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IMPROVEMENT OF THE MATHEMATICAL MODEL OF THE FINE DUST EMISSION IMPACT ON THE CIRCULATORY DISEASES MORBIDITY

Object of the research in the paper is the circulatory diseases morbidity in Ukraine. World Health Organization (WHO) established that fine dust particles influence more people all over the world than any other pollutants. Air pollution causes the growth of the morbidity rate and mortality rate in the world and is the priority factor of risk for the health of people, in addition, more than 80 % of the diseases depend on the air quality. That is why, the improvement of the mathematical model of the impact of fine dust particles emission on the circulatory diseases morbidity rate, which can be used for the prediction of such morbidity indices is the relevant scientific-engineering problem.

The study of the fine dust particles emission impact on the circulatory diseases morbidity was performed by means of the experiment planning of the second order, applying Box-Wilson method with the help of rotatable central composition design, using the developed software, protected by the Certificate of the State Registration of the Rights to the Copyright Object. Objective of the research is the improvement by means of the multifactor experiment planning the mathematical model of the fine dust particles emissions impact on the circulatory diseases morbidity.

Improved regression dependence of the fine dust particles emission impact on the circulatory diseases morbidity has been obtained. It was established that according to Fishers criterion the hypothesis, regarding the adequacy of the obtained regression model may be considered to be correct with 95 % validity. Correlation coefficient is 0.99865, this proves the sufficient validity of the obtained results. The obtained regression dependence can be used for the prediction of the indices of the circulatory diseases morbidity. Response surfaces of the objective function – number of the cases of circulatory diseases and their 2D cross-sections in the planes of the impact parameters, which enable to represent the obtained dependence and the character of the simultaneous impact of several factors on the objective function have been constructed.

Key words: *mathematical simulation, experiment planning, multifactor dependence, impact factors, response surface, emissions, fine dust particles, morbidity, diseases of circulatory system.*

Introduction

In industrial regions air pollution represents serious danger for the environment and human health as numerous epidemiological investigations reveal the link between the air pollution and wide range of harmful impacts on human health. Dust particles emissions also worsen the ecological state of the environment, cause the premature wear of the industrial equipment and public utility facilities [1]. From the point of view of sanitary-epidemiological welfare of the population, health risks, connected with fine dust particles of the diameter less than 10 and 2.5 μm which can penetrate deeply in lungs are of great interest. Particles of the diameter less than 2.5 μm can penetrate even in the blood flow, that may cause diseases of cardiovascular and respiratory systems [2 – 4] and damage other organs. Such social groups as the aged people, pregnant women, children and asthma patients may have more serious consequences for health from the impact of the polluted atmospheric air. Main source of air pollution with fine dust particles is fuel burning in various sectors of national economy, including transport, energy branch, industry, construction [5 – 8], municipal service and agriculture, as well as in household use.

Problem set-up

World Health Organization (WHO) established than fine dust particles influence greater part of people all over the world more than any other pollutants, air pollution leads to the growth of the morbidity and mortality rate, it is the priority factor of the health risks for the population, moreover, more than 80 % of all the diseases more or less depend of the quality of air. That is why, the improvement of the mathematical model of fine dust particles emissions impact on the circulatory diseases morbidity, which can be used for the prediction of the indices of such morbidity is an important scientific-technical problem.

Analysis of the recent research and publications

In the studies [9 – 11] it is noted that one of the most dangerous from the list of the polluting substances is fine dispersive dust with the diameter of particles up to 10 μm. Such dust is solid particles which can remain in the suspended state in the air for a long time, such dust cannot be efficiently captured by the available decontaminating devices and they spread in the atmosphere for large distances [12].

In accordance with the recommendations of WHO in the countries of European community the limits of the threshold impact for fine dust particles of the diameter less than 10 μm are established. For the average daily concentration the threshold level of 50 μkg/m^3 can not be exceeded more than 35 times during a year, average annual concentration must not exceed the level of 40 μkg /m^3 [13]. However, in the counties of Eastern Europe, Caucasus, Central Asia monitoring of the air borne particles of the diameter less than 10 μm is very limited: only small number of the monitoring stations is available in Belarus and Uzbekistan (Tashkent, Nukus), in Ukraine there are no such stations [14].

Great volumes of fine dust particles, consisting of chimney soot, cement chippings and other fine dust particles are found in the atmospheric air of the residential areas. Fine dust particles exercise irritant, fibro-genic, allergy-inducing and toxic action on human organism. Character of the impact depends on physical-chemical properties of the particles such as form, solubility, degree of hardness, chemical composition. Chemical activity relatively human organism determines specific surface of the dust [15].

Paper [1] considers main sources of the air pollution, impact of the harmful emissions on human health and the results of the experimental investigations of the developed dust-collectors. It is noted that complex solution of the ecological-hygienic problems will enable to perform purposeful control of the environment improvement and strengthening of the population health.

Negative impact of the dust can be intensified as a result of overcooling, hard physical work, certain gases, etc. Fine dust particles comparatively easy pass across human physiological filters and penetrate into lungs, where they are absorbed by the blood. Dust is deposited on the vessels walls and in the connective tissues around them. Narrowing of the vessels and blood flow degradation in the organism leads to the disorder of the human blood flow system [16, 17].

In themselves toxic fine dust particles emissions under the action of the sun rays and ozone can form in the atmosphere new, still more toxic compounds. However, atmospheric turbulence and wind do not always manage to remove from the air basin of the enterprises growing as a result of the production intensification dust emissions [18].

In the paper [19] the regression hyperbolic dependence of benzopyrene concentration in the soil of municipal solid waste landfill (MSW) was determined on the depth of measurement, by means of this regression it was revealed that the dangerous depth of chemical contamination of the soil of municipal solid waste landfill with benzopyrene is 152 mm. In the materials of the research [20] the regression dependence of the petroleum products concentration in the soil on the distance to MSW landfill was suggested, the given dependence enabled to determine that the safe distance of MSW landfill location from the agricultural lands according to the index of chemical contamination level of the soil with the petroleum products is 66 m. In the article [21] regression dependence of the lead concentration in the soil on the distance to MSW landfill has been determined, by means of this regression it was established that the distance from MSW landfill, at which soil contamination with lead does not exceed the background level (boundary of the zone of weak contamination) is 526 m.

Materials of the paper [22] are devoted to the determination of the regression power dependences of the spreading of different classes of the diseases among the adult population of the settlements, adjacent to the location of MSW removal on the distance to the landfill, these dependences are used for the determination of the safe distance for the location of MSW landfills from the settlements by the indices of spreading the pathologies of the respiratory organs and blood circulation diseases.

In the study [23] the negative impact of fine dust particles in the atmospheric air on the state of human health has been proved, also it has been established that among the types of dust, penetrating in the air from the anthropogenic sources of emission, the most dangerous type of the dust for the human being is the dust, containing solid particles of 2.5 to 10 μm of size. The following two-factor linear mathematical models of the diseases of blood flow systems morbidity has been suggested, each of which takes into consideration the impact of fine dust particles emission only of the general volume or only of a certain dispersity:

$$Y = -47.4665 + 0.02318N + 104.6041X_1; \quad (1)$$

$$Y = 1864.977 - 0.01372N + 364.5516X_2; \quad (2)$$

$$Y = -3477.74 + 0.1188N + 394.5634X_3, \quad (3)$$

where Y – is the number of diseases cases, persons; N –is the total number of the population in the country, persons; X_1 – are the total volume of fine dust particles emissions into the atmosphere, kg/person; X_2 – are total volumes of the fine dust particles of 2.5…10 μm emissions into the air, kg/person; X_3 – are volumes of fine dust particles of less than 2.5 μm of size emissions into the air, kg/person.

Determination factor R^2 for the dependences (1 – 3) is 0.9248; 0.9365; 0.8022, correspondingly, if they are used for the prediction the circulatory system diseases morbidity this leads to the considerable errors, that is why, these mathematical models, from our point of view, need improvement.

The authors did not reveal as a result of the analysis of the known publications the non-linear mathematical models of the simultaneous impact of fine dust particles emissions of different groups of dispersity with the interaction effects on the circulatory diseases morbidity.

Objective and task of the paper

Objective of the given paper is the improvement by means of multifactor experiment planning the mathematical model of the fine dust particles emissions impact on the circulatory systems morbidity.

Methods and materials

Improvement of the mathematical model of the impact of fine dust particles emissions on the morbidity of the circulatory system diseases was carried out by means of the rotatable central composite design of the experiment of the second order applying Box-Wilson method [24, 25]. Determination of the coefficients of the regression equation was performed by means of the developed computer program "PlanExp", protected by the Certificate of the state registration of the rights to the copyright object [26] and is described in details in the paper [27].

Results of the research

Among the parameters, the morbidity of the circulatory system diseases depends on, the following ones were considered: total number of the population in the country, volumes of fine dust particles emissions in the atmosphere, the values of these parameters are presented in Table 1.

Table 1

Morbidity of the circulatory system diseases, depending on the total number of the population in the country and volumes of fine dust particles emissions into the atmosphere [23]

Year	Number of registered cases of the circulatory system diseases, ths of cases	Factors of impact		
		Number of the population, ths of persons	Volumes of solid particles emissions, kg/person	
			2.5…10 μm	less than 2.5 μm
2012	2390	45633.6	2.910	0.889
2013	2346	45553	3.118	0.927
2014	2318	45426.2	2.966	0.757
2015	2256	42929.3	2.767	0.597
2016	1880	42760.5	1.971	0.559
2017	1844	42584.5	1.588	0.461
2018	1826	42386.4	1.717	0.801
2019	1781	42153.2	1.104	0.319

According to the data of the Table 1 the regression equation is obtained, it describes the dependence of the circulatory system diseases on the basic parameters of impact and it has the form:

$$B_{ds} = 1.088N + 14491m_2 - 280m_3 - 0.3801Nm_2 - 237.1m_2m_3 + 494m_2^2 + 753.9m_3^2 - 42900, \quad (4)$$

where B_{ds} – is the number of cases of circulatory system diseases, persons; N – is the total number of the population in the country, persons; m_2 – are volumes of fine dust particles emissions into the atmosphere of 2.5…10 μm of size, kg/person; m_3 – are volumes of fine dust particles emissions into the atmosphere of less than 2.5 μm of size, kg/person.

Using Student`s criterion the following was revealed: all factors, their paired effects of the interaction, except Nm_3, and quadratic effects, except N^2, turned out to be significant; number of cases of circulatory system diseases depend more on the volumes of the emission in the atmosphere of the fine dust particles of 2.5…10 μm of size than on the emissions of the particles, the size of which is less than 2.5 μm, this coincides with the conclusions, made by the authors of the article [23].

It was established that according to Fisher criterion the hypnosis, regarding the adequacy of the regression model (4) may be considered to be correct with the validity of 95 %. Correlation coefficient was 0.99865, this proves the sufficient validity of the results obtained.

Comparison of actual and theoretical numbers of the cases of circulatory system diseases, simulated by means of mathematical models (1 – 4), is presented in Fig. 1.

It is seen from Fig. 1 that the theoretical spreading of the number of cases of circulatory system disease, calculated by means of the regression model (4), does not differ greatly from the actual data [23], this proves the sufficient reliability of the dependence obtained before, it can be used for the prediction of the indices of such morbidity. Besides, the improved mathematical model (4) with the determination coefficient R^2 = 0.9973 enables to predict more accurately the number of circulatory system disease cases, as compared with the known models (1 – 3), obtained by the authors of the research [23], where R^2 is 0.9248; 0.9365; 0.8022, correspondingly.

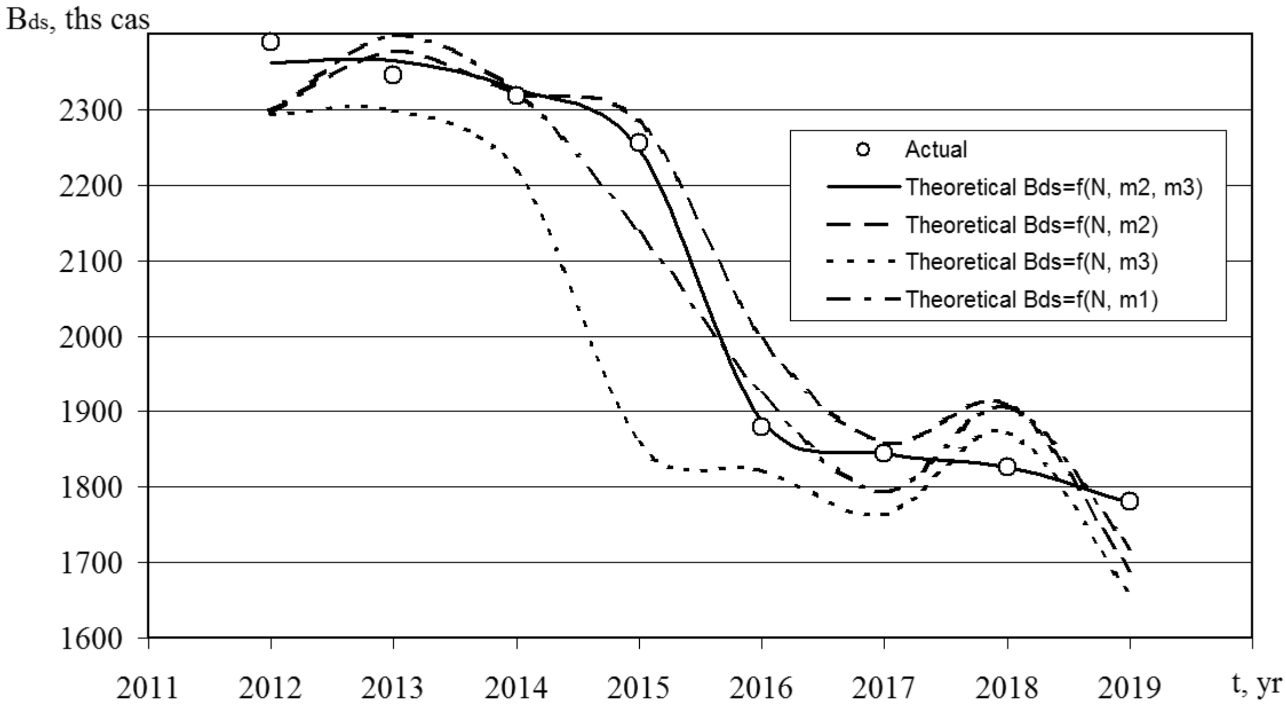
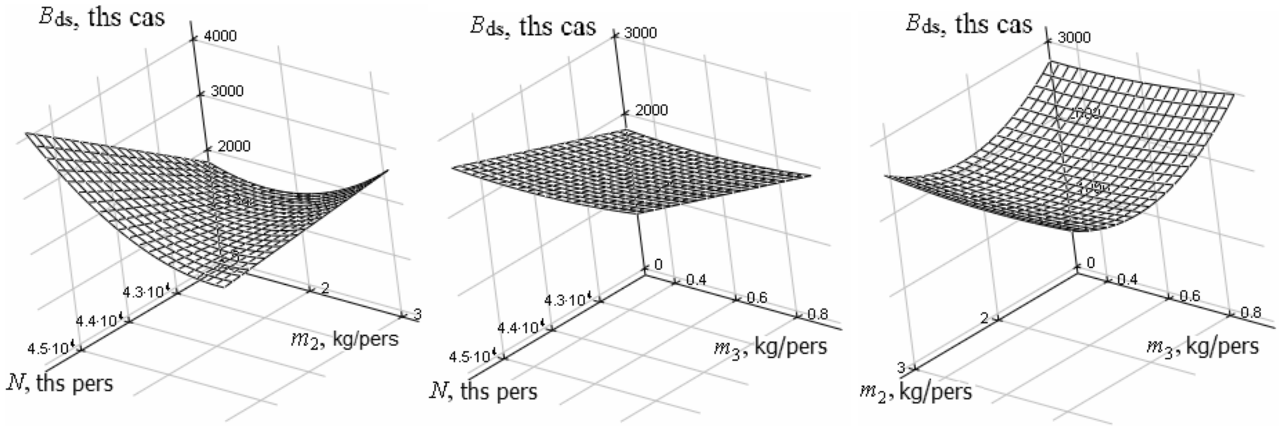


Fig. 1. Comparison of the actual and theoretical number of circulatory system disease cases, simulated by means of the known (1 – 3) and improved (4) mathematical models

Fig. 2 shows surface responses of the efficiency function – number of cases of circulatory system diseases and their 2D cross-sections in the planes of the impact parameters, which enable to illustrate the dependence (4) and the character of the simultaneous impact of several factors on the efficiency function.



a) b) c)

Fig. 2. Responce surfaces of the efficiency function – numbers of cases of circulatory system diseases and their 2D cross-sections in the planes of the impact parameters: a) – $B_{ds} = f\left(N, m_2\right)$; b) – $B_{ds} = f\left(N, m_3\right)$; c) – $B_{ds} = f\left(m_2, m_3\right)$

Conclusions

Improved adequate mathematical model of the second order with the effects of the interaction of the first order of the impacts of the fine dust particles emissions on the morbidity of circulatory system diseases which enables to predict more accurately the number of cases of the circulatory diseases as compared with the known models has been obtained, it can be used for the prediction of such morbidity indices.

Response surfaces of the efficiency function – number of circulatory system diseases cases have been constructed, they enable to illustrate the dependence of this efficiency function on certain impact parameters.

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