Analysis of industrial production in Russian cities with the most polluted atmospheric air

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Abstract. The quality of life depends directly on the environmental situation in cities. Experts from the world health organization have found that about thirteen million deaths worldwide each year could be prevented if the environment is improved by reducing environmental sources of risk.

1. Introduction
In accordance with the “Strategy for spatial development until 2025”, it is necessary to reduce interregional differences in the level and quality of people's life in Russian cities [1]. The quality of life depends directly on the environmental situation in cities. Experts from the world health organization have found that about thirteen million deaths worldwide each year could be prevented if the environment is improved by reducing environmental sources of risk.

In order to improve the quality of people's life in Russian cities in 2019, the national project “Ecology” was developed, which includes 11 Federal projects, and the project “Clean air” is one of them. In accordance with it, 12 major industrial centres with the most polluted air (Bratsk, Krasnoyarsk, Lipetsk, Magnitogorsk, Mednogorsk, Nizhny Tagil, Novokuznetsk, Norilsk, Omsk, Chelyabinsk, Cherepovets, and Chita) will introduce a new pollution monitoring system and summary calculations, and will receive Federal transfers [2].

However, according to the level of atmospheric pollution, there are more disadvantaged cities than those included in the program compiled by the Ministry of nature in the framework of the national project “Ecology”.

Experts from the Ministry of nature in their report published 10 cities in Russia with the dirtiest air for 2019. It includes: Shelekhov, Svirsk, Usolye-Sibirskoe, Barnaul, Angarsk, Chita, Lesosibirsk, Minusinsk, Zima, and Kyzyl [3].

To identify socio-economic factors that affect the potential of air pollution, the enterprises and emissions of substances in 10 most polluted cities and cities included in the national project "Ecology" were analysed. Toxicological characterization of emitted substances of such companies was given and the quality index of the urban environment of these cities was calculated.

The cities with the dirtiest air were primarily industrial territories where metallurgy, energy, mining, and construction industries were developed.

According to data for 2019, in Russia as a whole, 10 industries can be identified as air pollutants. These include metallurgical production (3.7 million tons per year, or 21 % of the total emissions of enterprises), energy (providing electricity, gas and steam, air conditioning; 3 million tons, or 17 %), and oil and gas production (2.4 million tons, or 14 %). This is followed by transport companies and
pipelines (1.7 million tons, or 10%), coal mining (1.3 million tons, or 8%), production of coke and petroleum products (721.6 thousand tons), production of mineral resources (i.e. mining: 622 thousand tons, or 3.6%), waste processing industry (557.8 thousand tons, or 3.2%), metal ore mining (491.6 thousand tons, or 2.8%), and production of other non-metallic mineral products (i.e. glass, refractories, concrete; 382.4 thousand tons, or 2.2%). Motor transport accounts for about a quarter of all emissions.

### Table 1. The main pollutants of atmospheric air of the cities.

| Pollutants                  | The main anthropogenic sources                                      | Impact on human health                                                                 | Cities that exceed the maximum permissible limit |
|-----------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------|
| Benz(a)pyrene               | Fuel combustion in industrial and domestic installations            | It has the property of bioaccumulation, can have a mutagenic effect                    | Shelekhov, Svirsk, Usolye-Sibirskoe, Barnaul, Angarsk, Chita, Lesosibirsk, Minusinsk, Zima, Kyzyl |
| Suspended solids            | Enterprises of the metallurgical industry, mechanical engineering, | Fine particulate matter induces damage to DNA cells, leading to lung and cardiovascular diseases and cancer | Shelekhov, Svirsk, Usolye-Sibirskoe, Barnaul, Angarsk, Chita, Lesosibirsk, Minusinsk, Kyzyl |
| Phenol and formaldehyde    | Petrochemical enterprises, wood chemical complexes, mining and     | Phenol causes functional disorders of the Central nervous system, secretory-motor activity of the stomach and liver, as well as dry skin, itching, dermatitis. Phenol is a cocancerogen. Formaldehyde negatively affects the reproductive organs and genetic apparatus, respiratory tract, eyes, skin, and Central nervous system, causing depression and convulsions | Angarsk, Chita, Lesosibirsk, Kyzyl               |
| Nitrogen dioxide           | Machine-building enterprises, mining and processing plants, motor  | It has an irritating effect                                                              | Svirsk, Usolye-Sibirskoe, Barnaul, Angarsk, Chita, Lesosibirsk, Minusinsk, Zima, Kyzyl           |
| Ground-level ozone         | Photochemical reactions in the atmosphere                            | Affects the respiratory tract, causes fatigue, nausea, headache, allergies, genotoxic | Shelekhov, Angarsk                               |
Substances in the emissions of enterprises and vehicles have different levels of danger—from relatively safe to very dangerous. For example, carbon monoxide and methane belong to the fourth, low-hazard class, while sulphur dioxide and nitrogen oxide are classified as the more dangerous third class. However, assigning a substance to the last hazard class does not mean that this compound is harmless—it depends on the concentration: an increased content of the corresponding substance can lead to chronic diseases and death of the body.

Enterprise emissions contain a range of substances of varying degrees of hazard, such as solids, volatile organic compounds, and other gaseous and liquid substances. For example, toluene, dust, and soot belong to the third class. Such substances as hydrogen sulphide, carbon disulphide, sulphuric acid, phenol, solid fluorides, hydrogen fluoride, and formaldehyde belong to the second class. The first and most dangerous class includes benzapyrene, lead, mercury, cadmium, and chromium compounds (Table 1).

Harmful substances have an impact on the human body. General toxic substances cause poisoning of the body as a whole. When exposed to them, convulsions, nervous system disorders, and paralysis are observed. For example, it is arsenic, benzene, lead, mercury, and carbon monoxide.

Irritating substances affect the skin, mucous membranes of the respiratory tract, lungs, eyes, and nasopharynx. Prolonged exposure leads to respiratory disorders, intoxication, and death (acetone, ammonia, chlorine, and nitrogen oxides). Sensitizers are chemicals that cause an allergic reaction (formaldehyde, hexachlorane, and dust).

Carcinogens are one of the most dangerous groups of substances that cause cancer (benzapyrene, asbestos, and beryllium). Mutagens are substances that change the human genotype. They reduce the body’s resistance to diseases, cause early aging, and can affect the health of offspring (benzapyrene, lead, mercury, and manganese). Substances affecting reproductive health cause developmental abnormalities in offspring, not necessarily in the first generation (ammonia and boric acid).

Harmful emissions are to some extent indicators of the development of the territory—they indicate the degree of industrialization and the number of cars. However, as global economic growth increases, this correlation weakens. Developed countries that have reached a certain level of well-being begin to reduce their negative impact on the environment. On the contrary, poor countries prioritize purely industrial indicators without regard to nature, since environmental issues are considered on a residual basis.

2. Methods
The national project "Ecology" is designed to improve the environmental situation in Russian cities, but so far most of them are located in cities that have industrial enterprises of international significance.

Despite exceeding the maximum permissible concentrations in the air of the most polluted cities of the Russian Federation in 2019, they were not included in the national project "Clean air".

In addition, the maximum permissible concentrations used in our country are not always justified by the effects directly related to health. 30% of the maximal permissible concentration (MPC) for atmospheric air in populated areas is determined by human reflex reactions. In this regard, the use of current hygiene standards as a risk assessment criterion is possible only if the substance is regulated according to sanitary-toxicological, resorptive, or reflex-resorptive criteria of harmfulness and there is confidence in their sufficient reliability. An additional factor that makes it difficult to apply the existing regulatory framework for risk assessment is the period when the MPC is averaged. As you know, average daily concentrations are regulated in our country, while average annual concentrations are required for risk assessment.

In this regard, it is necessary to propose conversion coefficients for the average daily MPC to the average annual MPC for substances released into the air of the most polluted cities of the Russian Federation in order to determine the health risk of environmental pollution.

The exposure assessment process usually consists of three main stages.
The first stage is a description of the environment, which includes an analysis of the main physical parameters of the study area (temperature, precipitation, relative humidity, wind speed and direction, altitude, number of days with stable snow cover, air mass circulation, etc.) and a description of populations potentially affected.

The second stage is identification of exposure routes, sources of pollution, potential distribution routes, and points of human exposure.

The third stage, quantitative characterization of exposure, provides for establishing and evaluating the magnitude, frequency, and duration of exposure for each analysed pathway identified in the second stage. Most often, this stage consists of two stages: assessment of the impacting concentrations and calculation of the receipt.

Analysis of industrial production in the above-mentioned Russian cities will allow us to offer a key factor in the deterioration of ambient air, which significantly affects the quality and duration of life of the population (Table 2).

| Table 2. Factors of probability of increase in morbidity of the population due to air pollution by emissions of industrial enterprises and transport. |
|-----------------------------|----------------|-----------------------------|
| Group of factors             | No., k          | Factor                                   |
| Type of harmful substance    | 1              | Hazard class of harmful substances involved in the production process |
|                              | 2              | Intensity and volume of emissions of pollutants |
| Manufacturing technology, industry, and transport | 3              | Compliance with requirements, norms, and regulations |
|                              | 4              | Type of fuel burned |
| Intended cleaning            | 5              | Technology used |
|                              | 6              | Number of accidents (non-standard situations) |
| Size of the territory        | 7              | Green spaces |
|                              | 8              | Availability of water bodies |
| The level of technogenic development of the territory | 9              | Population density |
|                              | 10             | Building density |
|                              | 11             | The layout and width of streets, the height of buildings |
| Quality of enterprise and production management | 12             | Average level of education of employees |
|                              | 13             | The number of violations of industrial discipline for the analysed period |
| Presence of external sources of danger | 14             | Influence of natural phenomena (dust storm, hurricane, volcanism, precipitation, etc.) |
|                              | 15             | The level of danger of nearby external man-made sources of danger |
|                              | 16             | Terrorism, military actions |

We tested the method of integral graphs zoning (clustering) of economic agents on environmental risk. Building a diagram of the level of environmental hazard of industrial enterprises located in a particular city includes the following steps: 1) information gathering; 2) the rationale for a statistically valid sample; 3) assessing the probability of occurrence for each industrial facility emissions with adverse environmental consequences; 4) the calculation of economic damage caused by these effects; 5) the histogram of the distribution of selected industries on the criterion of the value of economic damage; 6) the establishment of probability groups based on the choice of the number and boundaries of the intervals of damage estimates using the Harrington scale; 7) application of interval values of the
level of risk and damage in the form of scales, respectively, to the x-axis and y-axis of the chart; 8) zoning diagrams obtained by the level of environmental risk; 9) data localization probability and impacts for selected industries in the specified coordinate system and the establishment of facilities for every enterprise to a specific area environmental hazards; 10) determination of the groups on the criterion of the level of ecological danger.

Such a diagram is a two-dimensional coordinate system, on the abscissa of which the scale of probabilities of deterioration of atmospheric air quality with adverse environmental consequences is displayed, on the ordinate – the scale of the expected economic damage caused by these consequences. In both scales, the interval values of the corresponding criteria are used, along with the discrete ones. This allows them to be grouped according to the level of environmental danger. Horizontal – spacing low, medium, and high probability of deterioration of air quality with adverse environmental consequences; vertical – spacing low, middle, and high level the expected economic damage caused by these effects. For convenience, the intervals are assigned with sequential numbers. The intersection of three columns and three bars forms nine cells on the diagram, graphically displaying the level of environmental hazard of industrial enterprises. To determine (qualitative and quantitative assessments) the level of risk, a zoning derived matrix diagram is built: zone of low-level environmental hazards forms a cell with the lowest sequence number; the high level of ecological danger corresponds to the cells with at least one ordinal number – most, equal to three; the rest of the cell is zone of moderate level of ecological danger.

Knowing the degree of influence of each factor on the probability of deterioration of atmospheric air quality in cities, one can calculate the expected damage.

3. Results

Exposure determination is an integral part of not only risk assessment, but also the risk management process, because it allows you to determine:

- the distribution of chemical concentrations over time and space in various environmental objects;
- high-and low-risk populations or subpopulations;
- priority, effective, and most cost-effective risk reduction programs and activities;
- contribution to the levels of exposure from various sources of pollution;
- factors that affect the release of pollutants into the environment, the pathways of harmful substances, and the pathways of entry into the human body;
- compliance of the applied measures to reduce pollution with the achievement of safe levels for health.

The most sensitive subpopulations to the effects of chemicals may in some cases be newborns and children, the elderly, pregnant and lactating women, as well as patients with chronic diseases.

We used the method of forming the urban environment quality index to determine the quality of life of people in cities.

We will determine the urban environment quality index (for 2019) based on population groups. First, let us look at the list of cities with the most polluted atmospheric air. Shelekhov, Svirsks, Winter apply to small cities, Usoley-Sibirskoye, Lesosibirsk, Minusinsk are medium ones, Kyzyl and Angarsk are big cities, and Chita and Barnaul are large ones. In addition, all cities have an air pollution index less than 180, meaning that the urban environment is considered unfavourable: Shelekhov (177 points), Svirsks (148), Zima (138), Usoley-Sibirskoye (144), Lesosibirsk (125), Minusinsk (154), Kyzyl (152), Angarsk (180), Chita (148), and Barnaul (179).

Now let us look at the cities included in the program aimed at reducing air emissions: Bratsk (175), Krasnoyarsk (181), Lipetsk (200), Magnitogorsk (184), Mednogorsk (159), Nizhny Tagil (163), Novokuznetsk (167), Norilsk (199), Omsk (106), Chelyabinsk (161), Cherepovets (197), and Chita (148). Mednogorsk belongs to small cities, Norilsk and Bratsk – to big cities, Lipetsk, Magnitogorsk, Nizhny Tagil, Novokuznetsk, and Cherepovets – to large cities, and Krasnoyarsk, Omsk, and Chelyabinsk – to the largest. The quality index values for these cities do not exceed 200, i.e. they are close to the border of an unfavourable urban environment.
4. Conclusion
To determine the quality of life for people in cities with polluted air it is necessary to calculate the risks of increased morbidity, for example, a method of constructing integral graphs zoning (clustering) of economic agents on environmental risk for different groups of the population. This will allow you to make management decisions.

References
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