-forming units (CFU) per unit of volume of the dry weight of the material under study. Based on the data in the table. 1, it was planned to obtain paired regression dependences of the levels of microbiological bacteriological soil contamination on the distance to the landfill site.

Table 1

Levels of microbiological contamination of groundwater depending on the distance to the municipal solid waste landfill [42]

Distance to the MSW landfill, m	700	800	1100	1500
TC, CFU/100cm^3	291	258	50	0
TMC, CFU/cm^3	720	743	156	87

The regression was carried out on the basis of linearizing transformations, which allow to reduce the non-linear dependence to a linear one. The coefficients of the regression equations were determined by the method of least squares using the developed computer program "RegAnalyz", which is protected by a certificate of copyright registration for the work [43], and is described in detail in the works [44, 45].

The "RegAnalyz" program allows you to carry out regression analysis of the results of univariate experiments and other pairwise dependencies with the selection of the best type of function from the 16 most common options according to the criterion of the maximum correlation coefficient with saving the results in MS Excel and Bitmap format.

The results of the regression analysis are shown in Table 2, where the cells with the maximum values of the correlation coefficients R for each of the functions are marked in gray.

So, according to the results of the regression analysis based on the data in the table 1, the following regression dependencies [46, 47] were finally accepted as the most adequate:

$$\ln(TC) = 5.702 - 8.733 \cdot 10^{-22} x^7 \quad [\text{CFU}/100\text{cm}^3]; \tag{1}$$

or

$$TC = e^{5.702 - 8.733 \cdot 10^{-22} x^7} \quad [\text{CFU}/100\text{cm}^3], \tag{2}$$

$$TMC = \frac{1}{1.338 \cdot 10^{-5} x - 0.008559} \quad [\text{CFU}/\text{cm}^3], \tag{3}$$

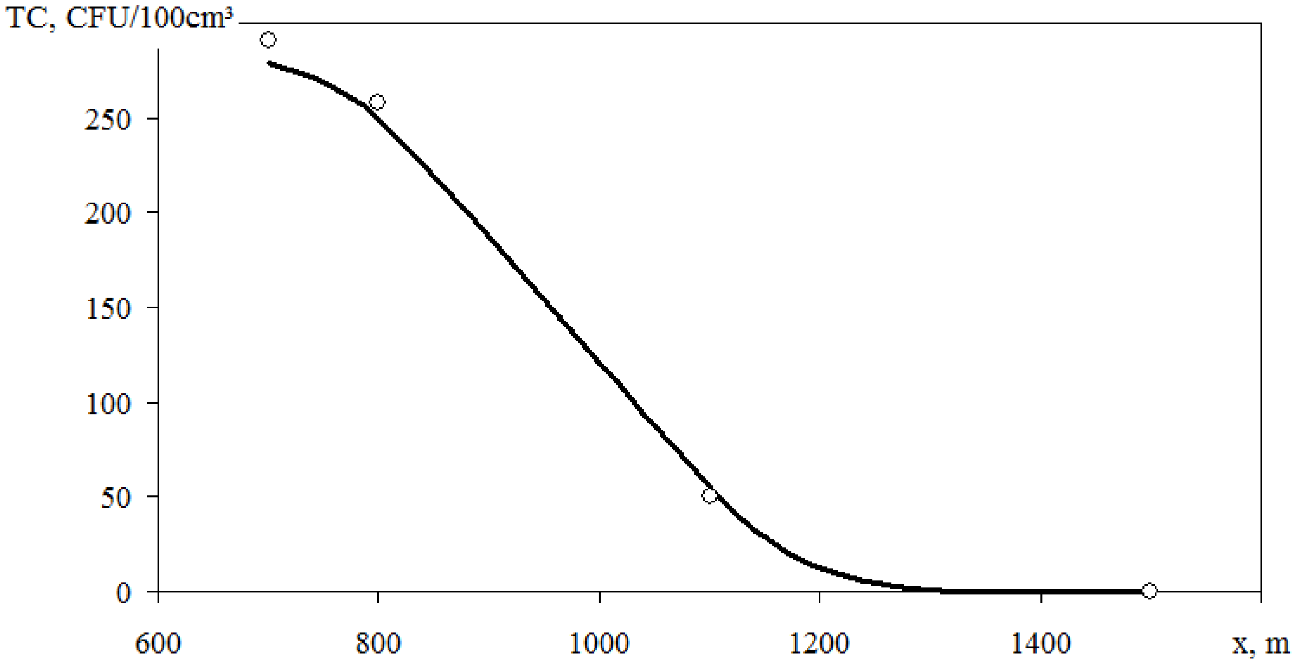
where *TC* – total coliforms, CFU/100cm^3; *TMC* – total microbial count, CFU/cm^3; *x* – distance to the landfill site, m.

Table 2

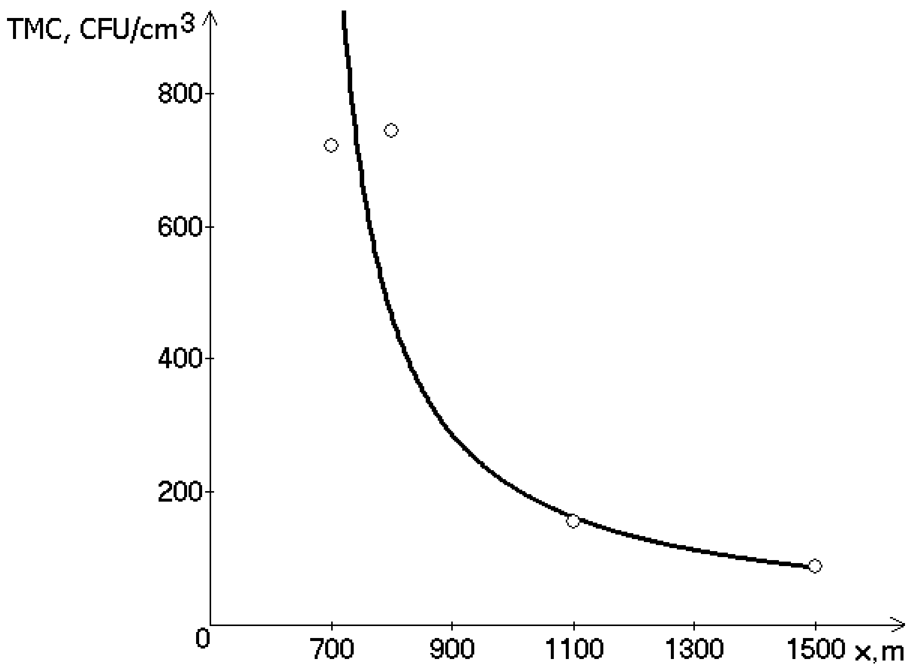
Results of the regression analysis of the level of microbiological contamination of groundwater from the distance to the municipal solid waste landfill

No	Type of regression	Correlation coefficient R		No	Type of regression	Correlation coefficient R	
		TC = *f*(*x*)	*TMC* = *f*(*x*)			*TC* = *f*(*x*)	*TMC* = *f*(*x*)
1	y = a + bx	0.92766	0.91361	9	$y = ax^b$	0.88661	0.97186
2	y = 1 / (a + bx)	0.75243	0.99259	10	y = a + b·lg x	0.88661	0.93677
3	y = a + b / x	0.83841	0.94702	11	y = a + b·ln x	0.88661	0.93677
4	y = x / (a + bx)	0.64041	0.98919	12	y = a / (b + x)	0.75243	0.99258
5	$y = ab^x$	0.92766	0.96027	13	y = ax / (b + x)	0.61777	0.96641
6	$y = ae^{bx}$	0.92766	0.96027	14	$y = ae^{b/x}$	0.77559	0.97118
7	$y = a \cdot 10^{bx}$	0.92766	0.96027	15	$y = a \cdot 10^{b/x}$	0.77548	0.97118
8	$y = 1 / (a + be^{-x})$	0.92766	0.96027	16	$y = a + bx^n$	0.99996	0.88052

In fig. 1 shows the actual and theoretical graphical dependences of the levels of microbiological contamination by total coliforms and the total microbial count of groundwater on the distance to the landfill site.



a)



b)

Figure 1. Change in the level of microbiological contamination of groundwater depending on the distance to the municipal solid waste landfill: a) total coliforms; b) by the total microbial count

A comparison of actual and theoretical data showed that the theoretical levels of contamination by total coliforms and by the total microbial count of groundwater from the distance to the landfill site, calculated using regression equations (2) and (3), do not significantly differ from the data given in the work [43], which confirms the previously determined accuracy of the obtained dependencies at the level of 0.99996 and 0.99259, respectively.

By substituting the normative value of *TC* = 1 CFU/100cm^3 [43] into the regression equation (2), we determine the safe distance of landfill sites from sources of drinking water based on the indicator of contamination with total coliforms

$$x_{TC} = \sqrt[7]{\frac{5.702 - \ln(TC)}{8.733 \cdot 10^{-22}}} = \sqrt[7]{\frac{5.702 - \ln 1}{8.733 \cdot 10^{-22}}} \approx 1307 \text{ (m)}.$$

By substituting the normative value of *TMC* = 100 CFU/cm^3 [43] into the regression equation (3), we determine the safe distance of placement of MSW landfills from sources of drinking water based on the total microbial count

$$x_{TMC} = \frac{74738}{TMC} + 639.7 = \frac{74738}{100} + 639.7 \approx 1387 \text{ (m)}.$$

Based on the obtained values, we will determine the safe distance of landfill sites from drinking water sources based on the indicator of the level of microbiological contamination of groundwater

$$x = \max(x_{TC}, x_{TMC}) = \max(1307, 1387) = 1387 \text{ (m)}.$$

So, the regression dependences of the levels of microbiological contamination by total coliforms and the total microbial count of groundwater on the distance to the municipal solid waste landfill were determined, which were used to determine the safe distance of placement of solid waste landfills from sources of drinking water based on the indicator of the level of microbiological contamination of groundwater.