Security and Human Health Risk Assessment: Actual Problems

V A Nikiforova¹, E A Vidishcheva² and D D Vidishcheva³
¹ FGBOOU WAUGH of "BRGU", lecture hall 3104, Makarenko St., 40, Bratsk, 665709, Russia
² FGBOU VO "BRGU", lecture hall 3115, Makarenko St., 40, Bratsk, 665709, Russia
³ FGBOOU WAUGH of "BRGU", lecture hall 3104, Makarenko St., 40, Bratsk, 665709, Russia

E-mail: nikiforovabr@mail.ru

Abstract. This paper presents data on specific chemical risks observed in the urbanized areas of Irkutsk Oblast. The most important air pollutants in Bratsk are nitrogen dioxide, fluoride compounds, sulfur-containing substances, benzo(a)pyrene, and formaldehyde. The paper addresses the issues of assessing risks to human health when exposed to chemicals contained in the air of residential areas. We use the risk assessment methodology to quantify the non-carcinogenic and carcinogenic risks for specific population cohorts. It is found that when exposed to chemicals through inhalation, the risk of experiencing toxic effects is high. We hereby evaluate how specific contaminants affect the human health risks. The existing pollution level in the city’s administrative districts causes a high risk of respiratory diseases (HQ = 4.28), musculoskeletal diseases (HQ = 1.74), immunity disorders (HQ = 1.74), respiratory system disorders (HQ = 14.1), ophthalmological diseases (HQ = 9.7), physical and mental maldevelopment (HQ = 9.4); the total population-wide carcinogenic risk is found unacceptable (PCR = 1.8×10⁻³). It is demonstrated that the risk concept can be used as a methodological tool to substantiate the administrative decision-making with respect to environmental protection and technogenic security.

1. Introduction

In recent years, the problem of population-wide health deterioration has become an ever-greater threat for Russia in general and some of its regions in particular. It can now be deemed proven that the anthropogenic environmental pollution has a strong effect on human health, especially under changing socio-economic conditions [4,11]. In this respect, it is becoming imperative to develop a concept of environmental, physiological, epidemiological, and hygienic security to eliminate apparent and potential threats to human health pertaining to adverse environmental risk factors [6,2].

In 2012, the President of Russia approved the Fundamentals of the Public Policy for the Environmental Development of the Russian Federation for Until 2030 [15]. The strategic objective thereof with respect to environmental development consists in solving socio-economic problems to ensure the environment-focused economic growth, to preserve a healthy environment, biodiversity, and natural resources to meet the demands of the current and future generations, to enable every human person to exercise their rights to a healthy environment, to strengthen the rule of law with respect to environmental protection and security.
The environment is now actively involved in the environmental and economic policies.

2. Relevance and Scientific Significance

In the Russian Federation, 55% of the urban population live in cities with either high or very high environmental pollution levels [4,12,14]. Negative trends in human health are observed in large industrial cities due to environmental problems [9,11,23]. The contribution of anthropogenic factors to various pathologies varies from 10 to 60 percent depending on the living conditions and location [7,22,24].

The environmental pollution problem is especially serious in Siberian and Far-Eastern cities [3,5,17]. Irkutsk Oblast is one of the most developed industrial entities of Russia. Air emissions from stationary sources account for 2.7% of Russia’s total emissions. Nine of the region’s cities have either high or very high mean air pollution level. Those are: Bratsk, Zima, Irkutsk, Shelekhov with very high pollution, and Angarsk, Baikals, Usolye-Sibirskoye, Ust-Ilimsk, and Cheremkhovo with high or average air pollution; this is 47% of the cities and towns that have been surveyed [7].

High risks to human health are induced by the continuous respiratory exposure to a range of substances, the most important ones being sulfur dioxide, carbon oxide, nitrogen dioxide, carbon disulfide, solid fluorides, and hydrogen fluoride [21].

Researchers have assessed the risks of developing non-carcinogenic and carcinogenic effects caused by air pollution. Such assessments describe alterations in the morphology, physiology, growth, development, and lifespan of an organism, a population, or an ecosystem, which manifest themselves in functional deterioration, in degradation of stress compensation capabilities, in sensitization to sundry environmental factors [7,10,24].

Such human-health risk assessments represent a quantitative and qualitative evaluation of adverse factors that can develop as a result of a specific population cohort being specifically exposed to environmental factors; thus, the effects of adverse technogenic environmental factors on human health can be assessed long before manifesting themselves[1,2,13,224]. A health risk assessment system can be organically integrated into a general management and decision-making system [16, 18]. Most of the environment-induced health risks are caused by polluted air [7,23,24].

The purpose hereof is to evaluate the chemical pollution of air as well as risks to human health in the city of Bratsk, Irkutsk Oblast.

Bratsk is one of the region’s largest industrial cities and has more than 800 emission sources. The city’s industrial power rests upon thermal power plants, a hydroelectric power plant, aluminum and pulp-and-paper industries. Major enterprises that contribute to air pollution are: Bratsk Aluminum Works, Russia’s largest aluminum works producing 30% of Russia’s and 4% of the world’s aluminum; Bratsk Forestry Complex, one of Russia’s largest zero-waste wood processing facilities; Bratsk Ferroalloy Plant, Eastern Siberia’s largest enterprise producing high-percentage ferrosilicon; and thermal power plants. For a few years in a row, Bratsk has been on the Federal Service for Hydrometeorology and Environmental Monitoring’s (“the Roshydromet”) short list of cities with extremely high air pollution levels.

The city is divided into two administrative districts, the Central District and the Padunsky District; those saddle the Bratsk Reservoir and are located quite far away from each other: the Central District is situated on the left bank, 2 kilometers away from the industrial sites of the Forestry Complex and a CHPP, 8 kilometers away from the Aluminum Works. 20 to 25 kilometers north-east of it is the Padunsky District, which contains a large CHPP. Air pollution was measured on the basis of data obtained from six stationary posts of the Roshydromet. We analyzed data for 2011–2016 for these two districts that feature high pollution levels in their residential areas. Air pollution was described by annual-average and peak concentrations as measured in one-time and daily-average air samples; we measured the concentrations of dust, , SO$_2$, CO, NO$_2$, H$_2$S, solid fluorides, and hydrogen fluoride. The non-carcinogenic effects of these contaminants on human health were evaluated in accordance with the general risk-assessment principles[19,20]. To evaluate the comprehensive chemical burden and to identify the risks factors relating to the adverse effects of these substances, we calculated the hazard
quotients (HQ) and the hazard indices (HI). Pursuant to the guidelines, we used the annual dose calculation method for respiratory exposure to airborne substances; to that end, we used parameters standardizes across all population cohorts.

3. Results and Discussion
According to the 2 TP-Air form, Bratsk ranks 2nd in Irkutsk Oblast in terms of total emissions; 318.9 to 501.8 kg/person of hazardous substances were released into air over the studied period.

The evaluation of air contents indicated the highest pollution levels in the urbanized areas of the Central District, which was characterized by excessive annual-average concentrations of benzo(a)pyrene and suspended substances, as well as high concentrations of carbon disulfide and hydrogen fluoride. Comparative analysis of the hazard index for simultaneous respiratory exposure to multiple substances in these two districts of Bratsk revealed that the Central District was more polluted with chemicals than the Padunsky District.

Table 1. Hazard indices for simultaneous respiratory exposure to multiple substances, M ±m.

| Year | Administrative district |
|------|-------------------------|
|      | Central | Padunsky |
| 2011 | 6.99 ± 0.06 | 6.28 ± 0.06 |
| 2012 | 7.43 ± 0.08 | 5.19 ± 0.09 |
| 2013 | 6.45 ± 0.04 | 5.49 ± 0.03 |
| 2014 | 4.9 ± 0.04 | 3.79 ± 0.03 |
| 2015 | 3.78 ± 0.08 | 3.46 ± 0.05 |
| 2016 | 4.6 ± 0.04 | 3.89 ± 0.03 |

Lower hazard indices in the Padunsky District and the Central District were observed in 2011–2016 due to the city’s major enterprises having taken measures to reduce air emissions.

Nevertheless, we have to note the insufficiency of upgrades and retrofitting measures taken by the leading core enterprises, a fact indicated by the results of our analysis. During the studied period, the Central District had the highest human health risks relating to the respiratory system (HQ = 4.28); high skeletal-system risks were related to the exposure to solid fluorides and hydrogen fluoride (HQ = 1.2); similar trends were observed in the Padunsky District, as the highest risks were associated with the exposure of respiratory organs (HQ = 3.6). General toxins are hazardous pose threat to the following organs and systems: the immune system (HQ = 19.4), the respiratory system (HQ = 14.1), the organs of sight (HQ = 9.7), the physical and mental development (HQ = 9.4), the skeletal system and the teeth (HQ = 1.74).

The inhalation of benzo(a)pyrene and carbon disulfide may affect the body’s development pace. The risk of adverse effects peaks when the person is exposed on a daily basis to benzo(a)pyrene and formaldehyde, which have both carcinogenic and non-carcinogenic effects.

Table 2 presents the calculated annual doses of respiratory exposure with breakdown by the city’s administrative districts and by pollutants; calculations are done for the studied period based on the population-wide standard parameters.
Table 2. Total annual dose (ΣI) of respiratory exposure to airborne substances: breakdown by the districts of Bratsk for 2010–2016.

| Years | Central District | Padunsky District |
|-------|------------------|-------------------|
|       | Adults 1, mg/kg-year | Children 1, mg/kg-year |
|       | Dust | SO₂ | CO | NO₂ | H₂S | Solid fluorides | HF | Dust | SO₂ | CO | NO₂ | H₂S | HF |
| 2011  | 1.8  | 0.045 | 11.3 | 0.86 | 0.045 | 0.11 | 0.056 | 1.8 | 0.047 | 11.8 | 0.9 | 0.047 | 0.06 |
| 2012  | 1.7  | 0.045 | 11.3 | 0.52 | 0.034 | 0.113 | 0.34 | 2.36 | 0.047 | 11.8 | 0.53 | 0.035 | 0.35 |
| 2013  | 2.26 | 0.045 | 11.3 | 0.68 | 0.045 | 0.079 | 0.068 | 2.36 | 0.047 | 11.8 | 0.7 | 0.047 | 0.08 |
| 2014  | 2.04 | 0.022 | 11.3 | 0.28 | 0.034 | 0.09 | 0.056 | 2.1 | 0.023 | 11.8 | 0.29 | 0.035 | 0.059 |
| 2015  | 1.13 | 0.022 | 11.3 | 0.29 | 0.022 | 0.113 | 0.056 | 1.18 | 0.023 | 11.8 | 0.3 | 0.23 | 0.059 |
| 2016  | 1.12 | 0.021 | 11.2 | 0.28 | 0.021 | 0.112 | 0.055 | 1.17 | 0.024 | 117 | 0.3 | 0.22 | 0.058 |
| ΣI,   | 69.4 |        |       |       |       |       |       |       |       |       |       | 73.4 |       |
| mg/kg |       |        |       |       |       |       |       |       |       |       |       |       |       |

It should be noted that the analysis of non-carcinogenic risks indicate the emergence of pathological processes in adults and children exposed to chemicals via inhalation.

According to the carcinogenic-risk acceptability criteria, individual risks induced by the presence of benzo(a)pyrene and formaldehyde in the air are not acceptable for the population as a whole. In 2011, the benzo(a)pyrene-induced risk of additional cases of malignant neoplasms was $2.9 \times 10^{-3}$, the formaldehyde-induced risk was $1.0 \times 10^{-2}$. Total population-wide carcinogenic risk was therefore deemed unacceptable (PCR = $1.3 \times 10^{-3}$).

4. Conclusion

Therefore, the methodology of assessment of environment-induced risks to human health is an important tool for improving the general system for monitoring and ensuring the sanitary-epidemiological well-being and technogenic security.

This study indicates a risk of adverse toxic effects to human health when exposed to chemicals in the city. Carcinogenic and non-carcinogenic risks associated with exposure to multiple chemicals indicate an unacceptable concentration of pollutants. We have found that nitrogen dioxide, fluoride compounds, sulfur-containing substances, benzo(a)pyrene, and formaldehyde are the most potentially
hazardous substances. The existing pollution creates risks of respiratory diseases, musculoskeletal and nervous-system diseases, and maldevelopment.

References

[1] Avaliani S L, Bezpalko L E, Bobkov A L, Mishin A L 2013 The Perspective directions of development of methodology of risk analysis in Russia Hygiene and sanitation 1 33-35
[2] Avaliani S L, Novikov S M, Shashina T A, Dodina N S, Kislitsin V A, Mishina A L 2014 Problems of improvement of a control system of quality of the environment on the basis of risk analysis to health of the population Hygiene and sanitation 6 5-8
[3] Bolashinov A B, Makarova L V, Hankhareev S S 2006 Materials of the Plenum of scientific council on ecology of the person and hygiene of the environment of the Russian Academy of Medical Science: "Modern problems of hygiene of the city, methodology and solutions", the Condition of a problem and the prospect of risk reduction to health of the population from pollution of atmospheric air in the Baikal region 239-241
[4] Gichev Yu P 2007 Human health and environment 184
[5] Goreva E L 2004 Environmental protection in municipal units at the present stage Materials II interregional 390-391
[6] Danilov-Daniylyan V I, Zalikhanov M Ch, Losev K S 2001 Environmental safety. General principles and Russian aspect. Mezhdunar publishing house it is independent. ecologist. - polytolite. un-that, pp16-19
[7] Yefimova N V, Matorova N I, Yushkov N N, Nikiforova V A, Pertseva T G 2008 Medico-environmental risks of the modern city 200
[8] Kozlov V K, Evseeva G P, Suprun S V 2003 Cities of the Far East: ecology and life Materials Ecological conditions of the city and health of children 18 65-68
[9] Kik P F, Veremchuk L V 2002 Risk assessment for health from adverse factors of the environment: experience, problems and ways of their decision Materials Assessment of environmental risk of influence of factors of the habitat on spread of diseases of respiratory organs 15 27-29
[10] Kireeva I S, Chernichenko I A, Litvichenko O N 2007 Hygienic assessment of risk of pollution of atmospheric air of the industrial cities of Ukraine for health of the population Hygiene and sanitation 1 17-21
[11] Manchuk V T, Kolesnikova L I 2004 Structural and metabolic features of an organism of the child in the conditions of Siberia and the North Materials XV (LXXVII) session of a general meeting of the Russian Academy of Medical Science; "Scientific bases of health protection of children" 12-14
[12] Nikiforova V A, Pertseva T G, Horoshikh N E, Nikiforova A A 2014 Ecological aspects of the state of health of the children's population of northern territories of Eastern Siberia Systems. Methods. Technologies 1(12) 140-147
[13] Novikov S M, Fokin M V, Unguryan T N 2016 Topical issues of methodology and development of evidential assessment of risk to health of the population at influence of chemicals Hygiene and sanitation 8 711-716
[14] Onishchenko G G 2007 Urban environment and human health Hygiene and sanitation 5 3-4
[15] Rakhmanina Yu A, Onishchenko G G 2002 Risk assessment Basis for health of the population at influence of the chemicals polluting the environment p. 408
[16] Rakhmanin Yu A, Novikov S M, Shashina T A 2007 Modern methodologies of assessment of risk Hygiene and sanitation 3 3-8
[17] RD 52.04.186-89 1989 Guide to air pollution control 16
[18] P 2.1.10.1920-04 2004 The guide to risk assessment for health of the population at influence of the chemicals polluting the environment 143
[19] Svinukhov V G, Senotrusova S V 2004 Research of air pollution and health of the population on the example of the city of Nakhodka (Primorsky Krai) Materials IV “Environmental problems of the present” 15 21-22

[20] Surzhikov D V 2006 Hygienic assessment of risk of violation of health of the population of the industrial city from influence of factors of the environment Hygiene and sanitation 5 33-34

[21] Yushkov N N, Bolsheshapov A V, Zinchenko S N, Bryukhanov I G 2008 Formation of health of the population which was affected by adverse factors of the environment Conference Materials: "Environmental protection in municipal units at the present stage” 60-72

[22] Environment and health in the WHO European Region: progress, challenges and lessons learned: working document: Regional Committee for Europe65th session // World Health Organization Vilnius 2015 p.15

[23] IPCS. Glossary of Exposure Assessment- Related Terms: A Compilation, Prepared by the Exposure Terminology Subcommittee of the IPCS Exposure Assessment Planning Workgroup for the International Programmer on Chemical Safety Harmonization of Approaches to the Assessment of Risk from Exposure to Chemicals. 2001

[24] Progress report on the European Environment and Health Process: working document: Regional Committee for Europe 66th session. World Health Organization Copenhagen 2016 p. 16