Analysis of the Population Morbidity Dependence on the Atmosphere State

O P Burmatova1* and T V Sumskaya1,2

1 Institute of Economics and Industrial Engineering, Siberian Branch of the RAS, 17 Academician Lavrentyev pr., Novosibirsk 630090 Russia
2 Novosibirsk State University of Economics and Management, 56 Kamenskaya str., Novosibirsk 630099, Russia

E-mail: burmatova@ngs.ru

Abstract. This paper is dedicated to presenting the practical approach proposed by the authors to study the state of atmospheric air and population incidence. The Lesosibirsk industrial unit in the Lower Angara region of the Krasnoyarsk Territory (Russia) is considered as a territorial object of study. Contaminant objects are coal-fired thermal power plants. Calculations made allowed us to evaluate the quantitative relationships between the incidence of children and the factors influencing it, including territorial climate features (pressure and air temperature) and air pollution. The calculations demonstrate the possibility of increasing incidence in children, provided that a large power station is located and functioning in the Lesosibirsk industrial unit. Emissions from this station can hurt the state of atmospheric air and increase the incidence of people. The authors conclude that it is inexpedient to place a heat power facility of the considered capacity in Lesosibirsk. The research novelty lies in the practical implementation of the proposed methods, which allows us to assess the impact of atmospheric air (temperature, pressure, and pollution) on the population’s health when predicting the formation of a local production system.

Keywords: Public health · Morbidity · Industrial hub · Air pollution · Climatic features of the territory · Respiratory diseases

1. Introduction

People’s health is influenced by a wide variety of factors, among which in recent years, environmental pollution factors have become increasingly important [1, 3, 12, 13, 16, 20, 21, 22, 23]. According to the World Health Organization (WHO), 22% of the years of healthy life lost are due to environmental factors; 1/3 of the global disease burden is due to an environmentally unhealthy habitat; annually in the world, the mortality of children from adverse environmental conditions is more than 5 million people. Children under five years of age are the most susceptible to environmental pollution. Over the past decade, asthma’s childhood incidence has more than doubled [2, 14, 17, 18, 22].

The analysis of the relationship between environmental pollution and human health are among the extremely complex problems that have not yet been adequately developed. This situation's reasons are primarily associated with the complexity of the interaction of various environmental factors that cause diseases in people and identify them.

This research aims to develop a methodological approach to establishing interconnections between environmental factors such as chemical pollution of atmospheric air and climatic conditions of the study area (air temperature and atmospheric pressure), on the one hand, and human health, on the other.
The purpose of this paper is to suggest a methodological approach to establishing interconnections between environmental factors such as chemical pollution of atmospheric air and the climatic conditions of the study area (air temperature and atmospheric pressure), on the one hand, and human health, on the other.

The implementation of the goal requires the solution of 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 identify the possibilities of locating thermal power facilities (on Kansk-Achinsk coals of the western part of the Kansk-Achinsk brown coal basin) in the Lower Angara region (covering the territory of the lower Angara river and the middle Yenisei river) in terms of the possible impact of their emissions on human health;

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

4) 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).

2. Materials and Methods

The implementation of the proposed methodology for assessing the influence of environmental factors on public health was carried out using materials from 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 children's incidence in a given territory and reveal the possibility of locating heat-and-power facilities within it from the potential effect of their emissions on health.

The logic of building links in the system “environment – public health” for analyzing the problems posed are shown in figure 1.

**Figure 1.** The logic of building relationships in the system “Environment – Health” for their analysis purposes. *Source: Compiled by the authors.*

Our analysis's starting point is the choice of production facilities and the study area (figure 1). 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.). Justifications of solutions to these problems in this
article are not considered. The Lesosibirsk industrial unit (or the city of Lesosibirsk) was chosen as the study area.

The main ingredients of the pollution prevailing in thermal power plants’ emissions into the atmospheric air are ash, nitrogen oxides (NO\textsubscript{x}), and sulfur dioxide (SO\textsubscript{2}).

In addition to these emission ingredients, factors that can affect human health include climatic features of the research territory, atmospheric pressure, and air temperature (see figure 1). Of all cities and districts of the Lower Angara region, only Lesosibirsk has the highest atmospheric pollution potential. This indicator reflects the combination of meteorological factors determining the atmosphere's scattering capacity and, accordingly, the level of possible air pollution from emission sources in a given place [8, 10].

Respiratory diseases combined with eleven nosological forms, including otitis media, tonsillitis, rhinitis, laryngitis, sinusitis, pharyngitis, tonsillitis, etc., were selected types morbidity. The object of the study is the morbidity of children aged three to fourteen.

Upper respiratory tract diseases take the first place in the overall morbidity structure globally, and the proportion of this pathology is 27.6% in adults, 39.9% in adolescents, and 61% in children [4, 9, 12, 21]. 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 [15, 22].

The following circumstances explain the choice to study the relationship between atmospheric pollution and respiratory morbidity: increased air pollution, the general nature of the effect of polluted air on human health, the most excellent knowledge of this type of dependency (mainly its qualitative side).

Lesosibirsky industrial hub is located on the Yenisei River below the Angara River (including the city of Lesosibirsk with adjacent new industrial sites suitable for accommodating potential industrial facilities). Lesosibirsky Industrial Center, located on the Yenisei River below the Angara River (includes the city of Lesosibirsk with adjacent new industrial sites suitable for accommodating potential industrial facilities). Currently, Lesosibirsk specializes mainly in the forestry cycle's lower floors, including logging, woodworking, and woodworking.

In the future, this region, due to the successful combination of large reserves of high-quality forest and water resources, is considered as a possible center for the development of timber industry facilities, including enterprises for the deep chemical processing of wood, primarily pulp and paper, as well as hydrolysis and yeast enterprises. Moreover, non-ferrous metallurgy (mainly aluminum and lead-zinc) is already developing here. In the future, it is planned to increase further it and the creation of gas and oil processing facilities.

Such a direction of economic development will require forming a healthy fuel and energy base, one of the options for creating, which could be the placement of large thermal power plants operating on the Kansk-Achinsk coal Lesosibirsk region. Although the area has its coal deposits (for example, the Kokuyyskoye coal deposit), the local coal reserves to provide thermal power plants with the estimated capacity are not enough.

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 region's economic complex, its production structure, the scale of development, and the layout of production facilities, is the problem of creating 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 Boguchan 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 Nizhneboguchan 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 products at the stage of pre-project and project development.

The study’s main objective is primarily a large thermal power plant (with 1,200 MW) operating on Kansk-Achinsk coal. The possibility of its removal in the Lower Angara region is considered an alternative to the further construction of hydropower plants on the Angara and Yenisei rivers. As already noted, choosing industrial sites for the studied objects was solved in other tasks in the Lower Angara region. In this paper, another and specific (possibly narrow) goal is to determine how such an object (like a large thermal power plant if placed) affects people’s health.

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 thoroughly 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 sizeable thermal power plants and comparing them with the ecological implications of hydropower engineering to select energy development options that best meet environmental protection requirements.

The establishment of quantitative dependencies between an industrial hub's health 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 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.

The proposed approach to solving the tasks consists of a phased study of the selected problem and provides for:

- determination of quantitative relationships between factors affecting children's diseases and the incidence of the child population itself;
- calculation of dispersion of harmful emissions in a specific area, taking into account the characteristics of the climate, location of objects, and attributes of emissions;
- Combining the results of the first two stages determines the options for predicting the child population's incidence.

The relations between the health of the population and the environment were established using correlation and regression analysis, which makes it possible to identify quantitative relationships between indicators characterizing residents' health status and air pollution and evaluate the reliability of the results.

The formation of observation groups was carried out based on the method of directed selection [9, 11], which allows one to study the strength of the studied factors' influence on a small number of materials. The initial information needed to analyze the impact of environmental factors on public health included, firstly, individual records from clinics on the incidence of children with differentiation by gender, age, date of referral to medical institutions and diagnosis, as well as qualitative characteristics of the level of pollution of the place of residence. Secondly, information was used (metering books), reflecting indicators of air temperature and atmospheric pressure. Thirdly, to characterize the state of atmospheric air pollution, concentrations of harmful substances of a selected type that have a 6-hour periodization are set.

The data obtained are used to build a time series reflecting the above information, considering the time factors (climate, pollution, health). The single-quality nature of individual levels of the time series was achieved by typing the data on the child population's incidence. Following this, the data were grouped by combining children of the same sex and age living in the same region and suffering from diseases of a specific nosological form during the considered period.
As input into the task's solution, data were also used on the possible spatial structure of the industrial unit under consideration in the future, including the specified composition of production facilities and their placement on the site, options for essential technologies and environmental measures, etc. This information is the result of solving many problems on the Lower Angarsk region's materials using our proposed economic and mathematical apparatus [5, 6].

Note that possible other contaminating objects on the territory of Lesosibirsk industrial hub (primarily timber industry complexes, including a pulp and paper mill, etc.) are also taken into account, but not directly, but indirectly, as the exogenous parameters of the calculations (otherwise the problem would be very significant and unsolvable basically). To determine the relevant information at the preparatory stage of research, analyses were carried out according to the model of choice of a variant of economic decisions considering 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.

3. Results

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

The calculations were carried out in three stages.

![Figure 2. Stages and sequence of solving the tasks. Source: Compiled by the authors.](image-url)

The first stage (see figure 2) provided a quantitative dependence on children's incidence of factors characterizing the territory's climatic features and air pollution. Eleven nosological forms of respiratory diseases represented the incidence by the WHO methodology [9, 22].

Among the types of air pollution, ash, nitrogen oxides, and sulfur were considered. The calculations were based on monthly average pollutants (average annual values are usually taken into account). This provided the opportunity to obtain more reliable results.

The source of information on the incidence of children (aged three to fourteen) for the calculations at the first stage was the data of the Novosibirsk Research Institute of Hygiene of the Russian Federal Service for Supervision of Human Welfare. Simultaneously, the requirement was observed concerning both a sufficiently representative volume of observations and the number of children in each of the selected groups (up to thirty or forty children).

The reasons for the choice of the child population for this study were as follows:

1) children’s health does not depend on the influence of various production factors, bad habits, etc. This eliminates the need to take them into account;
2) many characteristics of the child population's anatomical and physiological structure make them more sensitive to environmental factors and changes. The timing of the onset of adverse effects in children is shorter than in adults. Due to this, the reliability of statistical observations increases, and it becomes possible to identify adverse effects at earlier stages;
3) the data on the incidence of children practically coincide with the information on the appeal to medical institutions. This ensures high data accuracy.

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

Considering 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%, vote 2 – error is 1%). Further, according to the obtained series, the rank correlation coefficients were calculated, the matrix of which is given in table 1.

### Table 1. Standardized values of pollutant concentrations and climate characteristics by calculation options.

| Months   | Ash, mg/m³ | Nitrogen dioxide, mg/m³ | Sulfur dioxide, mg/m³ | Air temperature, °C | Atmosphere pressure, mm Hg |
|----------|------------|-------------------------|-----------------------|----------------------|-----------------------------|
|          | 1          | 2          | 1          | 2          | 1          | 2          | 1    |
| 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 engagements; 2– values of concentrations for missing words are assigned zero values. Source: Compiled by the authors.

Based on 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 values of the missing observations and 5% error of measuring instruments;
2) the average monthly concentration of sulfuric anhydride according to the variant with nonzero values of the missing words and 5% error of measuring devices;
3) average monthly ambient air temperature;
4) the 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 in table 2.

**Table 2.** Identified significant factor relationships and their corresponding Rank correlation coefficients.

| Productive attribute | Factors and their corresponding coefficients rank correlations |
|-----------------------|-------------------------------------------------------------|
| 12 years              | Monthly averages:                                          |
|                       | • value of atmospheric pressure (ρ = 0.76)                 |
|                       | • air temperature (ρ = 0.59)                               |
|                       | • concentration of sulfur dioxide (ρ = 0.21)               |
|                       | • ash concentration (ρ = 0.16)                             |
| 13 years              | Monthly averages:                                          |
|                       | • concentration of nitrogen dioxide (ρ = 0.75)             |
|                       | • air temperature (ρ = 0.59)                               |
|                       | • value of atmospheric pressure (ρ = 0.20)                 |
| 14 years              | Monthly averages:                                          |
|                       | • air temperature (ρ = 0.73)                               |
|                       | • value of atmospheric pressure (ρ = 0.31)                 |
|                       | • nitrogen dioxide concentration (ρ = 0.21)                |

*Source:* Compiled by the authors.

The close dependence between the indicators characterizing the air temperature and atmospheric pressure, on the one hand, and the incidence of respiratory diseases in children, on the other, is explained by the following factors:

- the impact of air temperature on atmospheric pressure (p=0.65);
- adverse climatic conditions and relief of territory 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 five years, 4 and 3 years is equal, respectively, for a group of 12 years old children 40%, 40%, 20%, and 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 immediate 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.

To compose regression equations, the initial data were normalized, and a matrix of standardized values of the variables was obtained (with an average cost of zero and a single dispersion).

The equations obtained in the course of further analysis have the following form:

\[ Y_{14} = 1.367V_6 + 1.65 \quad R=0.71, \]

where \( Y_{14} \) is the incidence of respiratory diseases in children aged 14 years (the third nosological groups according to the WHO methodology);

\( V_6 \) – average monthly air temperature (°C);

\( R \) is the multiple correlation coefficient.

The calculated value of the F – criterion (Fisher) is \( F = 10.4 \). The table value \( F \) is the criterion for 10 degrees of freedom, and a significance level of 0.05 is 4.96. Accordingly, the ratio \( F \) – calculated and \( F \) – tabular for these variables is much larger than unity and reflects a high proportion of the variance explained by the regression.
The value of the multiple correlation coefficient, equal to $R = 0.71$, makes it possible to consider this model reliable and reflecting factor relationships.

$$Y^1_{13} = 1.363V_5 - 0.693V_6 + 1.196$$  \[R=0.90, \]  

(2)

where $Y^1_{13}$ – the incidence of children 13 years old;

$V_5$ – the average monthly concentration of nitrogen dioxide (mg/cubic meter);

$V_6$ – average monthly air temperature ($^\circ$C);

$R$ is the multiple correlation coefficient.

The calculated values of the $F$ – criterion (Fisher coefficient) are equal for the variables and $F = 20.133$ and $F = 5.38$, respectively. The table value $F$ is the criterion for 9 degrees of freedom, and a significance level of 0.05 is 4.26. The ratio $F$ – calculated, and $F$ – tabular is also greater than unity. The multiple correlation coefficient values are $R = 0.90$, i.e., close to an agreement, which shows the model’s high accuracy.

$$Y^2_{12} = 0.961V_6 - 0.566V_2 + 0.707$$  \[R=0.89, \]  

(3)

where – the $Y^2_{12}$ incidence of 12 years old children with respiratory diseases (the third nosological group according to method WHO);

$V_6$ – monthly average atmospheric pressure (mm Hg);

$V_2$ – the average monthly concentration of ash in the atmosphere (mg/cubic m);

$R$ is the multiple correlation coefficient.

The F – criterion (Fisher) calculated values for the variables equal to $F = 8.2$ and $F = 23.9$, respectively. The F-criterion’s tabular value for 9 degrees of freedom and a significance level of 0.05 is 4.26. Therefore, the ratio $F$ – calculated and $F$ – tabular for these variables is also much more extensive than unity, reflecting a high proportion of the explained variance. The value of the multiple correlation coefficient, equal to $R = 0.89$, and the independence of the factors’ costs also make it possible to talk about the equation’s reliability.

Thus, the first stage of calculations allows us to establish quantitative relationships between the child population’s incidence and environmental factors.

At the second stage of the study, the concentrations of the individual emission ingredients (ash, nitrogen oxides, and sulfur dioxide) coming into the air from the considered heat and power objects are calculated. This takes into account the location of these facilities, emission indicators, and specific local environmental conditions.

To calculate the concentration of pollutants, the Ecologist unified program for calculating atmospheric pollution was used to automate atmospheric pollution by harmful emissions from industrial enterprises [11, 19].

Using this program, it seems possible to determine the nature of the dispersion of harmful substances in the atmosphere’s surface layer. Following this, a system of points corresponding to the values of the concentrations of toxic substances is determined. The information base for such calculations is data characterizing the following parameters of sources and types of pollution and the territory [19].

For emission sources, the following parameters are taken into account: the height of the chimney, the diameter of its mouth, the speed and temperature of the air-gas mixture at the outlet of the duct.

For various types of pollution, the calculations use the volumes of their emissions, the effects of the interaction of multiple substances with each other, the maximum permissible concentrations in the atmospheric air of populated areas, and the rate of deposition of harmful substances in the atmospheric air.

The territory’s specificity is estimated, considering its geographical and climatic conditions, such as the region’s geographical latitude, air temperature, the wind rose, background pollution, and others.
In addition to the listed parameters, the calculations also varied in terms of the degree of neutralization of dust and gas emissions: option 1 – up to 95%, option 2 – up to 85%. The characteristics of air pollution by calculation options are shown in table 3.

According to the results of the calculations, it was found that even the environmental indicators used in the design materials of the heat and power facilities used for dust and gas collection technologies (purification level up to 95%) are not able to ensure complete dispersion of harmful substances outside the established sanitary protection zone. A calculation option that allows a possible decrease in the degree of purification of exhaust gases by 10% (up to 85%) is accompanied by a significant expansion of the area of the contaminated area and, accordingly, a sharp increase in the concentration of the considered types of pollution within it (see table 3).

4. Discussion
At the final, third stage of the research, the results obtained in the first two stages are combined. Such a union makes it possible to determine a variant for predicting the incidence of children in Lesosibirsk. The basis for the calculation is the obtained distribution of concentrations of harmful substances on the site, as well as the quantitative dependencies “incidence of children – emissions of ash, nitrogen and sulfur oxides” and “the incidence of children – atmospheric pressure and air temperature.”

### Table 3. Characteristics of air pollution by calculation options.

| Harmful substances | Concentrations of harmful substances in emissions from pollution sources | On the border of the sanitary break zone | At the level of MPC | On the border of the 200 km zone |
|--------------------|-------------------------------------------------|-------------------------------------|------------------|-----------------------------|
|                    | Maximum                                         |                                     |                   |                             |
| SO₂                | 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 |
|                    | 2.5 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 |                                     |                   |                             |
|                    | 2.5 MPC at a distance of 8–10 km east of emission sources | at a distance of 36–40 km | 0.2–0.3 MPC |
| NOₓ                | 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 |
|                    | 1.8 MPC at a distance of 5 km north of emission sources and 12 km northeast of emission sources |                                     |                   |                             |
|                    | 1.5 MPC – in the west, 2.0 MPC – in other directions | at a distance of 25–30 km | 0.2 MPC |
|                    | 2.0 MPC at a distance of 5–10 km from emission sources |                                     |                   |                             |
| Ash                | 1.0 MPC at a distance of 10–12 km from emission sources | at a distance of 15 km | 0 |
|                    | 1.5 MPC at a distance of 12–14 km from emission sources | at a distance of 15–20 km | 0 |

*Note: MPC – maximum permissible concentration of harmful substances in the air. Source: Compiled by the authors.*
As shown above, the highest incidence of respiratory diseases occurs in children 13 years old due to the initial exposure to high concentrations of nitrogen dioxide. According to the results of the forecast, it was found that in conditions of compliance with the specified indicators of the technologies for the neutralization of harmful emissions from thermal power plants in Lesosibirsk, the average monthly incidence of children in May and December will be [7, pp 94-97]:

- 14 people per 1,000 inhabitants within a radius of 35 km from emission sources and 13 people per 1,000 inhabitants within a radius of 70 km (in May);
- 30 and 29 people per 1000 inhabitants at an appropriate distance from air pollution (in December).

In the context of a possible deterioration in the neutralization of emissions into the atmosphere as a result of a decrease in the quality of their treatment at dust and gas collection facilities, the incidence of children of the corresponding age on the territory of the Lesosibirsk industrial hub will be [7, pp 94-97]:

- in May, 15 people per 1000 people within a radius of up to 35 km from emission sources;
- It will more than double and reach 31 persons per 1000 inhabitants within a radius of up to 70 km in December.

According to foreign authors, in initially healthy children, it is quite understandable and acceptable to have 6–10 respiratory diseases per 1,000 people per year [15]. A similar incidence corresponds to the prevalence of upper respiratory tract diseases in children in environmental disadvantage areas in Russia [18].

Thus, the calculations showed that the assumption about the possible location and functioning of the considered heat and power facilities in Lesosibirsk, operating on the Kansk-Achinsk coal, may be accompanied by noticeable deterioration in the health of the child population due to an increase in the incidence of up to 15–30 cases per 1,000 inhabitants per month or up to 260–280 cases per 1,000 inhabitants per year [7, pp 94-97].

The study results give reason to consider thermal power plants' placement of the assumed capacity in the Lesosibirsk industrial hub area as inexpedient.

5. Conclusions

The main results of the completed research consist in the development and practical implementation of an original methodological approach to the analysis of the dependence of individual environmental factors on the health of the child population and the identification of the possibility of placing heat power facilities within a particular territory from the standpoint of the possible impact of their emissions on public health when predicting the formation of a local production system. Therefore, the population is considered the primary recipient of the negative anthropogenic impact on the environment.

Based on the results of the study, the following conclusions can be drawn:

1. the method is proposed for quantitatively assessing the incidence of upper respiratory tract diseases on environmental factors (climatic features of the territory and air pollution), which was implemented using specific region materials.
2. The possible factor relationships between the incidence of the child population and environmental pollution are established.
3. The calculations of possible options for the concentration of harmful substances in atmospheric emissions on the industrial unit territory under consideration were made, taking into account changes in the conditions for cleaning emissions from thermal power enterprises.

The calculations showed that the possible construction of large thermal power plants in the Lesosibirsk industrial complex, combined with the prospective creation of several timber chemistry enterprises, could lead to an increase in emissions of pollutants into the air and thereby create extremely unfavorable conditions for the health of people living in Lesosibirsk.

In addition to the factors affecting health considered in the article, the negative effect can be associated with the combined impact of atmospheric emissions on people coming from thermal power
plants and forest chemistry, as well as due to changes in microclimatic conditions in the area of the projected Middle Yenisei waterworks on the Yenisei River [5].

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 territory's state from the standpoint of the influence of environmental factors on the child population's health. 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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