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USAGE OF REGRESSION ANALYSIS METHOD FOR THE DETERMINATION OF BENZOPYRENE CONCENTRATION IN THE SOILS OF THE LANDFILLS AND REFUSE DUMPS OF SOLID MUNICIPL WASTE

In recent years the total area of the landfills and refuse dumps of solid municipal waste, including overloaded facilities and those, where the norms of ecological legislation are violated and are the objects of the intensive ecological loading has greatly increased in Ukraine. This may cause the pollution of the environment by chemical substances and leads to chemical pollution of the soil. Determination of the regression dependence of benzopyrene concentration in the soils of the landfills of solid municipal waste on the depth of measuring is an important scientific engineering problem.

Aim of the research is to determine the regression dependence of benzopyrene concentration in the soils of the landfills of solid municipal waste on the depth of measuring. In the process of study the method of 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 the maximum value of the correlation factor was used.

Regression was carried out on the base of linearized transformations, which enable to reduce the non-linear dependence to linear one. Determination of the coefficients of the regression equations was carried out by means of the least squares method, using the developed computer program "RegAnaliz", protected by the Certificate of the state registration of the rights to the copyright object.

Adequate regression power dependence of benzopyrene concentration in the soils of the landfills of solid municipal waste on the depth of measuring was obtained, the dependence was used for the determination of the dangerous depth of chemical pollution of the soils. Graphic interpretation of the dependence of benzopyrene concentration in the soils of the landfill of solid municipal waste on the depth of measuring 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 0.96975. It was established that the dangerous depth of chemical pollution of the soils of the landfill of solid municipal waste with benzopyrene is 152 mm.

Key words: *refuse dump, landfill, solid municipal waste, chemical contamination, concentration, benzopyrene, soil, regression analysis.*

Introduction

Solid municipal waste (SMW) [1, 2] represent great danger for the environment and human health , solid municipal waste is a mixture of the components, unlike the construction waste, which are generally homogeneous and can easily be recycled [3, 4]. Volume of SMW, formed on the territory of our country, 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 SMW are widely used [5]. During 1999 - 2014 the total area of the landfills and refuse 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 dumpsites where 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, promoting the spreading diseases of living organisms [6], pollution of the adjacent land plots [7], including agricultural land, increased three times. That is why, to reduce the growth rates of the landfills and refuse dumps area and their adverse impact on the environment the technological operation of SMW compaction during waste loading into the dust-cart is performed

[8, 9]. Dehydration of SMW will also help to reduce the growth rate of landfills area [10].

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 SMW to avoid adverse impact on the environment and human health is among the priority directions of SMW management in Ukraine [11]. That is why, the determination of the regression dependence of benzopyrene concentration in the soils of the landfills of solid municipal waste on the depth of measuring, which can be used for the determination of the dangerous depth of chemical contamination of the soil, is an important scientific and technical task.

Analysis of the recent studies and publications

The paper [12] suggests for the consideration mathematical models for the forecasting the volumes of SMW formation and areas of the landfills and dump sites in Ukraine, by means of these models it is established that the total area of the landfills and refuse dumps as well as the area of the landfills that do not correspond to the norms of ecological safety increases in time approximately by exponential law and the area of the overloaded landfills and dumps both which correspond and do not correspond to the norms of ecological safety annually increases almost linearly. In order to decrease the growth rate of landfills technological operation for SMW compaction during loading into the dust-cart is carried out [8, 9]. High compaction coefficient of SMW provides more efficient usage of the landfill area [13, 14].

The papers [15 – 18] note the significant contamination of the soils with heavy metals as a result of SMW burial. Paper [19] contains data, regarding the impact of heavy metals on microbiota of soddy-weak podzolic soil. In the paper [20] it is noted that the most toxic substance (among the pollution substances of the first class of danger) is the representative of the class of polycyclic aromatic carbonhydrates – benzopyrene,which even in nanoquantity negatively influences the living organisms as cancerogen and mutagen.

Authors of the paper [21] suggested the survey of the most widely-spread methods of the remediation of heavy metals in the soil. In [22] data, regarding specific energy consumption for the reduction of the concentration by means of the method of electric chemical remediation of such heavy metals in the soil of the SMW landfills as cadmium, lead and zink. This method is based on the application of electric current for the separation of the corresponding polluting substances. Applying the remediation method the soils can be renovated directly on the surface without extraction into special tanks, this makes the process less energy-consuming. In the paper [23] the regression dependence of the specific energy requirements for cleaning the soils of SMW landfills as a result of heavy metals pollution (cadmium, lead and zink) on their concentration and MAC are determined. In the research [24] the improved mathematical model in the form of the dependence of the specific energy consumption needed for the soils of SMW landfills cleaning due to heavy metals pollution on the concentration of cobalt, copper, nickel, chrome, vanadium, manganese is published, this model enables to evaluate energy consumption, needed for the cleaning of the polluted soils from these substances.

It is noted in the study [25] that conventionally urban environment solves the problem of the waste products accumulation at the expense of rural territories, as a result, there appears the problem of pollution of these territories, namely, worsening of soils, water, air quality. Also it was established that the landfill of SMW may be the cause of worsening the quality of tap water and sanitary-hygienic state of soils on the adjacent rural territories. The paper [26] contains chemical characteristic of soils of the territory of SMW landfill in the city of Mykolaiv. However, as a result of the analysis of the known publications the author did determine any specific mathematical dependences of the concentration of benzopyrene concentration in the soils of SMW landfills on the depth of measuring.

Aim and tasks of the research

Aim of the given research is to use the method of regression analysis for the determination of benzopyrene concentration in the soils of solid municipal waste landfills, that can be used for the determination of the dangerous depth of chemical contamination of the soils.

Methods and materials

For the determination of the regression dependence of the benzopyrene concentration in the soils of SMW landfills on the depth of measuring the following methods were used: regression analysis of the results of single-factor experiments and other pair dependences, computer modeling.

Results of the research

Table 1 shows concentrations of benzopyrene in the soils of Mykolaiv landfill of SMW (village Velyka Korenykha, Mykolaiv Region) [26], obtained by means of the method of high-efficient liquid chromatography and supplemented with the results of research [20]. On the base of the data from the Table 1 it was planned to obtain pair regression dependence of benzopyrene concentration in the soils of SMW landfills on the depth of measuring.

Table 1

Concentration of benzopyrene in the soils of SMW landfill [26, 20]

Depth of measuring, cm	2,5	12,5	60	150
Concentration of benzopyrene $C_{20}H_{12}$ in the soil, mg/kg	0.05645	0.03246	0.0059	0.005
Literature source	[20]	[20]	[26]	[26]

Regression was performed on the base of the linearized transformations, enabling to reduce the nonlinear dependence to linear one. Determination of the regression equations coefficients was performed by means of the method of the least squares [27], using the developed computer program "RegAnaliz" [28], the program is protected by the Certificate of State Registration of the rights to the copyright object and described in [29].

Program "RegAnaliz" enables to perform the regression analysis of the results of the 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 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 coefficient R is marked with grey color.

Table 2

Results of the regression analysis of the dependence of the benzopyrene concentration in the soils of SMW landfill on the depth of measuring

№	Type of the regression	Correlation coefficient R	№	Type of the regression	Correlation coefficient R
1	$y = a + bx$	0.79876	9	$y = ax^b$	0.96975
2	$y = 1 / (a + bx)$	0.90309	10	$y = a + b \cdot \lg x$	0.96081
3	$y = a + b / x$	0.93210	11	$y = a + b \cdot \ln x$	0.96081
4	$y = x / (a + bx)$	0.96806	12	$y = a / (b + x)$	0.90309
5	$y = ab^x$	0.86158	13	$y = ax / (b + x)$	0.74575
6	$y = ae^{bx}$	0.86158	14	$y = ae^{b/x}$	0,.82869
7	$y = a \cdot 10^{bx}$	0.86158	15	$y = a \cdot 10^{b/x}$	0.82869
8	$y = 1 / (a + be^{-x})$	0.61791	16	$y = a + bx^n$	0.65155

Thus, based on the results of the regression analysis on the base of the data of the Table 1, the

following regression dependence is accepted as the most adequate:

$$C_{C_{20}H_{12}} = 0{,}1187 h^{-0{,}6542} \quad \text{[mg/kg]}, \tag{1}$$

where $C_{C_{20}H_{12}}$ –is the concentration of benzopyrene $C_{20}H_{12}$ in the soil, mg/kg; h – is the depth of measuring, cm.

Fig. 1 shows the actual and theoretical graphic dependences of benzopyrene concentration in the soils of SMW landfill on the depth of measuring.
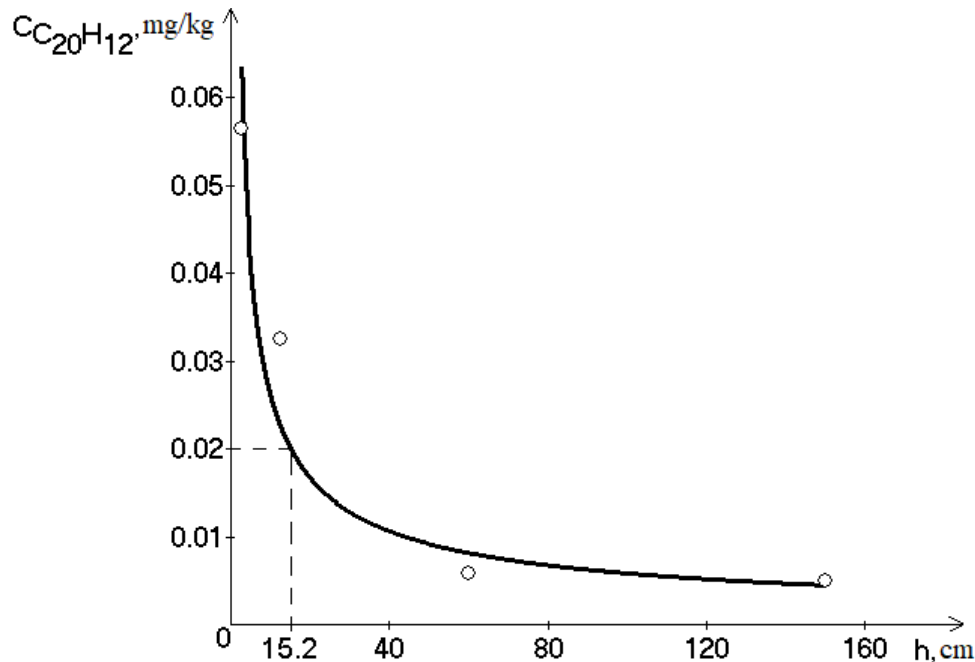

Fig. 1. Change of benzopyrene concentration in the soils of SMW landfill on the depth of measuring

Comparison of the actual and theoretical data showed that the theoretical concentrations of benzopyrene in the soils of SMW landfill, depending on the depth of measuring, calculated by means of regression equation (1), do not significantly differ from the data, presented in the study [26], this fact proves the accuracy, determined before, of the obtained dependence on the level of 0.96975.

Having substituted the value of the maximum admissible concentration of benzopyrene in the soil MAC= 0.02 mg/kg [26] in the regression equation (1) the dangerous depth of chemical contamination of the soils will be determined.

$$h = \left(\frac{C_{C_{20}H_{12}}}{0{,}1187}\right)^{\frac{1}{0{,}6542}} = \left(\frac{0{,}02}{0{,}1187}\right)^{\frac{1}{0{,}6542}} \approx 15{,}2 \text{ (cm)} = 152 \text{ (mm)}.$$

Conclusions

1. Method of regression analysis is used for the determination of benzopyrene concentration in the soils of solid municipal waste landfills, the dependence is used for the determination of the dangerous depth of chemical pollution of the soil.

2. Graphic change of benzopyrene concentration in the soil of the solid municipal waste landfill is constructed, it enables to illustrate visually this regression dependence and show the coincidence of the theoretical results with actual results on the level of 0.96975.

3. It is determined that the dangerous depth of chemical contamination of the soils of solid municipal waste landfill with benzopyrene is 152 mm.

REFERENCES

1. Sagdeeva O. A. Assesment of the level of ecological danger of solid municipal waste refuse dumps / O. A. Sagdeeva, G. V. Krusir, A. L. Tsikalo // Ecological safety. – 2018. – № 1. – P. 75 – 83. (Ukr).

2. Hamer G. Solid waste treatment and disposal : effects on public health and environmental safety / G. Hamer // Biotechnology advances. – 2003. – Vol. 22, № 1 – 2. – P. 71 – 79. – https://doi.org/10.1016/j.biotechadv.2003.08.007.

3. Kovalskyi V. P. Usage of fly ash of electric stations in construction materials / V. P. Kovalskyi, O. S. Sidlak // Modern technologies, materials and structures in construction industry : scientific-engineering collection. – Vinnytsia : UNIVERSUM-Vinnytsia, 2014. – № 1 (16). – P. 35 – 40. (Ukr).

4. Lemeshev M. S. Resource-saving technology of the construction materials production, using technogenic waste / M. S. Lemeshev, O. V. Krystych, S. Yu. Zuziak // Modern technologies materials and structures in construction industry : scientific technical collection. – 2018. – № 1. – P. 18 – 23. (Ukr).

5. Moroz O. V. Economic aspects of the ecological problems solution of solid household waste disposal : monograph / O. V. Moroz, A. O. Sventukh, O. T. Sventukh. – Vinnytsia : UNIVERSUM-Vinnytsia, 2003. – 110 p. (Ukr).

6. Piskun R. P. Functional morphology of the brain in case of atherosclerosis in the experiment and under the impact of vinpocetine / R. P. Piskun, S. M. Gorbatiuk // Tavria Medical-Biological Bulletin. – 2006. – V. 9, № 3. – P. 100 – 113. (Ukr).

7. Bereziuk O. V. Modeling of the dynamics of the sanitary-bacteriological composition of solid municipal waste during summer composting / O. V. Bereziuk, S. M. Horbariuk, L. L. Bereziuk // Bulletin of Vinnytsia Polytechnic Institute. – 2013. – № 4. – P. 17 – 20.(Ukr).

8. Bereziuk O. V. Ways of improving the efficiency of solid municipal waste pressing in the dust-carts / O. V. Bereziuk // Modern technology, materials and structures in construction industry : scientific-technical collection. – Vinnytsia: UNIVERSUM-Vinnytsia, 2009. – № 1 (6). – P. 111 – 114. (Ukr).

9. Bereziuk O. V. Structure of the machines for the collection and primary recycling of solid municipal waste / O. V. Bereziuk // Bulletin of machine-building and transport. – 2015. – № 2. – P. 3 – 7. (Ukr).

10. Bereziuk O. V. Experimental study of solid municipal waste dehydration process by means of the worm press / O. V. Bereziuk // Bulletin of Vinnytsia Polytechnic Institute. – 2018. – № 5. – P. 18 – 24. (Ukr).

11. Cabinet of Ministers of Ukraine. Decree № 265 "On the approval of the Program of solid household waste management" [Electronic resource] March 4, 2004. Access mode : http://zakon1.rada.gov.ua/laws/show/265-2004-%D0%BF. (Ukr).

12. Bereziuk O. V. Mathematical modeling of the forecast of the volume of solid domestic waste formation and landfills areas in Ukraine / O. V. Bereziuk // Modern technologies, materials and structures in construction industry : Scientific-engineering digest. – Vinnytsia: UNIVERSUM-Vinnytsia, 2009. – № 2. – P. 88 – 91. (Ukr).

13. Bereziuk O. V. Dehydration and compaction drive of solid municipal waste in the dust-cart / O. V. Bereziuk // Bulletin of machine-building and transport. – 2016. – № 2. – P. 14 – 18. (Ukr).

14. Popovych V. V. Efficiency of the dusk-carts operation in the environment "city-landfill" / V. V. Popovych, O. V. Prydatko, M. I. Sychevskyi // Bulletin of National Forest Engineering University of Ukraine(NFEUU) . – 2017. – Vol. 27, № 10. – P. 111 – 116. (Ukr).

15. Impact Assessment of Contamination Pattern of Solid Waste Dumpsites Soil: A Comparative Study of Bauchi Metropolis / D. S. Buteh, I. Y. Chindo, E. O. Ekanem [et al.] // World Journal of Analytical Chemistry. – 2013. – Vol. 1, № 4. – P. 59 – 62.

16. Chao Su. A review on heavy metal contamination in the soil worldwide: Situation, impact and remediation techniques / Chao Su, LiQin Jiang, WenJun Zhang // Environmental Skeptics and Critics. – 2014. – № 3 (2). – P. 24 - 38.

17. Heavy metal distribution in soil and plant in municipal solid waste compost amended plots / F. Ayari, H. Hamdi, N. Jedidi [et al.] // Int. J. Environ. Sci. Tech. – 2010. – № 7 (3). – P. 465 – 472.

18. Tripathi A. A study of physico-chemical properties and heavy metals in contaminated soils of municipal waste dumpsites at Allahabad India / A. Tripathi, D. R. Misra // International Journal Of Environmental Sciences. – 2012. – Vol. 2, № 4. – P. 1 – 10.

19. Grynchyshyn N. M. Impact of the heavy metals on microbiocenosis of soddy-weak podzolic soil / N. M. Grynchyshyn, T. M. Lozovytska // Scientific Bulletin of Lviv S. Z. Gzhytsky National University of Veterinary Medicine and Biological Technologies. – 2009. – V. 11, № 2 (41), P. 4. – P. 54 – 57. (Ukr).

20. Gorobtsova O. N. Role of soil covering in accumulation and migration of polycycle aromatic carbonates in case of technogenic pollution / O. N. Gorobtsova, O. G. Nazarenko, T. M. Minkina, N. I. Borisenko, A. V. Jarotchuk // Bulletin of higher education establishments of North-Caucasian Region. Natural Sciences. – 2005. – № 1. – P. 73 – 79. (Rus).

21. Nanda S. Remediation of heavy metal contaminated soil / S. Nanda, J. Abraham // African Journal of Biotechnology. – 2013. – Vol. 12 (21). – P. 3099 – 3109.

22. Lysenko L. Prospects of the solution of the problem of heavy metals contamination of soils / L. Lysenko, M. Ponomariov, B. Kornilovich // Ecotechnology and resource saving. – 2001. – № 4. – P. 59 – 63. (Rus).

23. Bereziuk O. V. Modeling of specific energy consumption for dumpsites soils clearing from heavy metals contamination / O. V. Bereziuk // Urban municipal service. Series: vital activity safety – education, science, practice. – 2015. – № 1 (120). – P. 240 – 242. (Ukr).

24. Bereziuk O. V. Improvement of the mathematical model of the specific energy consumption for the cleaning of soils of solid municipal waste landfills from heavy metals contamination / O. V. Bereziuk // Ecological safety as the basis of the sustainable development of the society. European experience and prospects : IInd International scientific-practical conference : materials of the conference. – Lviv : Lviv State University of Life Safety, 2015. – P. 185 – 187. (Ukr).

25. Makarenko N. A. Impact of the solid municipal landfills on the adjacent agricultural territories / N. A. Makarenko, O. O. Budak // Tavria Scientific Bulletin. – 2015. – № 93. – P. 227 – 233.

26. Kulichkova A. O. Study of the filtrate on the landfill of solid municipal waste in Mykolaiv / A. O. Kulichkova, L. M. Markina // Actual problems of modern chemistry : Proceedings of the materials of the reports of the participants of the IIIrd All-Ukrainian scientific-practical conference. – Mykolaiv, 2019. – P. 143 – 146. (Ukr).

27. Mikhailevich V. M. Mathematical systems of computer algebra as the tool for improving the efficiency and quality of education process in higher mathematics / V. M. Mikhailevich, O. I. Shevchuk, N. L. Buga // Modern information technologies and innovation technique for training specialists : methodology, theory, experience, problems. Proceedings of scientific works. – Kyiv-Vinnytsia : Publishing House «Vinnytsia», 2007. – Issue 14. – P. 357 - 360. (Ukr).

28. Bereziuk O. V. Computer program "Regressive analysis" ("RegAnaliz") / O. V. Bereziuk // Certificate of the State Registration of the Rights to the Copyright Object № 49486. – K. : State service of the intellectual property of Ukraine. – Date of registration: 03.06.2013. (Ukr).

29. Bereziuk O. V. Determination of the regression of the compaction coefficient of the solid municipal waste on the height of the landfill on the base of computer program "RegAnaliz" / O. V. Bereziuk // Automated technologies and production processes. – 2015. – № 2 (8). – P. 43 – 45. (Ukr).

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