Criteria of urban air quality for carcinogenic substances

Ekaterina N. Bel'skaya[1], Ulyana S. Ivanova[2], Olga V. Taseiko[1,2]

[1]Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, Russian Federation, ketrin_nii@mail.ru
[2]Institute of Computational Technologies SB RAS, Krasnoyarsk, Russian Federation, taseiko@gmail.com

Abstract. A quantitative assessment of human health risk is carried out, at influence of carcinogenic chemicals with using their annual concentrations. The calculated values of air quality standards for priority carcinogenic substances are offered to different categories of the population.

Keywords:urban air pollution, risk assessment, air quality standards, carcinogenic substances.

Environmental pollution is one of the significant factors contributing to poor health and high mortality [1-3]. About 50% of the population lives in ecologically unfavorable regions in Russia, and air pollution causes up to 17.5% of the total mortality of the urban population [1.4]. In European cities, polluted air causes up to 23 thousand additional deaths per year [5].

To the air quality assessment in Russian cities today uses hygienic standards. In the Russian Federation, more than 1000 AQS (air quality standards) have been approved and this is the most extensive of the existing national air quality standardization systems [6]. The system of criteria that determines the safe state of the environment, including AQS, is imperfect and does not allow determining the measure of human exposure and damage to public health if the established standards are exceeded [7]. An alternative to the AQS concept is a risk assessment system. A number of parameters are introduced for risk assessment - risk markers, which make it possible to assess the danger of toxic symptoms with short-term, long-term or chronic effect (exposure) of certain pollution levels (concentration of pollutants) for different population groups.

According to the "Guidelines for assessing the risk to public health under the influence of chemicals polluting the environment. R 2.1.10.1920-04" (approved by the Chief State Sanitary Doctor of the Russian Federation 05.03.2004) [8] the assessment of the risk to human health is a quantitative and / or a qualitative description of the harmful effects that can develop as a result of the influence of environmental factors on a specific group of people under specific exposure conditions.

Currently, the concept of risk assessment in all countries of the world and international organizations is considered as the main mechanism for the development and adoption of managerial decisions both at the international, state or regional levels, and at the level of an individual production or other potential source of environmental pollution [8]. Despite the obvious advantages of the risk assessment methodology, which allows one to take into account, among other things, non threshold of the effects of carcinogenic substances on public health, it is difficult to manage the use of maximum permissible concentrations when implementing programs for monitoring air quality in settlements. Therefore, there is a need to take into account health risks when determining the levels of hygiene AQS.

The following tasks were solved in the work:

- on the example of some cities of the Siberian Federal District, air quality standards were calculated based on the concept of a methodology for assessing inhalation risk to public health using actual average annual concentrations of priority harmful substances with a carcinogenic effect;
- proposed AQSs for priority carcinogenic substances are proposed taking into account acceptable risk levels for different categories of the population.

The actual average annual concentrations of priority carcinogens used in the calculation of individual carcinogenic risk in the cities of Krasnoyarsk, Kemerovo, Omsk and Chernogorsk were obtained from air pollution monitoring posts of the Middle Siberian, West Siberian and Ob-Irtysh UGMS and the Federal Service for Hydrometeorology and Environmental Monitoring [10] for 2008-2018, and from the posts for monitoring atmospheric pollution by the Khakass center for hydrometeorology and monitoring of a branch of the FSBI Srednesibirsky UGMS for 2010-2017.

Figure 1 shows the dynamics of the average annual concentrations of benzo(a)pyrene and formaldehyde for 2010-2017 for four cities in the Siberian Federal District.

The highest content of benzo(a)pyrene is observed in the cities of Krasnoyarsk and Chernogorsk (Republic of Khakassia), the highest formaldehyde content in Krasnoyarsk and Kemerovo. Moreover, in all cities examined, the content of these substances exceeds the annual air quality standards of populated areas.

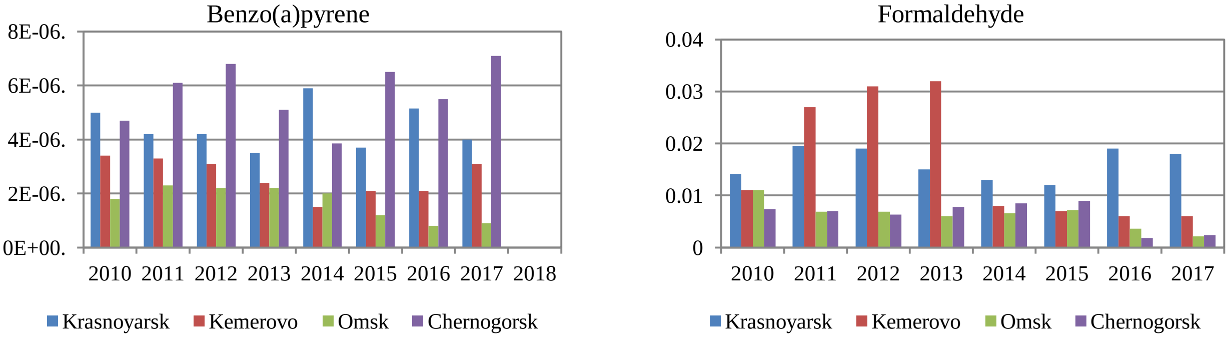

Figure 1. Average annual concentrations of benzo(a)pyrene and formaldehyde in some cities of the Siberian Federal District

Unit risk, according to [8], is calculated according to formula 1, using the values of carcinogenic potential factors *SF* and standard values of a person's body weight (BW=70 kg), daily air consumption (DAC=20 m^3 / day).

$$UR_i = SF_i \cdot \frac{1}{BW} \cdot DAC = SF_i \cdot \frac{1}{70} \cdot 20 \qquad (1)$$

Calculation of individual carcinogenic risk is carried out according to formula 2, using data on the magnitude of exposure and values of a single risk. As a rule, for carcinogenic chemicals, the additional likelihood of developing an individual cancerogenic risk throughout life (ICR) is estimated using a unit risk (UR) value as follows:

$$ICR = C \cdot UR, \qquad (2)$$

where C is the average concentration of the substance in the studied environmental object for the entire period of exposure averaging (air, mg / m^3); UR - single risk for air (risk per 1 mg / m^3).

Table 1 shows the results of the calculation of ICR by averaged average annual concentrations of carcinogenic chemicals.

Table 1. Individual cancerogenic risk

year/ substance	Krasnoyarsk					Kemerovo		
	Benzo(a) pyrene	Formaldehyde	Lead	Ethylbenzene	Benzene	Benzo(a) pyrene	Formaldehyde	Aniline
2010	**$5,57\cdot10^{-6}$**	$1,83\cdot10^{-4}$	**$1,44\cdot10^{-6}$**	$1,80\cdot10^{-5}$	$2,08\cdot10^{-4}$	**$3,79\cdot10^{-6}$**	$1,43\cdot10^{-4}$	<$1,6\cdot10^{-3}$
2011	**$4,68\cdot10^{-6}$**	$2,54\cdot10^{-4}$	**$2,04\cdot10^{-6}$**	$1,70\cdot10^{-5}$	$1,84\cdot10^{-4}$	**$4,29\cdot10^{-6}$**	$3,15\cdot10^{-4}$	<$1,6\cdot10^{-3}$
2012	**$4,68\cdot10^{-6}$**	$2,47\cdot10^{-4}$	**$2,04\cdot10^{-6}$**	$1,70\cdot10^{-5}$	$2,32\cdot10^{-4}$	**$3,45\cdot10^{-6}$**	$4,03\cdot10^{-4}$	$1,6\cdot10^{-3}$
2013	**$3,90\cdot10^{-6}$**	$1,95\cdot10^{-4}$	-	$1,70\cdot10^{-5}$	$2,72\cdot10^{-4}$	**$2,67\cdot10^{-6}$**	$4,16\cdot10^{-4}$	<$1,6\cdot10^{-3}$
2014	**$6,57\cdot10^{-6}$**	$1,59\cdot10^{-4}$	-	$1,40\cdot10^{-5}$	$1,68\cdot10^{-4}$	**$1,67\cdot10^{-6}$**	$1,04\cdot10^{-4}$	$1,6\cdot10^{-3}$
2015	**$4,12\cdot10^{-6}$**	$1,56\cdot10^{-4}$	-	**$7,00\cdot10^{-6}$**	$1,92\cdot10^{-4}$	**$2,34\cdot10^{-6}$**	$0,91\cdot10^{-4}$	<$1,6\cdot10^{-3}$
2016	**$5,74\cdot10^{-6}$**	$2,47\cdot10^{-4}$	-	**$3,00\cdot10^{-6}$**	$9,60\cdot10^{-5}$	**$2,34\cdot10^{-6}$**	$0,78\cdot10^{-4}$	$1,6\cdot10^{-3}$
2017	**$4,64\cdot10^{-6}$**	$2,34\cdot10^{-4}$	-	-	-	**$3,45\cdot10^{-6}$**	$0,78\cdot10^{-4}$	$1,60\cdot10^{-3}$
2018	-	-	-	-	-	**$3,79\cdot10^{-6}$**	$0,78\cdot10^{-4}$	0
year/ subst.	Chernogorsk				Omsk			
	Benzo(a)pyrene		Formaldehyde		Benzo(a)pyrene		Formaldehyde	

2008	**$5{,}24 \cdot 10^{-6}$**	$9{,}62 \cdot 10^{-5}$	**$2{,}01 \cdot 10^{-6}$**	$1{,}43 \cdot 10^{-4}$
2009	**$6{,}80 \cdot 10^{-6}$**	$9{,}10 \cdot 10^{-5}$	**$2{,}56 \cdot 10^{-6}$**	$8{,}97 \cdot 10^{-5}$
2010	**$7{,}58 \cdot 10^{-6}$**	$8{,}19 \cdot 10^{-5}$	**$2{,}45 \cdot 10^{-6}$**	$8{,}97 \cdot 10^{-5}$
2011	**$5{,}68 \cdot 10^{-6}$**	$1{,}01 \cdot 10^{-4}$	**$2{,}45 \cdot 10^{-6}$**	$7{,}80 \cdot 10^{-5}$
2012	**$4{,}29 \cdot 10^{-6}$**	$1{,}11 \cdot 10^{-4}$	**$2{,}23 \cdot 10^{-6}$**	$8{,}58 \cdot 10^{-5}$
2013	**-**	$1{,}17 \cdot 10^{-4}$	**$1{,}34 \cdot 10^{-6}$**	$9{,}36 \cdot 10^{-5}$
2015	**$6{,}50 \cdot 10^{-6}$**	**-**	**-**	**-**
2016	**$6{,}13 \cdot 10^{-6}$**	$2{,}34 \cdot 10^{-5}$	**$8{,}91 \cdot 10^{-7}$**	$4{,}68 \cdot 10^{-5}$
2017	**$7{,}91 \cdot 10^{-6}$**	$3{,}12 \cdot 10^{-5}$	**$1{,}00 \cdot 10^{-7}$**	$2{,}73 \cdot 10^{-5}$

Note: «-» no data; the allocated risk values exceed the level of acceptable risk for the population.

An individual risk of developing carcinogenic effects is considered acceptable if its values do not exceed 10^{-6} year^{-1} for the population (one victim per million people) [8] and for professional groups from 10^{-4} year^{-1} (for functioning facilities) to 10^{-5} year^{-1} (for newly constructed facilities) [9].

The risk to public health from inhalation exposure, exceeding an acceptable level, is formed under the influence of benzo(a)pyrene, ethylbenzene and lead in all considered cities of the Siberian Federal District. In general, for the same substances, the levels of individual carcinogenic risks in different cities differ insignificantly.

Given the levels of acceptable individual risk of carcinogenic effects of 10^{-6} year^{-1} for the population and 10^{-4} year^{-1} for professional groups, a ratio of 3 was obtained to determine the AQS of the above substances:

$$AQS_{calculated} = ICR \cdot \frac{BW}{SF \cdot DAC} \quad (3)$$

The calculation results of the $AQS_{calculated}$ are given in table 2.

Table 2.Information on hazard indicators of cancerogenic effects and threshold concentrations [8, 10, 11]

Substance/ indicator	Benz(a)pyrene	Formaldehyde	Lead	Ethylben-zene	Benzene	Aniline
IARC	2A	2A	2A	2B	1	3
EPA	B2	B1	B2	D	A	B2
Carcinogenic potencial factor (inhalation) *SFi*, ((kg ·day) / mg)$^{-1}$	3,9	$4{,}6 \cdot 10^{-2}$	$4{,}2 \cdot 10^{-2}$	$3{,}9 \cdot 10^{-3}$	$2{,}7 \cdot 10^{-2}$	$5{,}7 \cdot 10^{-3}$
Single risk (inhalation) URi (m^3/mg)	1,114	$1{,}3 \cdot 10^{-2}$	$1{,}2 \cdot 10^{-2}$	$1{,}0 \cdot 10^{-3}$	$8{,}0 \cdot 10^{-3}$	$1{,}6 \cdot 10^{-2}$
Hazardclass	1	2	1	3	2	2
AQS (daily average) (mg / m^3)	$1{,}0 \cdot 10^{-6}$	$3{,}0 \cdot 10^{-3}$	$3{,}0 \cdot 10^{-4}$	$2{,}0 \cdot 10^{-3}$	0,1	$3{,}0 \cdot 10^{-2}$
AQS (maximal-times), (mg/m^3)	-	$3{,}5 \cdot 10^{-2}$	$1{,}0 \cdot 10^{-3}$	$4{,}0 \cdot 10^{-2}$	0,3	$5{,}0 \cdot 10^{-2}$
Reference concentrations for chronic inhalation exposure (mg/kg)	$1{,}0 \cdot 10^{-6}$	$3{,}0 \cdot 10^{-3}$	$5{,}0 \cdot 10^{-4}$	1	$3{,}0 \cdot 10^{-2}$	$1{,}0 \cdot 10^{-3}$
$AQS_{calculated}$ for the population (mg/m^3)	$8{,}97 \cdot 10^{-7}$	$7{,}61 \cdot 10^{-5}$	$8{,}3 \cdot 10^{-5}$	$9{,}1 \cdot 10^{-4}$	$1{,}3 \cdot 10^{-4}$	$6{,}1 \cdot 10^{-4}$
$AQS_{calculated}$						

for professional groups (mg/m^3)	$8{,}97 \cdot 10^{-5}$	$7{,}61 \cdot 10^{-3}$	$8{,}3 \cdot 10^{-3}$	$9{,}1 \cdot 10^{-2}$	$1{,}3 \cdot 10^{-2}$	$6{,}1 \cdot 10^{-2}$

Note:
classifications of agents using IARC – International Agency for Research on Cancer
- Group 1 –The agent is carcinogenic to humans, Group 2A – The agent is probably carcinogenic to humans, Group 2B – The agent is possibly carcinogenic to humans, Group 3: The agent is not classifiable as to its carcinogenicity to humans.

Standard US EPA Cancer Classification:
- Group A: "Human Carcinogen", Group B1: "Probable Human Carcinogen", Group B2: "Probable Human Carcinogen", Group D: "Not Classifiable as to Human Carcinogenicity"

SFi-carcinogenic potency slope(mg/kg/day);
URi -unit inhalation risk for 1 mg/ m^3.

Table 2 shows the main hazard indicators for the development of carcinogenic effects - information established by various hygienic regulatory documents: a single risk for the inhalation route of intake, daily and maximum single doses, reference concentrations for the above substances, and also established revised AQS values for the population and professional groups, taking into account the acceptability of the risk.

The standards for the content of pollutants in the air, taking into account their impact on public health, determined in accordance with the methodology for assessing public health risks, are less than the AQS established for the relevant substances by 1-3 orders of magnitude. The greatest difference between the current AQS level and the calculated one, based on the direct effect of the substance on human health, was revealed for benzene. At the same time, benzene is one of the priority substances in the study of the environmental impact on public health. Underestimation of the levels of urban air pollution by this substance can lead to an increase in the number of pathological conditions associated with its effect, such as blood diseases and cancer [12].

Another difference of the proposed standards from the current AQSs is that the maximum permissible concentrations used in our country are not always justified by the effects directly related to health: 53% of the AQS for water bodies (maximum permissible concentration) are based on the organoleptic sign of harmfulness and 20% - according to the general sanitary indicator; 30% of the AQS of populated areas is established by human reflex reactions [13]. While the risk assessment used in this approach is based solely on criteria reflecting the direct impact of chemicals on the health of the most sensitive populations. In addition, the regulated AQSs refer to the average daily standards, while the proposed standards are average annual standards.

A comparison of the proposed standards for average annual maximum permissible concentration with the observed level of pollution in industrial centers of Siberia shows a significant excess of the main indicators of the carcinogenic hazard of atmospheric air for public health, such as benzo(a)pyrene, formaldehyde, lead, benzene and ethylbenzene.

In the course of further studies, the calculated average annual AQS standards will be determined taking into account the real effect of pollution on public health for other substances of a carcinogenic and non-carcinogenic effect that enter the human body not only by inhalation, but also by oral route. In addition, the proposed approach can be used to revise the industrial exhaust standards and clarify the amount of damage associated with the effects of air pollution on public health.

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