Assessment of Risk of Population Health Damage with Polluted Air of Industrial Megacity

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Abstract. The assessment of risk of the population health damage in industrial cities stipulates for a mandatory use of such indicators as expected duration of the working career, the level of life satisfaction and the level of medical service in the region, DALY, climate in the region considered, the state and quality of the natural environment, especially, the state of atmospheric air. Air pollution causes causes the deterioration of organism functions, adaptation and intellectual capabilities of the population. The problem considered in the article involves the activity of specialists on various levels and professional areas in health care, environmental protection, management of vital activities and the regional viability. Joint complex solutions allow developing complementary natural protection and therapeutic measures for improving the population health in the Krasnoyarsk Territory (exemplified by Krasnoyarsk) and decreasing population mortality.

1. Introduction

The conventional method for analyzing the impact of the polluted environment on the population health is comparing various health indicators on the polluted facility and the regulated value of the pollutant initiating the diseases [4]. The level of atmospheric air pollution hazard is assessed by two main substances classes: carcinogenic substances which can cause malignant tumors and non-carcinogenic substances. A number of carcinogenic substances impacts the genetic background inducing genetic effects, increase in the morbidity of a range of genetic diseases. Carcinogenic and genetic effects are close interconnected and comparable by their significance [3, 8]. The research were conducted by the weighed substances (dust), sulphurous oxide, carbonous oxide, nitrogen oxide with the account of the maximum single and time-weighed average concentrations. A long-term impact of increased nitrogen oxide concentrations causes a wide range of organism responses, in particular, from the respiratory system. This is especially relevant for the sensitive population share, for example, the people suffering from asthma. Sulphurous oxide has an explicit irritant action combined with a strong acrid odor. The following organs are affected in the first place: respiratory organs, eyes, central nervous system, skin. It also suppresses oxidation processes. The increase in the substance concentration in the atmospheric air by 10 ug/m³ causes the growth of total mortality rate by 0.6%. The mortality because of cardiovascular and respiratory diseases increases even more (up to 0.9% per
10 ug/m³ of sulphurous oxide). The growth in the number of hospitalization cases or addresses for emergency medical services because of respiratory diseases in people of the age 65+ is assessed at 0.5% per 10 ug/m³ of sulphurous oxide. The impact of high concentrations of carbonous oxide causes acute intoxication while at the chronic impact one can observe the reduction in oxygen transportation to the tissues due to the growth of carboxyhemoglobin in the blood and change in psychomotor reactions [5, 8, 10]. At the death from cancer caused by chemical cancerogen the mean DALY is approximately 15 years per one case of lethal cancer. Premature death caused by the impact of weighed particles cause to the loss of 14 years of life on average [2, 6, 7]. All these research point to the need of fighting with the sources of contaminating substance occurrence to preserve the healthy nation. Taking into account the fact that in 2021 Kransnoyarsk was included in the top of the most polluted cities of the planet, the study of diseases incidence under the action of contaminating substances is a top priority for the region.

2. Methods
To assess the impact of the polluted atmospheric air on the population health in Kransnoyarsk, the authors applied the methodology of risk assessment in terms of population health deterioration because of chemical factors [12].

The analysis of morbidity and mortality rates in the region was conducted with the account of adjustment weather indicators, such as temperature, speed of air masses motion, air humidity by the data from the stationary posts monitoring the state of the atmospheric city FGBU “Mid-Siberian UGMS (Weather Control and Environmental Monitoring Service)” on each administrative Krasnoyarsk district [11].

Morbidity and mortality rates for the Kransnoyarsk Territory population were taken from the base of statistical data Rosstat for the reporting period 2018-2020 [9].

By the research results the authors assessed the risk for the population health with the account of calculation formulas provided in the Method for Emergency Risk Assessment and Standards of Permitted Emergency Risks (Guidelines for Assessment Technogenic Emergency Risks, Including at Operation of Critical Objects in the Russian Federation). Approved by First Deputy Minister of Civil Defense Affairs, Emergencies, and Liquidation of Consequences of Natural Disasters of the Russian Federation R.Kh. Tsalikov on January 9, 2008 No. 1-4-60-9. and Р 2.1.10.1920-04 and comparison with statistical data on the population morbidity and mortality [13].

3. Results
The mathematic processing of statistical data by the morbidity and mortality assessment in the Kransnoyarsk Territory resulted in the following. When assessing the mortality of the working-age population from individual causes of death, an increase in the number of deaths from respiratory diseases by 2020 was revealed, and the number of deaths from various neoplasms occupies a stable third position in comparison with other causes, Figure 1.
Figure 1. Cause-specific mortality rate in the working population (number of deceased per 100 thousand people of the corresponding age). (people, annual indicator) for the Krasnoyarsk Territory.

The assessment conducted for the total cause-specific mortality rate points to the identical situation in terms of the assessment for the working population mortality rate, Figure 2.

Figure 2. Number of deceased by main classes and death causes per year (number of people, annual indicator, total population) for the Krasnoyarsk Territory.
A particular concern is caused by the amount of deaths because of neoplasms and malignant tumors; in this case one should talk about the interdependences between the health and the environment not only in relation to the industrial plant workers being in direct contact with or situated in the area of emitted carcinogenic and non-carcinogenic substances but also to the ordinary residents of the industrial city. Thus, the authorities have to take crucial solutions directed not at construction of New cancer treatment centers but at the elimination of such diseases.

The peculiarity of such problem, its acuteness and significance are stressed by high values of data on the mortality because of neoplasms over the Siberian Federal District, Figure 3.

![Figure 3](image-url)

**Figure 3.** Mortality of neoplasms, including malignant tumors (per 100 thousand people) (number of people, annual indicator) for the Siberian Federal District.

By their further calculations and results the authors confirm.

The sources of air pollution from the stationary objects in the Krasnoyarsk Territory are metallurgical, mechanical engineering, FES and petro-chemistry plants.

Individual non-carcinogenic risk is calculated by the formula:

\[ INR = \frac{LADC}{RfC} \cdot \alpha \]

where

- \( LADC \) - daily average dose of contaminant absorption, \( \frac{mg}{body\ weight\ per\ day} \)

\[ LADC = \frac{C \times DP}{MT} \]

- \( RfD \) - reference dose, \( \frac{mg}{m^3} \)

- \( \alpha \) - constant showing the time during a whole life when one could observe the harmful impact given the risk assessed during a whole life: \( \alpha = \frac{70}{70} \) where 70- average lifetime, years

- \( DP \) - consumption rate for air = 20 \( \frac{mg}{day\ m^3} \)

- \( MT \) - average body weight, \( MT = 70 \) kg.
C- daily average concentration of contaminating substances averaged for 2020-2021 incompliance with the data of KBGU Center for Implementation of Nature Management and Environmental Protection Measures of the Krasnoyarsk Territory” of the Ministry of Ecology and Rational Nature Management of the Krasnoyarsk Territory.

Estimated values are provided in Table 1 and expressed by the characteristic curves, Figure 4.

Table 1. Individual non-carcinogenic risk (INR).

| District of Krasnoyarsk | CO   | SO₂  | NO₂  | Weighed substances (up to 2.5) |
|------------------------|------|------|------|-------------------------------|
| Zheleznodorozhny       | 0.036| 0.38 | 0.034| 0.69                          |
| Oktyabrskiy            | 0.022| 0.0194| 0.0085| 0.8                           |
| Sovetskiy              | 0.024| 0.46 | 0.044| 0.4                           |
| Leninskiy              | 0.023| 0.44 | 0.055| 0.4                           |
| Kirovskiy              | 0.034| 0.65 | 0.044| 0.55                          |
| Tsentralniy            | 0.036| 0.38 | 0.034| 0.69                          |
| Sverdlavskiy           | 0.037| 0.025| 0.042| 0.52                          |

Figure 4. Individual non-carcinogenic risk.

Population non-carcinogenic risk (annual morbidity rate) is defined by the formula:

\[ RNR = \frac{INR \times N}{70} \]

N- population size

Estimated values are provided in Table 2 and expressed by the characteristic curves, Figure 5.
Table 2. Population non-carcinogenic risk.

| District of Krasnoyarsk | Harmful substances | Weighed substances (up to 2.5) |
|-------------------------|-------------------|--------------------------------|
|                         | CO    | SO₂   | NO₂   |                  |
| Zheleznodorozhny        | 48    | 515   | 46    | 935              |
| Oktyabrskiy             | 56    | 50    | 22    | 2064             |
| Sovetskiy               | 111   | 2127  | 203   | 1850             |
| Leninskiy               | 49    | 943   | 117   | 55               |
| Kirovskiy               | 56    | 1082  | 73    | 920              |
| Tsentralniy             | 38    | 411   | 36    | 746              |
| Sverdlovskiy            | 75    | 52    | 85    | 1054             |

Figure 5. Population non-carcinogenic risk.

Time of the toxic effect onset is defined by the formula:

$$\log(T) = \log(T_0) - \log\left(\frac{C}{\text{ПДК}}\right)^B$$

$T_0$ - time for the warranted no effect, $T_0$=5 years
$B$ - isoefficiency index, for $C>\text{MAC}$ $B=2,4;1,3;1;0,86$ for the substances I, II, III, IV of hazard categories, correspondingly $C<\text{MAC}$ $B=1$ regardless of the hazard category, Table 3.

Table 3. Time of toxic effect onset.

| District of Krasnoyarsk | Harmful substances | Weighed substances (up to 2.5) |
|-------------------------|-------------------|--------------------------------|
|                         | CO    | SO₂   | NO₂   |                  |
| Zheleznodorozhny        | 0.68  | 0.55  | 0.46  | 0.04             |
| Oktyabrskiy             | 0.47  | 0     | 0     | 0                |
| Sovetskiy               | 0.5   | 0.47  | 0.57  | 0.26             |
| Leninskiy               | 0.48  | 0.47  | 0.66  | 0.26             |
| Kirovskiy               | 0.65  | 0.33  | 0.63  | 0.12             |
| Tsentralniy             | 0.68  | 0.55  | 0.46  | 0.03             |
| Sverdlovskiy            | 0.68  | 0     | 0.54  | 0.15             |
Individual and population carcinogenic risks are provided for the Sovetskiy, Leninskiy and Zheleznodorozhny districts and for the whole city of Krasnoyarsk on benzopyrene, Table 4. Individual carcinogenic risk is calculated by the formula:

\[ \text{IKR} = \text{LADC} \times \text{SF} \times \alpha \]

where

\[ \text{SF} \text{- carcinogenic potential factor.} \]

\[ \text{SF=6.11} \]

Population carcinogenic risk is defined by the formula:

\[ \text{PKR} = \frac{\text{IKR} \times N}{70} \]

\[ N \text{- population size} \]

**Table 4. Individual carcinogenic (INR) and population carcinogenic (PKR) risk on benzopyrene.**

| Krasnoyarsk district/Risk | Carcinogen Benzopyrene |
|---------------------------|------------------------|
|                           | Individual carcinogenic risk on benzopyrene (INR) | Population carcinogenic risk on benzopyrene (PKR) |
|                           | 0.079                  | 107                  |
| Zheleznodorozhny          | 0.036                  | 166                  |
| Sovetskiy                | 0.03                   | 64                   |
| Leninskiy                |                        |                      |

Average individual carcinogenic risk and Population carcinogenic risk for the Krasnoyarsk population are the following:

\[ \text{IKR}_{\text{ср}}=0.048 \]

\[ \text{PKR}_{\text{ср}}=749 \text{ cases per year} \]

Correspondingly, the number of additional cancer cases per annum for the Krasnoyarsk population of 1,092,851 is estimated as 749.

4. **Conclusion**

The evaluation obtained reflects the assessment of health damage on a microlevel. It should be used to pass weighted management resolutions by the executive and legislative authorities in a certain city. Such decision making should also take into account regional economic data and population health indicators. Such assessment is explained by the fact that, given the contemporary state of medicine, cancerous diseases are characterized by the need of large material expenditures in the process of treatment and significant irreplaceable social losses because of mortality and invalidation in all age groups [1,14].

By the results of the calculations presented for atmospheric pollution, an opportunity arises to identify hazardous substances on which the excess of the existing criteria of atmospheric air quality is registered. Naturally, this allows making up more efficient action plans to decrease the existing levels of atmosphere pollution by these substances to the permitted levels. In Krasnoyarsk these plans should include the measures connected with technological manufacturing processes.

5. **References**

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