Analysis of emission estimates using the Atmospheric Pollution Index in the Baikal Natural Territory

O Lavygina and O Grebneva

1Melentiev Energy Systems Institute of SB RAS, Department of pipeline systems of Energy, 664033, 130, Lermontov street, Irkutsk, Russia

2Irkutsk National Research Technical University, Institute of Architecture and Construction, Department of Urban development and Economy, 664074, 83, Lermontov street, Irkutsk, Russia

E-mail: olgakot81@mail.ru

Abstract. Over the past few years, the Irkutsk Region has been included in the priority list of territories with the maximum degree of air pollution. In this case, the Atmospheric Pollution Index is used as the main criterion. In this work, the calculation of the complex index of atmospheric pollution formed during the operation of the heat supply system in the settlement of Listvyanka of the Irkutsk region is made. Heat consumers are multi-apartment residential buildings, public and business buildings. Heat supply of Listvyanka is carried out from four boiler houses. The API analysis showed that during the operation of the fuel and energy complex of small settlements, the degree of air pollution can be classified as “low”. Thus, the contribution of the fuel and energy complex to the total background air pollution can be considered insignificant.

1. Introduction

In modern conditions, one of the main factors for economic and industrial activities in the Baikal natural territory is the assessment of possible negative consequences for the components of the environment, in particular, for atmospheric air.

The cities of the Irkutsk region, according to the state of atmospheric air, are annually included in the priority list of the Russian Federation with the highest level of atmospheric air pollution. Increased sanitary and hygienic requirements in the study area determine not only the control of recreational, industrial, but also economic activities [1-4]. According to some authors [5], one of the main sources of pollution is the fuel and energy complex (FEC). Complex analysis of the impact on the atmospheric air is carried out by determining the complex Atmospheric Pollution Index (API) in accordance with RD 52.04.667-2005 [6]. This takes into account both stationary and mobile sources of pollution. According to RD 52.04.667-2005, four gradations of atmospheric air quality are distinguished, which corresponds to low, increased, high and very high levels of pollution. Such methods make it possible to assess the processes in aggregate, to determine priority directs, and to identify regional environmental problems [7-9].

The value of the complex API is calculated from the values of the average annual concentrations. The indicator characterizes the level of chronic, long-term air pollution. It can be noted that approach is used not only to estimate the degree of pollution for atmospheric air, but for other components of...
the environment, in particular, for water resources [10]. Snow cover surveys are also used to assess air quality [11].

2. Factors causing the dispersion of pollutants in the air

Assessment of the state of atmospheric air in urban areas upon the ingress of pollutants requires taking into account both the physical, geographical and climatic features of the territory, and the diversity and interaction of pollutants emissions sources, most of which are included in the fuel and energy complex of our country.

In megalopolises and large cities, especially high levels of air pollution are observed in the winter months, the period of the highest heating load and the least ability of the atmosphere to self-purify due to climatic features.

According to the Methodology for calculating the concentration of pollutants in the air [3], there are a number of factors that determine the maximum distance over which these pollutants are able to spread. With regard to the territories of the Russian Federation, such factors include the height of the emission source, the strength and prevailing direction of the wind, the coefficient of sedimentation, the relief, and seasonal fluctuations in the properties of the atmosphere.

In order to ensure the safety of the population and in accordance with the requirements of environmental and sanitary and epidemiological legislation, along the perimeter of objects and industries that are sources of negative impact on the environment and human health, a special territory (sanitary protection zone – SPZ) is established, on which a special regime of use is imposed, the value which ensures the reduction of the effect of pollution on the atmospheric air (biological, chemical, physical) to the values determined by hygienic standards.

The scattering schema shows the mechanism of the pollutants spread in the atmospheric air, in which the main factors are both the distance to the residential area and the chimney height from which the gas-air mixture is emitted. In this case, the maximum concentration of pollutants should not go beyond the sanitary protection zone. Moreover, on its border, the excess of the established standards of maximum permissible concentrations (MPC) should not be fixed.

Within urban areas, the distribution of pollutants is also influenced by ordered vertical movements caused by the heterogeneity of the underlying surface. In the conditions of rough area, on the windward slopes, ascending movements occur, and on the leeward ones – descending movements, over water in summer – descending movements, and in coastal areas – ascending movements. With downgrades, surface concentrations increase, with ascending ones, they decrease.

In some forms of relief, such as deepening, the air stagnates, which leads to the accumulation of harmful substances near the underlying surface, especially from low emission sources. In hilly terrain, the maximums of the surface concentration of impurities are usually higher than in the absence of relief irregularities.

The dispersion of pollutants in a city is significantly influenced by the layout of streets, their width, direction, height of buildings, green areas and water objects, which form, as it were, different forms of ground obstacles to the air flow and lead to the occurrence of special meteorological conditions in the city.

With regard to the territory of the Russian Federation, it should be noted that in the European part meteorological features contribute to the accumulation of pollutants in the atmospheric air.

Thus, the main sources of urban pollutants are heat and power facilities. It is during the combustion of hydrocarbon raw materials that the maximum air pollution is noted. The maximum contribution of this industry is due to both the volume of combustion products and the widespread distribution of energy facilities. An important role is played by enterprises of ferrous and non-ferrous metallurgy, which have smelting facilities in their technological mode. The consequences of atmospheric air pollution have a negative impact primarily on the health status of the population.

When considering the process of distribution of pollutants in the air, it was revealed that the scattering ability is determined by a number of factors: the specifics of pollutants, the height of the emission source, as well as climatic features.
Quantitative reduction in emissions into the atmospheric air can be achieved only with complex work, which includes a set of measures implemented not only at the enterprise in question, but also at the federal, regional and local levels.

Distance protection is the primary method for reducing human exposure to pollutant emissions. In other words, the farther residential buildings are located from the heat supply source, the less negative impact is manifested (Fig. 1).

![Figure 1](image)

**Figure 1.** Dependence of the concentration of pollutants on the distance from the emission source [6].

Due to the peculiarities of dispersion of pollutants in atmosphere air, the main protection measure is the creation of sanitary protection zones around heat supply sources. And at the pre-project stage, the degree of negative impact of the source can be assessed in detail using complex API.

### 3. Method of complex API determination

A complex analysis of the degree of air pollution in populated areas is carried out by determining the complex API, which is calculated by the formula [3]:

\[
I_n = \sum_{i=1}^{n} I_i = \sum_{i=1}^{n} \left( \frac{q_{av,i}}{MPC_{d,av,i}} \right) C_i
\]

- \( I_i \) – API for the \( i \)-th pollutant;
- \( n \) – amount of pollutants;
- \( q_{av,i} \) – average annual concentration of \( i \)-th pollutant;
- \( MPC_{d,av,i} \) – daily average maximum permissible concentration \( i \)-th pollutant;
- \( C_i \) – dimensionless coefficient (Table 1), allowing to bring the degree of pollutant of the \( i \)-th pollutant to the degree of harmfulness of sulfur dioxide (3rd hazard classes).

| Hazard class | 1    | 2    | 3    | 4    |
|--------------|------|------|------|------|
| \( C_i \)    | 1,7  | 1,3  | 1,0  | 0,9  |

According with the level of air pollution in the city and the values \( I_n \) are given in Table 2.

| Value \( I_n \) | Air pollution level          |
|----------------|------------------------------|
| \( \leq 5 \)   | Below the average            |
| \( 5 < I_n \leq 8 \) | Approximately equal to the average |
| \( 8 < I_n \leq 15 \) | Above average                |
\( I_n > 15 \quad \text{Significantly above average} \)

The average daily maximum permissible concentration of the \( i \)-th pollutant is determined taking into account dispersion. An example of a dispersion map is shown in Fig. 2.

![Dispersion Map](image)

**Figure 2.** Example of dispersion map.

4. Results of calculating of complex API for a small settlement of the Baikal natural territory

Assessing the contribution of the fuel and energy complex of small settlements to the API, its structure was considered on the example of Listvyanka, Irkutsk region.

The total living area of the heated housing stock is 22294 m², including: 1\(^{st}\) Boiler house – 9200 m²; 2\(^{nd}\) Boiler house – 4510 m²; 3\(^{rd}\) Boiler house – 5372 m²; 4\(^{th}\) Boiler house – 3212 m². At the same time, the area of residential areas within the boundaries of the settlement is 114.8 hectares [12].

According to some authors [13], for recreational facilities in Listvyanka, it is recommended to replace electric boilers with pellet ones. The use of a solar heat supply system in the conditions of Listvyanka is economically unjustified.

Table 3 shows the results of calculating the API when operating the «Mazutnaya» boiler house on the main fuel and when transition to an alternative source (pellets) [14, 15].

| Emission name       | MPC  | Fuel oil boiler | Pellet boiler | Oil API | Pellet API |
|---------------------|------|----------------|---------------|---------|------------|
| Nitrogen dioxide    | 0.04 | 0.34           | 0.28          | 0.0034  | 0.0028     |

Table 3. Calculation of API (the boundary of the lake Baikal).
Nitrogen oxide 0.06 0.1 0.1 0.001 0.001
Sulfur dioxide 0.05 0.27 0.04 0.0027 0.0004
Summation group 0.05 0.33 0.19 0.0033 0.0019

\textbf{Complex API} 0.0104 0.0061

As can be seen from Table 3, the complex API, which is formed during the operation of the 1st boiler house, is 0.01 and 0.006 when using fuel oil and pellets, respectively. Considering that there are 4 sources of heat supply in the study area, it can be assumed that API of the settlement of Listvyanka, formed by the fuel and energy complex will be no more than 0.04.

Analysis of API indicators on the territory of Listvyanka, presented according to the data of the Irkutsk Department for Hydrometeorology and Environmental Monitoring, indicates a «low» level of atmospheric air pollution, i.e. API ranges from 1 to 2.3.

5. Conclusions
Comparison of the data obtained by the API generated by the fuel and energy complex in Listvyanka has shown that the level of atmospheric air pollution can be classified as «low». The total contribution to the API level, determined by the total amount of emissions from four boiler houses in Listvyanka, is expected to not exceed 10%. Thus, it is not the fuel and energy complex that plays a significant role in the background pollution, but other sources of pollution: vehicles and other sources of emissions.

Thus, the use of complex indicator of API makes it possible to obtain an aggregated assessment for the subsequent in-depth assessment of the harmful effects of various sectors of the national economy and the development of appropriate measures to protect the air basin.

Acknowledgments
The studies were carried out in the framework of project III.17.4.3 of the Program of basic research of the SB RAS (AAAA-A17-117030310437-4)

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