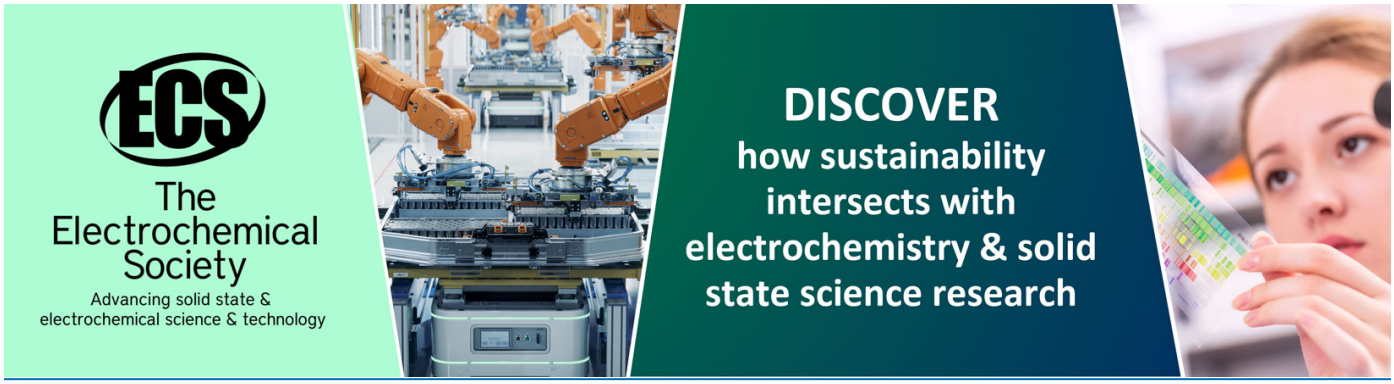
Instrumental determination of the location of benzo[a]pyrene emission sources



IOP Conf. Series: Materials Science and Engineering **537** (2019) 062070 doi:10.1088/1757-899X/537/6/062070

Instrumental determination of the location of benzo[a]pyrene emission sources

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Abstract. Instrumental determination of the location of the most powerful source of emissions of benzo[a]pyrene, in the presence of many other less powerful sources, is an actual problem of monitoring. As a result of processing the data obtained at the automated monitoring posts "Krasnoyarsk-Severny" and "Krasnoyarsk-Solnechny", it was found that the identification of the main atmospheric pollutant is possible on the basis of analysis of the data set of benzo[a]pyrene concentrations and wind directions measured during sampling for determine the content of this pollutant in the air. It is shown that the main contribution to air pollution in the area of the "Krasnoyarsk-Severny" and "Krasnoyarsk-Solnechny" posts is made by industrial enterprises located in two territorial zones. The greatest contribution to pollution is made by emissions from the industrial site, in the center of which the Krasnoyarsk Aluminum Plant is located. The second significant contribution to atmospheric pollution with benzo[a]pyrene is made by emissions from the site located in the SNT “Aluminum” area.

1. Introduction

In the city of Krasnoyarsk for several decades there is a very high level of air pollution. The value of the air pollution index (API_5), calculated for five pollutants, is more than 14. The contribution of the concentration of benzo[a]pyrene in the value API_5 is more than 80%.

According to the Russian standard GN 2.1.6.3492-17 the maximum permissible concentration daily average of benzo[a]pyrene in the air of populated areas, MPC_{da}, equals 1 ng/m^3. In Europe, the concentration of benzo[a]pyrene not exceeding 0.12 ng/m^3 is considered safe [1]. If this concentration is exceeded, the air is considered contaminated. Pollution occurs mainly as a result of emissions from domestic combustion of coal and wood [2, 3].

Benzo[a]pyrene has a negative effect on human health [4, 5].

The main source of emissions of benzo[a]pyrene in the city is the Krasnoyarsk aluminum plant (KrAP). Over the past decade, KrAP has reduced emissions of this pollutant. In 2017, 1150 kg of benzo[a]pyrene was released into the atmosphere. Other industrial enterprises emit benzo[a]pyrene in smaller quantities. There are several hundreds of such enterprises and they are scattered throughout the city. This circumstance determines their role in the formation of the concentration field of benzo[a]pyrene in the air.

The contribution of each enterprise to the formation of the concentration of benzo[a]pyrene at a specific point is determined using methods for calculating the dispersion of emissions of harmful (polluting) substances in the air (MCD-2017) (Order of the Ministry of natural resources and ecology

of the Russian Federation of June 6, 2017 N 273). However, till now such calculations have not been verified for the conditions of Krasnoyarsk.

Wind speed and direction are important indicators in the analysis of the propagation of benzo[a]pyrene in the atmosphere. Such data are recorded at automated monitoring stations (AMS) for the level of air pollution (http://krasecology.ru). In order to establish the azimuth of the enterprise, which makes the main contribution to air pollution in the area of the specifically selected AMS, it is necessary to analyze the data array of benzo[a]pyrene concentrations and wind directions measured during the sampling of benzo[a]pyrene. The two azimuths defined for the two AMS can be used to determine the location of the source of benzo[a]pyrene emissions.

The aim of the paper was to carry out such analysis of the data obtained on two AMS: "Krasnoyarsk-Severny" and "Krasnoyarsk-Solnechny".

2. The data used

The layout of the automated air pollution observation posts and the results of measuring the concentration of benzo[a]pyrene, wind speed and direction for the period from 2015 to the beginning of 2017 are presented on the official website (http://www.krasecology.ru/).

3. Results and discussion

In 2017, the average annual wind speed at the "Krasnoyarsk-Severny" AMS was 0.63±0.06 m/s, and the maximum wind speed reached 5.8 m/s [6].

In the Severny district annual average concentration of benzo[a]pyrene in the atmosphere according to the data of the Implementation of Environmental Management and Environmental Protection of the Krasnoyarsk Region was 4.2 and 6.3 shares of MPC_{da} in 2015 and 2016 respectively. In general, the average annual concentration of benzo[a]pyrene in the city of Krasnoyarsk in 2015 was 3.7 shares of MPC_{da} and in 2016 - 5.1 shares of MPC_{da}.

The dependence of the concentration of benzo[a]pyrene on the wind direction for the period 2015-2017 in this microdistrict is presented at figure 1. It is seen that the highest concentration of benzo[a]pyrene was 118 MPC_{da}. During the observation period 3 cases of 100-fold excess of MPC_{da} and 37 cases of twenty-five-fold excess of MPC_{da} were recorded.

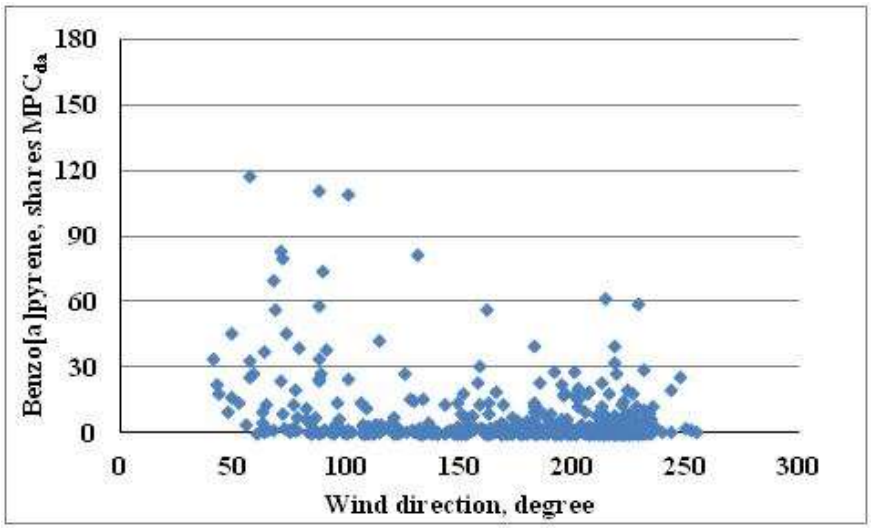

Figure 1. The dependence of the concentration of benzo[a]pyrene from the wind direction at observation station "Krasnoyarsk-Severny".

From the data presented in figure 1, it can be seen that if we consider the wind direction with a gradation of one degree, then for each azimuth there are either several values of the concentration of

benzo[a]pyrene or none. In this regard, it was decided to abandon the calculation of the average concentration of benzo[a]pyrene in azimuth.

The range of wind direction, shown in figure 1, was divided into sectors: 40-70, 70-110, 110-140, 140-170, 170-200, 200-230 and 230-260. For these sectors, mean benzo[a]pyrene concentrations were calculated. It should be noted that the data obtained at wind speeds of less than 0.5 m/s were excluded from the calculation. The results are presented in figure 2.

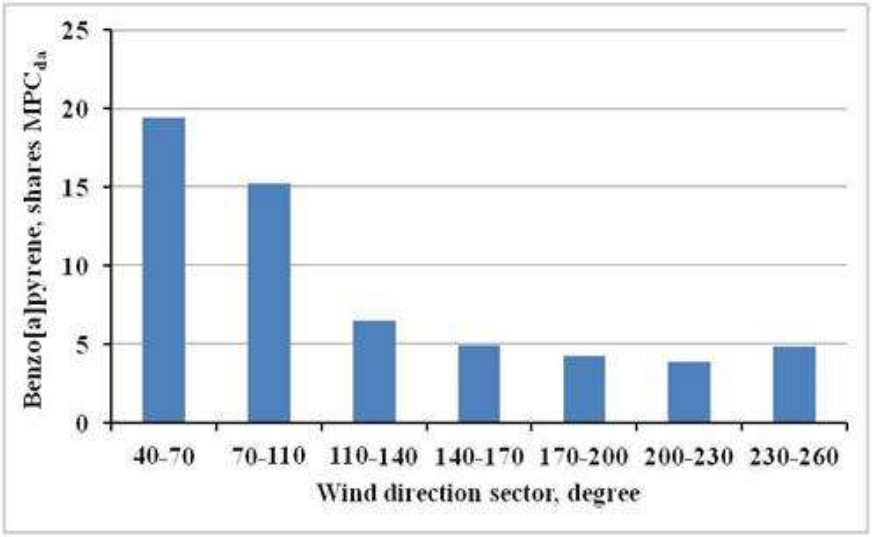

Figure 2. Average concentrations of benzo[a]pyrene recorded at "Krasnoyarsk-Severny" AMS depending on the sector of wind direction.

Analysis of variance showed that highly significant are the two concentrations of benzo[a]pyrene: 19.4 shares of MPC_{da} for the sector of 40-70 degrees and 15.3 shares of MPC_{da} for the sector 70-110 degrees (figure 2). For other sectors, the average concentrations of benzo[a]pyrene among themselves are not significantly different.

A similar analysis was carried out for the data obtained at the "Krasnoyarsk-Solnechny" AMS.

In 2017, the average annual wind speed at the "Krasnoyarsk – Solnechny" AMS was 2.13±0.12 m/s, and the maximum wind speed reached 9.7 m/s [6].

There are no industrial enterprises on the territory of Solnechny microdistrict, however, the average annual concentrations of benzo[a]pyrene in the atmosphere of this microdistrict were 3.9-4.0 shares of MPC_{da} in 2015-2016.

At an azimuth of 170 degrees from the "Krasnoyarsk-Solnechny" AMS at a distance of 5.5 km is the "Krasnoyarsk-Severny" AMS. In view of this fact, and on the assumption that the range of wind direction at which the benzo[a]pyrene was recorded, is in the range from 23 to 308 degrees, it was divided into sectors 0-45, 45-90, 90-135, 135-166, 166-225, 225-270 and 270-315.

Average concentrations of benzo[a]pyrene were calculated for these sectors (figure 3).

Analysis of variance showed that two concentrations of benzo[a]pyrene are extremely significant: 24.3 shares of MPC_{da} for the sector of 90-135 degrees and 7.7 shares of MPC_{da} for the sector of 135-166 degrees (figure 3). For other sectors, the average concentrations of benzo[a]pyrene among themselves are not significantly different.

Thus, relative to the location of the "Krasnoyarsk-Severny" AMS and "Krasnoyarsk-Solnechny" AMS, two wind direction sectors were determined, at which the concentration of benzo[a]pyrene was significantly higher than in other sectors.

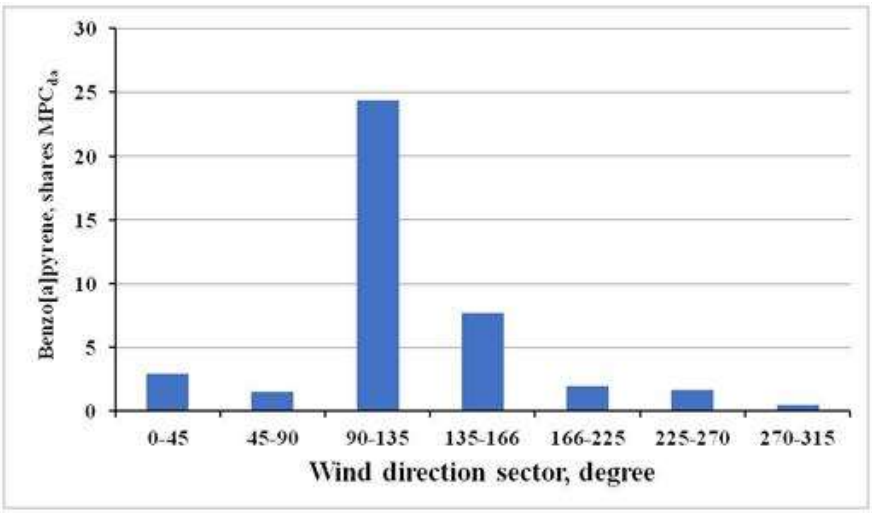

Figure 3. The average concentrations of benzo[a]pyrene recorded on the "Krasnoyarsk-Solnechny" AMS, depending on the wind direction sector.

A satellite map of the city of Krasnoyarsk was used to determine the location of the emission sources of benzo[a]pyrene. On this map, the location of the AMS was marked and the sectors of wind directions marked by which high concentrations of benzo[a]pyrene are observed (figure 4 and figure 5).

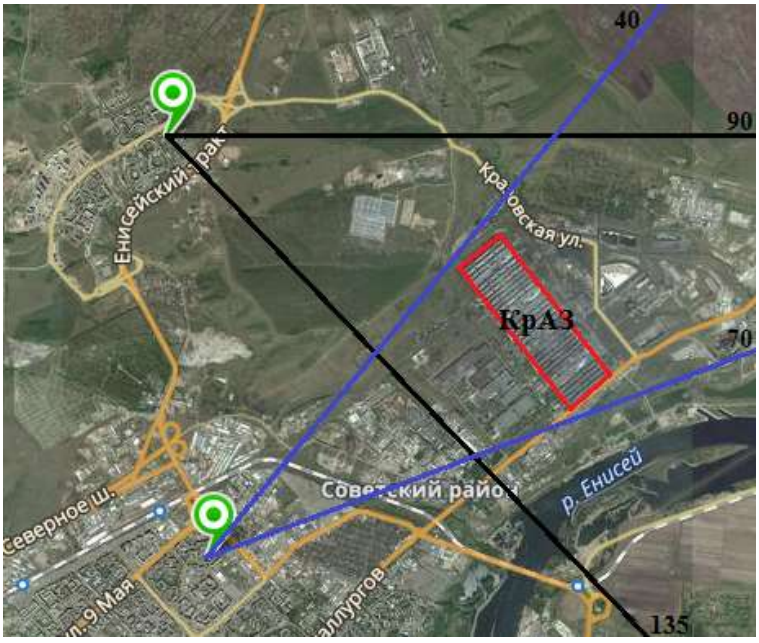

Figure 4. The location of the AMS and sectors of the directions of the wind, which form the highest (averaged over the observation period) concentration of benzo[a]pyrene. Black lines indicate the sector or the "Krasnoyarsk-Solnechny" AMS (pollution of 24.3 shares of MPC_{da}), and blue lines-for the "Krasnoyarsk-Severny" AMS (pollution of 19.4 shares of MPC_{da}).

Figure 4 shows the area of intersection of the sectors 90°-135° and 40°-70° from which the wind is transferred to the benzo[a]pyrene in the district "Krasnoyarsk-Solnechny" AMS and "Krasnoyarsk-Severny" AMS. In this territory there are enterprises of KrAP and CHP-3 and smaller industrial facilities. The main source of emissions of benzo[a]pyrene at this site is KrAP.

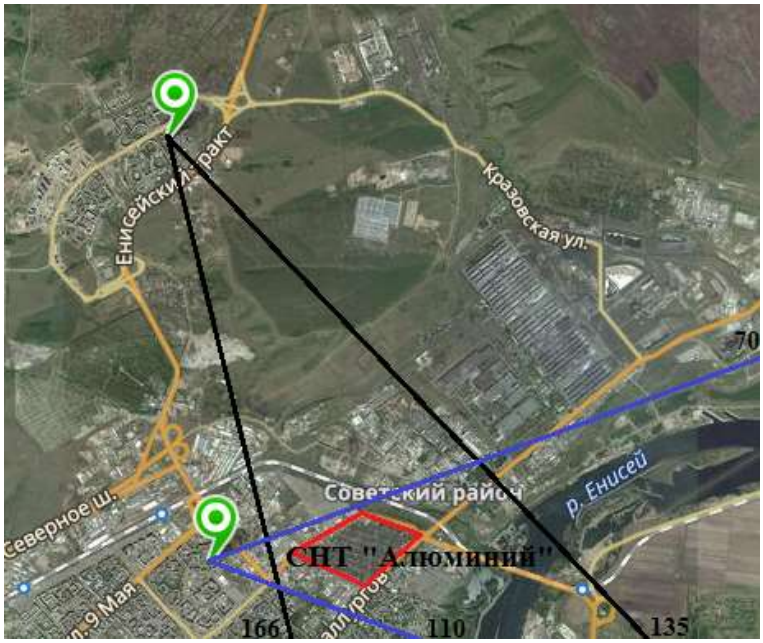

Figure 5. The location of the AMS and sectors of the directions of the wind, which form a high (averaged over the observation period) concentration of benzo[a]pyrene. Black lines indicate the sector for the "Krasnoyarsk-Solnechny" AMS (pollution of 7.7 shares of MPC_{da}), and blue lines-for the "Krasnoyarsk-Severny" AMS (pollution of 15.3 shares MPC_{da}).

Figure 5 shows the area of intersection of the sectors 135°-166° and 70°-110° from which the wind is transferred to the benzo[a]pyrene in the district "Krasnoyarsk-Solnechny" AMS and "Krasnoyarsk-Severny" AMS. There are no large industrial facilities in this area. As an alleged source of air pollution can be area emission within the boundaries of the horticultural non-profit partnership (SNT) "Aluminum" (figure 5). A lot of autonomous sources of heat supply (ASHS), operating on coal is on the territory of this SNT. Not only country houses, but also numerous care centers, facilities, small businesses, are heated by coal. Should be noted that 3 grams of benzo[a]pyrene is emitted in the atmosphere by burning one ton of Borodino coal in ASHS.

4. Conclusions

Thus, as a result of the analysis of the data obtained at the "Krasnoyarsk-Solnechny" AMS and the "Krasnoyarsk-Severny" AMS, it was reliably established that atmospheric pollution with benzo[a]pyrene in the Severny and Solnechny microdistricts is caused by wind transfer from two sites located in the South-Eastern part of Krasnoyarsk. The main contribution to air pollution is caused by emissions from the site on which territory KrAP is located. The second (in importance of contribution to air pollution) source is located in the area of SNT "Aluminum". It should be noted that there are no large industrial enterprises in the area of SNT.

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