

## Chemical pollution of environment in the cities of Central Siberia: risk for the health of the population

### Chemiczne zanieczyszczenie środowiska w miastach Środkowej Syberii: zagrożenie dla zdrowia ludności

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#### ABSTRACT

**Introduction.** This article will deal with environmental pollution in cities including the problem of risk assessment. The aim of the study is to determine carcinogenic and non-carcinogenic risks for the health of the population due to chemical contamination of air, water and food in the cities of the Krasnoyarsk region.

**Material and methods.** The research was conducted in the Center of Hygiene and Epidemiology in the Krasnoyarsk region. 5122 samples of air, 4863 samples of water and 6915 samples of food stuff have been analyzed. Concentration of chemical substances was the base on which individual carcinogenesis risk (ICR) and population carcinogenic conventional risks (PCCR) and non carcinogenic risks [1] have been calculated. In the industrial cities chemical pollution of air, water and food stuff including carcinogenic substances creates carcinogenic and non-carcinogenic risks of morbidity of the population with the reinforcement of the complex impact, "with" which greatly exceeds the maximum acceptable risks.

**Results.** Chemical pollution of environmental facilities in cities of the Krasnoyarsk region produce complex carcinogenic and non-carcinogenic risks which exceed maximum limit. The greatest shares in structure of complex carcinogenic risks are made in food stuff and water consumption in structure of complex non-carcinogenic risks as a result of air pollution and food stuff pollution.

**Conclusions.** Obtained data could be used to set priorities in preventive measures to preserve health of the population in industrial cities of the Krasnoyarsk region.

**Key words:** air pollution, water pollution, food pollution, carcinogenic and non-carcinogenic, Krasnoyarsk region

#### STRESZCZENIE

**Wstęp.** Artykuł zajmuje się problemem zanieczyszczenia środowiska w miastach oraz problemem oceny ryzyka zdrowotnego. Celem pracy jest określenie ryzyka kancerogennego i niekancerogennego dla zdrowia populacji z powodu zanieczyszczenia powietrza, wody i żywności w miastach regionu Krasnojarskiego.

**Materiał i metody.** Badania przeprowadzono w Centrum Higieny i Epidemiologii regionu Krasnojarskiego. Wykonano 5122 analizy powietrza, 4863 analizy wody i 6915 analiz żywności. Na podstawie stężenia substancji chemicznych obliczono indywidualne ryzyko kancerogenezy (ICR) oraz populacyjne umowne ryzyko kancerogenezy (PCCR) i ryzyko niekancerogenności. W miastach przemysłowych zanieczyszczenie chemiczne wody, powietrza i żywności, stwarza kancerogenne i niekancerogenne ryzyko zachorowalności populacyjnej, co jest potęgowane przez kompleksowy udział dodatkowych czynników i znacznie przekracza maksymalnie dopuszczalne ryzyko.

**Wyniki.** Zanieczyszczenie chemiczne z obiektów środowiskowych w miastach krasnojarskich charakteryzuje kompleks kancerogennego i niekancerogennego ryzyka, które przekracza dopuszczalne maksimum. Największy udział w strukturze kompleksu ryzyka kancerogennego wykazuje konsumpcja żywności, natomiast udział wody pitnej wykazano w strukturze kompleksu ryzyka niekancerogennego, jako wynik skażenia powietrza i wody.

**Wnioski.** Uzyskane dane powinny być wykorzystane celem określenia pierwszeństwa w kierunkach opracowywania działań zapobiegawczych dla zachowania zdrowia populacyjnego w przemysłowych miastach regionu Krasnojarska.

**Słowa kluczowe:** zanieczyszczenia powietrza, zanieczyszczenia wody, zanieczyszczenia żywności, ryzyko kancerogenne i niekancerogenne, region Krasnojarska

## INTRODUCTION

The Krasnoyarsk region is located in Central Siberia. It is one of the largest in Russia (2,366,800 km<sup>2</sup>) with prevalence of the urban population (76.4%) [2].



Fig. 1. Location of the Krasnoyarsk Krai, Russia (source: <http://en.wikipedia.org/wiki/Krasnoyarsk>)

Ryc. 1. Położenie Kraju Krasnojarskiego, Rosja (źródło: <http://en.wikipedia.org/wiki/Krasnoyarsk>)

Reports 2006–2011 of Federal Service for Supervision of Consumer Rights Protection and Human Welfare (Rospotrebnadzor) of the Krasnoyarsk Territory showed that environmental policies have made substantial progress in improving the state of the environment in the region. However, it also stressed that major environmental challenges remain. Air, water and food pollution have declined but not enough to achieve good quality for the health of the urban population [3]. Widespread exposure to multiple pollutants and chemicals and concerns about long-term damage to human health together attest the need for more integral and precautionary approaches. Given the complex links between environmental challenges, identification of environmental risks to human health should be necessary in the Krasnoyarsk region.

The aim of the study is to determine carcinogenic and non-carcinogenic risks for the health of the population due to chemical contamination of air, water and food in the industrial cities of the Krasnoyarsk region.

## MATERIALS AND METHODS

In this research we used the database of social-hygienic monitoring (2006–2011) Center for Hygiene and Epidemiology and Federal Service for Supervision of Consumer Rights Protection and Hu-

man Welfare (Rospotrebnadzor) of the Krasnoyarsk Territory. Chemical pollution of air, water, foodstuff were studied in industrial cities of the Krasnoyarsk region: Norilsk, Lesosibirsk, Krasnoyarsk, Achinsk, Kansk, Nazarovo, Minusinsk.

Short characteristics of cities:

- **Norilsk** is the world's northernmost city inside the Arctic Circle, which population is 175,365 [4].
- **Krasnoyarsk** is a city and the administrative center of Krasnoyarsk Krai, is an important producer of aluminium, well communicated (there is Trans-Siberian Railway). The population is 1,035,528 [4]. Cities near Krasnoyarsk are Achinsk, Kansk, Nazarovo.
- **Achinsk**. The krai town of Achinsk is incorporated as Achinsk Urban Okrug, is 184 kilometers west of Krasnoyarsk and the population is 109,155. The largest enterprise of the city is the Achinsk Alumina Plant. Also the city operates a cement plant which produces about two million tons of cement per year [4].
- **Kansk**. The krai town of Kansk is incorporated as Kansk Urban Okrug. The town is a center of the Kansk-Achinsk lignite basin, which in the early 1980s was developed into one of the largest coal areas of the Soviet Union. It also has cotton, timber hydrolysis, and food industries. The population of Kansk is 94,226 [4].
- **Nazarovo**. The krai town of Nazarovo is incorporated as Nazarovo Urban Okrug and is 239 kilometers west of Krasnoyarsk. Nazarovo has 52,817 of citizens [4]. It is a place of brown coal (lignite) deposits.
- **Minusinsk**. It is located in the south of the region. As a municipal division, the krai town of Minusinsk is incorporated as Minusinsk Urban and the population of Minusinsk is 71,170 [4].
- **Lesosibirsk**. In the town are large wood-processing plants. The population of the town is 61,139 [4].

The results of air samples (5122), water (4863) and food stuff (6915) were analyzed. With the support of "Guidelines for risk assessment for public health under the influence of chemical pollutants in the environment" [1] individual carcinogenic risks (ICR) and population carcinogenic conventional risks (PCCR) were calculated by carcinogenic substances (benzopyrene, formaldehyde, benzene) and also non-carcinogenic risks by median concentrations of pollutants in air, water and food. Air, water and food pollutants were presented in daily concentrations in fractions permissible level

from min to max. The values of the probability of an adverse response from the health obtained during mathematical modeling to quantify the individual non-carcinogenic risk of developing a specific response from the health conditions of admission of certain chemical components with one of the possible ways [1]. Assessment of chemical pollution of the environmental facilities was carried out on the basis of produced carcinogenic and non-carcinogenic risks. By concentrations of chemical substances in air, water and food stuff it has been defined in accordance with a document [1]. With its guidance [1] individual carcinogenic risks (ICR) and population carcinogenic conventional risks (PCCR) and also non-carcinogenic risks of diseases (on the danger index) have been defined. Complex carcinogenic and non-carcinogenic risks for the health of the population have been calculated taking into account the complex impact of chemical substances at the pollution expense of environmental facilities.

## RESULTS

More than half the population lives in cities of the Krasnoyarsk region. Growing urbanization have created a number of problems, such as deteriorating living conditions and quality of food, water and air.

### Air

The integrated exponent of atmospheric pollution called the index of air pollution, is calculated as the sum of the average concentrations of permissible level considering the hazard class of the respective pollutant. The highest rates of API (more than 14). Air pollution index -5 in Krasnoyarsk – benzopyrene, formaldehyde, nitrogen dioxide (NO<sub>2</sub>), particulate matter (PM10, PM2.5). Air pollution index -5 in Norilsk – Ni, Cu, Co oxides, sulphur dioxide (SO<sub>2</sub>), particulate matter (PM10, PM2.5). Generally air pollution index -5 included 5 components: hydrocarbons, particulate matter (PM10, PM2.5), sulphur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), heavy metals. According to the state report “On the state and protection of the environment in the Russian Federation in 2011”, published on the official website of the Ministry of Nature of Russia in February 2013, was made on the basis of the cities of the Russian Federation. The data compiled a list of 100 of the most polluted cities with a population of 100 thousand or more. The list covers the following cities: Krasnoyarsk Krai – Achinsk (API-5 – 19.21), Krasnoyarsk (API-5 – 23.75), Lesosibirsk (API-5 – 14.4), Minusinsk (API-5 – 14.91).

The Blacksmith Institute [5] included Norilsk in its 2007 list of the ten most polluted places on Earth. Norilsk has the world's largest heavy metals smelting complex developed in the early 2000s. Annual air emissions of Norilsk smelting complex is 1,959,500 tons, nearly 500 tons each of copper and nickel oxides and 2 million tons of sulfur dioxide. Life expectancy for factory workers in Norilsk is 10 years below the Russian average. While the exact number of people potentially affected by pollution in Norilsk is unknown, it is estimated that over 130,000 local residents are being exposed to particulates, sulfur dioxide, heavy metals, and phenols discharged into the air each day. Past studies have found elevated copper and nickel concentrations in soil nearly everywhere within a 60 km radius of the city. The Russian Federal State Statistics Service named Norilsk the most polluted city in Russia. In 2010, Norilsk produced 1.924 million tons of carbon pollutants, compared to a mere 333 thousand tons of pollutants generated by Russia.

Assessment of chemical pollution of the air, which was carried out using the risk assessment methodology, had been conducted in the cities with developed coal [6], machinery [7] and multi-branches of the industry [8], metallurgy [9] and at the same time some works [10, 11] have been devoted to the multi-environmental complex impact of chemical pollution on different environmental facilities which influences the population of the city with monitoring of the complex carcinogenic and non-carcinogenic risks. 2.43 million tons of air pollutants per year (nitrogen dioxide, sulphur dioxide, ammonia, formaldehyde, phenol, petrolpyrene, carbon oxide, dust, hydrogen sulphide, carbon bisulphide, benzene, chlorine) have been recorded (table I).

Air pollution (daily concentrations in fractions permissible level from min to max) were by petrolpyrene 0.7–4.3, suspended substances 0.3–2.2, sulphur dioxide 0.1–9.5, nitrogen dioxide 0.2–1.4, carbon oxide 0.2–0.6, carbon bisulphide 1.1–1.3, nickel composition 0.9–3.1.

Higher total levels of pollution are found in Norilsk and Krasnoyarsk, where air pollution index is 15.3–20.4; in other cities it is 6.5–13.3.

Carcinogenic risks have been created by air pollution by carcinogenic substances (benzopyrene, formaldehyde, benzene). Values ICR reach in cities was 0.3 E-5 – 69 E-5, PCCR 0.004–0.98<sup>0</sup>/<sub>0000</sub> (table II). They exceed maximum allowed ICR (10 E-5) and PCCR (0.14<sup>0</sup>/<sub>0000</sub>). In Lesosibirsk and in Norilsk it is connected with high level of air pollution in formaldehyde (Lesosibirsk) and in nickel composi-

tions (Norilsk). Non-carcinogenic risks were caused by air pollution in cities which are equal on the danger index. Such diseases may appear: diseases of breathing organs – 2.8–15.7, diseases of the central nervous system – 0.24–2.31. Excess hazard in-

dex was observed (more than 1.0): diseases of blood and blood forming organs of diseases in all cities, diseases of the nervous system and warm vascular system in Krasnoyarsk, diseases of the central nervous system in Norilsk.

**Table I.** Air pollution and risk of diseases in population (by air monitoring and epidemiologic studies of humans in the Krasnoyarsk region)

**Tabela I.** Zanieczyszczenie powietrza i ryzyko chorób w populacji (na podstawie monitoringu powietrza i epidemiologicznego badania ludzi w Kraju Krasnojarskim)

Air pollutants	Risk of diseases	Population (in thousands)
Benzopyrene, formaldehyde	Cancer	690.0
Carbon bisulfide	Deterioration of reproductive function	150.0
Phenol, hydrogen sulfide, chlorine, carbon monoxide	Respiratory system	690.0
Oxides of nitrogen, hydrogen sulfide	Blood and blood forming organs	690.0
Phenol, hydrogen sulphide	Circulatory system	690.0

## Water

One of the cornerstones of a public health policy is safeguarding access to water of good quality for consumption, for recreation and as a source for food. Due to effective potable water purification, outbreaks of water-borne diseases are infrequent and often associated with small scale potable water supplies in rural areas [12]. To provide potable water, there are 1121 water pipes and 1218 wells supplying the population in Krasnoyarsk krai.

Dumping of not fully purified sewage in water cisterns, usage of pesticide and mixed fodder, existence of non organized dumps of industrial wastes create the pollution by chemical substances of surface and underground springs of centralized industrial – potable water supply in cities of the region.

Higher levels of chemical pollution of potable water by limiting sanitary-toxicological indication are found in cities of Achinsk, Kansk and Nazarovo. Potable water pollution (daily concentrations in fractions permissible level from min to max) iron – 0.6–1.2, manganese – 0.1–0.9, arsenic – 0.2–0.52, cadmium – 0.1–0.43, lead – 0.1–0.5, chrome – 0.05–0.2, beryllium – 0.15–0.25, chloroform – 0.14–0.26, bromine dichloromethane – 0.16–0.6, dibrominechlormethane – 0.08–0.2.

Carcinogenic risks have been created owing to carcinogenic substances found in potable water. Values ICR were: 12 E-5–37 E-5, PKOR 0.17–0.53<sup>0/0000</sup> (table II). It exceeds maximum allowed standards ICR (10 E-5) and PCCR (0.14<sup>0/0000</sup>) in all cities and were estimated as not allowable. Non-carcinogenic risks of the central nervous system diseases, endocrine system diseases, warm vascular

system diseases, urogenital system diseases, digestive organs diseases, blood and blood forming organs diseases caused by usage of potable water were 0.19–0.57 on the danger index and do not exceed the permitted level of (1.0 on the danger index).

## Food

Basic kinds of food stuff consumed by the population of the Krasnoyarsk region contain heavy metals and carcinogenic substances whose concentrations do not exceed the permissible level. Concentration medians in mg/kg in vegetables were: lead – 0.036–0.049, cadmium – 0.007–0.012, arsenic – 0.06–0.10 and mercury – 0.0010–0.0014; in bread products: lead – 0.033–0.040, cadmium – 0.007–0.011, arsenic 0.018–0.025 and mercury – 0.0013–0.0016; in dairy products: lead – 0.01–0.02, cadmium – 0.002–0.003, arsenic – 0.004–0.007 and mercury – 0.0011–0.0015; in meat products: lead – 0.001–0.008, cadmium – 0.001–0.003, arsenic – 0.002–0.005 and mercury – 0.0002–0.0005.

Calculated ICR taking into account physiological need of daily consumption of food stuff and actual concentrations of cadmium, arsenic and lead reach in cities 40 E-5–47 E-5, PCCR – 0.57–0.67<sup>0/0000</sup> have been made. They exceed the maximum allowed risks and are estimated as not permissible and not acceptable.

Non-carcinogenic risks (on the danger index) of the central nervous system diseases, warm vascular system diseases, urogenital system diseases, digestive organs diseases, blood and blood forming organs diseases are 0.06–0.92 and do not exceed the allowed levels. Non-carcinogenic risks of endocrine

system diseases equal 1.3–1.5 are higher than allowed levels.

Taking account of the complex impact of carcinogenic substances consumed from different en-

vironments, total ICR and PCCR are identified. They are  $67.7 \text{ E-}5$ – $126 \text{ E-}5$  and  $0.96$ – $1.79^{0}/_{0000}$ , respectively and exceed the maximum allowed carcinogenic risks in 6.8–12.6 fold (table II).

**Table II.** Carcinogenic risks in connection with chemical pollution of environmental facilities in the industrial cities of the Krasnoyarsk region

**Tabela II.** Ryzyko kancerogenności w związku z chemicznymi zanieczyszczeniami z obiektów środowiskowych w przemysłowych miastach Kraju Krasnojarskiego

Kind of carcinogenic risk	Environmental facilities	Name of the city						
		Achinsk	Kansk	Krasnoyarsk	Lesosibirsk	Minusinsk	Nazarovo	Norilsk
Carcinogenic individual risk	air	5.9 E-5	0.3 E-5	8.7 E-5	11 E-5	6.4 E-5	9.9 E-5	69 E-5
	water	37 E-5	32 E-5	12 E-5	29 E-5	23 E-5	30 E-5	17 E-5
	foodstuff	46 E-5	45 E-5	47 E-5	42 E-5	44 E-5	48 E-5	40 E-5
	Total	88.9 E-5	77.3 E-5	67.7 E-5	82 E-5	73.4 E-5	87.9 E-5	126 E-5
Carcinogenic population risk, number of cancer cases in 100 000 per year	air	0.08	0.004	0.12	0.16	0.09	0.14	0.98
	water	0.53	0.46	0.17	0.41	0.33	0.43	0.24
	foodstuff	0.66	0.64	0.67	0.60	0.63	0.69	0.57
	Total	1.27	1.10	0.96	1.17	1.05	1.26	1.79

The highest levels of complex carcinogenic risks are in Norilsk, Achinsk, and Nazarovo. In structure of complex carcinogenic risks, with the exception of Norilsk, first position is occupied by carcinogenic risks created as a result of food stuff consumption (51.2–69.4%), second – as a result of potable water and the third place is occupied as a result of air pollution. In Norilsk in structure of complex carcino-

genic risks the first place is occupied by risk caused by air pollution. In the Krasnoyarsk region complex non-carcinogenic risks (on the danger index) of respiratory diseases, the central nervous system diseases, endocrine system diseases, cardio-vascular system diseases and urogenital system diseases, digestion organs diseases, blood and blood forming organs diseases exceed allowable risks (table III).

**Table III.** Non-carcinogenic risks (on the danger index) of morbidity of the population in connection with chemical pollution of environmental facilities in the industrial cities of the Krasnoyarsk region

**Tabela III.** Niekancerogenne ryzyko (wyrażone indeksem zagrożenia) chorobowości populacji w związku z zanieczyszczeniem chemicznym z obiektów środowiskowych w przemysłowych miastach Kraju Krasnojarskiego

Name of the city with chemical pollution of environment	Non-carcinogenic risks (on the hazard index*) morbidity of the population							
	Respiratory diseases	Nervous system diseases	Blood and blood forming organs diseases	Endocrine system diseases	Cardiovascular system diseases	Urogenital system diseases	Digestive system diseases	Total
Achinsk	10.8	1.7	3.1	1.8	1.5	1.5	1.1	21.6
Kansk	2.8	1.4	2.5	1.8	1.3	1.4	1.0	12.3
Krasnoyarsk	14.9	2.8	5.6	1.8	2.0	1.2	0.7	28.9
Lesosibirsk	8.0	2.1	1.7	1.9	2.1	1.4	1.0	18.2
Minusinsk	5.8	1.9	2.0	1.9	1.8	1.3	1.0	15.7
Nazarovo	7.2	2.2	2.9	1.9	1.9	1.5	1.1	18.8
Norilsk	15.7	3.2	3.4	1.6	1.7	1.1	0.8	27.4

\* limit value – 1.0

It is noted that there are the highest complex non-carcinogenic risks of respiratory diseases, blood and blood forming organs diseases, endocrine system diseases. The largest total complex of non-carcinogenic risks of breathing organs diseases are in Krasnoyarsk, Norilsk and Achinsk. The greatest shares of non-carcinogenic risks in structure of complex non-carcinogenic risks belong to those ones caused by air and food stuff pollution.

## CONCLUSIONS

The urgency of solving the environmental problems of the Krasnoyarsk Territory are due to the fact that emission of pollutants into the atmosphere from stationary sources constitute about 2.52 million tons in 2011. The Krasnoyarsk region and its industrial centers take a leading position in the Siberian Federal District, and the Russian Federation.

Chemical pollution of environmental facilities in cities of the Krasnoyarsk region causes complex carcinogenic and non-carcinogenic risks which exceed the maximum allowable. The greatest shares in structure of complex carcinogenic risks are a result of food stuff consumption and potable water in the structure of complex non-carcinogenic risks resulting from air and food stuff pollution. Risk assessments can provide a great deal of information to an epidemiological investigation and especially in understanding chemical pollution of environment-related health effects. They are often difficult to define if one considers controlling factors. Obtained data could be used for determination of priority directions while working out complex preventive actions aimed at preserving the health of the population of industrial cities of the Krasnoyarsk region.

**Acknowledgements:** *staff of the Medical Service of the Krasnoyarsk Territory for the material.*

**Funding:** *Federal Service for Supervision of Consumer Rights Protection and Human Welfare.*

## REFERENCES

1. Guidelines for risk assessment for public health under the influence of chemical pollutants in the environment. Moscow 2004.
2. <http://krasstat.gks.ru> [10.08.2014].
3. Top Ten Toxic Threats in 2013: Cleanup, Progress, and Ongoing Challenges, Nov. 4, 2013, New York, NY – Blacksmith Institute and Green Cross Switzerland. Available on: [www.worstpolluted.org](http://www.worstpolluted.org) [10.08.2014].
4. 2010 All-Russia Population Census. Federal State Statistics Service. Retrieved June 29, 2012.
5. EPA, 2007. Available on: [http://www.epa.gov/wed/pages/publications/abstracts/archive\\_2003/allen-gil03.htm](http://www.epa.gov/wed/pages/publications/abstracts/archive_2003/allen-gil03.htm) [10.08.2014].
6. Zenkov V.A.: Hygienic problems Kuzbass mining towns. Sciences, Moscow 2000.
7. Revich B.: Environmental pollution and public health. Introduction to Environmental Epidemiology: MNEPU, Moscow 2001.
8. Bobkov T.E.: Zoning perspective building using risk assessment methodology to public health. J. Hygiene and Sanitation 2009, 6: 38-40.
9. Shashin T.A., Novikov S.M., Kozlov A.V. et al.: Evaluation of health risk due to exposure to emissions from aluminum production. J. Hygiene and Sanitation 2006, 5: 61-64.
10. Zaitsev V.I., Mihayluts A.P.: Hygienic assessment of environmental pollution with long-term use of concentrated chemical enterprises. Chronicle, Kemerovo 2001.
11. Surzhikov V.D., Surzhikov D.V.: Assessment and management of risk to public health from environmental pollution multicomponent major center of metallurgy. J. Hygiene and Sanitation. 2006, 5: 32-35.
12. Environment and human health Joint EEA-JRC report No 5/2013. Available on: <http://www.eea.europa.eu/publications/environment-and-human-health> [10.08.2014].

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