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Methods for Taking into Account the Impact of Environmental Factors on Children'sHealth

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Abstract. The article proposes a method for accounting for quantitative relationships between the incidence of the child population and the state of the environment in the area of the location and operation of large thermal power plants (using the example of the Lesosibirsk industrial center in the Lower Angara region of the Krasnoyarsk Territory). Among the factors taken into account, the climatic features of the territory and air pollution are considered.The study has been performed the calculation of the dispersion of harmful emissions in the study area, depending on the climatic conditions within it, the location of production facilities and the characteristics of emissions. Scenario calculations to determine the concentrations of harmful substances on the territory of the industrial hub under consideration, taking into account the change in the conditions for cleaning emissions from thermal power plants, made it possible to conclude that it is inexpedient to locatethethermal power plants of a given capacity in the Lower Angara region due to a possible increase in the incidence of diseases of the upper respiratory tract in children.The studies carried out made it possible to determine the options for predicting the incidence of the child population and to propose recommendations for rationalizing environmental protection in a particular region to improve management methods.

Keywords: public health, morbidity, industrial hub, air pollution, climatic features of the territory, respiratory diseases.

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Методика учета влияния экологических факторов на здоровье детей

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Аннотация. В статье предлагается методика учета количественной зависимости заболеваемости детского населения от состояния окружающей среды в районе размещения и эксплуатации крупных тепловых электростанций (на примере Лесосибирского промышленного узла в Нижнем Приангарье Красноярского края). Среди принимаемых во внимание факторов учитываются климатические особенности территории и загрязнение воздуха. Выполнен расчет рассеивания вредных выбросов на исследуемой территории в зависимости от ее климатических условий, расположения производственных объектов и характеристик выбросов. Сценарные расчеты по определению концентраций вредных веществ на территории рассматриваемого промышленного узла с учетом изменения условий очистки выбросов от тепловых электростанций позволили сделать вывод о нецелесообразности размещения тепловых электростанций заданной мощности в Нижнем Приангарье в связи с возможным увеличением заболеваемости болезнями ЛОР-органов у детей. Проведенные исследования позволили определить варианты прогнозирования заболеваемости детского населения и предложить рекомендации по рационализации охраны окружающей среды в конкретном регионе с целью совершенствования методов управления.

Ключевые слова: общественное здравоохранение, заболеваемость, индустриальный хаб, загрязнение воздуха, климатические особенности территории, респираторные заболевания.

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Introduction: statement of the problem

The problem of the relationship between environmental pollution and public health is one of the extremely complex problems, many aspects of which still do not have sufficient study due to the complexity of the interaction of various factors and the difficulty of identifying the factors causing diseases in humans.

Among such aspects are in particular the following:

- permanent and widespread monitoring of the environment and its impact on human health;
- study of the interaction of various types of pollutants (taking into account the effects of antagonism, additivity and synergism);
- development of scientifically based integrated indicators of environmental pollution;
- assessment of the impact of harmful substances on individual organs, their systems and health in general, depending on the concentrations and combinations of pollutants and the development of a mathematical apparatus for determining the appropriate quantitative dependencies;
- creation of a unified automated state system for storing and processing data on environmental pollution and the state of public health, etc.

Ignoring the "environment-health" relationships in solving the problems of forecasting the socio-economic development of regions can give the wrong picture of the territory's capabilities in forming new economic complexes and increasing the anthropogenic load in old-industrial areas and lead to the adoption of erroneous management decisions. Such problems are especially acute in Siberia, where, on the one hand, the potential for developing new territories is great, and on the other, the possibilities of regenerative processes in the human body and various natural systems are reduced due to unfavorable climatic conditions. This makes it relevant to identify the effects of environmental pollution on human health.

This study aims to propose an approach to establishing relationships between environmental factors (including chemical pollution of the air and climatic conditions of the territory in question) and public health in predicting the formation of a local production system.

To achieve this goal it was necessary to solve the following main tasks:

1) to identify possible factorial links between the incidence of the population (children 3–14 years old) and environmental pollution in the area of location and operation of large thermal power plants;

2) to propose an approach to establishing quantitative dependencies between the morbidity of the population, on the one hand, and the climatic features of the territory and environmental pollution, on the other;

3) to carry out the implementation of the proposed approach to the definition of the relationship between the incidence of children and selected factors on the material a particular area, which is considered as Lesosibirsk industrial hub;

4) to carry out a forecast of the incidence of the child population in a given territory (taking into account the dispersion of harmful substances in the atmosphere and the calculation of quantitative dependencies between the studied factors);

5) to identify the possibilities of locating thermal power facilities (on Kansk-Achinsk coals of the western wing of the Kansk-Achinsk brown coal basin) in the Lower Angara region (covers the territory of the lower Angara river and the middle Yenisei river) in terms of the possible impact of their emissions on human health;

6) to determine the possible contribution to air pollution, and, consequently, to the deterioration of the health of people assumed here to accommodate a large thermal power plant;

7) to identify the possibilities of unloading the Kansk-Achinsk fuel and energy complex by moving a large thermal power station on Kansk-Achinsk coal to the region of the Lower Angara region subject to the avoidance of its possible negative impact on human health (as an alternative to hydropower construction in the lower course of the Angara).

The implementation of the proposed methodology for assessing the influence of environmental factors on public health was carried out using materials of the city of Lesosibirsk, located in the western part of the Lower Angara region of the Krasnoyarsk Territory (Eastern Siberia). The calculations made it possible to carry out a forecast of the incidence of children in a given territory and to reveal the possibilities of locating heat-and-power facilities within it from the point of view of the possible effect of their emissions on health.

Review of literature and development of hypotheses

Among the factors affecting the health of people, the greatest importance are factors of anthropogenic character[1]. At the same time, one of the important components of the anthropogenic impact on the environment and the effects of the changed environment on people's health and, above all, morbidity and life expectancy, is chemical pollution of the atmosphere(Ashraf et. al, 2013; Gilmundinov et.al., 2012; Protasov, 1999; Prokhorov, 2000; Zubkov, 2009). According to the World Health Organization (WHO)[2], 22 % of the years of healthy life lost are due to environmental factors; more than 5 million children die every year in the world from causes related to ecologically unhealthy habitat; adverse environmental factors account for 1/3 of the total global burden of disease; children under 5 are most susceptible to environmental pollution; over the past 10 years in Europe, asthma in children has increased by more than 2 times(Kutuzova, 2013; Revich et. al. 2004).

The proposed approach to solving the problems of determining the relationship between environmental factors and human health in predicting the formation of a local production system is based on the following logic of building relationships in the "environment – health" system (Fig. 1).

The starting point of the analysis is the choice of production facilities and the study area. Thermal power plants operating on brown coal are considered as production objects in the task. The construction of large coal-fired thermal power plants in the Lower Angara Region is connected with the emergence and necessity of solving a number of serious economic and environmental problems (in particular, transporting coal by rail and the need to reconstruct the Achinsk-Abalakovo railway section; possible excess of electric power in the region, etc. which are not considered in this part of the study. The Lesosibirsk industrial hub (or the Lesosibirsk town), located in the western part of the Lower Angara region (Krasnoyarsk Territory), was chosen as the study area.

Thermal power plants emit harmful substances into the atmosphere, among which ash, nitrogen oxides (NO_X) and sulfur dioxide (SO_2.) predominate. The release of these substances into the atmosphere is accompanied by the risk of its pollution and, accordingly, environmental degradation and, consequently, human health.

The Lesosibirsk industrial hub is considered taking into account the climatic features of the territory, which may affect the health of the population. These include, in particular, atmospheric pressure and air temperature, which also affect the adaptive abilities of the surrounding natural environment. In addition, the region has a high potential for air pollution, which creates unfavorable conditions for the dispersion of pollution in the atmospheric air.

One of the important reactions of the state of people's health to air pollution is the incidence. In our analysis, the focus is on the incidence of only the child population, and among the types of diseases are respiratory diseases that are grouped into 11 nosological forms of the respiratory tract morbidity (including otitis,

[1] Environmentally induced diseases. (2016). Retrieved May 11, 2019, from http://www.golkom.ru/book/29_4.html.
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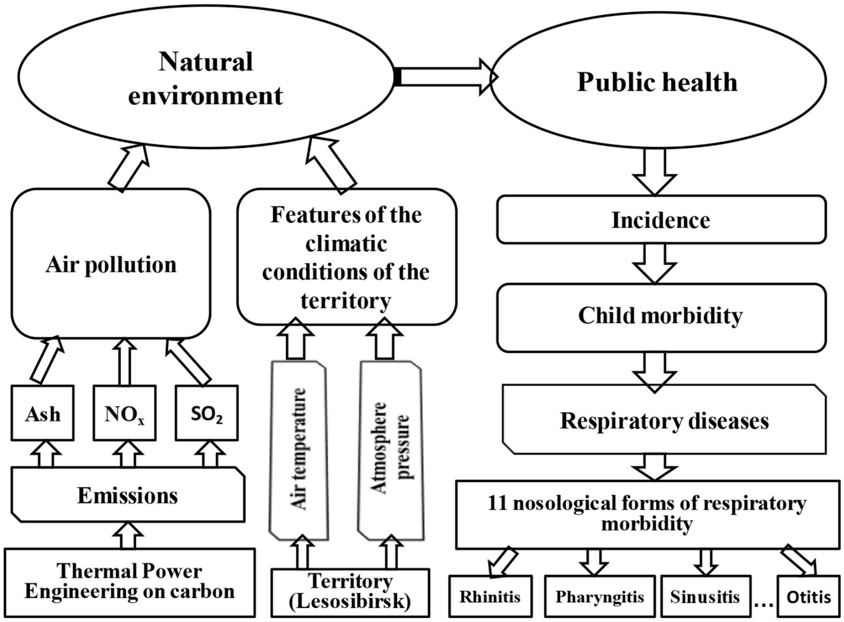

Fig. 1. The logic of building relationships in the system
"Environment – Health" for the purposes of their analysis
Source: own

sore throat, rhinitis, laryngitis, sinusitis, pharyngitis, tonsillitis, etc.).

Respiratory diseases take the first place in the overall morbidity structure in the world[3], and the proportion of this pathology is 27.6 % in adults, 39.9 % in adolescents and 61 % in children (Gilmundinov et. al, 2012; Protasov, 1999; Acute, 2011; Derbeneva, Guseva, 2017). People with diseases of the respiratory tract, including asthmatics and people with an increased allergic reaction, primarily respond to environmental pollution. According to experts, air pollution shortens life expectancy by an average of 3–5 years (Lapshin, Umanets, 2006).

[3] British Thoracic Society. (2019). BTS/SIGN British Guideline on the management of asthma 24 July 2019. Retrieved from https://www.brit-thoracic.org.uk/about-us/pressmedia/2019/btssign-british-guideline-on-the-management-of-asthma-2019.
Wimalawansa S.A. and Wimalawansa S.J. (2016). *Environmentally induced, occupational diseases with emphasis on chronic kidney disease of multifactorial origin affecting tropical countries*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/ PMC 4974668.
World Health Organization [WHO]. (2010). WHO Guidelines for indoor air quality: Selected pollutants Copenhagen, Denmark. 456. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0009/128169/ e94535.pdf.

The choice for the study of the relationship between atmospheric pollution and respiratory diseases is due, firstly, to the increased scale of air pollution, secondly, the general effect of polluted air on people's health(Lapshin, Umanets, 2006) and, third, most studied this type of dependencies (mainly its qualitative side) is most studied.

An attempt to take into account the relationship between the state of the environment and public health in predicting the formation of industrial hubs was undertaken using materials from the Lesosibirsk industrial hub located on the Yenisei River below the confluence of the Angara River (includes the town Lesosibirsk with adjacent new industrial sites suitable for accommodation of potential industrial facilities).

At present, large investment projects are being implemented in the Lower Angara region, mainly within the Boguchansky and Kodinsky industrial centers. The Lesosibirsk industrial hub specializes mainly in logging, woodworking and wood processing. The presence in the region of large reserves of high-quality forest resources in combination with favorable water supply conditions, makes it possible to consider it as an extremely promising area for the development of deep chemical processing of wood and, above all, pulp and paper and hydrolysis yeast plants. The location of a large pulp and paper mill and a number of non-ferrous metallurgy enterprises, as well as gas and oil refining facilities is predicted here.

Such a direction of economic development will require the formation of a powerful fuel and energy base, one of the options for the creation of which could be the placement of large thermal power plants (TPPs) operating on Kansk-Achinsk coal in the Lesosibirsk region. Although the region has its own coal deposits (for example, the Kokuyskoye coal deposit), however, local coal reserves to provide thermal power plants of the estimated capacity are not enough.

The arrival of such objects on the territory of the industrial unit may be accompanied by the risk of air pollution from thermal power plants (containing primarily ash, nitrogen oxides and sulfur dioxide) and their possible negative impact on public health. As a rule, the consequences of the effects of emissions from thermal power plants on human health are very diverse and can cause various disruptions in its condition, including respiratory diseases (Table 1).

From table 1 it can be seen that the qualitative connections "type of pollution – features of impairment of health" in most cases are specific and each type of pollution can be associated with several specific nosological forms of morbidity and changes in the activities of individual organs and body systems. This example is typical in the sense that, on the one hand, the qualitative changes in organs and body systems due to exposure to certain types of pollution have been theoretically determined and repeatedly confirmed. On the other hand, the problem of establishing quantitative dependencies between changes (deterioration) of health and factors affecting it is, in our opinion, a more complex problem and in many studies remains insufficiently disclosed.

The choice of Lesosibirsk as a territorial object of research is due to the fact that at the level of this industrial hub as a relatively small settlement, it is possible to sufficiently examine various aspects of the vital activity of the

Table 1. Impact of emissions from thermal power plants on public health

Main types of pollution	Disruption of human health
1. Dust, ash (containing free silica and compounds of practically all metals, including arsenic, vanadium, mercury, lead)	Reduced ventilation capacity and lung capacity; damage to the mucous membranes of the eyes and upper respiratory tract. Fibrous changes in the lungs. Accumulation in the body of silicon dioxide. Silicosis. Increased mortality from cancer of the lung and intestines. Skin irritation and damage
2. Sulfurous anhydride	General poisoning of the body, manifested in changes in the composition of the blood, damage to the respiratory system, increased susceptibility to infections, metabolic disorders, high blood pressure in children. Laryngitis, bronchitis, conjunctivitis, rhinitis and rhinopharyngitis, emphysema, bronchopneumonia, asthma, allergic reactions, acute diseases of the upper respiratory tract and circulatory system. With short-term contamination of the mucous membrane of the eyes – lacrimation, difficulty breathing, headaches, nausea, vomiting. Increase overall morbidity and mortality. Increased fatigue, weakening of muscle strength, loss of memory, slowing of perception, weakening of the functional ability of the heart, changing the bactericidal properties of the skin
3. Nitrogen oxides	Sharp irritation of the lungs and respiratory tract, the occurrence of inflammatory processes in them, the formation of methemoglobin, a decrease in blood pressure
4. Soot	Increased incidence of lung cancer

Source: (Protasov, 1999; Prokhorov, 20000) population in a particular territory, including its health, as well as environmental pollution, use of resources, and creation of infrastructure facilities.In addition, there are a number of favorable prerequisites for the study of the indicated problem at the level of the industrial hub, consisting in the fact that the industrial hub covers, as a rule, a limited number of enterprises located in fairly homogeneous natural conditions and characterized by a uniform atmosphere pollution situation, which facilitates the most typical pollution, the identification of specific perpetrators of pollution and a quantitative assessment of the consequences of their impact on public health.

Of all the cities and districts of the Lower Angara region, the Lesosibirsk center is characterized by the highest potential of atmospheric pollution (PAP), which characterizes the combination of meteorological factors determining the scattering capacity of the atmosphere and, accordingly, the level of possible air pollution from emission sources in a given place. The more favorable the meteorological conditions (better ventilation, etc.), the lower the PAP. This is due to adverse meteorological conditions for dispersion of harmful impurities in the air environment, predetermining the very high predisposition of the atmosphere to pollution.In particular, such local features of the Lesosibirsk industrial hub can be noted, such as varied terrain, often repeated anticyclonic weather (especially in winter), accompanied by weak winds and calm (average annual wind speed – 2,7 m/s) and forming prerequisites for the occurrence of temperature inversions, as well as frequent fogs, uneven distribution of precipitation throughout the year, and other adverse climatic conditions that cause difficulties for dispersion of atmospheric x pollution and create the possibility of accumulation in the surface layer of the atmosphere of high concentrations of hazardous substances(General, 2008; State, 2011).

All production facilities intended for placement in the Lesosibirsk industrial hub are, as a rule, large electricity consumers. This gives grounds to assert that one of the primary problems determining the formation of the economic complex of the region, its production structure, the scale of development and the layout of production facilities, is the problem of creating here a large and reliable energy base. The solution to this problem is possible in at least the following two ways.

The first way is the preferential development of hydropower, primarily through the development of significant reserves of hydropower resources of the Angara and Yenisei rivers. In addition to the already functioning Boguchany hydropower plant, questions are also being worked out on the possible construction of a number of other hydropower plants in the lower Angara and the middle Yenisei (primarily Nizhneboguchany and Motygino).

The second way to create an energy base in the region allows for the construction of large thermal power plants on the coals of the Kansk-Achinsk basin (using local coal reserves in the foreseeable future seems economically inexpedient, there are prospects for using natural gas, but they have not yet been determined). Both ways to solve the energy problem in the Lower Angara region can have serious environmental consequences, which requires the need to predict such consequences at the stage of pre-project and project development.

The main object of study is primarily a large thermal power plant (with a capacity of 1200 MW) operating on Kansko-Achinsk coal. It is the possibility of its removal in the Lower Angara region is considered as an alternative to the further construction of hydropower plants on the Angara and Yenisei rivers. As already noted, the question of choosing industrial sites for the studied objects was solved in other tasks on the Lower Angara region and in this paper another and specific (possibly narrow) goal is to find out how the operation of such an object (like a large thermal power plant if it is placed) affect people's health.

It should be noted that if the issues of the impact of hydroelectric power plants on the environment in the region under consideration are to some extent worked through, the environmental aspects of the creation and operation of large thermal power plants have not been completely studied yet. In our opinion, consideration of the possibility of developing heat and power engineering in the region as an alternative to hydropower engineering requires careful justification of the possible environmental consequences of building large thermal power plants and comparing them with the environmental consequences of hydropower engineering in order to select energy development options that best meet environmental protection requirements.

The establishment of quantitative dependencies between the health of the population of an industrial hub and the emissions of enterprises belonging to it may allow (subject to the practical implementation of measures to improve production activities) to reduce atmospheric pollution and thereby prevent the effects of factors that impair public health. In other words, an industrial hub is the rank of local production systems, at the level of which it is possible to identify specific "culprits" of pollution and quantify the consequences caused by them.

Methods

To solve the problems posed, an approach has been proposed, the essence of which is a phased study of the selected problem, including, firstly, establishing quantitative relationships between the incidence of the child population and factors affecting it, secondly, building emission dispersion maps in a separate area depending on from climatic conditions, location of objects and characteristics of emissions and, thirdly, on the basis of combining the obtained results of the first two stages, the definition of options for the prognosis of disease of the child population.

Thus, to achieve the set tasks, a set of methods was used, including:

1) model of the choice of economic decisions taking into account their environmental consequences;

2) correlation and regression analysis;

3) program for calculating air pollution.

To analyze the relationship between public health and environmental pollution, mathematical methods are widely used to determine possible quantitative relationships between individual health indicators and selected environmental factors and assess the reliability of the results obtained. For this purpose, a correlation-regression analysis is used (Sumskaya, 2007).

The multiple regression model for the standardized data used in the work is as follows (1):

$$Z_j^{kl} = \sum_{i=i_1 \cup i_2} a_i^{kl} X_i(z_{ij}) + e_j^{kl}, \quad \forall j = \overline{1,n};\ k, l, \tag{1}$$

where Z_j^{kl} is the incidence of the age and sex group k diseases of the nosological form l at the moment of observation j ($j = \overline{1,n}$), n is the number of observations (n=12); l is the index of the nosological form of morbidity, l=1, 2,…,11; $i = i_1 \cup i_2$, where i_1 is the index of the type of pollution, i_1=1, 2, 3, (1 –ash, 2 – NO_x, 3 – SO_2); i_2 climate characteristics index; i_2=1, 2 (1 – atmospheric pressure, 2 – air temperature);
$X_i(z_{ij})$ – incidence, formed under the influence of factors i included in the equation at the moment of observation j;
z_{ij} – standardized values of the initial data: concentration of type i_1 of pollution or numerical characteristic of the climate (i_2);
a_i^{kl} – parameters of the regression equation; $k = k_М \cup k_Д$, where k is the index of the gender and age group, $k_М$ – is the index of the gender and age group of boys, $k_Д$ – is the index of the gender and age group of girls; $k_М$ = 1, 2,…,8; $k_Д$ = 9, 10,…,16;
e_j^{kl} – mistake.

As an analytical function $X_i(z_{ij})$, characterizing the form of the relationship between the signs, the logarithmic function was accepted as the most preferable from the experience of previous studies from the point of view of solving the problem of establishing quantitative dependencies between the incidence of the population and environmental pollution.

As estimates of the significance of the regression equations were used:

1) coefficients of partial and multiple correlation;

2) the coefficient of determination;

3) standard error;

4) F – criterion (Fisher).

It should be noted that the success of this approach largely depends on the selection and theoretical substantiation of the variables introduced in the analysis; studies of the nature of dependencies between variables, which are often mistaken for linear, and also on the maximum expansion of the number of variables introduced into the analysis. These critical prerequisites are often violated, which can lead to inadequate reflection of the nature of the link between health and environmental quality.

It is important to emphasize that, in contrast to the usual practice, when the average annual concentrations of the types of pollution are identified as influencing factors, in our case, the average monthly concentrations are used. The average annual indicators, in our opinion, do not reflect intra-annual changes in concentrations that also affect health. Therefore, their inclusion in the analysis reduces the accuracy of the resulting models. In this work, the accounting of intra-annual changes in the concentrations of the types of pollution was taken into account by establishing monthly periodization. The month, of course, is a more homogeneous period than a year, which makes it possible to hope for obtaining a reliable result in determining the quantitative dependencies between the state of the environment and the morbidity caused by it in people. Therefore, the series, covering large periods of time (in this case – year), are divided into those that combine only single-quality periods of development of aggregates, characterized by one law (pattern) of development. From this point of view, we distinguished the smallest possible period of dynamics – the calendar month, which allows, on the one hand, to get rid of the influence of random (intramonthly) fluctuations, and on the other hand – to take into account seasonal (intra-annual) fluctuations.

When forming observation groups, the method of directional selection is used (Acute, 2011; Method, 1987), which allows studying the influence of the studied factors on a small volume of materials.

Baseline data for analyzing the influence of environmental factors on public health were collected as follows (Burmatova, 2015):

a) individual morbidity record cards indicating sex, age, place of residence (highly polluted area, poorly polluted area), dates of appealability to medical institutions and the diagnosis made;

b) notebooks for taking into account atmospheric pressure, air temperature and concentrations of pollution types with a 6-hour periodization (measurements were taken 4 times a day – at 01, 07, 13 and 19 hours.

On the basis of this material, dynamic series are formed, characterizing the change in the climatic characteristics of the territory under consideration, environmental pollution and public health over time. The indicators reflect the studied phenomena on the basis of the state at certain points in time, which is typical for the moment dynamic series.

To achieve the single-quality of individual levels of the time series, a typological grouping of the material on the incidence of the child population was made. Homogeneous gender-age groups living in the same area (for example, boys aged 3 years and living in a highly polluted area) who had diseases of a certain nosological form during the period under consideration were identified. The relationship between the dynamic series characterizing the climatic characteristics and the health of the population, and the series of morbidity was studied by methods of correlation analysis.

To solve the set tasks, information was needed on the formation of a possible spatial structure of the Lesosibirsk industrial hub in the future, taking into account environmental requirements. Such information was obtained as a result of solving a number of optimization tasks on the materials of the Lower Angara region using the model apparatus developed by us to analyze the ecological and economic interrelations that arise in the formation of regional economic systems (Burmatova, 2015; Burmatova, Sumskaya, 2017). Separate results of solving these tasks were used as input in the calculations for analyzing the dependencies between health and air pollution. In particular, the following information was used: the refined production structure of the industrial hub, taking into account its environmental acceptability, the choice of environmentally acceptable power options for the main newly commissioned facilities, the placement of possible new enterprises at the site's industrial sites, options for environmental measures and technologies, emissions atmospheric air, etc. This information is taken into account indirectly as exogenous parameters.

The direct use of this economic and mathematical apparatus for solving the problems posed in the article is difficult, first of all, because it is impossible to adequately reflect such a complex and specific factor as public health in terms of economic and mathematical models. Therefore, to study the dependencies between health and the environment, statistical and mathematical models are more applicable.

Note that possible other contaminating objects on the territory of Lesosibirsk (primarily timber industry complexes, including a pulp and paper mill, etc.) are also taken into account, but not directly, but indirectly, as exogenous parameters of the calculations (otherwise the problem would be very high and unsolvable basically). To determine the relevant information at the preparatory stage of research, calculations were carried out according to the model of choice of a variant of economic decisions taking into account their environmental consequences. The results of these calculations (the choice of possible options for locating new objects in the industrial hub, the volume and nature of emissions, and other indicators) were used as input information at the 1st and 2nd stages of calculations.

Results and discussion

The stages of the study, the apparatus used and the results of the analysis of dependencies between the health of the population and the state of the environment are presented in fig.2.

The calculations were carried out in three stages (Burmatova, 2015). *At the first stage,* using statistical-mathematical models (methods of regression and factor analysis), the quantitative dependence of the disease of the children's population, represented by 11 nosological forms (in accordance with the WHO methodology[4] of

[4] World Health Organization [WHO]. (2010). WHO Guidelines for indoor air quality: Selected pollutants Copenhagen, Denmark. 456. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0009/128169/ e94535.pdf.

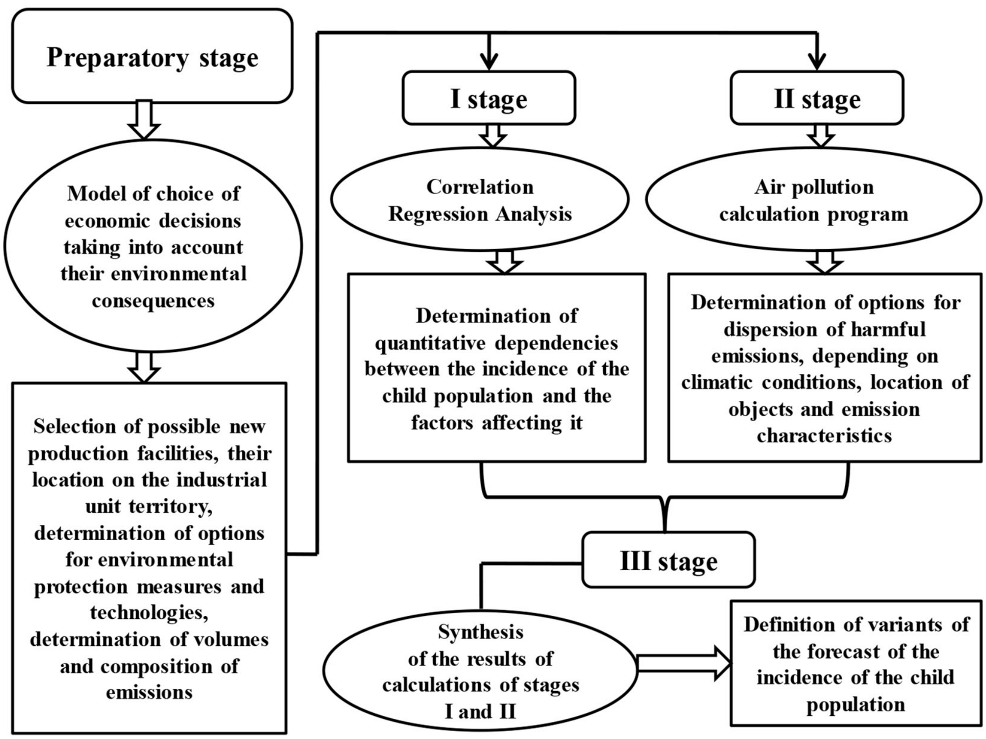

Fig. 2. Sequence of solving the tasks
Source: own

respiratory diseases) from environmental factors such as firstly, air pollution with ash, nitrogen and sulfur oxides, and secondly, climatic conditions, including atmospheric pressure and air temperature (Acute, 2011). The calculations considered the monthly average concentrations of the types of pollution, which provides more reliable results for determining the quantitative dependencies between the state of the environment and the incidence of children due to them (average annual ones are usually taken into account).

The determination of quantitative dependencies between the incidence of the population and factors characterizing climatic peculiarities and environmental pollution was carried out on the basis of information from the Novosibirsk Scientific Research Institute of Hygiene. When studying the incidence, children aged from 3 to 14 years were considered as the studied population. At the same time, the requirement of a sufficiently large volume not only of the entire set (number of observations), but also of the number of each of the groups allocated in it (30–40 children) was met.

The choice of the children's population to solve the task was due to the fact that, firstly, it is not subject to the effects of production factors, bad habits, etc., which allows to exclude their influence. Secondly, children, due to the well-known anatomical and physiological features, are more sensitive to changes in the quality of the environment. Therefore, the timing of the onset of adverse effects in them compared with the adult population is shorter. This increases the reliability of statistical observations and allows us to detect the presence of adverse effects at earlier stages. Thirdly, the actual incidence of children practically coincides with the incidence of accessibility to medical institutions, which ensures high data presentability.

Among the types of morbidity in terms of air pollution is dominated by respiratory diseases. Therefore, for the analysis, diseases of the upper respiratory tract were chosen, which depend not only on the state of the air basin, but also on the specific climatic conditions of the territory (see Fig. 1). Primary morbidity records allow us to group the child population in question taking into account gender, age, place of residence (highly polluted area, weakly polluted area) by the eleven nosological forms of morbidity under consideration. The time series of these data with monthly periodization are processed using correlation analysis and if there is a relationship between the incidence series and the series characterizing climatic conditions or air pollution, they are included in the regression equation. In these equations, the incidence of diseases of a certain nosological group is a productive sign, and the factor signs are the climatic features of the territory and the characteristics of types of air pollution.

As an indicator that determines the allocation of factors (qualitative variables that are further included in the regression equation and evaluated by statistical criteria), in this work, the Spearman's rank correlation coefficient.

Dynamic series of types of pollution, climatic characteristics and incidence were ranked in several ways, taking into account the following hypotheses. In the first version of the ranking of types of pollution (ash, nitrogen dioxide, sulfur dioxide) it was hypothesized that the missing values of the concentrations of substances are equal to the concentrations at the previous moment of observation. According to the second variant of ranking of types of pollution, the hypothesis of zero values of concentrations of types of pollution in the missing observations was accepted.

Taking into account possible errors of measuring instruments and signs characterizing the pollution and climatic features of the territory, the time series were ranged in several variants (for example, option 1 – measurement error is 0.5 %, option 2 – error is 1 %). Further, according to the obtained series, the rank correlation coefficients were calculated, the matrix of which is given in Table 2.

On the basis of the obtained coefficients, the factors introduced in the analysis of the links between incidence and pollution were identified. For example, the incidence of diseases of the respiratory system in children aged 12 years was attributed to the following factors as factors:

1) contamination of the atmospheric surface layer with ash average monthly concentration according to the variant with nonzero val-

ues of the missing observations and 5 % error of measuring instruments;

2) the average monthly concentration of sulfuric anhydride according to the variant with non-zero values of the missing observations and 5 % error of measuring devices;

3) average monthly ambient air temperature;

4) monthly average value of atmospheric pressure.

No other significant factor relationships were identified as a result of the study. Thus, the resulting factor relationships can be represented as a table 3.

The close relationship between air temperature and atmospheric pressure, on the one hand, and the incidence of respiratory diseases in children, on the other, is explained by the dependence of air temperature on atmospheric pressure (ρ = 0.65); adverse climatic

Table 2. Standardized values of pollutant concentrations and climate characteristics by calculation options

Months	Ash, mg/m^3		Nitrogen dioxide, mg/m^3		Sulfur dioxide, mg/m^3		Air temperature, t°C	Atmosphere pressure, mm Hg
	1	2	1	2	1	2		
January	-1,12	-1,19	-0,91	-0,90	-0,29	-0,26	-1,4	-1,1
February	-0,62	-0,77	-0,34	-0,26	1,26	1.43	-1,1	1,2
March	-0,57	-0,49	1,50	1,45	0,87	1,00	-0,60	1,6
April	-0,43	-0,39	-1,03	-1,00	0,13	0,27	+0,1	-1,7
May	-0,93	-0,83	0,03	0,06	-1,68	-1,53	+0,7	-0,6
June	-1,01	-0,95	0,28	0,32	0,39	0,53	+1,1	-1,2
July	0,03	-0,34	-0,72	-0,74	-1,77	-1,60	+1,3	-0,3
August	0,64	0,63	-0,78	-0,81	-0,23	-0,50	+1,1	-0,9
September	0,93	1,18	-0,84	-0,77	1,06	1,20	+0,7	0,2
October	1,14	1,19	0,09	-0,19	0,06	-0,26	+0,09	0,2
November	-0,49	0,39	2,09	2,06	0,90	0,43	-0,8	0,5
December	2,14	1,72	0,56	0,68	-0,84	-0,63	-1,3	0,0

Note: Options: 1 – values of concentrations of types of pollution on the missing observations are equal to previous concentrations; 2– values of concentrations for missing observations are assigned zero values

Source: own

Table 3. Identified significant factor relationships and their corresponding rank correlation coefficients

Productive attribute	Factors and their corresponding coefficients rank correlations
1. The incidence of respiratory diseases in children aged 12 years	1. The average monthly value of atmospheric pressure (ρ = 0.76) 2. Average monthly air temperature (ρ = 0.59) 3. The average monthly concentration of sulfur dioxide (ρ = 0.21) 4. Monthly average ash concentration (ρ = 0.16)
2. The incidence of diseases of the respiratory system in children aged 13 years	1. The average monthly concentration of nitrogen dioxide (ρ = 0.75) 2. Average monthly air temperature (ρ = 0.59) 3. The average monthly value of atmospheric pressure (ρ = 0.20)
3. The incidence of diseases of the respiratory system in children aged 14 years	1. The average monthly air temperature (ρ = 0.73) 2. The average monthly value of atmospheric pressure (ρ = 0.31) 3. Monthly average nitrogen dioxide concentration (ρ = 0.21)

Source: own

conditions and terrain to disperse harmful impurities, which leads to their accumulation in the surface layer of the atmosphere; accumulated morbidity (especially in the age groups of 12–13 years). The share of children living in this territory for 5 years, 4 and 3 years is equal, respectively, for a group of 12 years old children 40 %, 40 %, 20 % and for children 14 years old – 30 %, 60 %, 90 % respectively. For children of 13 years old, the corresponding indicator has the values of 0 %, 75 %, 25 %. Thus, in the group of children of 13 years, the incidence of diseases of the respiratory system occurs due to the primary effects of high concentrations of nitrogen dioxide, while for children of the age groups of 12 and 14 years, it has a predominantly provoking effect(Burmatova, 2015).

The result of the first stage of calculations is to obtain quantitative dependencies between the incidence of the child population and the factors affecting it.

The second stage of calculations involves determining the concentration of various harmful substances (ash, nitrogen oxides and sulfur dioxide) in the surface layer of the atmosphere created as a result of emissions from the objects under consideration (large thermal power plant and combined heat and power plant), taking into account their location, emission characteristics and local natural conditions.

Used for these purposesa unified program for the calculation of atmospheric pollution "Ecologist" (Method, 1987; Unified, 2003) was used for the automated calculation of atmospheric pollution by harmful emissions from industrial enterprises. This program allows you to build maps of the dispersion of harmful substances in the surface layer of the atmosphere (in the form of systems of points indicating the concentration value) based on the use of three groups of data characterizing:

1) emission sources (their height, diameter of the chimney mouth, exit velocity and temperature of the gas-air mixture);

2) the types of pollution (volumes of emissions, the interaction of various substances, their maximum permissible concentrations, the sedimentation rate of harmful substances in atmospheric air);

3) geographical and climatic features of the territory (air temperature, geographical latitude, nature of the wind rose, the level of background pollution, etc.).

The result of this stage of calculations are the options for dispersion of harmful emissions in the territory of the industrial center under consideration, depending on climatic conditions, location of facilities and characteristics of emissions. Variant calculations to determine the concentrations of harmful substances on the territory of the industrial hub under consideration were carried out taking into account various options for the degree of purification of dust and gas emissions from power plants (option 1 – up to 95 %, option 2 – up to 85 %) (table 4).

Calculations have shown that provided in accordance with design data the cleaning level at the facilities of power system, equal to 95 %, does not provide complete dispersion outside the sanitary protection zone. A possible decrease in the degree of purification by 10 % leads to a significant expansion of the area affected by pollution, and a sharp increase in the concentration of the types of pollution under consideration.

The third stage of calculations involves determining, on the basis of a synthesis of the results of the first and second stages, the prediction options for the incidence of the child population of the Lesosibirsk industrial hub. At the same time, variants of such a forecast are calculated based on the obtained distributions of concentrations of harmful substances in the site and obtained quantitative dependencies between the incidence and the state of the environment, including its climatic features and atmospheric pollution with ash, nitrogen and sulfur oxides (the latter are included in the regression equations as variables).

The results of the forecast showed, in particular, that the average monthly incidence of children aged 13 years living in Lesosibirsk (subject to compliance with the treatment of harmful emissions) will be in May, 14 people per 1000 residents within a radius of up to 35 km from emission sources, and within a radius of up to 70 km – 13 people per 1000 inhabitants. In December, the incidence will be re-

Table 4. Characteristics of air pollution by calculation options

Harmful substances	Options	Concentrations of harmful substances in emissions from pollution sources			
		Maximum	On the border of the sanitary break zone	At the level of MPC	On the border of the 200 km zone
SO_2	1	2,5 MPC at a distance of 5–7 km north-west from emission sources and at a distance of 10–12 km southeast from emission sources	1,0 MPC-in the north-west, 1,9 MPC-in the west, 1,8 MPC-in the south-west	at a distance of 30–40 km	0,2–0,3 MPC
	2	3 MPC at a distance of 8–10 km east of emission sources	2,5 MPC	at a distance of 36–40 km	0,2–0,3 MPC
NO_X	1	1,8 MPC at a distance of 5 km north of emission sources and 12 km northeast of emission sources	1,2–1,3 MPC-north and west, 1,6 MPC-in the south and east	at a distance of 20–25 km	0,15–0,2 MPC
	2	2 MPC at a distance of 5–10 km from emission sources	1,5 MPC-in the west, 2,0 MPC-in other directions	at a distance of 25–30 km	0,2 MPC
Ash	1	1,1 MPC at a distance of 10–12 km from emission sources	1,0 MPC	at a distance of 15 km	0
	2	1,15 MPC at a distance of 12–14 km from emission sources	1,0 MPC	at a distance of 15–20 km	0

Note: MPC – maximum permissible concentration of harmful substances in the air
Source: own

spectively 30 and 29 people per 1000 inhabitants.If the cleaning technology is violated, the incidence in May will be 15 people per 1,000 inhabitants, and in December the incidence of children will increase to 31 people per 1,000 people in an area within a radius of 35 km from emission sources and up to 30 people in an area in a radius of up to 70 km(Burmatova, Sumskaya, 2017; Unified, 2003).

A significant increase in air pollution in the Lesosibirsk industrial hub due to the possible deployment and operation of new heat and power facilities (working on the Kansk-Achinsk brown coal) also leads to an increase in the incidence of upper respiratory tract diseases among children: up to 15–30 cases per 1 thousand inhabitants per month or up to 260–280 cases per 1 thousand inhabitants per year.According to foreign authors, in initially healthy children it is quite understandable and the occurrence of 6–10 respiratory diseases per 1,000 people per year is acceptable (see, for example, (Lapshin, Umanets, 2006)).In addition, a similar incidence corresponds to the prevalence of upper respiratory tract diseases in children in zones of ecological trouble in Russia (Revich et. al, 2004). All this gives grounds to consider the placement of thermal power plants of the considered power in the area of the Lesosibirsk industrial hub as inexpedient.

Conclusions

The result of the study is the development and practical implementation of an original methodological approach to analyzing the influence of environmental factors on human health and identifying the possibility of locating heat and power facilities within a particular territory from the standpoint of the possible impact of their emissions on public health while predicting the formation of a local production system. The population, therefore, is considered as the main recipient of a negative anthropogenic impact on the environment.

The main concrete results of the study are, in our opinion, the following.

Firstly, the implementation of the proposed approach to predicting the incidence of the population as a result of environmental pollution and the climatic features of the territory has been implemented.

Secondly, possible factorial links between the incidence of the child population (children 12–14 years old) and environmental pollution have been identified.

Thirdly, an approach has been proposed to establish quantitative dependencies between the incidence of the population and its determining factors (climatic characteristics of the territory, environmental pollution) and its implementation has been implemented.

Fourthly, alternative calculations have been made to determine the concentrations of harmful substances on the territory of the industrial hub under consideration, taking into account changes in the conditions for cleaning up emissions from thermal power plants.

The calculations showed that the possible construction of large thermal power plants in the Lesosibirsk industrial hub combined with the prospective creation of a number of wood chemistry enterprises could lead to air pollution, cause irreparable damage to the environment of the surrounding area and create extremely unfavorable living conditions for the population. The factors negatively affecting the health of the population will also be the combined effect on people of atmospheric emissions from thermal power and wood chemistry facilities and changes in microclimatic conditions in the area of the predicted Middle-Yenisei hydroelectric complex on the Yenisei River.

As a whole calculations have shown that a significant increase in atmospheric air pollution in the Lesosibirsk industrial hub in connection with the possible operation of new heat power facilities (on the Kansk-Achinsk coals) can lead to an increase in the incidence of diseases of the upper respiratory tract among children: up to 270 cases per 1,000 people / year. This made it possible to draw a conclusion about the inexpediency of placing a thermal power facilities (on the Kansk-Achinsk coals) of the considered capacity in Lesosibirsk.

Thus, the proposed methodological approach makes it possible to predict various scenarios for the development of thermal power engineering in the region and provides an estimate of the state of the territory from the standpoint of the influence of environmental factors on the health of the child population. This opens up the possibility of expanding the information base for making more informed management decisions in the area of spatial and structural production development of the territory.

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