Methods and results of urban zoning by the impact on environmental pollution

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Abstract. The article presents results of the calculation of pollutants emitted into the atmospheric air in Chita. The approach to the zoning of the city territory with a population of more than 350 thousand people is described. By the results of calculation and assessment of health risks, which are based on the data of modeling the dispersion of harmful impurities, the zones of exposure to chemical impurities were identified. The zoning by the risk degree is relevant for assessing the danger to the population and the impact on the environment. The list of priority impurities was substantiated, taking into account carcinogenic and/or non-carcinogenic risks, and the results of calculations of dispersion and allocation of marker indicators for emissions from enterprises that make the greatest contributions to the air pollution. The methods used in Chita help identify areas with the greatest risks to public health.

1. Introduction

Urban areas tend to be heterogeneous in terms of pollution levels. For the spatial planning, it is necessary to know the zones of greatest risk and zones of maximum ecological well-being - placement of recreation zones, children's health institutions, parks and squares. Zoning is not an easy task, especially in difficult environments.

Chita is the administrative center of the Trans-Baikal Territory and Chita Region located in the east of Siberia. It forms a municipality - the urban district of Chita. The climate is sharply continental, influenced by the height of 650 m above sea level. The winter is very cold, with little snow and almost three months longer than the calendar winter. The distribution of pollutants on the territory is uneven. The main contribution is made by fuel and energy enterprises, vehicles and stove heating in the private sector [1].

According to the Report on the ecological situation in the Trans-Baikal Territory for 2019 [2], for 20 years Chita has had an air pollution index varying from 14 to 23, which is high and extremely [3]. For a number of indicators, the excess of hygienic standards (for hydrogen sulfide up to 1.94 MPCmr, suspended solids up to 27.6 MPCmr) is 50 or more times, which poses a danger to the health of the population. Decree of the President of Russia No. 204 of May 7, 2018 "On national goals and strategic objectives for the development of the Russian Federation for the period up to 2024" provides for the solution of large-scale tasks aimed at creating a comfortable and environmentally friendly environment [4]. To solve this problem, the Federal Project "Clean Air" has been implemented, which implies a phased achievement of the radical improvement in air quality. The key objective of the project is "to reduce the level of air pollution in large industrial centers".
Reducing the level of emissions without taking into account how this reduction will affect the medical and demographic indicators does not always allow us to assess the effectiveness of measures, obtain evidence of their environmental and sanitary-epidemiological significance, and use the data to relieve social tension arising from the dissatisfaction with atmospheric air [5].

The zoning of the populated areas by the degree of risk is relevant for assessing the risk to public health. For this purpose, zones with varying degrees of danger to the population have been indicated on the city map.

The study aims to zone the territory by the level of aerogenic risk to the health caused by the quality of atmospheric air in Chita.

2. Materials and methods

Chita is divided into 4 administrative districts: Railway District (47.886 thousand people), Ingoda District (88.753 thousand people), Central District (123.870 thousand people), Chernov District (91.275 thousand people). As of January 1, 2020, 351.784 thousand people live in Chita.

About 75.5 thousand tons of pollutants are emitted into the air. More than half of the stationary sources of emissions belong to various enterprises (CHPP-1, CHPP-2).

The risk was assessed on the basis of calculated data. The initial information for assessing the health risks was consolidated databases of stationary and mobile sources of emissions, which contain information on 99 types of pollutants, with a total mass of 75468.93 tons / year, mobile - 10 pollutants with a total mass of 994.8 tons / year, as well as records on 2705 sources of pollutants emitted into the air: 391 sources of vehicles, 188 enterprises, 1110 sources of AIT included in the subsequent assessment of health risks.

For the spatial assessment, the initial cartographic information was collected: electronic vector layers of Chita, including functional zones, administrative boundaries, boundaries of the urban district, boundaries of land plots, buildings and structures with an address register, hydrography.

The surface concentrations were calculated at 15126 points corresponding to the geometric centers of residential buildings.

The results of scattering calculations were visualized on the vector map of Chita in the geographic information system (GIS). ArcView 3.2 and ArcGIS 9.3.1 were used. On the vector map of Chita, electronic layers (residential buildings, road network, industrial sites, water bodies) with attribute data were displayed.

For zoning the territory by the public health risk, the cluster analysis was carried out using the standard methods that allow breaking the set of calculated points into groups of the "similar" ones according to the system of cluster parameters [6].

The preference for the calculated points over the regular grid was given taking into account several aspects:

• residential development is not a continuous territorial formation; individual residential areas are located at a considerable distance from each other and represent small zones that are incorrect to take into account with the recommended grid spacing of 200 x 200 m;

• the regular grid does not make it possible to eliminate the hit of individual points on industrial sites located in close proximity to housing, on roads, etc., which reduces the correctness of the health risk assessment [7];

The location of the points at the points of residence of the population is most consistent with the task of assessing the risks to human health and the urban zoning.

The zoning procedure was performed separately for each type of risk and each critical organ or system. The zones were located throughout the entire city.

To calculate the average annual concentrations of pollutants, the standardized calculation method was used.

Each site was assigned the following categories:

• 0 – by the type of risk, if the average risk was assessed as acceptable (carcinogenic - below 11.10^5, non-carcinogenic - HI <1.0);
• 1 - by the type of risk, if the risk was assessed as low (carcinogenic - in the range from 1·10^{-5} to 1·10^{-4}; non-carcinogenic 1.0 < HI < 3.0);
• 2 - by the type of risk, if the risk was assessed as alarming 3.0 < HI < 6.0;
• 3 - by the type of risk, if the risk was assessed as high HI > 6.0.

Based on the analysis of contributions of chemicals, health risks were identified as priority impurities, which included impurities that form more than 90% of unacceptable health risks.

For each object of the address register (calculated point), the population was determined. The total population living in each zone was determined as the arithmetic sum of the population at the calculated points. For the convenience of visualization, the points were combined into rectangles 200x200 m. When zoning the territory, it was taken into account that each rectangle is characterized by the average values of the points located there.

The calculated concentrations were initial data for assessing the risk, solving the problem of zoning of Chita, and determining the contribution of certain factors (chemicals), economic entities and / or road transport to air pollution and public health risks [8–10].

3. Results
15 carcinogenic impurities enter the atmospheric air of Chita with emissions from all types of sources: carbon (soot), benz / a / pyrene (3.4-Benzpyrene), chromium trivalent compounds (in terms of Cr3 +), chromium (hexavalent chromium) (in recalculated as chromium (VI) oxide), trichloroethylene, benzene, tetrachloroethylene (perchlorethylene), formaldehyde, acetaldehyde, tetrachloromethane (carbon tetrachloride), ethylbenzene (vinyl benzene, styrene), ethyl benzene, lead and its inorganic compounds for lead (in terms of lead) sulfate (sehydrin), dioxins.

According to the calculated data in Chita, no excess of the admissible total levels of individual carcinogenic risks (TCR > 1·10^{-4}) was established. The range of levels of the total carcinogenic risk in residential areas ranged from 2.20·10^{-6} to 5.74·10^{-5}.

The residential development of Chita is not a continuous territorial formation, individual residential areas are located at a considerable distance from each other and represent small zones.

The main contribution to carcinogenic risks is made by formaldehyde (from 25 to 72% depending on the zone), carbon (soot) - from 28 to 60%, benzo (a) pyrene (from 4.3 to 38%). The contribution of lead compounds is insignificant (no more than 1%). Other impurities do not contribute to the carcinogenic risk. The carcinogenic risk is about 2.3 cases per year.

Throughout the territory of Chita, the levels of acute non-carcinogenic risks are higher than HI > 1. In some territories, the hazard indices range from 3.0 to 28.33 HIac. In general, according to the level of the acute non-carcinogenic risk to the respiratory organs and the structure of contributions of priority pollutants, 24 heterogeneous zones have been identified. The range of hazard indices in these zones ranged from 1.68 to 8.94 (354 thousand people). The maximum value of the hazard index (8.94 HIac) was observed in the zone with a population of 710 people living in the Railway district, located in the southern part of Chita.

Priority substances that form more than 95% of the acute non-carcinogenic risk include dusts with priority inorganic dust (70–20%) SiO_{2}.

By the criterion of the acute non-carcinogenic risk of developmental disorders, 29 zones were identified; the average HI level varies from 1.08 to 23.21 (more than 46 thousand people). The maximum value of the hazard index (23.21) was observed in the area with a population of 29 people, located in the Inogoda district. The zones are local, insignificant in area and the number of the population.

Benzene is a substance that forms a contribution of more than 90% to the unacceptable acute individual non-carcinogenic risk (HI > 3).

By the negative impact of chemicals on the blood under the conditions of acute inhalation exposure, 28 zones were identified. The hazard index values ranged from 1.17 to 23.02 (more than 30 thousand people, which is about 9% of the total population of the city). The maximum value of the hazard index (23.02) was observed in the area with a population of 29 people. The risk zones for...
disorders of the blood and immune system are local, caused by benzene (contribution varies from 99.5 to 100%). Ingoda, Central, Railway and Chernov districts are at risk.

By the systemic effects of acute inhalation exposure, 25 zones were identified. The values of hazard indices ranged from 1.33 (more than 100 thousand people) to 20.07 HI. The maximum value of the hazard index (20.07) was observed in a zone with a population of 58 people living in the Railway district.

The analysis of the total levels of chronic non-carcinogenic risk revealed unacceptable risks to the respiratory system, blood, and development processes.

Under the chronic inhalation exposure, by the chronic non-carcinogenic risk, 13 zones were identified. The hazard index values ranged from 1.40 to 3.25 HI. The maximum value of the hazard index (3.25) was observed in the area with a population of more than 7 thousand people, located in the southern part of the city. Substances that form a contribution of 90% or more to the unacceptable chronic non-carcinogenic risk (HI> 3) include inorganic dust: 70–20% SiO2, sulfur dioxide (sulfur dioxide), nitrogen dioxide (nitrogen (IV) oxide).

There are zones, where the indices of developmental disorders ranged from 1.24 to 10.22 (more than 350 thousand people). The maximum value of the hazard index (10.22) was observed in the zone with a population of 1,048 people, located in the western part of the city of Chita.

The spatial conjugation of zones with different levels and types of risk made it possible to identify zones and individual areas where residents experience the greatest complex aerogenic risks [11]. The zoning results are shown in Figure 1.

![Figure 1. Spatial distribution of aerogenic risk in Chita](image)

As can be seen from the data presented, the population of the city is experiencing a heterogeneous negative impact of atmospheric air pollution. An unfavorable situation develops for residents of densely populated areas of the southern part of the Railway district, the southwestern part of the Ingoda district and the southeastern part of the Chernov district. To improve the air quality of these zones, air protection measures should be developed.
The zoning results by the criterion of the generated aerogenic risk to public health indicate that in the current situation, until the levels of acceptable risk are reached, it is advisable to develop and implement compensatory medical and preventive measures aimed at mitigating health risks associated with atmospheric air pollution [12 -13].

4. Conclusion
The levels of impact on the population and the environment can and should be considered as the most important criterion for the zoning for the purposes of spatial planning with the development of plans (programs of air protection measures).

The basis for the zoning can be dispersion calculations using a database that includes all city sources.

Approbation of methods on the example of Chita made it possible to identify the zones with the greatest risks - s zones of ecological well-being. It showed their effectiveness and made it possible to form information materials for decision-makers at the municipal level.

On the territory of the city, zones and areas where the population experiences the greatest aerogenic risks have been identified. These include the zones of influence of large industrial enterprises, covering large areas of the city; the contribution to risks is large at the calculated points (for example, high heated sources of CHP plants or large boiler houses).

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