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Regional risks and medical-socio-economic consequences in conditions of climate change

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BACKGROUND

- According to the World Health Organization, air pollution is closely associated with climate change and, in particular, with global warming. In addition to melting of ice and snow, rising sea level, and flooding of coastal areas, global warming is leading to a change of temperate ecosystems. Moreover, the effects of air pollution on airway and lung, cardiovascular, neurological diseases are well documented.

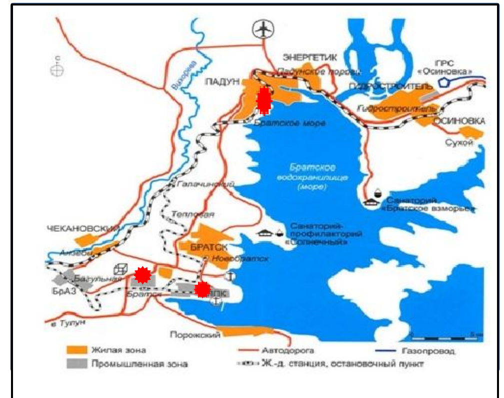
[S. Sujaritpong et al. Int J Biometeorol. 2014; 58(2); V. Patella et al. Clin Mol Allergy. 2018; 16: 20.;M. W. Gorr, M. J. Falvo, L.E. Wold Compr Physiol. .2020 May 26.]

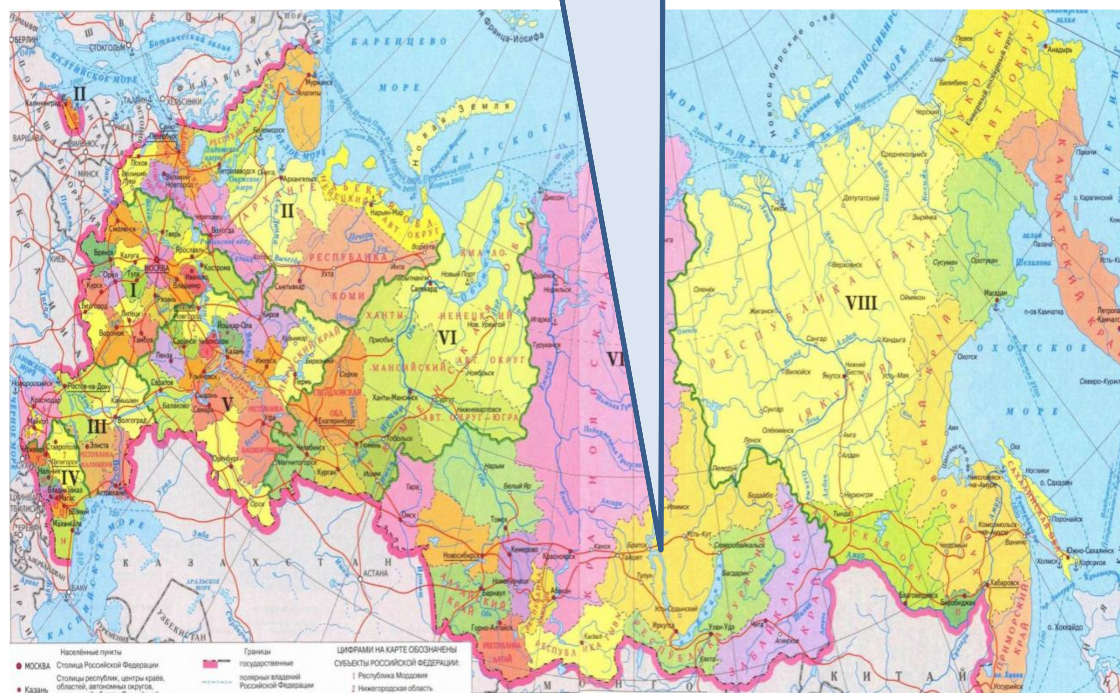
- The purpose of the work is a qualitative and quantitative assessment of the results of short- and medium-term forecasting of the child population morbidity when changing natural and anthropogenic environmental factors.
- The studies were carried out on the example of Bratsk, as it is characterized by severe climatic conditions and high air pollution.

CHARACTERISTICS OF THE RESEARCH OBJECT

Several major sources of pollution are located on the territory of Bratsk. The most important ones are : heat power plants, aluminum plants, wood chemical production. The territory of Bratsk belongs to the zone of ecological crisis. Air pollution with carbon disulfide, benzapyrene, and fluoride compounds exceeds the permissible level by 1.5-30 times. areoles of soil contamination with heavy metals and fluorine were found in the zone of influence of industrial enterprises.

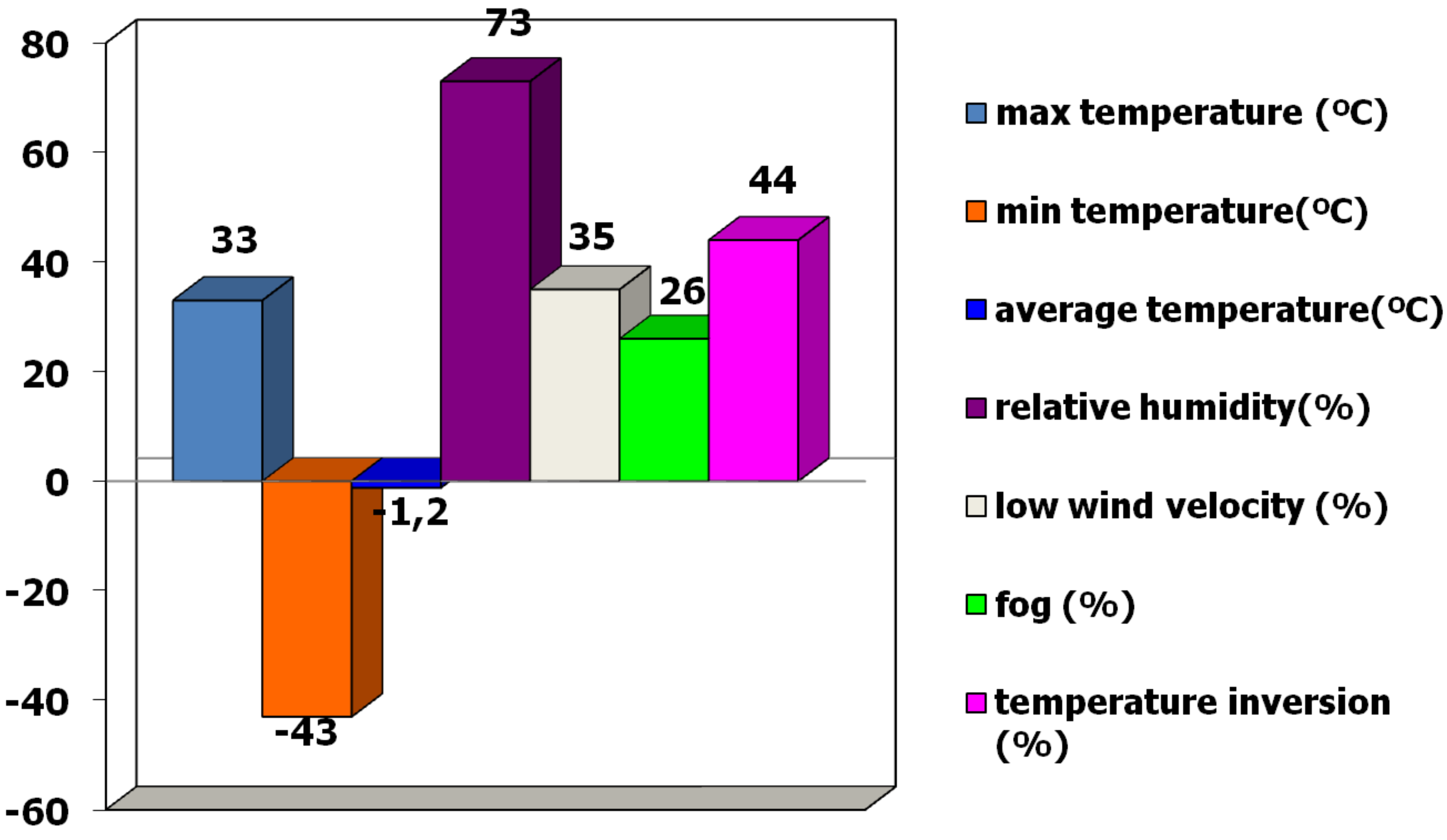
Bratsk





source of pollution

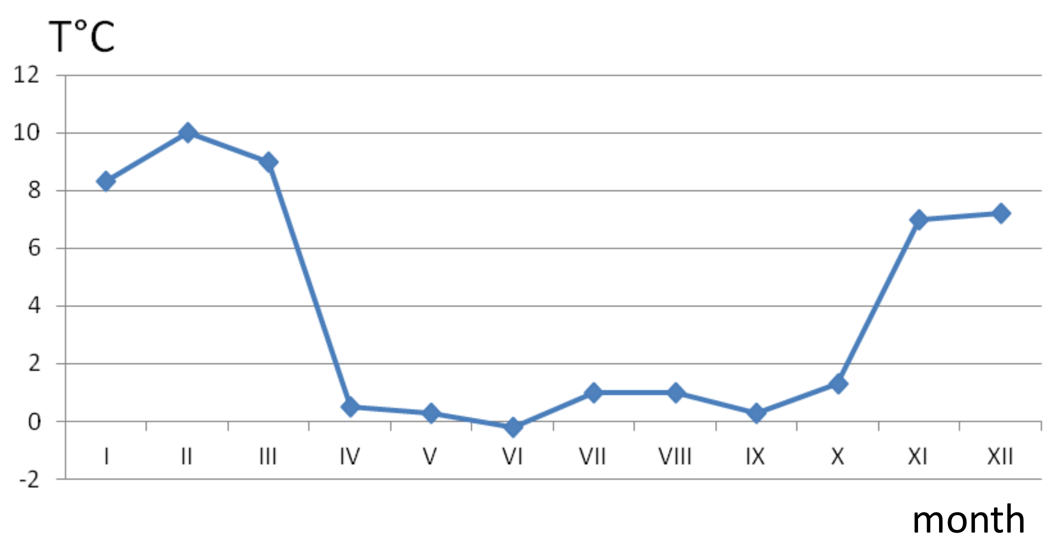
METEOROLOGICAL CONDITIONS OF BRATSK (IRKUTSK REGION)



- The climate in Bratsk is sharply continental with severe long winters and short summers.
- Due to the large water surface of the reservoir, fogs are often observed on the territory of the city.
- Adverse weather conditions for the dispersion of pollutants in the atmosphere are observed up to 50% of days a year.

The change in the average monthly air temperature in Bratsk compared to 1961-1990 occurred in the present period. There was a significant increase in air temperature in the winter months.

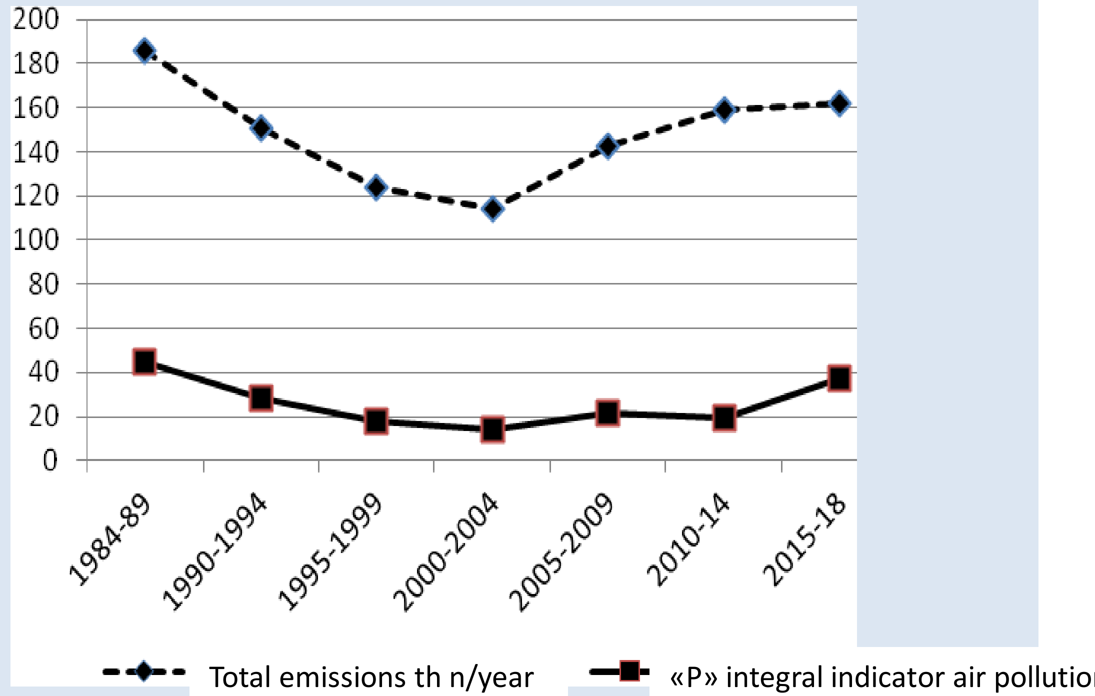
Change in the average monthly air temperature in Bratsk compared to 1961-1990



AIR POLLUTION IN BRATSK

- The average annual concentrations exceeded the permissible standards for suspended substances-by 1.5 times, for carbon disulfide-by 1.8 times, for formaldehyde-by 2.0 times, for Benz (a)pyrene - by 6.2 times.
- The maximum single concentrations of suspended substances reached 1.2 Maximum permissible concentration (MPC), carbon monoxide-1.6 MPC, nitrogen dioxide-3.6 MPC, hydrogen sulfide-1.3 MPC, carbon disulfide-1.6 MPC, solid low-soluble fluorides-1.7 MPC, hydrogen fluoride and formaldehyde - 2.0 MPC in 2018 year.

Dynamics of total emissions and integral indicator of air pollution



MATHEMATICAL MODEL
the influence of the environmental factors on the public health

$$Z_i(a) = a_1 \cdot T_i + a_2 \cdot W_i + a_3 V_i + a_4 \cdot \frac{LnP_i}{LnV_i} + a_5 LnC_i$$

T_i – the average annual air temperature (˚C),

W_i – the healthcare provision (the number of specialists per 1000 population),

V_i – the average annual wind speed (m/s),

P_i – the integral indicator of the atmospheric air pollution (the conventional units),

C_i – the level of social and living conditions of the city (the expert assessment, points),

The data for the parametric identification of the proposed model are presented by observations for the period from 1990 to 2005, $i = \overline{1,16}$.

To assess the accuracy of forecasts, the indicated data for 2009 and 2018 were used.

PROBLEM STATEMENT

- **Unconstrained minimization**

To search for unknown coefficients *a1, ..., a5* (the contributions of the corresponding factors to the formation of the studied indicator) was carried out using the least square method, based on the search for the minimum of the sum of squares of the differences of the calculated and experimental data:

$$F(a) = \sum_{i=1}^{m} (Z_i(a) - H_i)^2$$

Thus, the problem is reduced to finding the minimum of the function of several variables *F(a)* over all a from the set *D*, where *D* is a multidimensional parallelepiped:

$$\min_{a \in D} F(a), D = \{a \in R^n : \underline{a}_k \leq a_k \leq \overline{a}_k, k = \overline{1,n}\},$$
$$n = 5, m = 16$$

here *n* is the dimension of the finding vector

$Z_i(a)$ – calculated indicators

H_i – actual data on the population morbidity

The unconstrained minimization problem belongs to the traditional global optimization problems, for which many methods and algorithms have been developed. To solve the considered optimization problem at the first stage, the coordinate descent method is used to reduce it to an auxiliary one-dimensional search problem. For the global search for the minimum value of the function in the given area, a parabola algorithm is implemented (a step-by-step description of which is given below); for the auxiliary problem of the local one-dimensional search, the combination of the golden section and the parabolic interpolation methods is used.

METHODOLOGY

Methods for solving
unconstrained optimization problem

- Coordinate descent;
- One-dimensional search method.

Methods for investigating
one-dimensional optimization problem

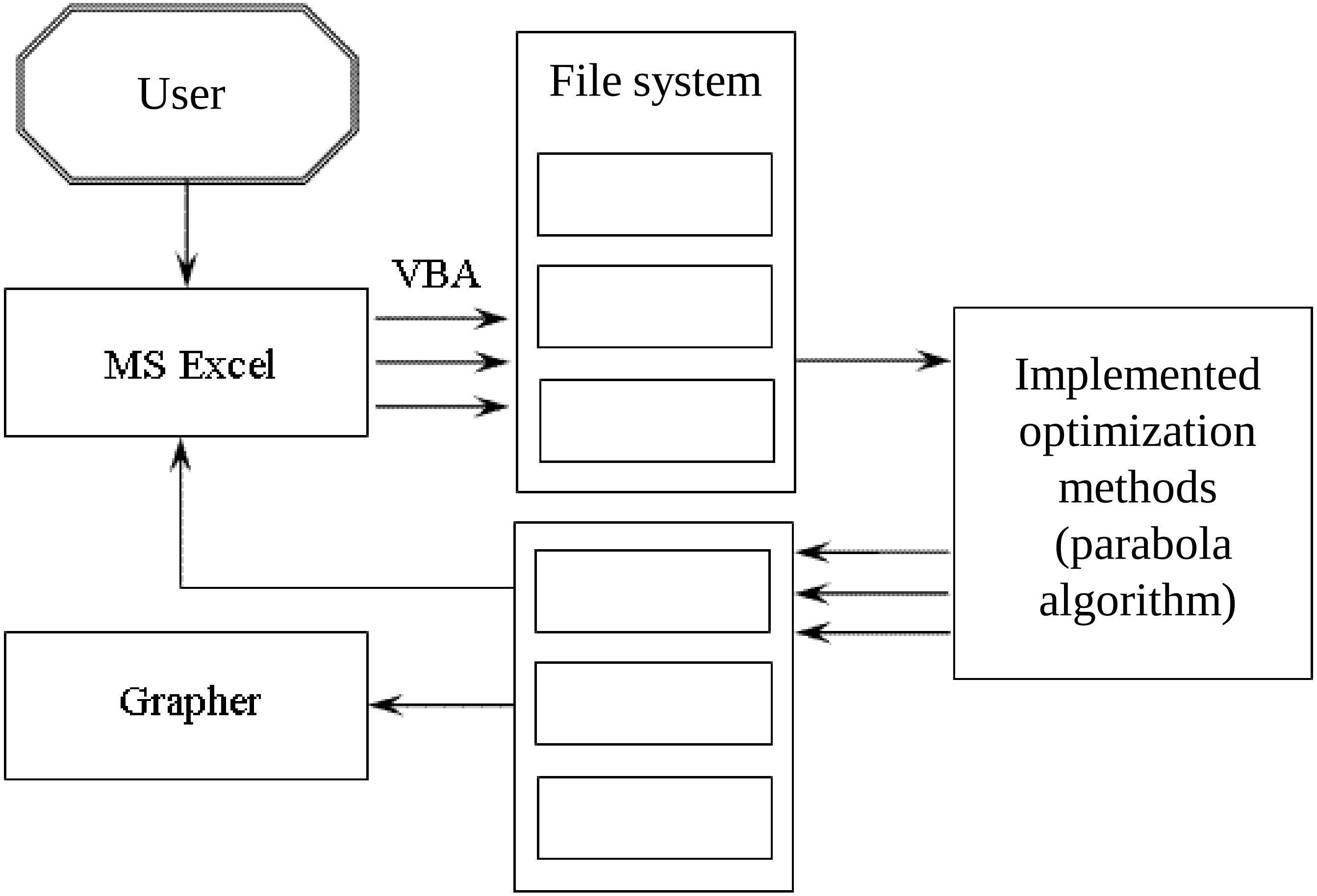
Global search:

- Parabola algorithm;

Local search:

- Combination of golden ratio and parabolic interpolation methods.

NUMERICAL TECHNOLOGY

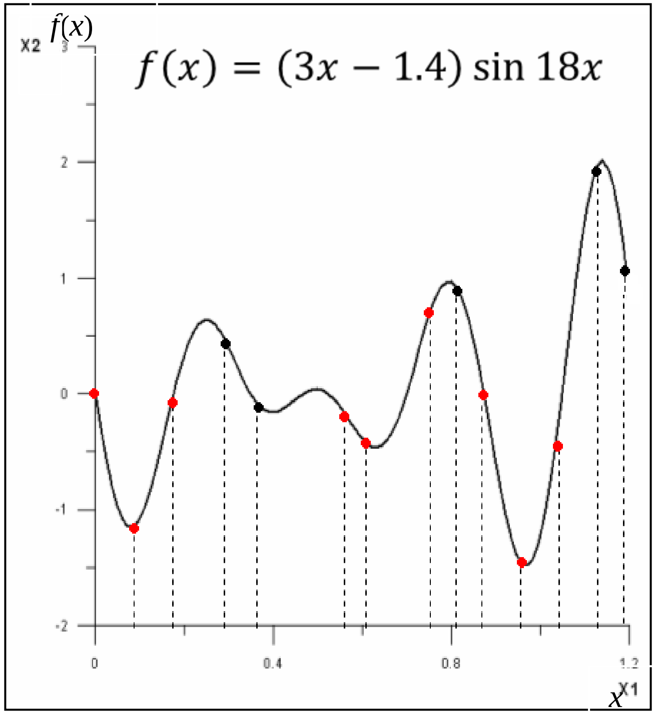


- A step-by-step description of the implemented parabola algorithm for global optimization, underlying the proposed technology, is presented on next slide.
- On a random generated grid, a search is carried out for «convex three nodes” (a set of points at which the value of the function at the central point is less than the values at the end points). In each such convex region, the minimum is found using the local optimization algorithm.
- This search is carried out over all coordinates and the smallest value is the solution to the initial problem. The slide on the right shows an illustrative example: for a given one-dimensional function, 3 convex regions containing extreme points are found, in the rightmost of which is the minimum value of the function.

PARABOLA ALGORITHM

At the k-th step:

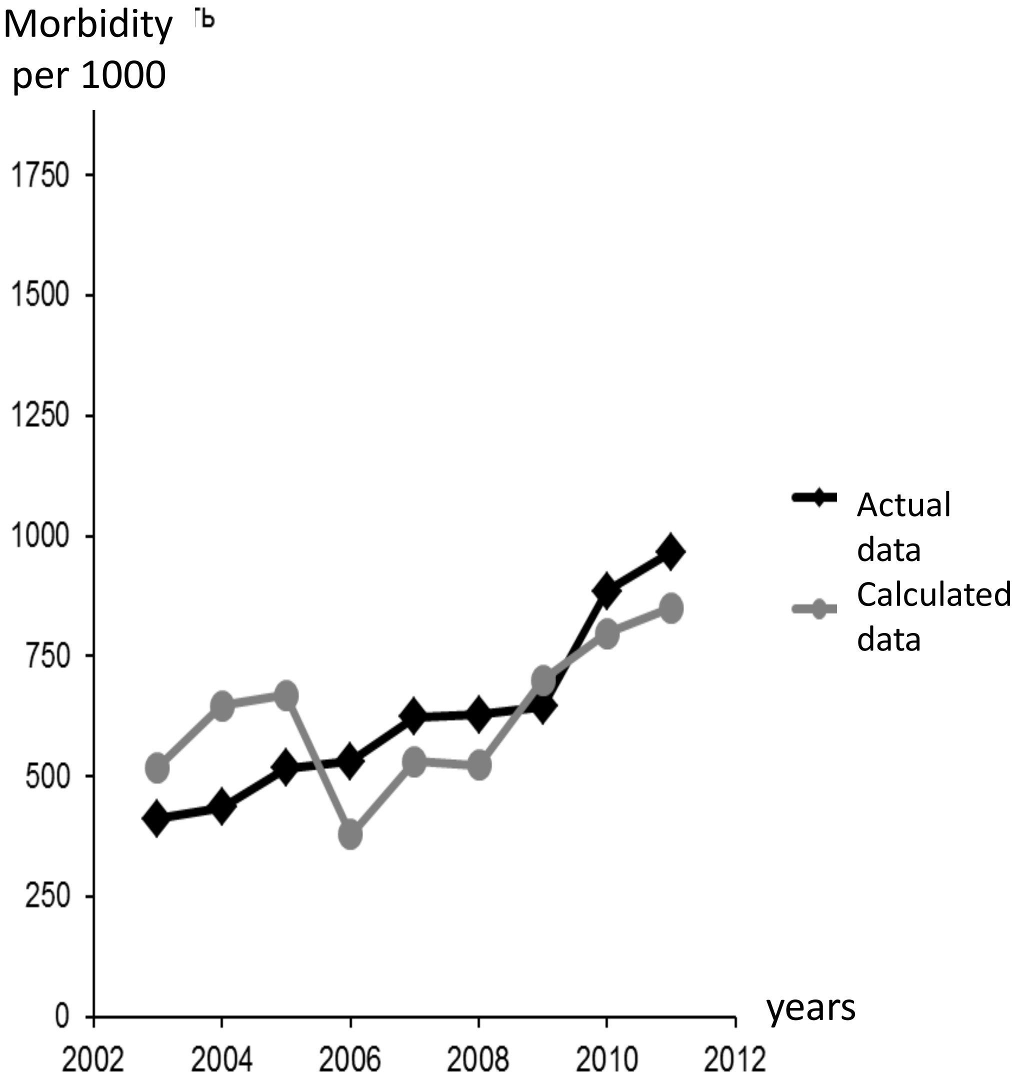
1. All coordinates of the function $F(a_1, a_2, \dots, a_n)$, are fixed, except for the k- th, where $k = \overline{1, n}$.
2. A random grid is generated $C = \{c_j\}_{j=\overline{1,M}}$, such that $c_1 = \underline{a}_k, c_M = \overline{a}_k$.
3. The function values are calculated at the grid nodes $f(c_j) = F(a_1, a_2, \dots, c_j, \dots, a_n), j = \overline{1, M}$.
4. Search for ”the convex three nodes”: $c_{j-1} < c_j < c_{j+1}, f(c_{j-1}) > f(c_j) < f(c_{j+1})$
5. On segments $[c_{j-1}, c_{j+1}]$ using the local one-dimensional search method, it is found $\min\limits_{a_k \in [c_{j-1}, c_{j+1}]} f(a_k)$.
6. The smallest value of the objective function is selected from those found in each ”the convex three nodes".



7. The resulting point $(a_1, a_2, \dots, a_k^*, \dots, a_n)$ is used as an initial approximation in the next step.

The iteration is complete.

COMPARISON OF CALCULATED AND ACTUAL DATA

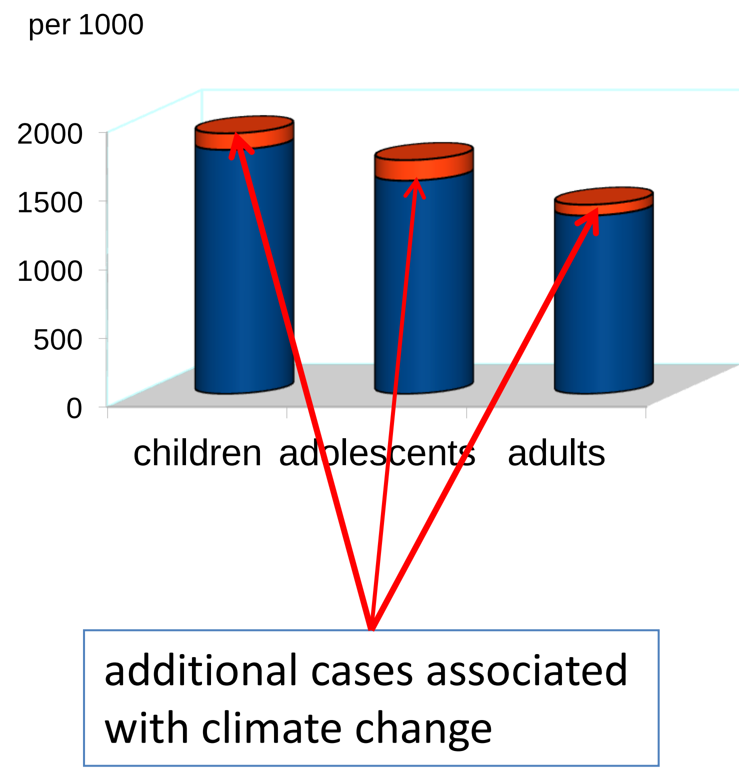


- The average calculated data were as follows: in children - 1756 cases pe 1000 people (95% confidence interva 1126-2386%), in adolescents-1756 cases per 1000 people (95% confidence interval 1126-2386‰).- 1256 ‰ (1122 - 1391 ‰), in adults, 846 % (558-1134%) according to data from 2002-2012.
- Comparison of calculated and actua indicators of morbidity showed that the actual indicator in children exceeded the upper limit of the calculated morbidity by 3.6%, in adolescents-by 6.7%. The primary morbidity rate of the adult population in recent years is 8.5% lower than the lower calculated limit.
- Average differences in all groups are not statistically significant (P> 0.05) which reflects good approximating properties of the model and allows us to use it for further research

THE FORECAST OF THE MORBIDITY in 2018

- It was shown that in the case of extremely high atmospheric air pollution, one conditional unit of this indicator “accounts for” 43 cases of diseases, and if the indicator decreases to a moderate level, with a general reduction in the requests number for medical help, one unit of the air pollution indicator will determine 92 cases.
- The contribution of natural factors (air temperature, wind speed), was relatively low (0.6-2%). In comparison with the previous forecast results, the share contribution of these parameters decreased (it was 8-11% in 2005)
- The forecast of the morbidity rate for 2018 in the child subpopulation had the good accuracy (82–83%). In the group of adolescents, the accuracy of the forecast of the morbidity in 2018 was low – only 20%.

Morbidity of the population of Bratsk



- In connection with the above, it is necessary to continue the study of the model and consider other approaches to predicting the behavior of the complex medical-ecological-social systems. Testing the simulation using the artificial neural network method according to the parameters of 2018 showed the following. The accuracy of the prediction of adolescents was 87 %, which makes it possible to use this alternative approach to study optimization problems of the considerable type.

Conclusion

- The obtained dependencies allowed to develop the prognosis of the morbidity for the various population groups based on the possible change in environmental conditions. In addition, the analysis of forecast uncertainties determines the further areas of the research: the expansion of the factors number included in the model; the use of the models, in one of which it is necessary to study the laws governing the formation of chemical pollution of atmospheric air when changing weather conditions and the composition of industrial emissions; the use of deep machine learning models and fractional rational functions approximating the initial data in order to increase the accuracy of the obtained solutions and form short-term and medium-term forecasts.