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IMPACT OF THE PROXIMITY TO THE LANDFILL OF MUNICIPAL SOLID WASTE ON THE LEVEL OF MICROBIOLOGICAL CONTAMINATION OF THE UNDERGROUND WATERS BY THE TOTAL MICROBIOLOGICAL COUNT (TMC)

In recent years the total area of municipal solid waste landfills and dumps, including the overloaded, which violate the norms of ecological safety and are the objects of the intensive ecological loading has grown. These landfills may cause the pollution of the environment with microorganisms (colibacilli bacteria, streptococci, staphylococci and ascarids) including bacteriological contamination of the soil and underground waters. Determination of the regression dependence of the level of microbiological contamination of the underground waters according to total microbiological count on the distance to the landfill of municipal solid waste is an important scientific-technical problem. Objective of the research is the determination of the regression dependence of the level of the microbiological contamination of the underground waters according to total microbial count on the distance to the landfill of municipal solid waste. In the process of the investigation 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 function from the sixteen most widely used options by the criterion of maximum value of the correlation factor was used. Regression was performed on the base of the linearizing transformations, which enable to reduce non-linear dependence to linear one. Determination of the coefficients of the regression equations was carried out, using the methods 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 contamination of the underground waters, according to the total microbial count of the ground waters on the distance to the landfill of municipal solid waste was obtained, the given regression is used for the determination of the safe distance of MSW landfill location from the sources of the portable water according to the level of microbiological contamination of the ground waters by the total microbic count. Graphic interpretation of the dependence of the microbiological contamination level of the underground waters according to the total microbial count on the distance to the landfill of municipal solid 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 0.99259. It was established that the safe distance for the location of municipal solid waste landfills from the sources of the portable water according to the level of microbiological contamination of the underground waters by total microbial count is 1387 m.

Key words: *landfill, dump, municipal solid waste, microbiological contamination, underground waters, total microbial count, regression analysis.*

Introduction

Municipal solid waste (MSW) pose threat to the safety of the environment and health of the population [1, 2], they are the mixture of the components, unlike the construction or industrial waste [5], which are generally homogeneous and can easily be recycled. Volume of MSW, formed on the territory of Ukraine annually exceeds 54 mil. m^3, greater part of this volume is buried on 6107 landfills and dumps, surface of which is almost 7700 ha and only minor part is 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 [5]. In the period of 1999 – 2014 the total area of the landfills and dumps in Ukraine increased three times and the area of the landfills and dumps where the norms of ecological safety are violated, threatening with the pollution of the environment (atmosphere, hydrosphere, and lithosphere), in particular, due to bacteriological contamination of the soil and ground waters with microorganisms (colibacilli bacteria, streptococci, staphylococci and ascarids) which are pathogenic organisms and transmitters of the diseases [9 – 11], of the

adjacent agricultural plots [12 – 14], ground waters and sources of the potable water. As a result of the biological processes, occurring in the depth of MSW the locations of the waste disposal are also the sources of long-lasting negative impact on the environment with the landfill gas, it contains green house gases and toxic substances [15] and with high toxic filtrate [16 – 18], that is why, to reduce the rate of the landfills area growth and limit the negative impact on the environment the technological operation of MSW compaction is performed in the process of the waste loading into the dust-cart [19, 20]. Dewatering of MSW [21, 22] will also promote the decrease of the landfills area growth.

Problem set-up

According to the Decree of the Cabinet of Ministers of Ukraine № 265 the list of priority directions in the sphere of MSW management in Ukraine contains the point dealing with the provision of the organization of control over the closed MSW landfills to prevent adverse impact on the environment and health of people [23]. That is why, the determination of the regression dependence of the level of microbiological contamination of the ground waters by total microbial count on the distance to the landfill of municipal solid waste, which can be used for the determination of the safe distance for the location of MSW landfills from the sources of the potable water according to the index of the level of the ground waters pollution by the total microbial count is urgent scientific-technical problem.

Analysis of the recent research and publications

Materials of the paper [24] contain predictive mathematical models of the MSW volumes formation , areas of the landfills and dump in Ukraine by means of these models it has been established that the total area of the landfills and dumps as well as those landfills and dumps that do not correspond to the norms of ecological safety increases exponentially, whereas the area of the overloaded landfills and dumps both those that correspond and those that do not correspond to the norms of ecological safety, annually increases almost linearly. To reduce the rate of landfills area growth technological operation of MSW compaction is performed in the process of waste loading in the dust-cart [19, 20]. High compaction coefficient of MSW provides more efficient usage of the landfill area [25, 26].

Paper [27] contains data, regarding the concentration of saprophytic bacteria in 0 – 20 cm layer of the soddy weak-podzolic soil, adjacent to the landfills of MSW disposal. Value of the sanitary-bacteriological composition of MSW is published in the study [28]. In the research [29] potentially-pathogenic and pathogenic types of microorganisms are detected in the depositing waste, qualitative and quantitative composition of the microorganisms, decomposing the organic substances in MSW at different stages of their life cycle, is determined. Authors of the paper [30] present data concerning the change of the sanitary-bacteriological composition of MSW during composting. Wider list of the sanitary-bacteriological composition of MSW was revealed in spring as a result of the research, performed in [12] (colibacilli bacteria, streptococci, staphylococci and ascarids) due to the presence of staphylococci and ascarids, absent in MSW during summer composting. In MSW environment along with saprophytic bacteria pathogenic bacteria are developing, they are transmitters of various diseases such as hepatitis, tuberculosis, dysentery, ascariasis, respiratory, allergic, skin and other diseases [31]. In the study [32] by means of Box-Wilson method of multifactorial experiment planning the regression dependence of the activity of biological processes in MSW on the degree of their compression in the course of time was determined, with the help of this dependence it was established that most of all the activity of biological processes in MSW depends on their density and least – on time.

Authors of the research [33] determined the regression power dependences of various classes of the diseases spreading among the adult population of the settlements, adjacent to the locations of MSW disposal on the distance to the landfill, these dependences are used for the determination of the

safe distance of the MSW landfills location from the settlements by the indices of pathology of the respiratory organs and diseases of blood circulation system spreading. In the article [34] mathematical models of only saprophytic bacteria concentration in the soil on the distance to the MSW landfill disposal have been constructed, these models enabled to determine that the concentration of saprophytic anaerobic bacteria, needed for the biochemical reactions of the decomposition of the organic function of MSW considerably decreases in the location of their disposal and self-cleaning of the soil from foreign organic substances.

It is noted in the paper [35] that the conventional urban environment solves the problem of waste accumulation at the expense of rural territories, namely, worsening of the quality of soil, water, air, also it was established, that the landfill of MSW may be the reason of worsening the quality of potable water and sanitary-hygienic state of soil at the adjacent agricultural territories, level of pollution according to microbiological indices, in particular, total microbial count, at various distances to Myroniv landfill of MSW (town Myronivka, Obukhiv District, Kyiv Region) are presented. Study [36] is directed at distinguishing natural, and anthropogenic impacts by means of synoptical analysis of hydro-geochemical, isotopic and microbiological characteristics of the underground water from the urban landfill of municipal solid waste in Central Italy. However, the authors did not reveal specific mathematic dependences of the level of microbiological contamination of the underground waters according to the total microbial count on the distance to the landfill of MSW as a result of the analysis of the known publications.

Objectives and tasks of the paper

Objective of the paper is the construction, by means of the regression analysis, the regression dependence of the level of microbiological contamination of the underground waters according to the total microbial count on the distance to the landfill of municipal solid waste, the regression can be used for the determination of the safe distance for MSW landfills location from the sources of the potable water by the index of the level of microbiological contamination of the underground waters according to the total microbial count.

Methods and materials

In the process of determining the regression dependence of the level of microbiological contamination of the underground waters according to the total microbial count on the distance to MSW landfill the following methods are used: regression analysis, results of multifactor experiments and other paired dependences, computer simulation.

Results of the research

Levels of contamination, according to microbiological index – total microbial count, are presented in the study [35], they are obtained according to DSTU 5667-1-2003 [37], DSTU 5667-2-2003 [38], MG 10.2.1.1-113-2005 [39] depending on the distance to Myronivskyi MSW landfill (town of Myronivka, Obukhiv District, Kyiv region), type of soil of this landfill refers to loam soil with a layer of loamy sand and fine-grained sand with the designated purpose “disposal of municipal solid waste”[35]. Level depth of the underground waters to the final bottom of the landfill in its upper part is 10 m, in the middle part – 8.5 m and in the lower part – 3.62 m. Supply of the water-bearing bed is realized as a result of the precipitation leaking. Total microbial count (TMC) is indirect index of the bacterial contamination of water as it characterizes the total content of the microorganisms in the water without their qualitative characteristic and is determined by the number of colony-forming units (CFU) per 1 cm^3 of dry mass of the studied material. Proceeding from the data of the article [35] it was planned to obtain paired regression dependence of the level of microbiological contamination of the underground waters according to the total microbial count on the distance to the landfill of MSW.

Regression was carried out on the base of the linearized transformations that enabled to reduce non-linear dependence to linear one. Determination of the coefficients of the regression equations was performed, applying the methods of the least squares [40] with the help of the developed computer program "RegAnaliz", protected by the Certificate of the state registration of the rights to the copyright object.

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

Results of the regression analysis are presented in Table 1, grey color indicates the cells with the type of regression with maximum value of the correlation coefficient *R*.

Thus, by the results of the regression analysis on the base of the data from the study [35], as the most adequate the following dependence is accepted:

$$TMC = \frac{1}{1{,}338 \cdot 10^{-5} x - 0{,}008559} \text{ [CFU/cm}^3\text{]}, \quad (1)$$

where *TMC* – is total microbial count, CFU/cm^3; *x* – is the distance to the MSW landfill, m.

Table 1

Results of regression analysis of the level of microbiological contamination of the underground waters according to the total microbial count depending on the distance to MSW landfill

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0.91361	9	$y = ax^b$	0.97186
2	$y = 1 / (a + bx)$	0.99259	10	$y = a + b \cdot \lg x$	0.93677
3	$y = a + b / x$	0.94702	11	$y = a + b \cdot \ln x$	0.93677
4	$y = x / (a + bx)$	0.98919	12	$y = a / (b + x)$	0.99259
5	$y = ab^x$	0.96027	13	$y = ax / (b + x)$	0.96641
6	$y = ae^{bx}$	0.96027	14	$y = ae^{b / x}$	0.97118
7	$y = a \cdot 10^{bx}$	0.96027	15	$y = a \cdot 10^{b / x}$	0.97118
8	$y = 1 / (a + be^{-x})$	0.96027	16	$y = a + bx^n$	0.88052

Fig. 1 shows actual and theoretical graphic dependence of the level of microbiological contamination of the underground water according to the total microbic count on the distance to MSW landfill.

Comparison of the actual and theoretical data showed that the theoretical level of the contamination of the underground waters according to the total microbial count from the distance to the landfill of MSW, calculated by means of the regression equation (1) does not differ substantially from the data, presented in research [35], this fact proves the accuracy of the obtained dependence on the level of 0.99259.

Having substituted the normative value of *TMC* = 100 CFU/cm^3 [31] in the regression equation (1), the safe distance for the location of MSW landfills from the sources of potable water according to the total microbial count will be determined

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

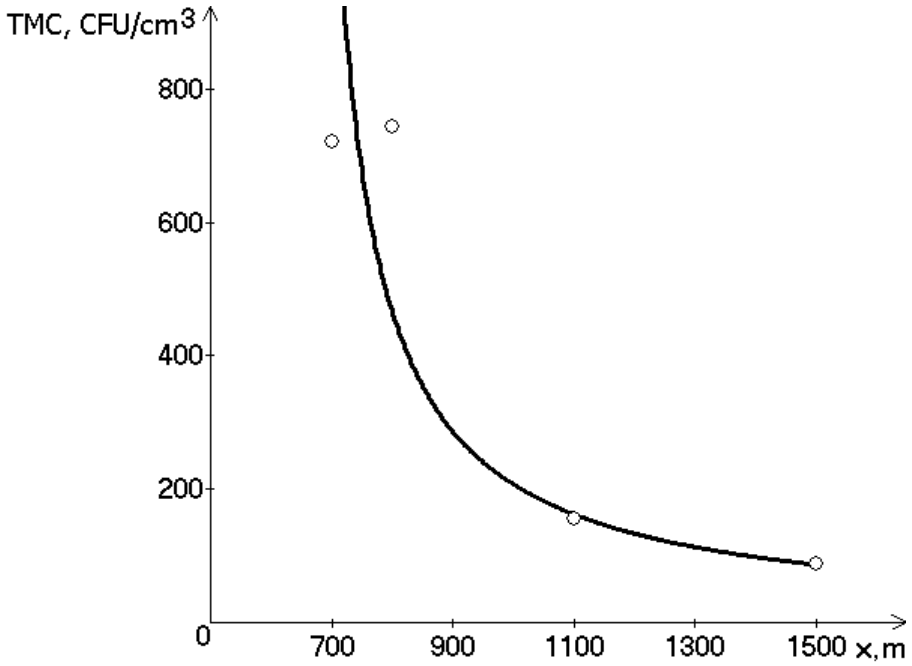

Fig. 1. Change of the level of microbiological contamination of the underground waters according to the total microbiological count on the distance to MSW landfill.

Conclusions

1. Regression dependence of the level of microbiological contamination of the underground waters according to the total microbial count on the distance to the landfill of municipal solid waste in the town of Myronivka, Obukhiv District, Kyiv Region, has been determined, it can differ for other landfills, the dependence is used for the determination of the safe distance for the location of MSW landfills from the sources of potable water according to the index of the level of microbiological contamination of the underground waters according to the total microbial count.

2. Graphic interpretation of the dependence of the level of microbiological contamination of the underground waters according to the total microbial count on the distance to the landfill of municipal solid waste has been constructed, it enables to illustrate the given dependence and show the coincidence of the theoretical results with actual on the level of 0.99259.

3. It is established that the safe distance for the location of MSW landfills from the sources of potable water according the index of the level of microbiological contamination of the underground waters by the total microbial count is 1387 m.

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