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Research article

CALCULATING THE NUMBER OF DISEASE CASES ASSOCIATED WITH ACUTE SHORT-TERM EXPOSURE TO HARMFUL CHEMICALS IN AMBIENT AIR

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The article addresses development of methodical approaches to calculating levels of health disorders caused by short-term exposure to ambient air pollution. We have established and parameterized relationships relevant for quantification of probable health outcomes as responses to elevated levels of chemicals in ambient air higher than their reference ones. These relationships were modeled using system analysis techniques and were based on dynamic data series on ambient air quality at the control points and the number of applications for medical aid in settlements with their overall population being more than 5 million people. We have formalized relationships that describe how intensively acute health disorders develop under short-term exposure to chemical levels in ambient air being higher than the reference ones that are identified at the control points. The resulting models rely on official data and can be used to predict and assess public health risks in any area where ambient air quality is monitored.

The formalized relationships were tested within identifying levels of incidence associated with acute short-term exposure to ambient air pollution in a large industrial center. It was established that, according to data collected in 2020, the highest associated incidence was caused by exposure to benzene (on average 0.364 mg/m^3 higher than the reference level) in ambient air and was detected as per such nosologies as 'Allergic rhinitis unspecified' and 'Predominantly allergic asthma'.

We are planning to use the results obtained at this stage in the research in further development of methodical approaches to assessing and predicting chemical health risks in areas influenced by hazardous chemical objects under short-term exposure to high levels of pollutants.

Keywords: *ambient air, public health risk, priority pollutants, mathematical modeling, applications for medical aid, chemical levels, associated incidence.*

Growth in life expectancy and life quality, health preservation and protection are priority trends in the state policy of the Russian Federation[1]. The set goals are being achieved by accomplishing a wide range of actions, including provision of sanitary-epidemiological wel-

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[1] O natsional'nykh tselyakh i strategicheskikh zadachakh razvitiya Rossiiskoi Federatsii na period do 2024 goda: Ukaz Prezidenta Rossiiskoi Federatsii ot 07.05.2018 № 204 [On national goals and strategic tasks of the Russian Federation development for the period up to 2024: the RF President Order dated May 07, 2018 No. 204]. *President of Russia: the official web-site*. Available at: http://www.kremlin.ru/acts/bank/43027 (December 19, 2022) (in Russian); O natsional'nykh tselyakh razvitiya Rossiiskoi Federatsii na period do 2030 goda: Ukaz Prezidenta Rossiiskoi Federatsii ot 21.07.2020 № 474 [On national goals of the Russian Federation development for the period up to 2030: the RF President Order dated July 21, 2020 No. 474]. *President of Russia: the official web-site*. Available at: http://www.kremlin.ru/acts/bank/45726 (December 19, 2022) (in Russian); Kontseptsiya demograficheskoi politiki Rossiiskoi Federatsii na period do 2025 goda (utv. ukazom Prezidenta RF ot 9 oktyabrya 2007 g. № 1351) [The Concept of the demographic policy in the Russian Federation for the period up to 2025 (approved by the RF President Order dated October 9, 2007 No. 1351)]. *President of Russia: the official web-site*. Available at: http://www.kremlin.ru/acts/bank/26299/page/1 (December 19, 2022) (in Russian).

fare[2]. Thus, within the Ecology National project[3], the Clean Air Federal project[4] is being implemented by the RF Government in 2019–2024. It is aimed at reducing ambient air pollution in large industrial centers.

The project envisages using health risk indicators as eligible criteria to estimate performance and effectiveness of activities aimed at raising ambient air quality[5]. Special attention should be paid to assessing acute non-carcinogenic health risks that can occur already under short-term exposure to harmful chemicals (when duration of exposure does not exceed 24 hours).

The classical methodology for assessing public health risks under exposure to environmental pollutants is described in the Guide R 2.1.10.1920-04[6]. It relies on calculating hazard quotients and hazard indexes (HQ и HI) of chemicals penetrating the body through different ways. The methodology described in this Guide is relatively simple and is widely used to solve both theoretical and practical tasks involving assessment and management of public health risks [1–3].

At the same time, if we consider a risk a quantitative characteristic that reflects probable negative health outcomes, then use of hazard indexes as the sole estimation criteria imposes considerable limitations on performing hygienic analysis of an ecological situation in examined areas, calculating economic losses, substantiating relevant activities, identifying their expected effectiveness and performance.

Given that, a system approach seems able to provide a substantially greater analytical toolkit for health risk assessment. It involves formalizing cause-effect relations between environmental quality indicators and public health.

It is noteworthy that creating a system of cause-effect relations is a nontrivial task that requires the maximum objectivity at any stage in modeling, from creating a learning sample to substantiating a type of applied mathematical models and methods to identify model parameters.

At present, epidemiological research is widely used to formalize relationships [4]. Epidemiological studies give grounds for establishing relevant parameters of ‘concentration – outcome’ or ‘dose – response’ relationships. Several health outcomes caused by ambient air pollution are used most frequently including all-cause mortality [5, 6]; mortality caused by circulatory and respiratory diseases [7, 8]; hospital admissions due to circulatory and respiratory diseases [9, 10].

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[2] O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossiiskoi Federatsii v 2021 godu: Gosudarstvennyi doklad [On sanitary-epidemiological welfare of the population in the Russian Federation in 2021: the State Report]. Moscow, The Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 2022, 340 p. (in Russian).

[3] Pasport natsional'nogo proekta «Ekologiya» (utv. prezidiumom Soveta pri Prezidente RF po strategicheskomu razvitiyu i natsional'nym proektam 24.12.2018 (protokol № 16)) [The profile of the Ecology National project (approved by the Presidium of the RF President Council on strategic development and national projects on December 24, 2018 (the meeting report No. 16))]. *The Russian Government: the official web-site*. Available at: http://static.government.ru/media/files/pgU5Ccz2iVew3Aoel5vDGSBjbDn4t7FI.pdf (October 02, 2022) (in Russian).

[4] Pasport federal'nogo proekta «Chistyi vozdukh»: prilozhenie k protokolu zasedaniya proektnogo komiteta po natsional'nomu proektu «Ekologiya» ot 21 dekabrya 2018 g. № 3 [The profile of the Clean Air Federal project: the supplement to the meeting report of the meeting held by the project committee on the Ecology National project dated December 21, 2018 No. 3]. *The Kuzbas Ministry of Natural Resources and the Environment*. Available at: http://kuzbasseco.ru/wp-content/uploads/2019/09/%D0%A4%D0%9F%D0%A7%D0%B8%D1%81%D1%82%D1%8B%D0%B9-%D0%B2%D0%BE%D0%B7%D0%B4%D1%83%D1%85-%D0%9F%D0%B0%D1%81%D0%BF%D0%BE%D1%80%D1%82.pdf (October 02, 2022) (in Russian).

[5] MR 5.1.0158-19. Otsenka ekonomicheskoi effektivnosti realizatsii meropriyatii po snizheniyu urovnei zagryazneniya atmosfernogo vozdukha na osnovanii otsenki riska zdorov'yu naseleniya: Metodicheskie rekomendatsii (utv. Glavnym gosudarstvennym sanitarnym vrachom RF 02.12.2019) [The Methodical Guidelines MR 5.1.0158-19. Assessing cost effectiveness of activities aimed at reducing pollution levels in ambient air based on public health risk assessment (approved by the RF Chief sanitary Inspector on December 02, 2019)]. *MEGANORM: the system for regulatory documents*. Available at: https://meganorm.ru/Data2/1/4293720/4293720160.pdf (October 10, 2022) (in Russian).

[6] R 2.1.10.1920-04. Rukovodstvo po otsenke riska dlya zdorov'ya naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh okruzhayushchuyu sredu [The Guide R 2.1.10.1920-04. Human Health Risk Assessment from Environmental Chemicals]. Moscow, The Federal Center for State Sanitary and Epidemiological Surveillance of the RF Ministry of Health, 2004, 143 p. (in Russian).

Attention should be paid to the fact that practically all the findings of epidemiological studies that are reported in research literature represent particular cases of incidence and mortality typical for certain age groups, natural conditions, climate, socioeconomic conditions, workplace-related and occupational peculiarities and other limitations of sample populations. This narrows an area where identified relationships could be eligible. Moreover, most significant epidemiological studies were conducted in 90ties last century and there is no unified summarizing document that provides parameters of established relationships eligible for being widely used in assessing acute health risks.

The aim of this study was to substantiate and parameterize models describing cause-effect relations for quantification of acute public health risks caused by exposure to harmful chemicals in ambient air.

Materials and methods. Influence exerted by ambient air pollution on occurrence of acute health outcomes was modeled based on dynamic data series. These data covered the results of laboratory tests aimed at identifying chemical levels at stationary monitoring posts. These tests were conducted within profound screening investigations in 2021–2022. The data also covered daily applications for medical aid. Our analyzed territories were represented by large industrial centers with considerable levels of ambient air pollution.

The modeling procedure was divided into three stages. At the first stage, all the data were preliminarily prepared for the analysis; the second stage involved conducting dynamic analysis of selected indicators; relationship models were created at the third stage.

The preliminary data preparation included copying necessary data from the registers of applications for medical aid in residential areas close to the posts for ambient air quality monitoring; copying results of laboratory control over ambient air quality at the control posts on the analyzed territories; agreeing on relevant data arrays as regards territories, dates, and control points.

Our initial data at the first stage in the research were electronic tables with information about registered disease cases provided by the territorial offices of the Fund for Mandatory Medical Insurance and data on levels of chemical pollutants in ambient air at the control points identified as per the results of social-hygienic monitoring (SHM) and provided by Rospotrebnadzor's offices on the analyzed territories.

Within the preliminary data preparation, we agreed on relevant data covering territories for analysis, dates, and geographical positions of residential areas relative to the control points of ambient air monitoring. To do that, we performed geocoding of all the obtained data and specified residential areas close to the control points. These residential areas were represented by residential buildings located within a circle with 500 meters radius. Figure 1 provides an example of identifying specific zones on a given territory to show representativeness of posts for ambient air quality monitoring.

Daily applications for medical aid were identified for these specified zones; the values were measured in a number of cases per 100 thousand people for three different age groups (children aged 0–17 years, working age adults, adults older than working age) as per nosologies characterizing acute health outcomes under short-term exposure to harmful chemicals in ambient air (Table 1).

Such diseases as 'Other allergic rhinitis' (J30.3) and 'Predominantly allergic asthma' (J45.0) are given in two places in Table 1 since they can be signs of health disorders both in the respiratory organs and the immune system.

Single maximum concentrations of pollutants identified at the analyzed control points were used as affecting factors for modeling of relationships. Table 2 provides the list of chemicals identified at the control points as well as potential critical organs and systems affected by the enlisted chemicals (according to the Guide on Health Risk Assessment[7]).

[7] R 2.1.10.1920-04. Rukovodstvo po otsenke riska dlya zdorov'ya naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh okruzhayushchuyu sredu [The Guide R 2.1.10.1920-04. Human Health Risk Assessment from Environmental Chemicals]. Moscow, The Federal Center for State Sanitary and Epidemiological Surveillance of the RF Ministry of Health, 2004, 143 p. (in Russian).

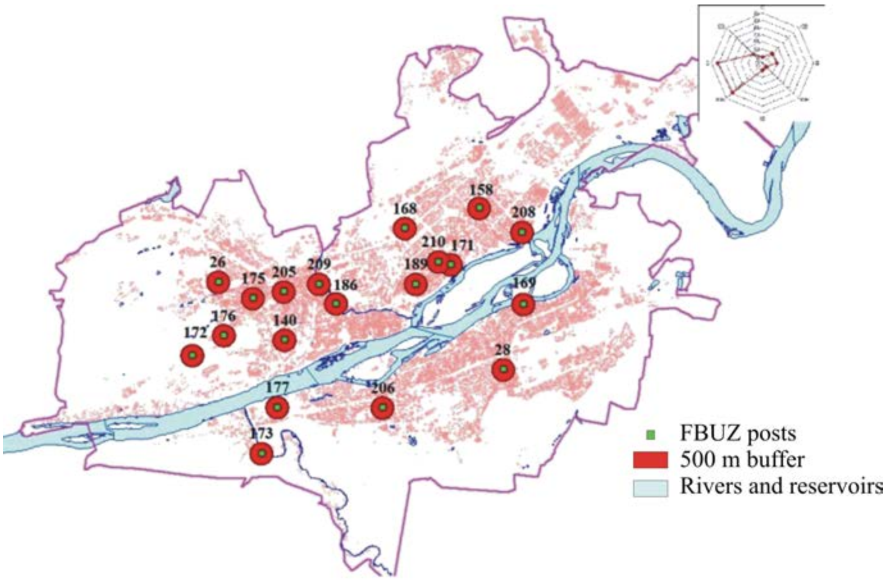

Figure 1. An example spatial location of residential areas close to the control posts of ambient air quality monitoring in a large industrial center

Table 1

The list of diseases that are considered typical health outcomes under acute short-term exposure to ambient air pollution

Critical organs and systems	Disease
Respiratory organs	J02.9 Acute pharyngitis, unspecified
	J04.0 Acute laryngitis
	J04.1 Acute tracheitis
	J04.2 Acute laryngotracheitis
	J20.9 Acute bronchitis, unspecified
	J30.3 Other allergic rhinitis
	J30.4 Allergic rhinitis, unspecified
	J31 Chronic rhinitis, nasopharyngitis and pharyngitis
	J37 Chronic laryngitis and laryngotracheitis
	J39.9 Disease of upper respiratory tract, unspecified
	J40 Bronchitis, not specified as acute or chronic
	J42 Unspecified chronic bronchitis
	J44 Other chronic obstructive pulmonary disease
	J45.0 Predominantly allergic asthma
	J45.8 Mixed asthma
	J45.9 Asthma, unspecified
	J46 Status asthmaticus
	J68 Respiratory conditions due to inhalation of chemicals, gases, fumes and vapors
	J96.0 Acute respiratory failure
Eyes and mucosa	H10 Conjunctivitis
	H16.1 Other superficial keratitis without conjunctivitis
	H16.2 Keratoconjunctivitis
	H16.8 Other keratitis
	H16.9 Keratitis, unspecified
Immune system	J30.3 Other allergic rhinitis
	J45.0 Predominantly allergic asthma
Central nervous system	R27 Other lack of coordination
	R51 Headache
	R53 Malaise and fatigue
	G47.9 Sleep disorder, unspecified

Table 2

The list of chemical identified at the control points for ambient air quality monitoring on the analyzed territories under short-term exposure

No.	Chemical	Critical organs and systems
1	1,2-dichloroethane	Immune system
2	Nitrogen (II) oxide	Respiratory organs
3	Nitrogen dioxide	Respiratory organs
4	Ammonia	Respiratory organs; eyes and mucosa
5	Acetaldehyde	Eyes and mucosa
6	Benzene	Immune system
7	Particulate matter	Respiratory organs
8	Particulate matter PM_{10}	Respiratory organs
9	Particulate matter $PM_{2.5}$	Respiratory organs
10	Phenol	Respiratory organs; eyes and mucosa
11	Hydrochloride	Respiratory organs
12	Dihydrosulfide	Respiratory organs
13	Dimethyl benzene (mixture of o-, m-, p- isomers)	Respiratory organs; eyes and mucosa; central nervous system
14	Dichloromethane (Methylene chloride)	Central nervous system
15	Copper oxide (recalculated as per copper)	Respiratory organs
16	Methylbenzene	Respiratory organs; central nervous system
17	Nickel (metallic nickel)	Respiratory organs; immune system
18	Nickel oxide	Respiratory organs; immune system
19	Ozone	Respiratory organs
20	Sulfur dioxide	Respiratory organs
21	Sulfuric acid	Respiratory organs
22	Tetrachloroethylene	Respiratory organs; eyes and mucosa
23	Formaldehyde	Respiratory organs; eyes and mucosa
24	Gaseous fluorides	Respiratory organs
25	Chlorine	Respiratory organs
26	Ethanethiol	Respiratory organs

Data on levels of pollutants in ambient air and public health were matched as per a component 'key parameter' that combined the analyzed territory, the number of a control point, and a date when examination (measurement) took place.

The data that were prepared at the first stage were analyzed in dynamics specifically for each chemical measured at control points. The analysis was aimed at identifying events characterized with levels of chemicals being higher than their reference values for acute exposure. In case no reference level was identified for a chemical, we applied single MPL instead. When such events occurred, their dates were fixed in a separate table together with values by which levels of chemicals exceeded the reference ones. A fact of a level being higher than its reference value was considered an exposure factor; a relative number of applications for medical aid during three days after the detected exposure was considered a probable response to it. Based on the results of this dynamic analysis, we drew up an electronic table that included the values by which chemical levels were higher than the reference ones and corresponding numbers of applications for medical aid during three days.

Relationships were modeled as per the results of dynamic analysis using regression analysis techniques and instruments provided by *R-studio* software package. Fixed values by which chemical levels were higher than reference ones were used as independent variables:

$$\Delta x_i\,(T) = x_i\,(T) - x_i^{ARfc}, \qquad (1)$$

where

Δx_i is the excess of the *i*-th chemical level over its reference level for acute exposure;

x_i is the maximum single level of the *i*-th chemical a day;

x_i^{ARfc} is the reference level for acute exposure to the i-th chemical;

T is a date when a level of a chemical was established to be higher than its reference level for acute exposure.

The summated numbers of applications for medical aid were used as dependent variables; they were summated over three days after a chemical level was established to be higher than its reference value for acute exposure for the first time:

$$z(T) = \sum_{t=0}^{2} z_{T+t}\ , \qquad (2)$$

where $z(T)$ is relative frequency of applications for medical aid during three days after a chemical level was established to be higher than its reference value for acute exposure, cases/100,000; z_{T+t} is relative frequency of applications for medical aid on the date $T+t$, cases/100,000.

The modeling itself involved creating models to describe cause-effect relations by using multiple linear regression analysis:

$$z = b_0 + \sum_i b_i\, \Delta x_i\ , \qquad (3)$$

where

z is relative frequency of health disorders, cases/100,000;

Δx_i is the value by which the level of the i-th chemical is higher than its reference level for acute exposure;

b_0, b_i are the model parameters.

We excluded certain chemicals from modeling in case their probable influence on incidence did not have any biological substantiation under acute exposure described in the biological plausibility matrix (Table 2).

Formalization of the relationships as regression models in the form (4) made it possible to quantify frequency of diseases associated with events involving acute exposure to levels of chemicals being higher than reference ones. Levels of associated incidence caused by single acute short-term exposure to chemical pollution in ambient air (Δz) were identified as per the following relationship:

$$\Delta z = \sum_i b_i\, \Delta x_i\ . \qquad (4)$$

Results and discussion. We analyzed levels of chemical pollution in ambient air at the selected control points on all the analyzed territories in dynamics over 2021–2022. As a result, we detected 4.7 thousand time intervals during which there were significant deviations in levels of chemicals from corresponding reference values identified for 26 pollutants.

Figures 2–5 provide typical examples of dynamics identified for levels of some chemicals measured at the selected control points with laboratory instruments. The green horizontal line in Figures 2–5 shows reference levels for acute inhalation exposures (Arfc); the red horizontal line shows maximum single permissible levels (single MPL).

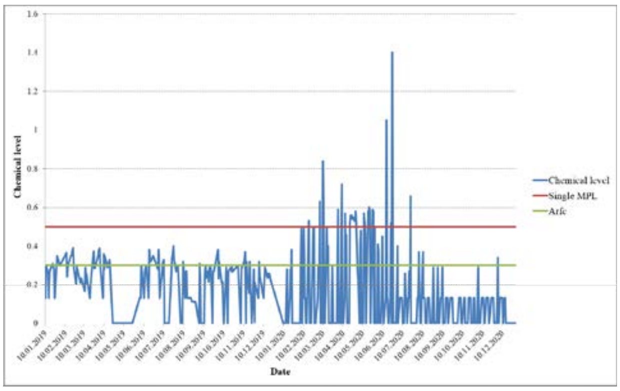

Figure 2. Levels of particulate matter measured at a control point for ambient air quality monitoring, in dynamics

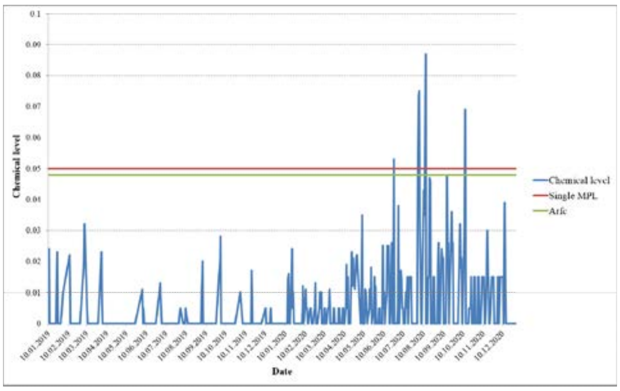

Figure 3. Levels of formaldehyde measured at a control point for ambient air quality monitoring, in dynamics

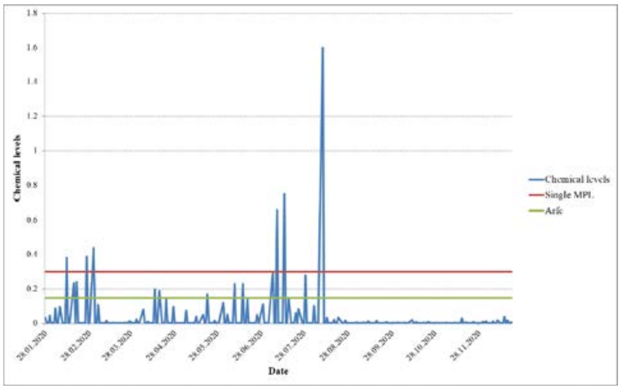

Figure 4. Levels of benzene measured at a control point for ambient air quality monitoring, in dynamics

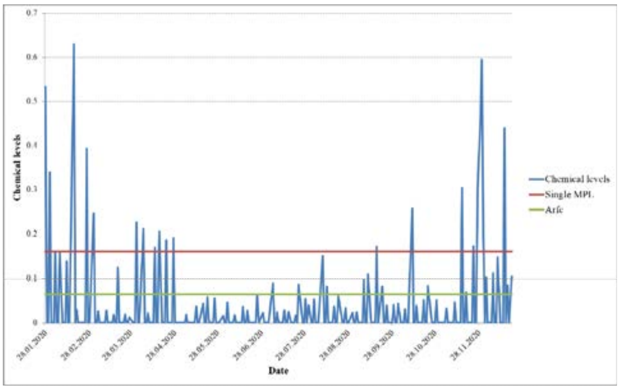

Figure 5. Levels of particulate matter $PM_{2.5}$, measured at a control point for ambient air quality monitoring, in dynamics

The detected events were compared with numbers of applications for medical aid by population living in close proximity to a control point for ambient air quality monitoring during three days after each detected event.

Having created aggregated data arrays on the events and frequency of diseases, we performed regression analysis of relationships between acute reactions represented by applications for medical aid and elevated chemical levels in ambient air. The analysis allowed establishing parameters for 13 multiple regression models presented in Table 3.

Within modeling, the formal relationships were tested to check their conformity with statistical significance; in addition, each model was examined to identify its biological plausibility together with explaining how diseases developed under acute short-term exposure to chemical pollutants.

Relationship modeling revealed that particulate matter produced most significant acute effects on public health. This pollutant is a major reason for growing number of applications for medical aid due to certain respiratory diseases. Multiple studies have reported the dust factor to be one of the most significant as regards both chronic and acute effects on health. Elevated levels of particulate matter in ambient air injure lung tissue and influence the development of non-communicable diseases [11]. PM of < 2.5 μm can cross the alveolar-capillary barrier, traveling to other organs within the body [12], and this can lead to a growing number of applications for medical aid. Thus, for example, growing numbers of applications for medical aid due to exacerbated respiratory diseases were registered in periods with elevated $PM_{2.5}$ levels in ambient air in Russia [13, 14], Taiwan [15], the USA [16, 17] etc.

Some international studies mention a correlation between growing levels of sulfur dioxide in ambient air and elevated risks of respiratory diseases. In particular, it was established that when a sulfur dioxide level grew by 10 $\mu g/m^3$, there was an associated growth in inpatient visits with respiratory diseases among working age people and people of retirement age, especially during a warm season (May – October) [18].

Moreover, profound investigations of comorbidity regularities established that ambient air pollution with benzene and particulate matter induced allergic rhinitis among children. Allergic rhinitis is diagnosed in 87.2 % [19] of preschool children under exposure to polycyclic aromatic hydrocarbons; each third child has bronchial asthma and recurrent bronchitis; respiratory diseases were accompanied with secondary immunodeficiency in 2/3 of the cases. Long-term exposure to $PM_{2.5}$ enhances allergic inflammatory cell expression in the nasal mucosa through increasing the expression of inflammatory cytokine and reducing the release of Treg cytokine [20].

Table 3

Parameters of the models describing relationships between acute reactions represented by applications for medical aid and elevated chemical levels

Age group	Nosology	Chemical factor	Model coefficients		Determination coefficient (R^2)	Model validity ($p < 0.05$)
			b_0	b_i		
Children	Other allergic rhinitis (J30.3)	Benzene	5.111	117.161	0.050	0.000
	Allergic rhinitis, unspecified (J30.4)	Particulate matter	4.045	33.598	0.012	0.031
	Conjunctivitis (H10)	Formaldehyde	9.005	3840.537	0.155	0.000
Working age adults	Chronic rhinitis, naso-pharyngitis and pharyngitis (J31)	Particulate matter	6.167	16.425	0.010	0.045
	Bronchitis, not specified as acute or chronic (J40)	Particulate matter	7.428	24.106	0.018	0.009
	Other allergic rhinitis (J30.3)	Particulate matter $PM_{2.5}$	0.155	5.301	0.014	0.018
	Chronic laryngitis and laryngotracheitis (J37)	Sulfur dioxide	0.768	256.443	0.119	0.000
Adults of retirement age	Predominantly allergic asthma (J45.0)	Benzene	9.932	120.676	0.049	0.000
	Predominantly allergic asthma (J45.0)	Particulate matter	10.597	55.258	0.032	0.000
	Asthma, unspecified (J45.9)	Particulate matter PM_{10}	0.269	11.949	0.013	0.023
	Acute bronchitis, unspecified (J20.9)	Particulate matter $PM_{2.5}$	0.136	4.557	0.010	0.047
	Asthma, unspecified (J45.9)	Particulate matter $PM_{2.5}$	0.211	14.128	0.041	0.000
	Unspecified chronic bronchitis (J42)	Sulfur dioxide	9.638	644.733	0.025	0.002

Table 3 provides the modeling results given as the formal relationships. They correspond to the requirements of statistical significance and biological plausibility. The value of the parameter b_i is interpreted as a value describing the number of disease cases (cases/100 thousand people) occurring under exposure to a level of chemical 1 mg/m^3 higher than its reference value for acute exposure.

We took the model coefficients and the detected values by which identified chemical levels were higher than the reference level at the control points during one calendar year; relying on these data, and in accordance with the relationship (4), we identified the integral estimates of the number of disease cases caused by acute exposure to chemical pollution in ambient air.

We tested how the methodology could be implemented for assessing associated incidence caused by acute short-term exposure to ambient air pollution as per the established relationships provided in Table 3. The assessment relied on data concerning ambient air pollution in 2020.

Table 4 shows the number of cases when chemical levels were higher than their reference values in a large industrial center in 2020; in addition, it provides average values of the detected excesses in chemical levels.

We established parameterized relationships between acute health outcomes and elevated levels of certain chemicals (Table 3). Among them, elevated concentrations higher than reference levels were detected in a large industrial center in 2020 for such pollutants as benzene, particulate matter, particulate matter PM_{10}, $PM_{2.5}$. Thus, elevated benzene levels higher than the reference one were detected up to 37 times per year depending on a monitoring post (the post No. 140) and 17.6 times per year on average in the city. An average value by which a benzene level exceeded its reference value equaled 0.364 mg/m^3 (Table 4).

We tentatively estimated incidence associated with the analyzed factors relying on the established relationships provided in Table 3, the number of cases when chemical levels were higher than their reference value (Table 4) and using the relationship (4). Associated incidence will be different depending on a place of living and exposure conditions; Table 5 provides the average estimates for the analyzed territory.

Thus, the highest associated incidence caused by exposure to benzene in ambient air was detected for such nosologies as 'Other allergic rhinitis' (J30.3) and 'Predominantly allergic asthma' (J45.0) and equaled 751.1 and 773.6 cases per 100, 000 people accordingly.

Table 4

The number of cases when chemical levels were higher than their reference values, average values of the detected excesses in chemical levels at the control points for ambient air monitoring on the analyzed territory

The control point No.	Benzene		Particulate matter		Particulate matter PM_{10}		Particulate matter $PM_{2.5}$	
	The number of peaks over a year	Average value Δx_i (T), mg/m^3	The number of peaks over a year	Average value Δx_i (T), mg/m^3	The number of peaks over a year	Average value Δx_i (T), mg/m^3	The number of peaks over a year	Average value Δx_i (T), mg/m^3
26	22	0.256	5	0.144	27	0.165	80	0.101
28	–	–	–	–	20	0.185	70	0.093
140	37	0.493	9	0.162	20	0.167	71	0.093
158	–	–	–	–	2	0.352	4	0.237
168	–	–	–	–	1	0.013	1	0.094
186	2	0.154	-	-	7	0.158	9	0.190
189	–	–	–	–	–	–	3	0.011
205	–	–	1	0.270	3	0.188	5	0.177
206	2	0.029	–	–	2	0.087	5	0.088
208	–	–	1	0.048	7	0.093	54	0.049
209	25	0.313	19	0.137	42	0.157	93	0.118
210	–	–	1	0.269	5	0.164	48	0.069
Average as per all posts	17.6	0.364	6	0.149	12.364	0.163	36.917	0.095

Table 5

Calculation of associated incidence: an example

Age group	Nosology	Chemical factor	Associated incidence, cases/100,000
Children	Other allergic rhinitis (J30.3)	Benzene	751.1
	Allergic rhinitis, unspecified (J30.4)	Particulate matter	30.1
Working age adults	Chronic rhinitis, nasopharyngitis and pharyngitis (J31)	Particulate matter	14.7
	Bronchitis, not specified as acute or chronic (J40)	Particulate matter	21.6
	Other allergic rhinitis (J30.3)	Particulate matter $PM_{2.5}$	18.7
People of retirement age	Predominantly allergic asthma (J45.0)	Benzene	773.6
	Predominantly allergic asthma (J45.0)	Particulate matter	49.5
	Asthma, unspecified (J45.9)	Particulate matter PM_{10}	24.0
	Acute bronchitis, unspecified (J20.9)	Particulate matter $PM_{2.5}$	16.0
	Asthma, unspecified (J45.9)	Particulate matter $PM_{2.5}$	49.7

To identify the absolute number of disease cases, it is necessary to perform additional calculations that consider a population number in a specific age group exposed to an analyzed factor. To achieve more qualitative estimates, it is necessary to assess spatial distribution of concentrations and a number of exposed people more profoundly. Ideally, we should use maps showing daily dispersal of pollutants over the whole analyzed territory with bound data on population numbers. These issues are possible areas for further research that addresses assessing acute health risks.

Conclusion. Therefore we have formalized the relationships based on system analysis and mathematic modeling; they describe how intensely acute health disorders develop under short-term exposure to elevated levels of chemicals in ambient air higher than their reference values observed at control points. The created models rely on official data and can be used to assess and predict health risks on any territory where ambient air quality is monitored.

The study results presented as methodical approaches and formalized relationships were tested in an actual urban environment; the resulting estimates are quite adequate and correspond to prior risks identified by using conventional methods.

We should point out that the model parameters described in this article can be applied in a wide area and provide an analytical base for identifying and ranking chemical health risks in areas influenced by hazardous chemical objects, estimating probable economic losses, analyzing possible demographic losses, etc.

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