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TAKING INTO ACCOUNT A NUMBER OF CLIMATIC INDICATORS IN ENVIRONMENTAL HEALTH ASSESSMENT OF AMBIENT AIR AND IN HEALTH RISK FORECASTING

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Abstract. The patterns of the influence of climate on the concentration change in the ground-level layer of ambient air were studied. It was shown that for the assessment of results of social and health-related monitoring, it is important to consider the factors affecting the sanitary parameters of air quality and the "behaviour" of air compounds: solubility, changes in the physical and chemical properties chemical reactions, and their absorption by the biosphere. For health risk modelling, the following parameters must be known: the constant circulating part, meteorological and orographic conditions of imbalance between the income and removal (run-off) of the compounds from the atmosphere. The risk arises when the combination of meteorological parameters leads to exceeding critical hazard thresholds for the compound. In the calculations of the emission limits, circulation coefficients for each ingredient emitted into the atmosphere, must be considered separately.

Key words: harmful substances in ambient air, health assessment, climatic characteristics, social and health-related monitoring.

For regulation of the ambient air quality using engineering, architectural and economic decisions, health standards are applied - maximum permissible concentrations for single-time and average daily exposure of harmful substances (SanPiN 2.1.6.1032-01, paragraph 2.1). To prevent the health effects of short-term increase of such concentrations and long-term exposure of the human body (SanPiN (Sanitary Regulations and Standards) 2.1.6.1032-01, paragraph 2.3), as well as for compensation of the damage caused to health (SanPiN (Sanitary Regulations and Standards) 2.1.6.1032-01, paragraph 4.2.8), the monitoring of the atmospheric processes of dispersion, accumulation of critical doses and assessment of the risk events [1, 2].

To improve the Safety and Health Certificates based on the monitoring results and health risk assessments, the calculations for the typical compounds were performed which are shown in the table below: particulate matters (dust), sulfur dioxide (SO₂), carbon monoxide (CO), nitrogen dioxide (NO₂), nitric oxide (NO), phenol (C₆H₅OH), smoke, hydrogen fluoride (HF), ammonia (NH₃), formaldehyde (CH₂O), controlled in the ambient air of Novosibirsk at 11 meteorological sites in 2008.

**Characterization of meteorological parameters and consistent health-related patterns
in assessment of ambient city air pollution and risk prediction**

Parameter	Dust	SO2	CO	NO2	NO	Phenol	Smoke	HF	NH3	CH2O
Proportion of concentrations determined at the levels below the detection limit ("null values"), %	81	44	9	3	4	55	64	59	39	6
Proportion of concentrations determined at the levels of 1 Average daily maximum permissible concentration and lower, %	85	98	95	10	35	65	96	79	76	6
Proportion of concentrations determined at the levels above 1 Average daily maximum permissible concentration but below 10 Average daily maximum permissible concentration, %	15	2	5	90	65	34	4	21	24	70
Proportion of concentrations determined at the levels of 10 or more Average daily maximum permissible concentration, %	0	0	0	0,1	0,02	1,3	0,04	0,3	0,4	24
Maximum registered concentration value in Average daily maximum permissible concentration units	4	3	3	19	13	26	11	13	17	27
Frequency of occurrence during the year 2008 of the maximum values of 10 or more Average daily maximum permissible concentrations per 1000 or 10000 measurements	Cannot be registered			1:10000	2:10000	4:10000	1:10000	1:1000	4:10000	2:10000
Contribution of the air temperature (°C) in the change in the compound concentration in the ambient air during the year. Coefficient of determination, %	2,0 direct	3,7 reverse	0,6 direct	0,5 direct	0,1 reverse	0,5 direct	5,7 reverse	none	0,5 direct	1,9 direct
Contribution of the wind speed (m/s) in the change in the compound concentration in the ambient air during the year. Coefficient of determination, %	none	none	1,8 reverse	0,2 reverse	0,3 reverse	1,2 reverse	0,5 reverse	none	0,4 direct	0,1 reverse
Multiple regression equation according to the monitoring data for 2008 $C \text{ (mg/m}^3\text{)} = K + A Q T \text{ (}^\circ\text{C)} + B V_q \text{ (m/s)}$ (for q = 7, 13 and 19 hours)	K7 = 0,207 A7 = 0,001 B7 = -0,003	K7 = 0,002 A7 = -0,00006 B7 = 0,00003	K7 = 1,895 B7 = -0,069	K7 = 0,124 A7 = 0,0002 B7 = -0,002	K7 = 0,086 B7 = -0,001	K7 = 0,004	K7 = 0,02 A7 = -0,0007 B7 = -0,001	K7 = 0,003	K7 = 0,03	K7 = 0,02 A7 = 0,0001
	K13 = 0,189 A13 = 0,002 B13 = 0,003	K13 = 0,002 A13 = -0,00006 B13 = 0,00003	K13 = 1,747 A13 = 0,01 B13 = -0,027	K13 = 0,116 A13 = 0,0004	K13 = 0,082	K13 = 1,452 A13 = 0,02 B13 = -0,1	K13 = 0,02 A13 = -0,0004	K13 = 0,003	K13 = 0,03 A13 = 0,0003 B13 = 0,001	K13 = 0,02 A13 = 0,0001
	K19 = 0,205 A19 = 0,001	K19 = 0,002 A19 = -0,00005	K19 = 1,911 B19 = -0,047	K19 = 0,122 A19 = 0,0003 B19 = -0,001	K19 = 0,087 B19 = -0,001	K19 = 0,003	K19 = 0,02 A19 = -0,0006 B19 = -0,001	K19 = 0,003	K19 = 0,03 A19 = 0,0003 B19 = 0,002	K19 = 0,02 A19 = 0,0001
Low boiling and melting points, °C		-10 and -75	-191,5 -205,02	+ 21,3 and -11,1	-152 and -163,6	+182 and +43		+19,9 and -87,2	-33,3 and - 77,75	-19 and -92

Pollutant levels below the detection limit ("null values") make arithmetic mean of the whole sample biased. The ambient air quality indicators in populated localities for dust, C₆H₅OH, smoke, SO₂, HF and NH₃ can be analysed as parameters with an asymmetrical distribution, i.e. up to 40% of the samples underestimate the current value. Only for CO, NO₂, NO and CH₂O the statistical assessment of distribution characterizes the health effects.

The arithmetic mean, set for the sanitary and hygienic purposes, may be typical only for a homogeneous sample. For the purposes of ambient air hygiene, the representative mean value can be set only for values not exceeding the standards values of the Average daily maximum permissible concentration. This determination range includes the values for dust, smoke, SO₂, CO, HF, and NH₃.

The second homogeneous sample includes the measurements indicating the exceeded the Average daily maximum permissible concentration, but not beyond the toxicological parameter of 10×Average daily maximum permissible concentrations. This determination range includes the values for NO₂, NO, and CH₂O.

The third sample, based on threshold principles and on measurements exceeding 10×Average daily maximum permissible concentrations, may indicate non-specific clinical effects. This level of prediction of the negative effect on human health can be attributed to CH₂O (24 % of samples with over 10×Average daily maximum permissible concentration), C₆H₅OH (1.3), NH₃ (0.4), HF (0.3), NO₂ (0.1), smoke (0.04) and NO (0.02).

Maximum concentrations of compounds indicate a non-calculable combination of meteorological parameters, which results in such conditions in the city which impose an expressed and significant risk to human health. It was found that the greatest hazard is formed by the following compounds: CH₂O with the highest concentrations of about 27× Average daily maximum permissible concentration and the frequency of occurrence during the year comprising 2 cases per 10 thousand measurements; C₆H₅OH with the highest concentrations of about 26×Average daily maximum permissible concentration and the frequency of occurrence during the year comprising 4 cases per 10 thousand measurements; NO₂ - about 19×Average daily maximum permissible concentration, 1 case per 10 thousand measurements; NH₃ - about 17× Average daily maximum permissible concentration, 4 cases per 10 thousand measurements; HF - about 13×Average daily maximum permissible concentration, 1 case per 1 thousand measurements; NO - about 13×Average daily maximum permissible concentration, 2 cases per 10 thousand measurements; smoke – about 11×Average daily maximum permissible concentration, 1 case per 10 thousand measurements. For dust, SO₂ and CO the maximum value registered during 2008 did not

exceed $5 \times$ Average daily maximum permissible concentration.

According to measurements of the compounds during 2008, the contribution of the ambient air temperature and the speed of the air masses are negligible and multidirectional. The coefficient of determination for the temperature reflects its influence on the concentration and comprises: for smoke – 5.7%; for SO₂ – 3.7 %, for dust – 2.0 %, and for CH₂O – 1.9%. Coefficient of determination for the wind speed in the air reflects the influence of the concentration of CO – 1.8% and of C₆H₅OH – 1.2%.

Meteorological processes are characterized by the following extent: during the 24 h – with the alternation of day and night, as the four seasons - with severe temperature variations, different types of precipitation, wind direction and formation of inversions. Together, these patterns have an annual cyclicity with environmental variability and solar-terrestrial relationships lasting over many years. For the assessment of daily fluctuations of compound concentrations, the multiple regression equation was calculated

$$C \text{ (mg/m}^3\text{)} = K + A_q T \text{ (}^\circ\text{C)} + B V_q \text{ (m/s)} \text{ (for } q = 7, 13 \text{ and } 19 \text{ hours).}$$

The K value (constant term of the equation) at the temperature and speed equal to zero, indicates the presence in the ambient air of the "constant" concentration, maintained due to natural and anthropogenic processes of income and meteorological processes of removal. The K-value, as an indicator of the average level of pollution, does not depend on a sampling time during the day for dust, SO₂, NO, smoke, HF, NH₃, and CH₂O. Coefficient values for the parameters of temperature and wind in the multiple regression equation reflect the processes of income and removal of compounds from the atmosphere.

An independent equation coefficient (K) in the morning and in the evening time was 0.2 and was equal to the median, mode and the arithmetic mean of statistical distribution of dust content in the ambient air of Novosibirsk in 2008. At noon, K value decreased due to the effect of temperature (T) and wind (V) resulting from increased solar activity. In the morning the wind effect on the concentrations of dust in the ground-level layer were converse, and in the evening - multidirectional. The content of suspended substances in winter were at the level of 0.1 mg/m (mode), and in other seasons - 0.2.

The income and removal of dust from the atmosphere does not disturbed the established pollution balance on K. Autumn is the season associated with health risk due to a sharp increase in dust concentrations up to $4 \times$ Average daily maximum permissible concentrations.

The calculated atmospheric lifetime of SO₂ [3, 4] is 4-5 days and, to our knowledge, the concentration of SO₂ in the atmosphere of Novosibirsk is 0.002 mg/m³. Oxidation to

sulfates by ozone or after absorption by solid or liquid aerosols leads to a decrease in concentration, and mostly after coal and oil burning - to its recovery. When predicting the risk, in addition to ecological processes, the change of the aggregate state of SO₂ must be taken into account, which occurs at air temperature of -10 °C. Thus, SO₂ in a gaseous form leads to pollution levels ranging from 0.0 to 0.03 g/m³ with the arithmetic mean of 0.0012. At the atmospheric air temperature below the SO₂boiling point, pollution levels are rising and are in the range of 0.0 to 0.172 mg/m³, with the arithmetic mean of 0.0036.

The calculated atmospheric lifetime of NO, the same as NO₂ [3, 4], is 5 days. Oxidation to nitrates after absorption by solid or liquid aerosols, and the photochemical reaction with hydrocarbons facilitate the removal of a compound from the atmosphere. The change of the aggregation state takes place at a temperature below the maximum registered in 2008 (-31 °C).

HF changes its aggregate state from gaseous to liquid at +19.9 °C and from liquid to solid at -87.2 °C. The content of HF in the gaseous state is not described by a multiple regression equation, while the HF content in the ambient air in the liquid state at temperatures below 19 °C is described by a multiple regression equation- where K is the only significant value equal to 0.0032.

The calculated atmospheric lifetime of NH₃ [3, 4] is 7 days. The removal of NH₃ occurs following the reaction with SO₂ with the formation of (NH₄)₂SO₄, oxidation to nitrates. The NH₃ solubility in atmospheric moisture is the highest among the compounds of interest (62.9 g per 100 g water). NH₃ changes its aggregate state from gaseous to liquid at -33,3°C and from liquid to solid at -77.2°C, which is below the minimum temperature registered in 2008 (-31 °C).

The CH₂O aggregate state changes from liquid to gas at -19.9 °C and from liquid to solid at -92 °C. The CH₂O content in the gaseous state is described by the multiple regression equation

$$C_{\text{CH}_2\text{O}} = 0.0218 + 0.00009 T.$$

The CH₂O content in the liquid state is described by the multiple regression equation

$$C_{\text{CH}_2\text{O}} = 0.0224 - 0.0012 V.$$

The K-value fluctuations during the day for CO, NO₂ and C₆H₅OH reflect the following ecological patterns.

The calculated atmospheric lifetime of CO [3, 4] is 0.3-3 years, which results from atmospheric circulation, as well as from soil processes and plant absorption. The proportion

of zero samples according to concentrations of CO is the highest (about half of all samples) in autumn. The arithmetic means, median and mode of concentration do not exceed 1.2 mg/m³, and the maximum detected concentrations are not higher than 5 mg/m³. In winter, the proportion of zero samples is reduced down to 36.7%, in spring - to 13.2 %, and in summer - to 4.5%. Accordingly, the arithmetic means for pollution indexes grow, but the maximum concentrations were determined only in winter. These patterns reflect the biospheric processes of absorption of carbon oxides at K-values from 1.7 to 1.9. Among all the controlled compounds CO is characterized by the lowest solubility in water which is 0.00284 grams per 100 grams of water.

The calculated atmospheric lifetime of NO₂, as well as NO [3, 4] is 5 days. Oxidation to nitrate after absorption by solid and liquid aerosols, and the photochemical reaction with hydrocarbons facilitates the removal of the compound from the atmosphere.

Up to the temperature of -11.1 °C NO₂ maintains the solid state. Its concentration in such aggregation state is described by the multiple regression equation

$$C_{\text{NO}_2} = 0.194 + 0.0033 T - 0.0044 V.$$

In the temperature range from -11.1 °C to +20.7 °C NO₂ is present in a liquid state, with the concentration described by the following equation:

$$C_{\text{NO}_2} = 0.115 + 0.0008 T.$$

In the temperature range above +20.7 °C it is present in a gaseous state, with the concentration described by the following equation:

$$C_{\text{NO}_2} = 0.114 + 0.0018 V.$$

Among all of the controlled compounds, NO₂ is characterized by a low solubility in water – 0.00618 g per 100 g water.

C₆H₅OH changes its aggregate state from gaseous to liquid at +188.7 °C and from liquid to solid at +40.9 °C. The aggregate state change occurs at the temperature which is above the highest registered in 2008 (+36 °C). Concentration fluctuations during the day can be caused by anthropogenic factors.

The solar activity changes the aggregation state of the compounds and contributes to physical and chemical reactions in the atmosphere. The income of the compounds into the atmosphere and their removal (run-off) leads to circulation of the compounds in the ambient air for some time and generation of long-term (chronic) effects on the human body. Meteorological measurements do not always reflect human sanitary living conditions. High concentrations of compounds in the ambient air cannot be determined with simple and

accessible meteorological parameters (such as air temperature and wind speed).

For assessment of the results of social and health-related monitoring, it is important to consider the factors affecting sanitary air quality indicators and the “behaviour” of air compounds: solubility, changes in physical and chemical properties, chemical reactions, and absorption of the compounds by the biosphere.

For health risk modelling, the following parameters must be known: the constant circulating part, meteorological and orographic conditions of imbalance between the income and removal (run-off) of the compounds from the atmosphere. The risk arises from the combination of meteorological parameters that lead to exceeding the critical hazard thresholds for a compound.

For calculations of emission limits according to the OND-86 procedure, the circulation coefficients must be known for each of the compounds emitted into the atmosphere, individually.

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