

Air Processes Resulting in a Surface Layer Pollution in Industrial Regions

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Abstract. The article describes the air quality research in Western Siberia (Kemerovo region). The problem of air quality preservation in the conditions of mining industry intensive development is caused by the weather conditions which lead either to the concentration of pollutants in the surface layer, or to their migration to other geosphere, or to dissipation as a result of convective mixing or advection of air masses. Zoning of the territory in view of the research results provides insight into areas where the greatest risk to human health and life is formed.

1. Introduction

The problem of environmental changes as a result of the mining activity is very important for the Kemerovo Region. It is known that the success of the conservation of local ecosystems depends on the success of the transition of the coal industry from extensive to more efficient methods of mining taking into account the various constraints (technology, seismic, transportation, environmental, energy, demographic, etc.). In the works of V.Oparin and A.Ordin [1] the problem of considering all factors of limiting the volume of coal production in the Kemerovo region was observed. One of the limiting factors of mined coal volumes sums ecological and demographic problems. Also the problem of providing mining industry with human resources [2] has a major influence on limits of mined coal.

One of the geospheres that changes as a result of mining activities is the atmosphere, in particular, its surface layer, which leads to adverse consequences for the population: increased mortality, morbidity and economic losses of the individuals. In highly urbanized regions, most of the population is located in cities, where industries are concentrated.

2. Material and Method

The air quality depends not only on the issue of contaminants (pollutants) from industry, road transport and other sources, but also on weather events that can neutralize the emissions of pollutants or cause their concentration near the source. The frequency and duration of periods of high air pollution depends on the mode of emissions (single, emergency, etc.), and on the nature and duration of the meteorological conditions that increase the impurity concentration in the surface layer.



The main pollutants of the air basin in the Kemerovo region are mining companies, energy and fuel manufacturers [3-5]. The share of enterprises extracting energy minerals in total pollution reach up to 61.1% and of manufacturing enterprises - 20.4% (including the steel industry – 17.9%), power generation and gas and water distribution - 16.3% [6]. The increase in emissions is observed for power generation and distribution, gas and water distribution (more than 10% of 2010-2014).

When a temperature inversion decreases the speed of air floods convection, the accumulation of pollutants in the surface layer of the atmosphere (SLA) increases. The long temperature inversion increases the concentration of pollutants in the atmosphere to levels that are dangerous to the people.

Meteorological conditions (wind, precipitation, humidity, etc.) are important for the dispersion of pollutants [7-9]. Kemerovo region has severely continental climate so anticyclones are often occur in the summer and winter, forming calm weather with low rainfall and low wind speed [10, 11]. That reduces the self-cleaning ability of the surface layer of the atmosphere. Also in the winter over the territory the temperature inversion phenomenon in the atmosphere is formed due to the special orography and climate of the region.

In order to avoid increasing air pollution level in unfavorable for dispersion of pollutants meteorological phenomena it is necessary to predict and define conditions of severe pollution. In this research zoning of the Kemerovo region territory was conducted to determine the most disadvantaged areas of human activity. Also, these areas were correlated with the areas with the highest pollutant emissions [12] and the number of people living in this territory [13]. All data have been reduced to municipalities' borders of in order to create proposals to improve the situation.

The method of assessment the scattering ability of the surface atmosphere layer was proposed by Selegey T.S. [14]. The calculation was made according to the formula (1):

$$MPAD = \frac{Rc + Rf}{Rp + Rw}, \quad (1)$$

where: MPAD - meteorological potential atmospheric dispersion; Rc - repeatability of calm days (wind speed is less than 1 m/sec); Rf - repeatability of days with fog (humidity above 80%); Rp - repeatability of days with precipitation at least 0.5 mm; Rw - repeatability of days with wind speeds at least 6 m/sec.

From the values of the potential of air pollutants scattering by the atmosphere the following grading was proposed [14]:

- for $MPAD > 2$, it means the extremely adverse conditions (EUC);
- for $MPAD > 1$, it means adverse conditions (AC);
- for $MPAD \leq 1$, it means favorable conditions (FC);
- for $MPAD \leq 0.5$, it means an extremely favorable conditions for dispersion of pollutants in the atmospheric boundary layer.

The indicator can be used for calculating the self-cleaning capacity of the atmosphere at any time.

3. Results and Discussion

For MPAD index calculation the data from 21 meteorological stations interpolated in the Mapinfo software was used.

For the spatial analysis of inversion phenomena occurrence in the atmosphere, we used in this study a 6-hourly data reanalysis by NCEP/NCAR, presented at National Oceanic & Atmospheric Administration website (the NOAA) [15], converted into the local time (+7 hours). NCEP/NCAR data have a horizontal extension of $2,5^\circ \times 2,5^\circ$. Geographical grid of research was $50.0^\circ \text{ N} - 57.5^\circ \text{ N}$, $82.50^\circ \text{ E} - 90.00^\circ \text{ E}$.

To study the inversion phenomena in the atmosphere there were selected three baric surfaces:

- 1000 hPa - isobaric surface of the Earth;
- 925 hPa - isobaric surface at an altitude of 750 m;
- 850 hPa - isobaric surface at an altitude of 1500 m.

Accordingly A.N. Akhmetshina methodology of layers selection [16] which is usually used for searching the presence of inversions, we use the following set of formulae:

$$\Delta T1 = T1000 - T925$$

$$\Delta T2 = T925 - T850$$

$$\Delta T = T1000 - T850$$

It is considered that the negative values of ΔT , $\Delta T1$, $\Delta T2$ indicate the presence of a temperature inversion.

The database was created using the MATLAB software, ncBrowser, and Microsoft Office Excel. The day with the inversion is the day in which there was either a high-altitude, or surface inversion [17].

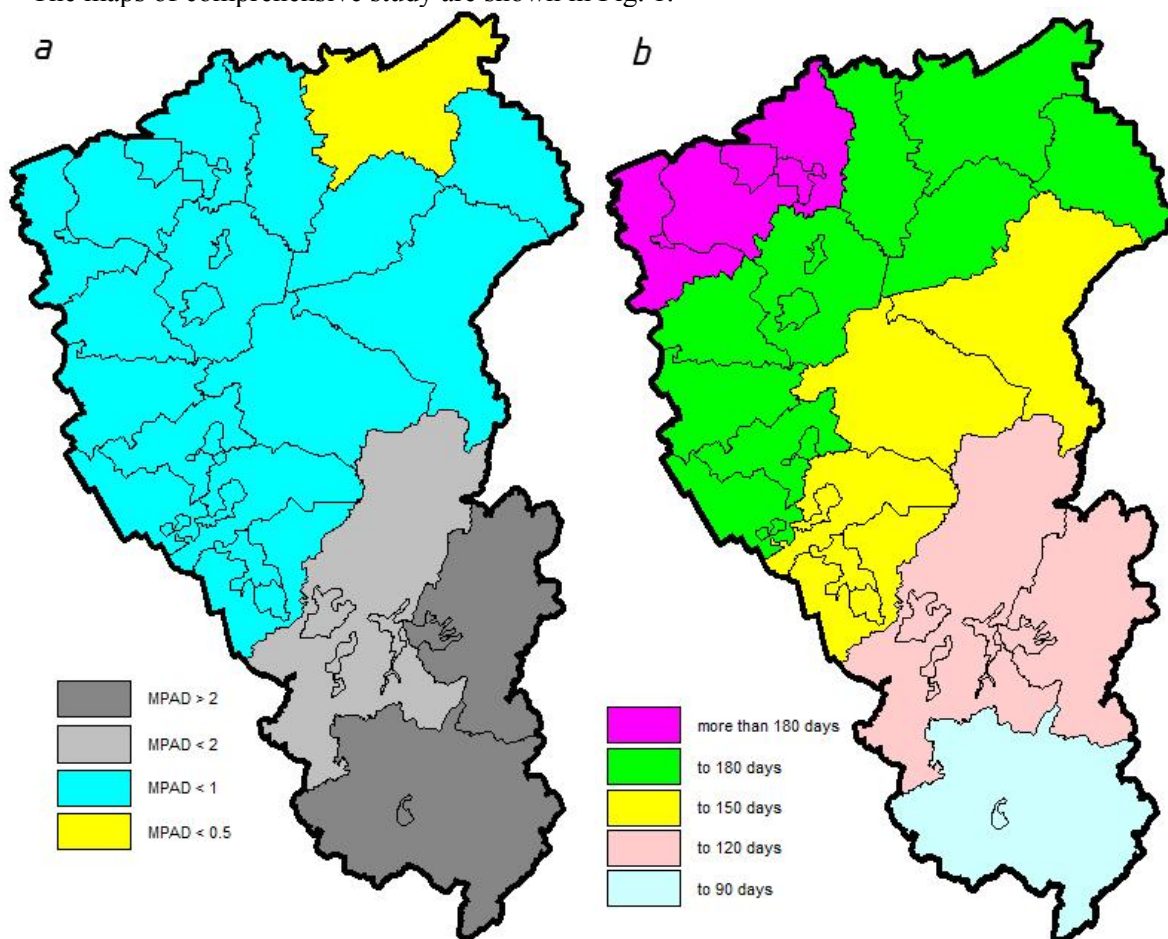
Nevertheless this level of detailing is not sufficient to analyze the thermal structure of the different baric levels for the complex orographic [17]. Since the coal industry enterprises located within the Kuznetsk depression, having small elevation differences, we can roughly estimate the time and the frequency of inversions, their duration, and their impact on the air quality [18].

Emissions of pollutants into the atmosphere and population were transferred to municipal boundaries.

For the processing and presentation of data we used the following software: MATLAB, ncBrowser, Microsoft Office Excel, Mapinfo.

Results and discussion

The maps of comprehensive study are shown in Fig. 1.



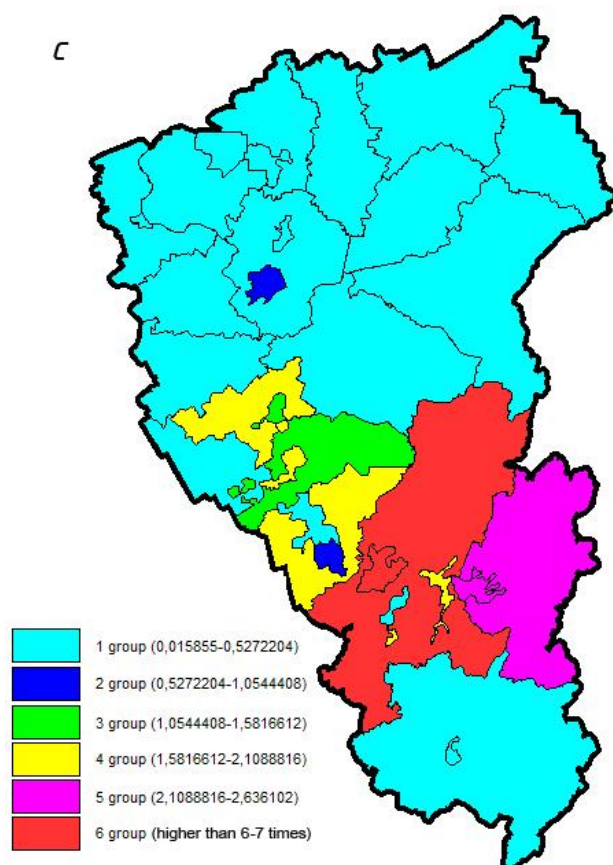


Figure 1. Schematic maps of Kemerovo region on various parameters: a – the map of meteorological potential of atmosphere pollutant scattering (MPAD); b – schematic map of number of days with temperature inversions in the atmosphere; c – schematic map of changes of standardized pollutants emitted to the atmosphere by stationary sources.

Over the territory of Kemerovo region in different times of the year various conditions for the accumulation of pollutants in the atmosphere is being formed. Fig. 2 shows the levels of MPAD in Kemerovo and Novokuznetsk – the main cities of the region.

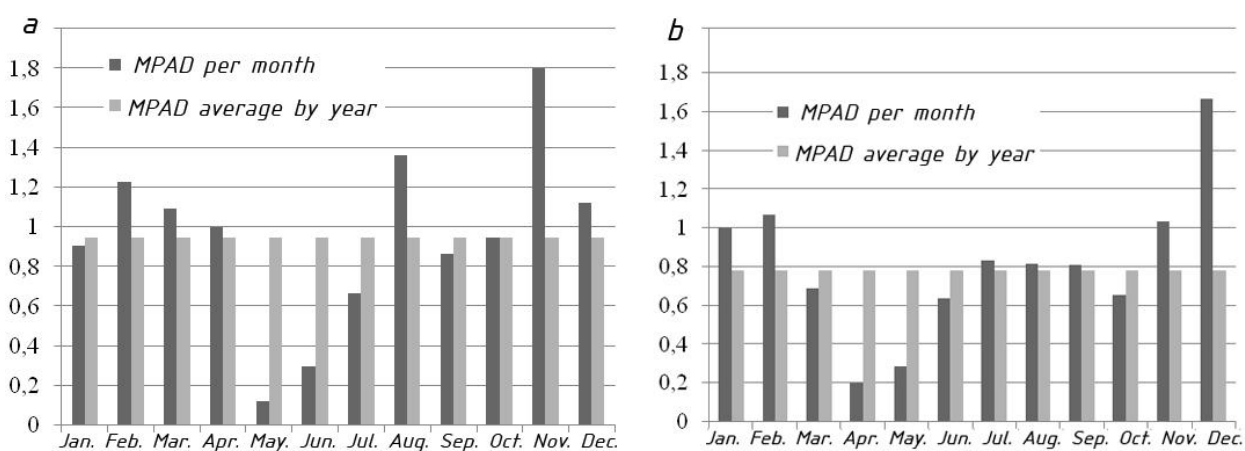


Figure 2. Change index MPAD (in points) in Kemerovo (A) and Novokuznetsk (B) during the year

As a result of meteorological potential research we concluded that the worst conditions for pollutants scattering for used parameters are formed during the winter, which worsens the condition of the surface atmosphere layer in the cities. The most favorable conditions for pollutants scattering are formed over the north area (Yaya, Izhmorsky, Mariinsky, Yurga areas). Deterioration of MPAD in the south-east of Kemerovo region threatens the whole environment, as well as they are the main areas of various pollutants' emission into the atmosphere [19-21].

Research of formation of inversions in Kemerovo region has shown that an increase in inversions from south to north, to north-west and to east-west. Temperature inversions were mostly close to surface in winter. There was also a simultaneous formation of surface and elevated inversions. Most often their joint forming took place in the winter months, and due to the air compression process in powerful anticyclones. Formation of prolonged inversions prevents convective mixing of air masses, which leads to pollutants concentrations increase in the surface layer and above the maximum permissible concentration.

The main areas of atmosphere pollutants' emission are located with mining specialized districts [22] (Novokuznetsk, Prokopevsk, Kiselevsk districts). The location of these areas in the MPAD interval of 1 - 2 prevents the scattering of pollutants in the atmosphere.

4. Conclusion

During the town-planning work not only the wind rose but the frequency of incidence and annual variation of temperature inversions over the planning area should be taken into account. This is especially important for Kemerovo region, as over its territory anticyclones' weather is often formed, which is associated with surface and elevated temperature inversions. If this phenomenon is not taken into account there is a risk for population and the local ecosystem. The problem of the formation of photochemical smog is available in Moscow, Tokyo, Sydney and others.

The use of MPAD indicators, the number of days with temperature inversions and the amount of pollutants emitted over the territory gives an overview of the changes in air quality, and allows determining the areas with the most favorable environment for people' living. In the transition to sustainable regional development these atmospheric processes must be considered.

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