A mathematical model of joint determining the risk to human health and the identification of hazardous states of the polluted urban atmosphere based on the measurement of current concentrations of pollutants was developed. The structure of the model includes two structural units. The input data for structural units are the results of measuring current concentrations of atmospheric pollutants at a checkpoint. The current risk to human health is calculated in the first unit, and recurrent states of atmosphere for early detection of dangerous pollution levels are determined in the second unit. A distinctive feature of the model is the use of only measurements of current concentrations of pollutants in the atmosphere at a control point. Meteorological or other information is not used. That is why the developed model is universal and can be used in any weather conditions and peculiarities of the urban infrastructure. The operation efficiency of the proposed model was tested experimentally using the example of measuring current concentrations of formaldehyde, nitrogen dioxide, and ammonia in the atmosphere of the typical urban infrastructure. It was established that the developed model makes it possible to determine the risk of immediate toxic effects and chronic intoxication for humans, caused by atmospheric pollution. It was proved experimentally that the proposed model makes it possible, together with the identification of relevant risks to human health, to detect hazardous states of the polluted atmosphere, in which pollutants are usually accumulated. It was established that determining the current probability of recurrent conditions of the polluted atmosphere makes it possible with various reliability degrees to detect the possible occurrence of negative effects of atmospheric pollution on human health 6–12 hours beforehand

Keywords: air pollution, current concentrations of pollutants, risks to human health, recurrent states

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MATHEMATICAL MODEL OF DETERMINING A RISK TO THE HUMAN HEALTH ALONG WITH THE DETECTION OF HAZARDOUS STATES OF URBAN ATMOSPHERE POLLUTION BASED ON MEASURING THE CURRENT CONCENTRATIONS OF POLLUTANTS

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1. Introduction

Air pollution is now a serious problem of environmental hygiene in the developed and developing world. Studies of the impact of atmospheric pollution on public health are particularly relevant because they allow decreasing the negative impact of air pollution on humans and the environment [1]. This is particularly true of the adverse effects of air pollutants on the health of the population in towns and cities [2]. This is explained by the fact that it is necessary to determine the level of the impact of air pollutants on public health in order to make prompt decisions on control and management of emissions polluting the air, industrial facilities in order to maintain normal living conditions of the population. In this regard, determining the risk of the influence of atmospheric pollution of industrial cities on the health of the population is becoming one of the main challenges of ensuring the safe development of world civilization.

2. Literature review and problem statement

In an effort to reduce or eliminate the effects of atmospheric pollution on humans, researchers focused on two key approaches. The first approach is based on models of quantitative determining the concentration of pollutants emitted into the atmosphere. This approach is characterized by the use of approximation models [3], scattering models [4], regression models [5], and interpolation models [6]. The second approach includes the model of the impact of atmospheric air pollution (AAP) on human health, taking into consideration the characteristics of population distribution [7]. For example, a model of the average impact of the AAP based on population characteristics was proposed to assess the individual impact of the AAP. The approach of dynamic modeling of activity of the AAP source was developed in [8] to identify the differences between static and dynamic impacts on the population. At the same time, the study is limited to PN_{10} and $PN_{2.5}$, while other characteristic types of atmospheric pollutants and their effects on human health are not considered. Although these models are characterized by higher accuracy and theoretical reliability in assessing the impact of the AAP, it is time-consuming and expensive to collect separate data about the impact in a region. Basically, the AAP is caused by emissions of harmful substances from several point and linear sources, such as various industrial processes, fires [9, 10], as well as exhaust emissions from road transport [11]. Studies showed that low SO_2 concentrations may be associated with adverse effects on human health [12], and peak concentrations may even be associated with mortality [13]. Current meteorological conditions and the amount of emitted pollutants are known to produce a considerable impact of the AAP level. At the same time, the relation between the levels of the AAP concentrations and meteorological conditions for different cities turns out to be similar. This is due to some similarities between the emission structure and characteristics of the urban infrastructure. The special importance of meteorological conditions is that they can contribute both to transfer and dispersion, and to the accumulation of harmful impurities in the atmosphere. Wind, air temperature, precipitation, and fogs make the most impact [14]. To monitor current concentrations of harmful substances in the atmosphere, stationary checkpoints, allowing tracking the dynamics of concentrations of harmful substances over time, are located on the territory of the cities. In general, transfer, dispersion, and accumulation of pollutants in the atmosphere are quite complex non-linear processes. That is why in the case of AAP consideration, the linearity principle usually is not met [15], which in turn leads to the incorrect use of the majority of the known models for real physical processes of the AAP. However, identifying hazardous concentrations of pollutants is of paramount importance in order to prevent them [16]. Due to the complexity and non-linearity of the AAP processes, the methods of non-linear dynamics [17] are becoming an active field of research. The methods based on fractal parameters [18] are most popular for the study of various complex systems. However, their application is based on long-term observations, which for actual natural systems are not always possible to obtain. Incorrect use of these methods often leads to false results [19].

In general, the AAP with harmful substances can be considered as a complex non-linear dynamic system, at the input of which there are pollutants emitted by production facilities into the atmosphere. It is better to use a non-linear toolset with a number of applied advantages to explore such a complex system [20]. Such tools are based on the fundamental property of dissipative dynamic systems – recurrence of states (RS). This property is expressed in the fact that even the smallest disturbance, causing an exponential increase in the state of a dynamic system after a while tends to return to a state close to the previous one while having a similar dynamic. In this case, the behavior of these complex dynamic systems can be displayed using a recurrent plot (RP) [21] method. It should be noted that applications of methods of the theory of deterministic and stochastic dynamical systems to the analysis of different ecosystems, including the AAP systems, are developing at the same time [22, 23]. The corresponding models are described by a system of deterministic or stochastic differential equations, and the more complex the system under study, the more equations need to be used to adequately describe it. However, most of these systems can be explored using modern methods of the theory of dynamic systems and fractal sets [23]. For example, an experimental study of the dynamics of the state of gas environment pollution with hazardous factors of indoor fire was carried out in paper [24]. In articles [24, 25], it was experimentally proved that the dynamics of the states of the gas environment is complex and non-stationary. Under non-stationary conditions of the gas environment, it is proposed to enhance the prompt response of measuring sensors [26] or to use self-adjusted sensors [27]. Paper [28] analyzes the dynamics of the threshold self-adjustment and probability of identifying dangerous states of the gas environment. In this case, the properties of the SR of the gas environment and its effect on humans are not considered. Research [29] is devoted to analyzing the correlation dimensionality of the states of the gas environment at the early ignition of materials. Temporary autocorrelations and reciprocal correlations for major hazards of the gas environment in fires are experimentally explored in [30]. It is noted that correlation indicators of their interactions are important in detecting dangerous states of the gas environment. The methods proposed in research [31] are based on the stationary approach that allows detecting only averaged energy distribution for hazardous states. This does not take into consideration their localization over time. Research [32] is devoted to reviewing modern methods of local temporal and frequency resolution. It was noted that the problem of frequency and temporal localization of dangerous states remains unresolved to the full, and the known methods turn out to be difficult to implement and unsuitable for real-time detection of dangerous states. The method of rapid detection of dangerous urban AAP of based on the RP method and the proposed RS measures is considered in research [33]. The method of RP computation in space with the scalar product is considered in [34]. It is noted that in the face of a priori uncertainty, it is advisable to use the proposed technique of adaptive RP calculation [35].

Paper [36] is devoted to the capability of using the uncertainty function to identify dangerous states of the AAP. At the same time, the impact of dangerous concentrations of the APP in urban areas on the health of the population is not considered. Temporary analysis of non-stationary states of complex systems, based on the Fourier transform for stationary fragments of the trajectory of states of atmospheric pollution is made in article [37]. However, the impact of the AAP concentrations in the cities on public health is not considered in this case. The general methods of frequency-temporal representation and identification of non-linear dynamic systems based on short-term Fourier transform are considered in [38, 39]. Application of short-term Fourier transform to the analysis of actual observations is considered in study [40]. At the same time, the methods of [38–40] are quite complex to implement and cannot be considered as constructive to identify dangerous states of the AAP. Paper [41] proposed the modification of the known frequency-temporal approach to the study of dynamics of hazardous states of the gas environment with the view to developing a constructive method for detecting dangerous states of the gas environment at the ignition of materials. At the same time, risks to human health caused by the pollution of the gas environment are not considered. However, numerous studies prove a stable link between atmospheric pollution and pollution of the gas environment of premises and negative consequences for the health of the population. Statistical analysis based on data monitoring and bio-monitoring also shows the relationship between the AAP level and the level of human mortality and morbidity. Unlike accidents, the AAP is not considered to be the cause of immediate death. In fact, this is believed to be the cause of premature death. It was proven that the AAP is associated with a large number of diseases such as cancer, respiratory, cardiovascular, and neurological diseases, as well as diabetes and sterility [42].

Thus, the AAPs currently remain one of the important sources of risk to the health of the population of industrial cities. A particular danger of the AAP is that the atmosphere is able not only to dissipate pollutants but also to accumulate them on a certain spatial-temporal scale. That is why along with the urgency of determining the current risk to the health of the population of industrial cities, there is a need to simultaneously identify these spatial-temporal areas of dangerous states of AAP. Some of the constructive methods for identifying dangerous states of the AAP are the RP methods and RS measures. These methods and the RS measures make it possible by the results of measuring current concentrations of air pollutants to display the dynamics of the AAP and to identify various structural features of the dynamics, including the RS, which cannot be identified based on the traditional methods. However, the RP methods and the RS measures of the AAP do not enable identification of the risk to human health caused by atmospheric pollution, taking into consideration individual risk levels. That is why an important and unresolved part of the problem under consideration is the joint identification of the risk to human health and the detection of hazardous states of the polluted urban atmosphere.

3. The aim and objectives of the study

The aim of this study is to develop a mathematical model that makes it possible to identify jointly the current risk to human health and detect promptly the health-threatening states of the polluted atmosphere of industrial cities by measuring current concentrations of pollutants. To accomplish the aim of the research, the following tasks were set:

– to substantiate the structure of the mathematical model of joint determining the risk to human health caused by atmospheric pollution and prompt detection of hazardous states of the polluted urban atmosphere by measuring current concentrations of pollutants;

– to conduct experimental studies to test the operational efficiency of the proposed model, using measurements of the concentration of typical air pollutants in the form of formaldehyde, ammonia, and nitrogen dioxide in an industrial city with a typical infrastructure.

4. Substantiation of the structure of the mathematical model of joint determining the risk to human health and detection of dangerous states of polluted atmosphere

The structure of the developed model should be determined by a series of requirements. Firstly, the model should make it possible to identify the risk to public health caused by current atmospheric pollution at an arbitrary checkpoint for any urban infrastructure, for different types and numbers of air pollutants, without regard to meteorological parameters. Secondly, in addition to these requirements, the developed model must detect dangerous states of the AAP. It is rather problematic to meet these requirements in the development of a model within the classical approach. That is why an approach that is based on the representation of the AAP and their impact on human health in the form of a unified complex non-linear dynamic system is explored in the paper. At the same time, the state of such a system is determined by the complex and non-linear interaction of a large number of different obvious and hidden processes, which are difficult to adequately describe mathematically and take into consideration in advance. In addition, the state of the system will also be determined by a variety of unknown parameters related not only to the processes of pollutants' injection but also to their transfer, scattering, and accumulation, taking into consideration the current weather conditions in the atmosphere and the features of the urban infrastructure at the pollution control point. This means that to meet the above requirements, the structure of the developed mathematical model must include two main structural units. It is a structural unit for determining the risk to human health caused by the AAP and a structural unit for detecting hazardous states of contaminated atmosphere for an arbitrary amount and type of pollutants, without taking into consideration the current meteorological parameters and configuration features of the urban infrastructure at the pollution control point. With a view to meeting the stated requirements, input data for structural units of the model should be only current measurements of concentrations of atmospheric pollutants at a control point of the urban configuration. The use in the model of only measured concentrations of pollutants at a checkpoint ensures its versatility. In general, as the measured concentration of pollutants, the model can use actual measurements of concentrations both at existing stationary AAP control posts in cities, and using portable or mobile means of measurements at arbitrary checkpoints.

Subsequently, we will assume that the concentration of pollutants in the atmosphere is measured at stationary control posts in accordance with the program of temporary sampling of corresponding pollutants. In the case of measuring concentrations for an arbitrary amount of atmospheric air pollutants, the measurement results at a fixed moment of time i for the model will be input vector $\bar{z}_i$, the components of which are measured concentrations of the studied air pollutants. The input vector $\bar{z}_i$ of the model will display the current state of the AAP at the moment of time i in the area of a stationary control post or a portable measurement device. It is known [24] that vectors $\bar{z}_i$ will display the unknown dynamics of the AAP system, no matter how complex it is.

In general, the risk to human health caused by the polluted atmosphere may manifest itself in the form of immediate toxic effects and chronic intoxication. That is why the first structural unit of the model, which determines the risk to human health by measuring current concentrations of pollutants, should determine both risk Ri_t of immediate toxic effects, and risk Ri_x of chronic intoxication caused by the AAP. These risks in the model are determined according to the expressions [43]:

$$Ri_t = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\alpha+b\lg(C/MPC_t)} \exp\left(-\frac{y^2}{2}\right) \mathrm{d}y, \tag{1}$$

$$Ri_E = 1 - \exp\left[-0.174 \cdot \left(\frac{C_x}{MPC_x \cdot K}\right)^{\beta} \cdot t\right]. \tag{2}$$

where α and b are the parameters depending on toxicological properties of the pollutant; C and C_x are the current values of the measured concentration of a pollutant in the atmospheric air and its current average daily value; MPC_t and MPC_x are, respectively, the admissible maximal single and average daily concentration of a pollutant, mg/m^3; y is the integration parameter; β is the factor taking into account the specific features of toxic properties of a pollutant; t is the time of pollutant influence on a person. K is the coefficient linking risk to the magnitude of pollutant concentration. In this case, risk (1) of immediate toxic effects determines the probability of death (disease) of a person. Numerical values of coefficients α and b in (1), as well as β and K is (2) are determined based on special toxicological studies of explored pollutants and are presented in the special literature.

The second structural unit of the model should provide the identification of hazardous states of the polluted atmosphere by measuring the current concentration for an arbitrary number and type of pollutants that determine vector $\bar{z}_i$, without taking into consideration meteorological parameters and specific features of the urban infrastructure at a pollution control point. To do this, it is proposed at the first stage to use the RP method, which makes it possible to display visually display on the plane the complex multidimensional dynamics of actual (physical) states of the AAP by the measured values of vector $\bar{z}_i$, [24]. The algorithm of such display for an arbitrary m-dimensional vector $\bar{z}_i$ can be represented by the ratio:

$$R_{i,j}^{m,\varepsilon} = \Theta\left(\varepsilon - \left\|\bar{z}_i - \bar{z}_j\right\|\right), \quad \bar{z}_i \in \Omega^m, \quad i,j = 1,2,\ldots,N_S, \tag{3}$$

where $\Theta()$ is the Heaviside function; ε is the size of neighborhood of the RS of the AAP for time moment i, and ‖*‖ is the norm operator; N_s is the size of sampling of the m-dimensional vector $\bar{z}_i$ of the current measurement of AAP concentration. The most dangerous in terms of risk to the health of the population of industrial cities are the AAP states, in which there is no dispersion of pollutants and they are locally accumulated. Such APP states are characterized by the RS in actual dynamics. However, the RP method (3) does not make it possible to detect promptly the RS of actual AAP. That is why at the second stage, it is proposed to use a window measure of RS, determined based on display (3) in the form of [36] for rapid detection of the RS in the dynamics of the AAP:

$$M_2(i,a,\varepsilon) = if\left(i < a, \frac{1}{i+1}\sum_{k=0}^{i} R_{i,k}^{m,\varepsilon}, \frac{1}{a}\sum_{k=0}^{a-1} R_{i,i-k}^{m,\varepsilon}\right). \tag{4}$$

where a is the parameter determining the size of an averaging window.

The numerical values of the RS measure (4) are used in the second structural unit of the model to detect hazardous states of the AAP, associated with the lack of the ability of the atmosphere to dissipate pollutants. At the same time, the RS of the APP will lead to the accumulation of pollutants in the atmosphere. If at the moments of the RS of the AAP there is an injection of pollutants from the sources, it can lead to an increase in the concentration of pollutants in the atmosphere over the MAC, which will lead to a significant increase in the risk to public health, including even instant or untimely death of a person.

Thus, the structure of the developed mathematical model of combined determining the risk to human health and identification of dangerous states of the polluted urban atmosphere will be determined by ratios (1) to (4). This model is a system of four analytical dependences. The first and the second analytical dependences are implemented in the first structural unit of the model and describe, respectively, the dependence of the risk of immediate toxic effects and chronic intoxication for humans on the current concentration of the corresponding pollutant of the atmosphere of the urban infrastructure. The third and fourth ones are implemented in the second structural unit of the model and describe, respectively, the dependence of the RP display on current measurements of the vector of concentrations of studied pollutants, the normal function, and recurrence threshold, as well as the dependence of current estimate of the probability of the RS of the AAP on the RP.

5. Experimental studies on testing the operational efficiency of the developed model

Experimental studies for testing the operational efficiency of the proposed model were based on actual measurements of the concentration of characteristic atmospheric pollutants produced at one of the route posts of a typical urban configuration. During the experiment, atmospheric air in the area of the post was contaminated with actual stationary and mobile sources in their normal operation mode. The urban infrastructure, for which the AAP index made up the magnitude of about 6.8 units, was considered as typical. Such AAP index for industrial cities of Ukraine (for example, Cherkasy) is considered average and is typical for most cities of the world with moderate technogenic infrastructure. The concentration of atmospheric gas pollution at the control post was measured with the help of the portable gas analyzer DRÄGER PAC 7000 (Germany), made based on modern sensors Dräger XXS. The device makes it possible to measure concentrations of H_2S, O_2, CO, CO_2, Cl_2, HCN, NH_3, NO_2, NO, PH_3, SO_2, and other harmful substances in the atmosphere. The concentration of atmospheric pollution was measured in accordance with the requirements of GOST 17.2.3.01-86 «Nature Protection. Atmosphere. Rules for controlling the air quality of populated areas». Experimental studies were conducted during May 2018 (the interval of discrete measurements is from 480 to 600 counts). Concentrations of nitrogen dioxide (hazard class 2), formaldehyde (hazard class 2), and ammonia (hazard class 4) were measured. Concentrations of the specified pollutants were measured in mg/m^3. Measurements were made six times a week four times a day (1.00, 7.00, 13.00, and 19.00).

The dependences of current C concentrations of the studied air pollutants exceeding the corresponding maximum admissible average daily concentrations (MAC_x) are shown in Fig. 1 as an example. The Mathcad-15 programming environment was used to produce the results shown in the figures.

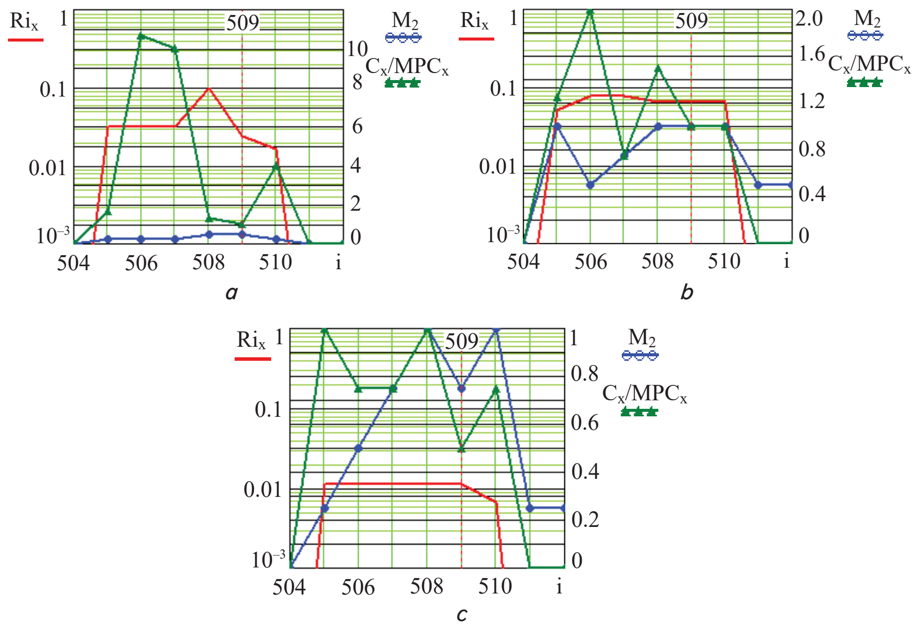

Fig. 2. Dynamics of risks of chronic action on humans, measured average daily concentrations of air pollutants, as well as the probability of the RS of the AAP: *a* — formaldehyde; *b* — ammonia; *c* — nitrogen dioxide

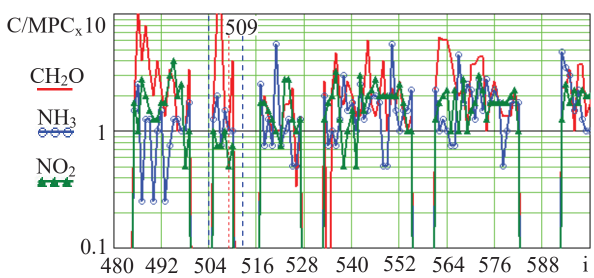

Fig. 1. Experimental data of concentrations of nitrogen dioxide, formaldehyde, and ammonia exceeding the MAC

The test interval for checking the model is highlighted in Fig. 1 with dotted blue lines.

In accordance with the proposed mathematical model, based on measured values of concentrations of the studied atmospheric pollutants, current risks of chronic and instantaneous action for humans, as well as current values of probability of the RS of atmosphere pollution, were determined. The measured concentrations of the studied atmospheric pollutants, risks of chronic action for humans, as well as current probabilities of the RS of the AAP on the test interval (shown in Fig. 1) are shown in Fig. 2 as an example.

During the experiment, it was found that according to the results of measurements of formaldehyde concentration in the test interval, the risk of instant action on human health did not exceed the magnitude of admissible individual risk. That is why only measured concentrations of ammonia and nitrogen dioxide were subsequently studied.

Fig. 3 shows the dynamics of the risk of instantaneous action of measured concentrations of ammonia and nitrogen dioxide on humans, as well as the probability of RS of the AAP for the above two pollutants mentioned in the considered test interval.

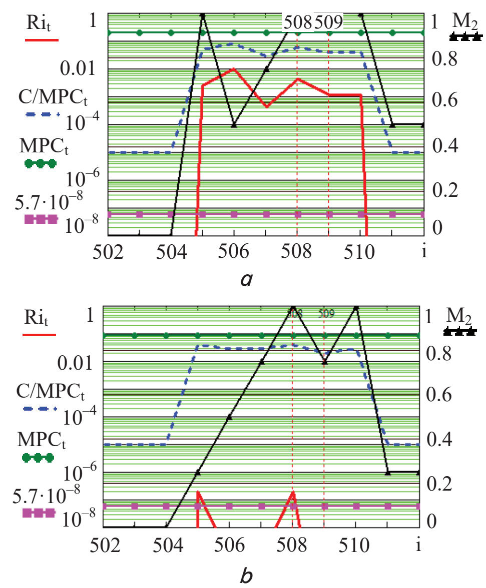

Fig. 3. Dynamics of risk of instantaneous action, measured concentrations for air pollutants, as well as the probability of RS of AAP: *a* — ammonia; *b* — nitrogen dioxide

In addition, for comparison, Fig. 3 shows the values of maximum single-time MAC for studied atmospheric air pollutants, as well as of recalculated limit level of unacceptable individual risk for humans, determined by the magnitude of $5.708 \cdot 10^{-8}$.

6. Discussion of the results of experimental testing of the developed model

Analysis of the data shown in Fig. 1 reveals that throughout the experiment all controlled pollutants constantly exceeded the MAC. At the same time, measurements (level 0.1) were not made on Sundays or holidays. The test interval with maximum exceeding the MAC by formaldehyde and average exceeding the MAC by nitrogen dioxide and ammonia was selected. The choice of the test interval, in general, did not matter much. It was possible to choose any other test interval during the entire period of the research. To test the operational efficiency of the model, the results of the studies of dynamics of concentrations of harmful substances, risks of chronic and instantaneous effects of pollutants on humans, as well as the RS of the AAP (Fig. 2, 3) are important. Analysis of the data in Fig. 2, 3 reveals that in the test interval, the concentration of formaldehyde, nitrogen dioxide, and ammonia cause negative effects on human health. At the same time, the risk of chronic action exceeds the upper limit of inadmissible individual risk by 1–2 orders of magnitude. This means that irreversible processes in health can start if a person is exposed to this concentration of atmospheric pollution for a long time. At the same time, the dynamics of the RS of the AAP makes it possible to detect such dangerous effects of pollution on humans at the early stages and to prevent the appearance of irreversible processes in health. However, if current concentrations of some pollutants do not exceed their respective MAC, it is not possible to identify unacceptable health risks from these atmospheric contaminants based on the known models (Fig. 2, *c*). For example, measured current concentrations of ammonia in the test interval cause the risk of instantaneous action on a person that by far exceeds the level of unacceptable individual risk (Fig. 3, *a*). Nitrogen dioxide in this case exceeds the limit of inadmissible individual risk only slightly and for a short time (Fig. 3, *b*). However, current measured concentrations of ammonia and nitrogen dioxide do not exceed the corresponding values of the MAC. At the same time, the proposed model in the specified test interval reveals a significant excess of the level of unacceptable individual risk by the risk of instantaneous action from ammonia contamination. In this case, it was experimentally established that, based on the dynamics of the probability of the RS of the AAP, determined according to the proposed model, ratio (4) makes it possible to identify exceeding the level of unacceptable individual risk for a human by the risk of instantaneous action 6–12 hours earlier. This information makes it possible to make prompt management decisions aimed at avoiding the dangerous level of risk to human health caused by the AAP. It should be noted that during the experimental test of the operational efficiency of the proposed model, only measured current concentrations of atmospheric pollutants served as source information. This proves that meteorological and other information was not actually used in the proposed model. In this sense, the developed model is universal and can be used in any weather conditions and specific features of the urban infrastructure. In the second structural unit of the model, the complex dynamics of current states of actual AAP is visualized by current measured values of concentration for three studied pollutants with the help of the RP method. Based on the current display of dynamics of the states of the AAP, the current RS of the AAP is determined in order to identify early the states of atmospheric pollution that are hazardous for human health. At the same time, the current value of the RS characterizes the moments when there is no pollution dispersion in the atmosphere, as well as the magnitude of the current probability of the RS. Based on this, it is possible to detect with varying degrees of certainty the appearance of dangerous effects of the AAP on human health. At the same time, it was experimentally shown that it does not seem possible to prevent the appearance of dangerous effects of the AAP on human health using the traditional approach based on exceeding single-time maximum admissible concentrations by current concentrations of atmospheric pollutants (Fig. 3).

In implementing this model, it is necessary to take into consideration the limitations associated with the choice of the norm operator and the size of the RS neighborhood when using the RP method to display the dynamics of the AAP states, as well as the width of the averaging window when determining the measure (4). We should consider possible to direct our work to the development of proposals regarding the removal of these limitations of the proposed model.

7. Conclusions

1. The structure of the mathematical model of joint identification of human health risks caused by atmospheric pollution and the rapid detection of hazardous states of the polluted urban atmosphere based on measurement of current concentrations of pollutants was substantiated. The model consists of two structural units that convert measurements of current concentrations for an arbitrary number of atmospheric pollutants into the magnitude of current risk to human health, as well as the current probability of the RS of the AAP in order to detect promptly the hazardous levels of pollution. A distinctive feature of the proposed model is the use of only measured current concentrations of pollutants in the atmosphere at a control point, without taking into consideration meteorological or other information. That is why the developed model is universal and can be used in case of any meteorological conditions and specific features of the urban infrastructure at the AAP control point.

2. The developed model was tested using the example of measuring current concentrations of formaldehyde, nitrogen dioxide, and ammonia in the atmosphere of the typical urban infrastructure. It was established that the proposed model makes it possible to assess the risk of immediate toxic effects and the risk of chronic intoxication inflicted on the health of the population by the AAP. It was experimentally proved that the developed model allows early detection of the moment when there is no pollutant dissipation and its accumulation in atmospheric air simultaneously with the assessment of corresponding risks to human health. In the course of testing the model, it was established that assessment of the current probability of the RS of the AAP makes it possible with varying degrees of certainty to detect the appearance of possible negative effects of the AAP on human health 6–12 hours earlier.

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