IV.2 Benzo[*a*]pyrene

IV.2.1 Air pollution by benzo[*a*]pyrene in 2021

Air pollution by benzo[*a*]pyrene is one of the main air quality problems in the CR. In 2021, the annual average concentration of benzo[*a*]pyrene exceeded the pollution limit value (1 ng·m^{-3}) at 40 % of stations, i.e., 19 of a total of 49 stations with a sufficient number of measurements for evaluation (Fig. IV.2.1). In 2021, the area with above-limit concentrations of benzo[*a*]pyrene covered 6.1 % of the area of the CR inhabited by approx. 20 % of the CR population (Fig. IV.2.2). The area with above-limit concentrations in 2021 was the second lowest in the last five years. The largest year-on-year increase in the area with above-limit concentrations of benzo[*a*]pyrene occurred in the Zlín and Olomouc regions. The regions with the highest concentrations of benzo[*a*]pyrene in the long term remain the Moravian-Silesia, Zlín and Olomouc regions (Fig. IV.2.3). However, exceeding the annual benzo[*a*]pyrene pollution limit in connection with local heating also occurs in a number of cities and municipalities outside the most heavily burdened regions.

The highest annual average concentrations of benzo[*a*]pyrene have long been recorded at all types of stations in the whole area of the O/K/F-M agglomeration (Fig. IV.2.4). High above-limit concentrations of benzo[*a*]pyrene occur there in connection with the highest emission load within the CR (from various types of sources), including the impact of cross-border transfer from Poland. As in previous years, also in 2021 the highest annual average concentration of benzo[*a*]pyrene (8.9 ng·m^{-3}) was recorded at the Ostrava-Radvanice ZÚ industrial station, where the annual benzo[*a*]pyrene pollution limit was exceeded almost ninefold. The results of the identification of air pollution sources and the evaluation of causes of air pollution in the eastern part of Ostrava within the ARAMIS project – Integrated system of research, evaluation and control of air quality (co-funded with the state support of the Technology Agency of the CR under the Environment for Life program) show that at this station, with limited representativeness of hundreds of meters from the station (corresponding to classification and purpose of the station), pollution by benzo[*a*]pyrene originates mainly from the site of the Liberty Ostrava a. s. metallurgical company (about two-thirds in the cold part of the year) and almost the entire remaining part involves household heating (Seibert et al. 2022). The second highest value of the annual average concentration of benzo[*a*]pyrene was identified at the Věřňovice border rural station (6.8 ng·m^{-3}) within the subsidized extension of monitoring by the Moravian-Silesia region (Hladký et al. 2022). In this locality, a combination of the impact of air pollution from southern Poland and the specific composition of small settlements on the Czech side of the border, together with the often poor dispersion conditions in the valley

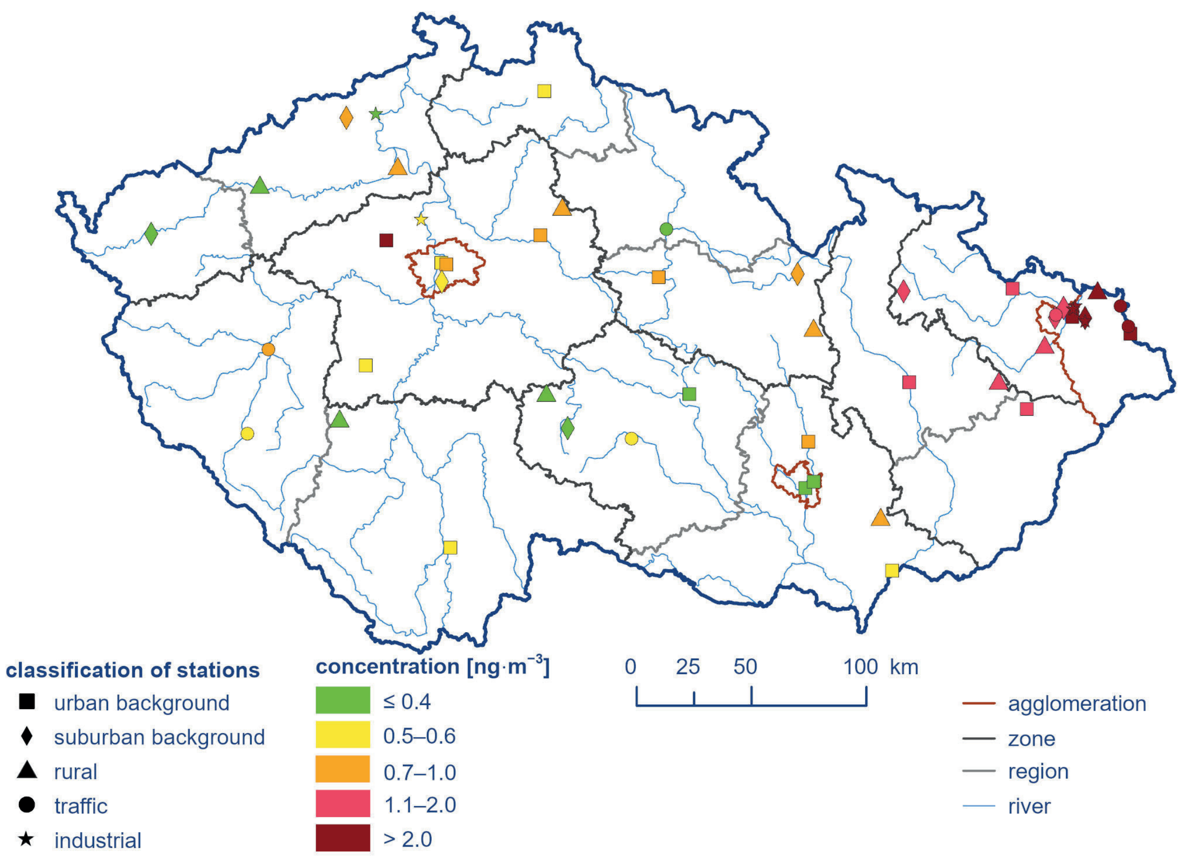

Fig. IV.2.1 Annual average concentrations of benzo[*a*]pyrene at air quality monitoring stations, 2021

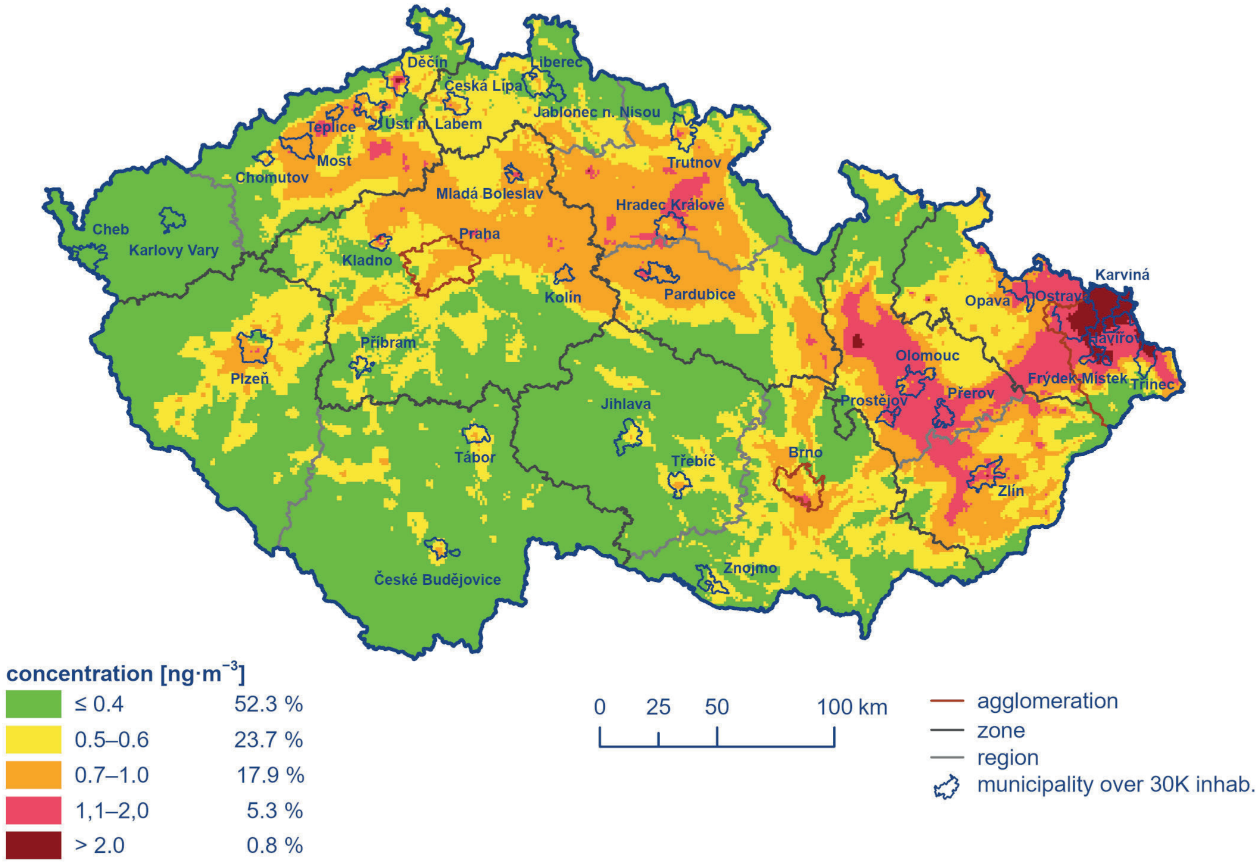

Fig. IV.2.2 Field of annual average concentration of benzo[*a*]pyrene, 2021

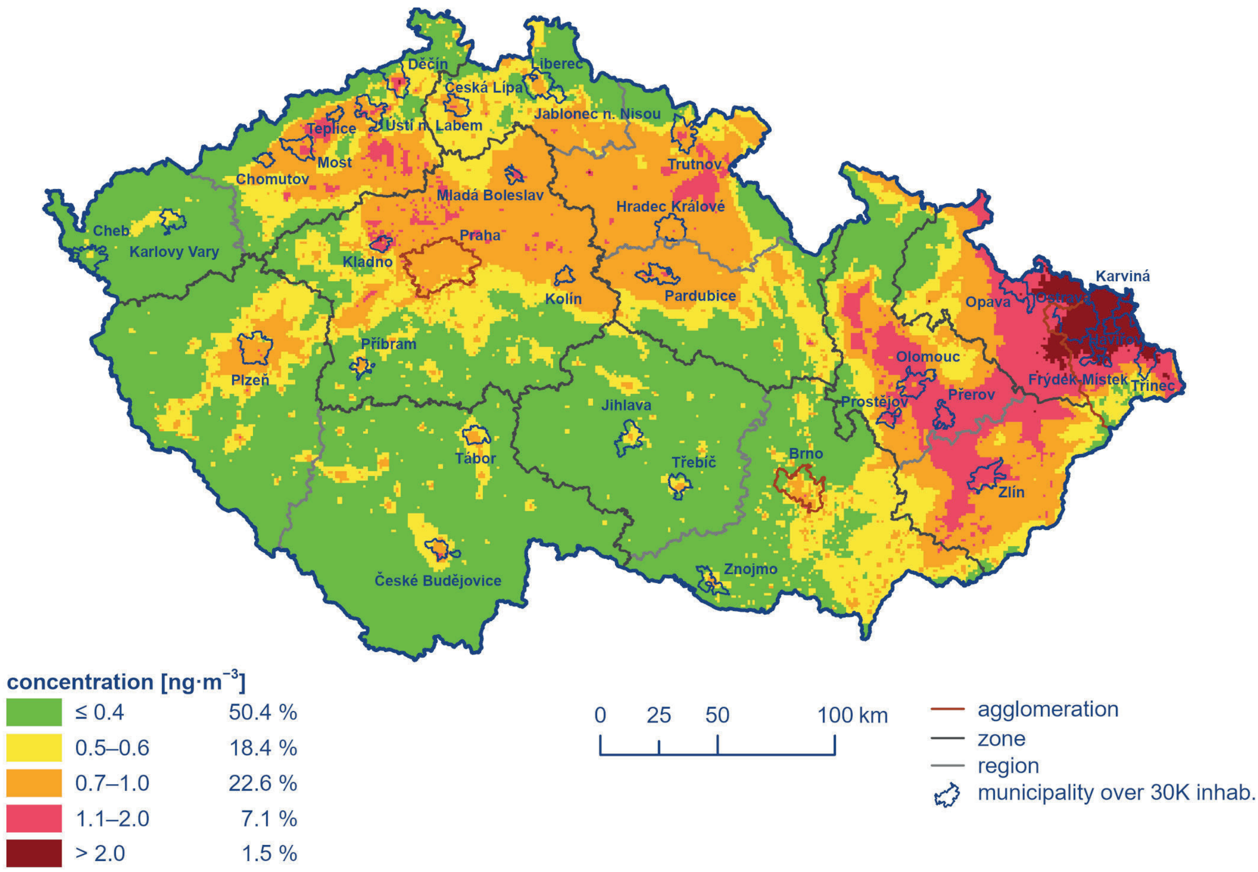

Fig. IV.2.3 Five-year average of annual average concentrations of benzo[*a*]pyrene, 2017–2021

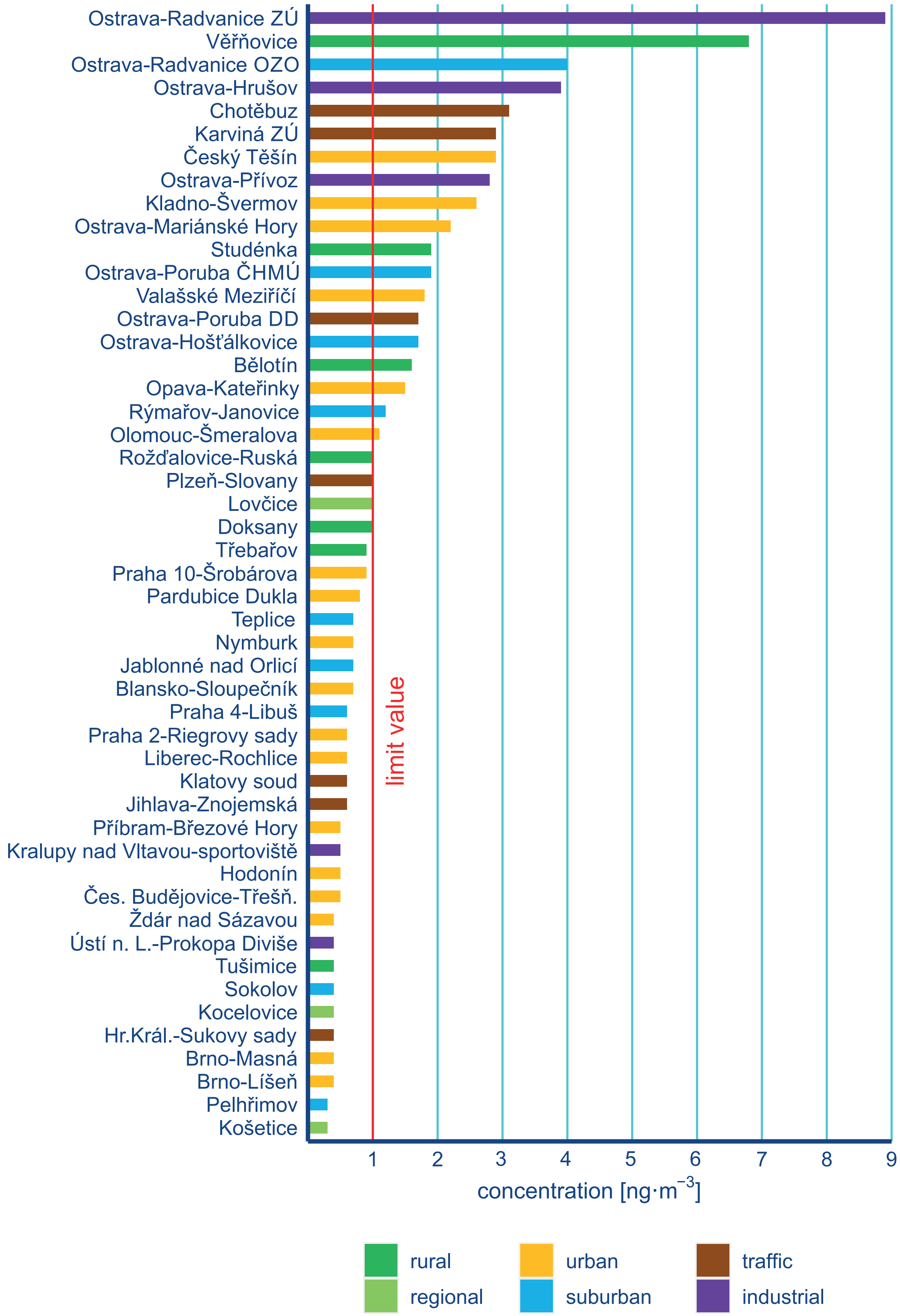

Fig. IV.2.4 Annual average concentrations of benzo[a]pyrene at monitoring stations, 2021

of the Olše River, is manifested. Benzo[*a*]pyrene-air pollution here comes from local household heating with coal (two-thirds to three-quarters of the average annual concentration) and biomass (less than 20 % of the average annual concentration). Above-limit values of benzo[*a*]pyrene were also measured at stations with the lowest concentrations of benzo[*a*]pyrene in the O/K/F-M agglomeration (Ostrava-Hošťálkovice and Ostrava-Poruba DD with 1.7 and 1.6 ng·m^{-3}, respectively). Benzo[*a*]pyrene concentrations exceeding the pollution limit were measured at all stations monitoring benzo[*a*]pyrene in the Moravian-Silesia, Olomouc and Zlín regions. Apart from the most burdened area in Moravia, higher concentrations of benzo[*a*]pyrene are recorded every year in the Kladno area (Kladno-Švermov station with 2.6 ng·m^{-3}), in connection with the dense development of family houses with local heating in the vicinity of the measuring station. Above-limit values can also be expected in other municipalities with a higher proportion of household heating with solid fuels where benzo[*a*]pyrene is not routinely measured. On the contrary, low annual average concentrations of benzo[*a*]pyrene were observed in the South Moravia and Vysočina regions. Conversely, low annual average concentrations of benzo[*a*]pyrene were found in the Brno agglomeration and in the South Bohemia, Karlovy Vary, and Vysočina regions. Below-limit values of benzo[*a*]pyrene concentrations are also observed in large cities (Prague, Brno, Plzeň), i.e., in cities with a high proportion of remote central heating. The lowest average annual concentration of benzo[*a*]pyrene (0.3 ng·m^{-3}) was observed at the Košetice regional station, which monitors background concentrations of polluting substances in the CR. Regional localities are not directly affected by local emission sources, but are only affected by the long-range transport

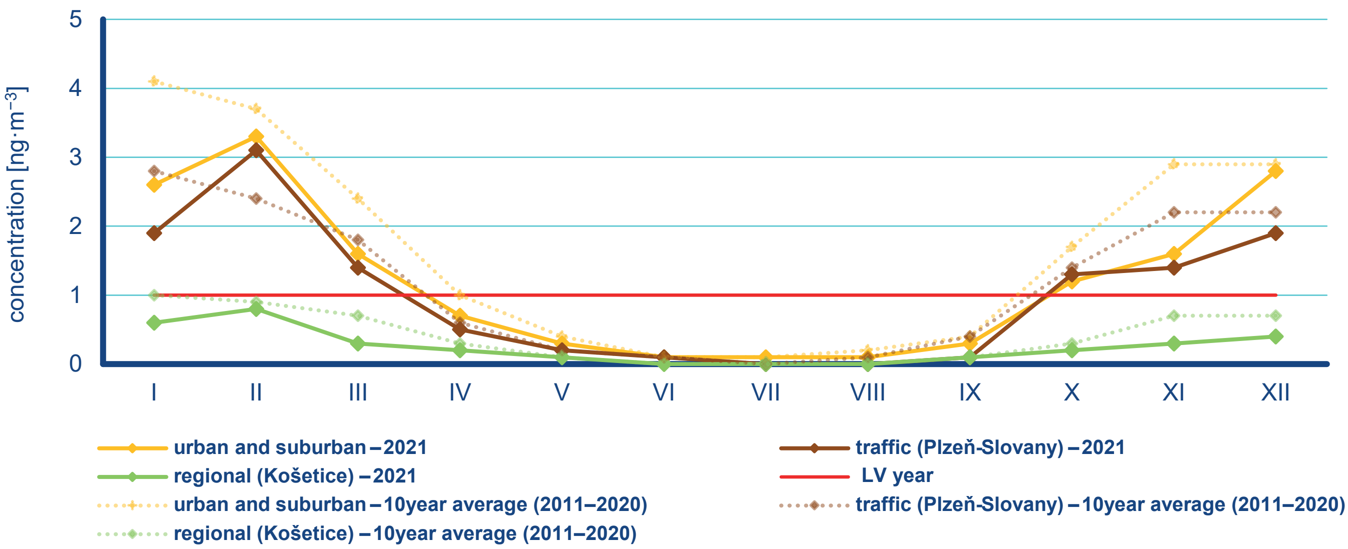

Fig. IV.2.5 Annual course of average monthly concentrations of benzo[*a*]pyrene (averages for a given type of station), 2021

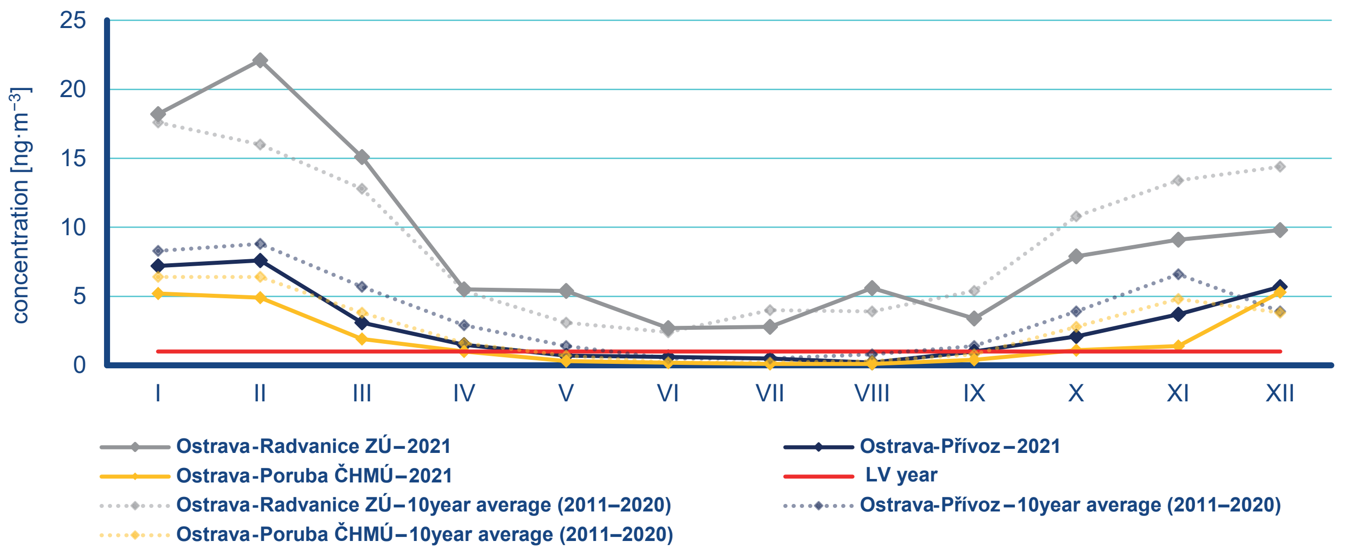

Fig. IV.2.6 Annual course of average monthly concentrations of benzo[*a*]pyrene at Ostrava-Radvanice, Ostrava-Přívoz and Ostrava-Poruba CHMI

of pollutants in combination with meteorological and dispersion conditions. Low concentrations of benzo[*a*]pyrene can therefore be expected also in places away from the direct impact of emission sources and in well-ventilated localities (e.g., natural mountain areas).

Benzo[*a*]pyrene concentrations exhibit a distinct annual variation with maxima in winter (Fig. IV.2.5, Fig. IV.2.6). The reason for the high concentrations of benzo[*a*]pyrene in the cold part of the year are emissions from seasonal anthropogenic sources — local heating units, additionally worsened by adverse meteorological conditions in this period. The annual variation of monthly benzo[*a*]pyrene concentrations clearly reflects the effect of emissions from local heating, with a rate (or intensity) influenced by the number of heating days during the heating season, which determines fuel consumption. In summer, concentrations decrease due to improved dispersion conditions, increased chemical and photochemical decomposition of PAHs at higher levels of solar radiation and high temperatures, and naturally mainly due to rapid decrease of emissions from anthropogenic sources (Li et al. 2009; Ludykar et al. 1999; Teixeira et al. 2012). In 2021, the highest monthly average benzo[*a*]pyrene concentrations at urban and suburban sites were recorded in connection with worsened dispersion conditions in February and December, when, in addition, the values were close to those of the ten-year average (2011–2020), and at some stations with a long series of measurements, they were even higher. On the contrary, significantly lower concentrations of benzo[*a*]pyrene compared to the ten-year average 2011–2020 at urban and suburban background stations were found in January and November (almost by 1.6 ng·m^{-3}, i.e., by 38 % and 1.3 ng·m^{-3}, i.e., by 44 %). The annual variation of monthly benzo[*a*]pyrene concentrations at the Košetice regional station is similar to that at suburban and urban stations, but with significantly lower values of benzo[*a*]pyrene concentrations.

Fig. IV.2.6 shows the annual variation at the Ostrava-Přívoz and Ostrava-Radvanice ZÚ industrial stations, where in addition to the cross-border transmission of pollution typical for the entire Ostrava-Karviná area, there is an enormous emission load from a combination of sources from local heating and industry. For comparison, the graph also shows data from the Ostrava-Poruba CHMI background urban station, which monitors the level of background concentrations in the city of Ostrava. At the Ostrava-Přívoz station, the monthly concentrations of benzo[*a*]pyrene were lower in all months, except for June and December, compared to the long-term average of 2011–2020. Compared to the CHMI city background station Ostrava-Poruba, the values at the Ostrava-Přívoz station are slightly higher, however, the annual variation is similar for both stations. Monthly concentrations of benzo[*a*]pyrene at the Ostrava-Radvanice ZÚ industrial station are several times higher than at the Ostrava-Přívoz and Ostrava-Poruba CHMI stations, with a slightly different annual variation. Compared to the long-term average 2011–2020, the concentrations of benzo[*a*]pyrene at the Ostrava-Radvanice ZÚ station fluctuate. The largest decrease in benzo[*a*]pyrene concentrations compared to the long-term average 2011–2020 at the Ostrava-Radvanice ZÚ station was recorded in December (4.6 ng·m^{-3}, 32 % lower) and in November (4.2 ng·m^{-3}, 32 % lower). On the contrary, the largest increase in concentrations was recorded in February (by 6.1 ng·m^{-3}, 38 % higher) and in May (by 2.3 ng·m^{-3}, 73 % higher). Concentrations above 1 ng·m^{-3} occur at industrial stations in the O/K/F-M agglomeration throughout the year, including the summer months, which demonstrates the year-round impact of emissions from industry in the localities. In December, as in the previous year, higher average concentrations of benzo[*a*]pyrene were recorded at the Ostrava-Poruba and Ostrava-Přívoz stations in comparison to the long-term average 2011–2020. Worsened dispersion and meteorological conditions at the end of the year contributed to the increased concentrations of benzo[*a*]pyrene in December, when the only smog situation was announced in 2021.

It must be borne in mind that the estimates of annual average benzo[*a*]pyrene concentrations (Fig. IV.2.2) is accompanied by considerably greater uncertainties than for the other evaluated substances. The uncertainty in the map is due in part to the limited number of measurements at rural regional stations and the absence of more extensive measurements in smaller settlements in the CR, where the effect of local heating units on air pollution by benzo[*a*]pyrene would be demonstrated. The CHMI is therefore using the so-called system of rotating stations, which makes it possible to monitor more locations over a period of several years. The assessment of the year-on-year change in the extent of the territory affected and population exposed to above-limit concentrations of benzo[*a*]pyrene is also accompanied by greater uncertainty. The number of stations with measurements of benzo[*a*]pyrene is limited particularly by the high costs of laboratory analyses and the capacity of laboratories for processing benzo[*a*]pyrene samples. The uncertainties in the maps are described in detail in Annex I.

IV.2.2 Trends in benzo[*a*]pyrene concentrations

Benzo[*a*]pyrene concentrations at individual types of stations and on average for all stations is evaluated for the period of the last 11 years, i.e., 2011–2021 (Fig. IV.2.7). The value of the annual average concentration of benzo[*a*]pyrene with a set pollution limit is significantly affected at all stations, except for the industrial stations in the O/K/F-M agglomeration, by the concentration levels during months of the cold season in the year, since in summer months, the concentrations of benzo[*a*]pyrene are minimal. In the evaluated period, the highest annual concentrations of benzo[*a*]pyrene were recorded in 2012, associated with the repeated occurrence of poor meteorological and dispersion conditions in the cold season of the year. From 2012 to 2016, it is possible to observe a gradual decrease or stagnation of benzo[*a*]pyrene concentrations. The slight increase in benzo[*a*]pyrene concentrations in 2017 was associated with poor dispersion conditions in the cold part of the year. Between 2018 and 2020, benzo[*a*]pyrene concentrations decreased again. After an excellent year 2020 from the point of view of air quality, BaP concentrations were slightly higher in 2021, however, BaP concentrations in 2021 were about 20 % lower on average (0.4 ng·m^{-3}), compared to the ten-year average 2011–2020. The annual concentration of benzo[*a*]pyrene averaged over all stations in 2021 was the second lowest in the evaluated period.

The average annual concentrations of benzo[*a*]pyrene at stations have been fluctuating during the evaluated period, with a decline seen in areas of the highest air pollution load (the O/K/F-M agglomeration and the Kladno area) (Fig. IV.2.8). Inter-annual variability is mainly affected by meteorological conditions in the cold part of the year. In the year-on-year comparison of 2020/2021, benzo[*a*]pyrene concentrations increased at more than half of the stations (i.e., at 28 of the total 38 stations) with data available for both years compared. The most significant decrease was recorded at the Ostrava Radvanice ZÚ industrial station, namely by 1 ng·m^{-3} (13 %). However, concentrations of benzo[*a*]pyrene

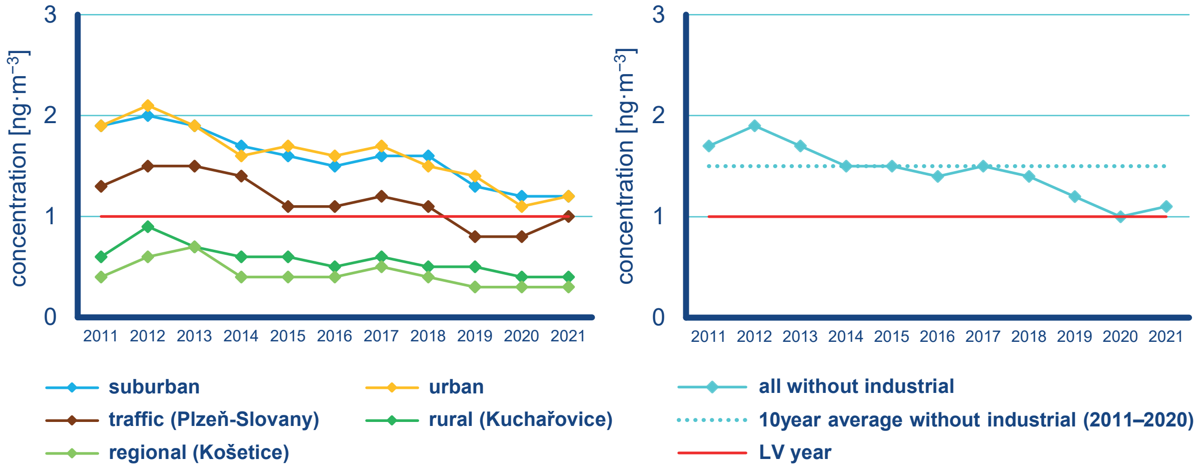

Fig. IV.2.7 Annual average concentration of benzo[*a*]pyrene at particular types of stations, 2011–2021

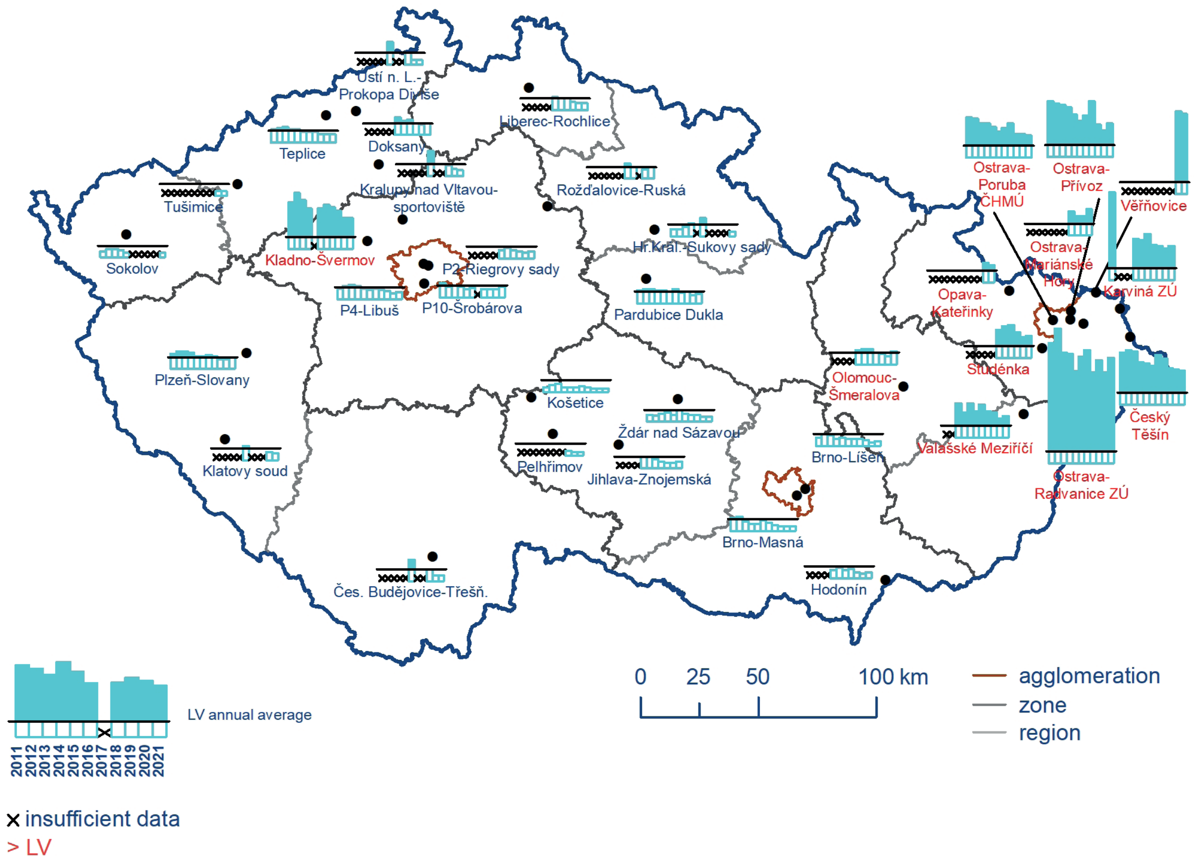

Fig. IV.2.8 Annual average concentration of benzo[*a*]pyrene at selected stations, 2011–2021

there still exceed the limit value by almost seven times. There was no increase in the annual average concentration of benzo[*a*]pyrene at any station in 2020. The highest year-on-year increase was recorded at the stations of Ostrava-Radvanice ZÚ (by 1.2 ng·m^{-3}) and Ostrava-Hrušov (by 1.1 ng·m^{-3}), both downwind of industrial sources of benzo[*a*]pyrene pollution in Ostrava.

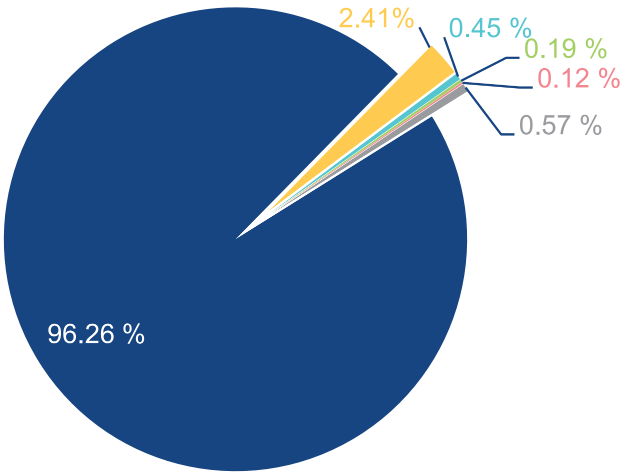

Fig. IV.2.9 Share of NFR sectors in total benzo[*a*]pyrene emissions, 2020

In assessing benzo[*a*]pyrene, there was a slight year-on-year increase in the annual average concentrations and the annual pollution limit was exceeded in many areas of the CR. In a number of cities and municipalities, in connection with local heating, benzo[*a*]pyrene concentrations above the limit are still found. However, compared to the long-term ten-year average 2011–2020, the measured concentrations of benzo[*a*]pyrene in 2021 were lower. In particular, less frequent occurrence of adverse conditions in January and November compared to ten-year values, as well as decreasing fuel consumption due to rising temperatures in the winter months in recent years, contributed to the improvement. Measures implemented to improve air quality, especially the renovation of boilers in households, have also contributed to the decrease in benzo[*a*]pyrene concentrations (Novák and Plachá eds. 2021).

IV.2.3 Emissions of benzo[*a*]pyrene

PAH emissions, of which benzo[*a*]pyrene in particular is monitored in view of air quality, are produced almost exclusively by combustion processes during which the organic combustible substances present are not sufficiently oxidised. Benzo[*a*]pyrene is a product of incomplete combustion at temperatures of 300 to 600 °C. Thus, one of its most important sources is the combustion of solid fuels in low-capacity boilers, particularly household heating units (sector 1A4bi – Residential: Heating, water heating, cooking, Fig. IV.2.9). The next significant source is the burning of plant waste (NFR 5C2), which accounts for 2.4 % of total emissions in 2020. The influence of traffic is mainly observed along

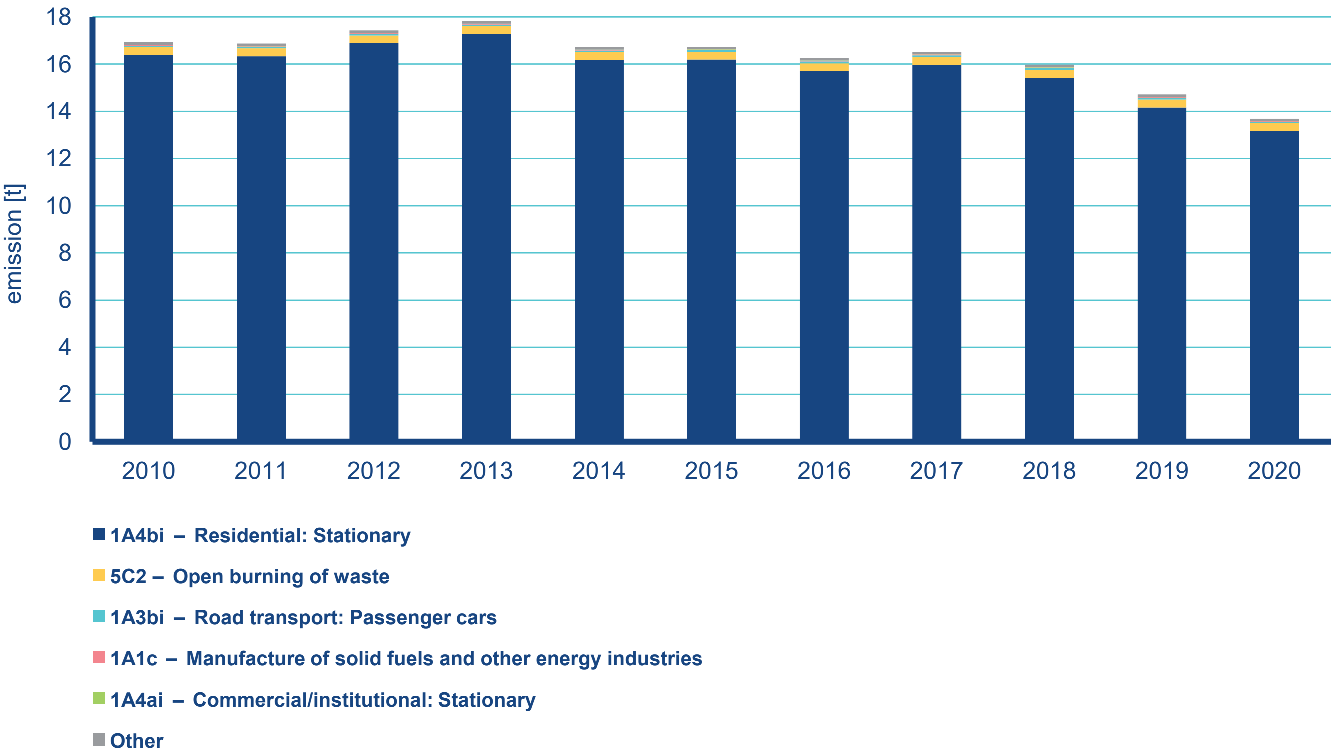

Fig. IV.2.10 Benzo[*a*]pyrene total emissions, 2010–2020

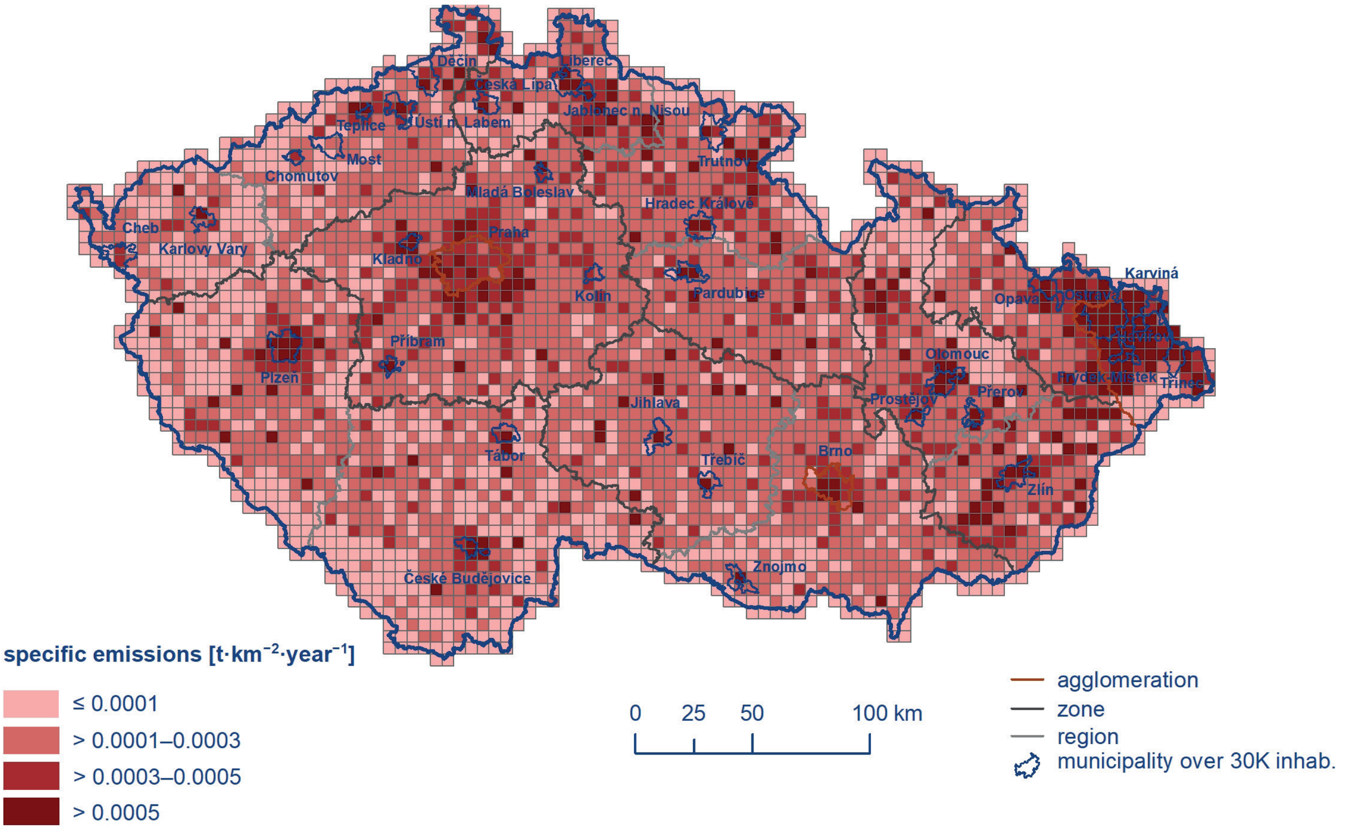

Fig. IV.2.11 Total benzo[*a*]pyrene emissions in 5×5 km spatial resolution squares, 2020

motorways, roads with intensive traffic and in the territory of large urban units. Benzo[*a*]pyrene emissions from industrial sources, especially from coal coke production, do not represent a significant proportion in total emissions, but on a local scale, even with regard to year-round operation, they can fundamentally affect air quality. The trend in total emissions in the period 2010–2020 (Fig. IV.2.10) is mainly related to the consumption of solid fuels in households, which depends on specific temperature conditions. The replacement of older boilers, the transition to natural gas or to non-emission sources, especially heat pumps, have also contributed to the reduction of emissions in recent years.

In view of predominant contribution of the sector 1A4bi, emissions of benzo[*a*]pyrene are distributed over the territory of residential buildings throughout the CR (Fig. IV.2.11). The O/K/F-M agglomeration is burdened most with emissions of benzo[*a*]pyrene. The reason is primarily the high population density, the higher proportion of coal burning in households in combustion-type boilers, as well as the metallurgical industry and coke production in the CR.