IOP Conf. Series: Materials Science and Engineering **262** (2017) 012209 doi:10.1088/1757-899X/262/1/012209

Assessment of Inhalation Risk to Public Health in the Southern Ural

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Abstract. A large number of iron and steel companies in the Southern Ural cause severe air pollution in the towns of Karabash (Chelyabinsk region), Sibay (Republic of Bashkortostan), Gai (Orenburg region). The article aims to assess the inhalation effects of hazardous substances on the Southern Ural population. The analysis focused on cancer and non-cancer risks to public health that arise from the surface air pollution caused by the metallurgical industry emissions. The assessment was carried out on the basis of methodological guidelines R 2.1.10.1920-04 using modern sanitary and hygienic standards. We analysed the level of ambient air pollution in the impact area of the metallurgical industry of Karabash, Sibay and Gai over the past eleven years. We established that the ambient air of all the studied towns contain carcinogenic substances that cause unacceptable cancer risks. Formaldehyde has the main share in this risk. We calculated the hazard quotients HQ for the identified priority pollutants and the total hazard indices HI. It is shown that the non-cancer inhalation risk to the Southern Ural population exceeds the safe level manyfold. Sulfur dioxide has the main share in this risk. The conducted assessment showed that in 2006-2016, there was a continuous inhalation exposure of the population to hazardous substances. Sanitary and technological solutions that will allow a reduction of risk to acceptable values are required.

1. Introduction

It is common knowledge that an adverse ecological situation can develop in the area of large industrial centers. The region of Southern Ural belongs to such kind of areas. The region comprises three federal subjects that have common borders. A large number of enterprises of non-ferrous and ferrous metallurgy are concentrated here. The town of Gai in Orenburg region has the ore mining and processing enterprise OJSC “Gaisky gorno-obogatitelny kombinat” (Gaisky GOK), the town of Karabash in Chelyabinsk region has the copper smelting plant CJSC “Karabashmed”, the town of Sibay in the Republic of Bashkortostan has the copper and sulfur industrial complex OJSC “Bashkirsky medno-serny kombinat”.

According to Russian Federal State Statistics Service, as of 2015, the population of Karabash urban district was more than 11.8 thousand residents, and that of Sibay district and Gai municipal district was 63.3 thousand and over 9.4 thousand respectively. The total number of residents that live in these cities and are constantly exposed to the inhalation effects of industrial emissions is more than 84 thousand people.

Therefore, the urgent task is to assess the health risks to the population living in the area of emissions of ferrous and non-ferrous metallurgy. The concept of risk assessment is now almost universally regarded as the main means to develop and adopt managerial decisions both at the international, national or regional level, and at the level of a particular enterprise [1-20]. This work aims to assess the inhalation risk to the public health in Southern Ural, namely, in the towns of Gai, Karabash and Sibay.

2. Materials and methods

A large number of iron and steel companies account for the high level of ambient air pollution in the industrial cities of Southern Ural. Table 1 shows the priority pollutants of the atmosphere [1], whose average annual concentrations exceeded the TLV level over the last eleven years [2].

Table 1. Average annual concentrations of the priority pollutants in the ambient air in 2006-2016.

№ CAS	Substance	Average concentration of the pollutant in the air ± standard deviation, mg/m^3		
		Karabash	Sibay	Gai
10102-43-109	Nitrogen oxide	1,70±0,58	0,05±0,01	1,24±0,34
10102-44-0	Nitrogen dioxide	0,107±0,064	0,103± 0,048	0,119± 0,027
7446-09-5	Sulfur dioxide	61,0±18,0	53,2± 7,4	32,7±7,3
7783-06-4	Hydrogen sulfide	0,010±0,012	0,012± 0,005	0,010± 0,005
7664-41-7	Ammonia	0,33± 0,31	0,18± 0,06	0,17±0,06
1314-13-2	Zinc oxide	0,24±0,06	0,11± 0,05	0,14±0,05
7664-93-9	Sulfuric acid	0,77± 0,27	0,45±0,28	0,56±0,21
50-00-0	Formaldehyde	0,042±0,035	0,012±0,005	0,035±0,029
50-32-8	Benzpyrene	$135\cdot10^{-6} \pm41\cdot10^{-6}$	$51\cdot10^{-6} \pm31\cdot10^{-6}$	$2,4\cdot10^{-6}\pm0,5\cdot10^{-6}$

According to official information, a very high level of pollution in the cities of Southern Ural is caused by the content of sulfur dioxide in the atmosphere. The average annual concentration of this substance in the ambient air exceeded the TLV manyfold every year over the past eleven years.

The most adverse conditions for public health in 2006-2016 were observed in Karabash. Apart from sulfur dioxide, its population was annually exposed to a negative inhalation effect of such compounds as nitrogen oxide (2.2-6.7 of TLV for the maximum onetime intake) and sulfuric acid (1.6-4.3 of TLV for the maximum onetime intake). And in some years, there was an exposure to ammonia (in 63% of cases) and hydrogen sulfide (in 2014-2016). Average annual concentrations of ammonia were registered at the level of 1.3-5.5 of TLV for the maximum onetime intake, and those of hydrogen sulfide - at a level of 1.5-3.8 of TLV for the maximum onetime intake.

Average daily concentrations of formaldehyde, benzpyrene, nitrogen dioxide, hydrogen sulfide and zinc oxide in the ambient air of Southern Ural exceeded the level of TLV almost every year.

To assess the public health risks under the conditions of acute and chronic inhalation exposure to atmospheric pollutants, we used the methods R 2.1.10.1920-04 “Guidelines for the assessment of public health risk from exposure to environmental pollutants” (2004) [3]. The analysis focused on cancer and non-cancer risks to health of adult working-age population that arise from surface air pollution in Southern Ural, namely, in the towns of Karabash, Gai and Sibay.

The existing assessment methods allow us to identify the relative contribution of particular environmental pollutants, which is an important aspect in planning risk management activities.

3. Results and discussions

Although a comprehensive assessment of health risks from all potentially hazardous substances is required, it is not feasible due to a large scope of research. Therefore, the compounds presented in

Table 1 were identified as the priority ones, which best characterize the real risks to public health in the impact area.

In Guidelines R 2.1.10.1920-04, all health risks that arise from the exposure to chemicals are classified according to their carcinogenic and non-carcinogenic effects. The risk factors for carcinogenic and non-carcinogenic effects are assessed separately and are not combined.

3.1. Cancer risks to public health

In accordance with Guidelines R 2.1.3.1920-04 [3], benzpyrene and formaldehyde are hazardous substances (from the list presented in Table 1) that produce a carcinogenic effect when inhaled. These compounds are inhaled simultaneously. When there is a combined effect of several chemical compounds, a cancer risk is regarded as additive (the effect of total exposure to the substances is equal to the total of the effects). Therefore, at the initial stage, the risk of the separate effect of each compound was calculated, and then it was summarized (Table 2).

When assessing cancer risks, lifetime average daily doses of a chemical intake (LADD), individual (CR) and population-based cancer risks (PCR) are calculated. Population-based cancer risks (PCR) reflect an additional (to the background) number of cases of malignant tumors that can originate in a lifetime due to the effect of the factor under analysis [3].

Table 2. Total magnitude of the cancer risk to public health (2006-2016).

Indices	Karabash	Sibay	Gai
Individual cancer risk (CR)	$6{,}6 \cdot 10^{-4}$	$2{,}0\cdot 10^{-4}$	$4{,}3 \cdot 10^{-4}$
Population-based cancer risk (PCR)	7,8	12,7	4,0

When characterizing a risk to public health, it is customary to focus on the system of risk acceptance criteria [3]. In accordance with these criteria, the individual cancer risk in the towns of Southern Ural refers to the third range of risk (individual risk during a lifetime is more than $1{\cdot}10^{-4}$, but less than $1{\cdot}10^{-3}$). This level of risk is acceptable only for professional groups and is unacceptable for the general population. Thus, although the population is small, the population-based cancer risk can make up from 4 to 13 additional (to the background) cases of malignant tumors that can originate during a lifetime (70 years). The current situation requires the development and implementation of systematic diagnostic and sanitary measures.

3.2. Non-cancer risks to public health

The assessment of non-cancer risks to public health from inhalation exposure to hazardous substances is carried out on the basis of calculating the hazard quotient HQ (Hazarad Quotient), which is defined as the ratio of the actual concentration of a pollutant in the air to its reference concentration. Information on the recommended values for the acute (ARfC) and chronic (RfC) reference concentration levels of inhalation exposure are given in the Guidelines [3].

If HQ <1, there is no hazard and risk to health. However, if HQ> 1, there is a risk of disease or poisoning, which increases the more the higher HQ exceeds 1.

The hazard index (HI) for the simultaneous intake of several substances by the same route is defined as the total of the hazard quotients for the separate components of the mixture (ΣHQi).

The calculation results of hazard quotients at inhalation exposure to toxic substances are shown in Tables 3-5.

The analysis of the obtained data indicates that the highest values of the calculated hazard quotients were obtained for the inhalation exposure to sulfur dioxide. In all cities and towns of Southern Ural, they exceed the safe level manyfold. This situation is exacerbated by the combined effects of other compounds, which leads to a high probability of massive acute inhalation poisoning and development of chronic diseases among the urban population.

Table 3. Hazard quotients (HQ) to public health at acute inhalation exposure to toxic substances in 2006-2016.

Substance	Karabash	Gai	Sibay
Sulfur dioxide	92,0±28,1	49,5±11,0	80,6±11,2
Sulfuric acid	7,7±2,5	5,6±2,2	4,5±2,7
Nitrogen (II) dioxide	2,4±0,8	**1,7±0,5**	**0,8±0,2**

Table 4. Hazard quotients (HQ) to public health at chronic inhalation exposure to toxic substances in 2006-2016

Substance	Karabash	Gai	Sibay
Nitrogen dioxide	2,8±1,5	3,0±0,7	2,6±1,2
Hydrogen sulfide	3,6±4,4	5,2±2,8	6,1±2,8
Amonia	3,3±3,1	**1,7±0,6**	1,8±0,6
Znc oxide	**7,0±1,9**	**4,0±1,5**	3,2±1,5

Table 5. Assessment of non-cancer risk (HI) to public health at combined inhalation exposure to toxic substances in 2006-2016

Public risks	Karabash	Gai	Sibay
Acute exposure	65 – 146	41 – 85	67 – 105
Chronic exposure	6– 34	9– 20	10– 21

4. Conclusion

The calculation data point to a very high annual level of cancer and non-cancer risks to public health in all the studied towns in Southern Ural.

While a non-cancer risk (HI between 41 and 146), primarily arises from high concentrations of sulfur dioxide in the air, a cancer risk is caused by formaldehyde.

The problem of inhalation poisoning is especially acute in Karabash. It has the highest hazard index (HI) with combined acute effects of hazardous substances and the highest cancer risk to public health.

According to our calculations, the individual cancer risk (CR) in all the studied towns exceeded 1·10-4. This level of risk is acceptable only for professional groups and is unacceptable for the general population.

Thus, the environmental situation in cities and towns of Southern Ural requires the development and implementation of systematic organizational, technical, technological and sanitary measures aimed at reducing the levels of existing cancer and non-cancer risks to public health.

Acknowledgments

The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0011.

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