Air pollution in the Czech Republic in 2019

Czech Hydrometeorological Institute

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Air Quality Division

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ACKNOWLEDGEMENT

SUMMARY

Ambient air pollution by benzo[*a*]pyrene, suspended particulates in the PM_{10} and $PM_{2.5}$ fractions, and ground-level ozone is a major problem for air quality in the Czech Republic. Most air pollution characteristics exhibit a decreasing course in the evaluation period 2009–2019 (Fig. 1). Nonetheless, the concentrations of these pollutants, which have serious consequences for human health, have exceeded the pollution limit values every year at a number of locations of the Czech Republic (Fig. 2).

The air pollution levels in a particular year depend on the amounts of emissions and the prevailing meteorological and dispersion conditions. **In 2019, the lowest air pollution concentrations of air pollutants were observed within the evaluation period 2009–2019** (except for ground-level ozone, benzene and cadmium). **The decrease in the concentration of air pollutants in 2019 can be attributed to a combination of factors.**

The year 2019 was extremely above-normal in terms of temperature and normal in terms of precipitation. Due to the occurrence of extremely above-normal temperature conditions, a lower number of heating days was also recorded in winter months of 2019. In addition, in 2019, compared to the ten-year average, there were improved dispersion conditions. These factors lead to lower emissions from heating and better diffusion of emissions from various sources. At the end of the year — in November and December — usual poor dispersion conditions did not occur in comparison with other years.

The preliminary emission assessment for 2019 indicates further reductions for all major pollutants (SPM, SO_2, NO_X, CO, VOC and NH_3). **The REZZO 1-2 sources contributed the most to the decrease in emissions of SO_2, NO_X (including precursors of suspended particles among other substances) and CO. The decrease in air pollution concentrations can also be attributed to the measures implemented to improve air quality, i.e. the replacement of boilers, the continuing renewal of the vehicle fleet and technical implementations in reducing emissions from the listed sources. Despite a slight increase in the number of degree days in the heating period of 2019 compared to 2018 (by about 4%), the estimate of emissions from fuel consumption in households demonstrates that the modernization of the composition of combustion equipment in households due to legislative measures affected the amount of emissions.**

There are significant regional differences in air quality within the Czech Republic. **The most loaded regions in terms of air quality have long been the Ostrava/Karviná/Frýdek-Místek agglomeration (O/K/F-M) and the Moravian-Silesia and Central Moravia zones.** Regions with deteriorated air quality include the agglomerations of Prague and Brno and the Central Bohemia, Northeast and Northwest zones. On the contrary, in the Southwest and Southeast zones, air pollution limits are only exceeded in very small areas (Chapter VII). In 2019, there was the most significant reduction of the area with above-limit concentrations in relation to a decrease in the concentrations of benzo[*a*]pyrene and suspended PM_{10} particles in the agglomerations of Prague and Brno and in the Central Moravia zone.
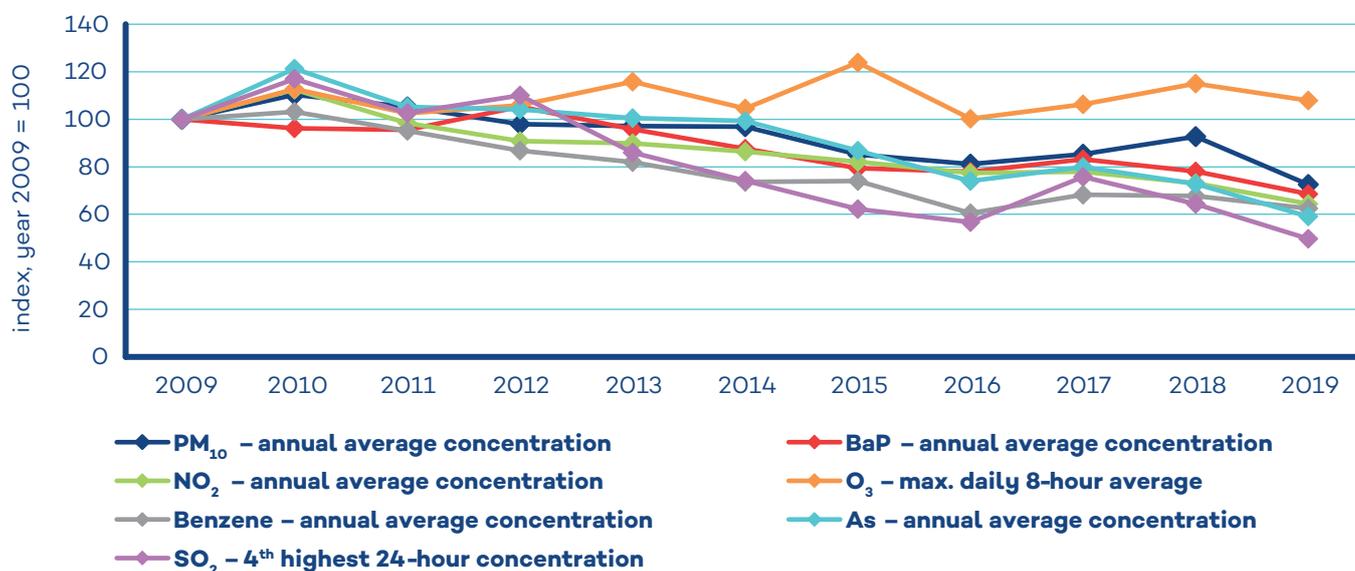
Fig. 1 Selected air pollutants characteristics, 2009–2019
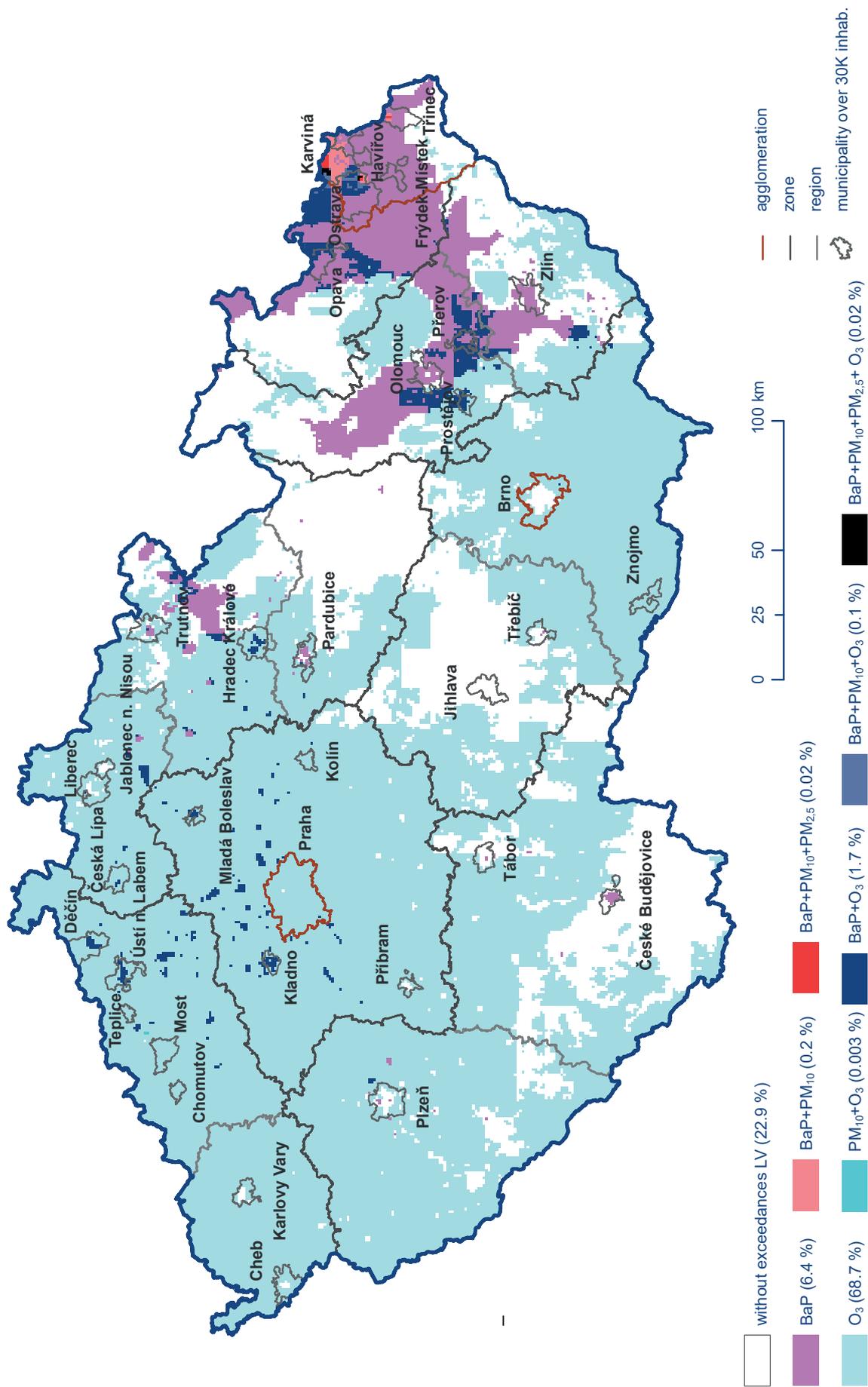
Fig. 2 Areas with exceeding of the health protection limit values for selected groups of pollutants, 2019

without exceedances LV (22.9 %)

BaP (6.4 %)

O₃ (68.7 %)

BaP+PM₁₀ (0.2 %)

PM₁₀+O₃ (0.003 %)

BaP+PM₁₀+PM₂.₅ (0.02 %)

BaP+O₃ (1.7 %)

BaP+PM₁₀+O₃ (0.1 %)

BaP+PM₁₀+PM₂.₅+ O₃ (0.02 %)

agglomeration

zone

region

municipality over 30K inhab.

0   25   50   100 km

The high concentrations of pollutants **in the O/K/F-M agglomeration** are caused not only by the Czech sources but also by transfer of emissions from Poland. Industrial production is highly concentrated on both sides of the border with a high density of built-up areas with local solid-fuel heating and a well-developed transportation infrastructure (Chap. V.3). **In the Prague and Brno agglomerations,** the most problematic are the high concentrations of suspended particulate matter and nitrogen dioxide at localities loaded by heavy traffic. The REZZO 3 (predominantly local heating of households) and REZZO 4 categories of sources contribute the most to SPM emissions, while the most important contributor to NO_X emissions is the REZZO 4 category (Chap. V.1 and Chap. V.2). Resuspension of particulate matter and soil erosion, not included in emission inventories, and locally also construction activities also play a significant role in the air pollution load by suspended particles.

Deteriorated air quality is a problem not only in agglomerations and larger cities, but also in small settlements where local heating makes a considerable contribution to air pollution by suspended particulates and benzo[a]pyrene. It can be assumed that increased to above-limit concentrations may also occur in municipalities where these pollutants are not measured as indicated by, for example, campaign measurements in eight small settlements of the Czech Republic[1] or measurement of benzo[a]pyrene concentrations at various stations subsidized from the budget of the Moravian-Silesia region[2] (Chap. IV.2).

A substantial part of the Czech Republic is exposed to above-limit concentrations of ground-level ozone every year. Generally, because of the chemistry of ozone formation, these areas are not the most densely populated ones like for benzo[a]pyrene and suspended particulates PM_{10} and $PM_{2.5}$. However, due to the size of the area, a significant part of the population of the Czech Republic is also exposed to the above-limit ozone concentrations.

Air quality in the Czech Republic in 2019 in relation to the pollution limit values for protection of human health

In 2019, areas with exceeded pollution limit levels, excluding ozone, covered approx. 8.4% of the territory of the Czech Republic inhabited by approx. 27.5% of the population. These areas were delimited because of exceeding the pollution limit values for benzo[a]pyrene and suspended particulates PM_{10} and $PM_{2.5}$. **Areas exceeding pollution limit values, including ground-level ozone, covered, in 2019, approx. 77.1% of the territory of the Czech Republic inhabited by approx. 75.6% of the population** (Chap. VII).

The daily pollution limit value for suspended particulates PM_{10} was exceeded at 0.3% of the territory of the Czech Republic inhabited by approx. 0.9% of the population. The annual pollution limit value for PM_{10} was not exceeded at any

station in the Czech Republic in 2019, for the first time in the evaluated period 2009–2019. **The annual pollution limit value for suspended particulates $PM_{2.5}$ was exceeded at 0.04% of the territory of the Czech Republic inhabited by approx. 0.1% of the population.** In 2019, above-limit concentrations of suspended particulates were observed in the O/K/F-M agglomeration, in the Moravian-Silesia region without the O/K/F-M agglomeration, and in the Ústí nad Labem and Central Bohemia regions. During the evaluated period, a gradual decrease was observed in the concentration of PM_{10} and $PM_{2.5}$ until 2016, including, a slight increase in 2017 and 2018, and a significant decrease in 2019 reaching the minima for the evaluated period 2009–2019.

Similar to previous years, **the pollution limit value for benzo[a]pyrene was exceeded in a number of cities and municipalities (8.4% of the area of the Czech Republic inhabited by approx. 27.5% of the population).** Estimation of fields of annual average concentrations of benzo[a]pyrene is affected by the greatest uncertainties of all the monitored substances resulting not only from insufficient density of measurements, especially at rural regional stations and in small settlements in the Czech Republic. From the viewpoint of pollution by benzo[a]pyrene, the air quality in small settlements is substantially affected by local heating units (Chap. IV.2). In the longer term, a modest slightly decreasing trend can be observed for benzo[a]pyrene concentrations between 2010 and 2016, with subsequent slight increase in 2017 and 2018 and a decrease in 2019. The annual average concentrations of benzo[a]pyrene at all types of stations were the lowest in 2019 within the evaluated period 2009–2019, however, above limit concentrations still remain in many cities.

The annual pollution limit value for nitrogen dioxide was exceeded in 2019 at a single station, namely the Prague 2-Legerova traffic hot spot. However, it can be assumed that the limit was also exceeded at other sites with high traffic load where measurements are not performed. The hourly pollution limit value was not exceeded for NO_2 (Chap. IV.3). In the longer term, NO_2 concentrations are slowly decreasing, and the lowest NO_2 concentrations for the entire evaluated period 2009–2019 were recorded in 2019.

The pollution limit value for ground-level ozone was exceeded at 70.5% of the territory of the Czech Republic inhabited by approx. 56.9% of the population (average for 2017–2019; Chap. IV.4). The cause is represented by favourable meteorological conditions for the formation of ground-level ozone (a year with highly above-normal temperature, occurrence of subnormal amount of precipitation in June and July) which led to increase of concentrations and more frequent exceeding the O_3 pollution limit value in 2019. O_3 concentrations do not show a significant course and their level in individual years depends mainly on the meteorological conditions of the given year; the highest concentrations were measured in 2013, 2015 and 2018. All these years are characterized by the occurrence of favourable meteorological conditions for the ozone formation.

The **pollution limit values for benzene, heavy metals, sulphur dioxide and carbon monoxide** were not exceeded in 2019 (Chap. IV.5, IV.6, IV.7 and IV.8).

Air quality in the Czech Republic in 2019 in relation to the pollution limit values for protection of ecosystems and vegetation

The limit value of O_3 for the protection of vegetation (AOT40 exposure index) was exceeded at 25 stations out of a total of 39 rural and suburban stations. At the same time, the area of the territory with the occurrence of above-limit AOT40 values increased. An increase in the AOT40 exposure index for 2019 compared to 2018 was observed at a majority of 32 stations evaluated in both periods.

The pollution limit values for sulphur dioxide and nitrogen oxides for protection of ecosystems and vegetation were not exceeded at any rural location where measurements were performed.

Exceeding the upper assessment limit (UAT) of the annual average concentration of SO_2 occurred in 2019 only in small areas of the Moravian-Silesia region. In this region and in the Ústí nad Labem region, the UAT of the average concentration for the winter period 2019/2020 was exceeded in a small area. In the Moravian-Silesia region, the limit value for annual and winter average concentrations was exceeded, but only in the cities of Ostrava and Třinec. This exceeding is based on a model calculation when constructing the map. Above-limit concentrations of NO_X occur mainly in the vicinity of roadways; the results of model evaluation indicate that for the most valuable natural areas of the Czech Republic the pollution limit value for NO_X was exceeded over only a very small area of three protected landscape areas (Chap. IV.3 and VII.2).

Smog warning and regulation system

In 2019, a total of 5 smog situations and 2 regulations due to elevated PM_{10} concentration were announced lasting overall 385 hours (or 162 hours for regulations). All smog situations and regulations occurred in January, in 5 of the 16 SWRS regions. Regulations were announced on the territory of the O/K/F-M agglomeration without the Třinec area and in the Třinec area. Only smog situations were announced in the Moravian-Silesia zone, and in the Zlín and Olomouc regions.

6 smog situations were also announced in 2019 due to high ground-level ozone concentrations lasting overall 90 hours. Smog situations were announced particularly in the third decade of June 2019 (5 situations) and in the Ústí nad Labem region also at the end of July. No alert has been issued in any SWRS area.

Emissions of pollutants

The year-on-year comparison of the production of emissions of the main pollutants in 2018 and 2019 confirms the expected reduction of emissions from energy and industrial sources. Preliminary data on emissions from transport indicate that there were no significant changes compared to 2018. **The model assessment of emissions from the use of fuels in households reflects a positive effect of boiler replacement determined from sales statistics and information on subsidies provided for boiler modernization or changes in the technique of heating. The decrease in emissions from household heating** took place for all pollutants except for SO_2 (a slight increase in the average sulphur content of brown coal) and NH_3 (an increase in the share of biomass).

The sector of **local household heating** continued in 2018 to make a significant contribution to pollution of the ambient air, specifically in emissions of **PM_{10} by 58%, $PM_{2.5}$ by 74%, carbon monoxide by 67%, VOCs by 43%, arsenic by 37%, cadmium by 44% and benzo[*a*]pyrene by 98.8%. A significant contribution by the public energy and heat production sector predominated in emissions of sulphur dioxide (20%) and nickel (11%). Sectors of road freight transport, passenger cars, off-road vehicles and other machinery, for example in agriculture and forestry**, contributed most in emissions of **nitrogen oxide (59%).**

Atmospheric deposition

The year 2019 was normal in terms of precipitation in the Czech Republic. The average annual precipitation of 634 mm represents 92% of the long-term normal 1981–2010.

The total deposition of sulphur in 2019 reached 33,032 tonnes over the area of the Czech Republic, compared to the value of 34,581 tonnes of the total deposition in 2018. The highest values were reached in the Krušné hory and the Ostrava area. Partial components of sulphur deposition also reached lower values.

The total nitrogen deposition on the area of the Czech Republic reached 54,749 tonnes in 2019, compared to 2018, when the total deposition was 57,674 tonnes. The highest values were reached in the Jeseníky, Moravian-Silesian Beskydy, Orlické hory, Šumava and Novohradské hory areas. Partial components of nitrogen deposition also reached lower values except for wet deposition of reduced forms and total wet nitrogen deposition.

The total deposition of hydrogen ions on the area of the Czech Republic was equal to 2,535 tonnes in 2019. Compared to 2018 (2,805 tonnes), this is a slight decrease. The deposition of hydrogen ions in the Šumava, Krušné hory, Jizerské hory, Orlické hory, Hrubý Jeseník and Moravian-Silesian Beskydy areas reached the highest values. A slight decrease has also been recorded for the dry component of hydrogen deposition, while the wet component was comparable to 2018.

Wet and dry deposition of lead in 2019 was lower compared to 2018. The highest values were attained in mountain areas and in the Ostrava area.

Wet deposition of cadmium increased in 2019, in the opposite, dry deposition of cadmium was lower compared to 2018. Similar to previous years, the highest values were attained in the Jablonec nad Nisou district.

I. INTRODUCTION

Polluted air has a demonstrable detrimental impact on human health and pollutants can cause a wide range of health problems from less serious to grave diseases and demonstrably increase the burden on the immune system, which can lead to premature mortality. It also has significant economic impacts as healthcare costs increase and productivity decreases in all sectors of the economy due to increased incapacity for work. Pollutants negatively affect vegetation, can influence its growth and result in decreased yields of agricultural crops and forests. In addition, they lead to eutrophication and acidification of soils and aquatic ecosystems[1] and subsequently to changes in species diversity and a reduction in the number of plant and animal species. Many pollutants accumulate in the environment, with a detrimental impact on ecosystems, and enter into the food chain. In addition, some of them directly or indirectly affect the climate system of the Earth. The damage caused by atmospheric pollutants to materials and

Legend:
- national borders
- zone
- agglomeration

Symbol	Label
■	CHMI
●	CHMI+Moravian-Silesian Region
+	ZÚ+ City Ostrava
✕	ZÚ Ústí n.L.
✚	ZÚ Ostrava
⊕	ZÚ+Moravian-Silesian Region
⊕	ZÚ+City Havířov
✹	ZÚ Ústí n.L./SZÚ
◇	City Plzeň
◆	City Otrokovice
◆	City Zlín
◆	City Šumperk
◆	City Štětí
◆	City Hranice
▲	City Brno
▲	City Třinec
⬠	Municipality Loštice
⬠	Municipality Nošovice
+	Letiště Praha a.s.
M	Severní energetická, a.s
▲	ÚVGZ AV ČR, v.v.i.
S	Středočeský kraj
◣	Českomoravský cement a.s
◉	HEL Cheb
▣	Vápenka Čertovy schody, a.s
◗	ČEZ, a.s.
❚	LfULG Germany
❚	GIOS Poland

Fig. I.1 Major station networks of ambient air quality monitoring, 2019

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1   Eutrophication is a process of enrichment in nitrogen and phosphorus, while acidification leads to increased acidity.

buildings, which are frequently historically important, must also be mentioned. Limiting the effects of these impacts also incurs economic costs related not only to the remediation of damage, but also to research focused on the quantification of pollution and related externalities.

Despite a number of measures implemented in the past years, particular sources produce an amount of emissions that can, in combination with meteorological and dispersion conditions, lead to exceeding the pollution limit levels for some substances. At the present time, of the monitored pollutants, the greatest problems are caused by suspended particulate matter and polycyclic aro-

matic hydrocarbons bound to them. In the spring and summer, the pollution limit levels for ground-level ozone are exceeded at a number of locations.

However, the specific contributions of the individual sources to ambient air pollution differ in various regions depending on the composition of sources at the given location and also on transfer of pollutants from other areas. The level of air pollution is objectively determined by means of a network of measuring stations that monitor the concentrations of pollutants of the ambient air (air pollution) in the ground layer of the atmosphere (Fig. I.1). Based on the mandate by the Ministry of the Environment, the Czech Hydrome-

Tab. I.1 Limit values (LV) and permitted number of instances exceeding the limit value, upper and lower assessment thresholds according to the Act No. 201/2012 Coll. on the air protection, as amended, and Decree No. 330/2012 Coll., on the method of assessing and evaluating the level of pollution, the scope of informing the public about the level of ambient air pollution and during smog situations

Pollutant	Averaging interval	Assessment threshold [$\mu g.m^{-3}$]		Limit value [$\mu g.m^{-3}$] LV
		Lower assessment threshold	Upper assessment threshold	
SO_2	1 hour	—	—	350 max. 24/year
	24 hours	50 max. 3x/year	75 max. 3x/year	125 max. 3x/year
NO_2	1 hour	100 max. 18x/year	140 max. 18x/year	200 max. 18x/year
	calendar year	26	32	40
CO	max. daily 8-hour running average	5 000	7 000	10 000
benzene	calendar year	2	3.5	5
PM_{10}	24 hours	25 max. 35x/year	35 max. 35x/year	50 max. 35x/year
	calendar year	20	28	40
$PM_{2.5}$	calendar year	12	17	25
Pb	calendar year	0.25	0.35	0.5
As	calendar year	0.0024	0.0036	0.006
Cd	calendar year	0.002	0.003	0.005
Ni	calendar year	0.010	0.014	0.020
benzo[a]pyrene	calendar year	0.0004	0.0006	0.001
O_3	max. daily 8-hour running average	—	—	120, 25x in 3-year average

Long-term objectives (LTO)

Pollutant	Application	Averaging interval	Long-term objective [$\mu g.m^{-3}$]
O_3	for the protection of human health	max. daily 8-hour running average	120

teorological Institute (CHMI) operates the State Air Quality Network in the Czech Republic, the Air Quality Information System (AQIS) of the Czech Republic and routinely processes the measured air pollution values in the form of tabular and graphical reviews.

Pollutants monitored and evaluated for demonstrably harmful effects on population health or vegetation and ecosystems have set limit values. In evaluating the air quality, the observed concentration levels are, in particular, compared with the respective air pollution limit values (Tab. I.1 and I.2), or with the permissible frequencies of these limits being exceeded, which are concentration levels that should not be exceeded under applicable legislation. Brief characteristics of pollutants, overview of their emission sources and their impacts are given in Tab. I.5.

The graphic yearbook contains twelve separate chapters and annexes. The summary and introductory chapter contains the most important information on air quality in a given year and general information on the issue. The next chapters contain detailed elaboration of individual topics related to emissions of polluting substances and greenhouse gases, i.e. production of pollutants and evaluation of the air quality, i.e. level of pollution.

Ambient air quality yearbooks are intended for authorities and organisations dealing with and managing issues related to the environment and air protection in the Czech Republic as well as to professional and wider public. The yearbooks are publicly available on the CHMI website. The publication is the basic information document on air quality in the Czech Republic. Its aim is to evaluate the air quality in a broader context based on available data and information.

I.1 Objectives of the publication

The "Air Pollution in the Czech Republic in 2019" yearbook, together with the electronically published "Summary Table Survey" data yearbook provide a comprehensive annual overview of information on the ambient air quality in the territory of the Czech Republic for the relevant year. The evaluation of air quality is based on the measured data collected within the AQIS using additional data sources and mathematical tools. The data yearbook presents verified measured pollution data and information on the chemical composition of atmospheric precipitation from the individual locations, including aggregated data, while the graphic yearbook provides a commented summary of information in a form of overview maps, graphs and tables.

I.2 Political and legislative framework of ambient air quality protection

The Thematic Strategy on Air Pollution (hereinafter the Strategy) is the basic EU strategic document in the area of assessing and managing ambient air quality. The objective of the Strategy, in accordance with the 6th Environment Action Programme, is to achieve "a level of ambient air quality which does not give rise to risks for human health and the environment and does not have

Tab. I.2 Limit values (LV) for the protection of ecosystems and vegetation according to the Act No. 201/2012 Coll., as amended

| Pollutant | Averaging interval | Assessment threshold | | Limit value [μg.m⁻³] LV |
		Lower assessment threshold	Upper assessment threshold	
SO_2	year and winter period (1. 10.–31. 3.)	8	12	20
NO_x	calendar year	19.5	24	30
O_3	AOT40, calculated from 1-hour values between May and July	—	—	[μg.m⁻³.h]
				18 000 average for 5 years

Note: AOT40 is the sum of differences between the hourly concentration higher than 80 μg·m⁻³ (= 40 ppb) and the value 80 μg·m⁻³ in the given period by using only hourly values measured every day between 8:00 and 20:00 CET.

Long-term objectives (LTO)

Pollutant	Application	Averaging interval	Long-term objective [μg.m⁻³.h]
O_3	for the protection of ecosystems and vegetation	AOT40, calculated from 1-hour values between May and July	**6 000**

Fig. I.2 The zones and agglomerations for ambient air quality assessment and evaluation of ambient air pollution level according to the Act No. 201/2012 Col/. on Clean Air Protection, as amended

markedly negative impacts on them". On the basis of the Strategy of 2005, the European Commission carried out a comprehensive review of current EU policy in the area of air protection. This resulted in the adoption of a package of measures (Clean Air Policy Package) in December 2013. The package contains, for example, the "Clean Air for Europe" programme document, outlining new objectives in ambient air quality for the period up to 2030 (EC 2013a).

Within the framework of the EU, the main tools for ambient air quality protection and improvement are Directive 2008/50/EC on ambient air quality and cleaner air for Europe, Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air, Directive 2016/2284/EU on the reduction of national emissions of certain atmospheric pollutants, and European Parliament and Council Directive No. 2010/75/EU on industrial emissions (integrated pollution prevention and control). Newly, EU Commission Decree 2015/1480 of 28 August 2015 amends several annexes to European Parliament and Council Directives 2004/107/ES and 2008/50/ES, which set the rules for reference methods, data verification and location of sampling sites for assessing ambient air quality.

Based on the requirement of the European Commission to prepare a coherent approach to air quality control in the Czech Republic, a Medium-Term Strategy (up to 2020) for improving air quality in the Czech Republic has been prepared. This conceptual document was approved in December 2015 and summarizes the outputs of the basic strategic documents for improving air quality – National Emission Reduction Programme of the Czech Republic and ten programmes for improving air quality (PZKO) elaborated for designated zones and agglomerations. Among other things, it acts as a basic document for financing measures for decreasing emissions and improving air quality from EU funds via operational programmes (MŽP 2015).

At the beginning of 2020, the Ministry of the Environment published an updated National Emission Reduction Program of the Czech Republic. The Czech Republic has been preparing this document continuously since 2004 and its main purpose is to ensure a reduction in the overall production of pollutants and the level of air pollution in the Czech Republic. The working group, of which CHMI was also an active participant, coordinated the meetings of working teams for individual sectors of interest – agriculture, transport, public energy and local household heating. In connection with the outcomes of these negotiations and analyti-

Tab. I.3 WHO Air Quality Guidelines for the protection of public health (WHO 2000, WHO 2005)

	Averaging interval	Guideline value
PM_{10}	calendar year	20 µg.m^{-3}
	24 hours	50 µg.m^{-3}
$PM_{2,5}$	calendar year	10 µg.m^{-3}
	24 hours	25 µg.m^{-3}
benzo[*a*]pyrene[a]		not recommended
NO_2	calendar year	40 µg.m^{-3}
	1 hour	200 µg.m^{-3}
O_3	max. daily 8-h running average	100 µg.m^{-3}
benzene[a]		not recommended
Pb	calendar year	0.5 µg.m^{-3}
Cd[a, b]		not recommended
As[a]		not recommended
Ni[a]		not recommended
SO_2	24 hours	20 µg.m^{-3}
	10 minutes	500 µg.m^{-3}
CO	1 hour	30 000 µg.m^{-3}
	8 hours	10 000 µg.m^{-3}

a) These are human carcinogens therefore no safe level of the substance can be established. The WHO guideline value is not established. More information on the risks of cancer occurrence see WHO (2000). The WHO only determines the unit risk value (UCR) for non-threshold active substances.

b) The recommended value of cadmium concentration in ambient air to prevent further increase of this element in agricultural soils is 0.005 µg.m^{-3}.

cal documents including emission and air pollution assessments of the situation since 2008, measures were proposed to reduce emissions of monitored pollutants. Measures according to their nature are divided into three groups, namely priority, support and cross-cutting measures. The responsible coordinator was designated for the implementation of individual measures. In the case of priority measures, in addition to the coordinator, the deadline for their fulfilment, the method of implementation and indicators for monitoring their implementation were also determined. The methods were also defined and the benefits of measures to reduce emissions below the level of emission ceilings set by the requirements of Directive 2016/2284/EU on the reduction of national emissions of certain pollutants were assessed (see Chapter II.).

The aim of air quality improvement programs is to set out measures to achieve the required air quality in the shortest possible time. PZKO set measures mainly at the regional and local level. Air quality improvement programs were issued by the Ministry of the Environment in 2016 for all zones and agglomerations of the Czech Republic. The Ministry of the Environment is currently preparing, in cooperation with CHMI, regions and municipalities, an update of air quality improvement programs for the 2020+ horizon.

The national legislation on air quality evaluation in the Czech Republic is based on the European legislation. The basic legislative norm in the CR is the Act No. 201/2012 Coll., on air protection, as amended (hereinafter the "Air Protection Act"), defining, among other things, the zones and agglomerations for which ambient air quality is being evaluated. A zone is a territory specified by the MoE for monitoring and managing the air quality; an agglomeration is a settlement area with at least 250 000 inhabitants. The Air Protection Act sets out three agglomerations and seven zones (Fig. I.2). Details are specified in Decree No. 330/2012 Coll., on the method of assessment and evaluation of ambient air pollution levels and on the extent of informing the public on the level of ambient air pollution and during smog situations.

This yearbook presents air quality evaluation in 2018 pursuant to the requirements of the Czech legislation on air quality protec-

tion. In accordance with the Air Protection Act, the evaluation is aimed at defining areas where the limit values for the protection of health and the protection of ecosystems and vegetation are exceeded (Tab. I.1 and I.2). Where a limit value is exceeded in a zone or agglomeration or if the limit value is exceeded in a zone or agglomeration multiple times and more than the permitted maximum number of instances, the Ministry of the Environment, in cooperation with the relevant regional or local authority, is obliged to develop a programme aimed to improve air quality in the given zone or agglomeration, which it must prepare within 18 months after the end of the calendar year. During the preparation of each programme to improve air quality, the MoE adopts measures to ensure that the pollution limit level is attained as soon as possible.

The pollution limit levels are based on the recommended (guideline) values set by the World Health Organization (WHO) based on a number of epidemiological studies or, in the case of substances without a set limit, from established carcinogenic risk values (Tab. I.3 and I.4). In the interests of protecting public health, WHO recommends maintaining pollutant concentrations at levels that are even lower than those at which negative effects on human health have been documented. Nonetheless, these values stem from conclusions regarding the impacts on health from ambient air pollution and do not take into account the aspects of technical and economic feasibility and further political and social factors. Consequently, the pollution limit levels set by the legislation may be higher, but the process heading towards meeting the WHO guideline values must be generally supported (WHO 2013).

Tab. I.4 WHO Air Quality Guidelines for the protection of vegetation (WHO 2000)

	Averaging interval	Vegetation category	Guideline value
NO_2	calendar year		30 $\mu g.m^{-3}$
	24 hours		75 $\mu g.m^{-3}$
SO_2	year and winter period	agricultural crops	30 $\mu g.m^{-3}$
	year and winter period	forests and natural vegetation	20 $\mu g.m^{-3}$
	calendar year	lichens	10 $\mu g.m^{-3}$
O_3	AOT40, calculated from 1-hour values between May and July	agricultural crops	6 000 $\mu g.m^{-3}$
	AOT40, calculated from 1-hour values between April and October	forests	20 000 $\mu g.m^{-3}$
	AOT40, calculated from 1-hour values between May and July	semi-natural vegetation	6 000 $\mu g.m^{-3}$

Tab. I.5 Brief characteristics, overview of major emission sources and major effects of ambient air pollutants

Pollutant and its sources	Health effects	Environmental effects
Suspended particles (atmospheric aerosol) Atmospheric aerosol consists of liquid or solid particles suspended in the air, originating from natural or anthropogenic processes. The natural sources include volcanic activity, wind borne dust particles and pollen, and natural fires. The largest anthropogenic source of suspended particles in the CR originates from residential combustion, road transport, farm-level agricultural operations (harvesting, tillage, etc.) and public energy and heat production. Suspended particles can be of primary or secondary origin. The primary particles are emitted directly into the air, the secondary particles are formed in the air by a gas-to-particle conversion. The main gas precursors of secondary particles are SO_2, NO_x, NH_3 and VOC (Pöschl 2011; EEA 2013a). The size range of atmospheric aerosol covers five orders of magnitude – from units of nm up to hundreds of μm. Based on similar particle properties, this scale can be divided into fine mode (particles $\leq$ 2.5 μm) and coarse mode (particles $\geq$ 2.5 μm). Fine particles are mainly products of imperfect combustion, coarse particles are formed mechanically (Hinds 1999; Seinfeld, Pandis 2006). Fine particles can be further divided into nucleation, Aitken and accumulation mode particles. Particles of the nucleation mode (< 20 nm) are released into the air directly or are formed in it, if they are not removed from the atmosphere by the diffusion process they are transformed into particles of the Aitken mode. Aitken mode particles (20–100 nm) are formed during combustion processes (Finlayson-Pitts and Pitts 1999). The accumulation mode of size between 100 nm and 2.5 μm is formed by transformed particles of the previous two modes (Seinfeld and Pandis 2006). Mobile sources produce particles of 10–100 nm. Stationary sources give rise to particles in the range of 50-200 nm. Long range particle transport transfers particles of 100–1000 nm (Gu et al. 2011, Hinds 1999, Zhang et al. 2004, Zhu et al. 2004, Zhou et al. 2005, Yue et al. 2008). Coarse mode particles consist of e.g. soil particles, sea salt, particles from industrial and agricultural activities. Their high sedimentation rate determines a short residence time in the atmosphere in the range of several hours to days. They are removed from the atmosphere by dry deposition and precipitation (Hinds 1999; Tomasi et al. 2017; Seinfeld and Pandis 2006). The legislation sets air pollution limits for the mass concentration of particles of the size fraction PM_{10} (particles with a diameter $\leq$ 10 micrometers) and $PM_{2.5}$ (particles with a diameter $\leq$ 2.5 micrometers). The mass of particles (especially ultra-fine particles < 100 nm) in the standard PM_{10} and $PM_{2.5}$ size spectrum is negligible in comparison with their numbers. Therefore, measurements of the number of particles and their size distribution are used for specific evaluations of the influence of aerosol particles (health impacts, climate impact) (Tuch et al. 1997, Stanier et al. 2004).	Suspended particles cause a broad spectrum of effects on the cardiovascular and respiratory systems. They irritate the respiratory tract, reduce defence mechanisms and facilitate the development of infection, cause an inflammatory reaction in lung tissue, contribute to oxidative stress and thus the development of atherosclerosis, affect the electrical activity of the heart and have been classified as proven human carcinogens since 2013 (IARC 2015). The effect depends on the size, shape and composition of particles. Short-term increase of daily PM_{10} concentrations contributes to increasing total morbidity and mortality due to mainly cardiovascular diseases, to the growth of the number of persons hospitalized due to respiratory diseases, increasing infant mortality and increasing the frequency of coughing and breathing problems, mainly in asthmatics (SZÚ 2015b). Long-term increased concentrations can result in reduced pulmonary function, increased morbidity due to respiratory diseases and increased incidence of chronic bronchitis symptoms and decreased lifespan, especially due to increased mortality of the elderly and sick persons due to cardiovascular and respiratory diseases, including lung cancer (SZÚ 2015b). A safe threshold concentration for the impact of aerosol particles in the air has not yet been determined.	They affect the Earth's radiation balance, cloud and precipitation formation, and visibility. They have a direct influence (by scattering of incoming solar radiation) and indirect influence (as condensation nuclei in the clouds affecting the reflection of radiation by the clouds). The particles reflect and / or absorb solar radiation and thus contribute to the cooling or warming of the Earth's climate system (IPCC 2013). Suspended particles affect both animals and humans, affect plant growth and ecosystem processes, and may damage and tarnish buildings (EEA 2013a).

Pollutant and its sources	Health effects	Environmental effects
Benzo[a]pyrene Benzo[a]pyrene, which occurs in the air primarily bound to particles, is a suitable marker of ambient air pollution caused by PAHs. The reason is its stability and relatively constant contribution to carcinogenic activity of the mixture of PAHs bound to particles (EC 2001a). Residential heating belongs to the major sources of benzo[a]pyrene in the Czech Republic.	PAHs represent a group of substances of which many have toxic mutagenic or carcinogenic properties, belong among endocrine disruptors (substances damaging the function of endocrine glands) or act immunosuppressively. They affect foetal growth. Prenatal exposure to PAH is related to markedly lower birth weight (Choi et al. 2006) and probably also adversely affects the cognitive development of young children (Edwards et al. 2010). Benzo[a]pyrene itself is classified as a proven human carcinogen (IARC 2020).	PAHs can bioaccumulate and enter the food chain (Brookes et al. 2013, EEA 2013b).
Nitrogen oxides The term "nitrogen oxides" (NO_x) refers to nitric oxide (NO) and nitrogen dioxide (NO_2). More than 90% of anthropogenic emissions of NO_x are represented by NO emissions. The major anthropogenic sources of NO_x in the Czech Republic are road transport and public energy production.	As concerns the impact on human health, the most significant nitrogen oxide is NO_2 (WHO 2006). NO_2 can affect mainly the respiratory tract. The main effect of short-term exposure to high concentrations of NO_2 is increased reactivity of the respiratory tract and ensuing worsened symptoms in people with asthma (Samet et al. 2000). Exposure to NO_2 impairs lung functions and increases the risk of respiratory diseases in children due to reduced immunity to infections (EEA 2013a, Peel et al. 2005). It is also linked to increase of the total, cardiovascular and respiratory mortality (Stieb et al. 2003, Samoli et al. 2003), however, it is difficult to separate the effects of NO_2 from other simultaneously acting substances, mainly aerosols (WHO 2006), hydrocarbons, ozone, and other substances (Brauer et al. 2002).	NO_x contribute to acidification and eutrophication of soil and water. High NO_x concentrations can lead to damage to plants. NOx act as precursors of ground-level ozone and particulate matter (EEA 2013b, Brookes et al. 2013)
Ground-level ozone Ozone (O_3) is a secondary pollutant without its own emission source; it is formed as a part of photochemical smog under the influence of solar radiation during a series of reactions mainly between NO_x, VOC and oxygen. (EEA 2013a). Ozone can be transported over long distances, accumulate and reach high concentrations far from its place of origin (Brookes et al. 2013)	The main effect of ozone on the human body is irritative. It irritates the conjunctiva, nasal mucosa and bronchi. Short-term studies show that O_3 concentrations can have adverse effects on lung function leading to inflammation and respiratory problems (EEA 2013a). At higher concentrations, respiratory tract irritation will narrow and make it difficult to breathe. People with chronic obstructive diseases of the lungs and asthma are more sensitive to ozone. Higher ozone concentrations are associated with an increase in daily mortality (WHO 2006).	Ground-level ozone damages vegetation, impairs plant growth and decreases crop yields; it can damage forest ecosystems and reduce biodiversity (EEA 2013b).
Benzene Benzene is present in the air mainly due to anthropogenic activities. The largest source of benzene emissions is represented by incomplete combustion of fuels by vehicles. Other sources of benzene emissions include domestic heating, oil refineries, petrol distribution and storage (EEA 2013a).	Benzene ranks among human carcinogens (IARC 2020). At high concentrations, it can have haematotoxic, genotoxic and immunotoxic effects (SZÚ 2015a).	Benzene can bioaccumulate; it can damage leaves of agricultural crops and kill plants (EEA 2013b).

Pollutant and its sources	Health effects	Environmental effects
Lead Most lead present in the atmosphere is released from anthropogenic emission sources. The main sources in the Czech Republic include road transport (tire and brake wear), iron and steel production, and public energy and heat production.	Long-term exposure is harmful to the biosynthesis of haem, the nervous system and blood pressure in humans. Exposure to lead also poses risks to developing foetus; it may negatively influence brain development and, consequently, mental development, (Černá et al. 2011; EEA 2013a). As concerns its carcinogenic effects, lead is classified within group 2B – possibly carcinogenic to humans (IARC 2020).	Lead can accumulate in the bodies of organisms (bioaccumulation) such as fish and can enter the food chain (Brookes et al. 2013, EEA 2013b).
Cadmium Cadmium is bound mainly to the particles with aerodynamic diameter of up to 2.5 µm (EC 2001b). The main sources in the Czech Republic are local household heating, iron and steel production, and public energy and heat production.	Long-term exposure to cadmium affects the function of kidneys. It can also have negative impacts on the respiratory tract; the effects of cadmium exposure also include lung cancer (WHO 2000).	Cadmium can bioaccumulate (EEA 2013b).
Arsenic Arsenic occurs largely in particles with aerodynamic diameter up to 2.5 µm (EC 2001b). The main sources in the Czech Republic include local household heating, public energy and heat production, and manufacturing of lead.	High concentrations affect the nervous system (SZÚ 2015a). Lung cancer is considered to be the critical effect following the long-term inhalation (EC 2001b; WHO 2000).	Arsenic can bioaccumulate; it reduces plant growth and crop yields from soils containing arsenic (EEA 2013b).
Nickel Nickel is found in particles in the form of several chemical compounds with various levels of toxicity to humans and also to ecosystems. The main sources in the Czech Republic are public electricity and heat production, stationary combustion in manufacturing industries and construction (chemical industry), and local household heating.	Nickel can affect the respiratory and immune systems in humans (WHO 2000, EEA 2013a). Nickel compounds are classified as proven human carcinogens; metallic nickel and its alloys are classified as possibly carcinogenic to humans (IARC 2020).	Nickel may cause the pollution of soil and water.
Sulphur dioxide Sulphur dioxide (SO_2) is emitted into the atmosphere during the combustion of sulphur-containing fuels. The main sources in the Czech Republic are public electricity and heat production, and residential combustion.	SO_2 causes irritation of the eyes and respiratory tract. High SO_2 concentrations can lead to respiratory problems. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis, and makes people more prone to infections of the respiratory tract. Those suffering from asthma and chronic lung disease are the most sensitive towards SO_2 exposure (EC 1997; WHO 2014).	SO_2 contributes to acidification of the environment. It also contributes to the formation of secondary suspended particles with a proven negative impact on human health (EEA 2013a).
Carbon monoxide Carbon monoxide (CO) is a gas emitted due to incomplete combustion of fossil fuels. The largest sources of CO emissions in the Czech Republic are household heating, road transport, combustion processes in industry and construction (iron and steel) and the production of iron and steel	CO binds to haemoglobin more strongly than oxygen and thus reduces the oxygen-carrying capacity of blood. The first subjective symptoms of poisoning are headaches followed by impaired coordination and reduced awareness. Those suffering from cardiovascular disease are again the most sensitive towards CO exposure (EEA 2013a). Toxic effects of CO become evident in organs and tissues with high oxygen consumption such as the brain, the heart and skeletal muscles. It is also dangerous to developing foetus (WHO 2000).	CO can contribute to the formation of ground-level ozone (EEA 2013b, Brookes et al. 2013).

Pollutant and its sources	Health effects	Environmental effects
Elemental carbon Elemental carbon (EC) is a product of incomplete combustion of organic materials (coal, oil, petrol, wood and biomass) (Schwarz et al. 2008). EC is emitted into the air only directly (primary particles). The term black carbon (BC) is also used in addition to the term EC. Black and elemental carbon basically designate the same component appearing in the atmosphere. While EC contains only carbon, BC can contain, apart from EC, also organic ingredients (Chow et al. 2009; Husain et al. 2007; Petzold et al. 2013). The use of terminology to denote elemental and black carbon differs in the concept of the nature of this substance. The term EC denotes volatility properties, while black carbon (BC) entails absorption properties across the spectrum of visible wavelengths (Seinfeld, Pandis 2006).	EC is a part of the fine fraction of aerosol particles ($PM_{2.5}$). It has been concluded from the evaluation of health impacts of $PM_{2.5}$ on human health that variability of epidemiologic results cannot be explained by only variance of concentrations of $PM_{2.5}$ in the environment. Causes can include just more active toxicological components of $PM_{2.5}$ (Luben et al. 2017). Compared to OC, EC (or BC) penetrates more readily into the human body and aggravates heart and lung diseases (Na, Cocker 2005). Organic particles (including organic carbon), which can contain among other components fractions of polycyclic aromatic hydrocarbon (PAHs), are studied for their carcinogenic and mutagenic effects (Seinfeld, Pandis 2006; Satsangi et al. 2012).	BC strongly absorbs solar radiation and contributes significantly to the warming of the Earth's climate system (Bachman 2009).
Organic carbon Organic (OC) carbon is formed during incomplete combustion, the production of biogenic particles (viruses, bacteria, pollen, fungal spores and all kinds of vegetation fragments) and the resuspension of transport-associated dust (Schwarz et al. 2008). OC is both primary and secondary particle, i.e. it can be formed by reactions of gaseous organic precursors.	OC is a part of the fine fraction of aerosol particles ($PM_{2.5}$). Organic particles (including organic carbon), which may contain, inter alia, polycyclic organic hydrocarbon fractions (PAHs), are being studied for their carcinogenicity and mutagenic effects (Seinfeld, Pandis 2006; Satsangi et al. 2012).	OC scatters solar radiation, which has a cooling effect on the Earth's climate system. (IPCC 2013).

II. AIR POLLUTION

The CHMI evaluates the level of air pollution under authorisation by the Ministry of the Environment for primary pollutants of anthropogenic origin. The basic background material for this evaluation consists of the "emission inventory" which combines direct collection of data reported by the operators of sources with model calculations of data reported by the operators of sources or determined in the context of statistical studies performed primarily by the Czech Statistical Office. The resulting emission inventories are presented in a form of emission balances in sectoral and territorial classifications (OEZ 2020). The accompanying document describing the methodologies for processing emission inventories is also presented on the CHMI website (CHMI 2020a). The current report (CHMI 2020b) presents the results of the emission inventory for the period 1990–2018 taking into account recommendations of the team reviewing the inventory methodology of the EU Member States. These relate mainly to the conversion of ammonia emissions from the application of mineral fertilizers, and the inclusion of emissions of the agricultural activities sector (NMVOC and NO_x) and food production (NMVOC). Time series for road transport were recalculated due to the update of the used balance COPERT model and new methodological recommendations for performing calculations by model.

Emission inventory in the Czech Republic

From the viewpoint of the means of monitoring emissions, air pollution sources are divided into individually monitored sources and collectively monitored sources. The sources listed in Annex No. 2 of the Act No. 201/2012 on the air protection are monitored individually. Pursuant to Article 17(3)(c), the operators of these sources are obliged to keep operating records of permanent and variable data on stationary sources, describing the source and its operation, and also data on inputs and outputs from these sources. They are also obliged to annually report information on the summary operating records (SPE) through the Integrated system of fulfilling reporting obligations (ISPOP). ISPOP data are then collected in the REZZO 1 and REZZO 2 databases. Reporting of data for the previous year takes place from January to the end of March.

Collectively monitored sources registered in REZZO 3 include emissions from unspecified combustion sources, construction and agricultural activities, surface use of organic solvents, filling stations, coal mining, fires of cars and buildings, waste and waste-water treatment, use of fireworks, etc. Emissions from these sources are determined using data collected by national statistical surveys and emission factors.

Data from mobile sources are also monitored collectively (REZZO 4) and include emissions from road (including VOC emissions from vehicle fuel system petrol evaporation and emissions from brake, tyre and road abrasion), rail, water and air transport, and operation of off-road machinery and mechanisms (agricultural, forest and construction machinery, military vehicles, greenery maintenance, etc.). Emissions from resuspension, i.e. dust swirling during vehicle operation, are not part of the emission inventory.
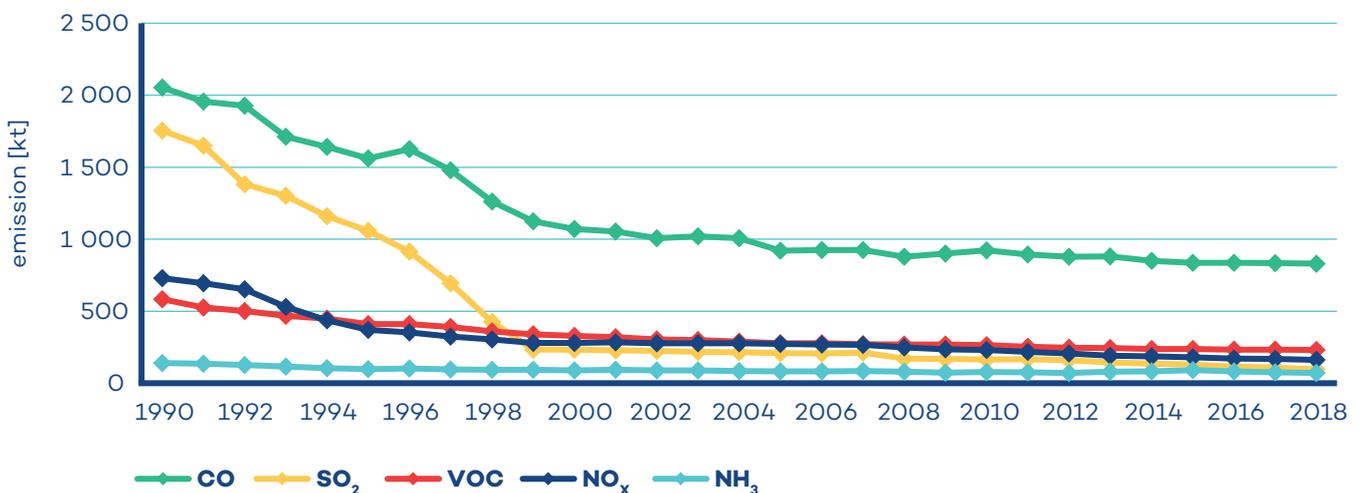
Fig. II.1 The development of main pollutants total emissions, 1990–2018
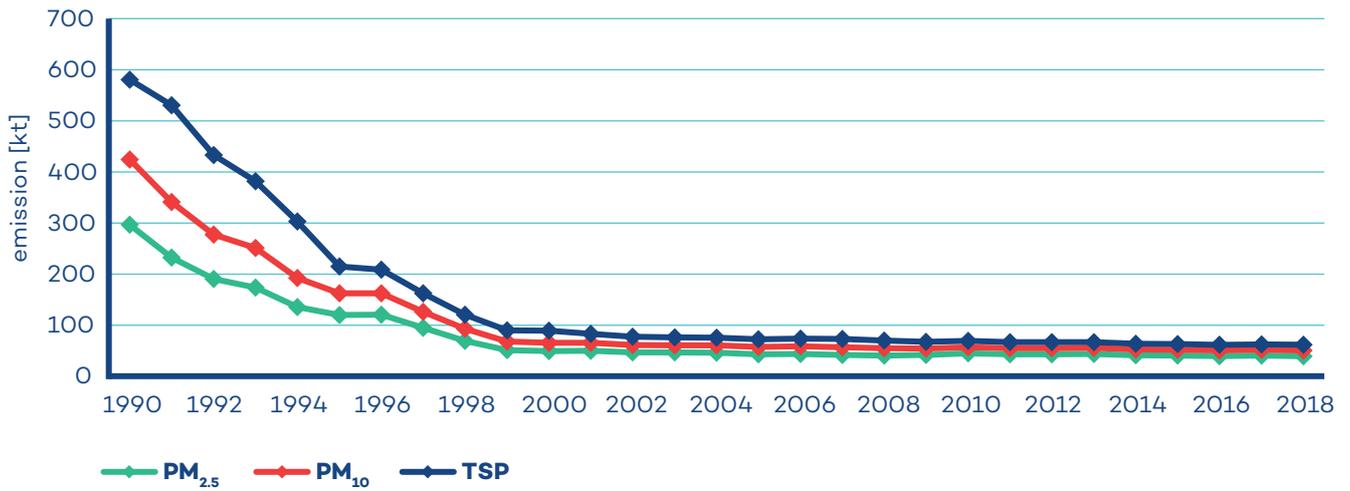
Fig. II.2 The development of particulate matter total emissions, 1990–2018
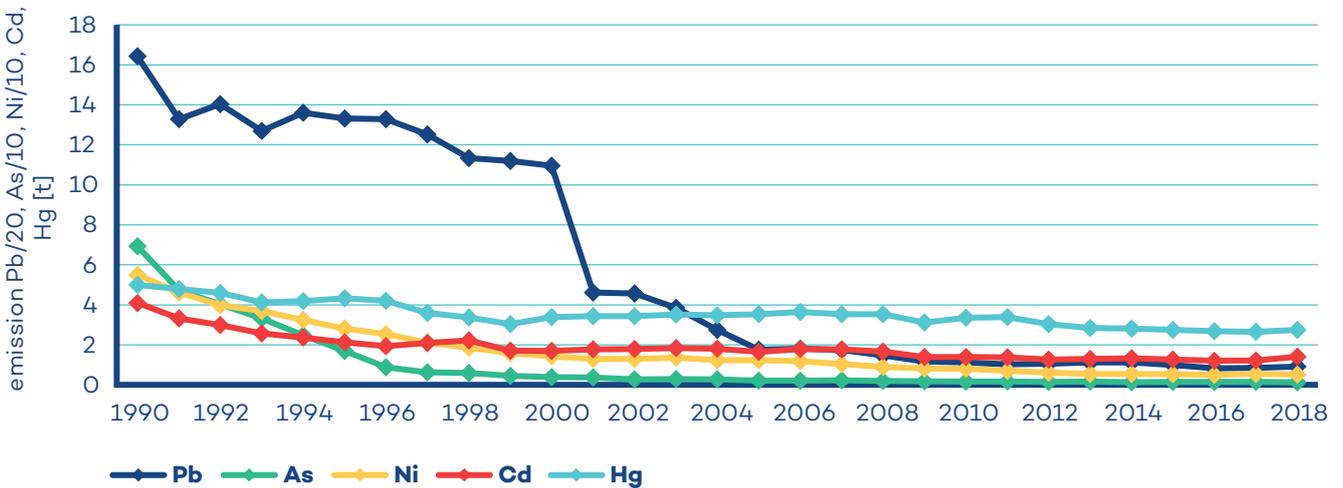
Fig. II.3 The development of heavy metals total emissions, 1990–2018
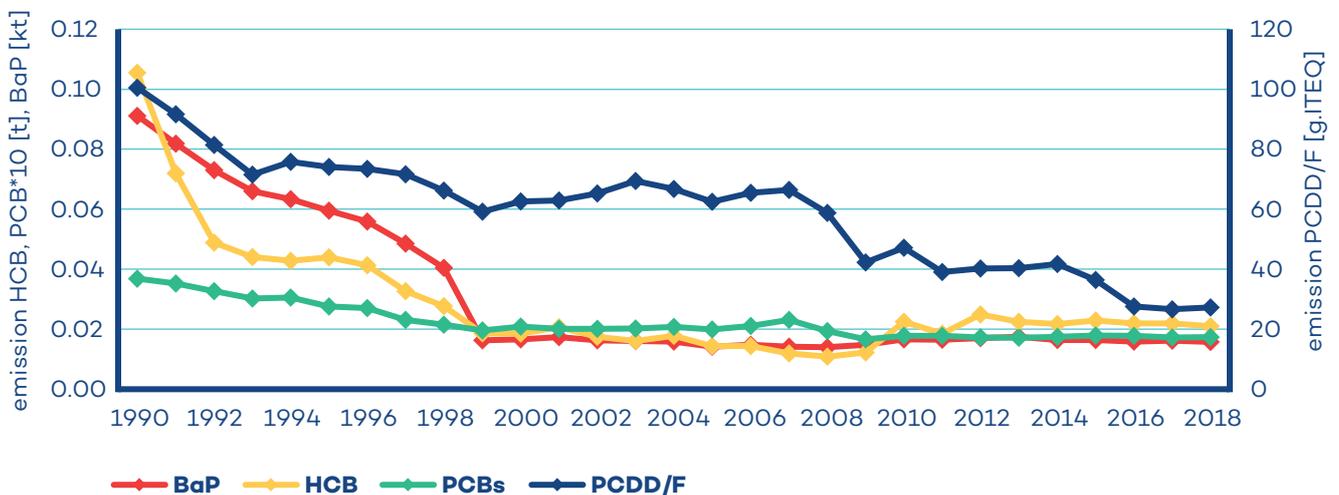
Fig. II.4 The development of POP emissions, 1990–2018

For the model assessment of pollution levels and display of emission densities (Chapter IV), emission factors are applied to determine emissions from domestic heating, that represent the estimated state when boilers are operated for part of the time at reduced output, meaning imperfect combustion and increased emissions (EU 2015).

Emission trends

The trends in air pollution levels are closely connected with economic and social-political conditions and with development of knowledge about the environment permitting more complete and accurate emission inventories. A time series of the 1990–2018 period separated for the main gas polluting substances, solid polluting particles, heavy metals and POPs is presented in Fig. II.1 to Fig. II.4. The emissions of all the main polluting substances decreased in this period by tens of percent. After an initial decrease in

the period up to 2008, the benzo[*a*]pyrene emissions started again to increase and by 2012 came close to the level of 2001. Due to higher rate of consumption of black coal in households after 2010 HCB emissions also increased. In 2012, they reached 35% higher levels than in 2000. Emissions from stationary sources in categories REZZO 1 and REZZO 2 decreased substantially as a result of introduction of an air quality control system which employs a number of instruments at various levels (normative, economic, information, etc.). The impacts of these instruments were manifested to the greatest degree at the end of the 1990s, i.e. at a time when the emission limits introduced by the then new legislation came into force. A substantial reduction in the production of emissions from the most important sources manifested positively on air quality, especially in the industrial areas of Northern Bohemia and Moravia, and there was, among other things, a significant reduction in the long-distance transmission of pollutants. Despite significant reductions in emissions from energy and industrial sources, compliance problems with air quality requirements persist in many
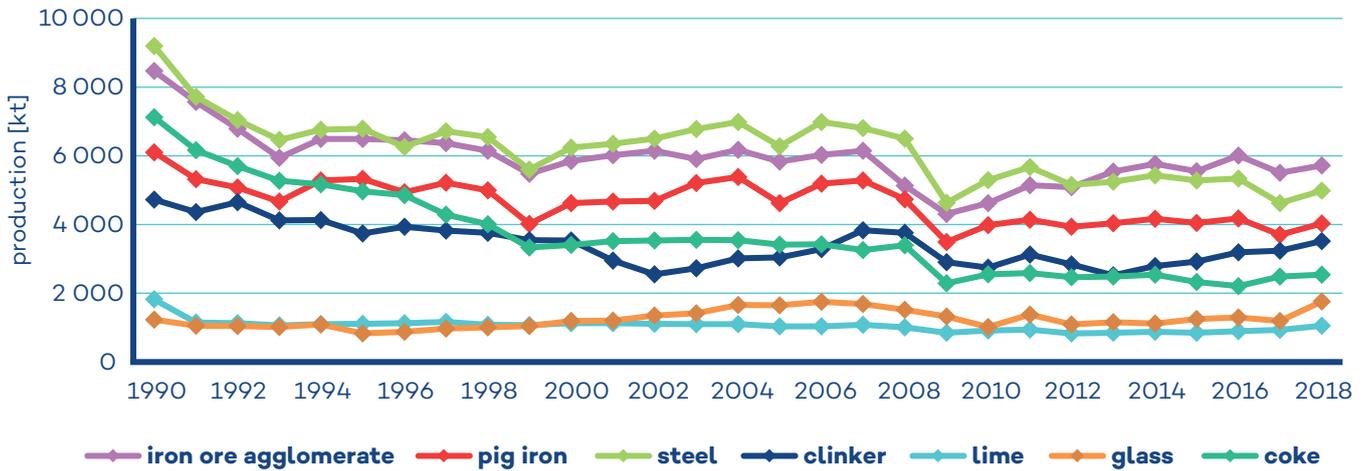
Fig. II.5 The output of basic industrial products, 1990–2018
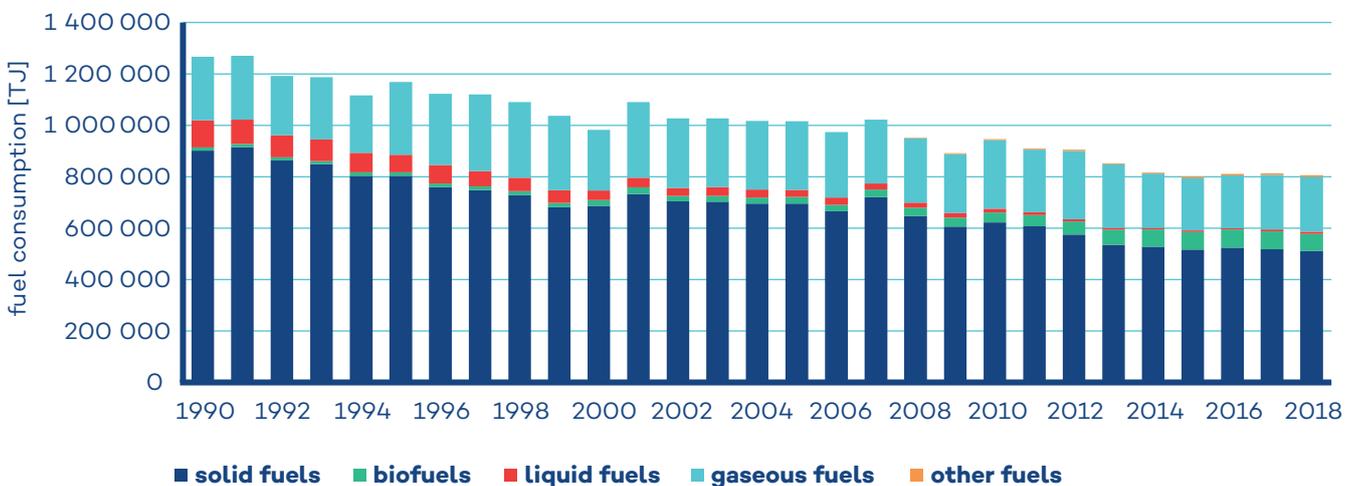
Fig. II.6 Fuel consumption in REZZO 1 and REZZO 2 sources, 1990–2018

places, and the attention has also been focused in recent years on REZZO 3 and REZZO 4 sources. Although there has been a significant reduction in emissions, especially in road transport, the impact of these sources on air quality is significant, especially in municipalities, and effective measures have not yet been applied throughout all the territory to regulate them. For these reasons, among other, the revision of the Göteborg Protocol and Directive of the European Parliament and Council (EU) 2016/2284 imposes on the Czech Republic the obligation to reduce the emissions by 2020 for $PM_{2.5}$ by 17%, SO_2 by 45%, NO_X by 35%, VOC by 18% and NH_3 by 7% and by 2030 for $PM_{2.5}$ by 60%, SO_2 by 66%, NO_X by 64%, VOC by 50% and NH_3 by 22% compared to 2005.

In 1991, Act No. 309/1991 Coll., on protection of the air, came into force, supplemented by Act No. 389/1991 Coll., on state administration in air protection and fees for pollution thereof, which introduced emission limits with validity from 1998 for the first time in the history of the Czech Republic. As a result of the

restructuring of the economy and the modernization of resources, there has been a significant decline in production in a number of sectors since 1990 (Fig. II.5). In combustion sources with lower heat output (heating plants/boiler rooms), solid and liquid fossil fuels were gradually replaced by natural gas (Fig. II.6).

Emissions from local household heating decreased most in the 1993–1997 period as a result of conversion to gas heating in municipalities and state support for heating with electricity. The consumption of household fossil fuels in 2001 was 67% lower compared with 1990 (Fig. II.7). Emissions of the main polluting substances and particulates of the REZZO 4 sources decreased due to natural vehicle fleet renewal. Termination of sale of leaded petrol in 2001 led to a substantial decrease of Pb emissions into the air (Fig. II.3).

The favourable trend in reducing consumption of fossil fuels in the local household heating sector did not continue after 2001,
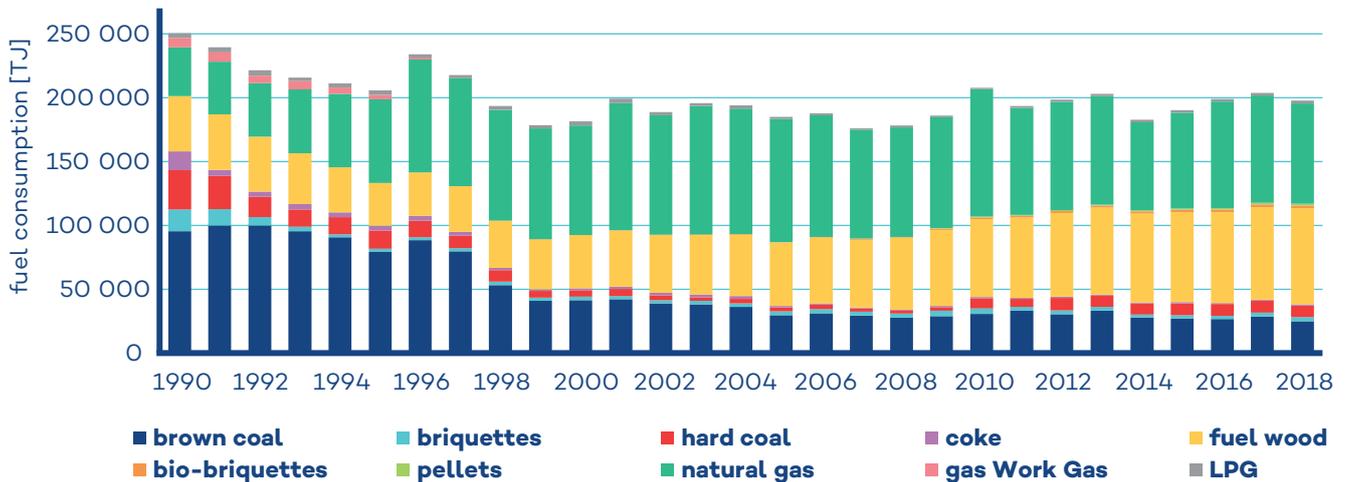
Fig. II.7 Fuel consumption in REZZO 3 sources (households), 1990–2018
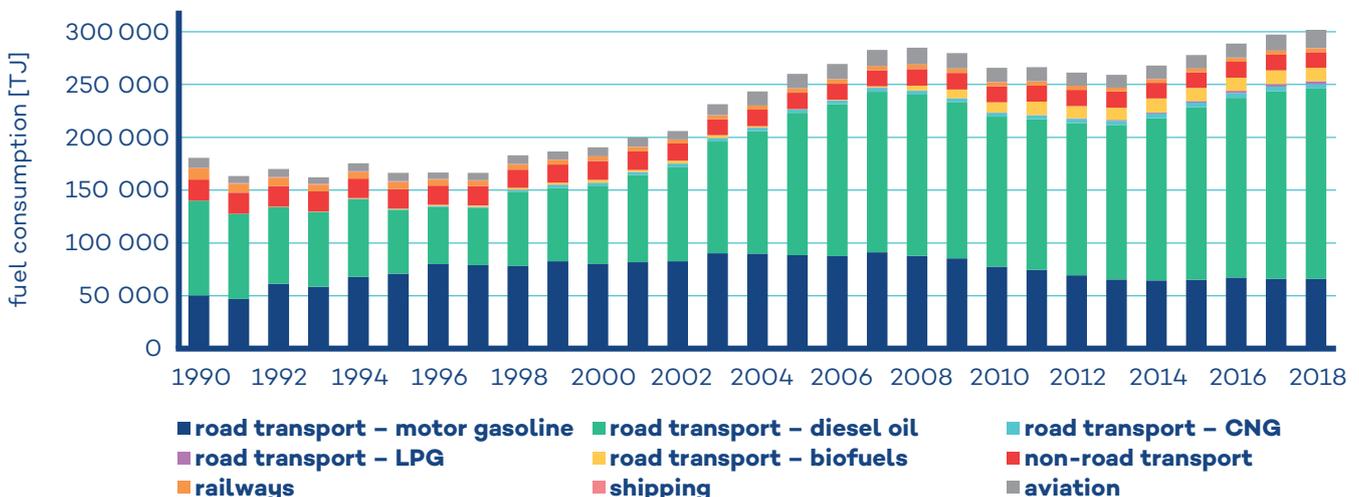
Fig. II.8 Fuel consumption in REZZO 4 sources, 1990–2018

mainly because of the increasing prices of natural gas and electricity. In the 2002–2008 period, the consumption of coal slightly decreased and was replaced by increasingly popular heating with wood. After 2009 the consumption of fossil fuels in households, particularly firewood, started again to increase (Fig. II.7). In 2009–2012, the Green Light for Savings programme helped in buildings being insulated and environmentally unsound heating being replaced by low-emission sources. Emissions of the main polluting substances and emission of particulates of the REZZO 4 sources decreased due to introduction of stricter emission standards for new vehicles placed on market. The impact of increased intensity of transport and consumption of diesel fuel led to increase of emission of heavy metals and POPs (Fig. II.8).

In 2012, the Act No. 201/2012 Coll. on air protection came into force, introducing stricter emission limits for sources pursuant to Directive 2010/75/EU on industrial emissions. The most important technical measures to reduce emissions in the 2013–2016 period included installation of sulphur-removal and nitrogen-removal equipment for combustion products (most power plants and larger heating plants) or installation of bag filters on the existing electrostatic separators (e.g. at metallurgical plants in the Moravian-Silesian region).

The new legislation concentrated more also on reducing emissions from the local household heating sector by introducing minimum emission parameter values for combustion sources with overall rated thermal input of up to 300 kW when placing the equipment on the market since 2014 and 2018. From 1 September 2022, it will be possible to operate only boilers complying with emission class 3 in this group of sources, which should lead to removal of old types of boilers and their replacement by more modern equipment with lower emissions. Replacement of boilers is taking place gradually and, together with reducing the energy demands of buildings, these measures are supported by the subsidy policies at national and regional levels.

The preliminary emission assessment for 2019 shows further reductions for all major pollutants (Tab. II.1). Of the listed REZZO 1-2

sources, emissions decreased the most concerning SO_2 by 17 kt, CO by 7.4 kt and NO_x by 6.5 kt. The evaluation of the trend of reported emissions of the most important production facilities, especially combustion sources for the production of electricity and supply of heat, metallurgy and oil processing sector, shows a reduction in SO_2 emissions by almost 25% and NO_x by 10.5%. In the case of collectively monitored stationary REZZO 3 sources, the decrease in SP emissions (by 2.8 kt) is mainly due to domestic heating and then other stationary sources, including coal mining which decreased by 4.4% year-on-year for lignite coal and by almost 25% for black coal. The results of the model evaluation of domestic heating include the available information on the ongoing replacement of boilers for domestic heating (the existing stages of replacement concerning approx. 48,800 boilers were included). The results show that despite a slight increase in the number of degree-days in the heating period in 2019 compared to 2018 (by about 4%), the estimation of emissions mainly affected the modernization of the composition of combustion equipment in households due to legislative measures documented in the Ministry of Industry and Trade statistics (MIT 2020). The preliminary assessment indicates a small reduction in total household heating emissions for all pollutants except SO_2 (a slight increase in the average sulphur content of lignite coal) and NH_3 (an increase in the use of biomass). A slight increase in fuel consumption was almost not reflected in the change in emissions from transport (REZZO 4). A more detailed evaluation of time variation of pollutant emissions, especially for the listed sources, can be found in the individual subchapters of Chapter IV.

Projections of emissions

Within the framework of reporting in relation to the Czech Republic's international obligations (CLRTAP) and Directive 2016/2284/EU, the CHMI provides projections based on emission inventories, trends of socio-economic indicators, legislation valid in the projection horizon and further emission reduction measures.

The emission projection for the period 2020–2030 (Fig. II.9) was prepared according to the WM (without additional measures) and

Legend: ■ 2017 ■ ceiling in 2020 ■ WM Scenario 2020 ■ ceiling in 2030 ■ WM Scenario 2030 ■ WaM Scenario 2030
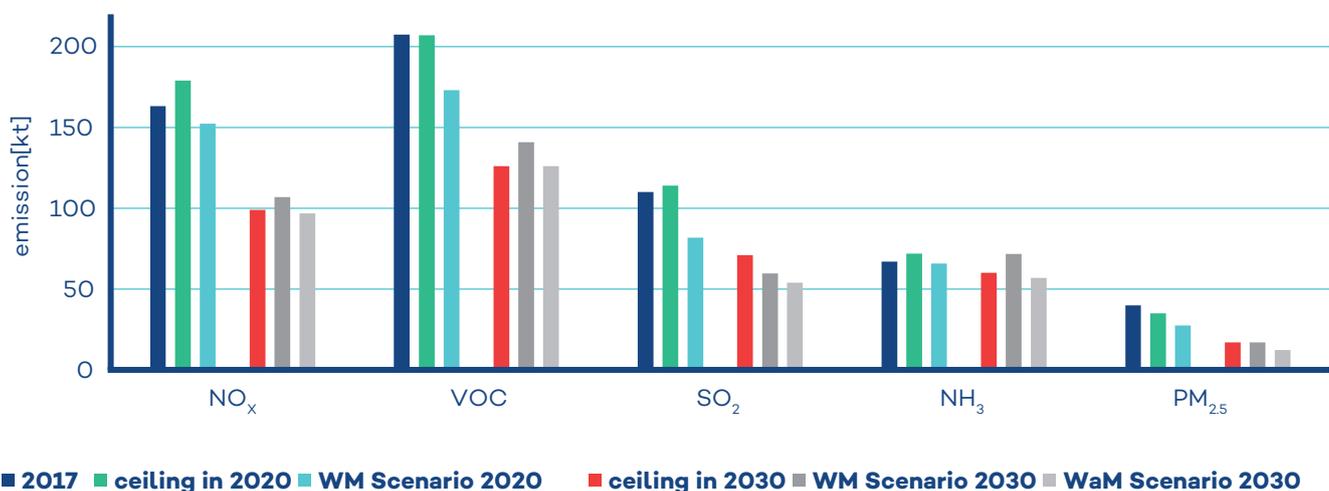
Fig. II.9 Comparison of emission ceilings and emission projection scenarios of basic air pollutants

WaM (with additional measures) scenarios for the purpose of updating the National Emission Reduction Programme (MŽP 2019). The projections for NO_x, VOC, SO_2, NH_3, and $PM_{2.5}$ particles are based primarily on expert evaluation of future emissions and activity data for significant source categories such as energy, transport, agriculture, solvent use or waste management.

By 2030, it is anticipated that emissions of all pollutants will be reduced, resulting from the replacement of heating facilities in the sector of the local household heating, vehicle fleet renewal including support for low-emission and zero-emission vehicles, greater support for renewable energy, tightening of obligations for the storage and application of fertilizers and other measures.

Tab. II.1 The comparasion of emissions of main pollutants, 2018–2019 (preliminary data)

Emission source category	TZL		SO_2		NO_x		CO		VOC		NH_3	
kt.year^{-1}												
Year	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
REZZO 1–2	7.4	6.7	76.7	59.6	74.2	67.7	166.8	159.4	21	20.3	0.7	0.6
REZZO 3	47.2	45.1	19.6	20.1	16.6	16.6	555.7	552.2	193.1	191.5	70	69.8
TOTAL stationary sources	**54.6**	**51.8**	**96.3**	**79.7**	**90.8**	**84.3**	**722.5**	**711.6**	**214.1**	**211.8**	**70.7**	**70.4**
REZZO 4	7.1	7.1	0.2	0.2	70.8	69.5	108.1	102.6	16.8	16.7	1	1
TOTAL	**61.7**	**58.9**	**96.5**	**79.9**	**161.6**	**153.8**	**830.6**	**814.2**	**230.9**	**228.5**	**71.7**	**71.4**

III. METEOROLOGICAL AND DISPERSION CONDITIONS

Apart from the respective air pollution sources, air quality is significantly affected by meteorological conditions. These conditions enable the dispersion of polluting substances in the air, influence the amount of emissions from anthropogenic or natural sources, resuspension, and affect the formation of secondary pollutants as well as the rate of their removal from the air. One of the ways in which the dispersion conditions can be expressed numerically is in terms of the ventilation index (VI) which is defined as a product of the mixing layer depth and the average air flow velocity in it[1]. However, situations with poor dispersion conditions do not necessarily mean occurrence of high concentrations of pollution substances. Important factors include duration of the situati-

on, starting level of pollution, distribution of sources, and their emissions to the layer under the inversion. The effect of meteorological conditions on anthropogenic emissions from heating is determined on the basis of calculation of heating days and temperatures that occurred during these days. Temperature conditions in the heating season (January–May, September–December) or parts thereof are characterized in terms of degree-days, i.e. the sum of the differences in the reference indoor temperatures and the average daily outdoor temperatures on heating days. A more detailed specification of the influence of meteorological conditions on air quality is given in (CHMI 2020d).
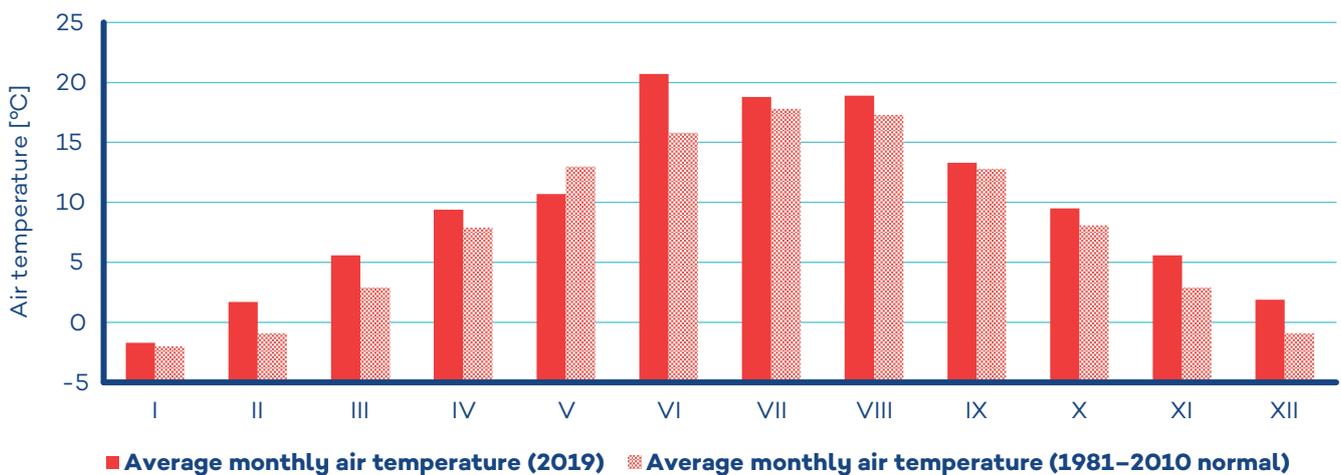
Fig. III.1 Average monthly air temperature in 2019 compared to the normal of 1981–2010

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1   The mixing layer is understood as the layer of air between the Earth's surface and the lower boundary of the lowest temperature-blocking layer.

Meteorological and dispersion conditions in 2019

In terms of temperature, the year 2019 was extremely above normal. The average annual temperature of 9.5 °C was 1.6 °C above the normal of 1981–2010. Consequently, after 2018, the year 2019 becomes the second warmest year observed in the series of annual average temperatures since 1961. During the year, only May recorded negative deviation (−2.3 °C) from the monthly temperature normal of 1981–2010. This month was classified as strongly subnormal. Three months, January, July and September, were assessed as normal in terms of temperature. The months of February (deviation +2.6 °C), April (deviation +1.5 °C), October (deviation +1.4 °C) and December (deviation +2.8 °C) were eva-luated as above normal in view of temperature. March (deviation +2.7 °C), August (deviation +1.6 °C) and November (deviation +2.7 °C) were assessed as strongly above normal in temperature and June (deviation +4.9 °C) as extremely above normal (Fig. III.1).

In view of precipitation over the territory of the Czech Republic, the year 2019 was normal. The average total annual precipitation of 634 mm corresponds to 92% of the normal of 1981–2010. During the year, 7 months were assessed as normal in terms of precipitation. Precipitation was below normal in April (60% of the normal), June (67% of the normal) and July (66% of the normal). The months of January (148% of the normal) and May (132% of the normal) were assessed as above normal concerning precipitation (Fig. III.2).
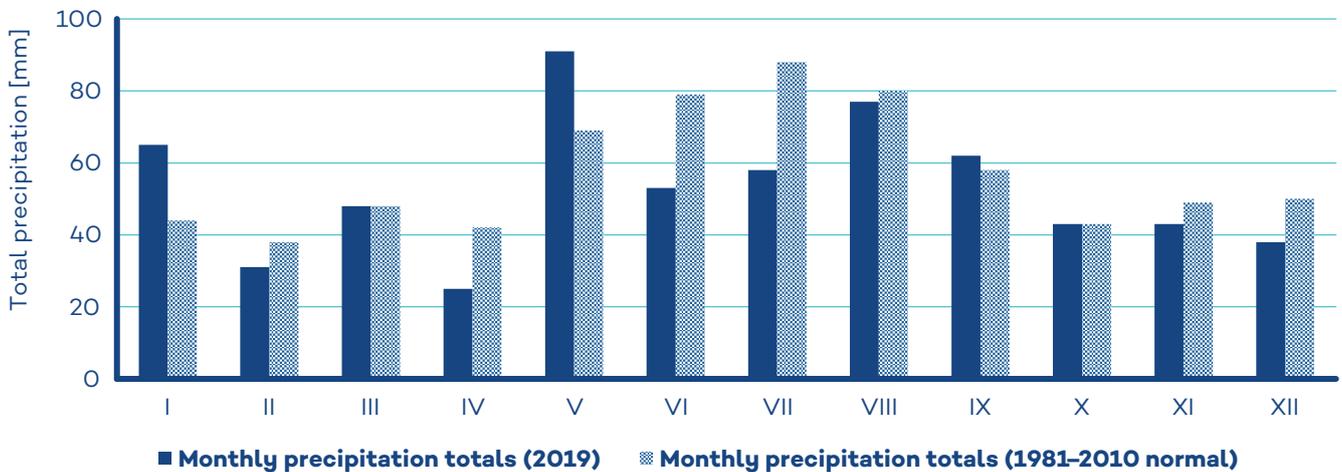
Fig. III.2 Monthly precipitation totals compared to the normal of 1981–2010
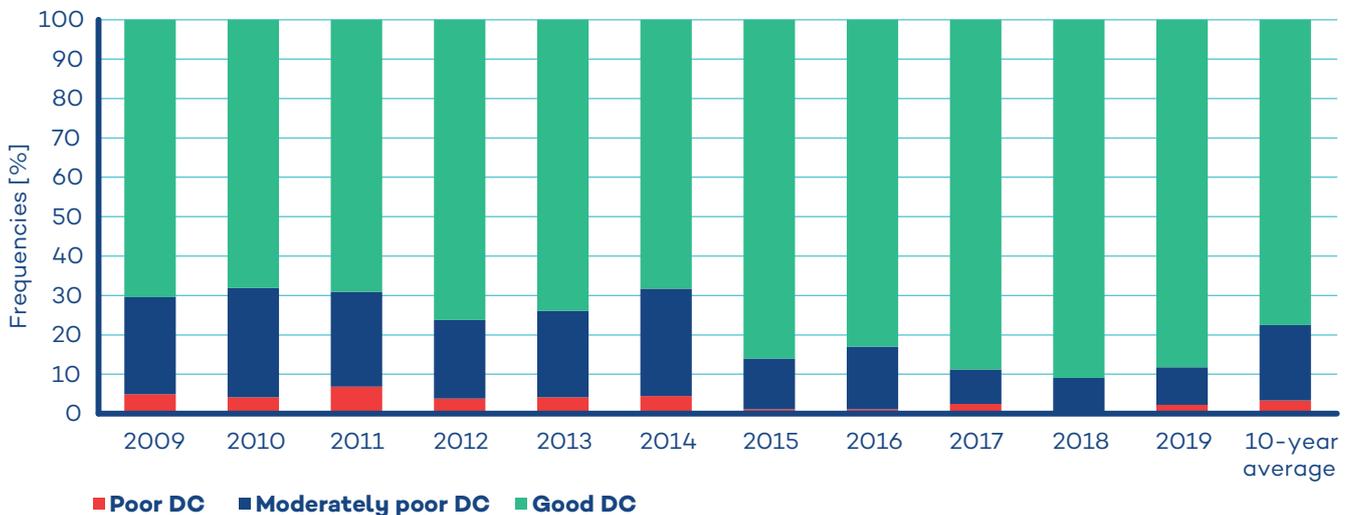
Fig. III.3 Frequency of occurrence of dispersion conditions (DC), 2009–2019

In 2019, the dispersion conditions were improved compared to the long-term average of 2007–2018. On a national average, good dispersion conditions occurred in 88% of cases, representing 115% of the long-term average. The year 2019 thus becomes the year with the most frequent occurrence of good dispersion conditions after 2018 (Fig. III.3). Based on the evaluation of the ventilation index averaged for individual regions and agglomerations, poor dispersion conditions occurred during the year in all regions and agglomerations (Fig. III.4). The most frequent occurrence of good dispersion conditions was recorded in the Moravian-Silesian region without the O/K/F-M agglomeration and in the South Moravian region without the Brno agglomeration (89%). The most significant improvement in dispersion conditions compared to the long-term normal occurred in the Ústí nad Labem, Liberec and Hradec Králové regions (Fig. III.5).
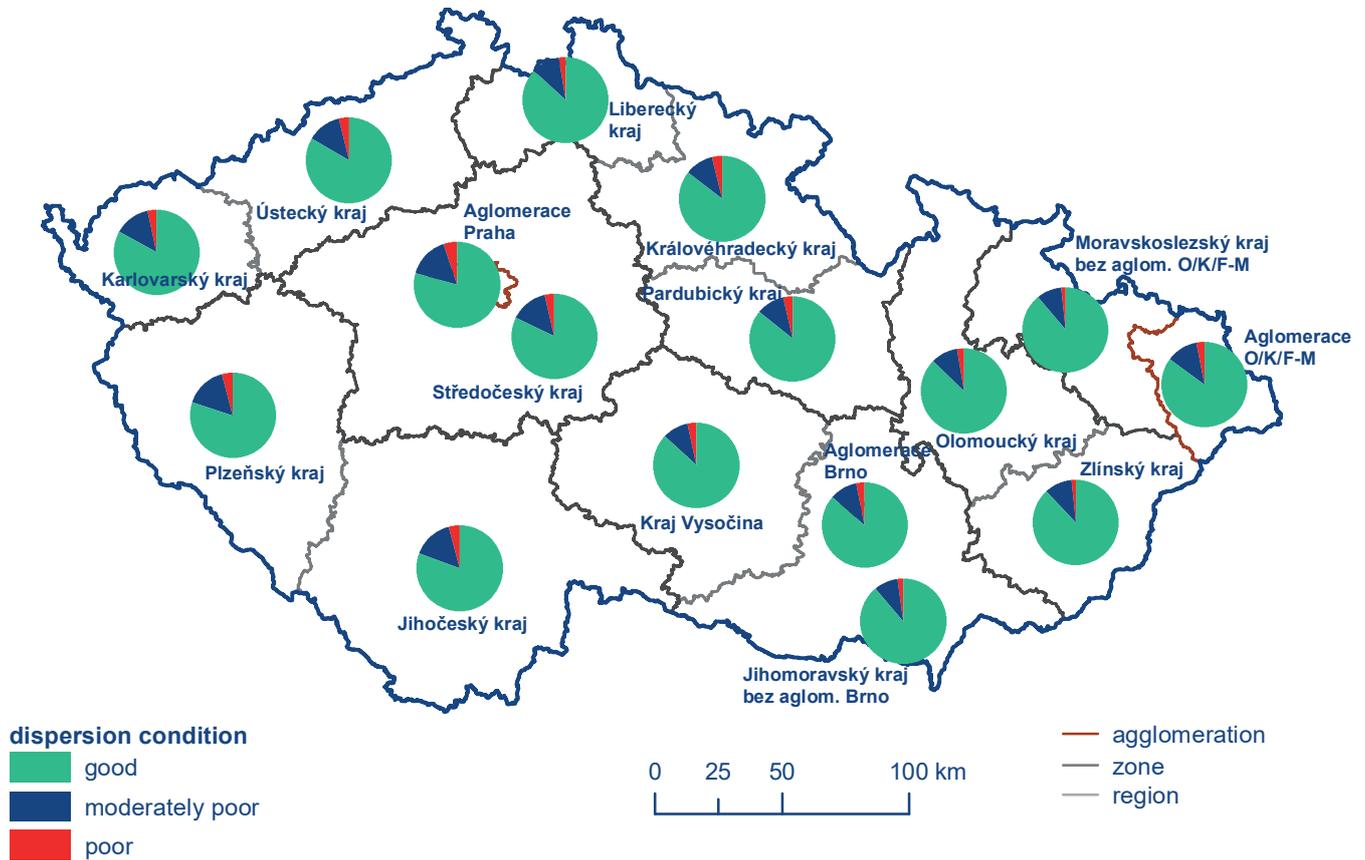
Fig. III.4 Composition of daily averages of ventilation index in regions and agglomerations of the Czech Republic in 2019
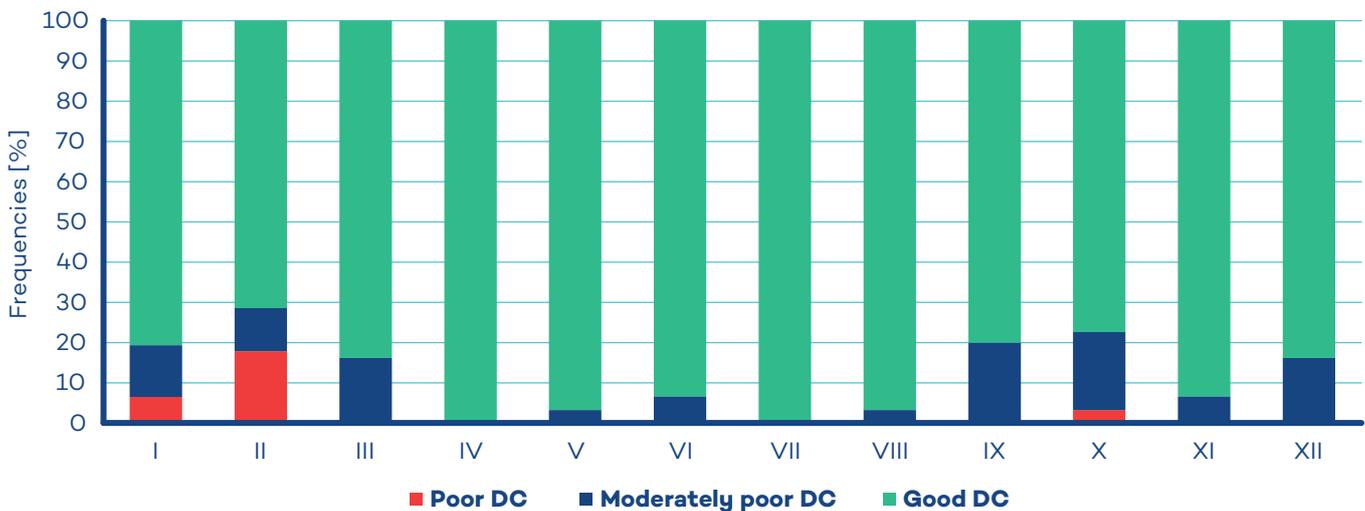
Fig. III.5 Frequency of occurrence of dispersion conditions (DC) by months of 2019

The number of degree-days during 2019 in the Czech Republic was significantly below normal compared to the long-term average 1988–2017, lower values were reached only in 2000, 2014 and 2018. In 2014, the highest average daily temperature on heating days was also reached. (Fig. III.6). During the individual months, the number of degree-days was below the long-term average, except for January and May with January assessed as normal in view of temperature and May as strongly below normal (Fig. III.7). The largest decrease in the number of degree-days compared to the long-term average was recorded in December, which is climatologically assessed as strongly above normal in temperature and has an improving effect on estimated emissions from domestic heating.
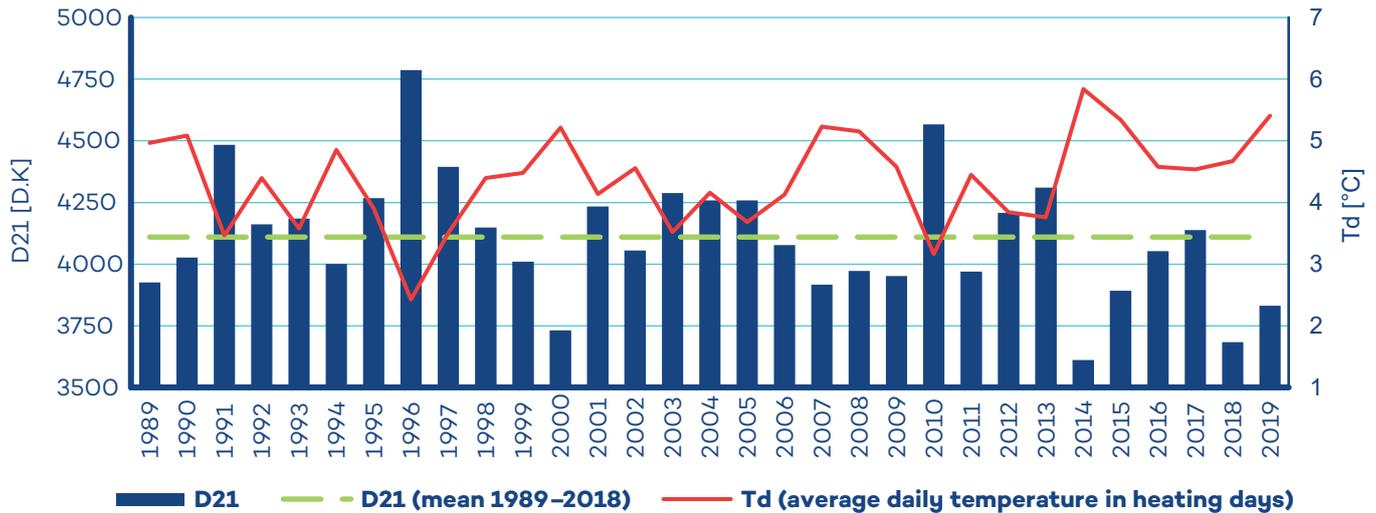
Fig. III.6 Annual heating seasons in the Czech Republic expressed as degree-days (D21) and their average for the 1989–2019 period
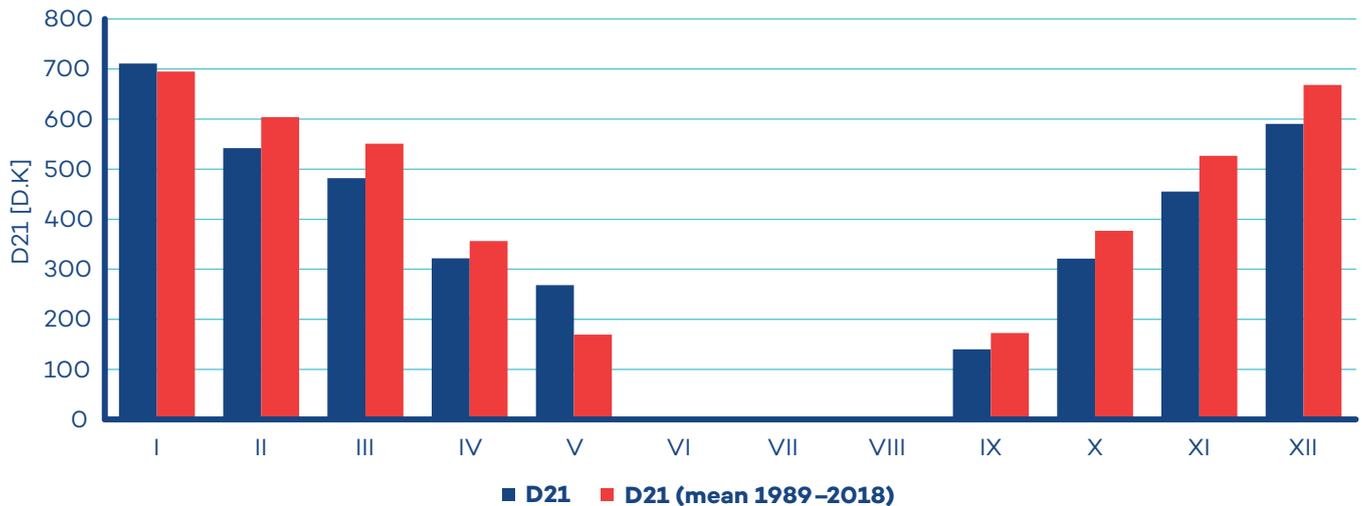
Fig. III.7 Annual variation of degree-days in the territory of the Czech Republic in the heating season 2019 (I–V, IX–XII) in comparison with the average of 1989–2019

IV. AIR QUALITY IN THE CZECH REPUBLIC

The evaluation of air quality set forth in this yearbook covers the entire territory of the Czech Republic. Documentation of compliance with legal requirements including areas where none of the pollution limit values are exceeded is one of the fundamental principles of Directive 2008/50/ES. Where the targets for ambient air quality stipulated in this Directive are not met the member states are obliged to take measures towards compliance with the pollution limit values and long-term air pollution targets. Air quality assessment is carried out with regard to the protection of population health and the protection of ecosystems and vegetation.

The air quality was evaluated for this yearbook employing the calculation criteria in Annex I of Directive 2008/50/ES and Annex IV of Directive 2004/107/ES. These annexes set the data quality targets for ambient air quality assessment. According to Annex I of Directive 2008/50/ES and Annex IV of Directive 2004/107/ES, air quality may be evaluated only using data from monitoring stations at which the requirement of minimum data collection of 90% was met, not including losses of data as a consequence of regular calibration or normal maintenance of the instrumental technology. Without prejudice to Annex I of Directive 2008/50/ES, data collection and calculation of statistical parameters are based on the criteria set forth in Annex XI of this Directive. As a consequence of these changes, some of the data presented in earlier yearbooks may differ slightly from the data presented in this yearbook.

The concentrations measured at the monitoring stations form the basis for evaluation of the air quality. The monitoring network is densest in areas with the highest pollution concentrations but nonetheless covers the entire Czech Republic. The National Air Quality Monitoring Network (NAQMN), operated by CHMI, forms the backbone of monitoring stations. It consists of both automated monitoring stations (AIM) and manual monitoring stations (MIM), from which samples are analysed in the CHMI laboratories. At many locations, the air pollution is monitored simultaneously by both automatic and manual methods. The national pollution monitoring network is supplemented by the monitoring stations of other organisations and their measurements are also employed in evaluating the air quality.

Fig. IV.1 Colour scale in the legend of the areal maps of polluting substances for classification of areas by assessment thresholds and areas above the pollution limit.

Map interpretation is an essential starting point for indication of areas where the pollution limit levels are exceeded from the viewpoint of protection of human health, for which the legislation requires preparation of programmes to improve the air quality or regulatory rules. A new uniform colour scale was introduced to improve orientation in the area maps of pollutants where a specific colour corresponds to a particular level of the air pollution (Fig. IV.1). Red symbols indicate substantial exceeding of the pollution limit level; other basic thresholds between categories consist in the lower and upper assessment limits. The diagram maps clearly depict the trends in pollution level characteristics in 2009–2019.

The graphs showing a course of pollution characteristics of selected pollutants in agglomerations and in the whole territory of the Czech Republic since 2009 (if data are available) show variations of air pollution levels, variations of pollution levels during the current year and pollutant concentrations at individual monitoring stations. A new uniform colour scale has been introduced to improve orientation in the graphs where a specific colour corresponds to a particular type of station (Fig. IV.2).

This is a simplified classification, which is based on the official EoI classification, including subcategories (for more detailed explanation and details, see CHMI 2020d). In the tables in the annex, the stations with the highest values of air pollution characteristics in 2019 are listed by individual pollutants. The values are arranged in descending order and the grey background indicates exceeding of the pollution limit level.

	Simplified classification	EoI locality classification
	regional stations (REG)	B/R/xxx-REG
	rural stations (R)	B/R/xxx-NCI
	suburban background stations (SUB)	B/S/xxx
	urban background stations (UB)	B/U/xxx
	traffic stations (T)	T/x/xxx
	industrial stations (I)	I/x/xxx

Fig. IV.2 Colour scale in the legend of the graphs for classification of monitoring stations by a type of station (x signifies any letter in the classification)

IV.1 Suspended particulate matter

Air pollution by suspended particulate matter of PM_{10} and $PM_{2.5}$ fractions remains one of the main problems to be resolved in ensuring air quality in the Czech Republic. Exceeding of the pollution limit levels for PM_{10} and $PM_{2.5}$ continues to make a significant contribution to the extent of areas with above-limit air pollution.

IV.1.1 Air pollution by suspended particulates in 2019

Suspended particulate matter PM_{10}

The 24-hour pollution limit level for PM_{10} (50 µg.m^{-3}, 35 permitted cases exceeding the limit value) was exceeded in 2019 at 5% of stations (7 stations of a total number of 147 with a sufficient amount of data for the evaluation; Tab. XII.1, Fig. IV.1.1, and Fig. IV.1.2). The cases exceeding the limit value occurred mainly in January, February and October (more than 70% of cases of the total

for all stations). It is a significant decrease compared to the year 2018 when exceeding of the daily PM_{10} limit value was recorded at 31% of stations (45 stations out of 144). The 24-hour limit value was exceeded only at stations in the O/K/F-M agglomeration and at the Kladno-Švermov urban station, where higher concentrations of suspended particles are measured due to emissions from local heating in the surrounding dense residential built-up area.

The pollution limit level for the average 24-hour concentration of PM_{10} was exceeded in 2019 on only 0.3% of the territory of the Czech Republic with approx. 0.9% of the population (Fig. IV.1.3). Compared to previous years (3.2% in 2018, 8.3% in 2017, 1.4% in 2016, and 2.5% in 2015), there was a decrease of the area of the Czech Republic exposed to the above-limit PM_{10} concentration (the 36th highest 24-hour concentration) corresponding also to low number of cases exceeding the limit value at the monitoring stations.

Inter-annual decrease of the territory where the 24-hour limit value was exceeded was apparent in all zones and regions of the Czech Republic. The most exposed continuous area, as in previous years (Fig. IV.1.4 and IV.1.5), was the O/K/F-M agglomeration where the 24-hour pollution limit level for PM_{10} was exceeded at one third of stations.

classification of stations
- ■ urban background
- ◆ suburban background
- ▲ rural
- ● traffic
- ★ industrial

number of LV exceedances
- 0
- 1–15
- 16–35
- 36–50
- > 50

0 25 50 100 km

- — agglomeration
- — zone
- — region
- — river
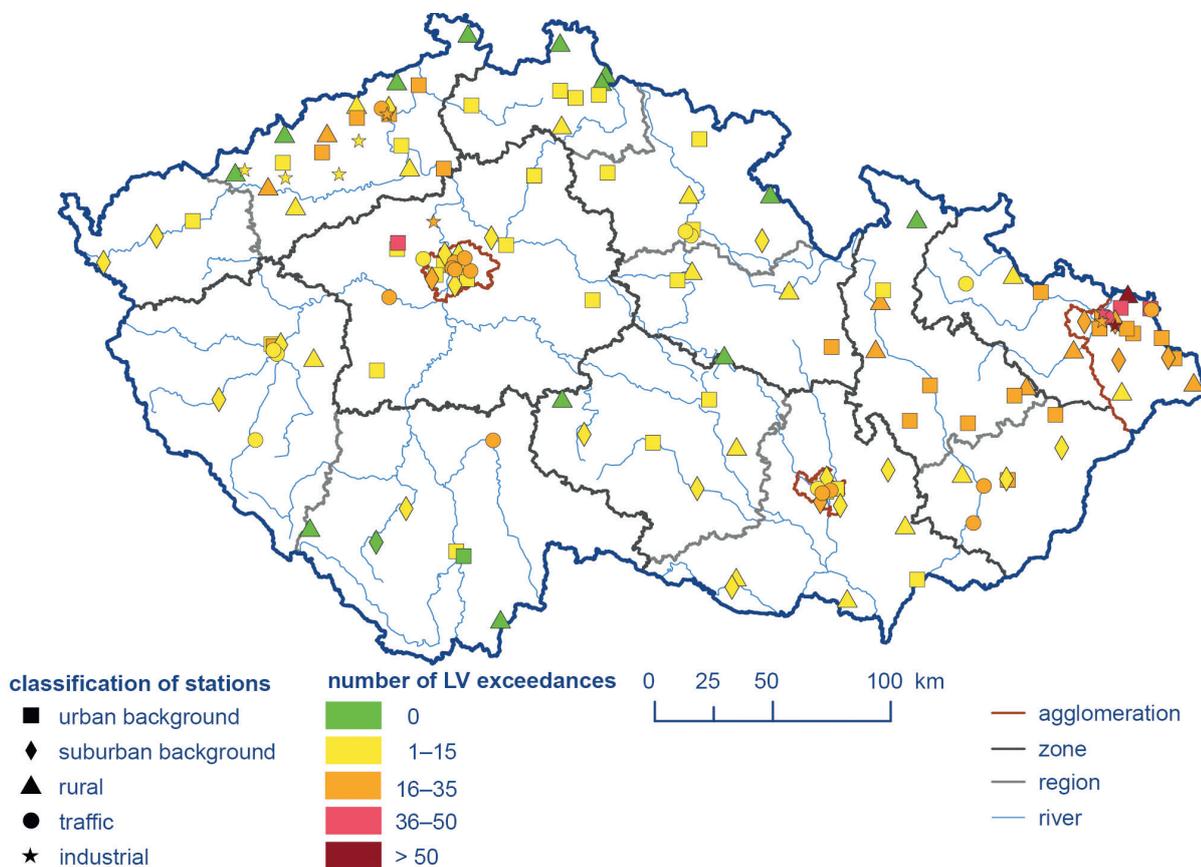
Fig. IV.1.1 Number of cases exceeding the pollution limit value of 24-hour average PM_{10} concentration at air quality monitoring stations, 2019

classification of stations

- ■ urban background
- ◆ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [μg.m⁻³]

- $\leq$ 25.0
- 25.1–35.0
- 35.1–50.0
- 50.1–60.0
- $>$ 60.0

0   25   50   100   km

— agglomeration
— zone
— region
— river
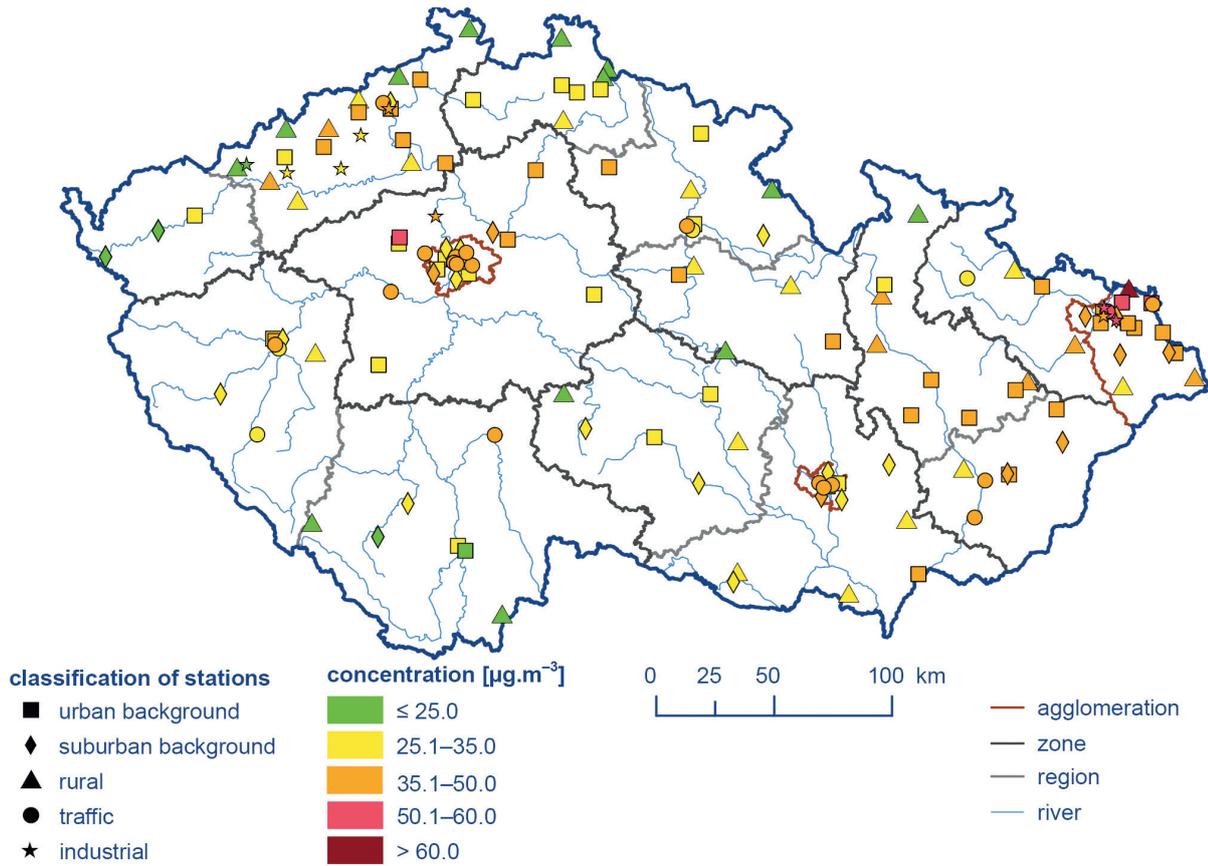
Fig. IV.1.2 36th highest 24-hour PM₁₀ concentrations at air quality monitoring stations, 2019

concentration [μg.m⁻³]

$\leq$ 25.0	31.10 %	
25.1–35.0	56.31 %	
35.1–50.0	12.32 %	
50.1–60.0	0.24 %	
$>$ 60.0	0.03 %	

0   25   50   100   km

— agglomeration
— zone
— region
⬡ municipality over 30K inhab.
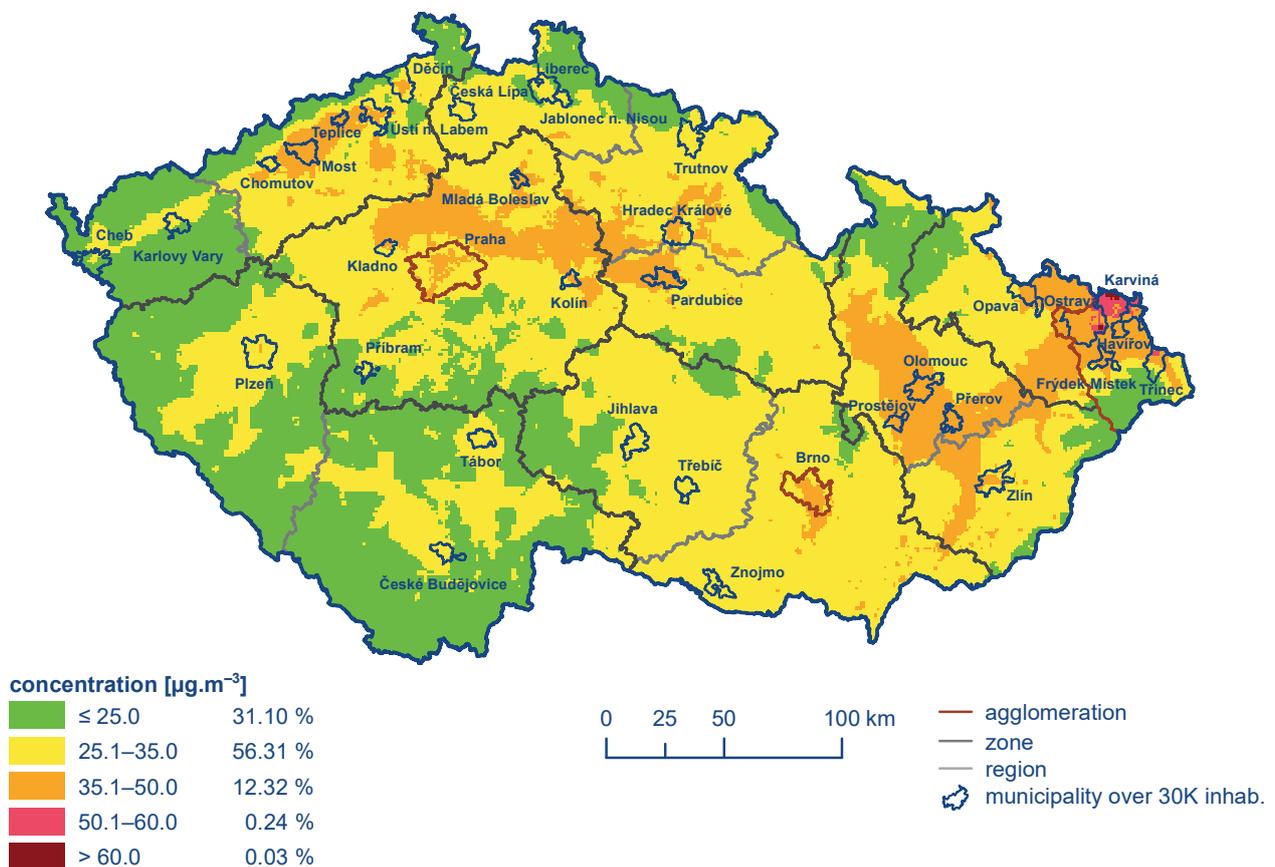
Fig. IV.1.3 Field of 36th highest 24-hour PM₁₀ concentration, 2019
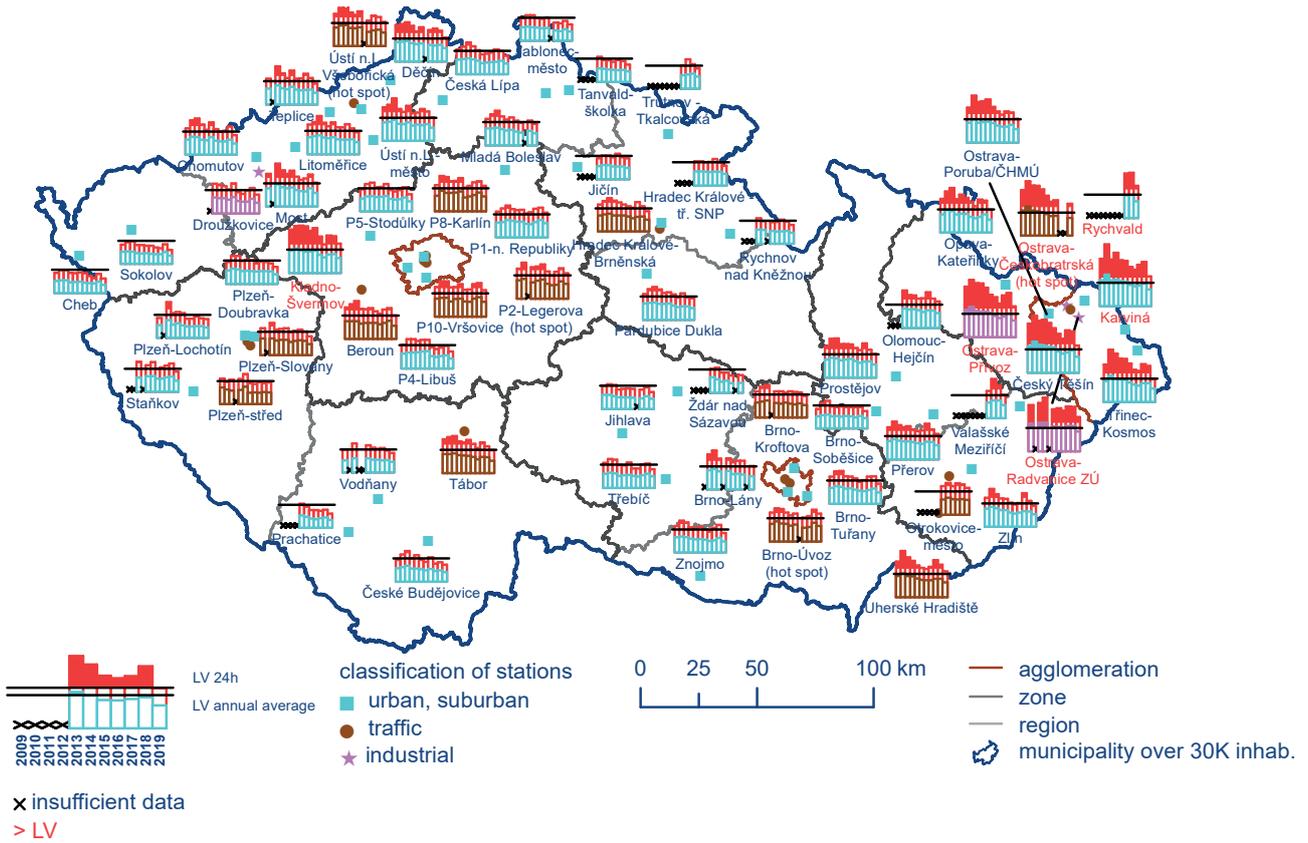
Fig. IV.1.4 36th highest 24-hour and annual average PM$_{10}$ concentrations at selected stations of UB, SUB, I, and T classification, 2009–2019
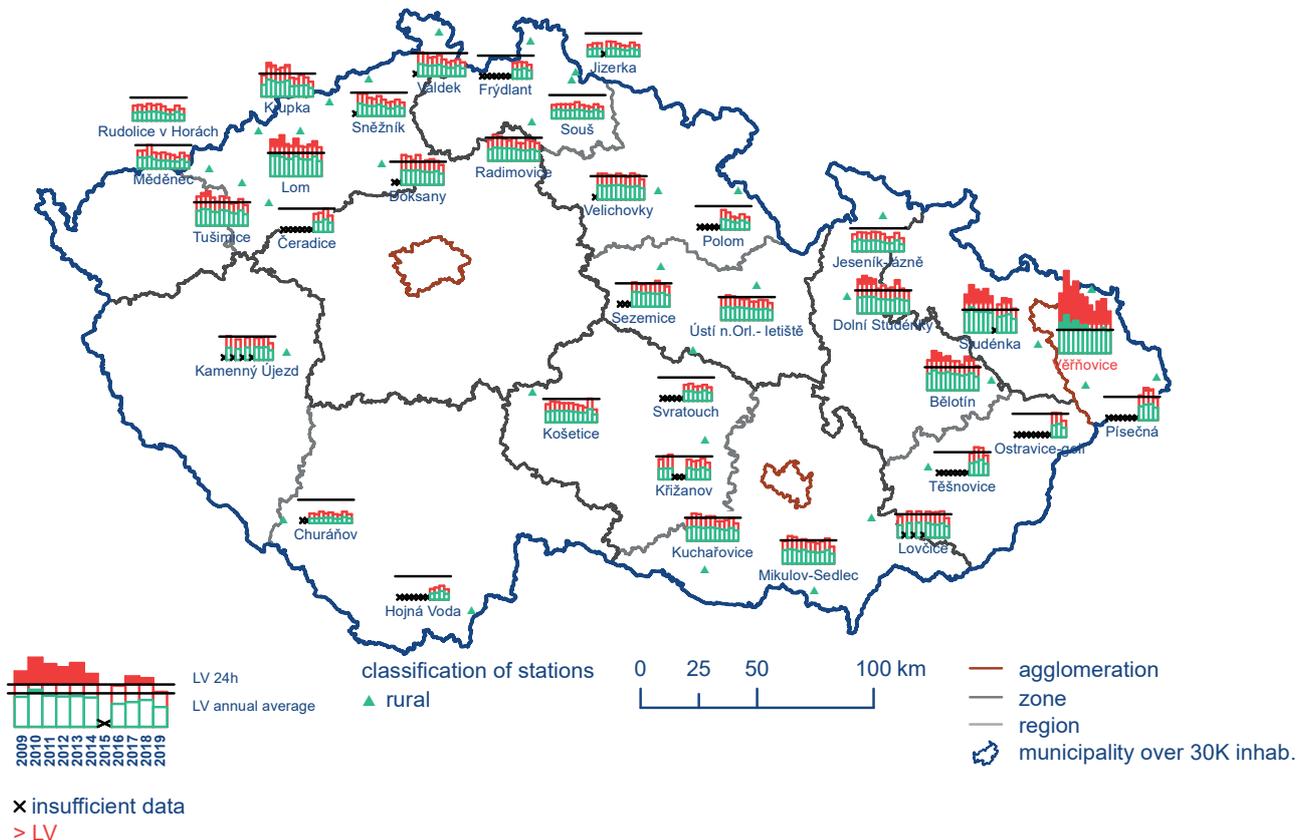
Fig. IV.1.5 36th highest 24-hour and annual average PM$_{10}$ concentrations at selected rural (R) stations, 2009–2019

The pollution limit level for the average annual concentration of PM_{10} (40 μg.m^{-3}) was not exceeded at any station in the Czech Republic in 2019, for the first time in the evaluated period 2009–2019 (Fig. IV.1.6, Fig. IV.1.7, Table XII.2). Subsequently, no territory of the Czech Republic with an above-limit annual average concentration of PM_{10} was defined (in a spatial resolution of 1x1 km) (Fig. IV.1.8). However, even in previous years, the annual average concentration of PM_{10} was exceeded only on 0.1% of the territory of the Czech Republic in 2018, on 0.02% of the territory in 2017, only local cases occurred in 2016 that were not reflected in the scale resolution of the map of annual average concentration, and 0.02% of the territory was affected in 2015. In terms of the five-year average of annual average concentrations, the most polluted area is the O/K/F-M agglomeration (Fig. IV.1.9).

classification of stations
- ■ urban background
- ♦ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [μg.m^{-3}]
- 🟩 ≤ 20.0
- 🟨 20.1–28.0
- 🟧 28.1–40.0
- 🟥 > 40.0

0 25 50 100 km

— agglomeration
— zone
— region
— river
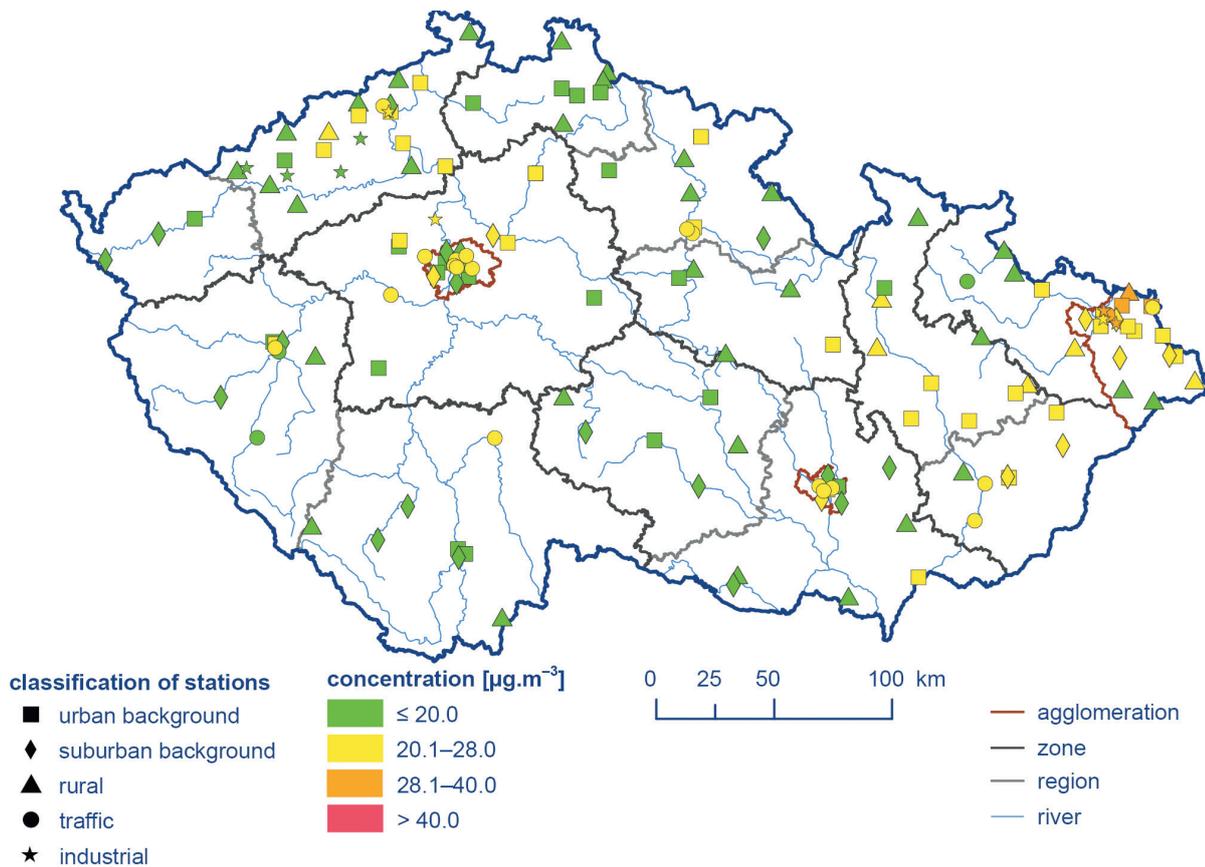
Fig. IV.1.6 Annual average PM_{10} concentrations at air quality monitoring stations, 2019

■ 24-hour concentration of PM_{10} ■ annual concentration of PM_{10} ■ annual concentration of $PM_{2.5}$
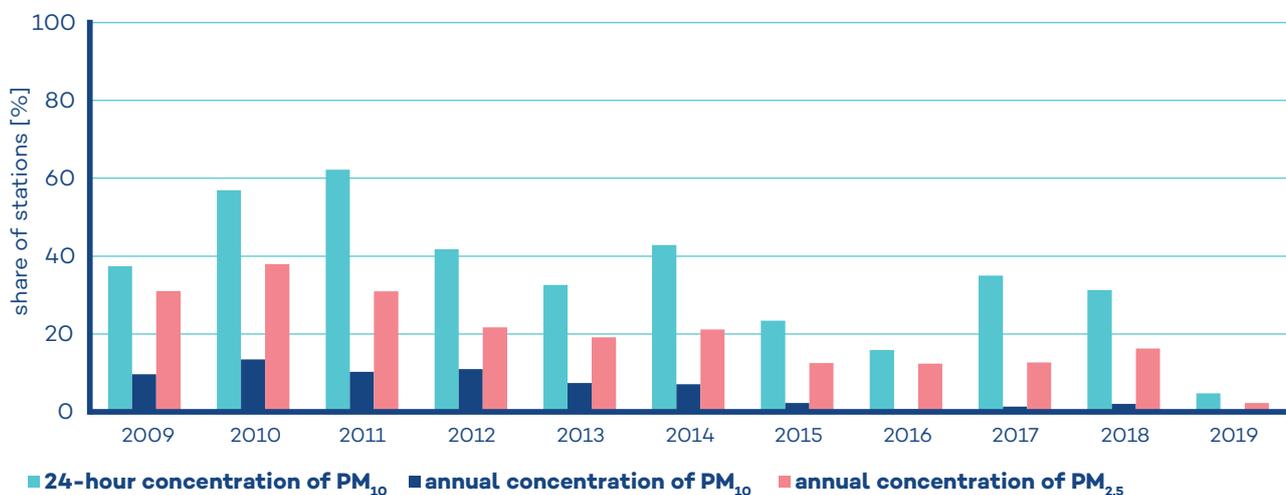
Fig. IV.1.7 Ratio of stations where the pollution limit level of 24-hour average PM_{10} concentration and of annual average PM_{10} and $PM_{2.5}$ concentration was exceeded, 2009–2019

concentration [µg.m^{-3}]

≤ 20.0	88.8 %
20.1–28.0	10.9 %
28.1–40.0	0.3 %
> 40.0	

agglomeration
zone
region
municipality over 30K inhab.
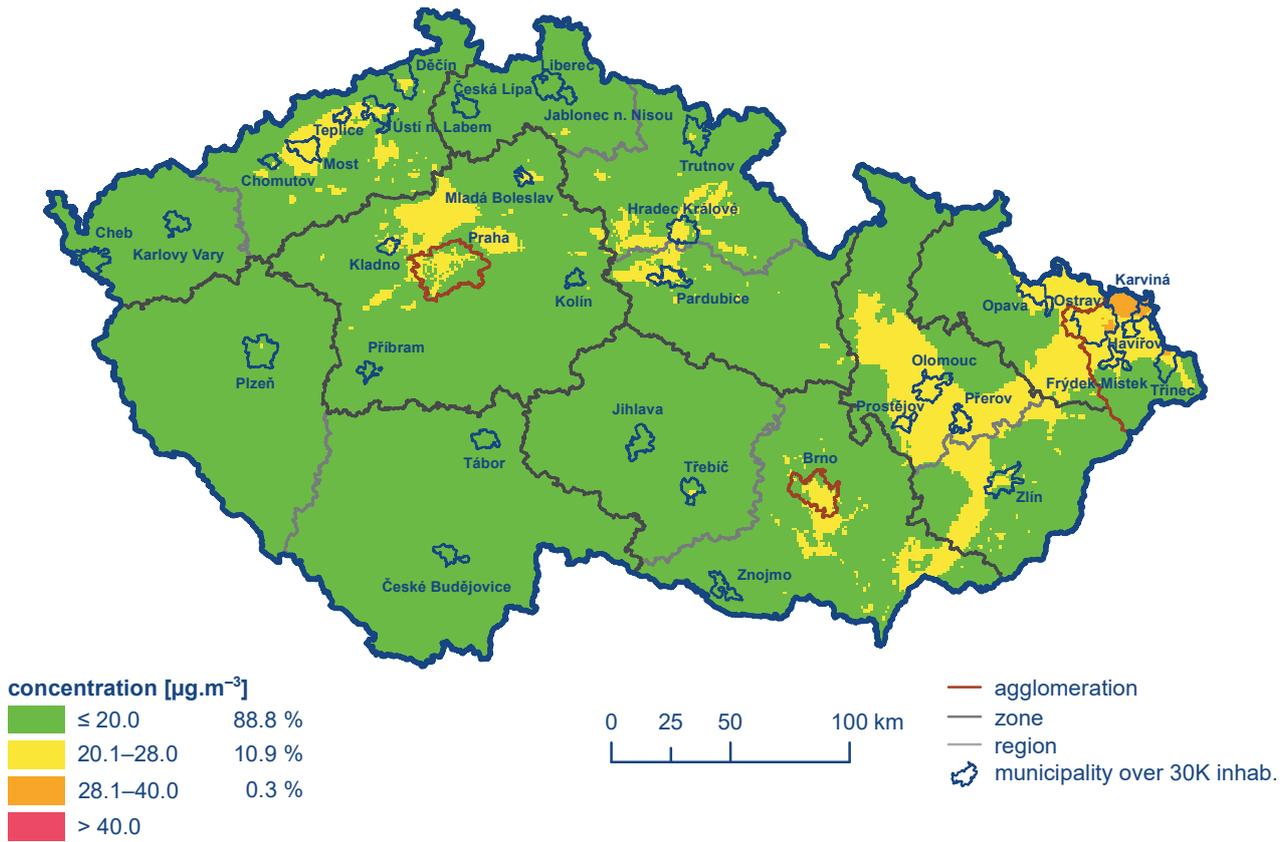
Fig. IV.1.8 Field of annual average PM$_{2.5}$ concentration, 2019

concentration [µg.m^{-3}]

<= 20.0	69.1 %
20.1–28.0	29.5 %
28.1–40.0	1.4 %
> 40.0	

agglomeration
zone
region
municipality over 30K inhab.
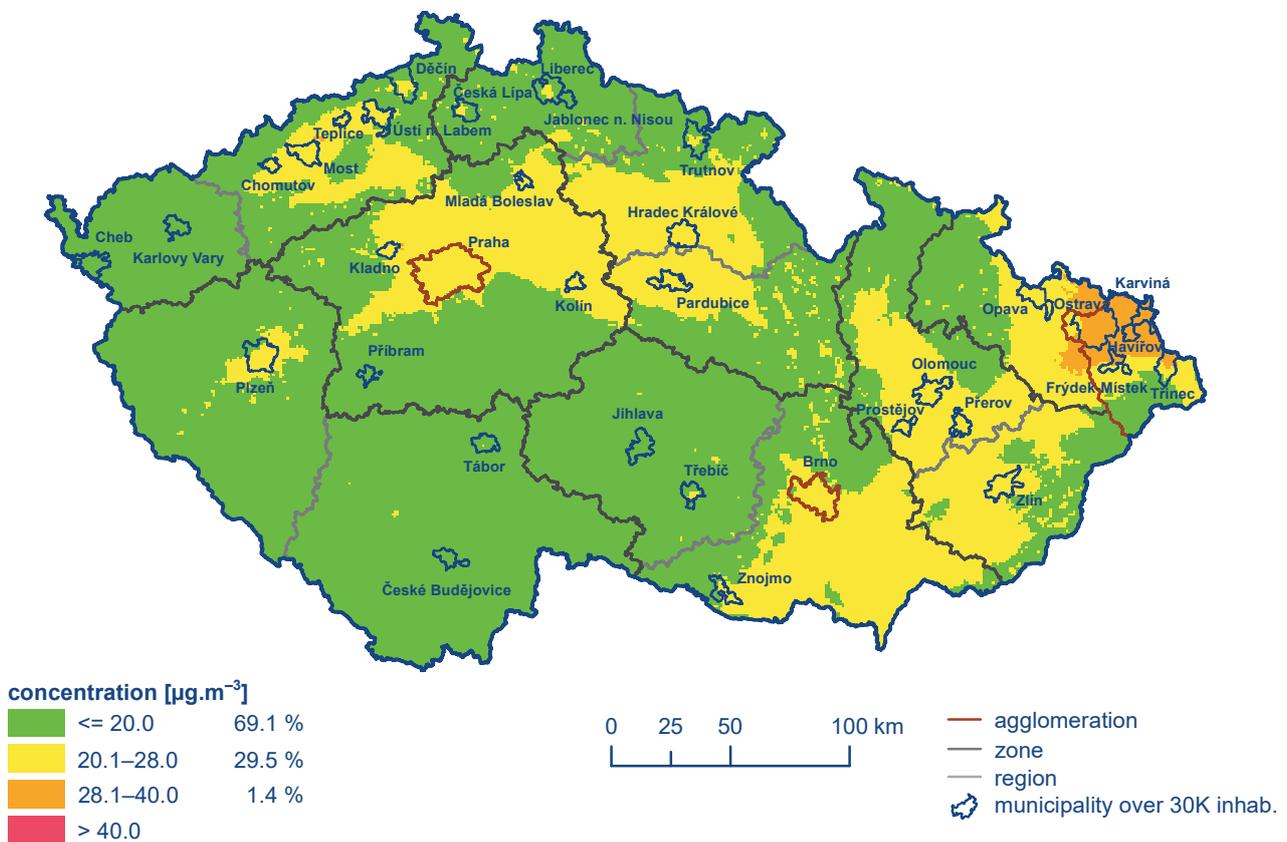
Fig. IV.1.9 Five-year average of annual average PM$_{10}$ concentrations, 2015–2019
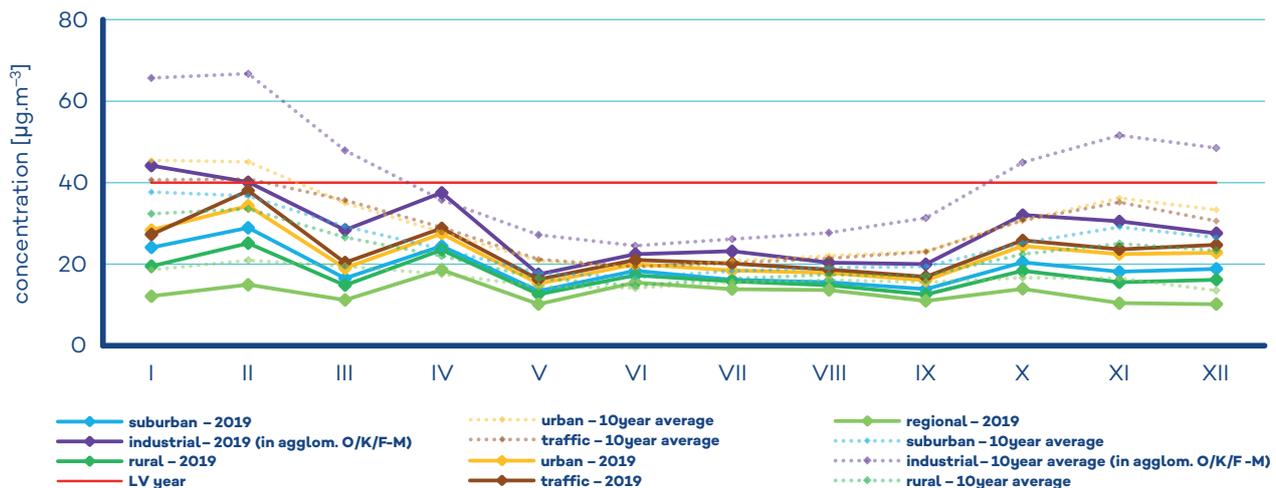
Fig. IV.1.10 Annual course of average monthly PM$_{10}$ concentrations (averages for a given type of station), 2019

The PM$_{10}$ concentrations exhibit a clear annual variation with the highest values in the colder months of the year (Fig. IV.1.10). Higher PM$_{10}$ concentrations in the air during the colder season are related both to greater emissions of particulates from the seasonally operated heating sources and also to deteriorated dispersion conditions. For example, local heating sources contribute nearly 59% to PM$_{10}$ emissions and 74% to PM$_{2.5}$ emissions in the Czech Republic (Fig. IV.1.20 and IV.1.22).

The annual variation of PM$_{10}$ concentrations in 2019 demonstrated less distinct shape compared to ten-year average having a clear dominance of autumn and winter months characterised by the least frequent occurrence of good dispersion conditions. In 2019, the highest concentrations of PM$_{10}$ were measured mostly in January and February which corresponds to the occurrence of moderately poor to poor conditions and, in addition, to below--normal precipitation amount in February. Higher concentrations were also measured in April, when the second lowest monthly precipitation total (after February) was recorded (in 2019).

Based on a comparison of monthly averages of PM$_{10}$ concentrations with ten-year average (2009–2019), it can be stated that average monthly concentrations at monitoring stations were lower (by about 20–40%) in all months of the year except April, June and July, when they remained at similar levels. The decrease in PM$_{10}$ concentrations at stations was significant especially in the winter months, the largest in January, March and November. In the period June – August, the change in monthly concentrations in 2019, compared to the ten-year average, was the smallest, which again points to the importance of seasonal sources and the importance of meteorological and dispersion conditions during winter months. The minimal change in concentrations until their increase in April 2019, compared to the ten-year average, corresponds to the already mentioned below-normal amount of precipitation in April 2019. The below-normal amount of precipitation probably caused a minimal change in concentration compared to the ten-year average at traffic stations in February 2019, experiencing stronger resuspension of particulates due to passing vehicles.

Due to the high concentrations of suspended PM$_{10}$ particles, 5 smog situations were announced. All smog situations and regulations occurred in January. Smog situations were announced in the territory of the O/K/F-M agglomeration without Třinec, further in the Třinec district, in the Moravian-Silesia zone and in the Zlín and Olomouc regions (for more details see Chapter VI.).

Suspended particulate matter PM$_{2.5}$

In 2019, exceeding of the pollution limit level for the average annual concentration of PM$_{2.5}$ (25 µg.m^{-3}) was recorded at 2 stations (2.2%) of a total of 89 stations (Tab. XI.3; Fig. IV.1.11). In 2018, the values were 13 stations (16.2%) out of a total of 80 stations and in 2017 at 10 stations (12.7%) out of 79. Both stations (the Veřňovice rural background station and the Ostrava-Radvanice ZÚ industrial station), where the average annual concentration of PM$_{2.5}$ was exceeded in 2019, are located in the territory of the Moravian-Silesia region in the O/K/F-M agglomeration (Fig. IV.1.6 and Fig. IV.1.11).

The pollution limit level for the average annual concentration of PM$_{2.5}$ was exceeded, in 2019, over 0.04% of the territory of the Czech Republic with approx. 0.1% of the population (Fig. IV.1.12). In 2018, it concerned 1.2% of the area with 6.1% of the population, in 2017, it concerned 0.9% of the area with 4.9% of the population, in 2016, it concerned 0.5% of the area with 3% of the population, and in 2015, the indicators were 0,9% of the area with approx. 5.1% of the population.

In the evaluated period 2009–2019, the above-limit annual average concentrations of PM$_{2.5}$ were observed mainly on the territory of the O/K/F-M agglomeration (Fig. IV.1.13). In terms of the five--year average of annual average concentrations of PM$_{2.5}$, the most polluted area is the O/K/F-M agglomeration (Fig. IV.1.14).

Higher concentrations of PM$_{2.5}$ occur mainly in the colder part of the year (Fig. IV.1.15) and, similar to PM$_{10}$, are a consequence of

classification of stations
- ■ urban background
- ♦ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [µg.m^{-3}]
- ≤ 10.0
- 10.1–12.0
- 12.1–17.0
- 17.1–25.0
- > 25.0

0 25 50 100 km

— agglomeration
— zone
— region
— river
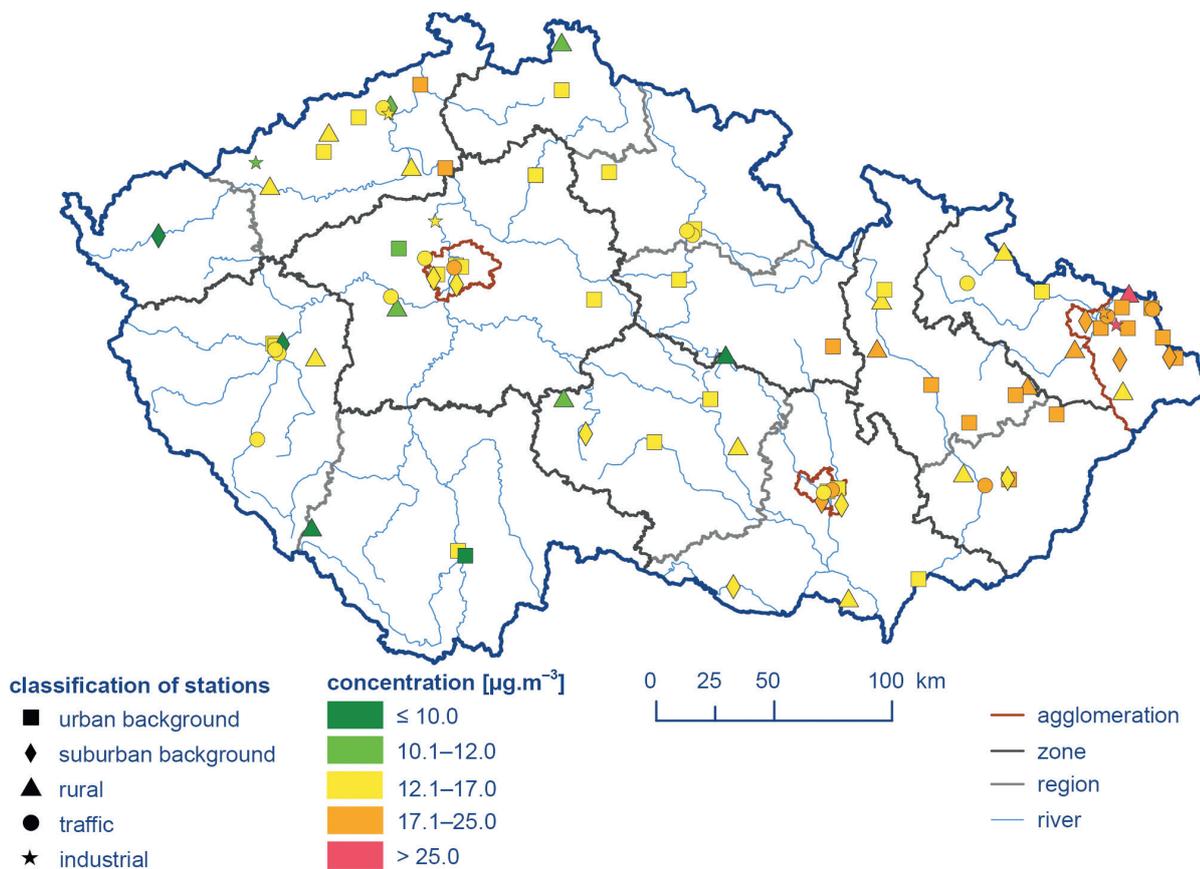
Fig. IV.1.11 Annual average PM$_{2.5}$ concentrations at air quality monitoring stations, 2019

concentration [µg.m^{-3}]

	≤ 10.0	27.78 %
	10.1–12.0	30.00 %
	12.1–17.0	39.69 %
	17.1–25.0	2.49 %
	> 25.0	0.04 %

0 25 50 100 km

— agglomeration
— zone
— region
— municipality over 30K inhab.
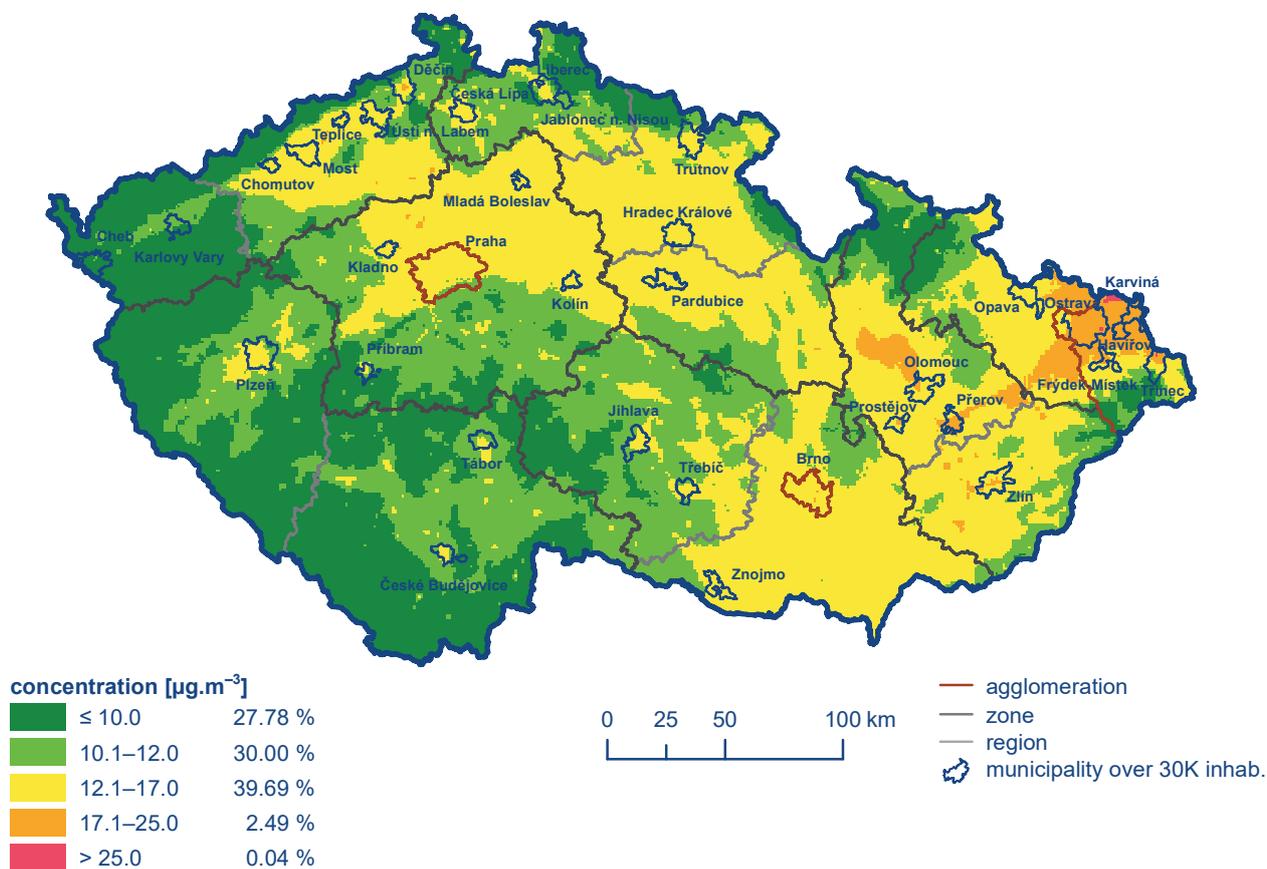
Fig. IV.1.12 Field of annual average PM$_{2.5}$ concentration, 2019

LV annual average

× insufficient data
> LV
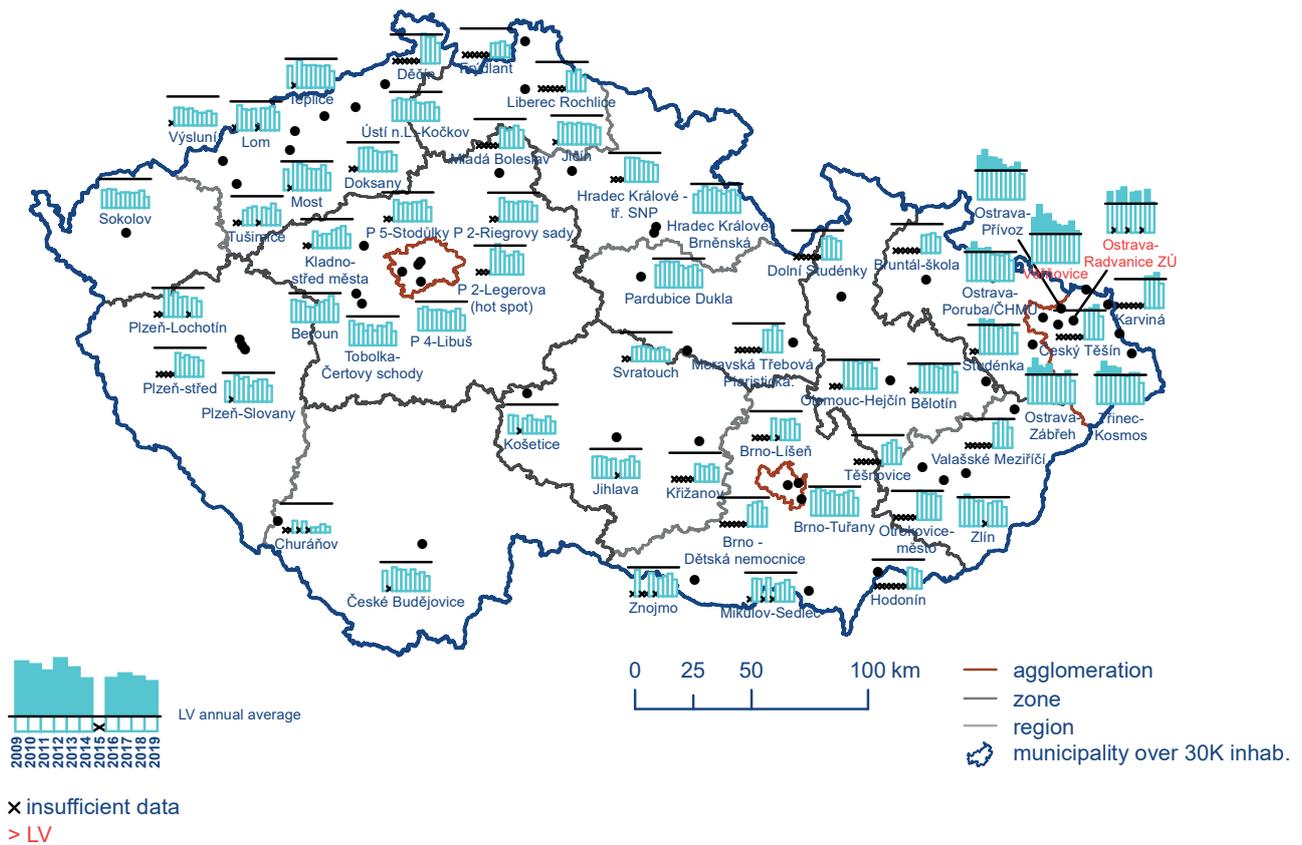
Fig. IV.1.13 Annual average PM$_{2.5}$ concentrations at selected stations, 2009-2019

concentration [µg.m^{-3}]

≤ 10.0	10.4 %
10.1–12.0	19.9 %
12.1–17.0	56.1 %
17.1–25.0	13.0 %
> 25.0	0.6 %

agglomeration
zone
region
municipality over 30K inhab.
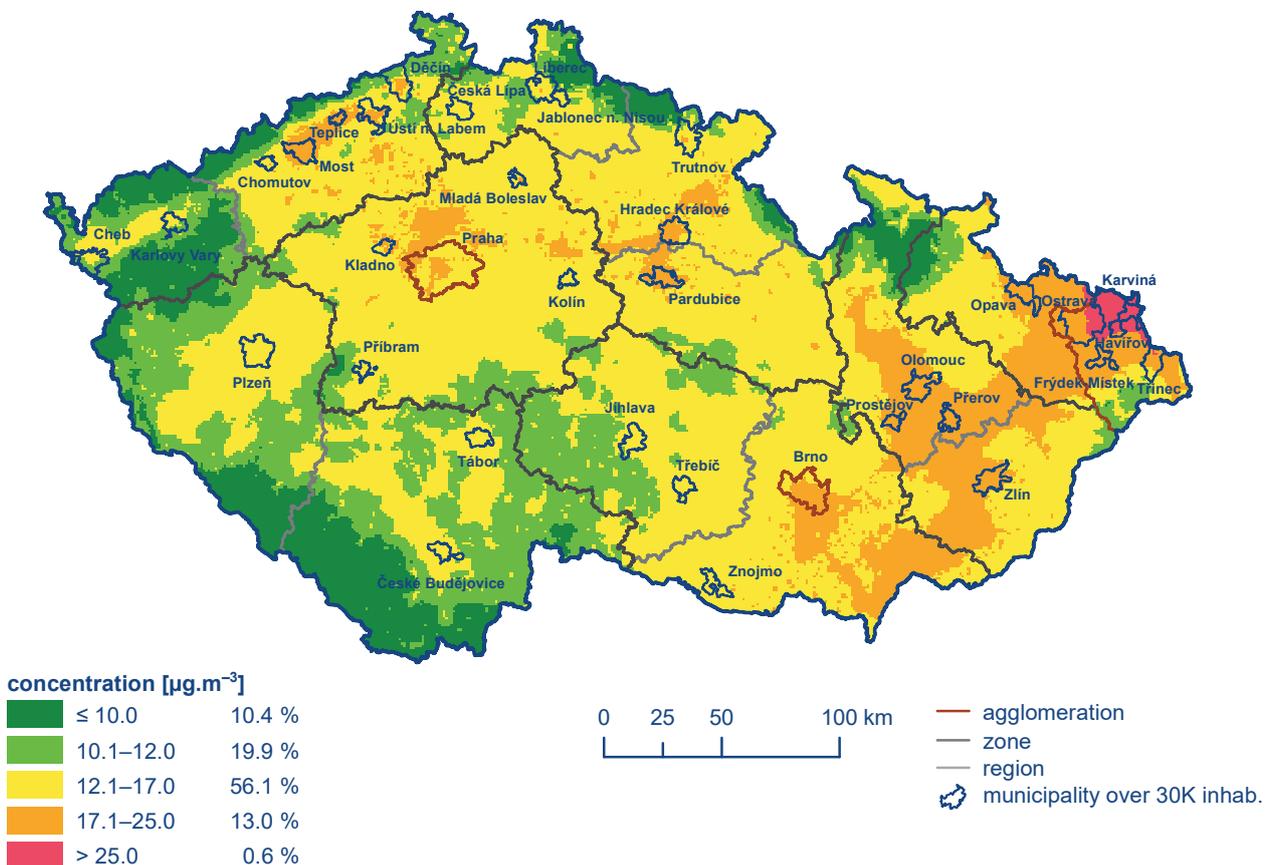
Fig. IV.1.14 Five-year average of annual average PM$_{2.5}$ concentrations, 2015–2019
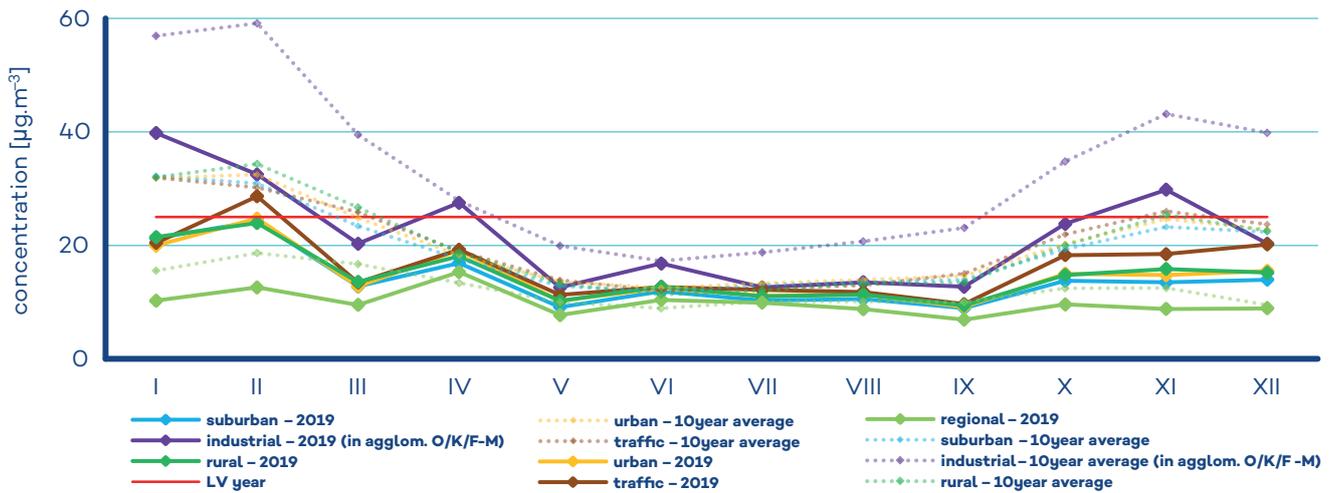
Fig. IV.1.15 Annual course of average monthly PM$_{2.5}$ concentrations (averages for a given type of station), 2019

emissions from heating sources and of worsened dispersion conditions. Monthly PM$_{2.5}$ concentrations show a variation very similar to the annual variation of PM$_{10}$, including a significant decrease in average monthly concentrations compared to their ten-year average.

A new pollution limit value for the annual average PM$_{2.5}$ concentration will come into force in 2020. An evaluation of the situation with respect to the future limit value (20 µg.m^{-3}) based on the concentrations measured in 2019 can be found in Annex II.

Ratio of the PM$_{2.5}$ and PM$_{10}$ suspended particle fractions

The ratio of the PM$_{2.5}$ and PM$_{10}$ fractions is not constant but exhibits seasonal variations and is also dependent on the character of

the location (Fig. IV.1.16). In 2019, this ratio varied on an average from measurements at 58 stations in the Czech Republic, where PM$_{2.5}$ and PM$_{10}$ are measured simultaneously and the locations have a sufficient number of measurements for the evaluation, in the range from 0.61 (July and September) to 0.84 (January). In Prague, where the annual variations are affected by the high fraction of traffic locations, this ratio was in the range from 0.57 (September) to 0.85 (January), in Brno from 0.62 (September) to 0.85 (January), in the Moravian-Silesia region from 0.65 (June, August, and September) to 0.87 (January) and in the Ústí nad Labem region from 0.58 (September) to 0.84 (January).

When the ratio of PM$_{2.5}$ and PM$_{10}$ fractions is compared by a type of location, the ratio at rural locations ranges from 0.58 (July) to 0.86 (January), at urban background from 0.62 (September) to 0.85 (January), at suburban background from 0.60 (September) to 0.85 (January), at traffic locations from 0.58 (July) to 0.81 (Ja-
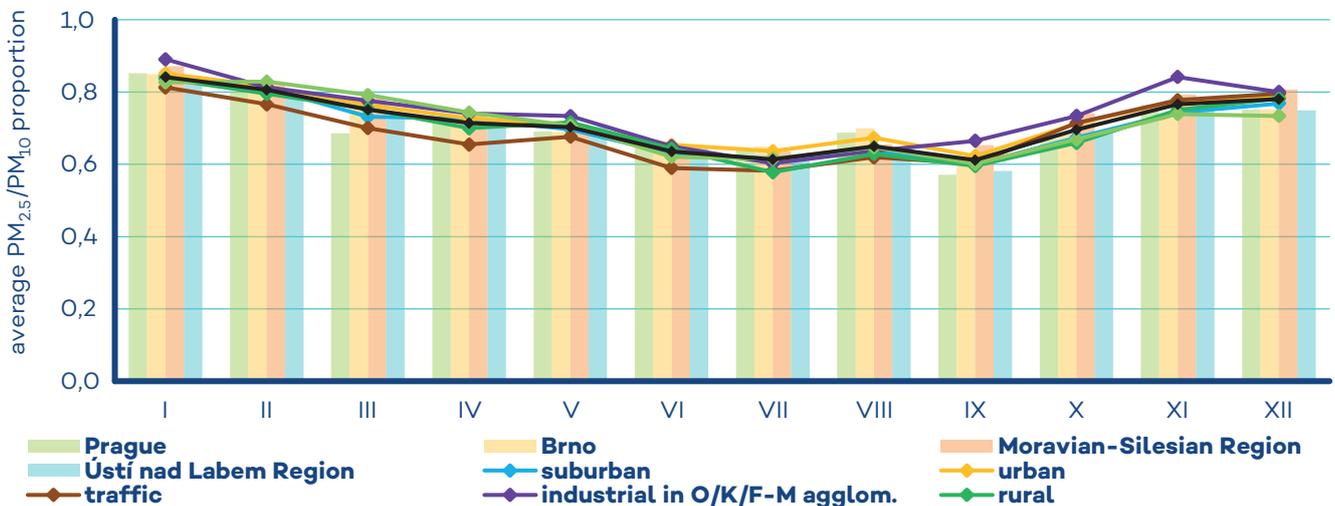
Fig. IV.1.16 Monthly average ratios of PM$_{2.5}$/PM$_{10}$, 2019

nuary), and at industrial locations from 0.60 (July) to 0.89 (January).

The annual variation in the ratio of the $PM_{2.5}$ and PM_{10} fractions is related to a seasonal character of certain emission sources. Emissions from combustion sources exhibit a greater content of the $PM_{2.5}$ fraction than, e.g., emissions from agricultural activities and resuspension during dry and windy weather. Heating in winter can thus lead to a greater content of the $PM_{2.5}$ fraction in the PM_{10} fraction. The decrease during the spring and beginning of the summer is explained by some studies also as being a result in the amount of larger biogenic particulates, e.g. pollen (Gehrig, Buchmann 2003).

The $PM_{2.5}$ to PM_{10} ratio is the smallest at traffic locations (Fig. IV.1.16). In combustion of fuel in traffic, the particulates belong mainly to the $PM_{2.5}$ fraction and the ratio should therefore be high at traffic locations. The fact that this is not the case emphasises the importance of emissions of the largest particulates from abrasion of tyres, brake linings and roads. The content of the larger fraction at traffic stations also increases as a consequence of resuspension of particulates from winter grit scattering. An increase in the PM_{10} concentration can also occur as a result of greater abrasion of the road surface by grit and subsequent resuspension of the abraded material (EC 2011). On the contrary, the higher ratio of $PM_{2.5}$ and PM_{10} fractions resulting from emissions from combustion processes is observed at industrial stations.

Suspended particulate matter PM_1

The fine particulate PM_1 fraction was measured at 24 stations in 2019, of which 19 stations had a sufficient amount of data for evaluation. These included four stations in Pilsen, three stations in the Brno agglomeration and in the Prague agglomeration, two stations in the O/K/F-M agglomeration and in the Ústí nad Labem district and one station each in the districts of České Budějovice, Klatovy, Litoměřice, Mělník and Zlín (Table XI.4). The highest annual concentrations (19.9 µg.m⁻³) and the maximum daily concentrations (235.3 µg.m⁻³) were measured at the Ostrava-Českobratrská traffic station (hot spot).

IV.1.2 Trends in the concentrations of suspended particulates PM_{10} and $PM_{2.5}$

The time variation of concentrations of suspended PM_{10} particles at particular types of stations is evaluated for the last 11 years, i.e. 2009–2019 (except for industrial stations where valid data are not available for 2009 and 2010). The highest concentrations of suspended particulates observed in 2010 were caused especially by the occurrence of poor meteorological conditions in winter and the coldest heating season since 1996 (Fig. III.6). In the period 2011–2016, the 36th highest 24-hour concentrations and the annual average concentrations show a decrease. The decrease in the PM_{10} concentrations was manifested at stations in all the categories (Fig. IV.1.17–18). A slight increase of concentrations occurred in 2017 mainly due to poor dispersion conditions at the beginning and at the end of the year. In 2018, the concentrations at individual types of stations remained at similar levels or slightly increased and, compared to 2017, increased on an average. In 2019, a significant decrease in the 36th highest 24-hour concentration and the annual average concentration of PM_{10} was observed. In 2019, the concentrations at most stations reached their minima in the evaluated period as well as since the beginning of measurements in the 1990s. Compared to the eight-year average of concentrations from all stations (which is almost the same as the ten-year average from all stations except industrial stations due to lack of valid data), the 36th highest 24-hour concentration and annual average concentration of PM_{10} decreased by about 23% and 22%, respectively.

The annual average concentrations of $PM_{2.5}$ show a similar time variation as the concentrations of PM_{10}, i.e. they reached their maxima in 2010, and then, by 2016, a decrease is apparent. In 2017 and 2018 there is an increase and in 2019 a significant decrease. Compared to the seven-year average (decades cannot be evaluated due to lack of valid data), annual average concentrations of $PM_{2.5}$ ranged around the average value of 19.4 µg.m⁻³, in 2019 they decreased compared to the seven-year average by about 24% (Fig. IV.1.19).

The decrease in the concentrations of suspended particulates PM_{10} and $PM_{2.5}$ can be attributed to a combination of factors — the year 2019 was extremely above-normal in terms of temperature and normal in terms of precipitation. In addition, in 2019, compared with the ten-year average, there were improved dispersion conditions. These factors lead to lower emissions from heating and better dispersion of emissions from various sources. At the end of the year — in November and December — poor dispersion conditions did not occur as usual in comparison with other years (for more see Chapter III). The decrease in concentrations can also be attributed to the measures already implemented to improve air quality (replacement of boilers), the progressive renewal of the vehicle fleet and measures at large sources (see subchapters II and IV.1.3).
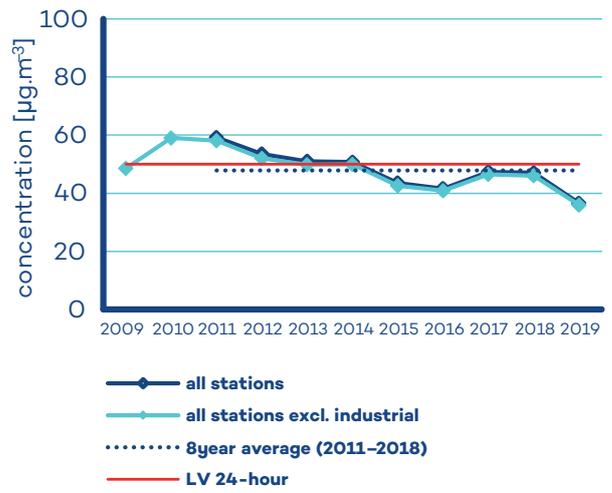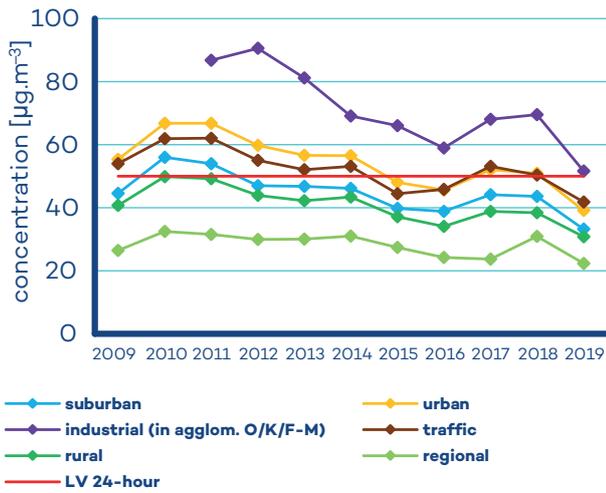
Fig. IV.1.17 36ᵗʰ highest 24-hour PM₁₀ concentrations at particular types of stations in the Czech Republic, 2009–2019
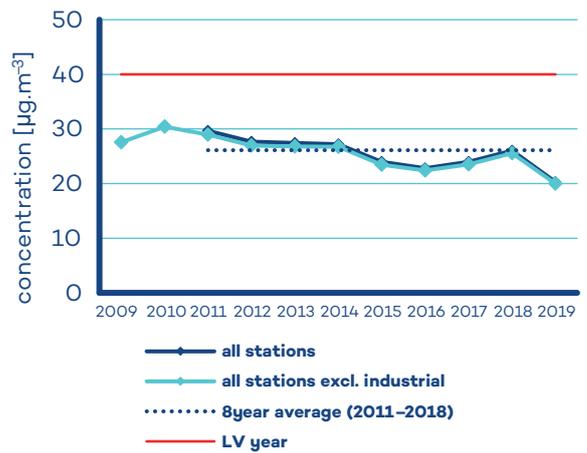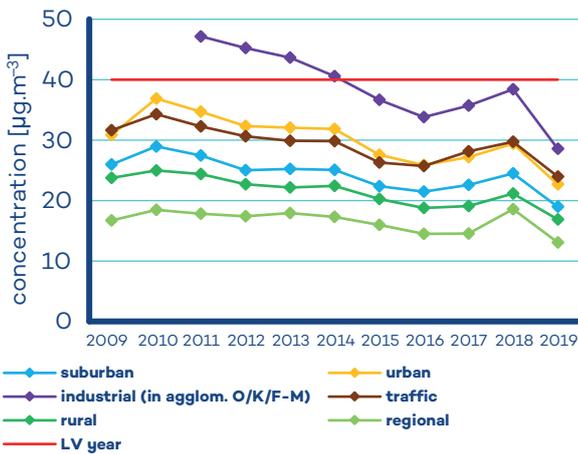
Fig. IV.1.18 Annual average PM₂.₅ concentrations at particular types of stations in the Czech Republic, 2009–2019
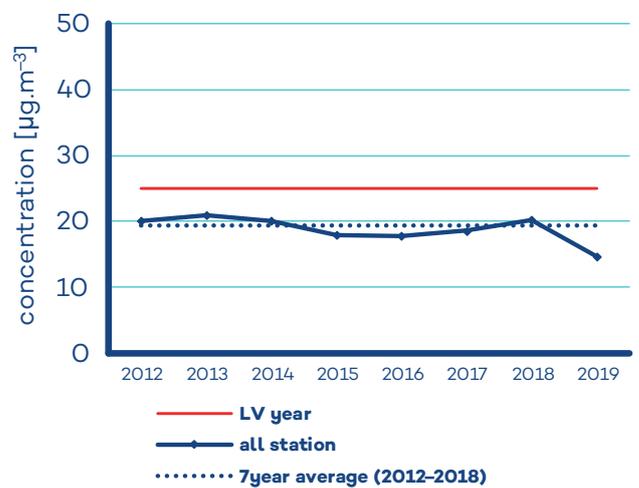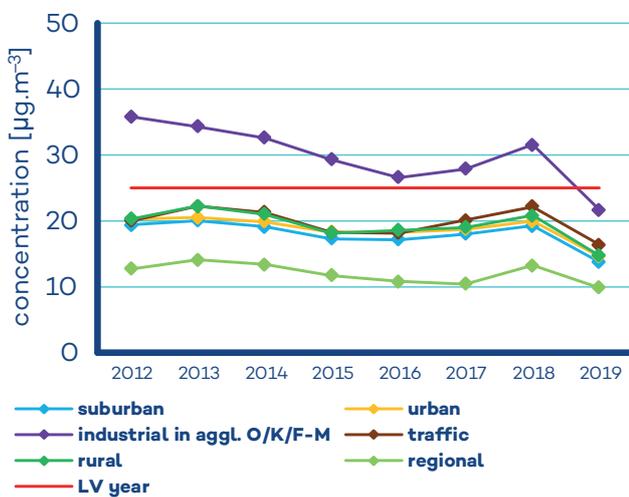
Fig. IV.1.19 Annual average PM₁₀ concentrations at particular types of stations in the Czech Republic, 2009–2019

IV.1.3 Emissions of PM$_{10}$ and PM$_{2.5}$

Aerosols originating from fuel combustion and other industrial activities can exist in a form of solid, liquid or mixed suspended matter. In their complexity, these aerosols are denoted as solid pollutants (SP) in the Czech legislation and as Total Suspended Particulates (TSP) in foreign literature. SP emissions have varying size and chemical composition resulting from the characteristics of the source and the mode of formation. They can contain heavy metals and act as a carrier medium for VOC and PAH. PM$_{10}$ and PM$_{2.5}$ size fractions are most frequently distinguished in emission inventories in relation to pollution limit levels.
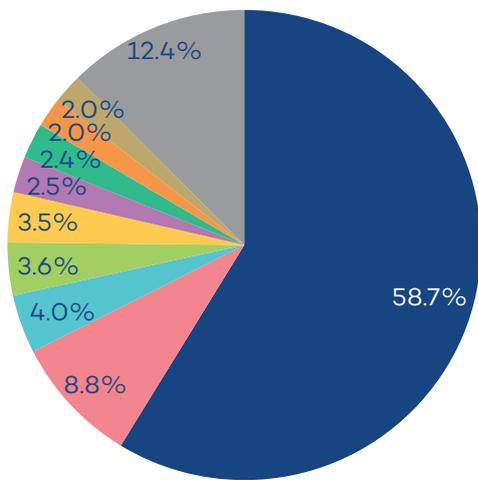
Emission inventories of PM$_{10}$ and PM$_{2.5}$ prepared according to current regulations include only the primary emissions of these substances. Simultaneously, a considerable contribution to concentrations of PM$_{10}$ and PM$_{2.5}$ measured in the air comes from secondary suspended particulates formed directly in the air from gaseous precursors by physical-chemical reactions. The fraction of secondary suspended inorganic particulates in total PM$_{2.5}$ concentrations in urban environments can vary between 20 and 40% (Vlček, Corbet 2011). The contribution of secondary suspended organic particulates of biogenic origin under European conditions can equal 2−4 µg.m^{-3} (Fuzzi et al. 2015).

Compared to emissions of other pollutants, particulate matter emissions in the air originate from a great many significant groups of sources. In addition to sources from which these substances are emitted through controlled chimneys or stacks (industrial sources, local heating units, transport), significant amounts of PM emissions originate from fugitive sources (quarries, dusty material dumps, operations involving dusty materials, etc.). Emissions from abrasion of tyres, brake linings and abrasion of roads calculated from traffic levels are also included. The quality of the air is also affected by resuspension of particles (stirring-up), which is not included in the standard emission inventories.

The main sources of particulate matter emissions in 2018 included 1A4bi sector — Residential: Stationary, which contributed to air pollution on a country-wide scale with 58.7% PM$_{10}$ substances and 73.9% PM$_{2.5}$ substances. Further important sources of PM$_{10}$ emissions included the 3Dc sector – Farm-level agricultural operations including storage, handling and transport of agricultural products where these emissions are formed during tillage of the soil, harvesting and cleaning agricultural crops. This sector represented 8.8% of PM$_{10}$ emissions. A substantial risk to human

Fig. IV.1.20 Share of NFR sectors in total PM$_{2.5}$ emissions, 2018

Other

2A5a – Quarrying and mining of minerals other than coal

1A3bi – Road transport: Passenger cars

1A4cii – Agriculture/Forestry/Fishing: Off-road vehicles and other machinery

2G – Other product use

1A3bvi – Road transport: Automobile tyre and brake wear

1B1a – Fugitive emission from solid fuels: Coal mining and handling

1A1a – Public electricity and heat production

3Dc – Farm-level agricultural operations

1A4bi – Residential: Stationary

Fig. IV.1.21 Total PM$_{10}$ emissions, 2009–2018

health is caused by particulates coming from transport, especially from fuel combustion in diesel engines which produce particles with a size of units to hundreds of nanometres (Vojtíšek 2010). Transport contributed 11.2% to PM_{10} emissions and 11.1% to $PM_{2.5}$ emissions (Fig. IV.1.20 and Fig. IV.1.22).

Fuel consumption in households in the period 2009–2018 can be characterised by a gradual growing trend in the use of biomass in

contrast to other solid fuels related to a wide availability, affordability and subsidy support for the replacement of boilers. Natural gas consumption shows a slightly declining trend. The reduction in the consumption of not only natural gas but also coal fuels between 2017–2018 (Fig. II.7) can be attributed to the increased supply of firewood due to the bark beetle calamity. There is a slight reduction in PM emissions due to the natural renewal of the vehicle fleet, a decrease in agricultural production and steadily declining emissions of the listed sources, e.g. due to the application of the best available techniques for reducing SP emissions (fabric filters) in energy and industry. Total PM_{10} and $PM_{2.5}$ emissions in the period 2009–2018 declined (Fig. IV.1.21 and Fig. IV.1.23).

In individual regions of the Czech Republic, the contribution by sectors varies depending on the composition of sources in a given area. As the main source of PM_{10} and $PM_{2.5}$ emissions is represented by local heating, the production of these substances is also distributed throughout the territory of the Czech Republic with residential buildings (Fig. IV.1.24 and Fig. IV.1.25). When the territory of the Czech Republic is divided into 5x5 km grid, areas with higher emissions correspond to sites where important energy sources burning solid fossil fuels (the Ústí nad Labe region) and large industrial complexes (the Moravian-Silesia region) are located. The fraction of emissions from transport is greater primarily in large cities.
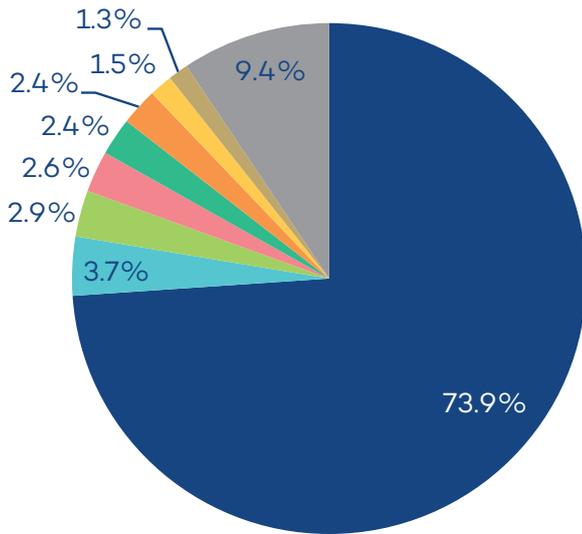
Fig. IV.1.22 Share of NFR sectors in total PM_{10} emissions, 2018

■ Other

■ 1A3bvii– Road transport: Automobile road abrasion

■ 2A5a – Quarrying and mining of minerals other than coal

■ 2G – Other product use

■ 1A3bvi– Road transport: Automobile tyre and brake wear

■ 1A3bi – Road transport: Passenger cars

■ 1A4cii– Agriculture/Forestry/Fishing: Off-road vehicles and other ma

■ 1A1a – Public electricity and heat production

■ 1A4bi– Residential: Stationary

Fig. IV.1.23 Total $PM_{2.5}$ emissions, 2009–2018

specific emissions [t.km⁻².year⁻¹]

- ☐ ≤ 0.1
- 🟩 > 0.1–0.5
- 🟨 > 0.5–1.0
- 🟧 > 1.0–2.5
- 🟥 > 2.5–5
- 🟫 > 5–10
- 🟪 > 10

0 25 50 100 km

—— district
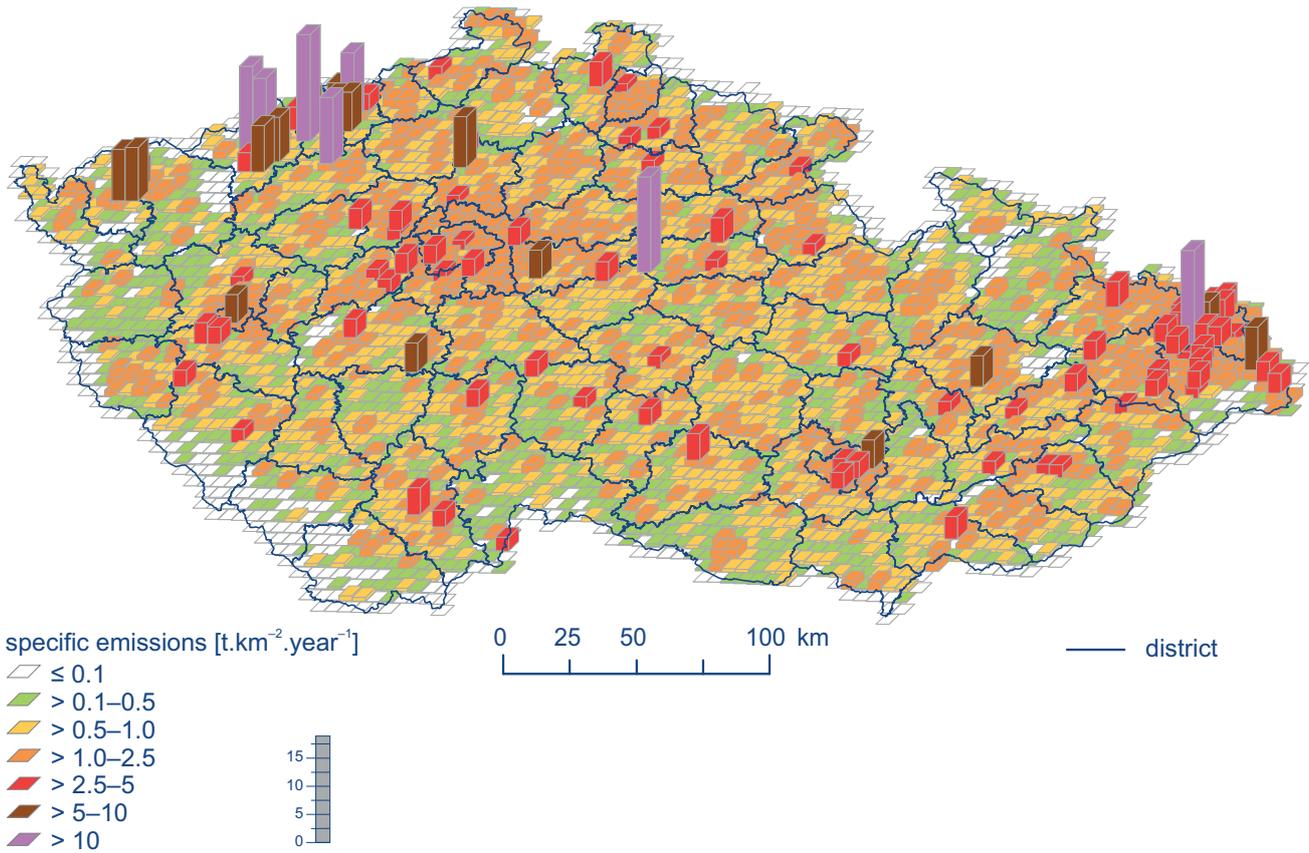
Fig. IV.1.24 PM$_{10}$ emission densities in 5x5 km spatial resolution squares, 2018

specific emissions [t.km⁻².year⁻¹]

- ☐ ≤ 0.1
- 🟩 > 0.1–0.5
- 🟨 > 0.5–1.0
- 🟧 > 1.0–2.5
- 🟥 > 2.5–5
- 🟫 > 5–10
- 🟪 > 10

0 25 50 100 km

—— district
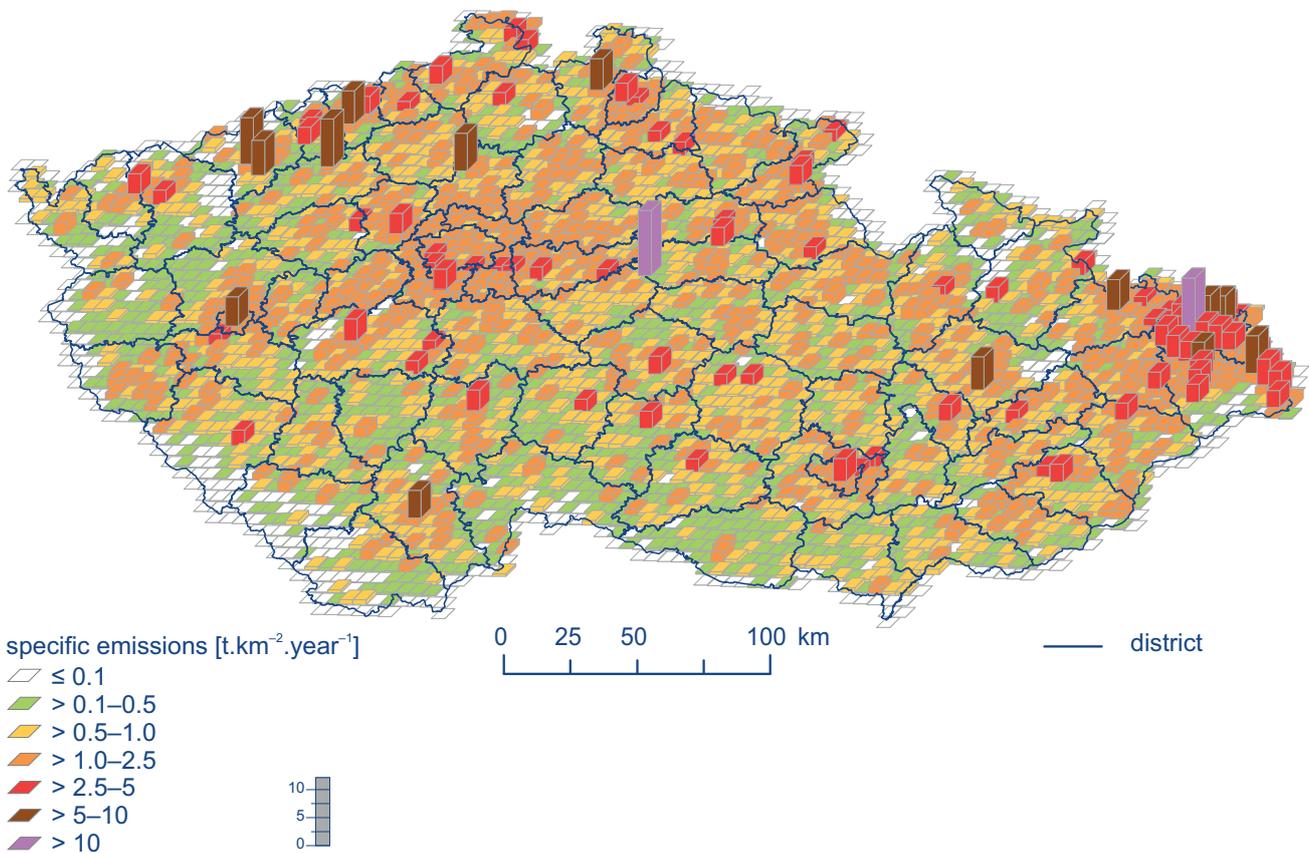
Fig. IV.1.25 PM$_{2.5}$ emission densities in 5x5 km spatial resolution squares, 2018

IV.2 Benzo[*a*]pyrene

IV.2.1 Air pollution by benzo[*a*]pyrene in 2019

Air pollution by benzo[*a*]pyrene is one of the main air quality problems in the Czech Republic. In 2019, the annual average concentration of benzo[*a*]pyrene exceeded the pollution limit value (1 ng.m^{-3}) at 41% of stations (i.e. 19 of a total of 46 stations with sufficient number of measurements for evaluation; Fig. IV.2.1). Thus, in the year-on-year comparison 2018/2019, there was a further decline, as in 2018 exceeding of the limit was recorded at 58% of stations (in 2017 at 66%). A number of cities and municipalities, similar to previous years, were evaluated as territories where the pollution limit levels were exceeded (Fig. IV.2.2). In 2019, the area with above-limit concentrations of benzo[*a*]pyrene decreased and the pollution limit was exceeded on 8.4% of the area of the Czech Republic (in 2018 on 13% of the area of the CR) with approx. 27.5% of the population of the CR (in 2018 with approx. 35.6%). The largest decrease of the area in which the limit value of benzo[*a*]pyrene was exceeded in comparison with the previous year 2018 occurred in the Krušné hory and Kladno areas. The regions with the highest concentrations of benzo[*a*]pyrene remain the Moravian-Silesia, Zlín and Olomouc regions (Fig. IV.2.3).

It must be borne in mind that the estimate of the fields of annual average concentrations of benzo[*a*]pyrene (Fig. IV.2.2) is accompanied by considerably greater uncertainties than for the other evaluated substances. Limited number of measurements at rural regional stations and the absence of more extensive measurements in smaller settlements in the Czech Republic where the air pollution by benzo[*a*]pyrene would demonstrate the fundamental effect of local heating units take also part in the uncertainty of the map. The CHMI is trying to counter this effect with the method of rotating stations which will allow monitoring of multiple sites over a period of several years. Thus, 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 a capacity of laboratories for processing the benzo[*a*]pyrene samples. The uncertainties in the maps are described in detail in Annex No. 1.

The highest annual average concentrations of benzo[*a*]pyrene have long been recorded in the whole area of the Ostrava/Karviná/Frýdek-Místek agglomeration (O/K/F-M) (Fig. IV.2.4) due to the highest emission load in the Czech Republic (from various types of sources) and the impact of cross-border transmission from Poland (for details see Chap. V.3). As in previous years, in 2019 also, the highest annual average concentration of benzo[*a*]pyrene (8.7 ng.m^{-3}) was recorded at the Ostrava – Radvanice ZÚ industrial station where the limit value was thus exceeded more than eight times. Apart from the O/K/F-M

classification of stations
- ■ urban background
- ◆ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [ng.m^{-3}]
- ≤ 0.4
- 0.5–0.6
- 0.7–1.0
- 1.0–2.0
- > 2.0

0 25 50 100 km

— agglomeration
— zone
— region
— river
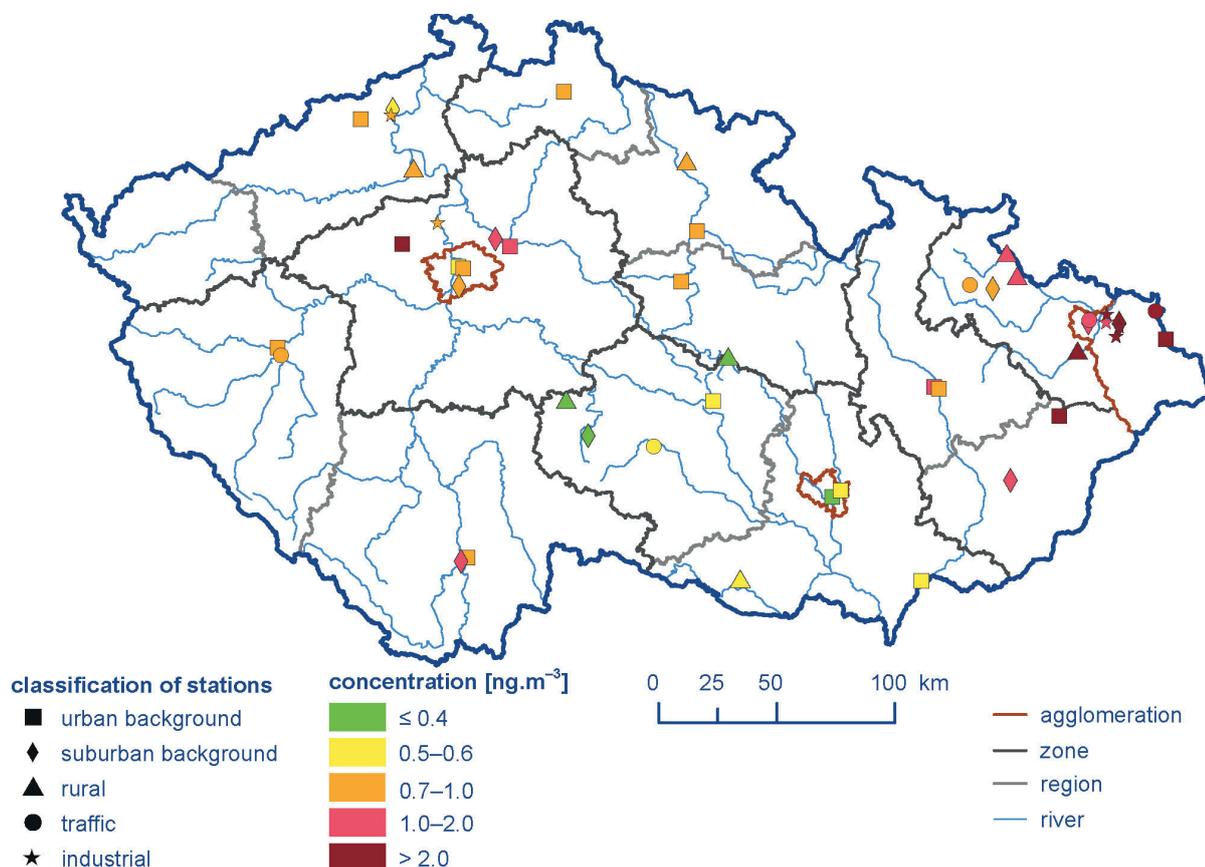
Fig. IV.2.1 Annual average concentrations of benzo[*a*]pyrene in the ambient air quality network, 2019

concentration [ng.m^{-3}]	
≤ 0.4	50.6 %
0.5–0.6	17.5 %
0.7–1.0	23.5 %
1.1–2.0	7.1 %
> 2.0	1.3 %

—	agglomeration
—	zone
—	region
⬡	municipality over 30K inhab.
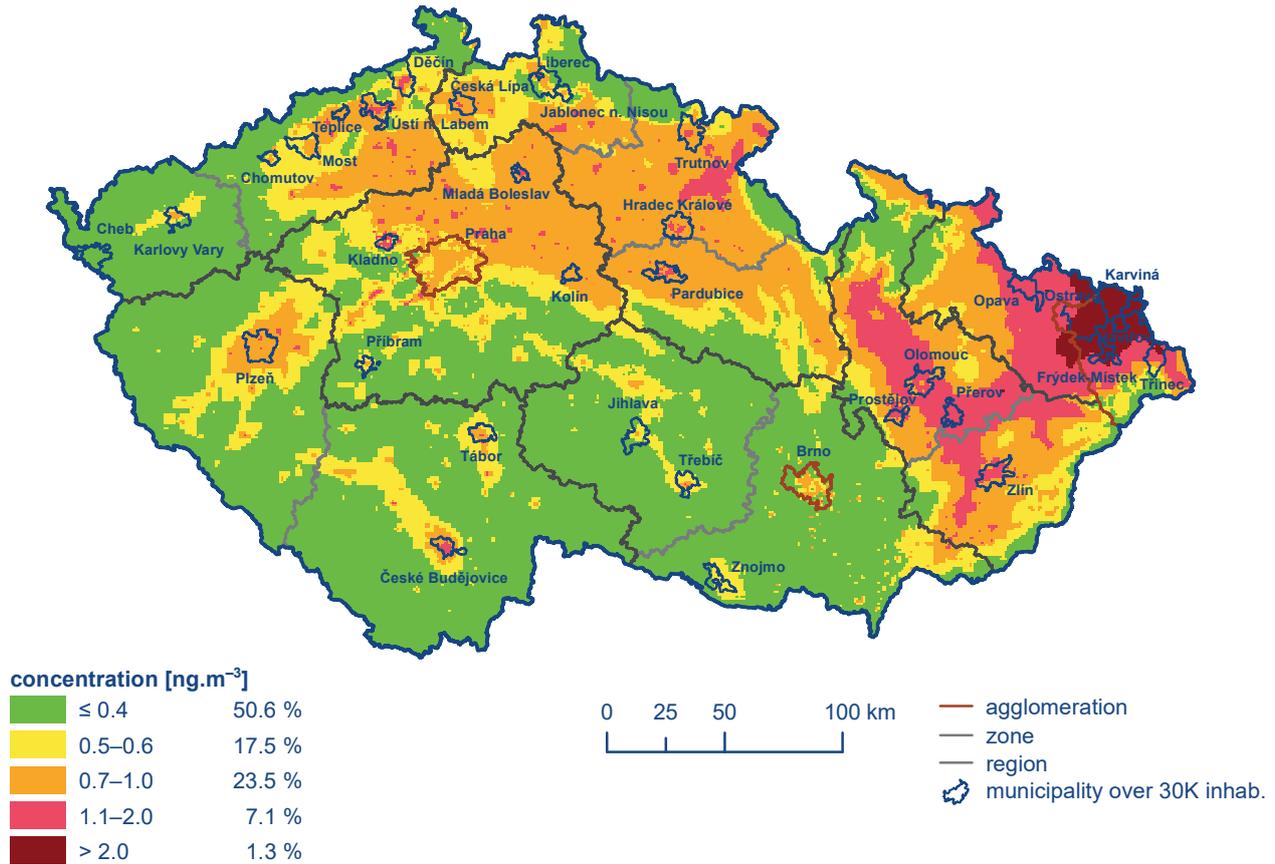
Fig. IV.2.2 Field of annual average concentration of benzo[*a*]pyrene, 2019

concentration [ng.m^{-3}]	
≤ 0.4	38.4 %
0.5–0.6	19.5 %
0.7–1.0	27.1 %
1.1–2.0	12.8 %
> 2.0	2.2 %

—	agglomeration
—	zone
—	region
⬡	municipality over 30K inhab.
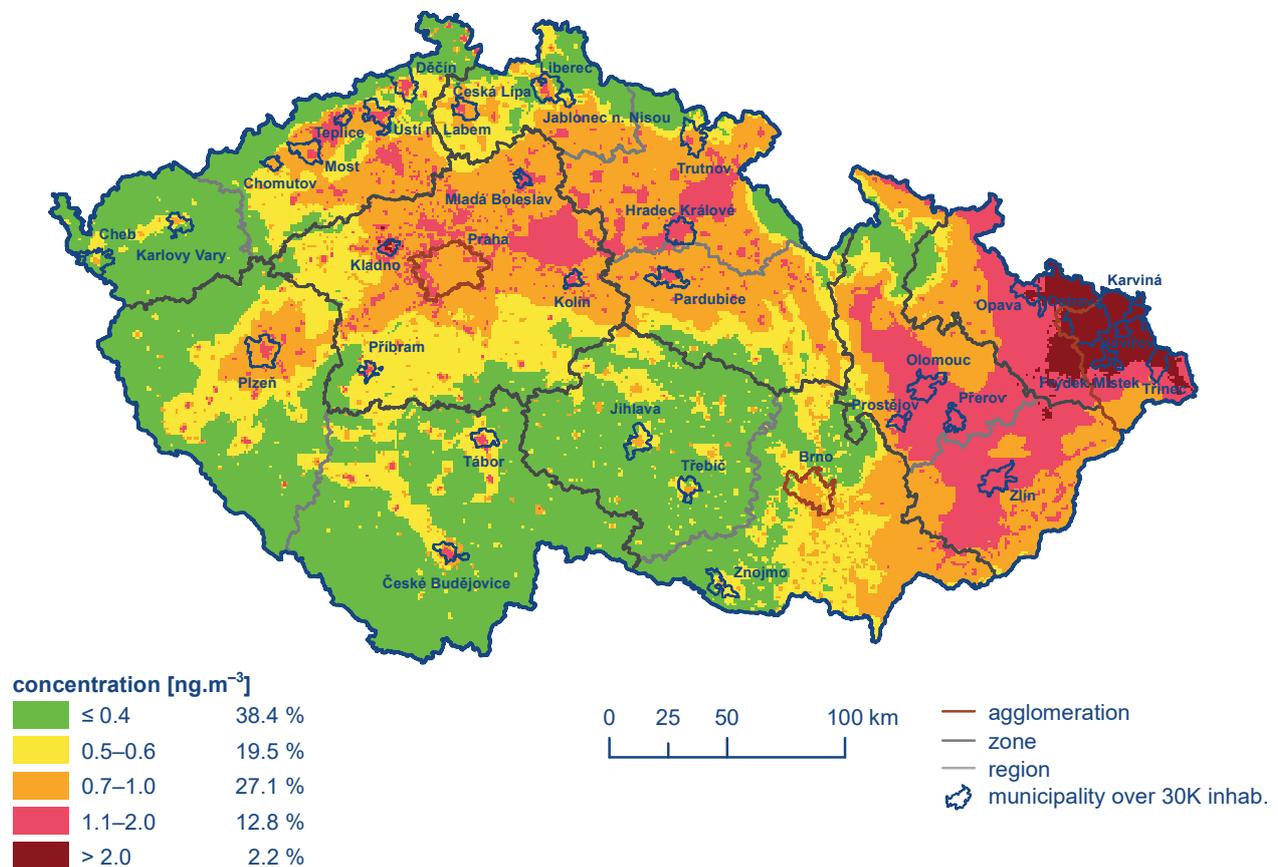
Fig. IV.2.3 Five-year average of annual average concentrations of benzo[*a*]pyrene, 2015–2019
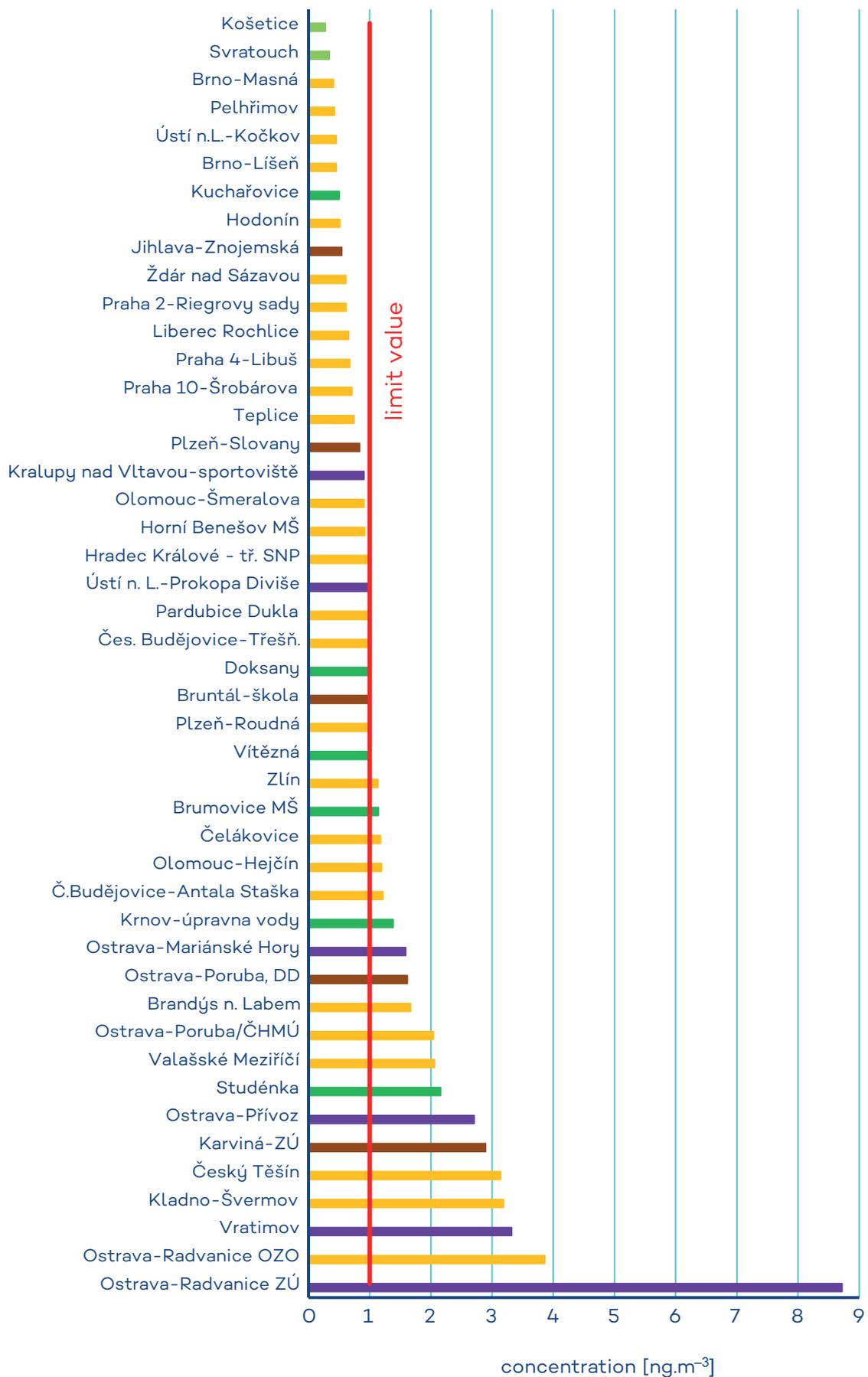
Fig. IV.2.4 Annual average concentrations of benzo[*a*]pyrene at monitoring stations, 2019

agglomeration, higher concentrations of benzo[a]pyrene linked to the dense built-up area of family houses with local heating units close to the monitoring station are recorded in the Kladno area (Kladno – Švermov station). Above-the-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, the lowest annual average concentrations of benzo[a]pyrene can be expected in places distant of direct exposure to emission sources and well ventilated localities (natural mountain areas). The lowest average annual concentration of benzo[a]pyrene (0.3 ng.m^{-3}) was observed at the Košetice and Svratouch regional stations, i.e. stations that monitor background concentrations of polluting substances in the Czech Republic. These stations are not directly affected by local emission sources, but are only affected by the long-range transport of pollutants in combination with meteorological and dispersion conditions. Below-limit values of benzo[a]pyrene concentrations are also recorded in large cities with congested traffic (Prague, Brno) where this traffic does not have a major increasing effect on the average annual benzo[a]pyrene concentrations, similarly as a link to local heating, because there is a high proportion of remote central heating in these cities.

On the contrary, exposure to above-limit levels of benzo[a]pyrene occurs also in municipalities in which its concentrations are not routinely monitored. This is repeatedly confirmed by measurement of concentrations of benzo[a]pyrene at various stations subsidized from the budget of the Moravian-Silesia region[1], such as Krnov (1.4 ng.m^{-3}) and Bruntál-škola (1.0 ng.m^{-3}) in 2019, Třinec-Konská (3.1 ng.m^{-3} in PM$_{2.5}$) and Třinec-Nebory (2.4 ng.m^{-3} in PM$_{2.5}$) in 2018 and Český Těšín-bus station (4.4 ng.m^{-3}), Vražné (3.3 ng.m^{-3}), and Opava-University garden (1.8 ng.m^{-3}) in 2017. High values of daily benzo[a]pyrene concentrations in winter months associated with local heating of households were also recorded during three-year (2015–2017) campaign measurements in small settlements of Ostopovice and Moravany in the South Moravia region (CHMI 2018). On the basis of the above observations, it can be assumed that in small

settlements where benzo[a]pyrene concentrations are not regularly monitored and where solid fuel heating predominates, carcinogenic benzo[a]pyrene levels may reach above the limit level.

Benzo[a]pyrene concentrations exhibit a distinct annual variation (Fig. IV.2.5) with maxima in winter that are related to emissions from seasonal anthropogenic sources – local heating units (i.e. the most significant source of benzo[a]pyrene emissions; Fig. IV.2.9) and worsened dispersion conditions. The annual course of monthly benzo[a]pyrene concentrations clearly copies the effect of emissions from local heating, the rate (or intensity) of which is mainly influenced by the number of heating days during the heating season, which determines fuel consumption and can be expressed using so-called degree-days. In summer, on the other hand, concentrations decrease due to improved dispersion conditions, increased chemical and photochemical decomposition of PAHs at higher levels of solar radiation and high temperatures, and of course mainly due to decreased emissions from anthropogenic sources (Li et al. 2009; Ludykar et al. 1999; Teixeira et al. 2012). The average monthly concentrations of benzo[a]pyrene in summer at background stations often range around the limit of detection (0.03 ng.m^{-3}) while at industrial locations in the agglomeration (O/K/F-M) daily concentrations reach even more than 1 ng.m^{-3} which shows the year-round effect of emissions in these areas. A comparison of the monthly averages of benzo[a]pyrene concentrations with ten-year average (2009–2018) shows that the average monthly concentrations at urban and suburban background stations were lower (by about 20–60%) in all months of the year except April and May when they remained at a similar level. Significant decrease in benzo[a]pyrene concentrations at urban and suburban background stations occurred especially in the winter months. The decrease in concentrations can be attributed to a decrease in benzo[a]pyrene emissions from local furnaces, a decrease in the number of heating days in individual months and good dispersion conditions, but also to measures already implemented (e.g. boiler replacement). The evaluation of the impact of the implemented measures is examined within the project TITSMZP704
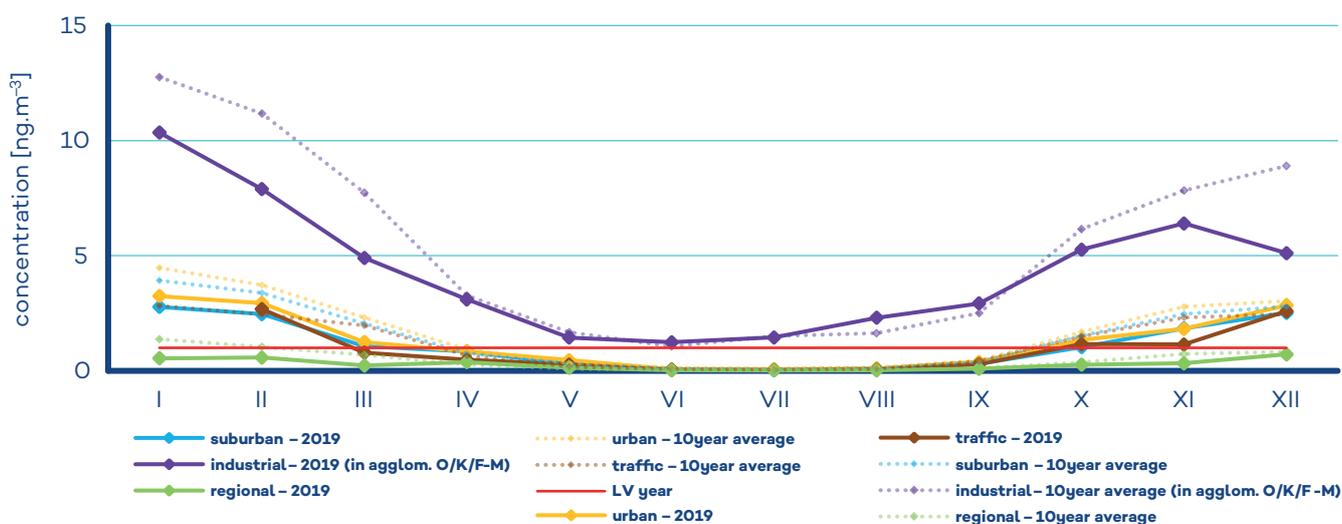
Fig. IV.2.5 Annual course of average monthly concentrations of benzo[a]pyrene, 2019

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1   For detailed annual evaluation see www.chmi.cz, https://air.zuova.cz/DAUS/article/detail/1.

– Measurement and analysis of air pollution with emphasis on the evaluation of the share of individual groups of sources – funded with state support of the Technology Agency of the Czech Republic under the BETA2 Program, the results of which will be available at the end of 2021. The annual course of monthly 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. A significant drop in monthly concentrations in the winter months at the beginning of the year was recorded at industrial stations in the Ostrava/Karviná/Frýdek-Místek (O/K/F-M) agglomeration where in addition to the cross-border transmission of pollution, typical for the entire Ostrava-Karviná area, an enormous emission load from a combination of emission sources from local heating and industry takes place.

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

Benzo[*a*]pyrene concentrations at individual types of stations is evaluated for a period of the last 11 years, i.e. 2009–2019. The average annual concentrations of benzo[*a*]pyrene at localities have been fluctuating in the last ten years during the evaluated period and do not show a significant trend. They decrease in the areas of the highest air pollution load (Kladno area and the Ostrava/Karviná/Frýdek--Místek agglomeration) (Fig. IV.2.6). Although there was an increase in the number of heating days in the year-on-year comparison 2018/2019, resulting from subnormal temperature conditions in May, benzo[*a*]pyrene concentrations decreased at 25 of 33 stations (i.e. at 76% of stations) with data available for both years compared.

The most significant decrease was recorded at the Ostrava-Přívoz industrial station, namely by 2 ng.m^{-3} (60%). However, the concentrations of benzo[*a*]pyrene still exceed there the limit value almost three times. Significant decreases in benzo[*a*]pyrene concentrations were recorded at all stations in the Moravian-Silesia region except the Ostrava-Radvanice ZÚ industrial station where an increase in the average annual concentration of benzo[*a*]pyrene by 1 ng.m^{-3} (approx. 12%) was recorded. In the year-on-year comparison 2017/2018 there was a decrease at 22 stations out of 33 (i.e. to 67%) that had data available for both years compared. The highest decrease, by 1.9 ng.m^{-3}, was recorded in the Ostrava-Radvanice industrial site but it is still the locality with the highest values of benzo[*a*]pyrene concentrations in the Czech Republic. A significant decrease of concentrations (by 0.6 ng.m^{-3}) was recorded in both localities in the Zlín region (Zlín and Valašské Meziříčí) but again the values exceeded the limit value. Good dispersion conditions and the overall warm character of the winter period in 2018 contributed positively to the decrease in annual average benzo[*a*]pyrene concentrations in most regions having a positive effect on the annual heating season expressed in degree-days which was considerably below normal (Fig. III.5). Lower number of heating days results in lower fuel consumption. A slight increase in the average annual concentrations of benzo[*a*]pyrene was recorded in 8 localities of which 6 were in the Moravian-Silesia region and further at the Doksany and Hodonín stations where the annual average concentration increased only slightly by 0.1 ng.m^{-3}. The highest increase of 1.2 ng.m^{-3} was identified at the Ostrava-Přívoz industrial site (4.7 ng.m^{-3}).

Annual average concentrations of benzo[*a*]pyrene at all types of stations were the lowest in 2019 for the evaluated period 2009–
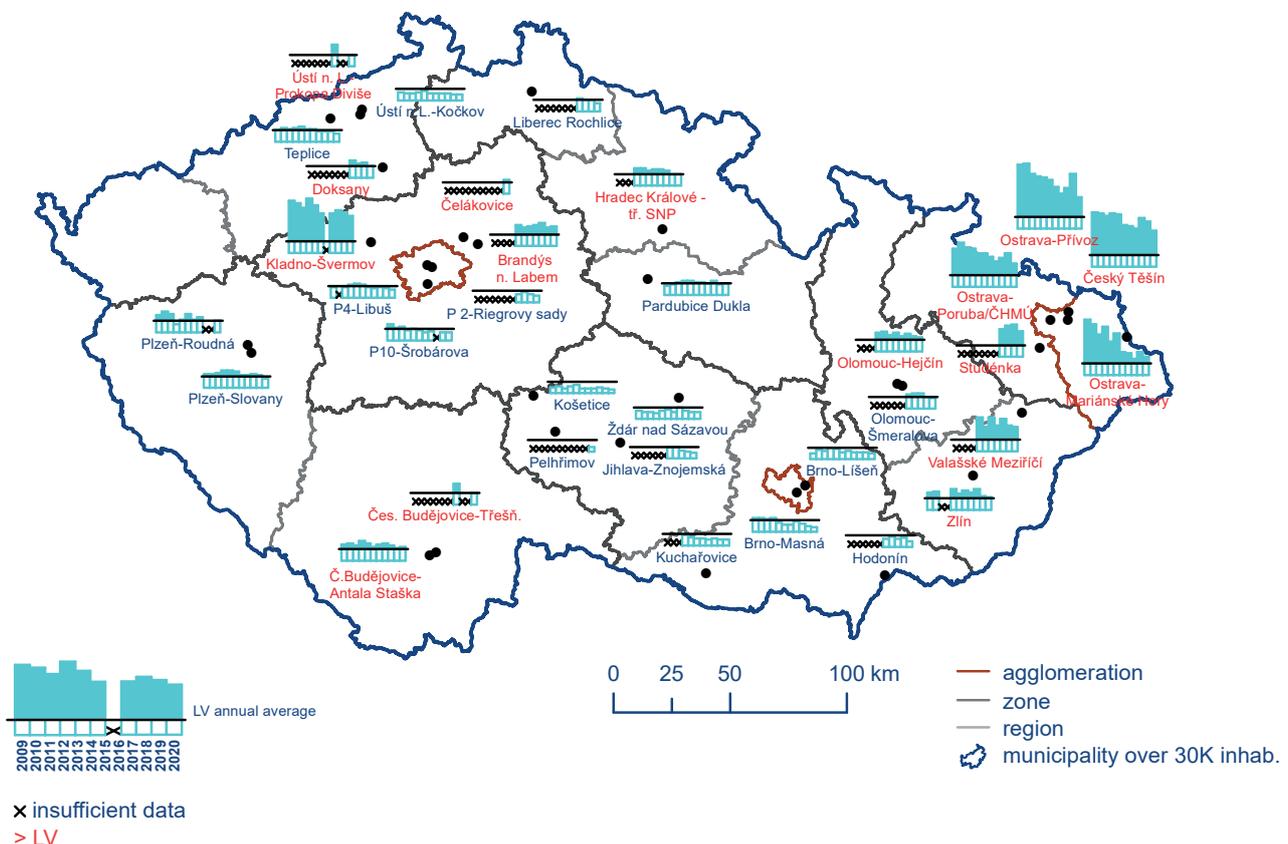
Fig. IV.2.6 Annual average concentrations of benzo[*a*]pyrene in the ambient air at selected stations, 2009–2019
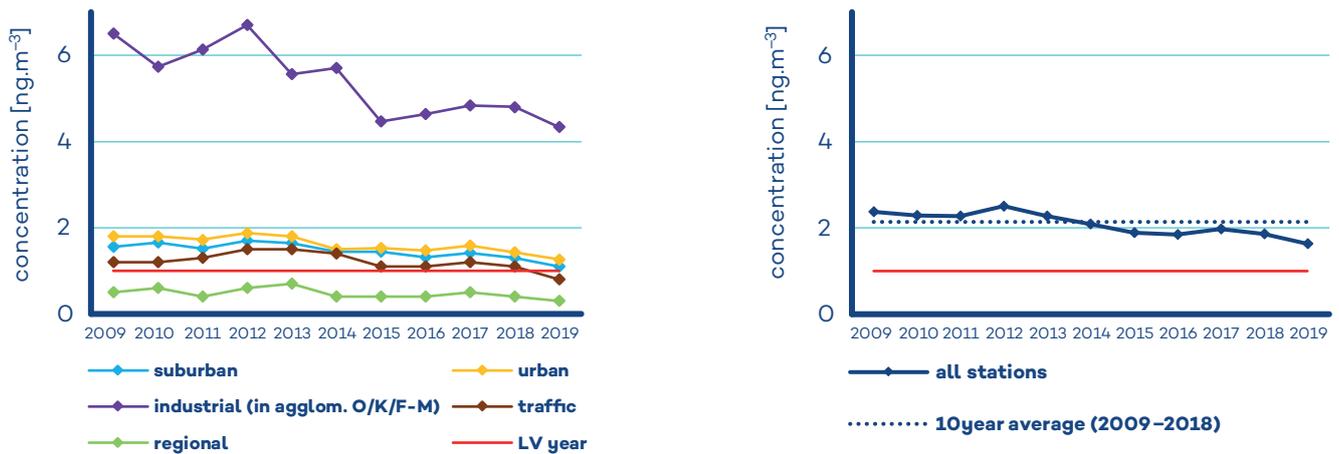
Fig. IV.2.7 Annual average concentration of benzo[*a*]pyrene at particular types of stations in the Czech Republic, 2009–2019
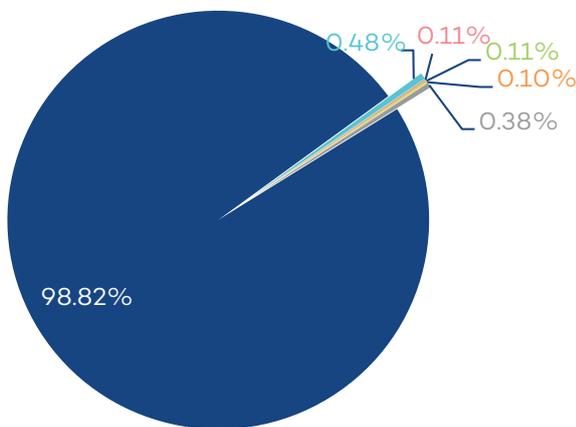
Fig. IV.2.8 Total emissions of benzo[*a*]pyrene sorted out by NFR sectors, 2018

2019 (Fig. IV.2.7), however, in many cities they still remain above the limit level. Compared to the ten-year average 2009–2018, in 2019 there was a decrease in benzo[*a*]pyrene concentrations at all stations by an average of about 20%. The good dispersion conditions that have occurred in the Czech Republic in the last five years, the lower number of heating days in the winter months and the measures implemented to improve air quality, including the renewal of boilers in households, have contributed to the improvement of the situation.

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

Emissions of PAHs, of which benzo[*a*]pyrene is monitored in view of air protection in particular, 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
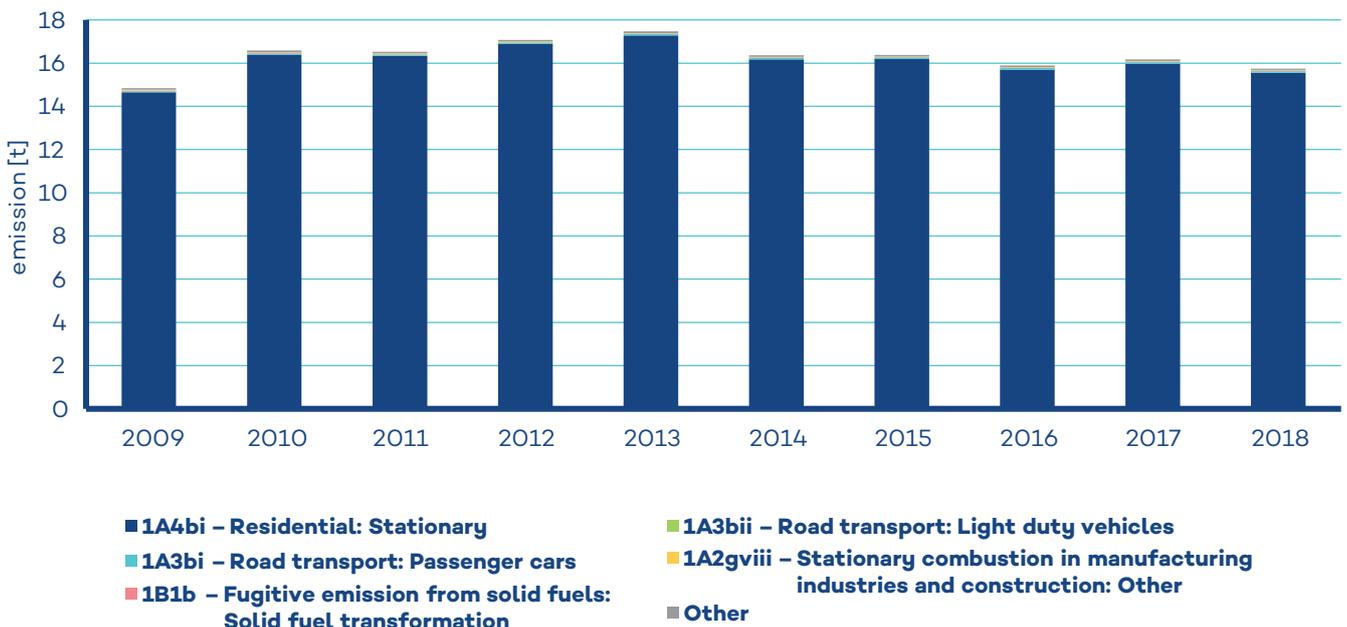
Fig. IV.2.9 The development of benzo[*a*]pyrene total emissions, 2009–2018

to 600 °C. Thus, one of its most important sources is the combustion of solid fuels in low-capacity boilers, particularly household heating systems.

Sector 1A4bi – Residential: Stationary contributed 98.8% to national benzo[a]pyrene emissions in 2018. The combustion of solid fuels, especially coal, in older types of boilers (top-burning and bulk-burning type of combustion) is the main reason for such a large percentage. According to estimates, up to 69% of all boilers for burning solid fuel in households in the Czech Republic in 2018 consisted of top-burning and bulk-burning boilers. The impact of the transport sector is estimated at 0.8% (Fig. IV.2.8).

In view of predominant contribution of sector 1A4bi, emissions of benzo[a]pyrene are distributed over the territory of residential buildings throughout the Czech Republic and their amounts in the 2009−2018 period depended primarily on evolution of consumption of solid fuels in households (Fig. IV.2.9). The impact of transportation is apparent mainly along motorways, roadways with high traffic and in the territories of larger urban units. The greatest burden by emissions of benzo[a]pyrene occurs in the Moravian-Silesia region due to higher proportion of black coal combustion in bulk-burning type boilers in households (Fig. IV.2.10).

specific emissions [t.km^{-2}.year^{-1}]

☐ ≤ 0.00001
▱ > 0.00001–0.00005
▱ > 0.00005–0.0001
▱ > 0.0001–0.0002
▱ > 0.0002–0.0005
▱ > 0.0005–0.001
▱ > 0.001

0   25   50   100   km

——— district

0.002
0.001
0
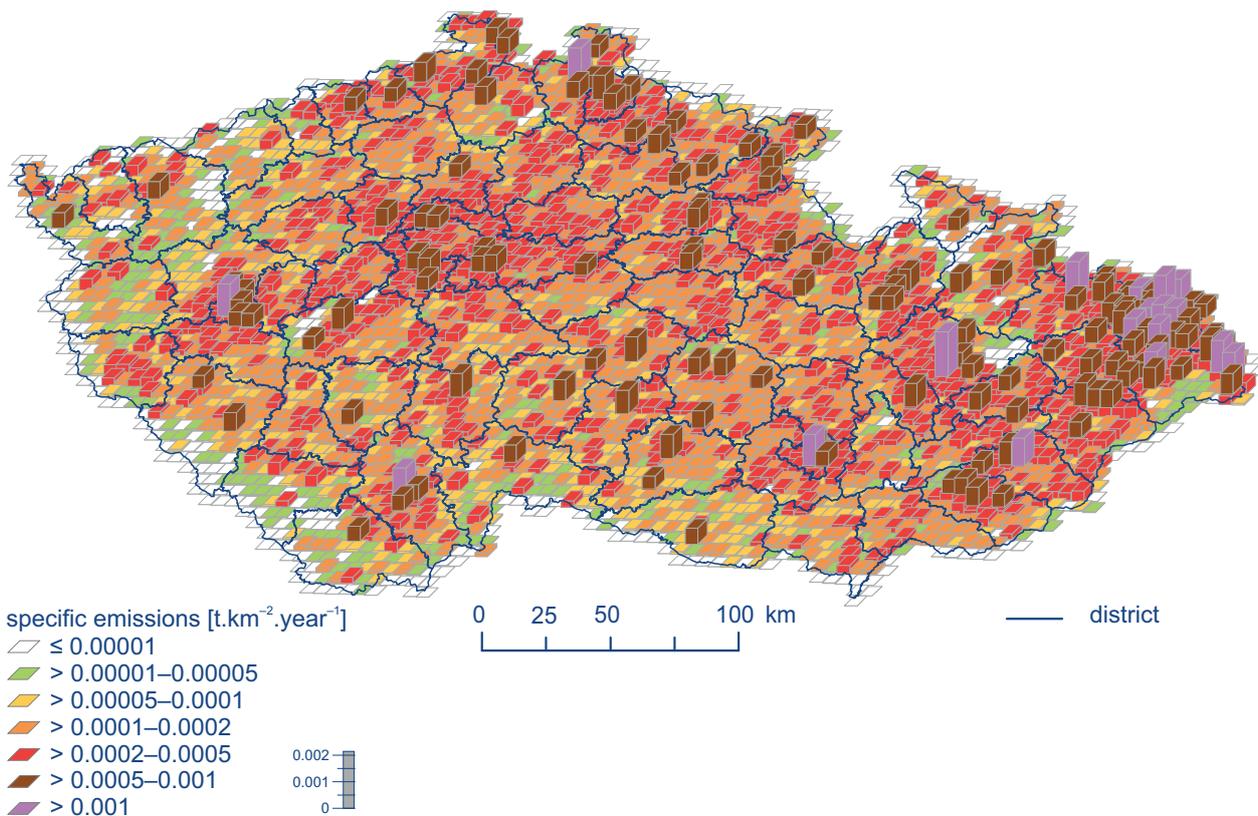
Fig. IV.2.10 Benzo[a]pyrene emission density from 5 x 5 km squares, 2018

IV.3 Nitrogen oxides

IV.3.1 Air pollution by nitrogen oxides in 2019

In monitoring and evaluating the quality of ambient air, the term nitrogen oxides (NO_x) is understood to refer to a mixture of nitrogen oxide (NO) and nitrogen dioxide (NO_2). The pollution limit level for protection of human health is set for NO_2, the limit level for protection of ecosystems and vegetation is set for NO_x.

Air pollution by nitrogen dioxide in 2019 in relation to the pollution limit level for protection of human health

The annual pollution limit level for NO_2 is exceeded only at a limited number of stations (from 2% to 4% of stations in the last five years) in locations with high traffic intensity in agglomerations and large cities. Of the total number of 99 monitoring stations with a sufficient amount of data for evaluation, the annual pollution limit level of 40 µg.m^{-3} was exceeded at 1% of stations

(1 station – Prague 2-Legerova (hot spot)) in 2019 (Tab. XI.8; Fig. IV.3.1). The Prague 2-Legerova (hot spot) station is classified as urban traffic. High values of NO_2 concentrations at the Prague 2-Legerova station (hot spot) are related to high intensity of traffic in the immediate vicinity of the station and its location in a street canyon where the possibility of ventilation is significantly reduced. In view of its low range of representativeness, exceeding the limit value at this station was not reflected in the map of the annual average concentration (Fig. IV.3.2) which has a resolution of 1x1 km. In most areas of the Czech Republic (99.9%), however, the average annual concentration has long been lower than 26 µg.m^{-3}, i.e. below the value of the lower assessment limit (Fig. IV.3.3).

In 2019, the limit value for hourly NO_2 concentration of 200 µg.m^{-3} was not exceeded at any location (Table XI.7).

The highest concentrations of NO_2 are attained at traffic stations in Prague, Brno and Ostrava (Fig. IV.3.1). Greater pollution of cities by NO_2 compared to rural localities is caused by traffic. Higher NO_2 concentrations can also be expected in the vicinity of local roads in municipalities with intensive traffic, higher urban development and a dense local transport network where traffic flow often drops. NO_2 concentrations decrease with increasing distance from roads.

classification of stations
- ■ urban background
- ♦ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [µg.m^{-3}]
- ≤ 26.0
- 26.1–32.0
- 32.1–40.0
- > 40.0

0 25 50 100 km

— agglomeration
— zone
— region
— river
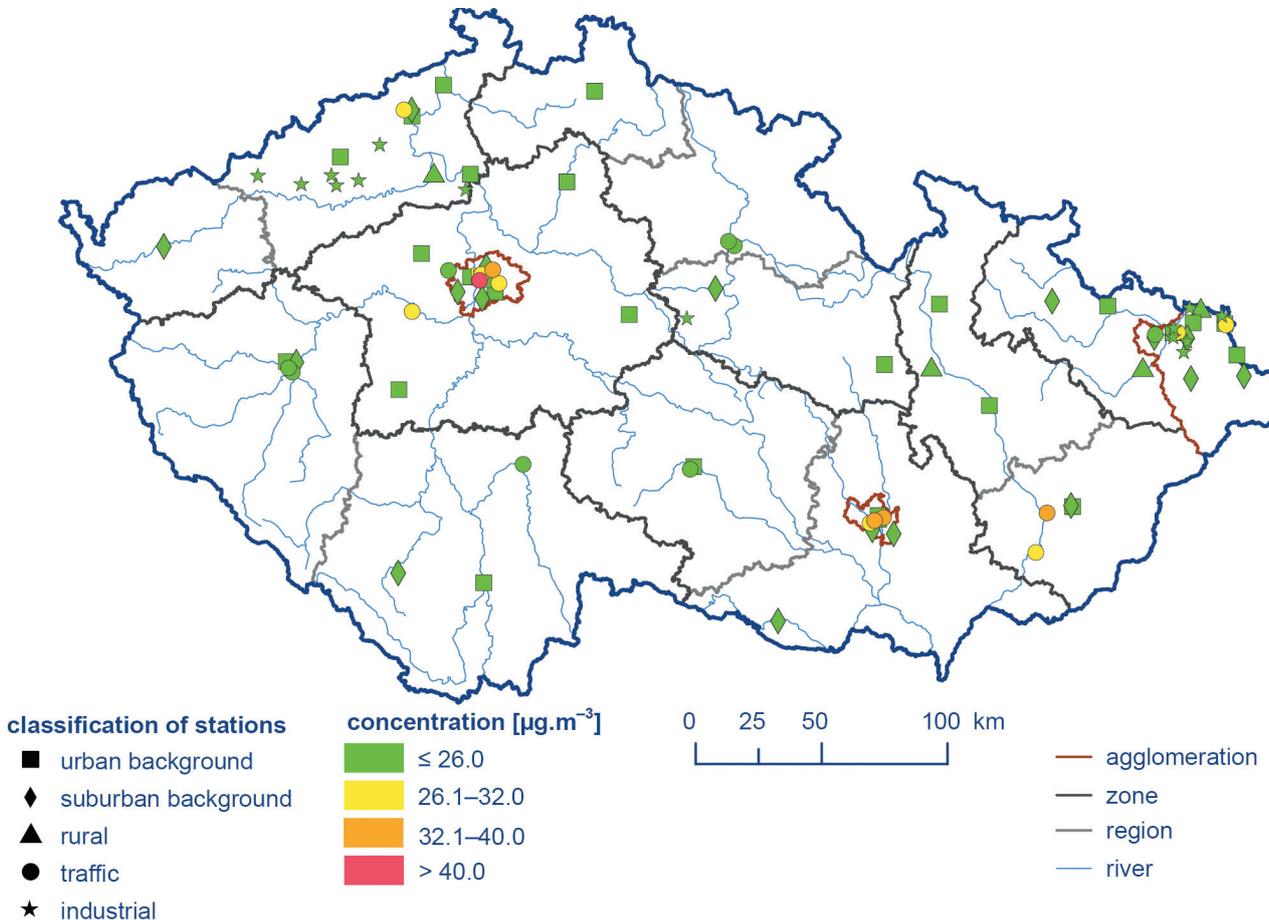
Fig. IV.3.1 Annual average NO$_2$ concentrations at air quality monitoring stations, 2019

concentration [µg.m⁻³]

≤ 26.0	99.9 %
26.1–32.0	0.1 %
32.1–40.0	
> 40.0	

0   25   50   100 km

— agglomeration
— zone
— region
municipality over 30K inhab.
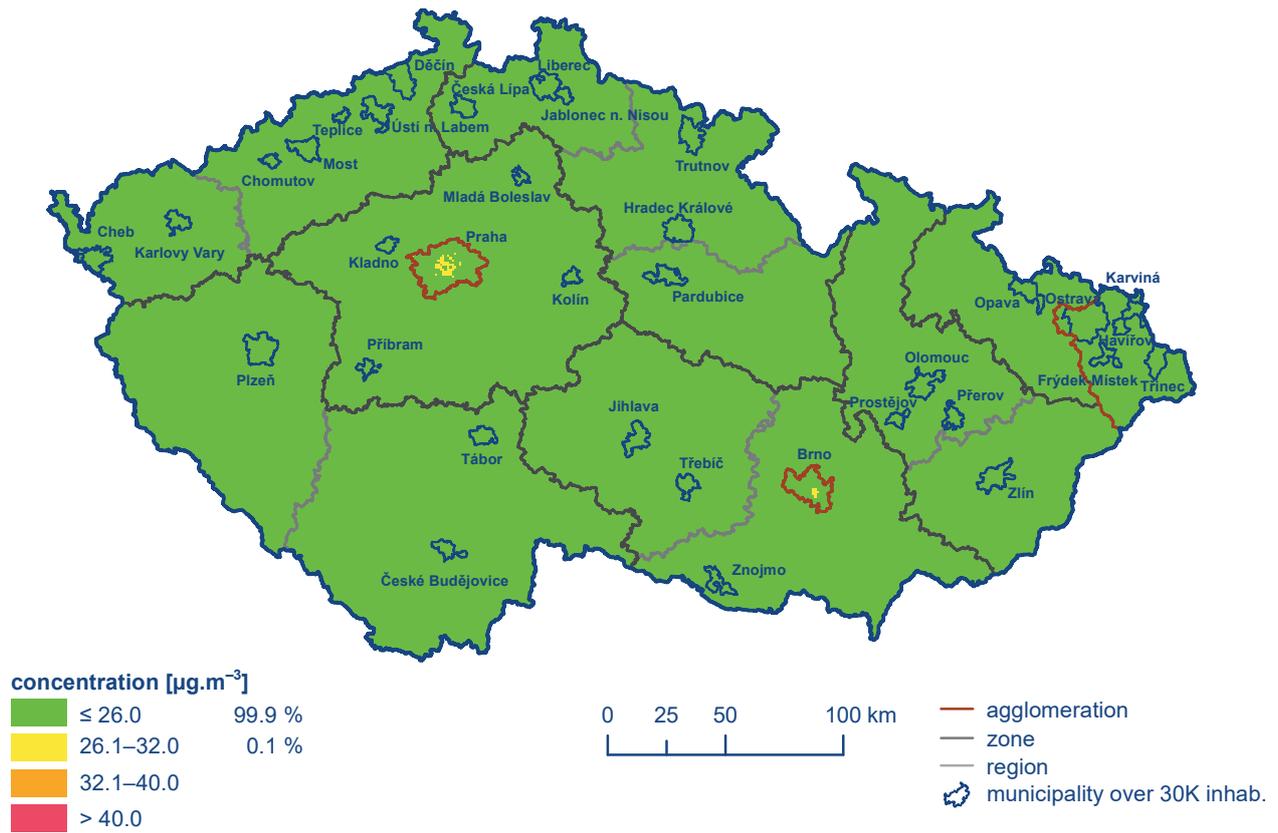
Obr. IV.3.2 Field of annual average NO₂ concentration, 2019

concentration [µg.m⁻³]

≤ 26,0	99.9 %
26.1–32.0	0.09 %
32.1–40.0	0.01 %
> 40.0	

0   25   50   100 km

— agglomeration
— zone
— region
municipality over 30K inhab.
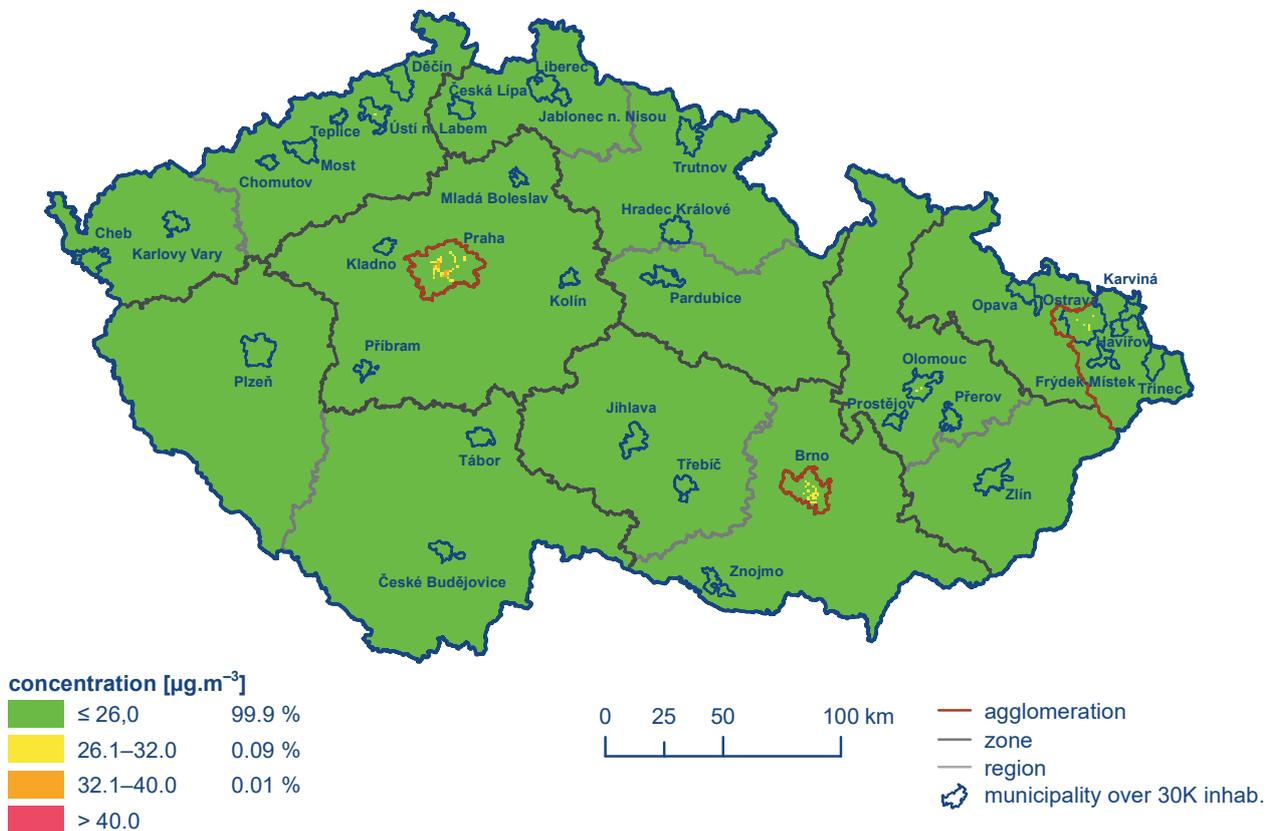
Fig. IV.3.3 Five-year average of annual average NO₂ concentrations, 2015–2019

Monthly average NO_2 concentrations were lower than ten-year average 2009–2018 throughout 2019 at all types of stations (Fig. IV.3.4). Average monthly NO_2 concentrations show an annual course with peaks in winter associated with meteorological conditions (lower intensity of solar radiation and deteriorated dispersion conditions). On the contrary, in the period April-September, there is generally a decrease in NO_2 concentrations. The reason for this decrease is the higher intensity of solar radiation (in particular at wavelengths < 400 nm) in this time of year which results in photodissociation of NO_2 to NO and O (Warneck 2000). Ground-level ozone is formed from photodissociation products under appropriate conditions and therefore ground-level ozone concentrations are higher in the April-September period (Fig. IV.4.8). In 2019, there was no significant increase in NO_2 concentrations in the winter at the end of the year at traffic stations, where the highest NO_2 concentrations are measured, due to favourable meteorological and dispersion conditions in this period, especially in November. At regional rural localities remote from direct exposure to emission sources, the average monthly NO_2 concentration is the lowest and is well below the lower assessment threshold (LAT), showing thus less distinct annual course. In the winter months, background concentrations of NO_2 increase mainly due to worse dispersion conditions, lower intensity of solar radiation, eventually the effect of seasonal emission sources.

Air pollution by nitrogen oxides in 2019 in relation to the pollution limit level for protection of ecosystems and vegetation

The pollution limit level for protection of ecosystems and vegetation for the average annual concentration of NO_X ($30\,\mu g.m^{-3}$) was not exceeded in 2019 at any of 19 rural stations with a sufficient amount of data for the evaluation (Tab. XI.9). The concentration map of annual average NO_X concentrations was prepared using combined data from all stations measuring NO_X and a dispersion model. Higher NO_X concentrations are measured in the vicinity of busy roads in municipalities. On the map, point symbols designate only rural stations because only at these locations the average annual NO_X concentrations are evaluated following the Czech legislation in force in relation to the pollution limit level for protection of ecosystems and vegetation (Fig. IV.3.5).

IV.3.2 Trends in nitrogen oxide concentrations

During the 1990s there was a marked decrease in the average annual concentrations of both NO_2 and NO_X and also in the 19th highest hourly NO_2 concentration. This was a result of the sharp decrease in emissions in this period as a result of coming into force of Act No. 309/1991 Coll., and the related introduction of new technological measures to reduce emissions. This was also affected by a change in the composition of industrial production and the vehicle fleet and also in the composition of automotive fuels. Meteorological and dispersion conditions have a great impact on inter-annual variations in NO_2 and NO_X concentrations and also on the concentrations of other pollutants. Between 2000 and 2008, there have been alternating increases and decreases in both the average annual concentrations and also in the 19th highest hourly concentration. In the period under consideration between 2009 and 2019 (Figures IV.3.7 and IV 3.8), higher concentrations were recorded in 2010, probably due to poor meteorological and dispersion conditions. Since 2011, it has been possible to observe a moderate decreasing trend in all the monitored characteristics of nitrogen oxides. In inter-annual comparison 2018/2019, decrease occurred in the annual NO_2 and NO_X average concentration at all types of stations. The average 19th highest hourly NO_2 concentrations (Fig. IV 3.9) show a clear decrease in all types of localities except for regional stations, where a slight increase in concentrations is caused by an increase in concentrations at the Sněžník station. The Sněžník station is affected by long-range transport, and increases in short-term concentrations indicate the influence of large sources in the wider vicinity of the station. In 2019, the lowest concentrations of NO_2 and NO_X were recorded for the entire evaluated period. Good dispersion conditions and the overall warm character of the winter period in 2019 (Chap. III) contributed to the improvement of the situation, as well as the decrease in NO_X emissions related mainly to the gradual renewal of the vehicle fleet and the introduction of emission ceilings and stricter emission limits for NO_X emissions from sources in the sector 1A1a – Public electricity and heat production.
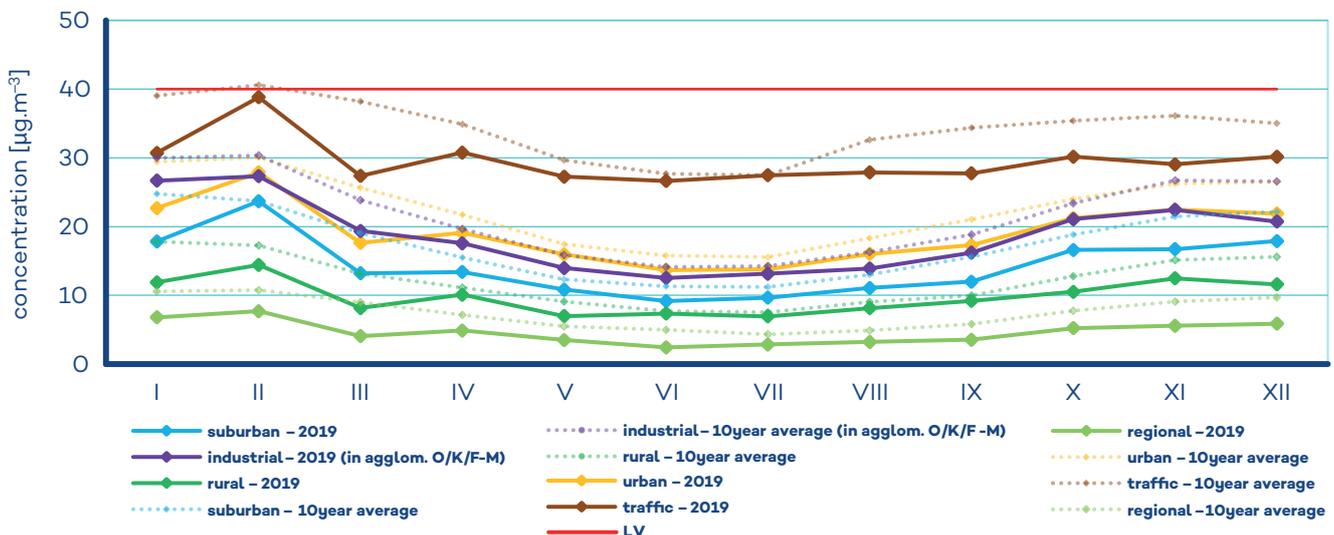
Fig. IV.3.4 Annual course of average monthly concentrations of NO_2, 2019

concentration [µg.m⁻³]

- ≤ 19.5
- 19.6–24.0
- 24.1–30.0
- > 30.0

▲ rural station

agglomeration
zone
region
municipality over 30K inhab.
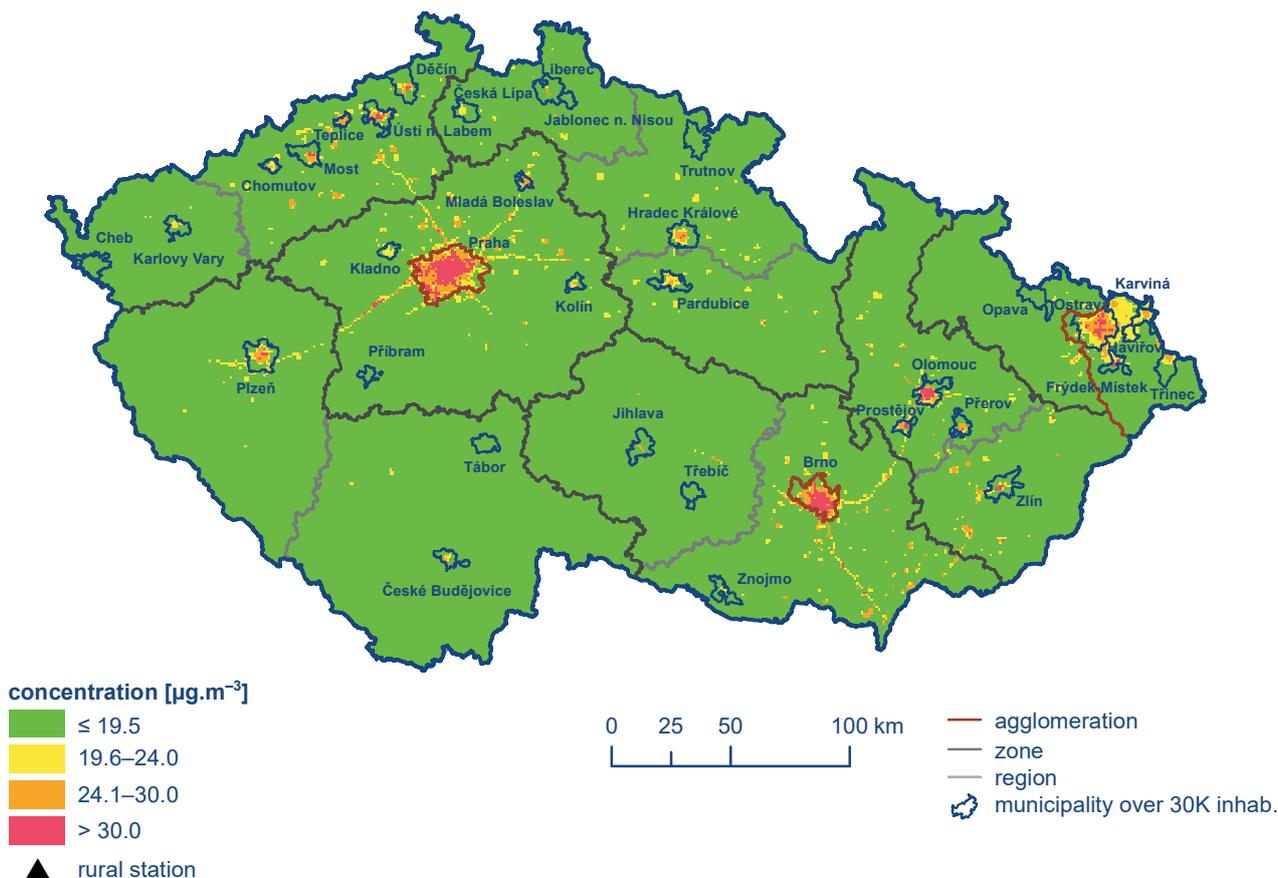
Fig. IV.3.5 Field of annual average NO$_x$ concentration, 2019

LV 1h
LV annual average

✕ insufficient data
> LV
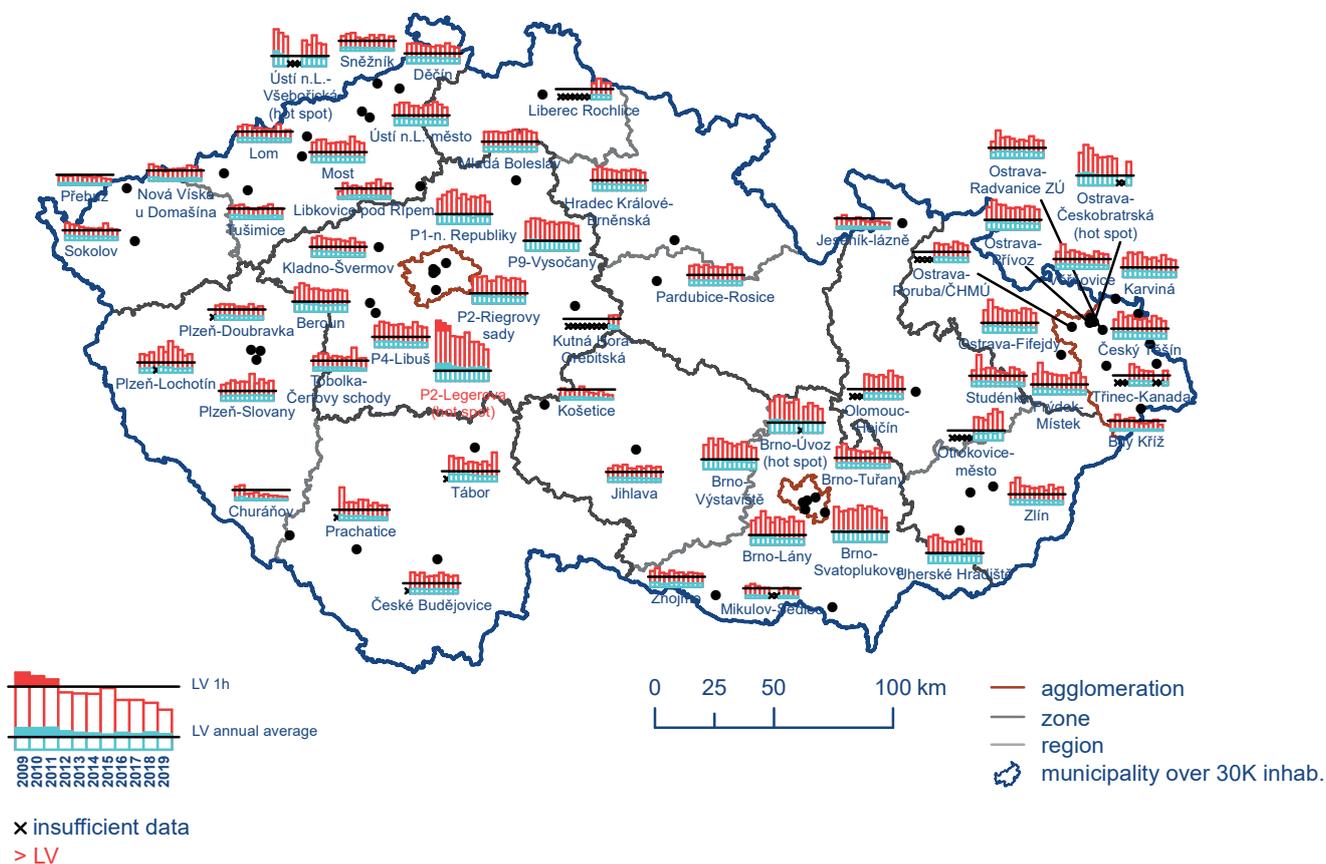
Fig. IV.3.6 19th highest hourly and annual average NO$_2$ concentrations at selected stations, 2008–2019
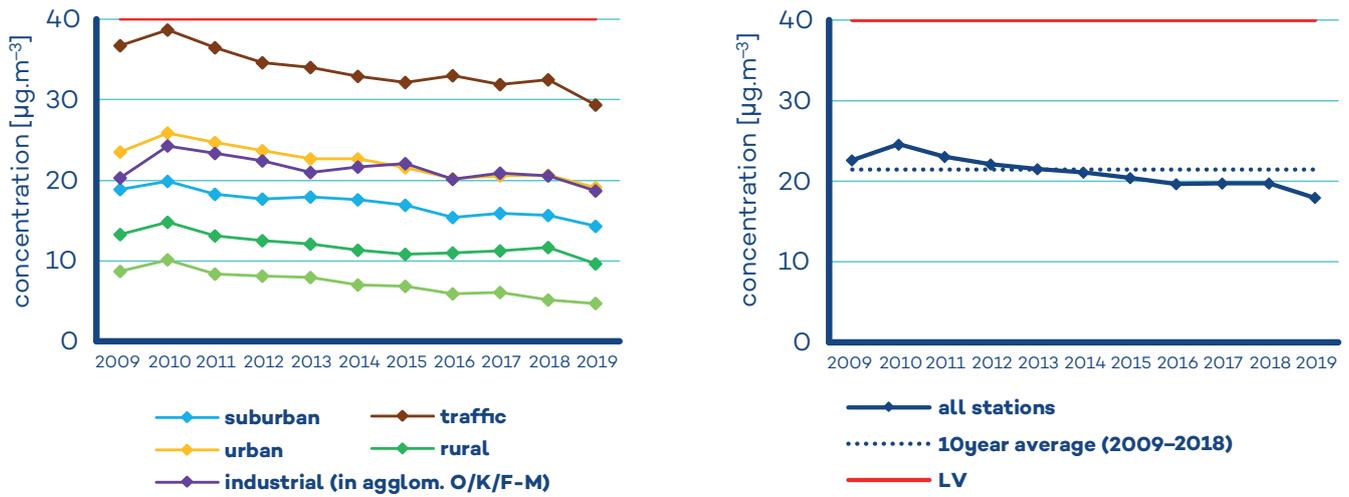
Fig. IV.3.7 Annual characteristics of NO$_2$ at particular types of stations in the Czech Republic, 2009–2019
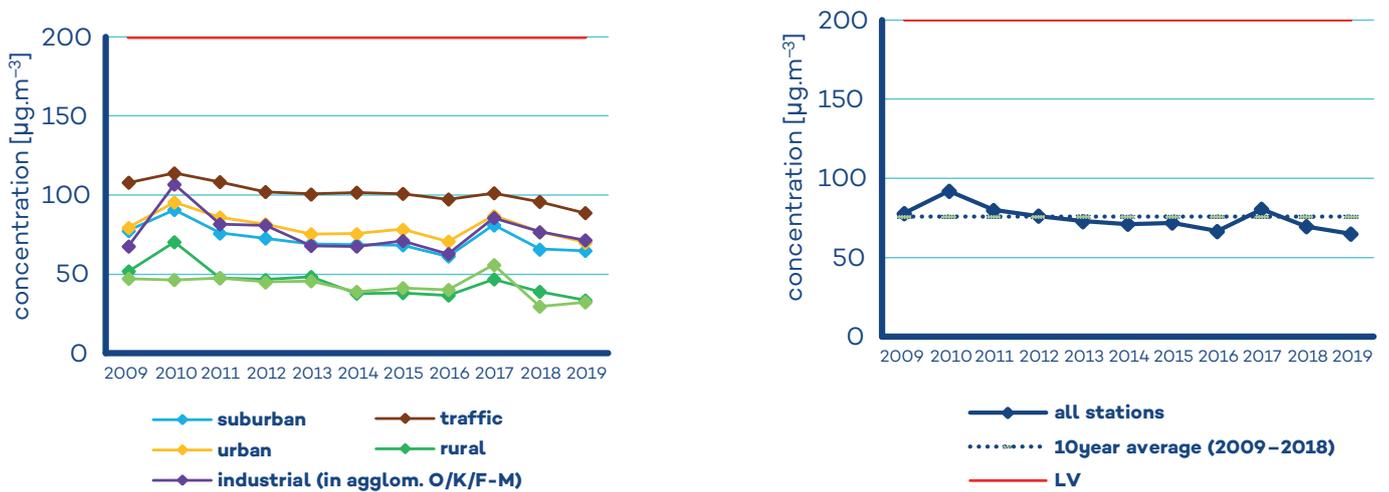
Fig. IV.3.8 Annual characteristics of 19th highest hourly NO$_2$ concentrations at particular types of stations in the Czech Republic, 2009–2019
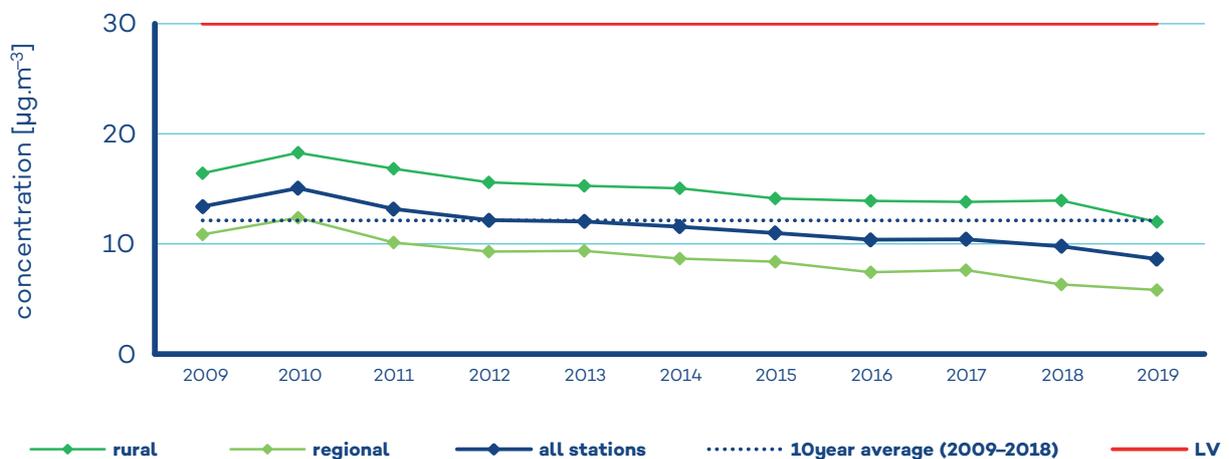
Fig. IV.3.9 Annual characteristics of NO$_x$ at particular types of stations in the Czech Republic, 2009–2019

IV.3.3 Nitrogen oxide emissions

Nitrogen oxides (NO_x) are formed in combustion of fuels in dependence on the temperature of combustion, nitrogen content of the fuel and excess of combustion air, and are also formed in some chemical-technological processes (production of nitric acid, ammonia, fertilisers, etc.). While in combustion of fuels in boilers the fraction of NO_2 in NO_x emissions is usually up to 5%, the fraction of NO_2 in some chemical-technological processes can reach up to

100% of total NO_x emissions (Neužil 2012). NO_x emissions with higher fraction of NO_2 (10–55%) are produced by diesel engines (Carslaw at al. 2011).

The largest amount of NO_x emissions comes from transport. Sectors 1A3bi – Road transport: Passenger cars, 1A4cii – Agriculture/Forestry/Fishing: Off-road vehicles and other machinery, 1A3biii – Road transport: Heavy duty vehicles over 3.5 tons, and 1A3bii – Road transport: Light duty vehicles contributed 41.3% to national NO_x emissions in 2018. An amount of 24.4% of NO_x emissions was emitted into the air in the sector 1A1a – Public electricity and heat production (Fig. IV.3.10). The decrease in NO_x emissions in the 2009–2018 period is related primarily to natural renewal of the vehicle fleet and the introduction of emission ceilings and stricter emission limits for NO_x emissions from sources in the sector 1A1a – Public electricity and heat production (Fig. IV.3.11).

The contribution of particular emission sources differ depending on the composition of sources in a given area. The production of NO_x emissions is concentrated primarily along motorways, roadways with heavy traffic, in large cities, and in the regions where more significant energy production facilities are located (Ústí nad Labem, Central Bohemian and Moravian-Silesian regions) (Fig. IV.3.12).
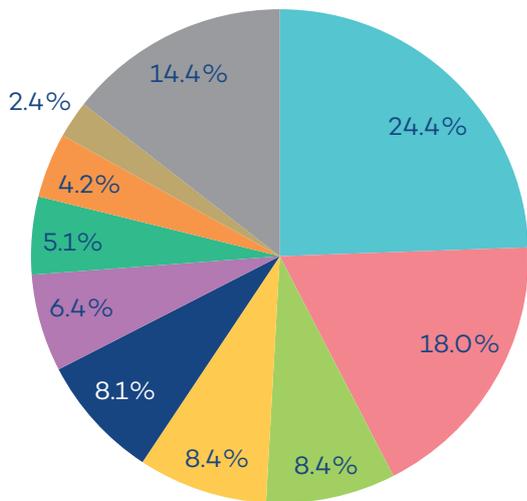
Fig. IV.3.10 Share of NFR sectors in total NO$_x$ emissions, 2018

- 1A1a – Public electricity and heat production
- 1A3bi – Road transport: Passenger cars
- 1A4cii – Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
- 1A3biii – Road transport: Heavy duty vehicles and buses
- 1A4bi – Residential: Stationary
- 1A3bii – Road transport: Light duty vehicles
- 1A2f – Stationary combustion in manufacturing industries and construction: Non-metallic minerals
- 1A4ai – Commercial/Institutional: Stationary
- 1A2c – Stationary combustion in manufacturing industries and construction: Chemicals
- Other

Fig. IV.3.11 Total NO$_x$ emissions, 2009–2018

specific emissions [t.km^{-2}.year^{-1}]

- ≤ 0.5
- > 0.5–1
- > 1–3
- > 3–10
- > 10–50
- > 50–100
- > 100

0   25   50   100 km

district

200
100
0
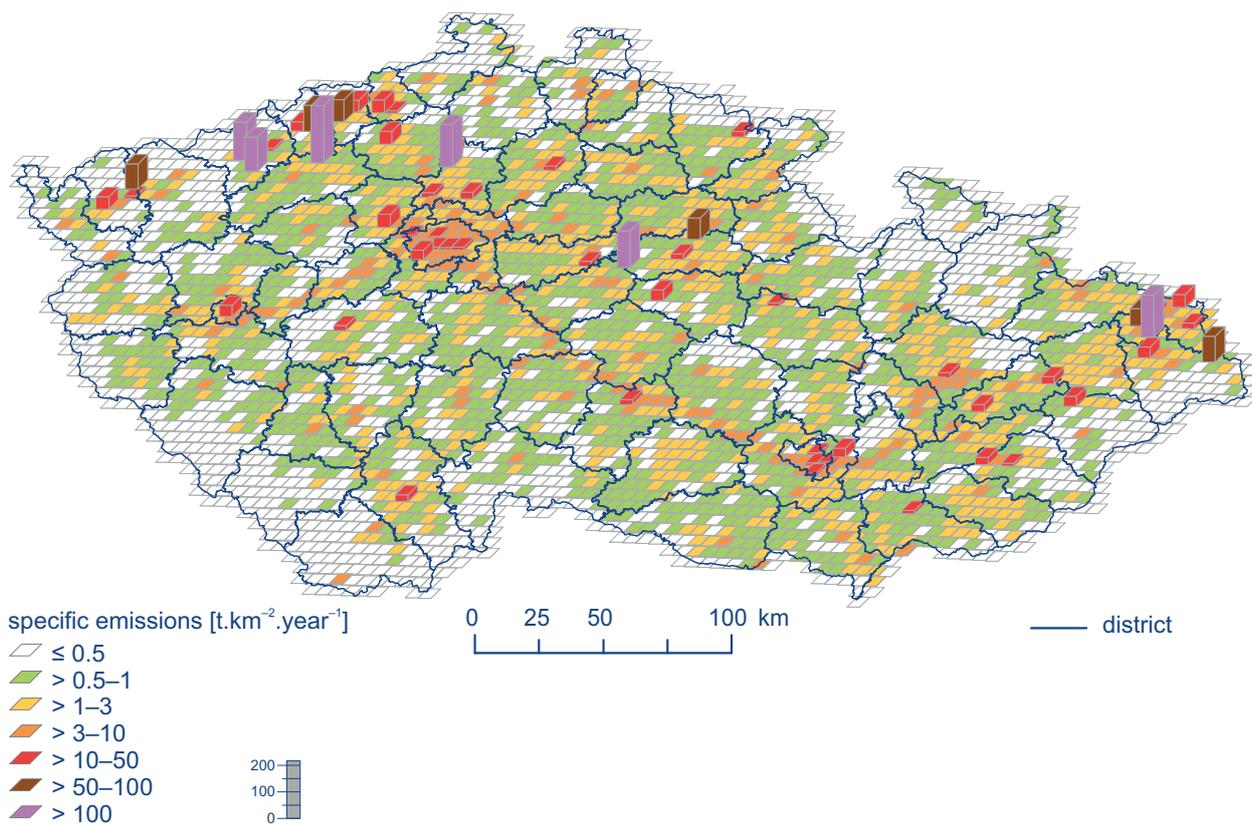
Fig. IV.3.12 NO$_x$ emission densities in 5 x 5 km spatial resolution squares, 2018

IV.4 Groud-level ozone

IV.4.1 Air pollution by ground-level ozone in 2019

Air pollution by ground-level ozone in 2019 in relation to the limit values for protection of human health

The ground-level ozone limit value (O_3) was exceeded at 56% of stations in the three-year period 2017–2019[1], i.e. in 36 out of 64 stations where the O_3 concentrations were measured (Tab. XI.10; Fig. IV.4.1 and IV.4.2). For the previous three-year periods 2016–2018 and 2015–2017, the ground-level O_3 limit value was exceeded at 33 out of 65 (51%) and at 21 of 71 (30%) stations respectively.

The O_3 limit value was exceeded in the three-year period 2017–2019 over 70.5% of the territory of the Czech Republic with approximately 56.9% of the population (Fig. IV.4.3). Compared to the previous five three-year periods, it is the second largest extent of the area exceeding the limit value for O_3 (80% of the territory in the period 2016–2018, 31.2% of the territory in the period 2015–2017, 18.1% of the territory in the period 2014–2016 and 26.8% of the territory in the period 2013–2015). The reason is the persistently favourable meteorological conditions for the formation of ground-level ozone (for more see Chapter III) that led to increased concentrations and more frequent cases exceeding the O_3 limit value in 2019 (Fig. IV.4.4).

classification of stations
- ■ urban background
- ♦ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [μg.m⁻³]
- ≤ 120
- > 120

0   25   50   100 km

— agglomeration
— zone
— region
— river
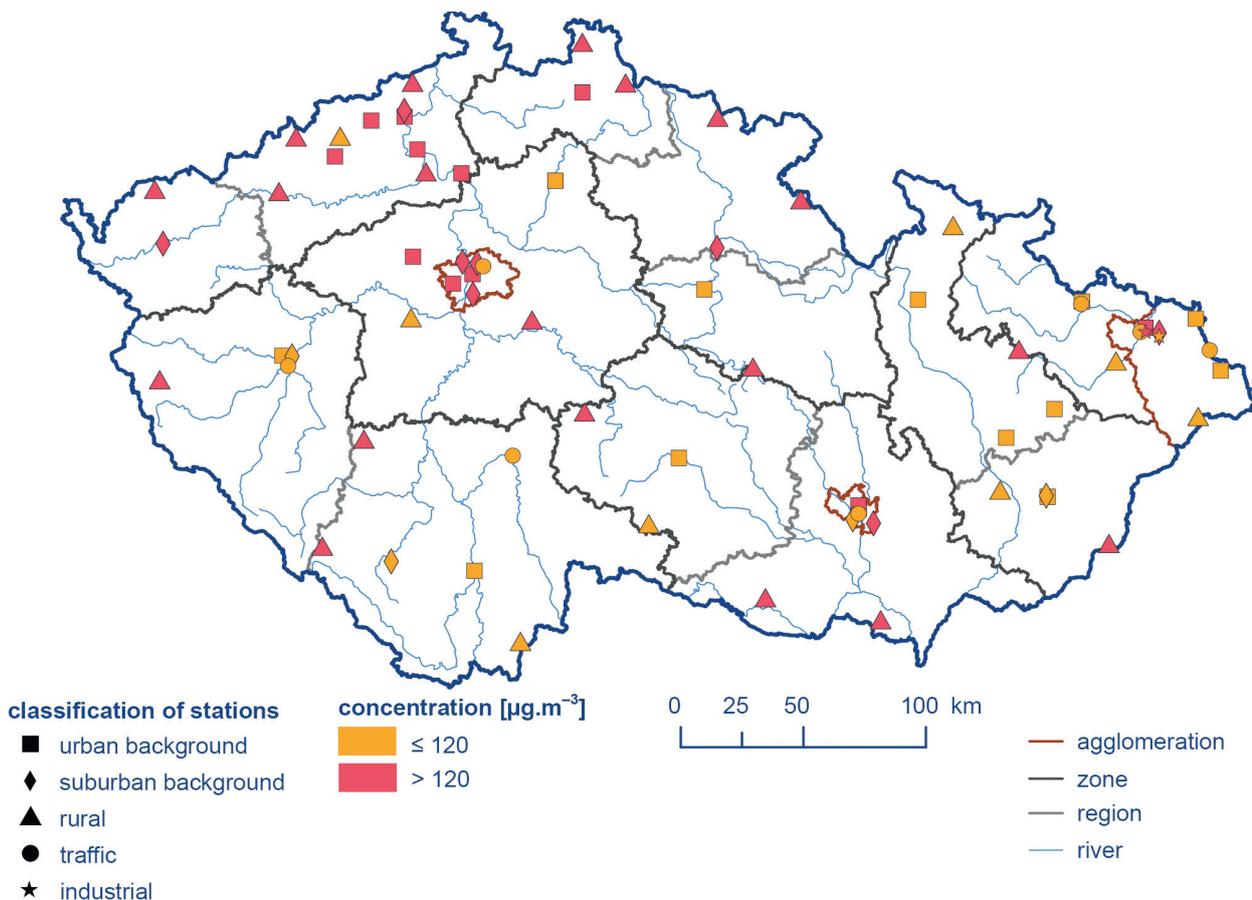
Fig. IV.4.1 26ᵗʰ highest values of maximum daily 8-hour running average of ground-level ozone concentrations (three-year average) in the ambient air quality network, 2017–2019

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1   The limit value is exceeded if the O_3 maximum daily 8-hour running average was higher than 120 μg.m⁻³ at least 26 times in three-year average.

classification of stations
- ■ urban background
- ◆ suburban background
- ▲ rural
- ● traffic
- ★ industrial

number of LV exceedances
- 0
- 1–13
- 14–25
- 26–35
- > 35

0   25   50   100   km

- —— agglomeration
- —— zone
- —— region
- —— river
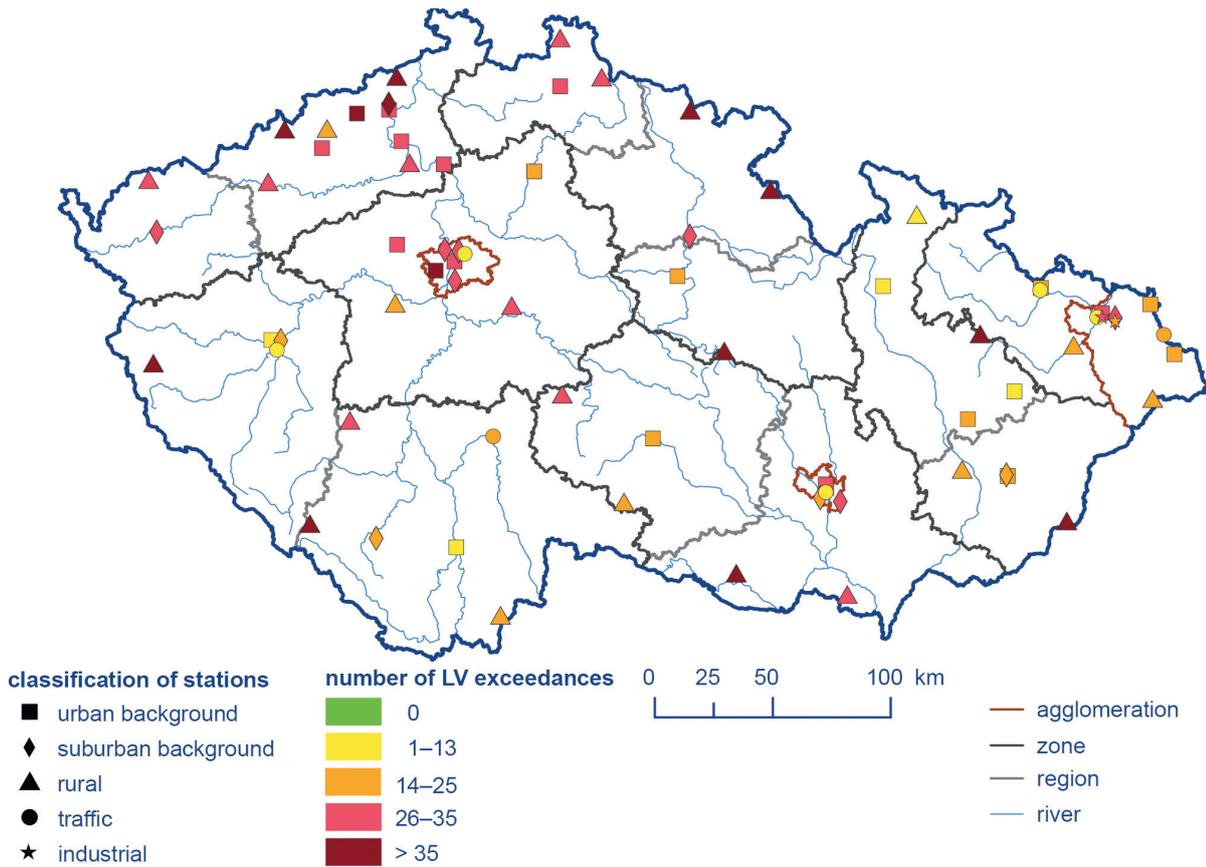
Fig. IV.4.2 Numbers of exceedances of the limit value for the maximum daily 8-hour running average of ground-level ozone concentrations in three-year average, 2017–2019

concentration [µg.m^{-3}]
- ≤ 120   29.5 %
- > 120   70.5 %

0   25   50   100   km

- —— agglomeration
- —— zone
- —— region
- ⬡ municipality over 30K inhab.
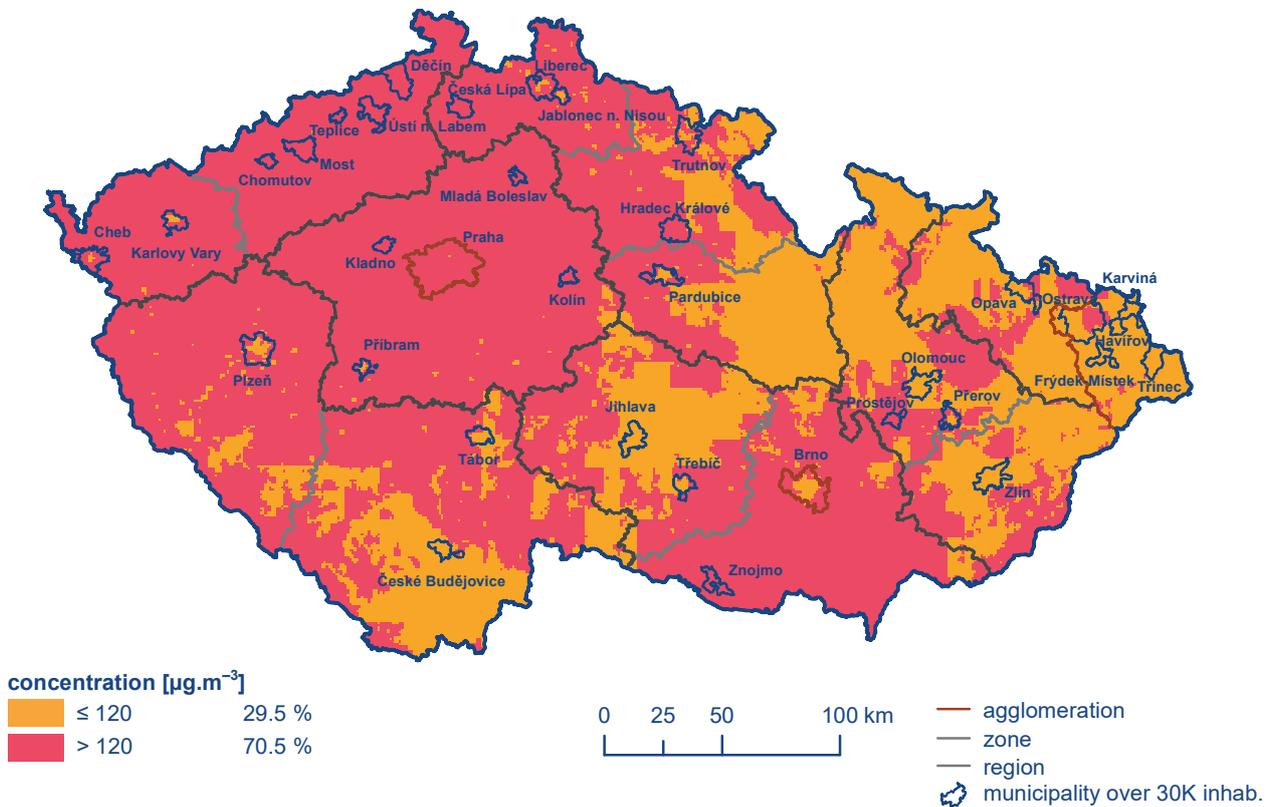
Fig. IV.4.3 Field of the 26th highest maximum daily 8-hour running average of ground-level ozone concentration in three-year average, 2017–2019
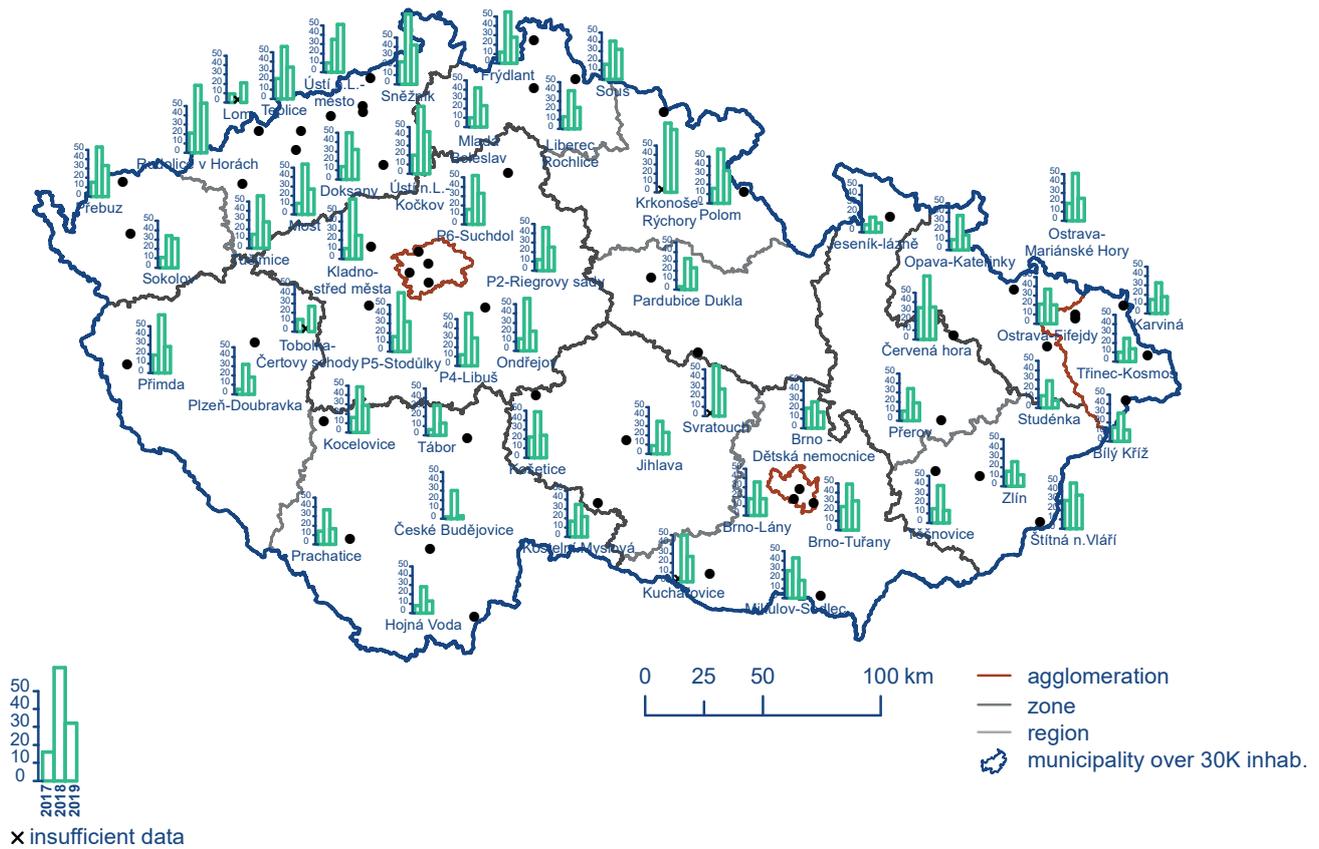
Fig. IV.4.4 Number of exceedances of 8-hour limit value of ground-level ozone per year for selected stations, 2017 – 2019

Fig. IV.4.5 Annual course of average monthly concentrations of max. 8-hour running average of O₃ (averages for the given type of station), 2019

The annual course of average monthly and daily concentrations of O₃ (maximum 8-hour average for a given month and day) is characterized by an increase in concentrations in spring and summer months (Fig. IV.4.5) due to favourable meteorological conditions for formation of O₃. In 2019, the average monthly concentrations were above the O₃ pollution limit value from April until August (until September at background and regional stations).

The highest concentrations of O₃ were measured from June to August, which corresponds to the usual occurrence of conditions favourable for the formation of ground-level ozone (for more see subchapter IV.4.3).

Based on a comparison of monthly averages of O₃ concentrations with ten-year average (2009–2019), it can be stated that average monthly

concentrations at monitoring stations in the period April – September, when O₃ concentrations reach elevated to above-limit levels, were similar or higher (by approximately 6% to 13%). The increase of concentrations in June is probably related to the occurrence of extremely above-normal temperatures and below-normal precipitation in June 2019. In the opposite, a slight drop in ground-level ozone concentrations in May 2019 corresponds to the occurrence of lower temperatures and higher precipitation (May is characterized as strongly below normal in temperature and above normal in precipitation).

From this evaluation it is evident that the lowest concentrations are measured at localities subject to traffic load (Fig. IV.4.5 and IV.4.9) where O₃ is decomposed by chemical reactions with NO. It can be assumed that the O₃ concentrations are also lower or below the limit in other areas with heavy traffic where, however, because of the lack of measurements, this probable reduction cannot be documented using current methods of map preparation. The values of concentrations at rural, suburban and urban stations are higher compared to concentrations at traffic stations and reach similar levels (Fig. IV.4.5). This is also confirmed by the study by Paoletti et al. (2014) when, between 1990 and 2010, a decreased difference was observed between the concentrations measured at rural and urban stations in Europe and the USA (Paoletti et al. 2014). Simultaneously, the maximum values measured at these stations also decreased. The mentioned decrease in the concentrations of ground-level ozone is attributed, amongst other things, to a reduction in emissions of precursors, especially of NO_x, in developed countries where there is no as strong decomposition of O₃ in cities due to the reaction with NO. The reduction in con-

centrations in relatively clean areas is attributed to the reduction of both NO_x and VOC emissions on a wider (European to global) scale (Sicard et al. 2013). An increase in O₃ concentrations due to a decrease in NO_x emissions (modernization and denitrification of large emission sources) is also observed in north-western Bohemia (Hůnová, Bäumelt 2018).

Six smog situations with a total duration of 90 hours were announced for the ground-level ozone in 2019. Smog situations were announced mainly in the third ten-day period of June 2019 and in the Ústí nad Labem region also at the end of July (for more see Chapter VI). The warning threshold value was not exceeded at any representative SWRS station in 2019.

Ground-level ozone in 2019 in relation to the limit value for protection of ecosystems and vegetation

The O₃ limit value for protection of vegetation of 18,000 μg.m⁻³.h was exceeded at 25 stations (64.1%) of the total number of 39 rural and suburban stations (Fig. IV.4.6) for which calculation of the exposure index AOT40 is relevant according to the legislation (it concerns the 2015–2019 average). The highest AOT40 values were measured at the Rudolice v Horách, Kuchařovice, Krkonoše-Rýchory, Sněžník with Brno-Tuřany stations (for a comprehensive overview, see Table XI.11). Based on the same set of 32 rural and regional stations, it can be stated that the AOT40 index was exceeded at 20 stations in 2019 (average 2015–2019) compared
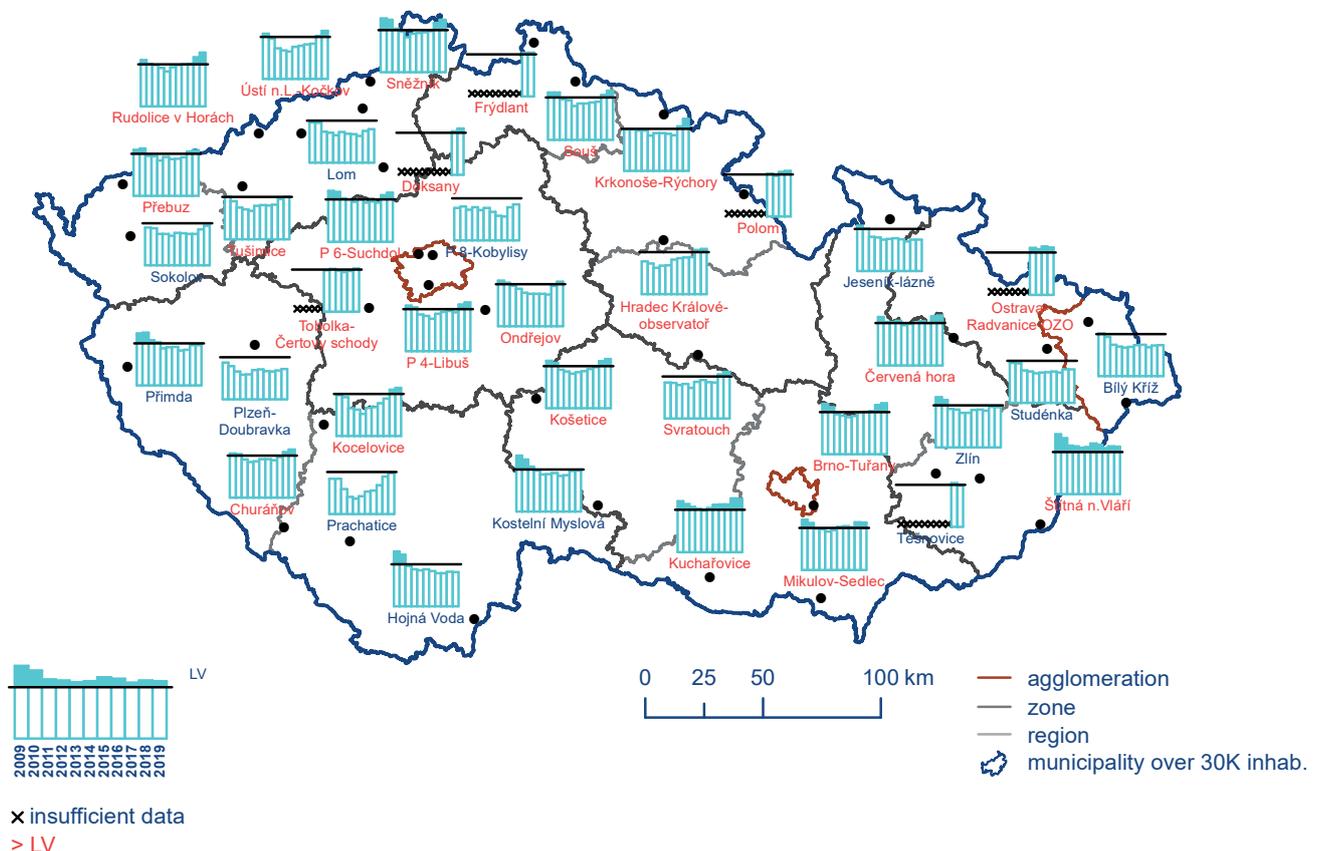
Fig. IV.4.6 Exposure index AOT40 values at selected stations, average of 5 years, 2009–2019
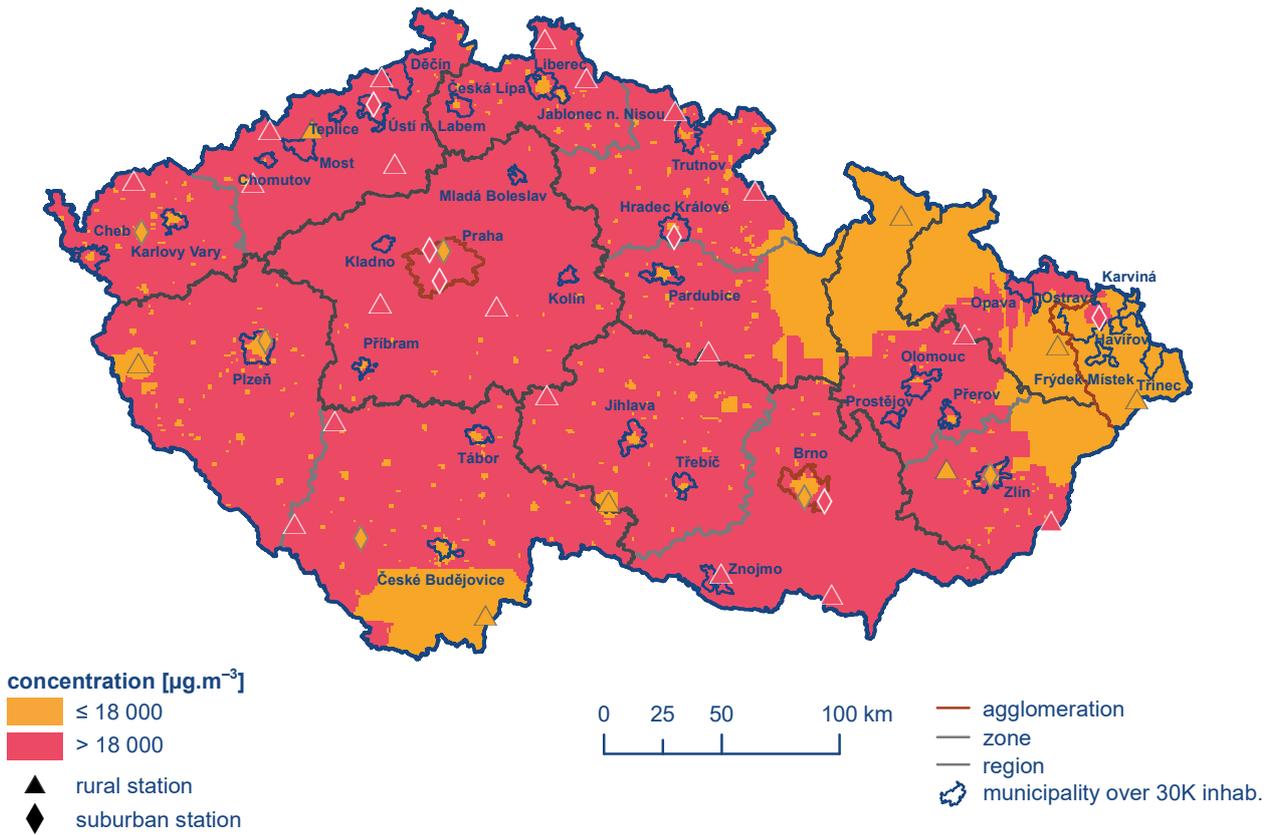
Fig. IV.4.7 Field of AOT40 exposure index values, average of 5 years, 2015–2019
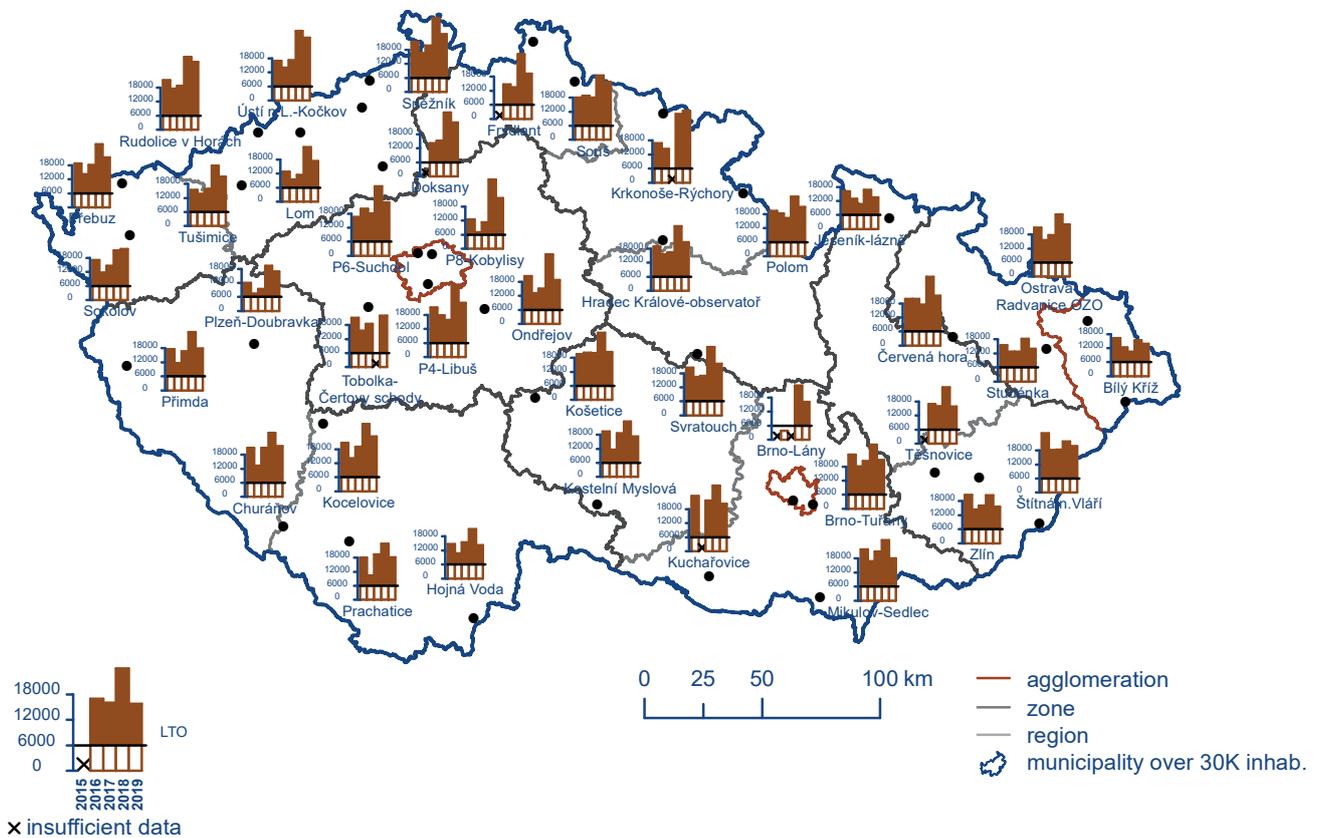
Fig. IV.4.8 Annual exposure index AOT40 values at selected stations in comparison with the long-term objective (LTO), 2015–2019

to 18 stations in 2018 (average 2014–2018). At the same time, the area of the territory with the occurrence of above-limit AOT40 values also increased (Fig. IV.4.7). The increase in the AOT40 exposure index value for 2019 compared to 2018 occurred at most of 32 stations evaluated in both periods, by up to 3,183 µg.m⁻³.h.

The annual values of the exposure index AOT40 have long exceeded the value of the long-term pollution limit value (6,000 µg.m⁻³.h, Tab. I.2) at all rural and regional stations (same set of stations for the last five years, Fig. IV.4.8). Within the evaluated five-year period, the values of the AOT40 index in 2019 were the second highest after 2018 at most stations.

IV.4.2 Trends in ground-level ozone concentration

The development of ground-level ozone concentrations, unlike previous assessments based mainly on three-year periods, is based on air pollution characteristics in one year, specifically, on average maximum daily 8-hour concentration for a given type of station and for all stations. This air pollution characteristic can be compared with the long-term air pollution target for ground-level ozone (120 µg.m⁻³, Tab. I.2). Maximum daily 8-hour concentration (average for all stations for which the measurement is available for the whole evaluated period) ranged from approx. 140 µg.m⁻³ to 170 µg.m⁻³ in the 2009–2019 period.

Ozone concentrations have not shown a significant course since 2009; the highest concentrations (average for all stations) were measured in 2013, 2015 and 2018 (Fig. IV.4.9). All these years are characterized by the occurrence of favourable meteorological conditions for the formation of ozone – in 2013 high concentrations of O_3 occurred especially at the turn of July and August during a number of tropical days. The years of 2015 and 2018 were exceptionally above average in terms of temperature and strong below average in terms of precipitation. The value of the concent-

ration in 2019 (150.7 µg.m⁻³) ranks fifth in the eleven-year period 2009–2019 and is very close to the value of the concentration of the ten-year average.

Emissions of precursors and meteorological conditions, i.e. intensity and length of sunshine, temperature, wind speed and precipitation or relative air humidity, respectively, play a crucial role in evaluating concentrations (Blanchard et al. 2010; Ooka et al. 2011). However, the relationship between the amount of precursors emitted and ground-level O_3 concentrations is not linear. This non-linearity is caused by complicated atmospheric chemistry of O_3 formation and destruction, long-range transport of O_3 and its precursors and other factors including meteorological conditions (Chap. IV.4.3), and climate change, emissions of non-methane volatile organic compounds (NMVOC) from vegetation and forest fires (EEA 2013b). With regard to the above mentioned factors and also to the dependence of O_3 concentrations not only on absolute quantity but also on the relative share of its precursors in the air, it is difficult to comment on the year-to-year changes.

Based on the results of long-term monitoring in the CR where a 25-year series of O_3 concentrations is available at a number of stations, its long-term trends can be meaningfully evaluated despite the high year-to-year variability of O_3 (Weatherhead et al. 1998). A detailed analysis of spatio-temporal trends of long-term monitoring by 26 stations of varying types (urban, rural, mountain) for the 1994–2015 period indicated that despite substantial decrease of precursors emissions and of O_3 pollution concentrations at a majority of stations, O_3 represents still a considerable problem for the Czech Republic. It has been clearly demonstrated that for the appropriate decrease of O_3 levels the NO/NO_2 ratio is critical and a concurrent substantial decrease of NO_X emissions alone is not therefore sufficient for decrease of O_3 concentrations (Hůnová, Bäumelt 2018). The analysis of changes in the spatial distribution of O_3, specifically the characteristics of the AOT40 exposure index for the 2000–2015 period indicated that the area permanently affected by high exposure is mainly the southern part of the Czech Republic, probably related to the length and intensity of solar ra-
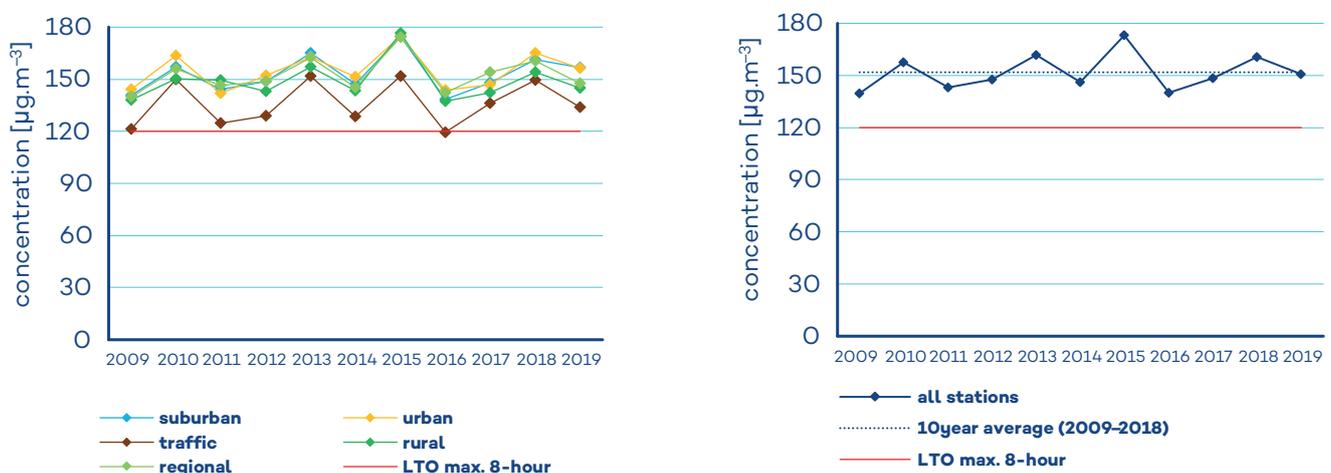
Fig. IV.4.9 Concentrations of ground-level ozone (maximum daily 8-hour running average), at particular types of stations in the Czech Republic, 2009–2019

diation (Hůnová et al. 2019a). The significant influence of meteorological conditions and air pollution on the daily variability of O_3 concentrations was confirmed also through the measured data. In addition to the influence of individual explanatory variables on the daily O_3 concentrations, the interactions between certain meteorological characteristics, such as between temperature and solar radiation, temperature and relative humidity, and solar radiation and relative humidity, have also been statistically significant for daily variability of O_3 (Hůnová et al. 2019b).

IV.4.3 Formation of ground-level ozone

O_3 does not have a significant source of its own in the atmosphere. This is a "secondary" substance formed by a number of complicated non-linear photochemical reactions (e.g. Seinfeld and Pandis 2006). Precursors of O_3 include nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOC), while methane (CH_4) and carbon monoxide (CO) play a role on a global scale. The photolysis of NO_2 by solar radiation with wavelength of 280–430 nm is an important reaction, forming NO and atomic oxygen. O_3 molecules are formed by the reaction of atomic and molecular oxygen in the presence of a catalyst. Simultaneously, O_3 is titrated by nitrogen monoxide, NO, with the formation of NO_2 and O_2. If O_3 is replaced by radicals in this reaction, its concentration increases in the atmosphere. The OH radical plays an especially important role in this reaction (in more detail e.g. Hůnová, Bäumelt 2018). NO_x are formed in all combustion processes. NMVOC are emitted from a number of anthropogenic sources (transport, manipulation with petroleum and its derivatives, refineries, the use of coatings and solvents, etc.), and also natural sources (e.g. biogenic emissions from vegetation).

In the formation of O_3 not only the absolute amount of precursors is important but also their relative share (Sillman et al. 1990; Fiala, Závodský 2003). In areas where the regime is limited by NO_x, characterized by relatively low concentrations of NO_x and high concentrations of VOC, the O_3 concentrations increase with increasing NO_x concentrations, but only minimally with increasing VOC concentrations. On the other hand, in areas with a regime limited by VOC, the O_3 concentrations decrease with increasing NO_x concentrations and the O_3 concentrations increase with increasing VOC concentrations. Areas with a high NO_x/VOC ratio are typically polluted areas around the centres of large cities. The dependence of the formation of O_3 on the initial concentrations of VOC and NO_x is frequently expressed by ozone isopleth diagrams, which depict the maximum attained O_3 concentration as a function of the initial NO_x and VOC concentrations (Moldanová 2009). Not only the concentrations of precursors, but also meteorological conditions, play an important role in the formation of O_3 (Colbeck, Mackenzie 1994). The pollution concentrations of O_3 increase with increasing ultraviolet radiation and temperature but decrease with increasing relative air humidity. These relations were also demonstrated on the results of long-term CHMI measurements (Hůnová et al. 2019a). High concentrations are often related to prolonged anticyclone situations. In addition to the

above-described photochemical mechanisms, the concentrations of O_3 can also increase in episodes as a result of penetration of stratospheric O_3 into the troposphere and also during thunderstorms. Recently, there has also been an increase in the importance of long-range of O_3 in the northern hemisphere to Europe and North America from source areas in south-east Asia. O_3 is removed from the atmosphere by reaction with NO, the mechanism of dry or wet deposition and interaction with plants (stomatal uptake).

IV.5 Benzene

IV.5.1 Air pollution by benzene in 2019

The annual pollution limit value for benzene C_6H_6 (5 µg.m^{-3}) was not exceeded in 2019 at any of the total 36 localities with valid annual average (Tab. XI.13, Fig. IV.5.1). The highest annual average was detected at the Ostrava-Přívoz station (4.2 µg.m^{-3}). Compared to 2018 at 5.1 µg.m^{-3}, it is a decrease by 18%. The O/K/F-M agglomeration was loaded by the highest concentrations of benzene (Fig. IV.5.2).

In the long term, benzene concentrations in the Czech Republic, except for the O/K/F-M agglomeration, are very low and do not even reach half of the pollution limit value (Fig. IV.5.3). From the total of 31 stations measuring benzene concentrations in the Czech Republic in 2018 and 2019, the annual average concentration increased at 4 stations (14%), while it decreased at 23 stations (74%). The concentration did not change at 4 stations (14%).

IV.5.2 Trends in benzene concentrations

At most stations, the trend of annual average benzene concentrations is declining, at some stations the value of the annual average benzene concentration is stagnant. Since 2014, annual concentrations averaged over all types of stations have been below the ten-year average of 2009–2018. The year 2019 is the second year after 2016 with the lowest annual average concentration (Fig. IV.5.4). The highest annual average concentrations are observed at industrial sites which are situated mostly in the O/K/F-M agglomeration. The lowest annual average concentrations are observed at rural and regional localities, which is due to the location of the stations and small impact by the emission sources (Fig. IV.5.5).

IV.5.3 Benzene emissions

Benzene belongs to the group of organic compounds and it is used as a solvent or raw material for production of a range of chemical substances. Benzene is a part of crude oil and its small amount is added to automotive petrol to improve its octane number. It is produced mainly by processing the crude oil and from coal tar yielded during coal coke production. Together with other VOCs it also originates from incomplete combustion.

classification of stations
- ■ urban background
- ♦ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [µg.m^{-3}]
- ■ ≤ 2.0
- ■ 2.1–3.5
- ■ 3.6–5.0
- ■ > 5.0

0 25 50 100 km

— agglomeration
— zone
— region
— river
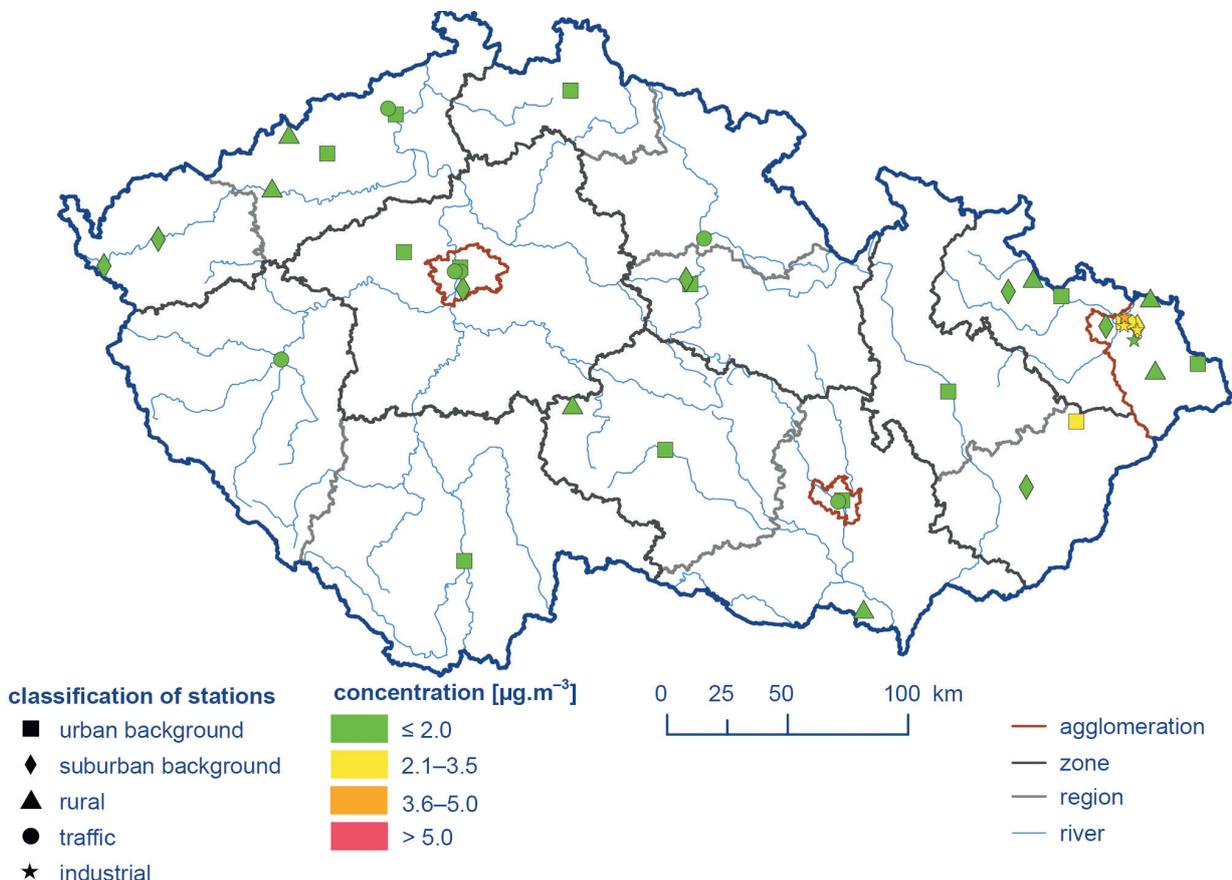
Fig. IV.5.1 Annual average concentrations of benzene at air quality monitoring stations, 2019

concentration [μg.m⁻³]

🟩	≤ 2.0	99.9 %
🟨	2.1–3.5	0.1 %
🟧	3.6–5.0	
🟥	> 5.0	

0   25   50   100 km

— agglomeration
— zone
— region
⬡ municipality over 30K inhab.
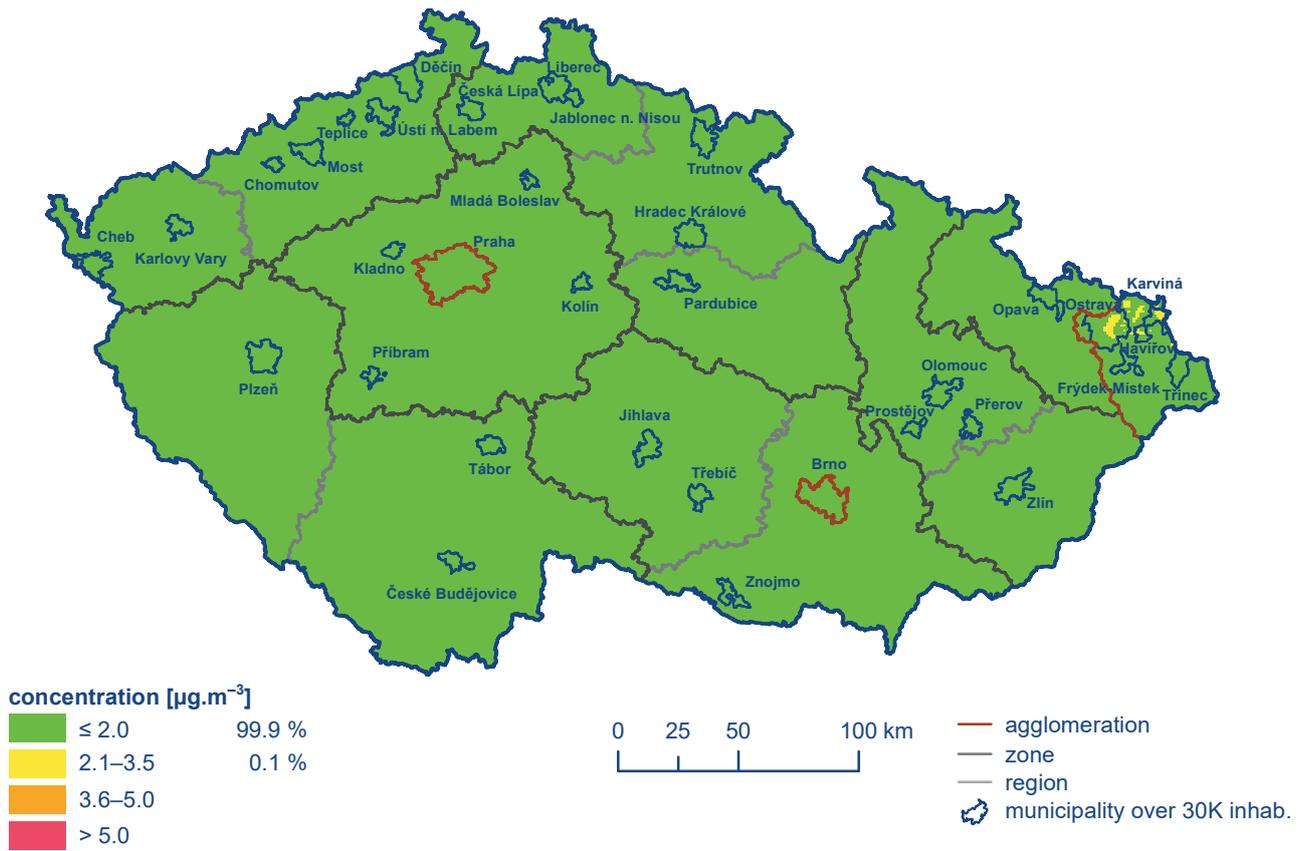
Fig. IV.5.2 Field of annual average concentration of benzene, 2019

concentration [μg.m⁻³]

🟩	≤ 2.0	99.7 %
🟨	2.1–3.5	0.3 %
🟧	3.6–5.0	
🟥	> 5.1	

0   25   50   100 km

— agglomeration
— zone
— region
⬡ municipality over 30K inhab.
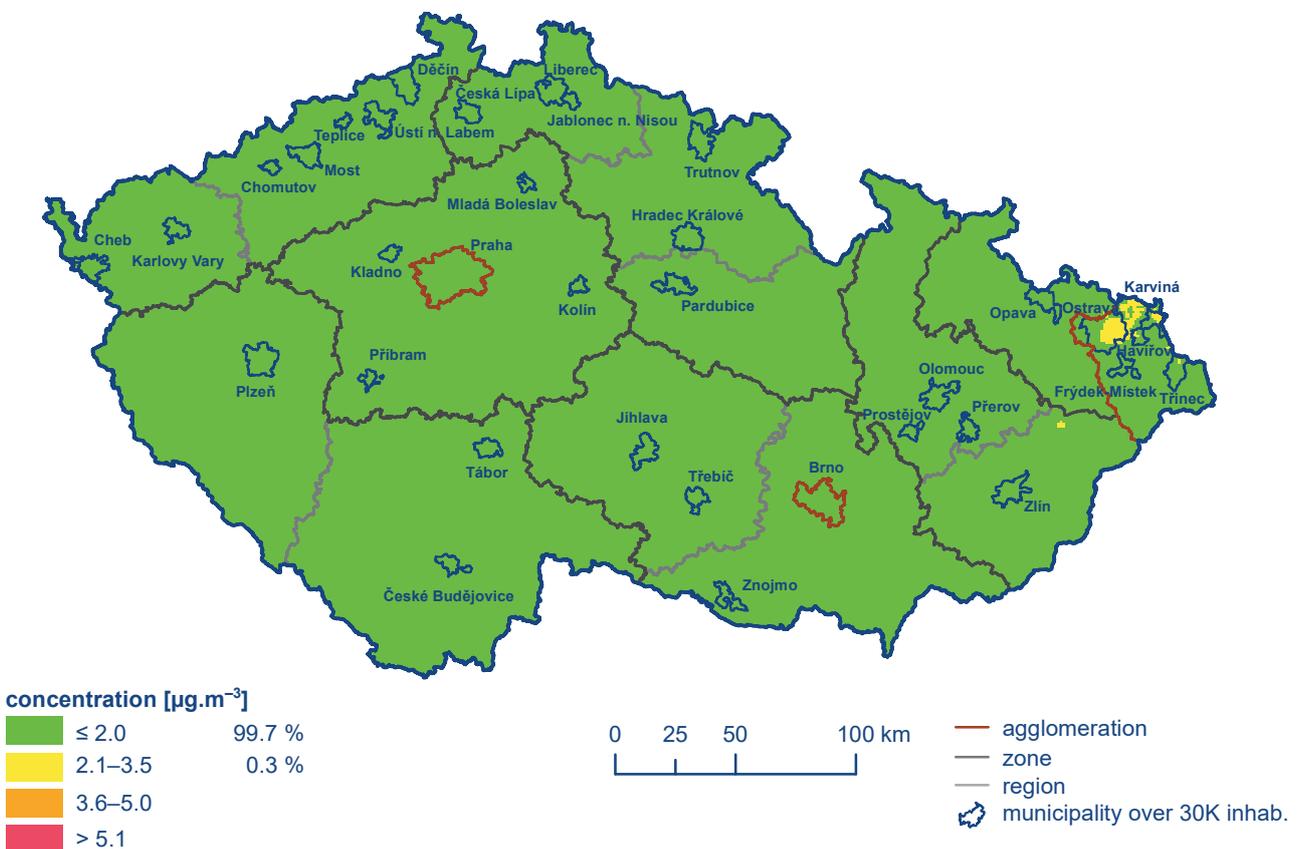
Fig. IV.5.3 Five-year average of annual average concentrations of benzene, 2015–2019

Benzene does not belong to the range of pollutants covered by the LRTAP Convention and therefore its inventory is not available according to the NFR sectors structure but by the REZZO categories only. According to the evaluation carried out for the purpose of updating the PZKO, 672.6 tonnes of benzene were released into the air in 2016. The biggest benzene emissions were produced by REZZO 4 category sources (75%) of which benzene is emitted through exhaust gasses and by leaking from vehicle fuel systems. A significant amount of benzene emissions were produced by

REZZO 3 category sources through household combustion of solid fuels (13%), flat use of organic solvents (5%) or fuel extraction (3%). A contribution of REZZO 1 and REZZO 2 category sources amounted 4% to the total benzene emissions of which the major share related to the Energy – fuel combustion (codes 1.1.–1.4. of the Annex No. 2 to the Act No. 201/2012 Coll., on protection of the air) reaching 2.2% and the Use of organic solvents (codes 9.1.–9.24. of the Annex No. 2 to the Act No. 201/2012 Coll., on protection of the air) reaching 0.7%.
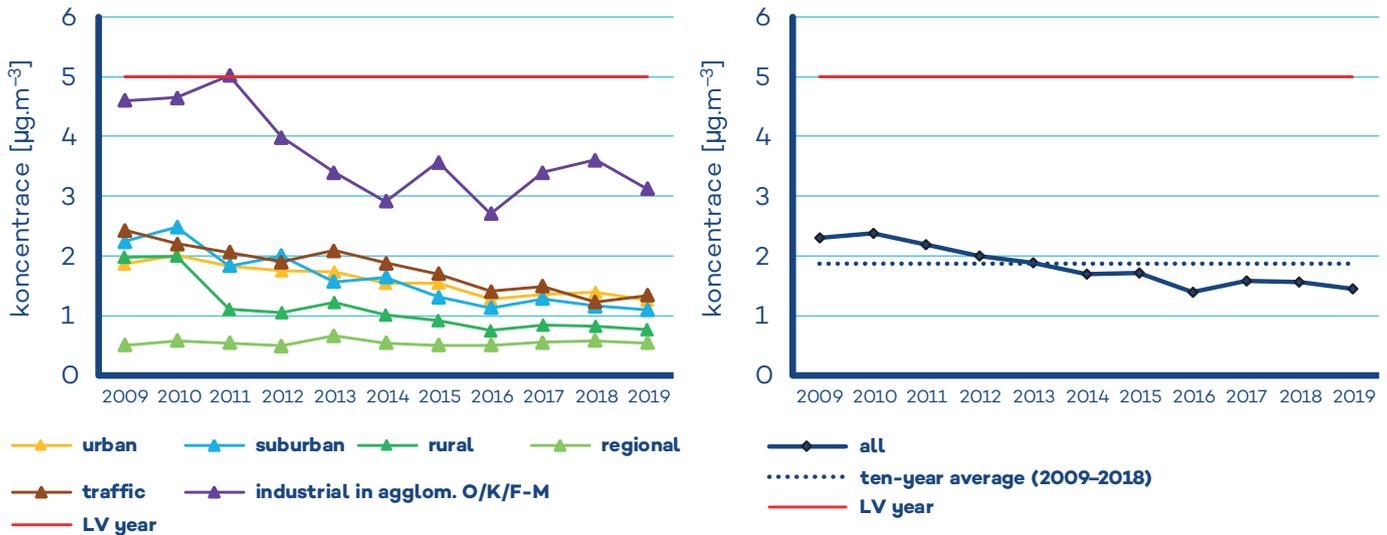
Fig. IV.5.4 Annual average concentrations of benzene at particular types of stations in the Czech Rebulic, 2009–2019
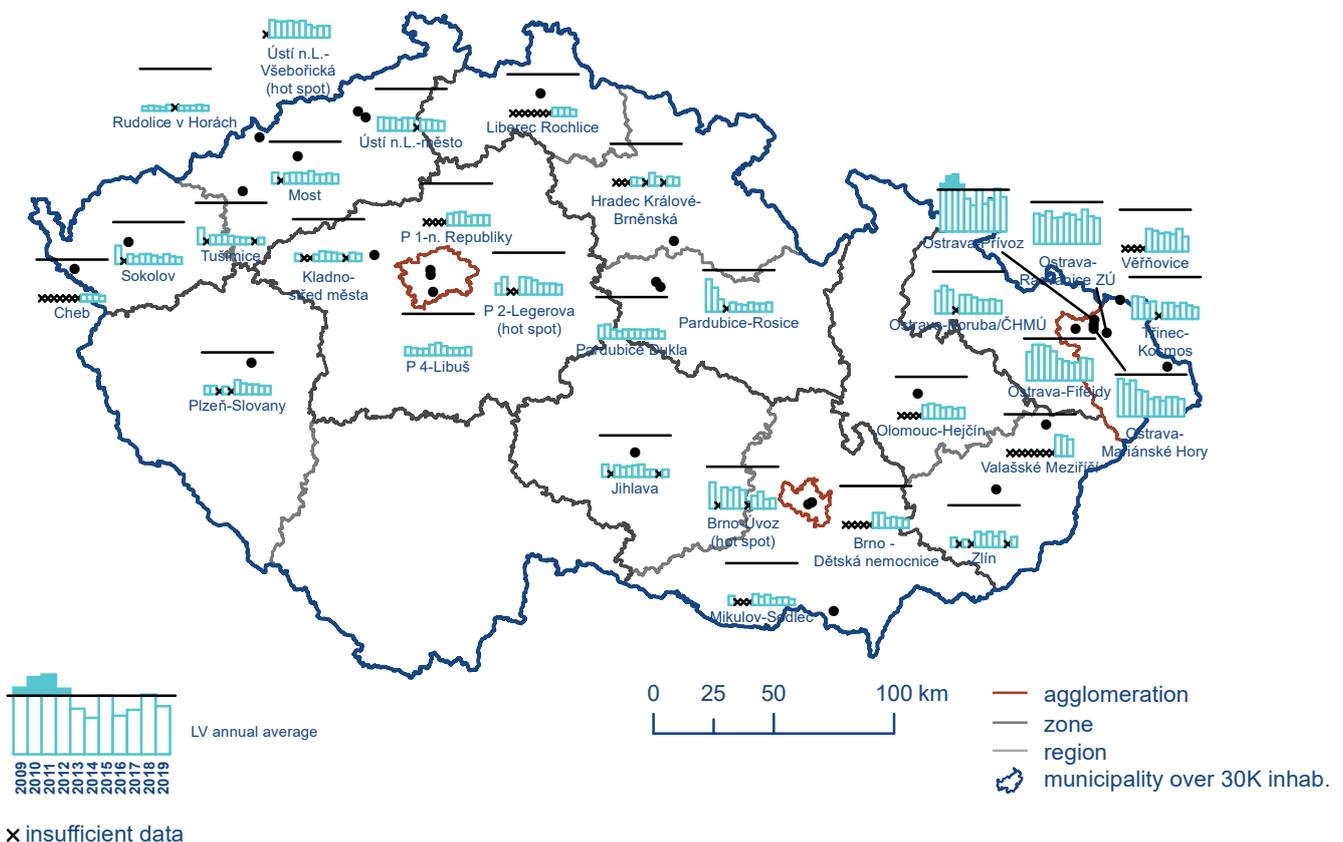
Fig. IV.5.5 Annual average concentrations of benzene at selected stations, 2009–2019

IV.6 Heavy metals

IV.6.1 Air pollution by heavy metals in 2019

Arsenic

The annual pollution limit level for arsenic (6 ng.m⁻³) was not exceeded at any of 52 stations with valid annual average value in 2019 (Tab. XI.16, Fig. IV.6.4). The highest annual average was observed at the Kladno-Švermov urban background station (3.3 ng.m⁻³). Compared to 2018 with 3.9 ng.m⁻³, it is a decrease by 15%. The Kladno district and the territory of the capital of Prague were loaded by the highest concentrations of arsenic in 2019. Following a support by the Moravian-Silesian region, a location with a similar concentration level was identified also in Bruntál (Fig. IV.6.2).

Arsenic concentrations have long been below the limit value over most of the Czech Republic, except for the Kladno and Prague areas (Fig. IV.6.3). In non-polluted areas, concentrations are below half of the limit value, in polluted areas, also above the limit value. Of the total number of 39 stations that measured arsenic concentrations in both 2018 and 2019, the annual average concentration increased at only 3 stations (8%), while decreased at 33 stations (85%). The concentration remained unchanged at 3 stations (8%).

Cadmium

The annual pollution limit level for cadmium (5 ng.m⁻³) was not exceeded at any of 60 stations with valid annual average value in 2019 (Tab. XI.15, Fig. IV.6.4). The highest annual average was observed at the Tanvald-školka urban background station (4 ng.m⁻³). Compared to 2018 with 3.2 ng.m⁻³, it is an increase by 20%. The highest annual average concentrations were identified mostly at stations in the Jablonec nad Nisou district (Fig. IV.6.5).

In the long term, cadmium concentrations are below the limit value over the territory of the Czech Republic, except for the Jablonec nad Nisou vicinity (Fig. IV.6.6). Of the total number of 39 stations measuring cadmium concentrations in both 2018 and 2019, the annual average concentration increased at 13 stations (33%), while it decreased at 11 stations (28%). The concentration remained unchanged at 15 stations (38%).

classification of stations
- ■ urban background
- ◆ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [ng.m⁻³]
- ≤ 2.4
- 2.5–3.6
- 3.7–6.0
- > 6.0

0 25 50 100 km

— agglomeration
— zone
— region
— river
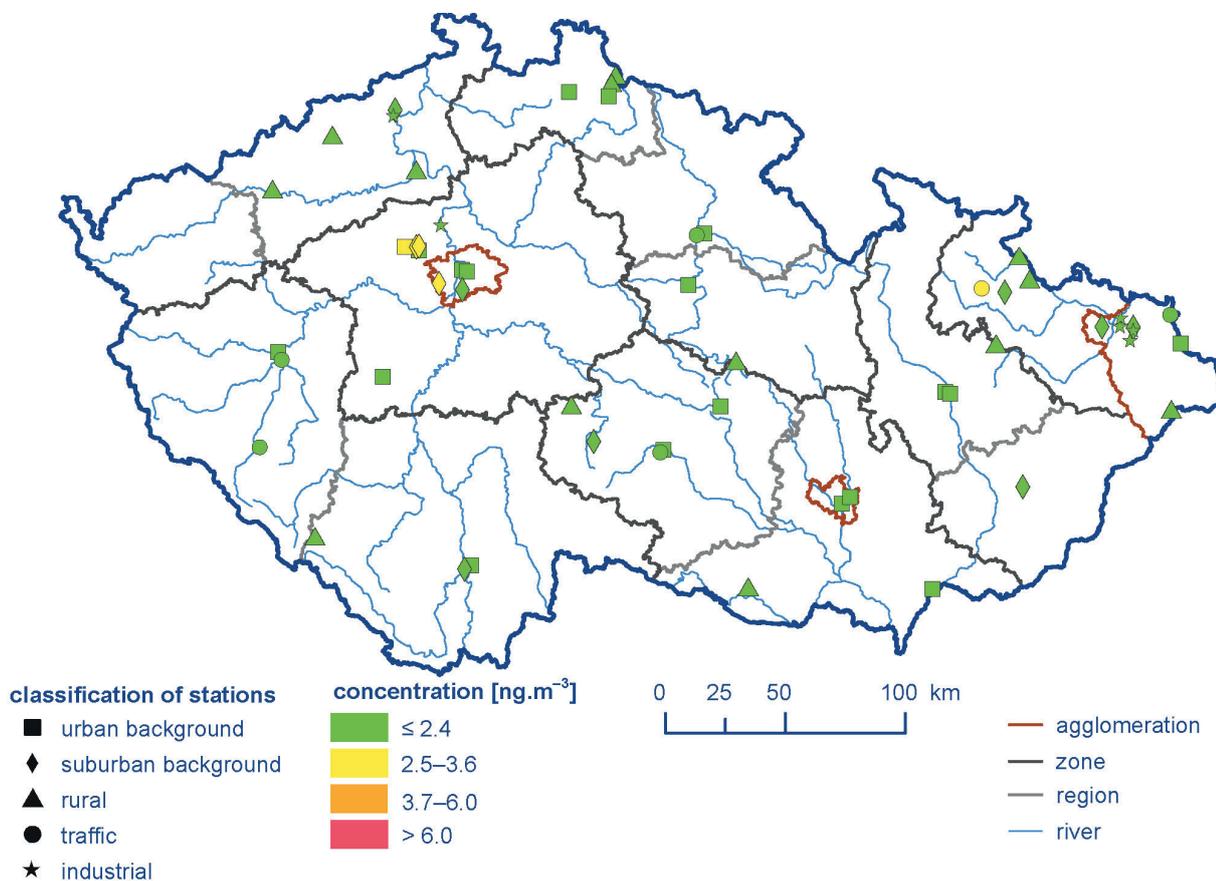
Fig. IV.6.1 Annual average concentrations of arsenic at air quality monitoring stations, 2019

concentration [ng.m^{-3}]

≤ 2.4	99.96 %
2.5–3.6	0.04 %
3.7–6.0	
> 6.0	

0   25   50   100 km

— agglomeration
— zone
— region
municipality over 30K inhab.
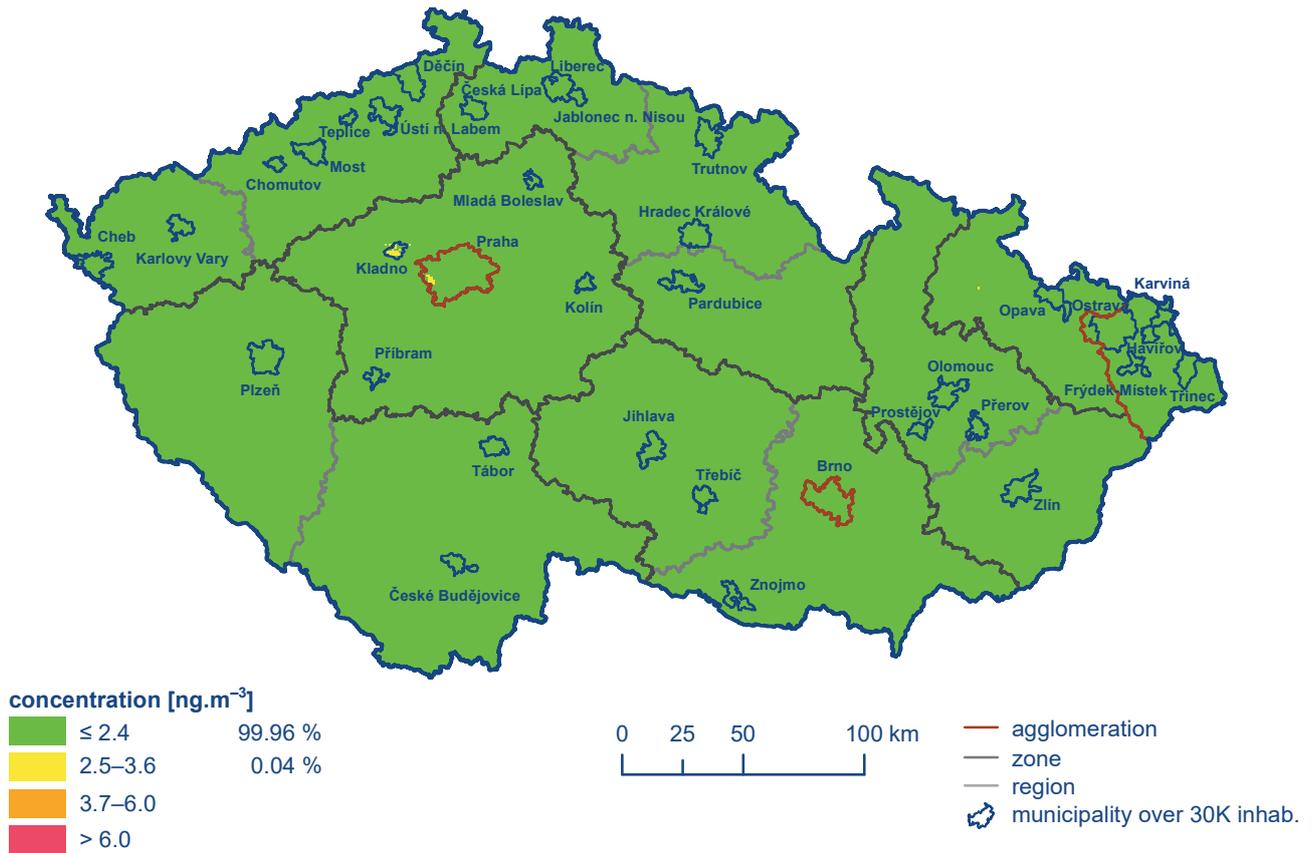
Fig. IV.6.2 Field of annual average concentration of arsenic, 2019

concentration [ng.m^{-3}]

≤ 2.4	99.77 %
2.5–3.6	0.22 %
3.7–6.0	0.01 %
> 6.0	

0   25   50   100 km

— agglomeration
— zone
— region
municipality over 30K inhab.
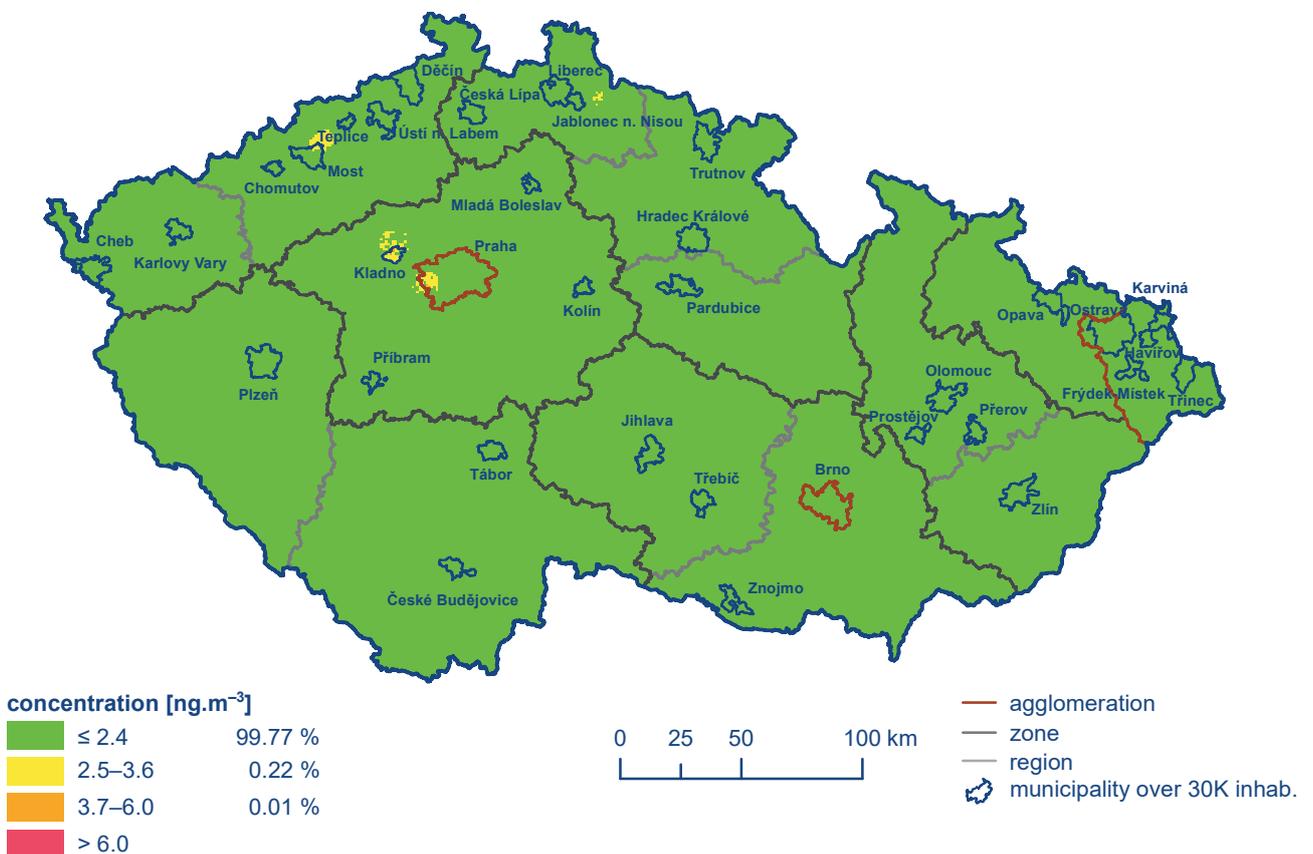
Fig. IV.6.3 Five-year average of annual average concentrations of arsenic, 2015–2019

Nickel

The annual pollution limit level for nickel (20 ng.m^{-3}) was not exceeded at any of 53 stations with valid annual average value in 2019 (Tab. XI.17). The highest annual average value (4 ng.m^{-3}) was observed at the Ostrava-Mariánské Hory industrial station. The same value was observed in 2018. The highest nickel concentrations are repeatedly measured in the O/K/F-M agglomeration.

Nickel concentrations have long been very low over the whole territory of the Czech Republic and do not even reach half of the pollution limit level. Of the total number of 39 stations measuring nickel concentrations in both 2018 and 2019, the annual average concentration increased at only 1 station (3%), while it decreased at 82 stations (82%). The concentration remained unchanged at 6 stations (15%).

Lead

The annual pollution limit level for lead (500 ng.m^{-3}) was not exceeded at any of 52 stations with the valid annual average value in 2019 (Tab. XI.14). The highest annual average (52 ng.m^{-3}) was observed at the Ostrava-Radvanice ZÚ station. Compared to 2018 with 47 ng.m^{-3}, it is an increase by 9%. The highest lead concentrations are repeatedly measured in the O/K/F-M agglomeration.

In the long term, lead concentrations are very low over the whole territory of the Czech Republic and do not even reach half of the pollution limit level. Of the total number of 39 stations measuring lead concentrations in both 2018 and 2019, the annual average concentration increased at only 2 stations (5%), while it decreased at 37 stations (95%).

classification of stations
- ■ urban background
- ♦ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [ng.m^{-3}]
- ≤ 2.0
- 2.1–3.0
- 3.1–5.0
- > 5.0

0 25 50 100 km

- agglomeration
- zone
- region
- river
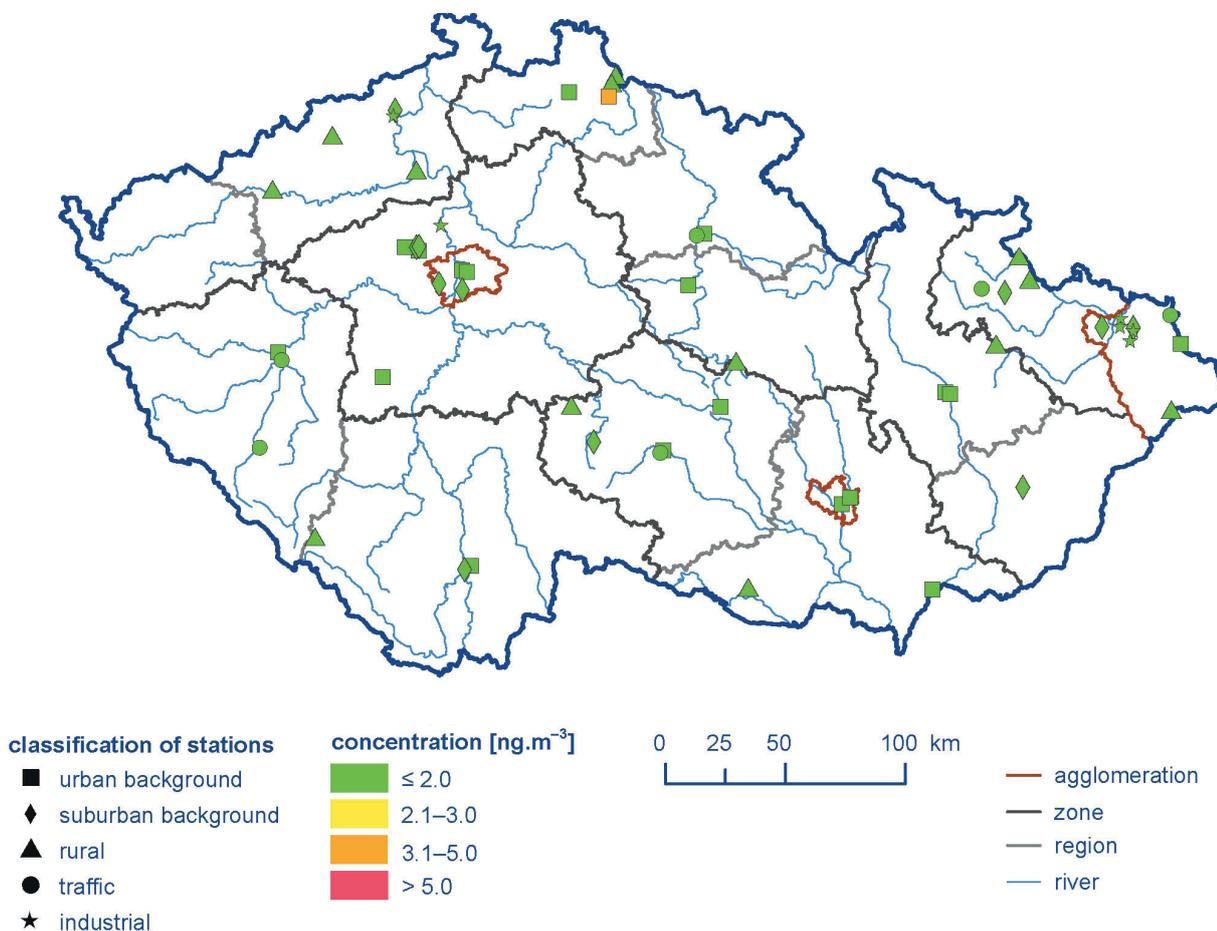
Fig. IV.6.4 Annual average concentrations of cadmium at air quality monitoring stations, 2019

concentration [ng.m⁻³]

🟩	≤ 2.0	99.88 %
🟨	2.1–3.0	0.09 %
🟧	3.0–5.0	0.03 %
🟥	> 5.0	

— agglomeration
— zone
— region
municipality over 30K inhab.
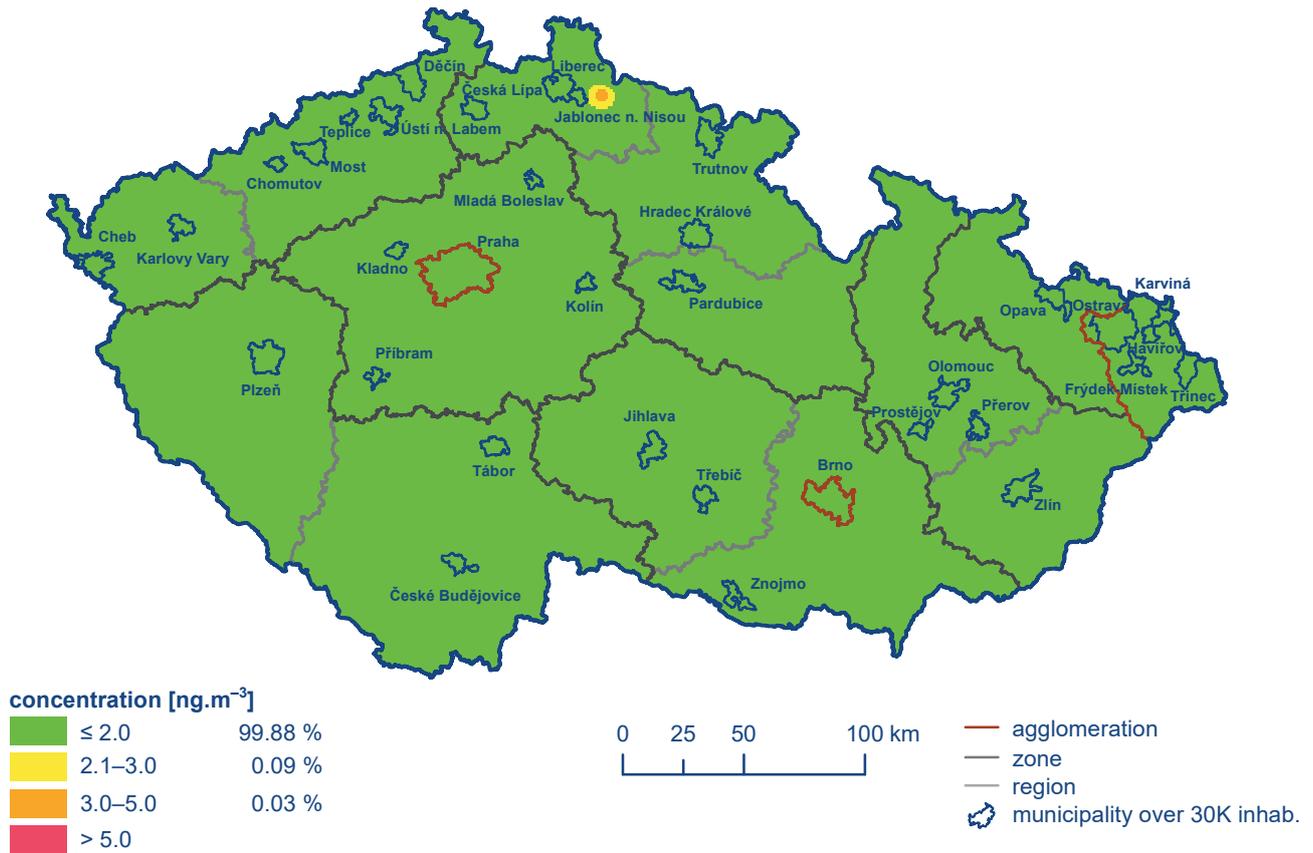
Fig. IV.6.5 Field of annual average concentration of cadmium, 2019

koncentrace [ng.m⁻³]

🟩	≤ 2,0	99,87 %
🟨	2,1–3,0	0,11 %
🟧	3,0–5,0	0,02 %
🟥	> 5,0	

— aglomerace
— zóna
— kraj
obce nad 30 tis. obyvatel
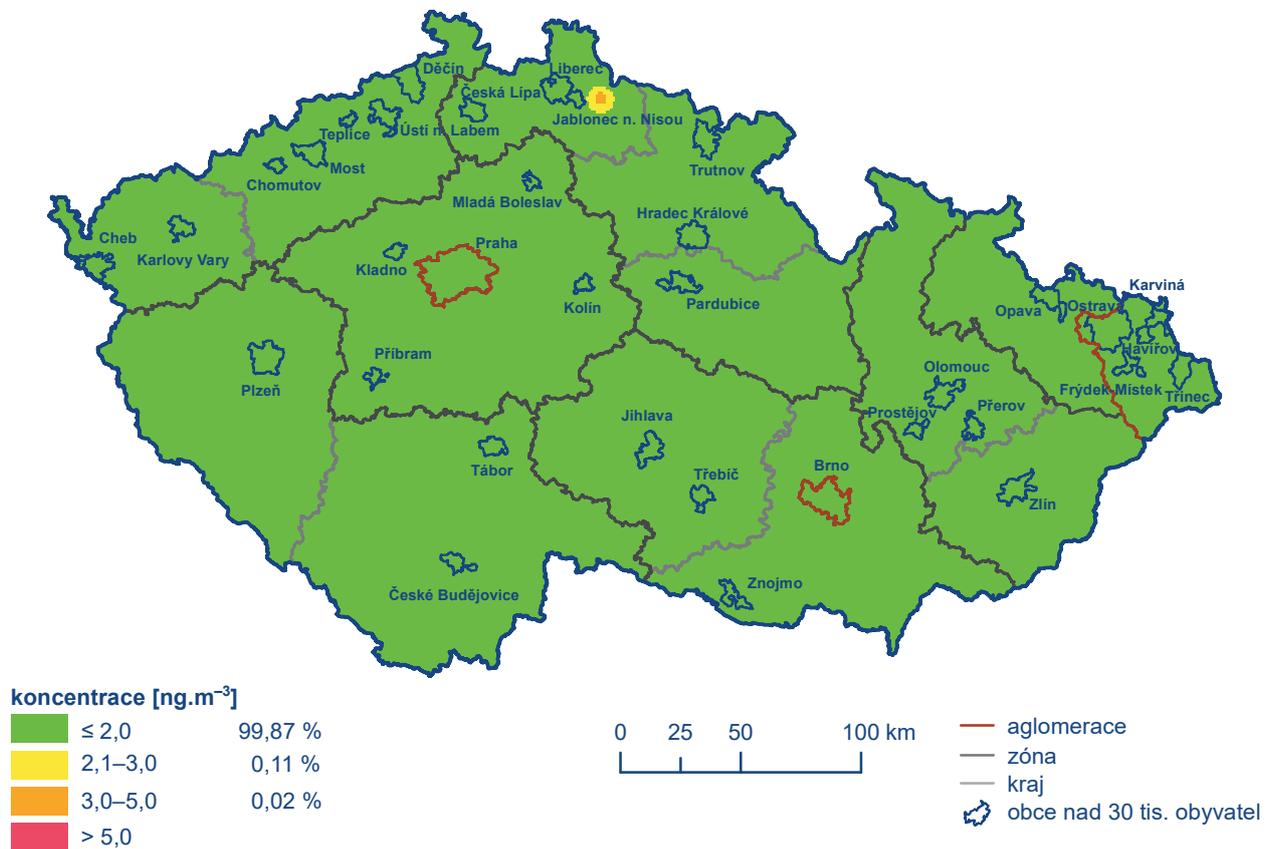
Fig. IV.6.6 Five-year average of annual average concentrations of cadmium, 2015–2019

IV.6.2 Trends in heavy metal concentrations

Arsenic concentrations have been stable over the last 11 years, and have been slightly declining since 2017 (Fig. IV.6.7). In the most polluted area, the Kladno district, the limit level for arsenic was being exceeded in the period under review until 2013. Since 2014, annual concentrations have been just above the upper assessment limit (Fig. IV.6.8). The Kladno district is one of the areas where the campaign measurement of heavy metal concentrations under the Technology Agency of the CR project (No. TIT-SMZP704) took place. Preliminary results show that the increased
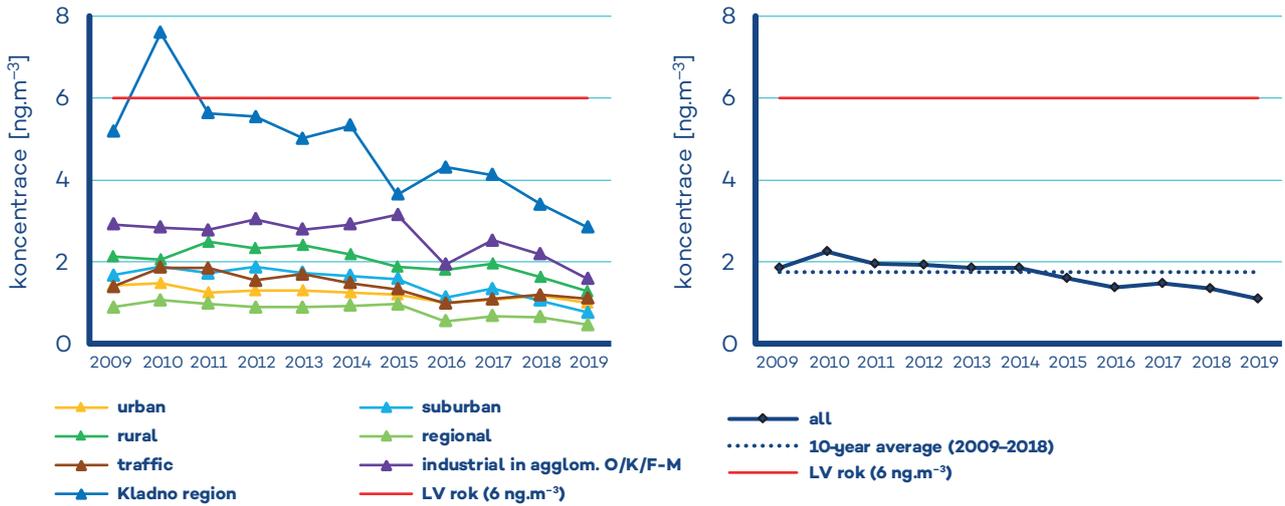
Fig. IV.6.7 Annual average concentrations of arsenic, at particular types of stations in the Czech Republic, 2009–2019
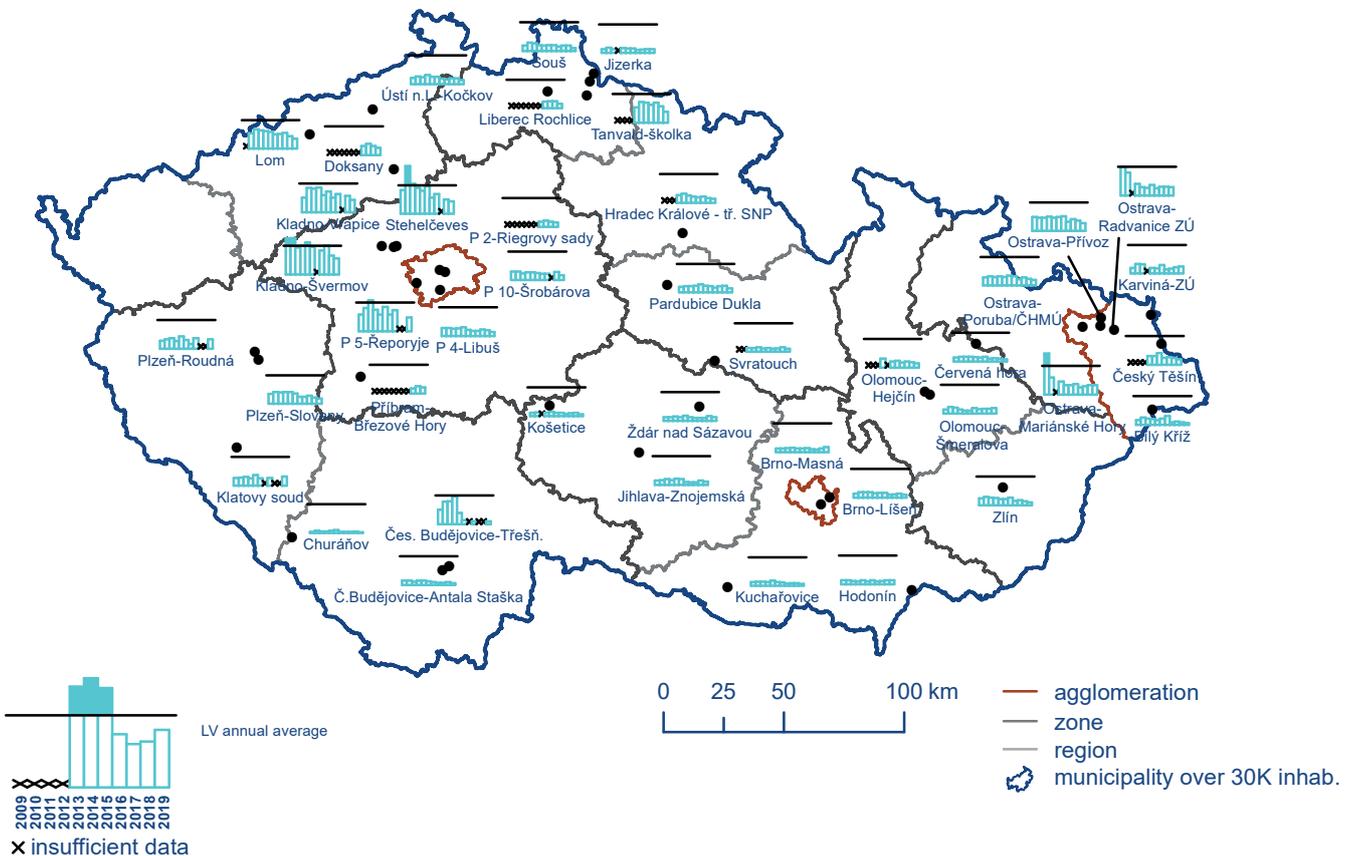
Fig. IV.6.8 Annual average concentrations of arsenic at selected stations, 2009–2019

arsenic concentrations in this region are due to the use of specific type of coal for individual household heating. The issue is subject to further investigation.

The national average of cadmium concentrations has been declining over the last 11 years (Fig. IV.6.9). In the most polluted area, in the Tanvald district, high to above-limit concentrations were observed between 2012 and 2015 (Fig. IV.6.10). The Tanvald area
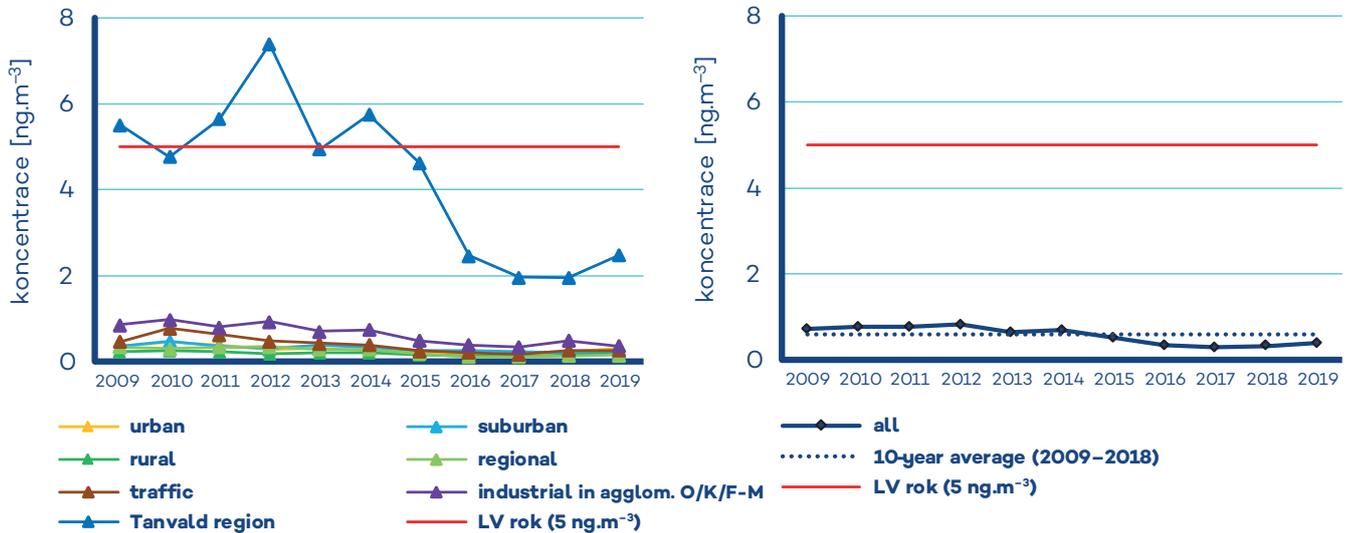
Fig. IV.6.9 Annual average concentrations of cadmium at particular types of stations in the Czech Republic, 2009–2019
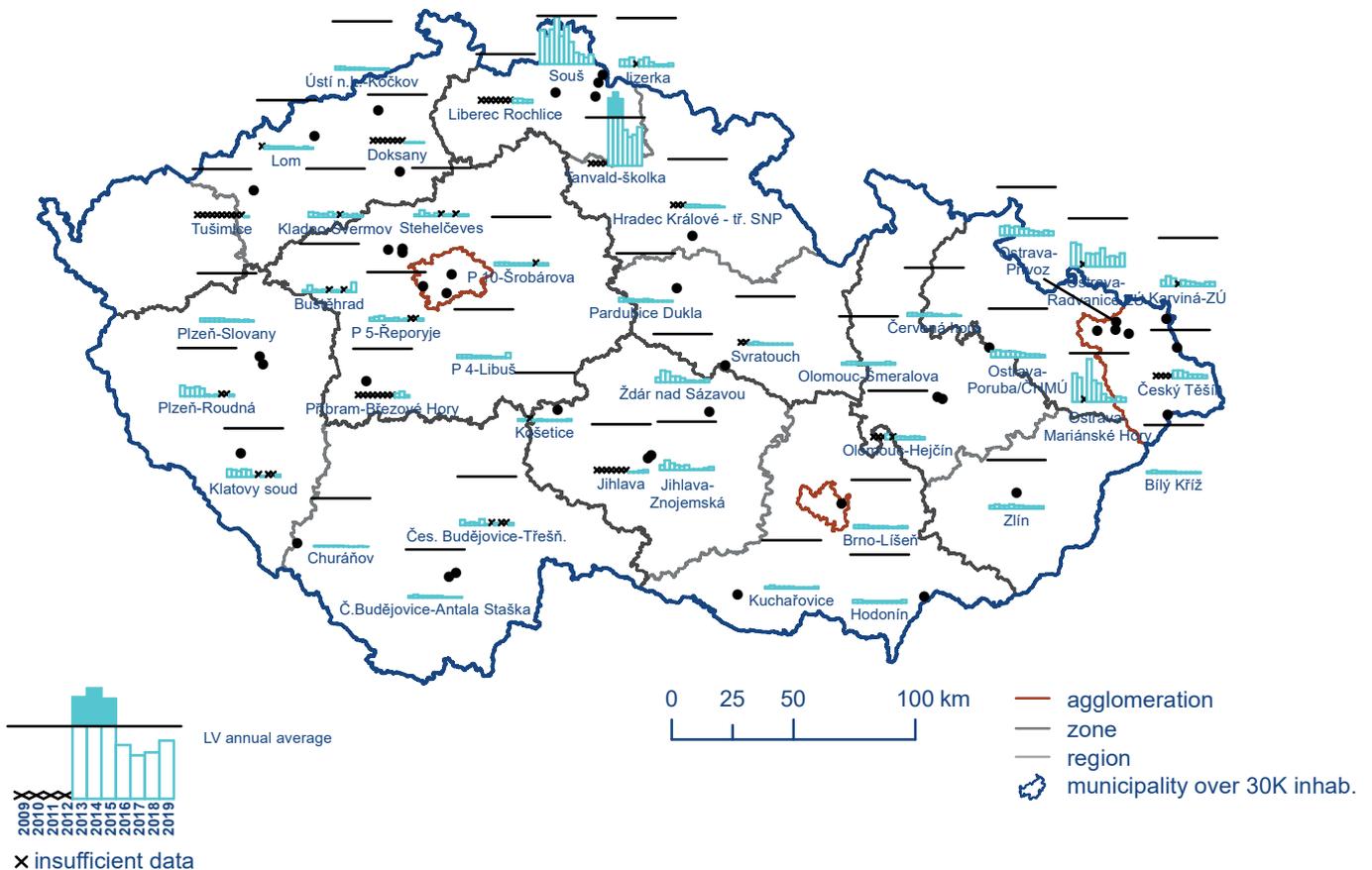
Fig. IV.6.10 Annual average concentrations of cadmium at selected stations, 2009–2019

is characterized by a high representation of the glass industry (AS-KPCR 2014) which is a significant source of cadmium emissions from application of paints and fluxing agents (Beranová 2013). In 2015 and 2016, the production operation was adapted to be ecologically favourable which led to a decrease of annual average cadmium concentrations below the limit level. However, an annual evaluation of measurements at the Tanvald-školka station and monitoring of results is still needed to assess the effectiveness of particular measures.

The national average of nickel concentrations has been slightly declining in the last 11 years, and has been developing steadily

after 2015 (Fig. IV.6.11). In 2013, there was a significant increase in nickel concentrations at traffic stations. The highest concentrations since 2009 were recorded at industrial stations in 2018 and 2019. The cause of these fluctuations has not yet been sufficiently clarified.

Lead concentrations show a declining trend in the last 11 years, except for 2018, when there was an increase in concentrations at all types of stations (Fig. IV.6.12).
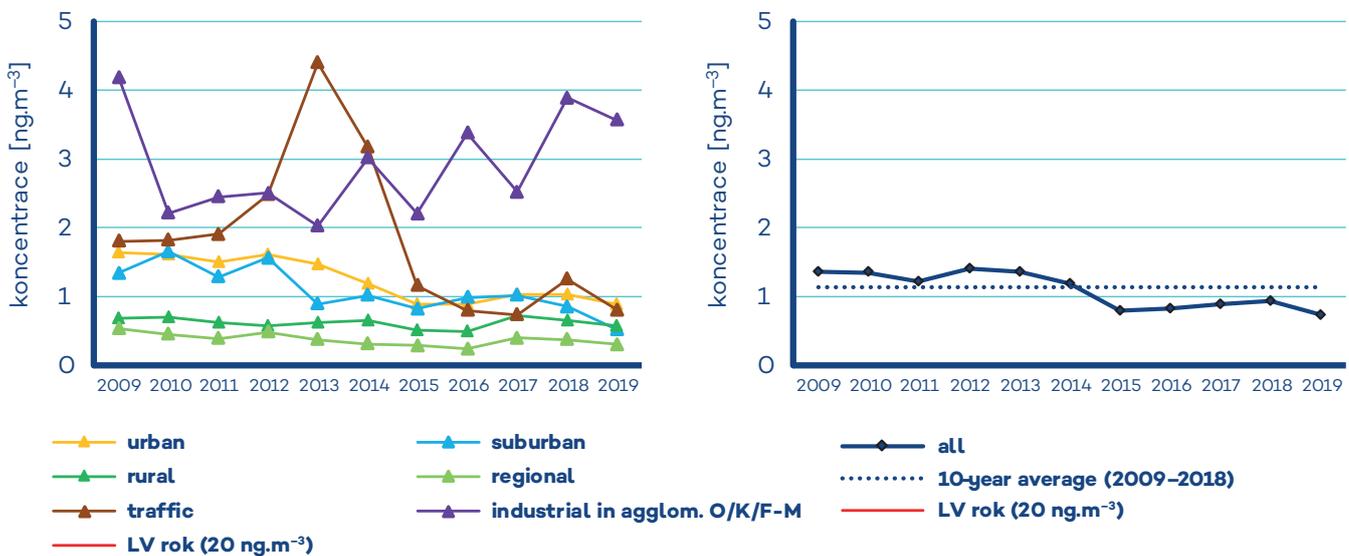
Fig. IV.6.11 Annual average concentrations of nickel at particular types of stations in the Czech Republic, 2009–2019
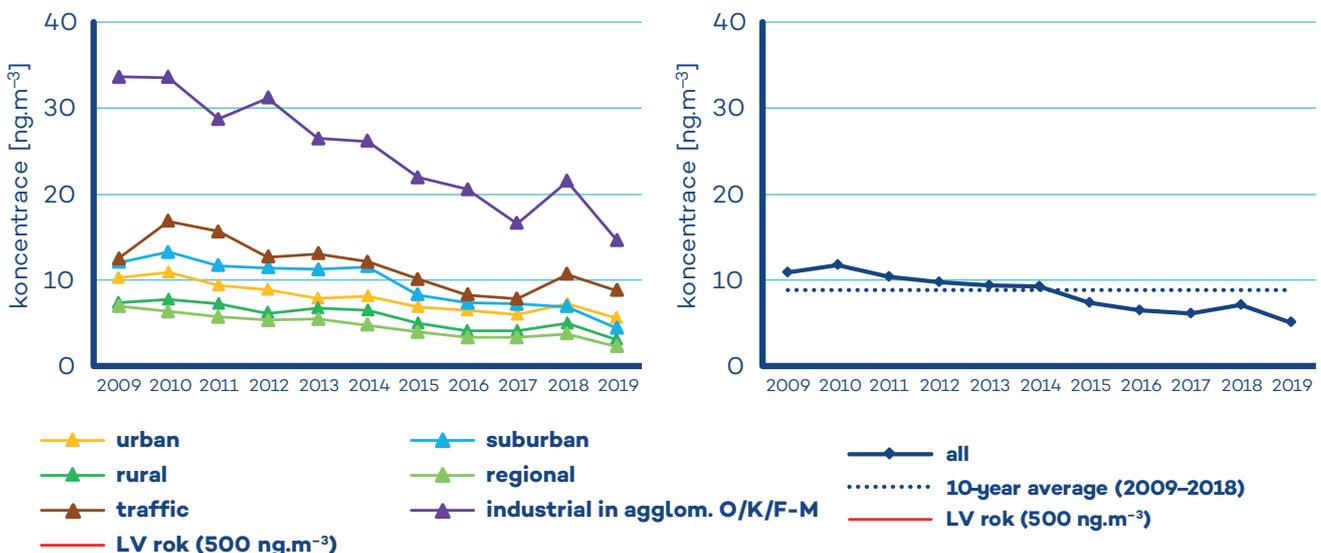
Fig. IV.6.12 Annual average concentrations of lead at particular types of stations in the Czech Republic, 2009–2019

IV.6.3 Emissions of heavy metals

The group of heavy metals comprises metals with a specific density greater than 4.5 g.cm^{-3} and their compounds. Heavy metals are a natural component of solid fuels and their contents in fuels vary in dependence on the mining site. The amounts of heavy metal emissions from the combustion of solid fuels depends primarily on the kind of fuel, type of combustion equipment, and combustion temperature which affects the volatility of the heavy metals. Heavy metal emissions are also formed in some technological processes because they are contained in the input raw materials (e.g. iron ore, scrap metal, glass batches, coatings, glass shards). In addition to these processes, there are also a number of sources of fugitive emissions containing heavy metals (for example, particles from abrasion of brakes and tyres or emissions related to old environmental burdens left by mining and metallurgical activities).

Combustion processes are of predominant importance primarily for emissions of arsenic and nickel. The most significant sectors at a national scale include 1A1a — Public electricity and heat production which contributed 26.8% to arsenic emissions and 37.5% to nickel emissions in 2018 (Fig. IV.6.13 and Fig. IV.6.15). In 2018, significant contributions from the sectors of iron and steel production (1A2a and 2C1) related primarily to lead emissions (22.5%; Fig. IV.6.19). The impact of sector 1A4bi — Residential: Stationary predominated for cadmium emissions with a share of 50.8% (Fig. IV.6.17) and was significant also for arsenic emissions (36.8%; Fig. IV.6.13). Significant share of total lead emissions is formed by emissions from triggering of fireworks and pyrotechnics (29.2%; Fig. IV.6.19) which belong to sector 2G – Other sources. The cadmium emissions accounted for 10.7% from 2G sector with the main source of emissions being tobacco smoke (Fig. IV.6.17). The decreasing trend in emissions of heavy metals in the 2008–2018 period relates to the rate of emissions of suspended particles (Chap. IV.1.3) to which these substances are bound (Figs. IV.6.14, IV.6.16, IV.6.18, and IV.6.20). Measures in the sector of production of iron and steel made a substantial contribution to the decrease in heavy metal emissions, especially the improvements in the dust-removal system for agglomeration sintering strands. Technical measures have also succeeded in reducing heavy metal emissions from glass production. In recent years, there has been an increase in the volume of secondary production of non-ferrous metals, especially aluminium and lead. Emissions of heavy metals from these sources are very variable in dependence on the quality of the processed scrap metal.

In view of the predominant contribution of the sector of public electricity and heat production and the sector of iron and steel production, the territorial distribution of heavy metal emissions (excluding emissions from sector 2G – Other sources) is determined mainly by the location of production facilities in these sectors. Emissions of arsenic and nickel are concentrated in areas in which thermal power plants and heating plants burning coal are located (Figs. IV.6.21, and IV.6.22). These are primarily enterprises in the Ústí nad Labem, Central Bohemian and Pardu-

bice regions. Emissions of cadmium and lead are predominantly produced in the O/K/F-M agglomeration due to concentration of enterprises producing iron and steel. A significant amount of lead emissions in the Central Bohemian region originates from secondary lead production at Kovohutě Příbram (Figs. IV.6.23, and IV.6.24).

■ **Other**
■ **1A2c – Stationary combustion in manufacturing industries and construction: Chemicals**
■ **2C1 – Iron and steel production**
■ **2C3 – Aluminium production**
■ **1B2aiv – Fugitive emissions oil: Refining and storage**
■ **1A4ai – Commercial/Institutional: Stationary**
■ **1A2f – Stationary combustion in manufacturing industries and construction: Non-metallic minerals**
■ **2A3 – Glass production**
■ **1A1a – Public electricity and heat production**
■ **1A4bi – Residential: Stationary**

Legend to Figs IV.6.13 and IV.6.16

■ **Other**
■ **1A4ai – Commercial/Institutional: Stationary**
■ **1A2f – Stationary combustion in manufacturing industries and construction: Non-metallic minerals**
■ **1A3bvi– Road transport: Automobile tyre and brake wear**
■ **2A3 – Glass production**
■ **2C1 – Iron and steel production**
■ **2G – Other product use**
■ **1A4bi – Residential: Stationary**
■ **1A2c – Stationary combustion in manufacturing industries and construction: Chemicals**
■ **1A1a – Public electricity and heat production**

Legend to Figs IV.6.17 and IV.6.18

■ **Other**
■ **1A2a – Stationary combustion in manufacturing industries and construction: Iron and steel**
■ **2C3 – Aluminium production**
■ **1B2aiv – Fugitive emissions oil: Refining and storage**
■ **2G – Other product use**
■ **1A1a – Public electricity and heat production**
■ **2C1 – Iron and steel production**
■ **2A3 – Glass production**
■ **1A4bi – Residential: Stationary**

Legend to Figs IV.6.19 and IV.6.20
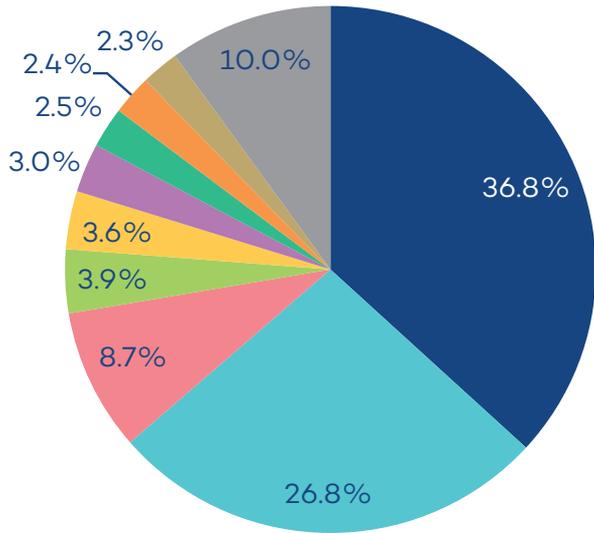
Fig. IV.6.13 Share of NFR sectors in total emissions of arsenic, 2018
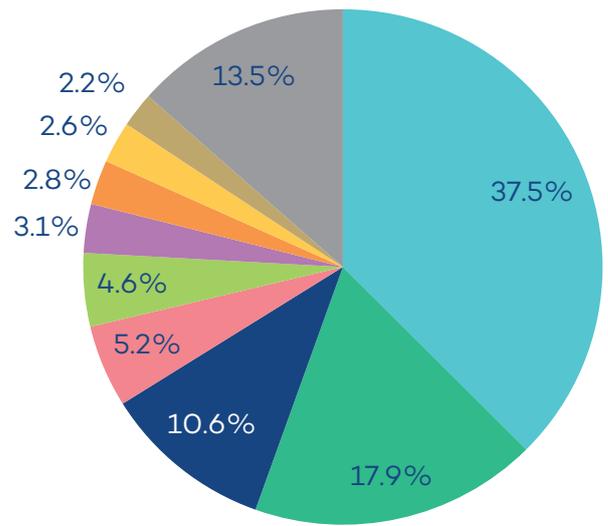
Fig. IV.6.15 Share of NFR sectors in total emissions of nickel, 2018
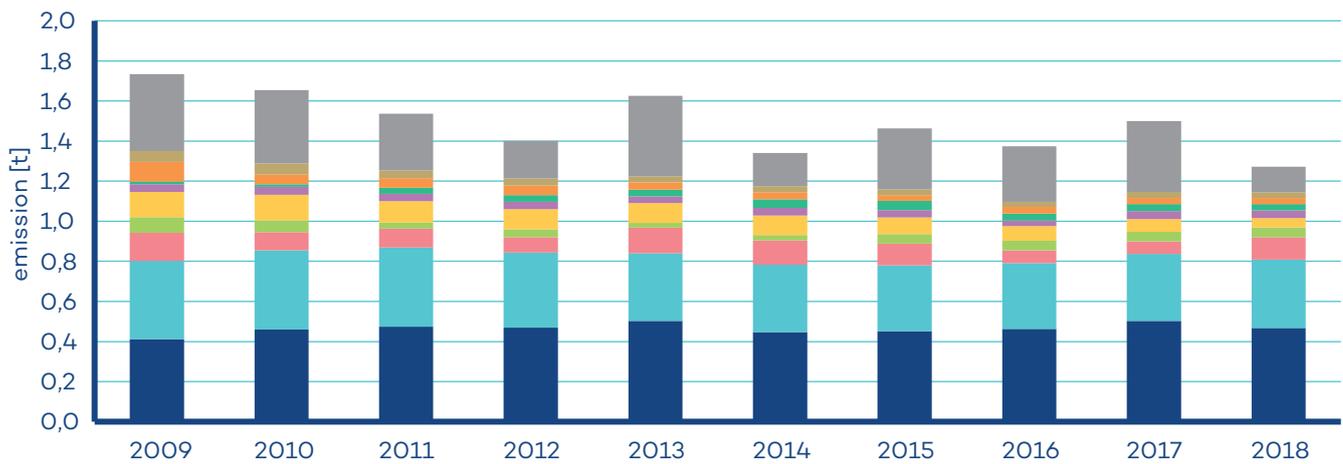
Fig. IV.6.14 Total arsenic emissions of arsenic, 2009–2018
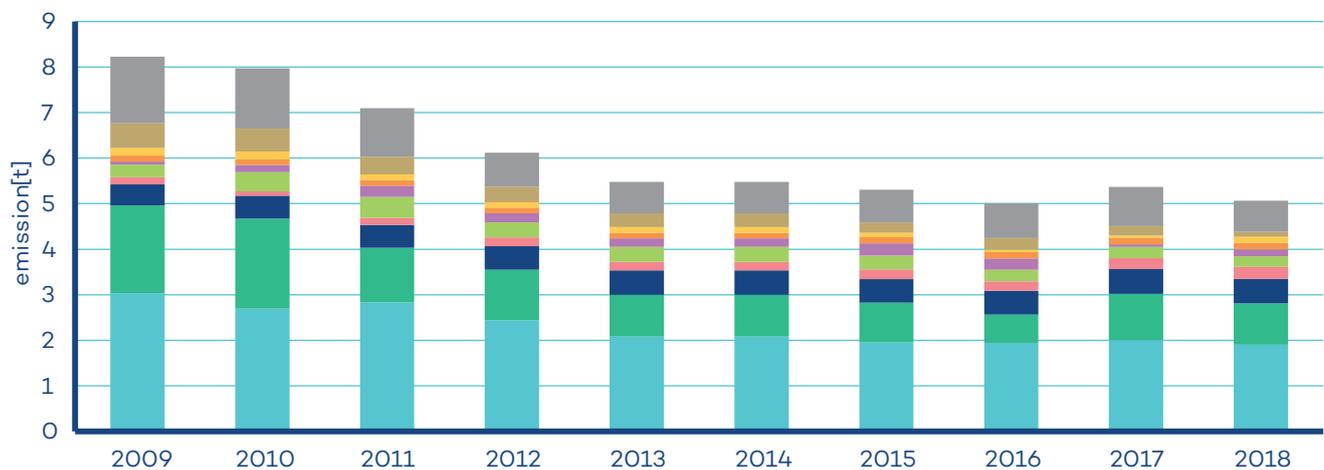
Fig. IV.6.16 Total emissions of nickel, 2009–2018
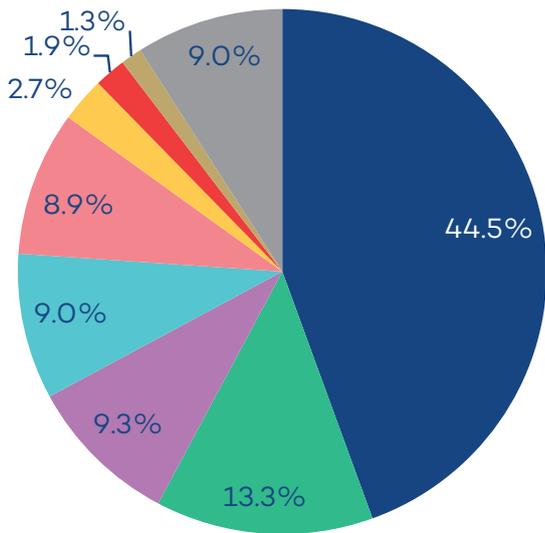
Fig. IV.6.17 Share of NFR sectors in total emissions of cadmium, 2018
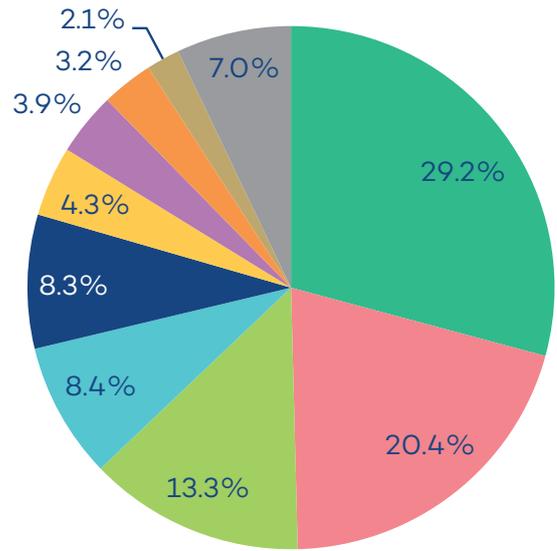
Fig. IV.6.19 Share of NFR sectors in total emissions of lead, 2018
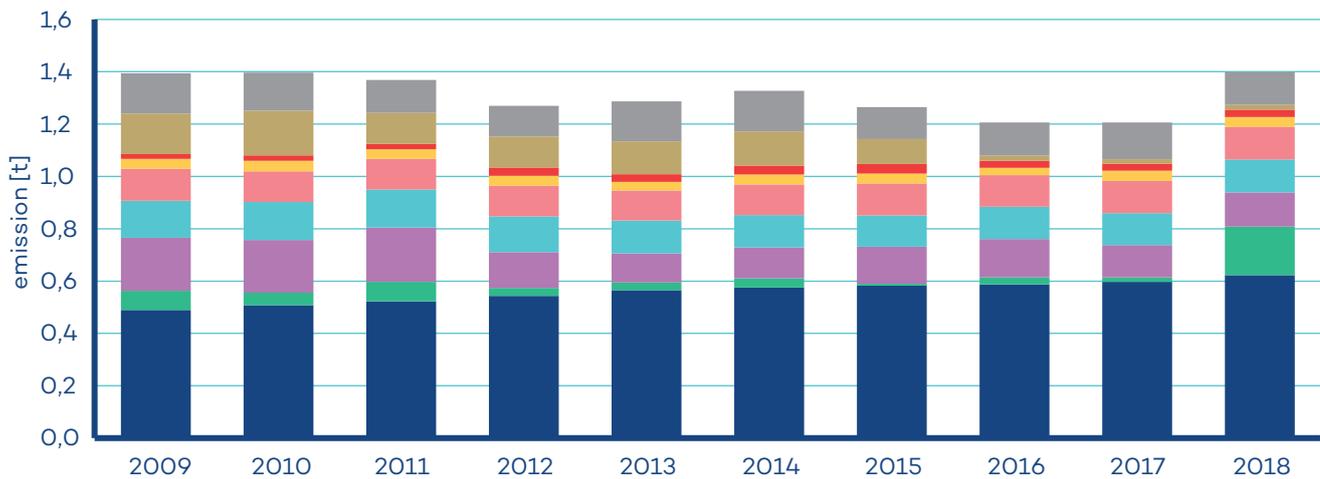
Fig. IV.6.18 Total emissions of cadmium, 2009–2018
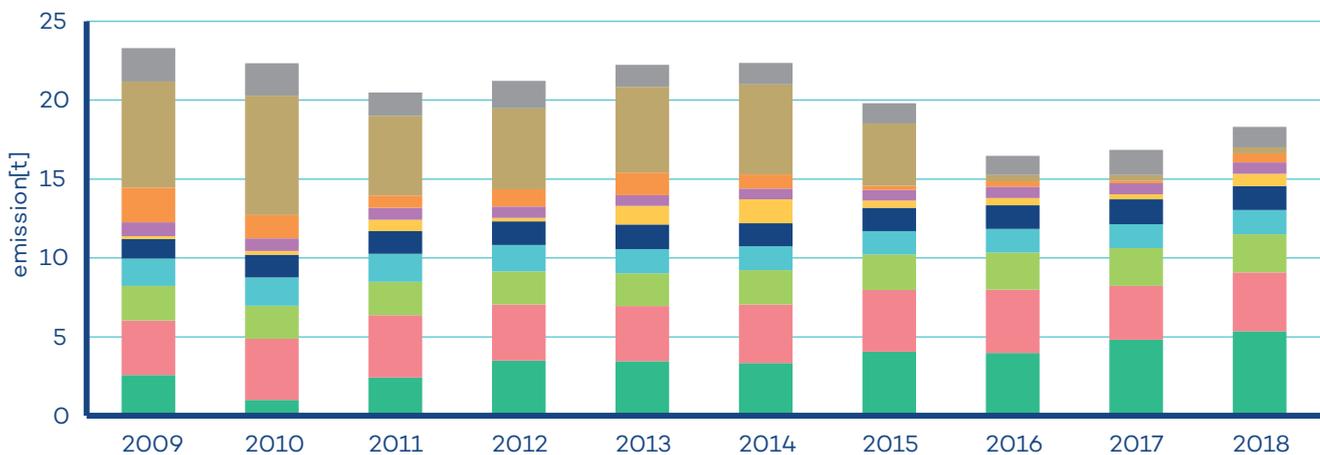
Fig. IV.6.20 Total emissions of lead, 2009–2018

specific emissions [t.km⁻².year⁻¹]

- ≤ 0.000001
- > 0.000001–0.000005
- > 0.000005–0.00001
- > 0.00001–0.00002
- > 0.00002–0.00005
- > 0.00005–0.001
- > 0.001

district

Fig. IV.6.21 Arsenic emission densities in 5×5km spatial resolution squares, 2018

specific emissions [t.km⁻².year⁻¹]

- ≤ 0.000001
- > 0.000001–0.000005
- > 0.000005–0.00001
- > 0.00001–0.00002
- > 0.00002–0.0005
- > 0.0005–0.001
- > 0.001

district
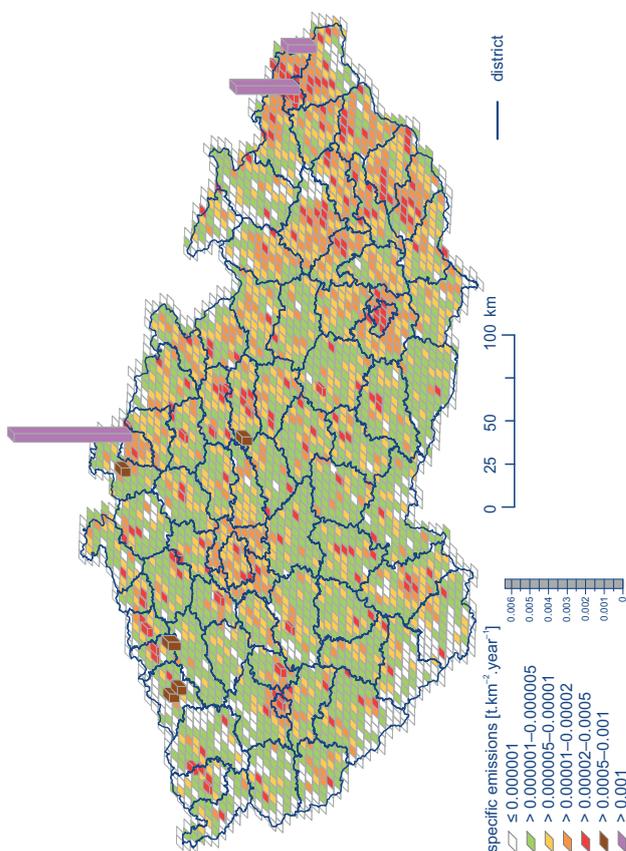
Fig. IV.6.23 Cadmium emission densities in 5×5km spatial resolution squares, 2018

specific emissions [t.km⁻².year⁻¹]

- ≤ 0.000001
- > 0.000001–0.00005
- > 0.00005–0.001
- > 0.001–0.025
- > 0.025–0.05
- > 0.05–0.1
- > 0.1

district

Fig. IV.6.22 Nickel emission densities in 5×5km spatial resolution squares, 2018

specific emissions [t.km⁻².year⁻¹]

- ≤ 0.00005
- > 0.00005–0.0005
- > 0.0005–0.001
- > 0.001–0.025
- > 0.025–0.05
- > 0.05–0.1
- > 0.1

district

Fig. IV.6.24 Lead emission densities in 5×5km spatial resolution squares, 2018

IV.7 Sulphur dioxide

IV.7.1 Air pollution by sulphur dioxide in 2019

Air pollution by sulphur dioxide in 2019 in relation to the pollution limit value for protection of human health

In 2019, the hourly or the 24-hour pollution limits for sulphur dioxide (SO_2) were not exceeded at any monitoring station in the Czech Republic, so both pollution limits were met (Tab. XI.18 and XI.19).

The highest 24-hour SO_2 concentrations were measured at the Ostrava-Radvanice ZÚ (70 µg.m^{-3}), Český Těšín (65 µg.m^{-3}), Sněžník (59 µg.m^{-3}), Petrovice at Karviná (49 µg.m^{-3}), Kostomlaty pod Milešovkou (46 µg.m^{-3}), and Ostrava-Poruba/CHMI (45 µg.m^{-3}) stations.

The 25th highest SO_2 hourly concentration attained the highest values at the Ostrava-Fifejdy (318 µg.m^{-3}), Ostrava-Přívoz (285 µg.m^{-3}), Ostrava-Radvanice ZÚ (138 µg.m^{-3}), Ostrava-Mariánské Hory (121 µg.m^{-3}), and Český Těšín (103 µg.m^{-3}) stations.

The 25th highest hourly concentration of SO_2 attained the highest values at the Český Těšín (128 µg.m^{-3}), Ostrava-Radvanice ZÚ (98 µg.m^{-3}), Karviná (70 µg.m^{-3}), and Ostrava-Radvanice OZO (69 µg.m^{-3}) stations.

The fourth highest 24-hour concentration of SO_2 attained the highest values practically at the same stations, namely Český Těšín (52 µg.m^{-3}), Ostrava-Radvanice ZÚ (52 µg.m^{-3}), and Petrovice at Karviná (38 µg.m^{-3}).

At the Ostrava-Radvanice ZÚ and Ostrava-Radvanice OZO stations, increased concentrations of SO_2 occur mainly in connection with local sources in the vicinity of the station. At the Ostrava-Poruba/CHMI station, the cause of increased hourly concentrations of this substance was also a local effect. In the case of the Český Těšín station, but also other border stations - Petrovice at Karviná, Věřňovice, and Šunychl, SO_2 emissions from local sources at the Czech-Polish border area are involved.

On 99.98% of the area of the Czech Republic, the 24-hour concentrations of SO_2 were under the lower assessment threshold (LAT). The lower assessment threshold was exceeded on only 0.02% of the territory. This applies only to cities of Ostrava and Český Těšín (Fig. IV.7.1). The point symbols at the stations designate 24-hour SO_2 concentration measured at the air quality monitoring stations (Fig. IV.7.2).

concentration [µg.m^{-3}]

≤ 50.0	99.98 %
50.1–75.0	0.02 %
75.1–125.0	
> 125.0	

— agglomeration
— zone
— region
municipality over 30K inhab.

0   25   50   100 km
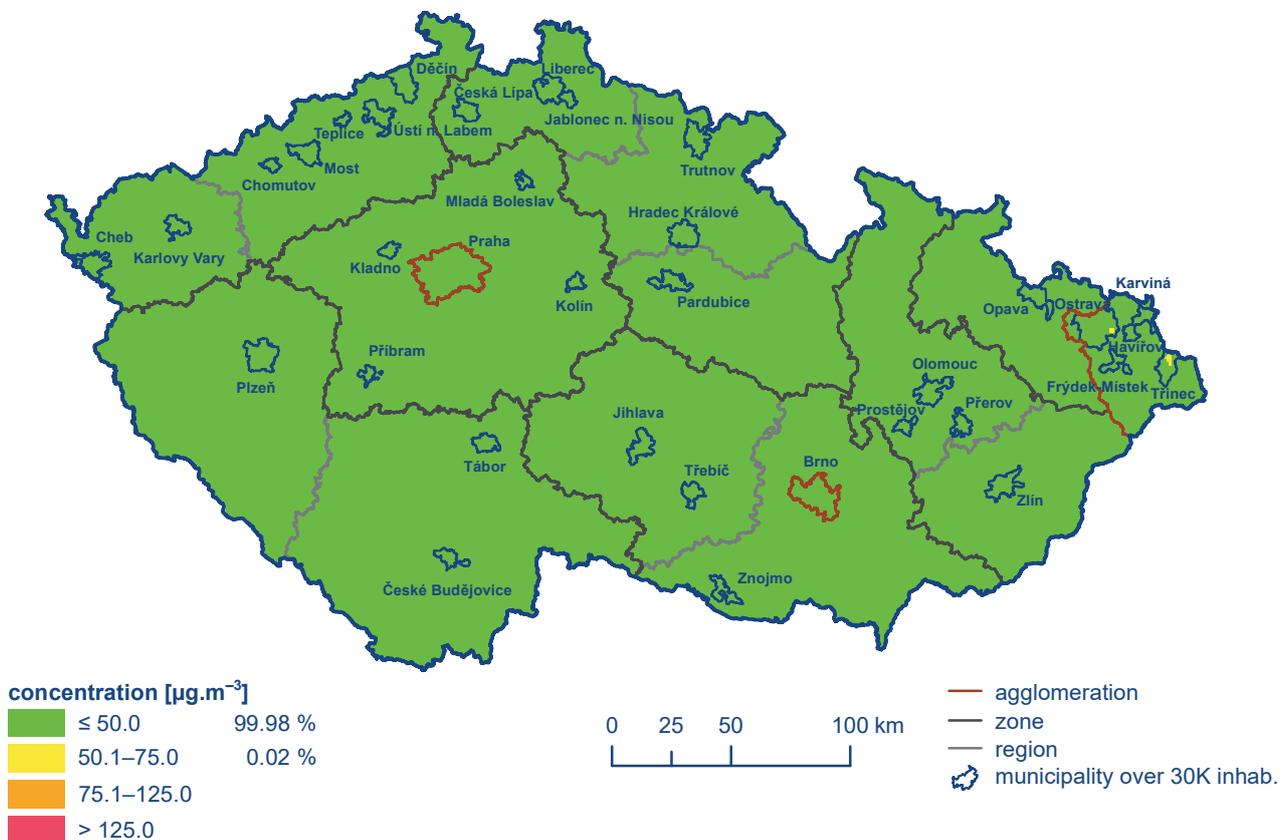
Fig. IV.7.1 Field of 4th highest 24-hour SO$_2$ concentration, 2019

classification of stations
- ■ urban background
- ♦ suburban background
- ▲ rural
- ● traffic
- ★ industrial

concentration [µg.m⁻³]
- $\leq$ 50.0
- 50.1–75.0
- 75.1–125.0
- > 125.0

0 25 50 100 km

- agglomeration
- zone
- region
- river
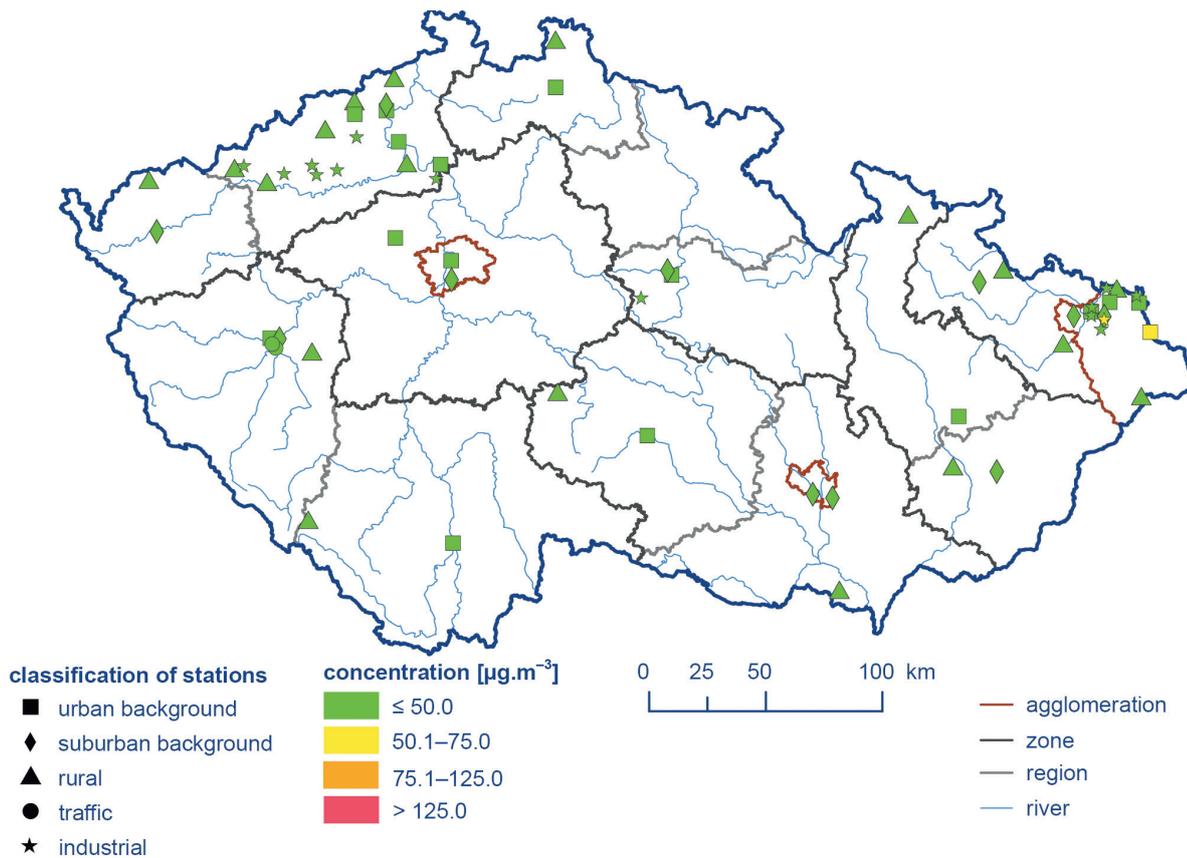
Fig. IV.7.2 4ᵗʰ highest 24-hour SO₂ concentration at air quality monitoring stations, 2019

Air pollution by sulphur dioxide in 2019 in relation to the pollution limit value for protection of ecosystems and vegetation

In 2019, neither the annual nor winter average concentrations exceeded the pollution limit value at rural locations (Tab. XI.21 and Tab. XI.22). The highest winter average concentrations were recorded at the Krupka (10 µg.m⁻³), Lom (9.7 µg.m⁻³), Sněžník (7.1 µg.m⁻³), and Věřňovice (6,2 µg.m⁻³) stations. The annual average concentrations attained maximum values at the same stations, Krupka (9 µg.m⁻³) and Lom (7.6 µg.m⁻³), and the Brumovice MŠ (6.8 µg.m⁻³) and Měděnec (6 µg.m⁻³) stations.

The upper assessment threshold for the annual average SO₂ concentration was exceeded in 2019 on only small areas in the Moravian−Silesia regions (Fig. IV.7.3). In this region and in the Ústí nad Labem region, the upper assessment threshold of the average concentration of the winter period 2019/2020 was exceeded on a small area (Fig. IV.7.4). In the Moravian-Silesia region, the limit value for the annual and winter average concentration of

20 µg.m⁻³ was actually exceeded, but only in the cities of Ostrava and Třinec. This exceeded value is based on a model calculation when constructing the map.

All the background stations measuring SO₂, taking into account their classification, were used to construct the two maps (Fig. IV.7.3 and Fig. IV.7.4). On the maps, point symbols designate only rural stations because only at these locations the average winter and annual average SO₂ concentrations are measured in relation to the pollution limit values for protection of ecosystems and vegetation.

concentration [µg.m^{-3}]

≤ 8.0
8.1–12.0
12.1–20.0
> 20.0

▲ rural station

agglomeration
zone
region
municipality over 30K inhab.
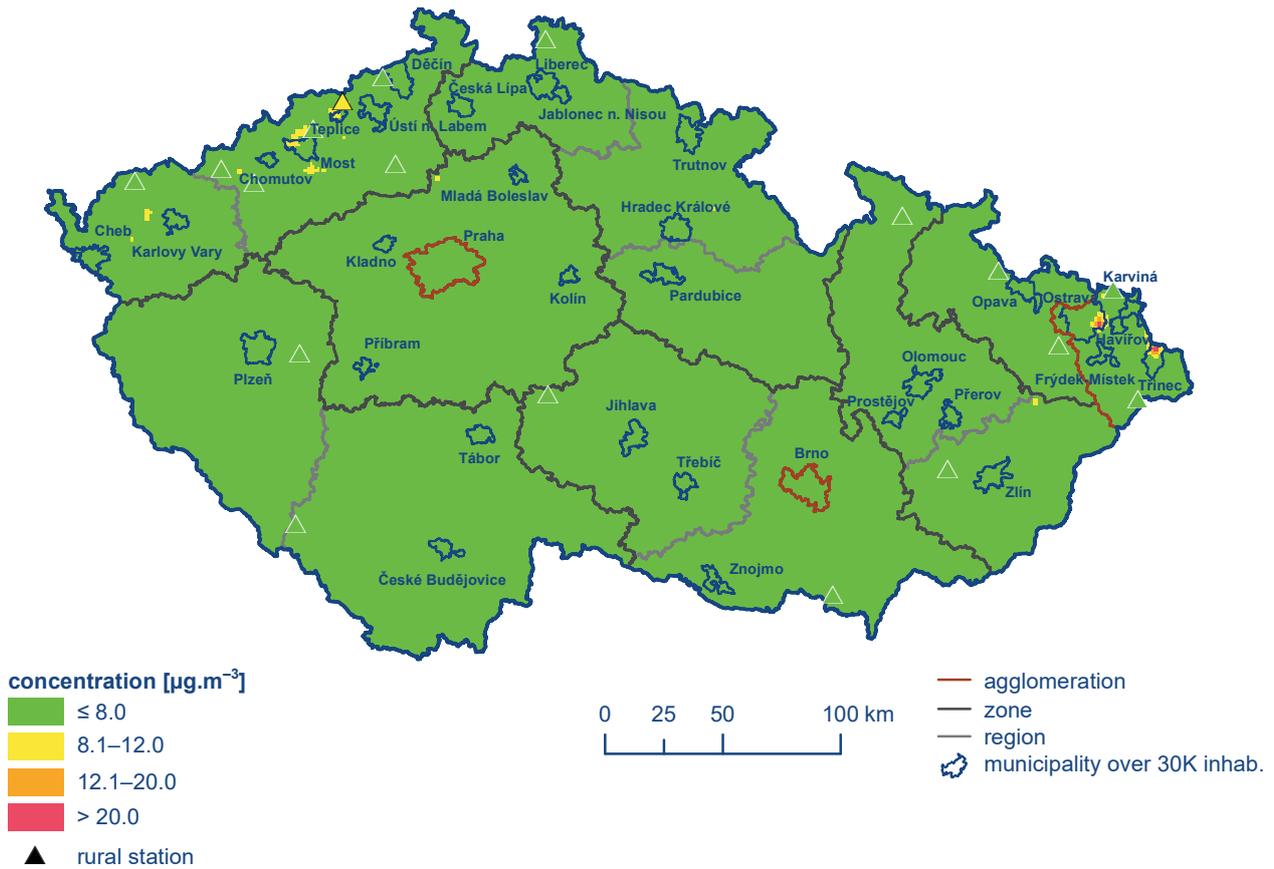
Fig. IV.7.3 Field of annual average SO$_2$ concentration, 2019

concentration [µg.m^{-3}]

≤ 8.0
8.1–12.0
12.1–20.0
> 20.0

▲ rural station

agglomeration
zone
region
municipality over 30K inhab.
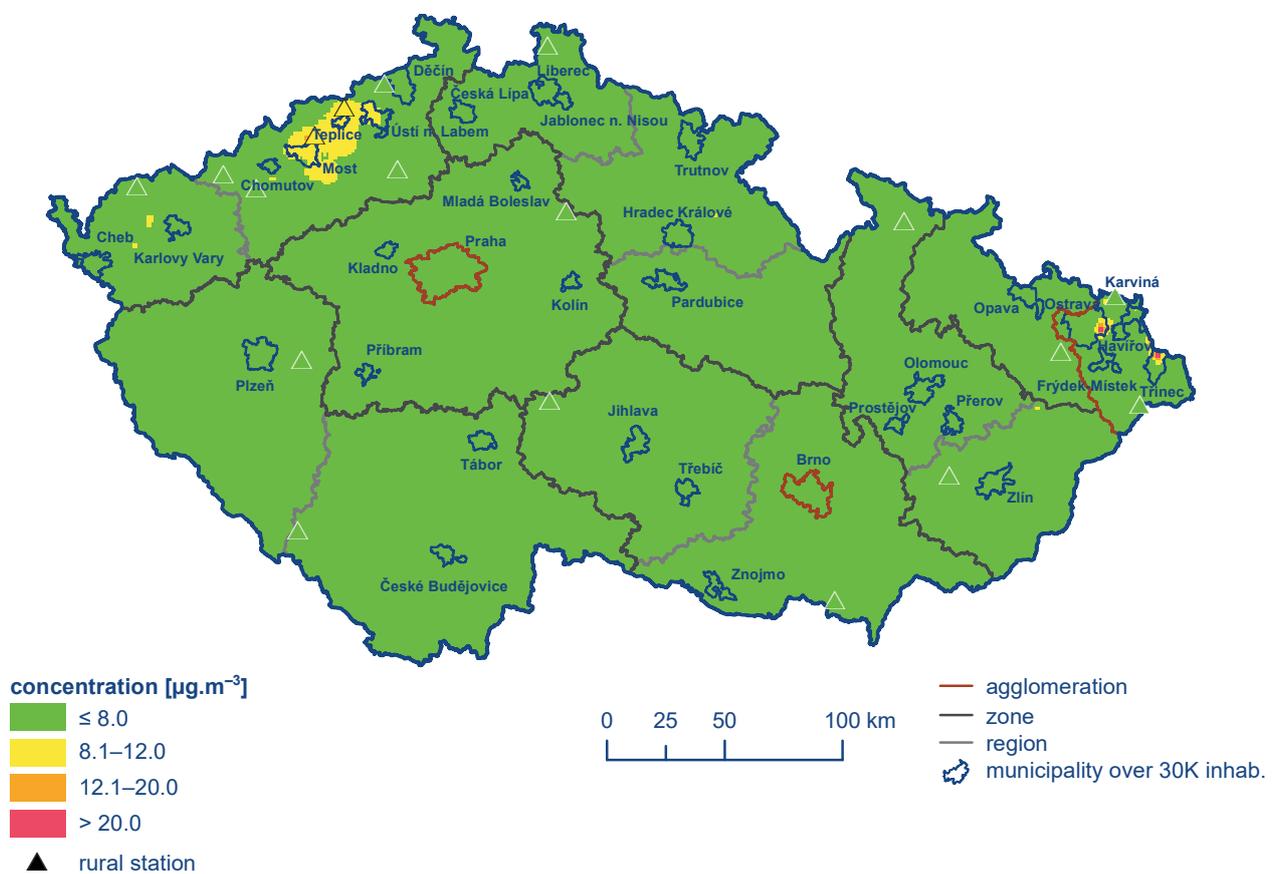
Fig. IV.7.4 Field of annual average SO$_2$ concentration in winter of 2019/2020

IV.7.2 Trends in sulphur dioxide concentrations

A substantial reduction in SO_2 concentrations occurred after 1998 in connection with coming into effect of Act No. 309/1991 Coll. and ensuring compliance with the prescribed emission limits. Since then, the annual average concentrations of this substance at rural locations have not exceeded the set pollution limit value of 20 µg.m^{-3}. A further reduction in SO_2 concentrations occurred throughout the Czech Republic in 2008. Conversely, in 2009 and 2010, a slight increase in SO_2 pollution was recorded, but from 2011 to 2016 a further declining course was evident. A decreasing trend discontinued in 2017 and there was an increase in SO_2 concentrations (Fig. IV.7.6 and IV.7.7). Since 2018, the decreasing course of 24-hour concentrations of this substance has continued at most types of stations and overall at all stations, as confirmed in 2019 (Fig. IV.7.7). On the contrary, there was a significant increase in hourly SO_2 concentrations at industrial and urban stations (Fig. IV.7.6). This increase was affected by concentrations observed at the Ostrava-Fifejdy, Ostrava-Přívoz and Ostrava-Mariánské Hory stations arising from remediation work on waste lagoons of the former OSTRAMO company. In 2019, the increase did not already continue and, on the contrary, there was a decrease in hourly SO_2 concentrations at all types of stations and overall at all stations (Fig. IV.7.6).

The annual and winter averages show a slight decrease in SO_2 concentrations in 2019 and 2019/2020. This decrease is apparent in all rural localities as well as in the category of regional localities. The 10-year annual and winter average (2009–2018) has a balanced course, the winter average is at a slightly higher level (Fig. IV.7.8).

The overall decreasing course in SO_2 concentrations follows a reduction in emissions, sulphur removal in coal-fired power plants and a change in the fuel types in use (see the emission trends in Chap. II). The varying meteorological and dispersion conditions in particular years also had an impact on the year-on-year variations in the concentrations of this substance.

Since 2008, a decreasing course has been apparent in the 4th highest 24-hour and 25th highest hourly SO_2 concentrations at a majority of selected stations (Fig. IV.7.5). This decreasing course is even more apparent in the 2011–2016 period. The decline discontinued in 2017 and it again resumed in most locations in 2018. Significant increase in concentrations of this substance in 2018 concerned only three Ostrava area stations of Fifejdy, Přívoz and Mariánské Hory, as a result of the impact of remediation of the OSTRAMO lagoons, as previously mentioned in the text. In 2019, the decrease in SO_2 concentrations continued at most stations.
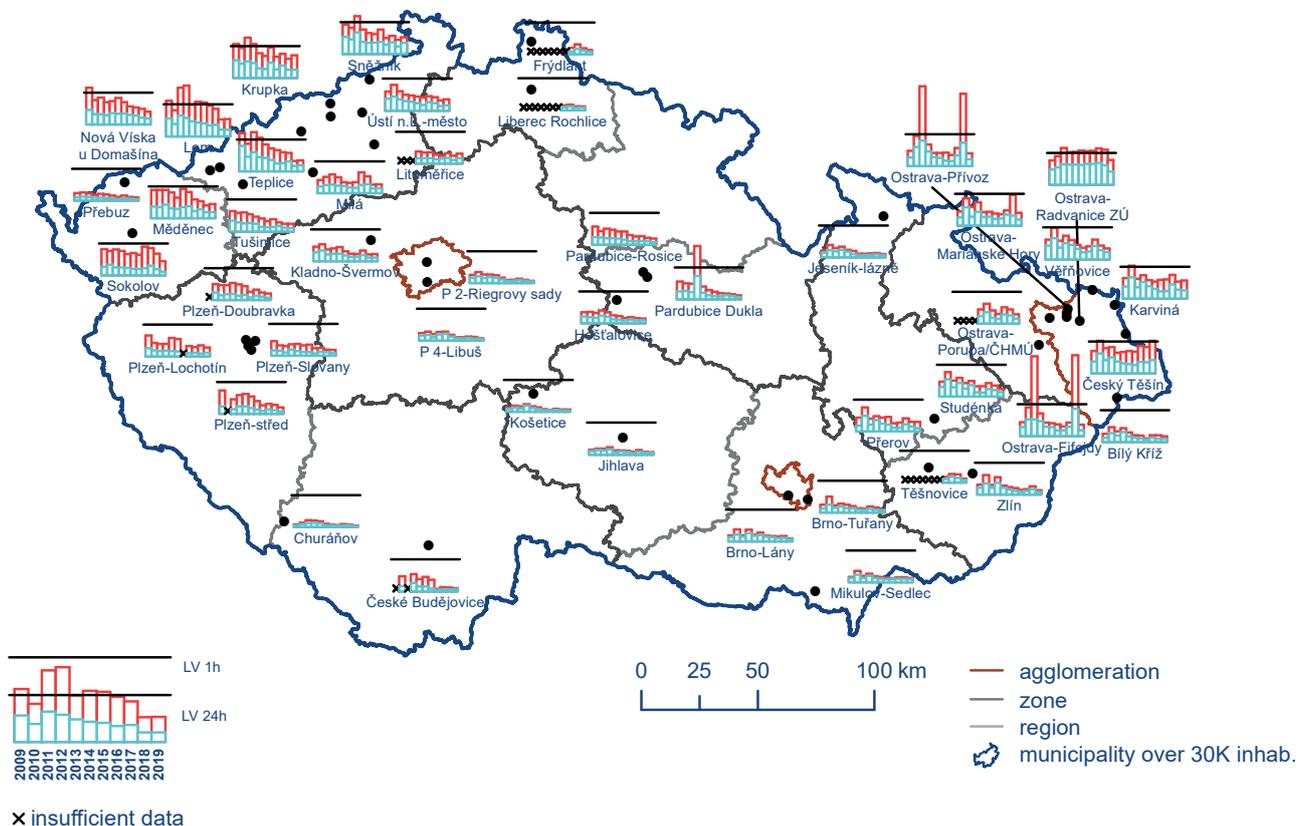
Fig. IV.7.5 4th highest 24-hour and 25th highest hourly SO$_2$ concentrations at selected stations, 2009–2019
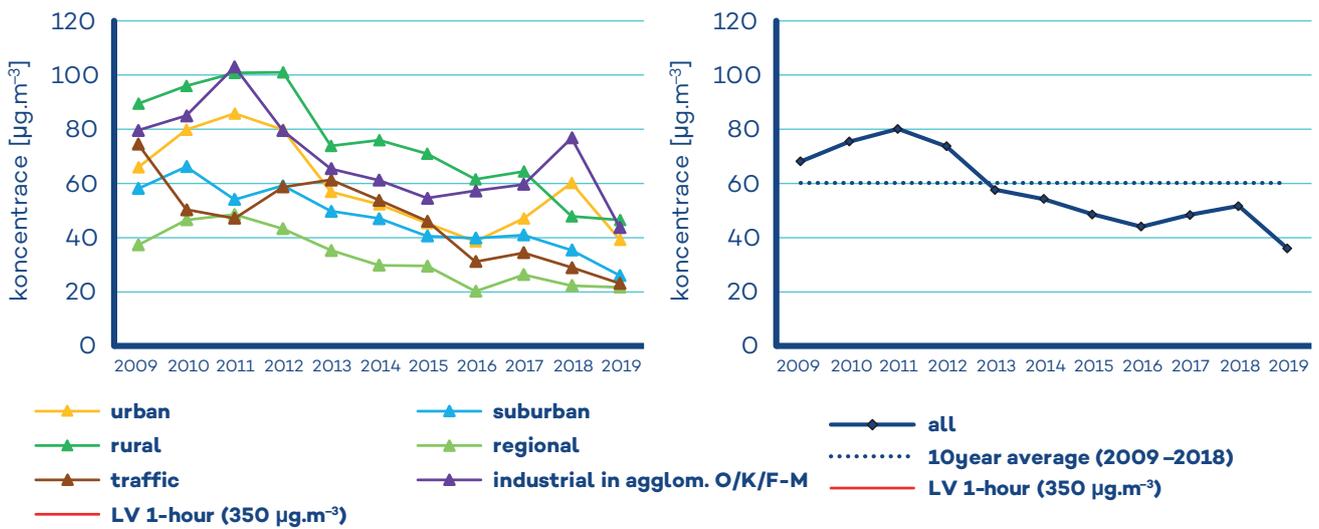
Fig. IV.7.6 Annual characteristics of SO$_2$ (25th highest 1-hour concentration) at particular types of stations in the Czech Republic, 2009–2019
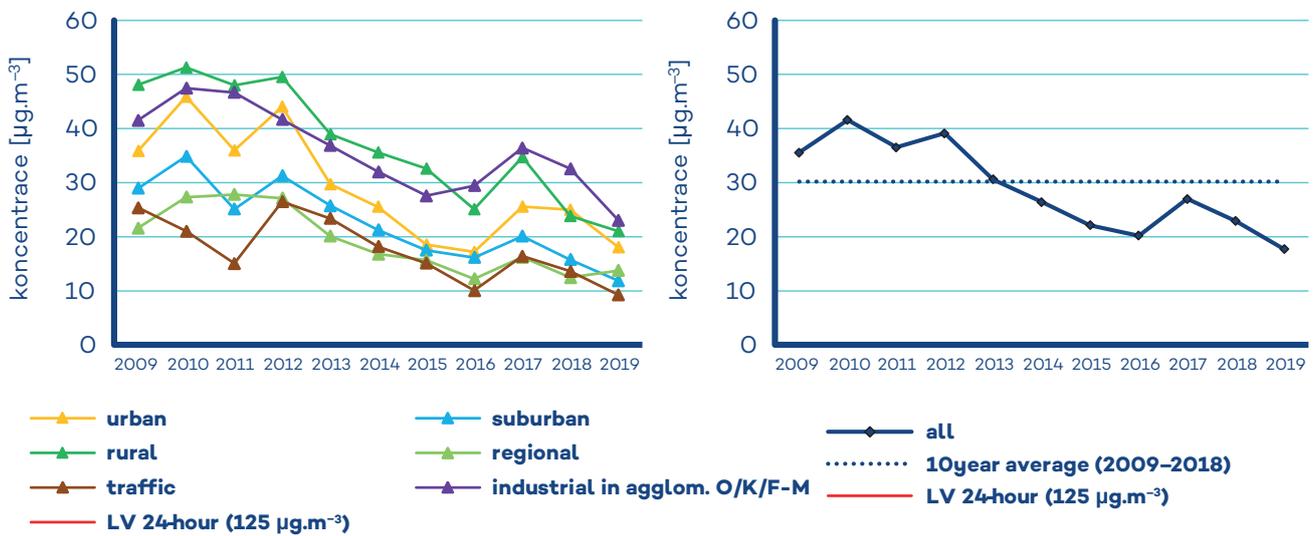
Fig. IV.7.7 Annual characteristics of SO$_2$ (4th highest 24-hour concentration) at particular types of stations in the Czech Republic, 2009–2019
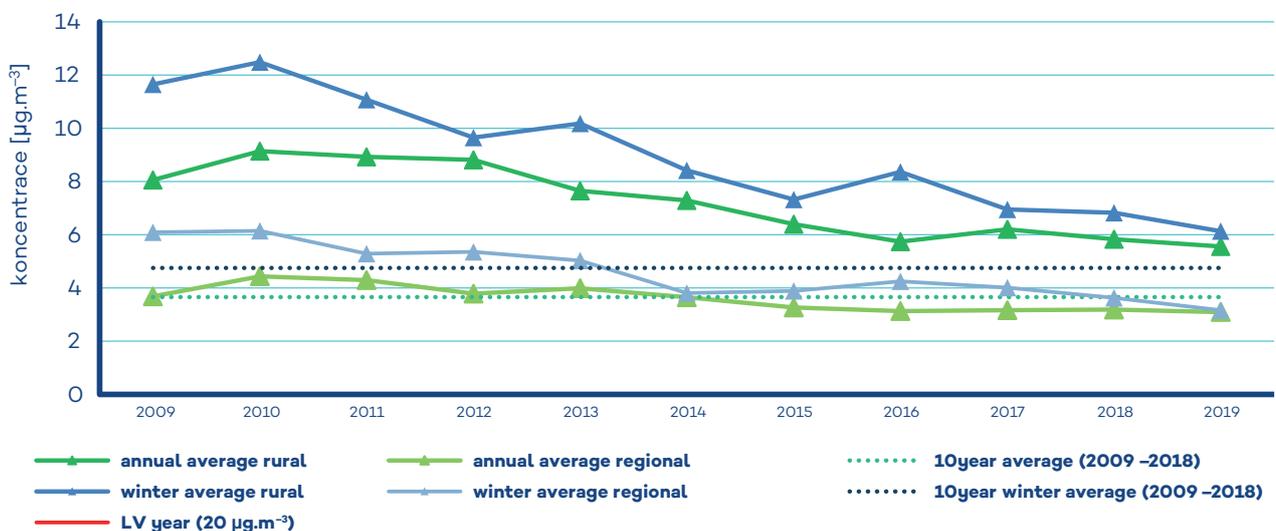
Fig. IV.7.8 Annual characteristics of SO$_2$ at particular types of stations in the Czech Republic, 2009–2019

IV.7.3 Sulphur dioxide emissions

Sulphur dioxide emissions originate mainly from the combustion of solid fossil fuels containing sulphur. In 2018, at a national scale, 54.9% of SO_2 emissions originated from sector 1A1a – Public electricity and heat production and 21.7% from sector 1A4bi – Residential: Stationary (Fig. IV.7.9). A reduction in SO_2 emissions in the 2009–2018 period took place after 2012 as a result of preparation of sources for stricter emissions limits (Fig. IV.7.10). In view of the predominant effect of the sector of public electricity and heat production, SO_2 emissions appear mostly in the Ústí, Moravian-Silesia and Central Bohemia regions in which the larger energy production facilities are located (Fig. IV.7.11).
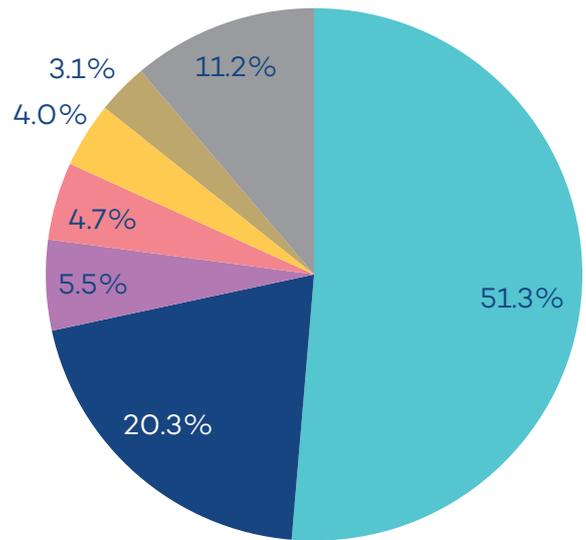
Fig. IV.7.9 Share of NFR sectors in total SO_2 emissions, 2018

- ■ **1A1a – Public electricity and heat production**
- ■ **1A2a – Stationary combustion in manufacturing industries and construction: Iron and steel**
- ■ **1A2f – Stationary combustion in manufacturing industries and construction: Non-metallic minerals**
- ■ **Other**
- ■ **1A4bi – Residential: Stationary**
- ■ **1A2c – Stationary combustion in manufacturing industries and construction: Chemicals**
- ■ **1A4ai – Commercial/Institutional: Stationary**

Fig. IV.7.10 Total SO_2 emissions, 2009–2018

specific emissions [t.km^{-2}.year^{-1}]

⬭ ≤ 0.5
▱ > 0.5–1
▱ > 1–5
▱ > 5–10
▱ > 10–100
▱ > 100–1000
▱ > 1000

0   25   50   100 km

——— district
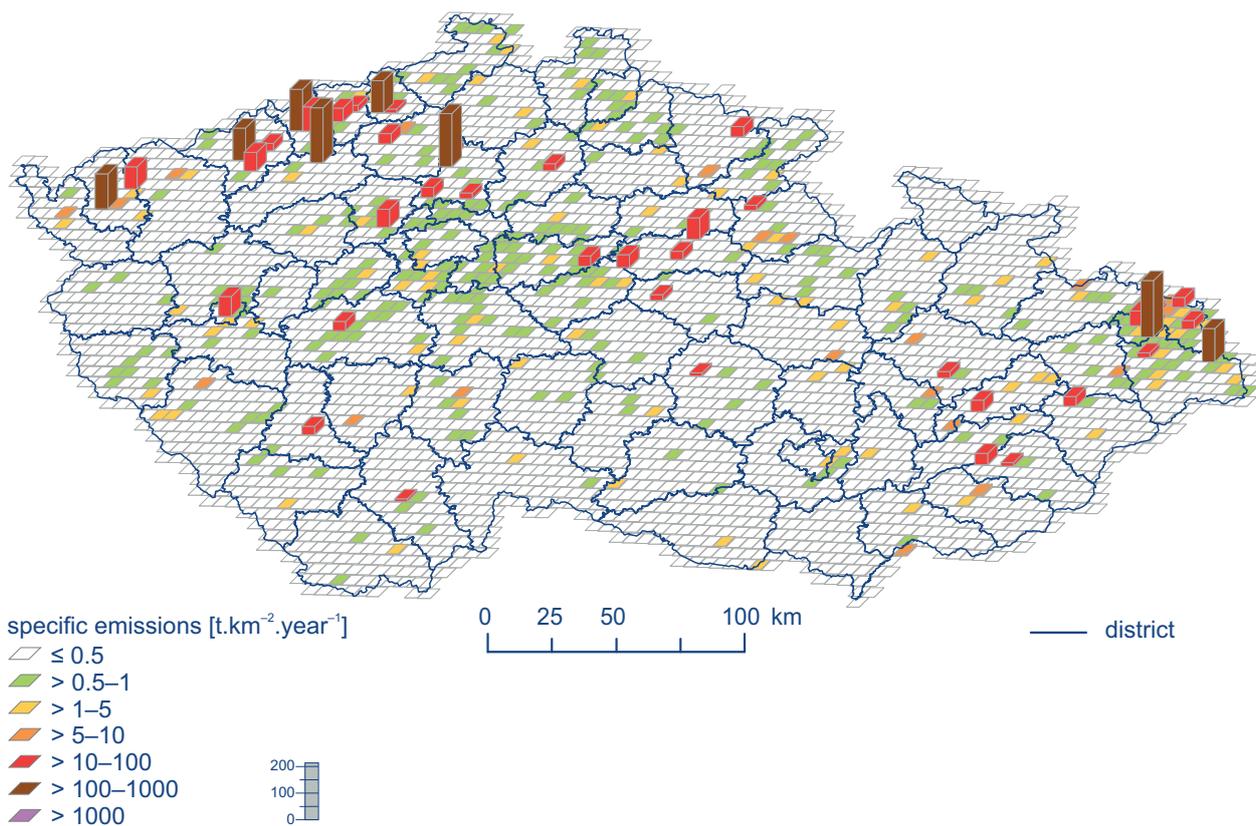
Fig. IV.7.11 Sulphur dioxide emission densities in 5 x 5 km spatial resolution squares, 2018

IV.8 Carbon monoxide

IV.8.1 Air pollution by carbon monoxide in 2019

Similar to previous years, the 8-hour pollution limit value for carbon monoxide (CO) was not exceeded in the Czech Republic in 2019 at any of 21 stations for which a sufficient amount of measured data was available for evaluating the air quality (Tab. XI.23). Overall, CO was measured at 24 stations. The highest daily 8-hour average CO concentration was measured at the Ostrava-Radvanice ZÚ station (3,656 µg.m⁻³) when the pollution limit value is 10,000 µg.m⁻³. This is a very exposed part of the city affected by industry, traffic and local emission sources. If only one maximum is reported at one station, then the second highest 8-hour CO concentration was measured at the Tobolka-Čertovy schody rural station (2,470 µg.m⁻³) where the influence can be assumed from the nearby Čertovy schody lime maniufacture. The third highest 8-hour concentration of this substance was measured at the Ostrava-Českobratrská station hot spot (2,347 µg.m⁻³) which is focused on monitoring air pollution from traffic.

Elevated CO concentrations occur primarily at urban locations affected by traffic and therefore measurement of this substance was retained at localities classified as traffic sites. At urban and rural background locations, the CO concentrations vary well below the pollution limit values except for the Tobolka-Čertovy schody location.

IV.8.2 Trends in carbon monoxide concentrations

A decreasing course in the maximum daily 8-hour CO concentrations can be seen at most stations in the Czech Republic, as shown in Fig. IV.8.1. CO concentrations were at about the same level in 2019 compared to the previous year. At some stations there was a slight decrease in CO concentrations (Ostrava-Radvanice ZÚ, Vratimov), at some there was a slight increase (Tobolka-Čertovy schody, Beroun).
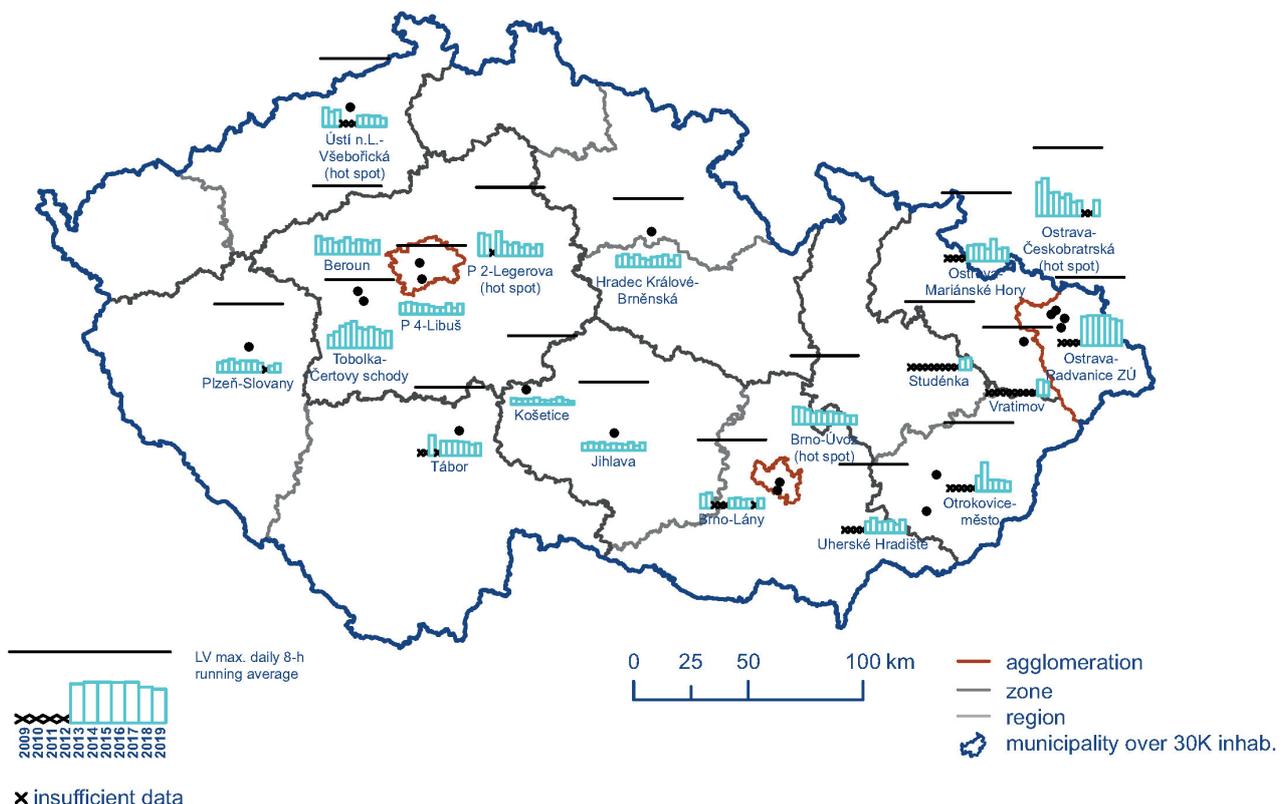
Obr. IV.8.1 Maximum hourly 8-hour running average concentrations of CO at selected stations, 2009–2019
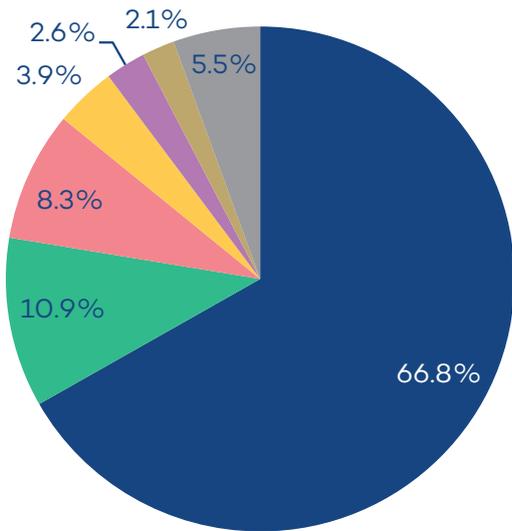
Fig. IV.8.2 Total emissions of CO sorted out by NFR sectors, 2018

IV.8.3 Carbon monoxide emissions

Carbon monoxide is a product of combustion of carbon-containing fuels at low temperatures and insufficient availability of air for combustion. The greatest amounts of CO are formed in sector 1A4bi – Residential: Stationary which produced 66.8% of national emissions in 2018. Other important sources included sectors 1A2a – Stationary combustion in manufacturing industries and construction: Iron and steel (10.9%) and 1A3bi – Road transport: Passenger cars (8.3%) (Fig. IV.8.2). The decrease in CO emissions in 2009–2018 (Fig. IV.8.3) was caused primarily by natural renewal of the vehicle fleet and a reduction in the production of iron and steel after 2007. In view of the predominant effect of sector 1A4bi this trend is substantially affected by evolution in consumption of solid fuels by households (Fig. II.7).

In the regions of the Czech Republic the contributions of the sectors differ in relation to the composition of sources in a given area. Due to predominant effect of the local heating, CO emissions in the Czech Republic are distributed over the entire residential built-up area. The impact of transportation dominates alongside motorways, roadways with high traffic levels and in larger urban units. The large amount of CO emissions in the O/K/F-M agglomeration originates from the production of iron and steel (Fig. IV.8.4).

- **2C1 – Iron and steel production**
- **1A3bi – Road transport: Passenger cars**
- **1A2a – Stationary combustion in manufacturing industries and construction: Iron and steel**
- **Other**
- **1A2f – Stationary combustion in manufacturing industries and construction: Non-metallic minerals**
- **1A4cii – Agriculture/Forestry/Fishing: Off-road vehicles and other machinery**
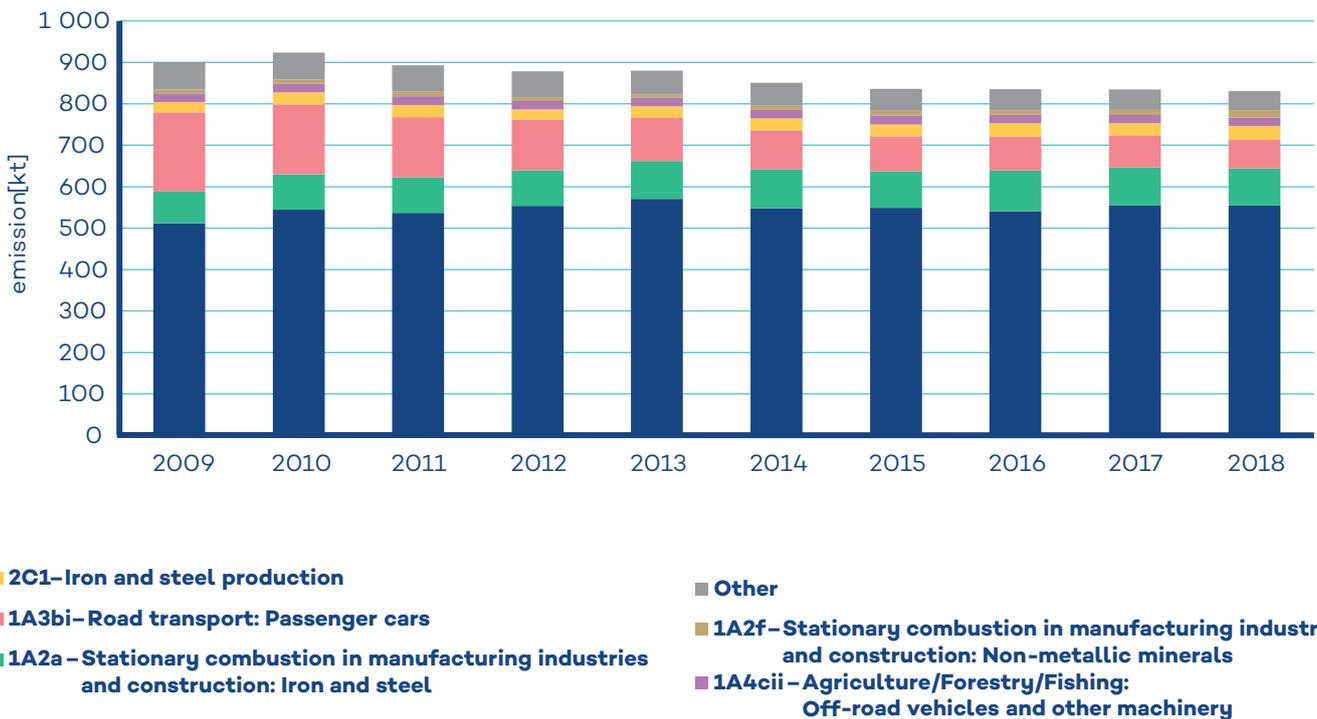
Fig. IV.8.3 The development of CO total emissions, 2009–2018

specific emissions [t.km⁻².year⁻¹]

- ≤ 0.5
- > 0.5–1
- > 1–5
- > 5–10
- > 10–100
- > 100–1000
- > 1000

district
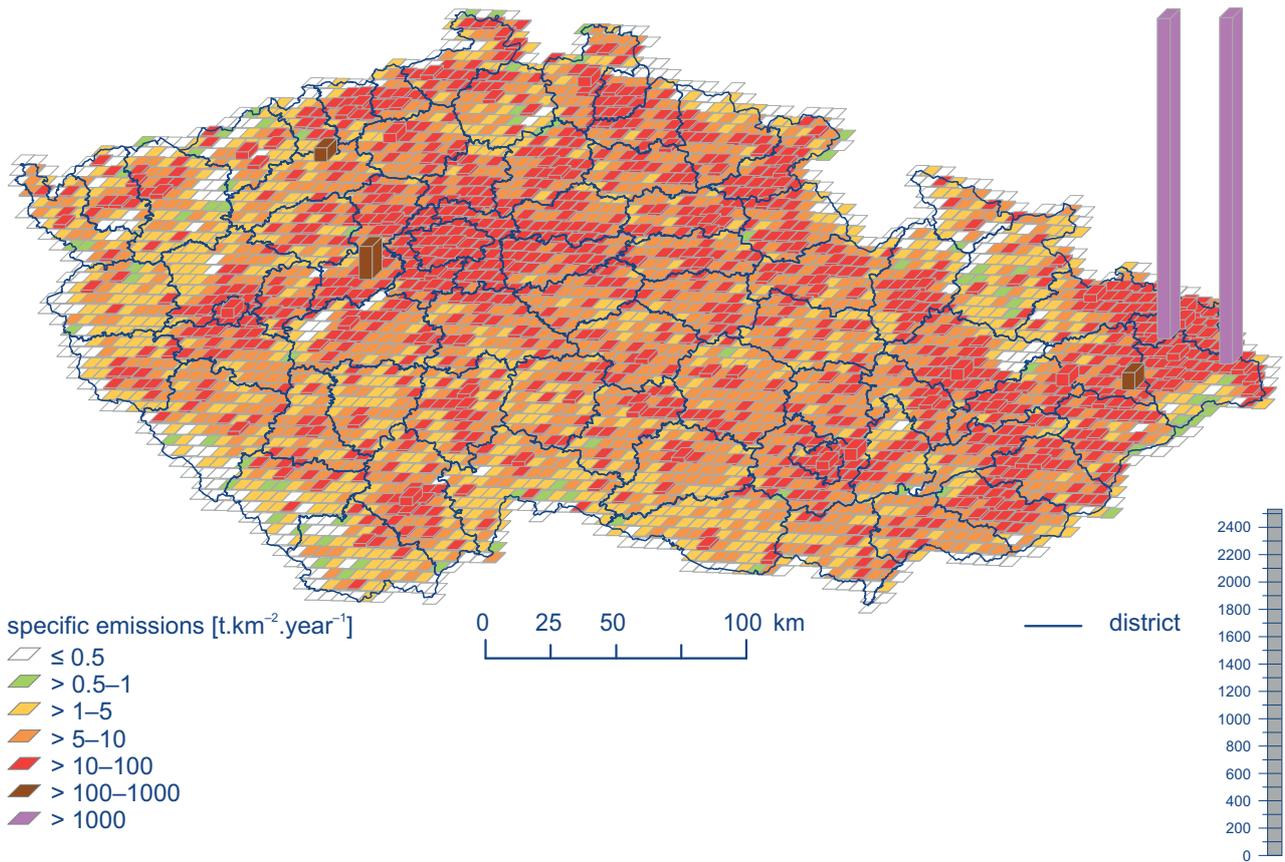
Obr. IV.8.4 Carbon monoxide emission density from 5 x 5 km squares, 2018

IV.9 Pollutants without set limit values

IV.9.1 Volatile organic compounds

According to the Air Protection Act, a volatile organic substance is any organic compound or mixture of organic compounds, except methane, that has a vapour pressure of 0.01 kPa or more at 20 °C, or has a corresponding volatility under the specific conditions of its use. Volatile organic compounds (VOCs) play an important role in atmospheric chemistry and thus in the oxidation strength of the atmosphere, affecting the condition and quality of the air. Together with nitrogen oxides, VOCs play an important role in the process of formation of ground-level ozone and other photo-oxidation pollutants. Conversion and decomposition of VOCs is usually initiated by reaction with a hydroxyl radical (Víden 2005). Because of the range of differing length of reactivity of particular VOCs and their amount, pollution limit levels were not established for these substances.

Monitoring of VOCs was included in the EMEP programme on the basis of a decision by the EMEP Workshop on Measurements of Hydrocarbons/VOCs in Lindau in 1989 (EMEP 1990). Regular mea-

surement at the Košetice Observatory was launched during 1992 and three years later it was supplemented by the identical measurement at the Praha-Libuš station. In the framework of EMEP, measurements were initially made at five stations; however, over 20 years the number of stations and range of measured hydrocarbons has changed several times. A homogeneous series of measurements has well been maintained at the Košetice Observatory until now. Since 2011, the Košetice Observatory has been involved in the ACTRIS project, carried out in the context of the EU 7th Framework Programme INFRA-2010-1-1.1.16: Research Infrastructures for Atmospheric Research. The successor ACTRIS-2 project identified as H2020INFRAIA-20142015 followed on from this project and was implemented in the May 2015–April 2019 period. The subject of VOCs is part of the work of the Trace gases networking working group: Volatile organic carbon and nitrogen oxides, in an attempt to improve and harmonise VOC measurements in Europe. In the framework of the project, standard operational procedures were developed and the best measuring techniques for ensuring quality were tested. The CHMI laboratory regularly participated in a round robin test where the results of the analyses of VOCs confirmed that the laboratory has been complying with the recommended parameters of the GC system and has been meeting the required uncertainty values for all the substances in both standards and real samples. The ACTRIS-2 project was completed in 2019. VOCs monitoring and research activities continue within the pan-European ACTRIS research infrastructure which has been part of the European Strate-

Tab. IV.9.1.1 Average annual concentrations of VOC in the ambient air at stations Košetice and Prague-Libuš

Volatile organic compound		Annual average [µg.m⁻³]									
		Košetice					Pha4-Libuš				
		1995	2005	2010	2015	2019	1995	2005	2010	2015	2019
Alkane	Ethane	2.34	2.07	2.51	2.20	2.07	3.62	2.43	1.94	1.97	1.98
	Propane	1.80	1.21	1.28	1.10	0.95	2.15	1.65	1.82	1.06	1.12
	Butane	1.16	0.60	0.71	1.04	0.46	1.76	1.02	1.15	1.15	0.74
	2-methylpropane	0.68	0.37	0.47	0.32	0.28	1.14	0.80	1.03	0.45	0.56
	Pentane		0.29	0.35	0.30	0.22	1.21	0.52	1.74	0.32	0.38
	2+3-methylpentane		0.03	0.06	0.06	0.12	0.90	0.47	0.31	0.22	0.34
	Hexane		0.09	0.11	0.07	0.09	0.60	0.16	0.18	0.09	0.23
	Heptane		0.03	0.06	0.06	0.08	0.30	0.07	0.14	0.08	0.11
	Octane		0.02	0.05	0.10	0.13		0.06	0.09	0.11	0.12
Alkene	Ethene	1.28	0.77	0.55	0.55	0.53	2.52	1.32	0.45	0.62	0.65
	Propene	0.32	0.15	0.16	0.12	0.11	0.68	0.34	0.30	0.14	0.15
	suma Butenes		0.14	0.20	0.18	0.19	0.87	0.42	0.38	0.26	0.37
	suma Pentenes		0.05	0.07	0.02	0.05		0.27	0.14	0.04	0.11
	Isoprene	0.14	0.09	0.13	0.17	0.32		0.38	0.47	0.37	0.72
Aromatic hydrocarbon	Benzene	1.05	0.42	0.58	0.41	0.44	1.51	0.62	0.72	0.42	0.44
	Toluene	0.99	0.31	0.40	0.30	0.34	2.07	0.86	0.94	0.53	0.99
	Ethylbenzene		0.06	0.06	0.19	0.28	0.42	0.19	0.18	0.27	0.43
	m,p-Xylene		0.78	0.55	0.55	0.71	1.42	0.55	0.57	0.71	1.02
	o-Xylene		0.05	0.04	0.29	0.45		0.16	0.14	0.35	0.58

gy Forum on Research Infrastructures (ESFRI) activities since 2016. The average annual VOC concentrations at the Košetice Observatory and the Praha-Libuš stations over 25 years of monitoring exhibit a statistically significant decreasing trend reflecting the decrease in VOCs emissions both in the Czech Republic and also in the entire European area (Tab. IV.9.1.1). The trend in ethane concentrations is much stronger at the suburban station of Praha-Libuš than at the background Košetice Observatory station. The only exception is isoprene which is of natural origin (emitted by deciduous trees), which exhibited an increasing trend at both stations. In general, it can be stated that the concentrations of the main VOCs at the suburban levels in the 1990's were approx. 50–100% higher than at the background station. The differences between the two stations have decreased substantially in the past decade.

The results obtained in 2019 do not in any way deviate from the long-term trends (Tab. IV.9.1.1). The annual variation in most VOC concentrations reflects the emission levels and thus maximum values in the winter and minima in the summer; the situation is the opposite only for isoprene (Fig. IV.9.1.1).

It follows from the report on VOC measurements in the context of EMEP (Solberg et al. 2018) that the VOC concentrations continuously decrease on a regional scale and thus reflect the decreasing

trend in emissions. The concentration level at the Košetice Observatory is comparable with those at the German, Swiss and French stations The Czech station has long been characterised by lower annual average ethane concentrations. For most VOCs the concentrations measured in the winter are usually similar to those at German stations, while the values at the Košetice Observatory are slightly lower in the summer.

The Geneva Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Transmission was adopted in November 1991 and came into effect in September 1997 (UN-ECE 1991). The Protocol contained three options for reducing VOCs:

1. 30% reduction in VOC emissions by 1999, where the base values were those for 1984 and 1990;
2. The same reduction as under (1) and the provision that the overall national emissions in 1999 do not exceed the 1988 level;
3. Where 1988 emissions did not exceed the set limits, countries could adopt the 1999 level as the emission ceiling.

In 1999, the Göteborg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone was adopted and it came into effect on 17 May 2005 (UN-ECE 1999). The Protocol contains the emission ceilings for 2010 for four pollutants including VOCs. According to the Protocol, European VOC emissions were to be reduced
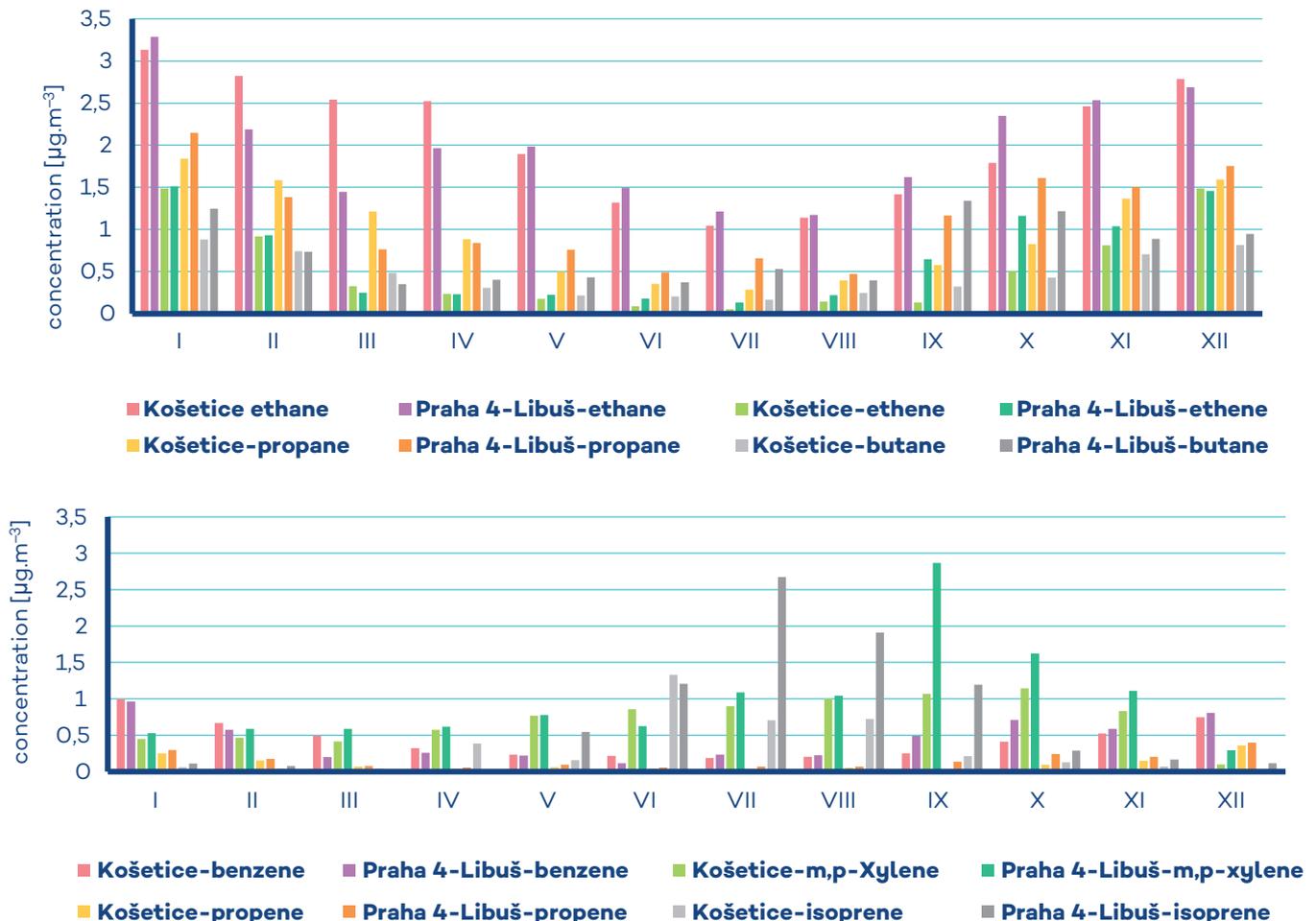
Fig. IV.9.1.1 Annual course of average monthly concentrations of VOC, 2019

by at least 40% compared to 1990. The Czech Republic, similarly to most Central European countries (except Poland), has fulfilled this limit – VOC emissions in the Czech Republic decreased by 51% in the 1990–2010 period (EEA 2013c).

Emissions of volatile organic compounds

Chemical products containing VOCs are used in a wide range of applications in households and industry as cleaning agents, solvents and degreasing agents. They can find use as components of coatings, varnishes, adhesives and pharmaceutical products.

VOCs are released during the storage and use of petroleum products. They are also formed in incomplete combustion.

In 2018, the largest amount of VOC emissions originated from the sector 1A4bi – Residential: Stationary (42.9%). Significant sources of VOC emissions in the Czech Republic belong to the sector of the use and application of organic solvents (NFR 2D3) which contributed by 29.3% to pollution of the air by these substances. This sector encompasses activities 2D3a – Domestic solvent use including fungicides (5.5%), 2D3d – Coating applications (11.7%), 2D3e – Degreasing (2.8%), 2D3f – Dry cleaning (0.03%), 2D3g – Chemical products (4.5%), 2D3h – Printing (1.6%) and 2D3i – Other solvent use (3.1%). Some of these emissions are released into the air in a controlled manner, but a substantial part of them escape into the air in the form of fugitive emissions which are difficult to control (Fig. IV.9.1.2). The share of transport, including evaporation from the fuel system of vehicles, was 7.3%. Livestock breeding contributed 8.9% to total VOC emissions, of which the largest share is from cattle breeding (6.9%).

Total VOC emissions in the 2008–2018 period exhibited a decreasing trend (Fig. IV.9.1.3), caused by the use of products with lower volatile organic compound contents, e.g. water-based coatings and plastic powders. Legislative regulations apply to retail packaging of coatings, limiting the maximum solvent contents in products placed on the market. The constant renewal of the vehicle fleet is leading to a continuous reduction in VOC emissions from transport.
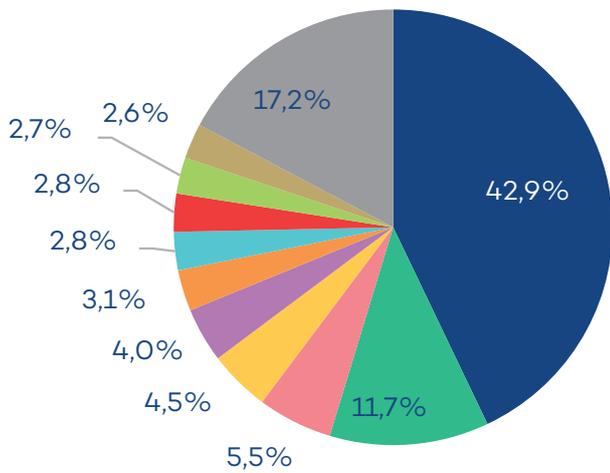
Fig. IV.9.1.2 Total emissions of VOC sorted out by NFR sectors, 2018

- 1A4bi – Residential: Stationary
- 2D3a – Domestic solvent use including fungicides
- 3B1b – Manure management –Other cattle
- 3B1a – Manure management –Dairy cattle
- 1A3bv – Road transport: Gasoline evaporation
- Other
- 2D3d – Coating applications
- 2D3g – Chemical products
- 2D3i – Other solvent use
- 2D3e – Degreasing
- 1A3bi – Road transport: Passenger cars
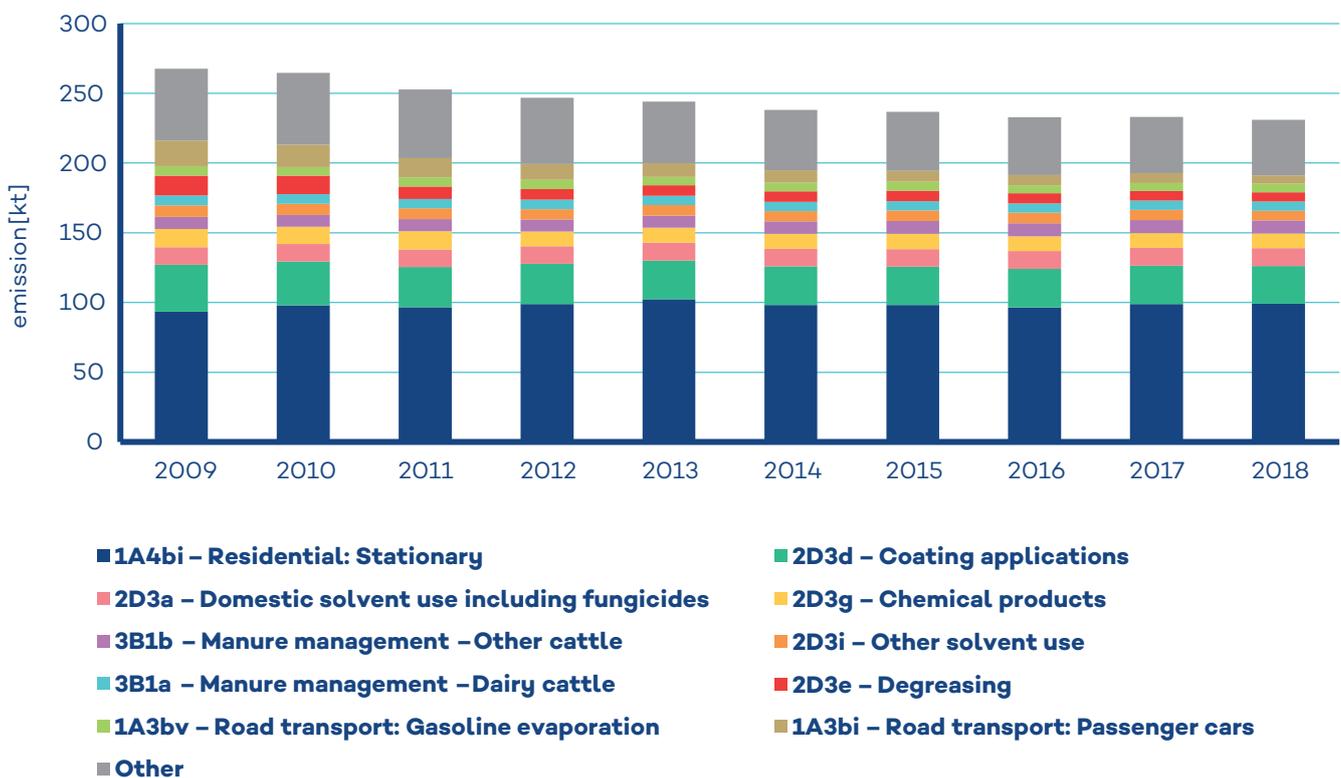
Fig. IV.9.1.3 The development of VOC total emissions, 2009–2018

IV.9.2 Measurement of the numerical size distribution of aerosol particles

The numerical size distribution of aerosol particles has been measured within the CHMI for several years at selected stations. Since 2019, the measurements described below have been extended by other regular measurements. Together, they form the basis of an emerging network of ultrafine particles.

The CHMI has a long-term cooperation with the Institute of Chemical Process Fundamentals of the Czech Academy of Sciences (ICPF CAS) which has been measuring the size distribution of aerosol particles at the Košetice Observatory since 2008. This measurement is part of the ACTRIS European Research Infrastructure monitoring network (Aerosols, Clouds, and Trace gases Research Infrastructure Network). Since 2016, these measurements have also been supported by the ACTRIS-CZ, the Czech part of the large research infrastructure project, which focuses on the Košice locality. For activities involving research activities of the CHMI, two institutes of the Academy of Sciences of the Czech Republic, and the Masaryk University, the collective designation of the locality is used, namely the National Atmospheric Observatory Košetice (NAOK).

In the daily spectra measured at four localities (Ústí nad Labem-city, Lom, NAOK and Ostrava-Fifejdy) it is possible to recognize at first sight the difference in the number of particles in different size categories which reflect the character of the localities. While the median spectra of stations in the Ústí nad Labem region are cha-racterized by the influence of local sources (transport, industry), the median spectrum of the NAOK in the Vysočina region is rather affected by long-distance transport. The Ostrava-Fifejdy station has a different range of measurement sizes, so it is not possible to accurately characterize the predominant source of particles of the typical spectrum and compare it with other stations. In general, however, spectra can be described using common features. The highest concentrations of the number of particles are usually measured in the late evening, night and early morning hours. This phenomenon is probably associated with the development of the boundary layer of the atmosphere and its stability during the night hours. At night, there can be an accumulation of pollutants, and therefore aerosol particles. After sunrise, in some cases, an increase in photochemical reactions between accumulated substances can be observed, which can lead to the formation of secondary aerosols.

The median daily particle size spectrum in 2019 was, as in previous years, less distinct at NAOK compared to other considered measurements. Relatively constant concentrations of accumulation mode particles can be observed, which decrease during the day (between 7:00 and 16:00 UTC) due to atmospheric dilution. On the contrary, the numbers of nucleation mode particles (particle size up to 20 nm) increase from the morning and reach a maximum after 15 hours. The increase in the number of nucleation mode particles is probably associated with the process of particle formation and their subsequent growth to higher sizes. It is at NAOK where the effect of long-distance transport of particles in the form of relatively stable concentrations of the accumulation mode, and the effect of dilution and stability of the atmosphere on the concentrations of particles can be well observed (Fig. IV.9.2.1)[1].
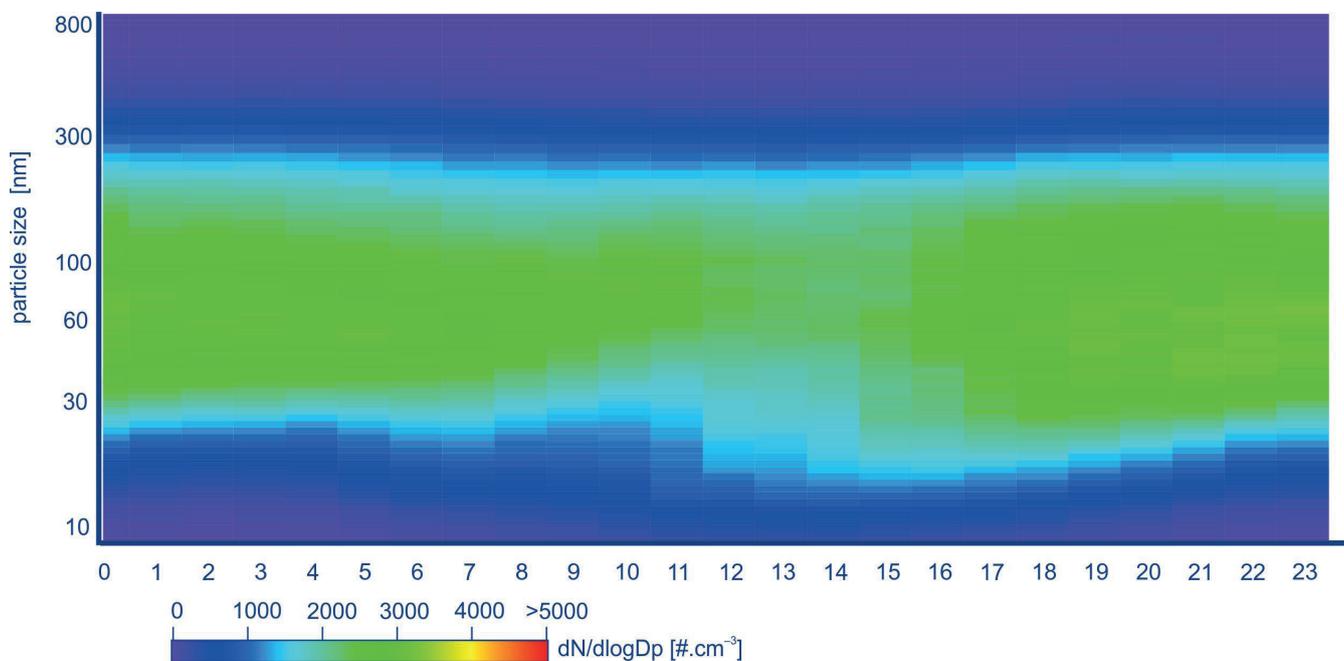
Fig. IV.9.2.1 Median spectrum of the daily progression of the number of particles, NAOK, 2019

1   The dN/dlogDp unit denotes the normalized number of particles in a given size category. The distribution of the number of aerosol particles does not correspond to a symmetrical normal distribution, therefore a logarithmic transformation is used to display the aerosol spectrum to obtain a log-normal distribution (Hinds 1999). The Y-axis indicates the nano-meter particle size categories of aerosol particles, the colour scale shows the number of particles in a given size category (the number of particles increases from cold to warm colours).

Daily variation of the number of particles at the Ústí nad Labem--city station is characteristic by an increase of the number of particles in all parts of the spectrum in the morning and afternoon hours, reflecting not only peak traffic conditions but also the increasing occurrence of combustion products from industrial sources. These sources are connected with elevated production of both particles and their gaseous precursors, from which secondary particles can be formed by photochemical processes. Increase of particles between 20 and 100 nm is the most distinct, reaching the

maximum between 6 and 9 hours in the morning (Fig. IV.9.2.2). As already mentioned earlier, changes in the counting concentration are affected by not only the sources but also by stability of the atmosphere. While during a day, the atmosphere is well mixed due to turbulent flow, in the evening when the turbulence ceases, the atmosphere gets stabilized (Stull 2003).

The Lom station in the Ústí nad Labem region started measuring the size distribution of aerosol particles in 2017. This background
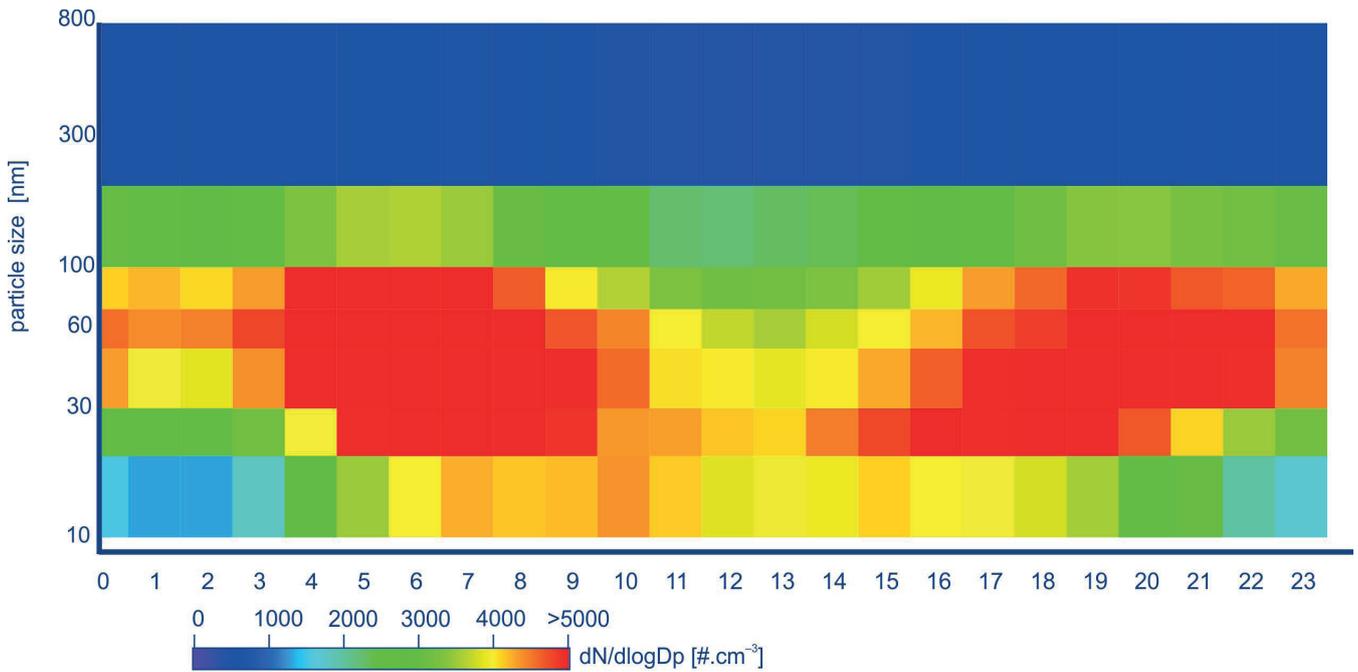
Fig. IV.9.2.2 Median spectrum of the daily progression of the number of particles, Ústí nad Labem-město, 2019
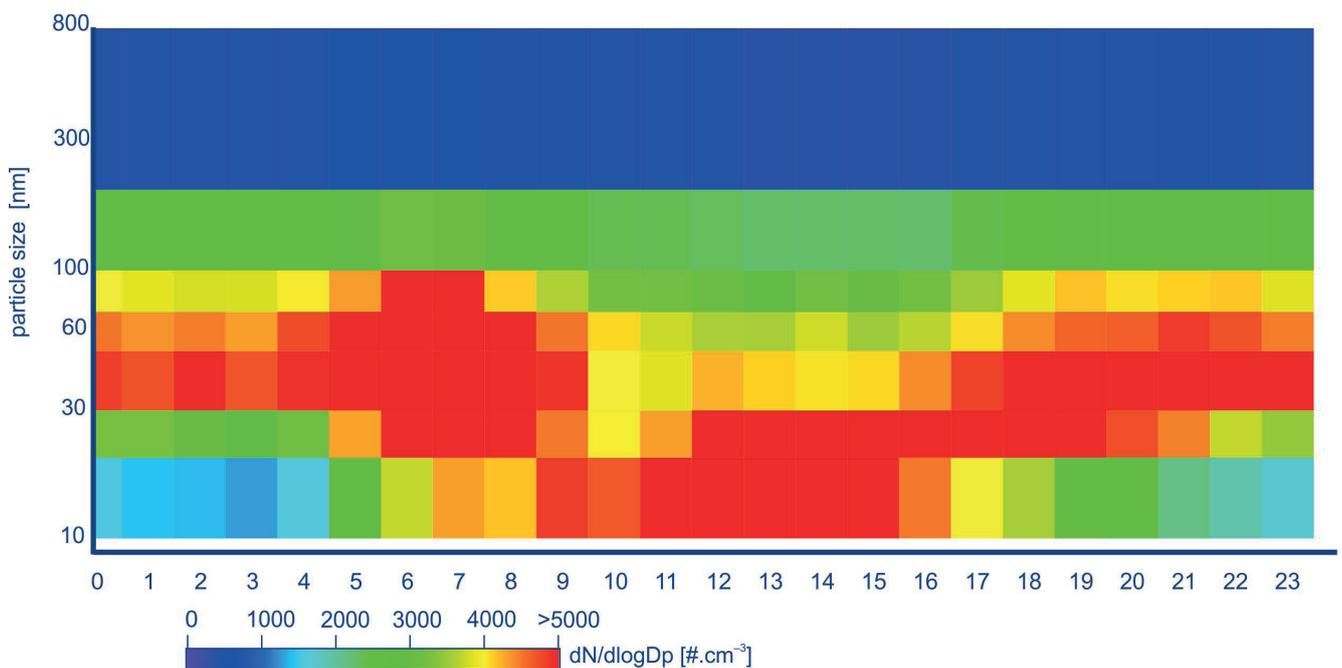
Fig. IV.9.2.3 Median spectrum of the daily progression of the number of particles, Lom, 2019
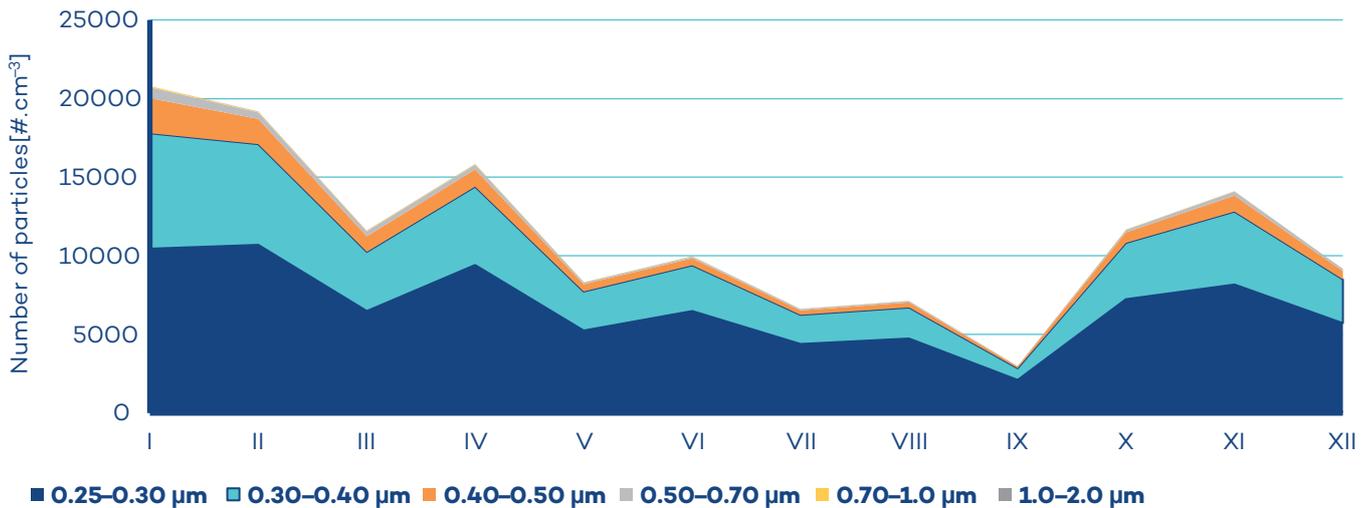
Fig. IV.9.2.4 Monthly variability of average particle numbers, Ostrava-Fifejdy, 2019
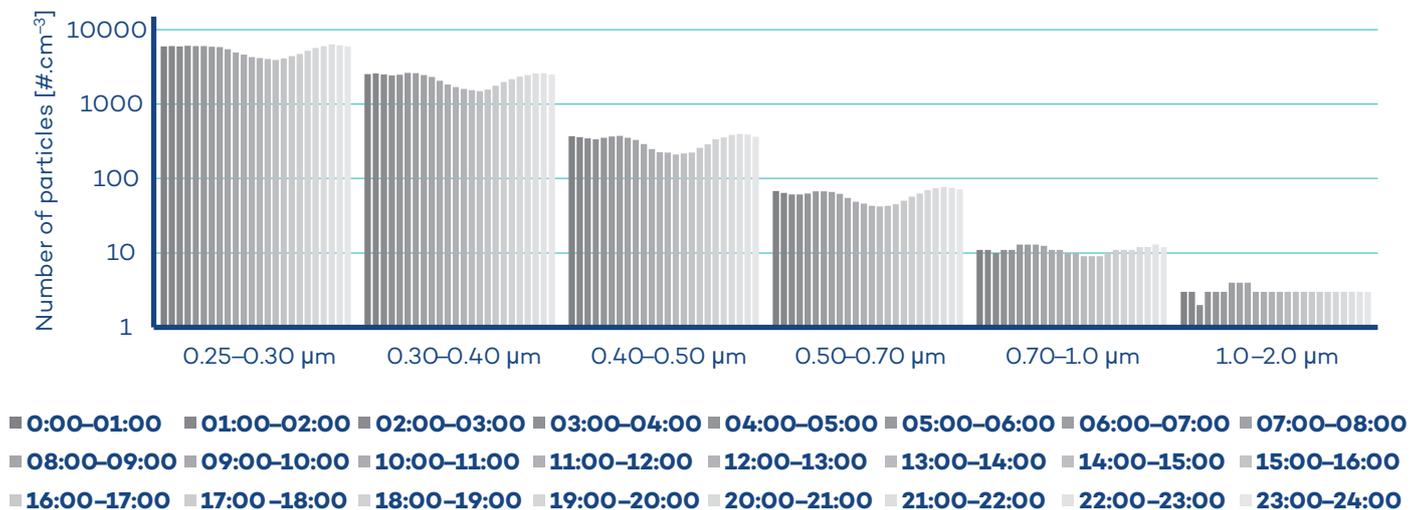
Fig. IV.9.2.5 Median spectrum of the daily progression of the number of particles, Ostrava-Fifejdy, 2019

industrial station is located approximately 4 km from the petrochemical complex and about 500 m from the town of Lom. In contrast to the other three stations, events of formation of new particles manifested by high concentrations of nucleation mode particles lasting from 9:00 to 15:00 accompanied by the transformation of nucleation mode particles into larger aerosol spectrum particles can be identified at this station in the year-round median spectrum. The described daily spectrum probably reflects the influence of industrial sources as well as transport and large cities in the vicinity (Fig. IV.9.2.3).

The Ostrava-Fifejdy urban background station is equipped with the GRIMM analyser which has been used to monitor the number of particles in 32 size fractions in the range of 0.25 to 3.20 µm since 2008. The number of particles was also monitored by the GRIMM analyser in the Moravian-Silesian region in the past at the background suburban Ostrava-Poruba locality (2012–2015) and

from 2016 to April 2018 at the background rural Věřňovice locality.The average number of monitored particles at the Ostrava-Fifejdy station was 11,400 in 2019.

The highest number of particles from the monitored size intervals is represented in smaller size fractions up to 0.30 µm and making about 67% of all measured particles at the Ostrava-Fifejdy locality. Particle numbers show significant differences during the year. The highest average number of particles is reached in January, February, April and November. The differences in the average numbers of particles between the hot (April to September) and cold (January to March and October to December) parts of the year in 2019 are 26% (Fig. IV.9.2.4).

The median daily course of the number of particles is more pronounced in smaller fractions up to 0.7 µm, in larger size fractions the daily course is more balanced (Fig. IV.9.2.5) and at

the same time it reaches the lowest values. During the day, the lowest values are reached in the afternoon, the highest during the evening, night and morning. There is no noticeable increase in the number of particles during daily rush hour. Therefore, there is no significant effect of traffic or this method is not able to follow this effect.

In the annual variability of the total number of particles, the highest values are reached at the Ostrava-Fifejdy station, even though it measures the number of particles of a size above 250 nm. During some months, the total number of particles is up to three times higher than at the other stations. There are different variations of the total number of particles between stations during the year. At the Ústí nad Labem-city station, the highest total concentrations were measured in February (10,700 particles per cm^3), at

the Lom station in June (10,600 particles per cm^3), at the NAOK in July (5200 particles per cm^3), and at Fifejdy in January (20,800 particles per cm^3). At all three compared stations, an increase in the number of particles caused by heating during the winter and more stable atmospheric conditions can be observed, as well as a secondary increase in concentrations in the spring and summer. The increase in the total number of particles is associated with the events of the formation of new particles, which are bound to the period with a high vegetation activity, and therefore an increased production of VOCs (a precursor of secondary particles). The described process is also supported by the increasing intensity of sunlight. The secondary increase in the total number of particles in October and November was not reflected at the NAOK station. Thus, the increase at the Ústí nad Labem-city and Lom stations may be caused by local influences (Fig. IV. 9.2.6).
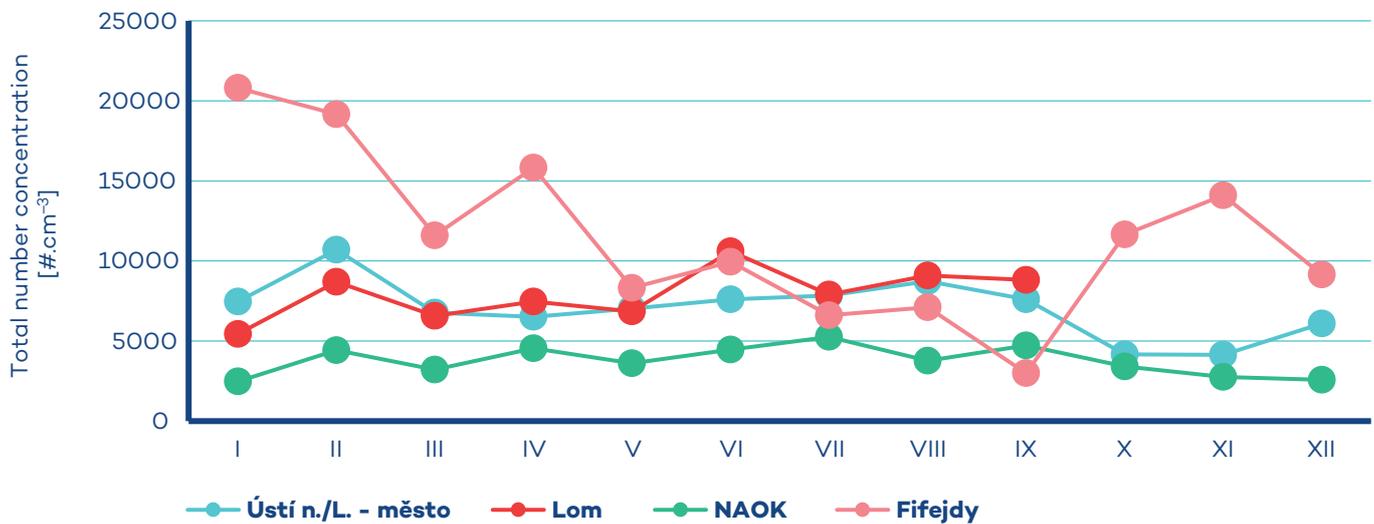
Fig. IV.9.2.6 Average monthly variability of the total particle number concentration, Ústí Labem-město, Lom, NAOK, Fifejdy, 2019

IV.9.3 Monitoring concentrations of elemental, organic and black carbon

The first regular measurement of EC/OC in the Czech Republic was launched in February 2009 at the Košetice Observatory (OBK). The average concentration of total carbon (TC) in 2009–2019 in the sampled $PM_{2.5}$ fraction was 3.4 µg.m^{-3}, of which the EC amounts to 0.4 µg.m^{-3} and OC to 3.0 µg.m^{-3}. In 2019, the highest average concentration of TC (3.8 µg.m^{-3}) was measured in January. January was the coldest month of 2019 at OBK (average temperature −1.9 °C), and the results of carbon concentration measurements were probably affected by temperatures that were mostly below freezing for a month, which could increase the need for heating and the associated increase of these products of combustion. In 2019, the average concentration of TC

(2.8 µg.m^{-3}) was 0.6 µg.m^{-3} higher than in 2018. This decrease was probably affected by higher temperatures in the winter of 2019 compared to the previous year. Adverse meteorological conditions together with increased production of carbon particles due to heating increase the measured TC concentrations. In the last two years, we have observed an increase in OC concentrations in the summer, which may be caused by higher temperatures, supporting the formation of secondary OC. The average annual EC concentration in 2019 was 0.3 µg.m^{-3} and the OC concentration reached 2.5 µg.m^{-3}. Overall, considering the course of concentrations during the period of measurements, a slightly decreasing trend can be identified despite the increase in average annual concentrations in some years. While the EC concentration (2009 – 0.6 µg.m^{-3}) has been gradually decreasing since the beginning of the measurement, in 2012, 2013, and 2018, the concentrations increased again. After the renewal of the measurement in 2016, the annual average concent-
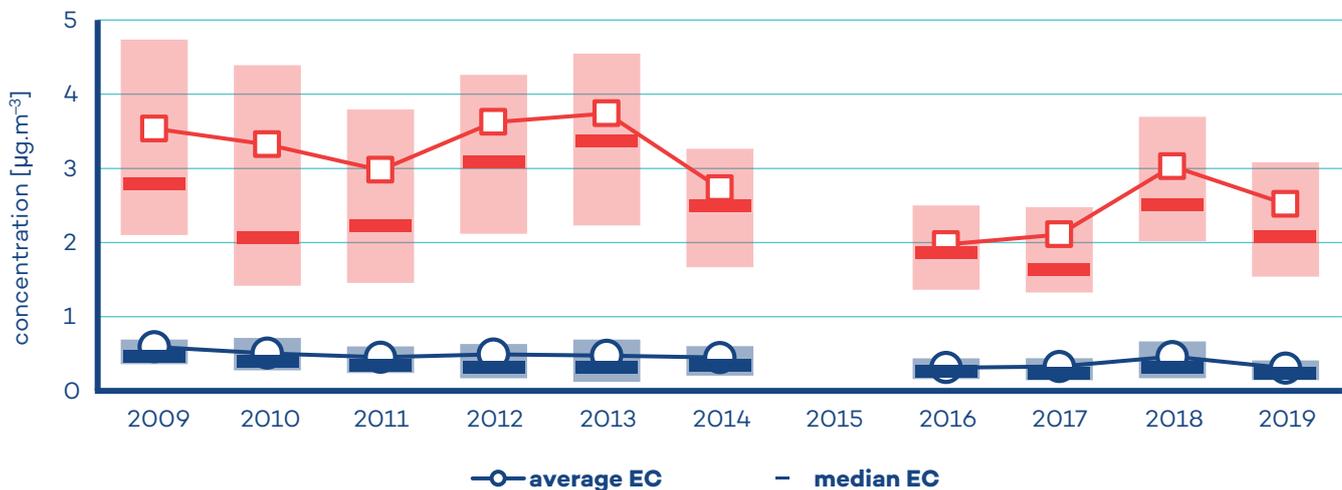
Fig. IV.9.3.1 Annual average concentrations of EC and OC, Košetice Observatory, 2009–2019
Note: The range of daily values is indicated by the top/bottom border of the boxes representing the value of 75th and 25th percentile respectively; the horizontal line indicates the median.
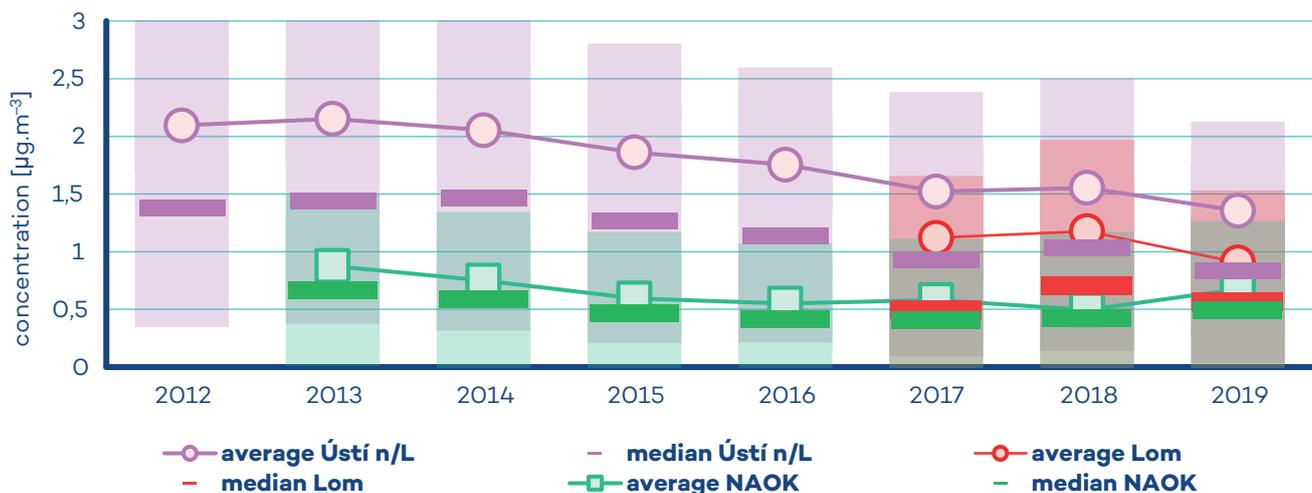
Fig. IV.9.3.2 Annual average concentrations of BC, NAOK, Lom, Ústí nad Labem-město. 2012–2019
Note: The range of daily values is indicated by the top/bottom border of the boxes representing the value of 75th and 25th perectentile respectively; the horizontal line indicates the median.

rations were slightly above 0.3 μg.m⁻³. Significant increase was recorded in 2018. Similar but more noticeable course was also observed for the OC. The highest average value was observed in 2013 (3.7 μg.m⁻³), while the lowest OC concentration was characteristic for 2016 (2.0 μg.m⁻³) (Fig. IV.9.3.1).

Measurements of concentrations of BC take place at three stations, namely the Ústí nad Labem-město, Lom, and NAOK (the core station is the Košetice Observatory). The Ústí nad Labem-město and NAOK stations measure BC since 2012, the station Lom since 2017.

The annual variability of concentrations of BC reflects higher amount of emissions produced during the heating season; increased values are recorded during the cold part of the year. Apart from the heating season, weekly maxima can be identified namely due to traffic. Another source of BC is barbecue taking place in the summer months.

The evaluation of BC concentrations at all three stations cannot be performed with a sufficient reliability in terms of the average annual concentration. Data coverage does not meet the required number of measurements. In addition, outages occurred mainly in the winter, which may have led to underestimation of the results. The annual average BC concentration of 1.4 μg.m⁻³ at the Ústí nad Labem-město station is therefore probably underestimated. In the previous period, however, a declining trend was observed showing a decrease of the average annual concentrations in the period 2012–2018 since the beginning of the measurements by 0.6 μg.m⁻³. During this period, variability of data also decreased reaching the peak in 2014. Although the levels of 1st and 3rd quartiles in 2014 reached 0.7 and 2.7 μg.m⁻³ respectively, the 1st quartile of 2018 amounted to 0.5 μg.m⁻³ and the 3rd quartile to 2.1 μg.m⁻³. Insufficient data coverage also applies to the Lom station where the average annual concentration in 2019 was 0.9 μg.m⁻³. This figure should also be considered as slightly underestimated. Although the Lom and Ústí nad Labem-město stations are located in an industrial region, lower concentrations of BC can be observed at the Lom station due to its location outside the traffic arteries. The long-term monitoring of BC concentrations at the NAOK station gives two to three times lower the values recorded at the Ústí nad Labem-město station. The annual average concentration dropped from the level of 0.9 μg.m⁻³ in 2013 to 0.7 μg.m⁻³ in 2019. The variability of measured data was the lowest in 2016 (1st and 3rd quartiles reached the values of 0.3 μg.m⁻³ and 0.7 μg.m⁻³ respectively) the following year the variability moderately increased, similarly to the average concentration. Compared to the previous year, a slight increase in BC concentrations was recorded in 2019 (from an annual average of 0.5 to 0.7 μg.m⁻³). However, this increase does not necessarily mean deterioration in air quality. Last year, the NAOK renewed the monitoring device with a higher measurement frequency and more advanced measurement technology. This change in instrumentation, along with missing data, can cause slight changes in results. Despite the mentioned shortcomings in the measurement, it can be concluded in view of multiple years

of concentrations data that the overall course of concentrations at the mentioned stations is not quite identical. Despite the fact that since 2013 the BC concentrations have been decreasing, the NAOK has seen an increase in concentrations in 2017 and 2019, however, the slight increase in concentrations at the stations in the Ústí na Labem region was observed only in 2018. These differences may be associated with a different structure of sources, affecting BC concentrations (Fig. IV.9.3.2).

Based on the results of inventories in the Czech Republic in 2018, up to 46.9% of BC emissions originated from the transport sector, particularly from combustion of fuel in diesel engines. Of this, the following sectors contributed the most to the total BC emissions: Road transport: Passenger cars (1A3bi) by 16.7% and Agriculture, forestry, fishing: Off-road vehicles and other machinery (1A4cii) by 14.6%. Of stationary sources, the most BC emissions were produced by the Residential: Stationary sector (1A4bi) with a share of 51.1% to total emissions (Fig. IV.9.3.3). Developments in total BC emissions in the 2009–2018 period can be characterised by a decreasing trend, particularly due to measures in the transport sector (Fig. IV.9.3.4)[1].

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1   The share of BC emission by sectors has recently been recalculated and the results given in previous years can therefore differ.
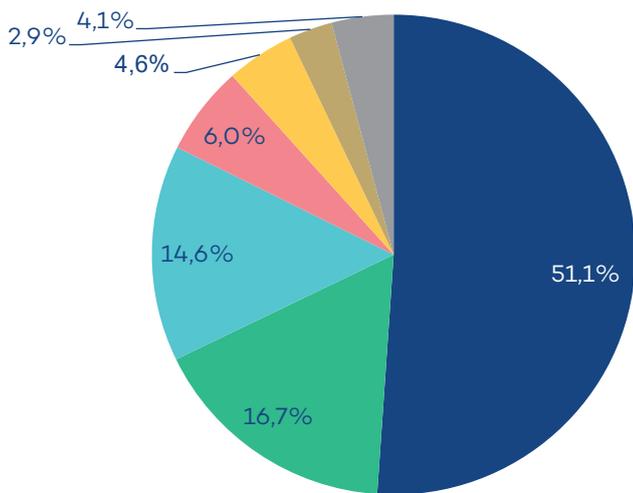
Fig. IV.9.3.3 Total emissions of BC sorted out by NFR, 2018

- ■ **1A3biii – Road transport: Heavy duty vehicles and buses**
- ■ **1A3bvi – Road transport: Automobile tyre and brake wear**
- ■ **1A3bii – Road transport: Light duty vehicles**
- ■ **1A4cii – Agriculture/Forestry/Fishing: Off-road vehicles and other machinery**
- ■ **1A3bi – Road transport: Passenger cars**
- ■ **1A4bi – Residential: Stationary**
- ■ **Other**
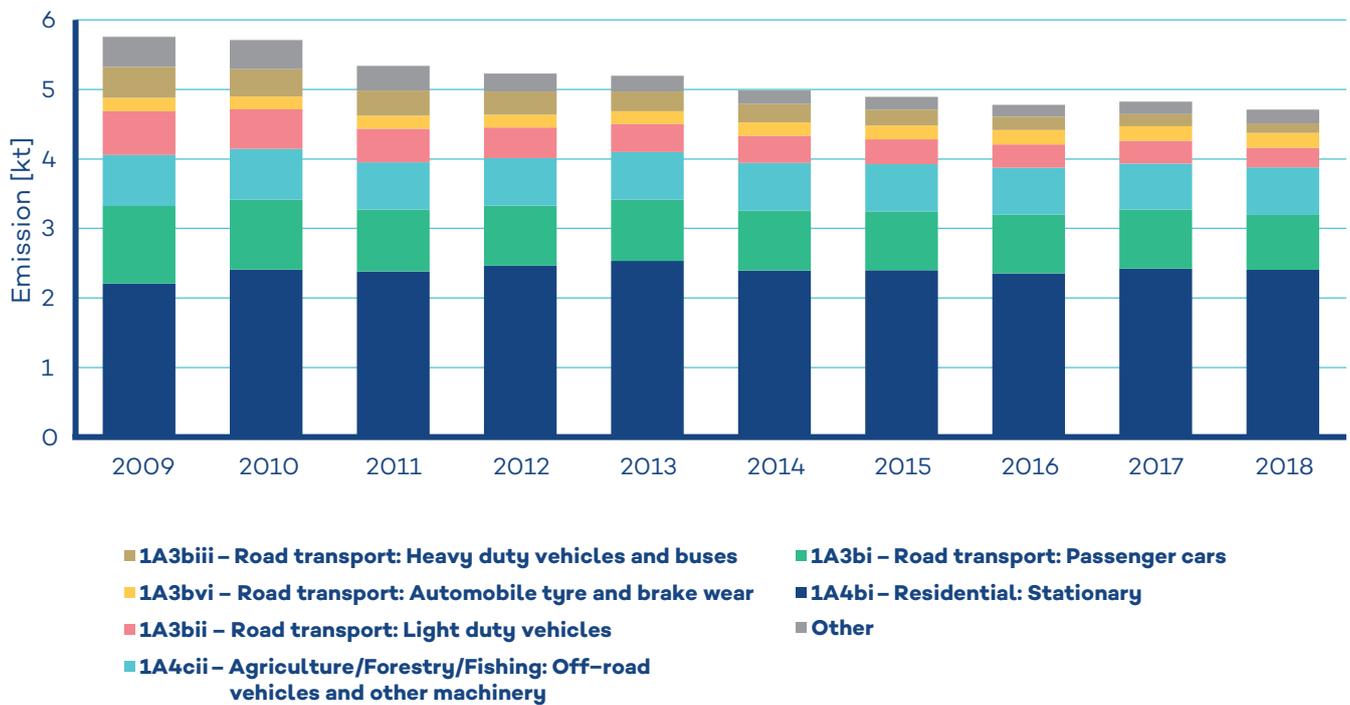
Fig. IV.9.3.4 The development of BC total emissions, 2009–2018

V. AIR QUALITY IN AGGLOMERATIONS AND CITIES

V.1 Prague agglomeration

In terms of air pollution, the capital of Prague ranks among the most polluted areas in the Czech Republic (Tab. VII.1.2). This situation is a result of the interaction of a number of anthropogenic and natural factors.

A specific location of Prague in the complex terrain of the Prague basin fundamentally affects the climatic conditions and dispersion conditions in the territory (Ložek et al. 2005). The Vltava River valley is generally insufficiently ventilated and, especially in the colder part of the year, suitable conditions appear here for the formation of temperature inversions resulting in accumulation of concentration of harmful substances in the ground layer of the atmosphere (ČHMÚ 2020d).

For assessing and evaluating the level of air pollution, the Act No. 201/2012 Coll., on protection of the air, divides the territory of the Czech Republic into zones and agglomerations. This chapter deals with detailed evaluation of the air quality in the agglomerations of Prague, Brno and Ostrava/Karviná/Frýdek-Místek, these areas have high population densities; thus the fraction of the population that is exposed there to above-limit concentrations is not negligible. The air quality index also assesses the situation in other, mostly regional, cities of the CR.

The worsened quality of the air in Prague is related mainly to the heavy traffic load. Due to its location, Prague is not only the main cross-road of the road network of the Czech Republic, but is also an important cross-road in international transport. A large portion of main transport roads goes through the centre of Prague. However, the current roadway network inside the city is not capable of absorbing such an enormous concentration of traffic and is overloaded, often even with traffic jams. The factor of high traffic load by vehicles is also a result of the economic strength of the region and the highest rate of motorization in the Czech Republic which reached 715 vehicles per 1,000 inhabitants in 2018, representing 132% of the national average (CENIA 2019). Partial improvement of traffic conditions should follow primarily from completion of by-pass circuit roads around Prague, substantial reduction of individual automotive transport in the most crowded areas and emphasis on railway and municipal mass transport (IPR Praha 2016).

Tab. V.1.1 The territory of the Prague agglomeration with the exceeded limit values of the individual pollutants

Year	PM$_{10}$ annual average	PM$_{10}$ 24h	PM$_{2.5}$ annual average	NO$_2$ annual average	Benzo[a]pyrene annual average	O$_3$
2012	–	5.61 %	–	1.36 %	88.11 %	0.20 %
2013	–	0.42 %	–	0.56 %	59.61 %	0.20 %
2014	–	5.96 %	–	0.20 %	75.81 %	–
2015	–	–	–	–	41.70 %	0.20 %
2016	–	–	–	0.60 %	54.26 %	2.01 %
2017	–	0.67 %	–	–	67.70 %	15.52 %
2018	–	1.98 %	–	–	19.03 %	97.38 %
2019	–	–	–	–	0.35 %	99.83 %

Due to its historical development, Prague has a developed industrial infrastructure (IPR Praha 2016). In the recent past, a number of unsatisfactory industrial facilities have been closed or production reduced, however, the services sector has grown in importance leading to construction of new commercial and administrative centres, placing considerable demands on transportation services and consumption of energy, including heating. The consumption of solid fuels for heating family houses, especially in suburban parts of the city, also has a considerable effect on the air quality in Prague. The growing popularity of the use of fireplaces and fireplace stoves contributes to deterioration of the air quality. Despite the significant share of gasification, the pollution load from local heating remains significant, especially in the outskirts of the city (MHMP 2020).

V.1.1 Air quality in the Prague agglomeration

Suspended particulate matter PM$_{10}$ and PM$_{2.5}$

In 2019, the limit value for the average 24-hour PM$_{10}$ concentration in the Prague agglomeration was not exceeded at any of 16 monitoring stations with sufficient amount of data for evaluation. The limit value has not been exceeded even in traffic localities where the occurrence of above-limit concentrations was typical in previous years. Most days with daily average PM$_{10}$ concentration exceeding the pollution limit value occurred in January and February (Fig. V.1.1), nevertheless, the permitted limit of 35 cases exceeding the limit value (50 µg.m^{-3}) was not exceeded at any station. In January to February, 53–80% of average daily concentrations higher than the limit value were recorded at individual stations, probably in connection with the occurrence of moderately poor to poor conditions in January and especially in February (Chapter III). Furthermore, the limit value was significantly exceeded in April, which was the month with the lowest total precipitation in 2019. In October, the cases exceeding the limit value related to the occurrence of poor

dispersion conditions. In December, the limit value was exceeded mainly at traffic locations in relation both to the occurrence of lower temperatures during the year and more intensive heating, and to higher emissions from traffic due to increased abrasion of road material due to road maintenance in winter and subsequent resuspension of the material (EC 2011). In 2019, as in previous years, the annual limit values for PM$_{10}$ (40 µg.m^{-3}) and PM$_{2.5}$ (25 µg.m^{-3}) were not exceeded at any site that was relevant for the assessment of annual average concentrations (Fig. V.1.2, Fig. V.1.3). In Prague, the highest annual average concentrations of PM$_{10}$ and PM$_{2.5}$ are observed at traffic sites. The highest values of the average annual concentration of PM$_{10}$ in 2019 were observed at the stations of Prague 8-Karlín (25.7 µg.m^{-3}), Prague 2-Legerova (25.5 µg.m^{-3}) and Prague 10-Vršovice (25, 4 µg.m^{-3}). A similar concentration was also observed in the centre of Prague at the Prague 1-nám. Republiky city station (24.8 µg.m^{-3}). In 2019, the highest values of the average annual PM$_{2.5}$ concentration were measured at the Prague 2-Legerova traffic station (17.3 µg.m^{-3}). The second highest annual average concentration was measured at the Prague 5-Řeporyje suburban station (17 µg.m^{-3}) which is located near the residential built-up area where the increase in concentrations occurs due to emissions from heating using solid fuels.

In terms of longer time series of concentrations of suspended particles PM$_{10}$ or PM$_{2.5}$ for the period of 2009–2019 or 2012–2019, respectively, it can be stated that all air pollution characteristics reach higher average values in traffic localities compared to urban and suburban ones (Fig. V.1.2, V.1.3). In the period under review, the highest concentrations were measured in 2010, when the increase in concentrations was due to the repeated occurrence of unfavourable meteorological and dispersion conditions in the winter at the beginning and end of the year. The lowest concentrations were measured in 2015 and 2016, i.e. in the years when there was a significant decrease in the occurrence of poor dispersion conditions. In 2017 and 2018, annual average concentrations of PM$_{10}$ and PM$_{2.5}$ show increase; in 2018 the increase was more significant and was probably related to a strongly below-normal amount of precipitation or with reduced intensity of self-clea-
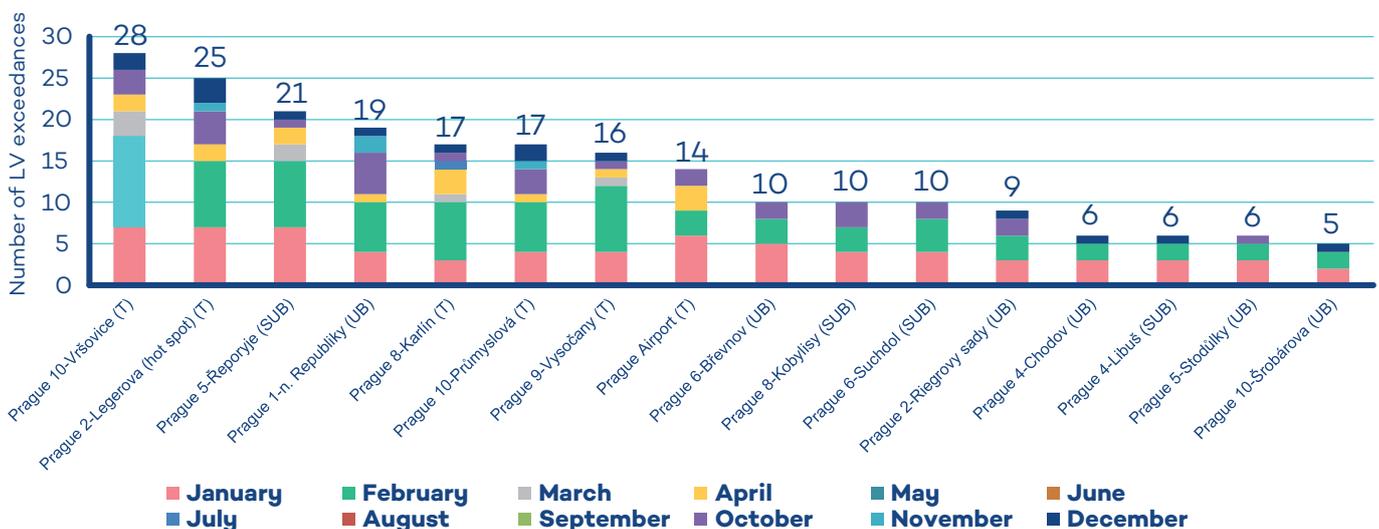
Fig. V.1.1 Number of days with concentrations of PM$_{10}$ > 50 µg.m^{-3} by months, including total number of cases exceeding the pollution limit, 2019
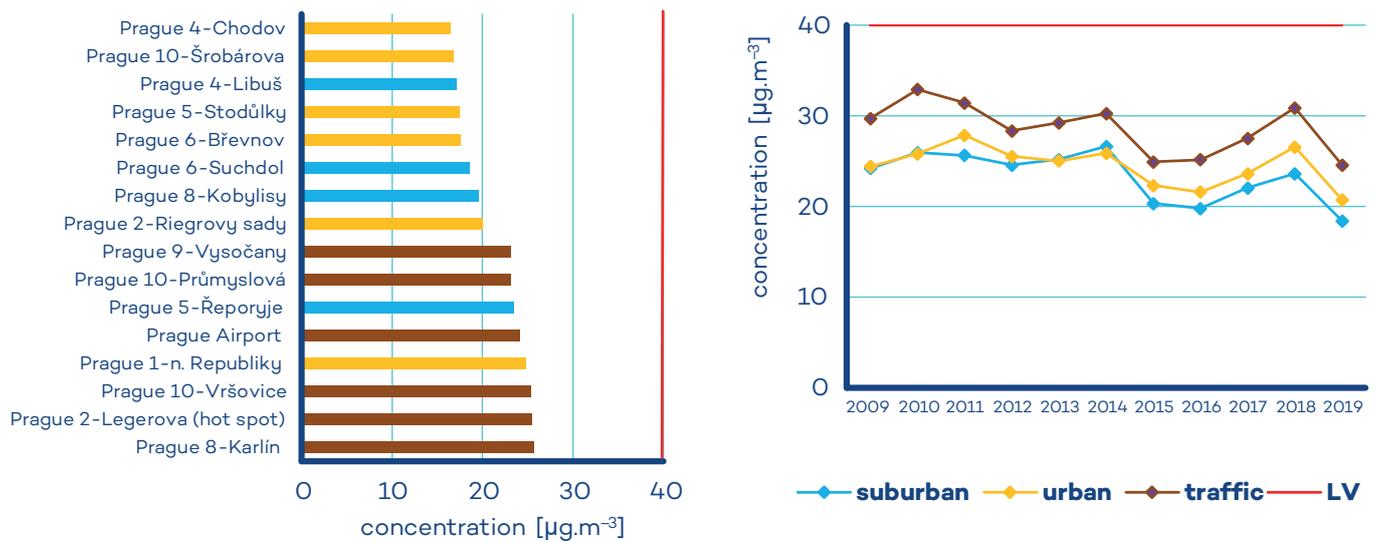
Fig. V.1.2 Annual average concentration of PM$_{10}$ in 2018 and variation of concentrations in 2009–2019
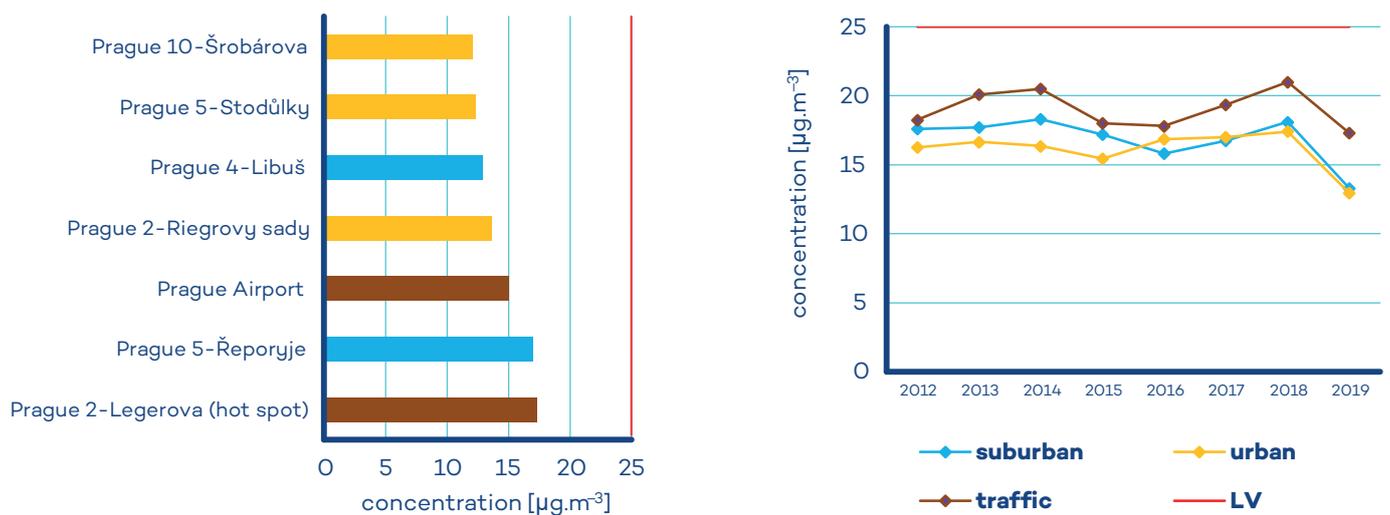
Fig. V.1.3 Annual average concentration of PM$_{2.5}$ in 2018 and variation of concentrations in 2012–2019

ning of the atmosphere and higher resuspension (CHMI 2019). In 2019, there was a significant decrease in the concentrations of suspended particulates PM$_{10}$ and PM$_{2.5}$. Concentrations reached their minima during the evaluated period in urban, suburban and traffic localities. This decrease is due both to the occurrence of abnormally high temperatures in the winter (leading to a reduced need for heating or reduced emissions from sector 1A4bi — Households: heating, water heating, cooking) and the occurrence of mostly good dispersion conditions in the cold season at the end of the year (October-December). It can be expected that the reduction in the emission intensity of vehicles due to the modernization of the vehicle fleet and the ongoing replacement of boilers in households contribute to the improvement of the situation in the Prague agglomeration despite the continuing growth of traffic intensities (CENIA 2019).

Benzo[a]pyrene

In 2019, the pollution limit level for the annual average concentration of benzo[a]pyrene was not exceeded at any of three stations in the territory of the Prague agglomeration meeting the requirements for the quantity and quality of the monitored data. These include a suburban station of Prague 4-Libuš, and city stations of Prague 2-Riegerovy sady and Prague 10-Šrobárova. Until 2014, the limit value was exceeded annually in at least one monitoring station in the Prague agglomeration (Fig. V.I.4), while in recent years the highest concentrations have been measured in the suburban locality Prague 4-Libuš. In the last five years, the limit was not exceeded at any monitoring station in the territory of Prague, moreover, in 2019, there was the lowest annual average concentration of benzo[a]pyrene recorded at Prague stations
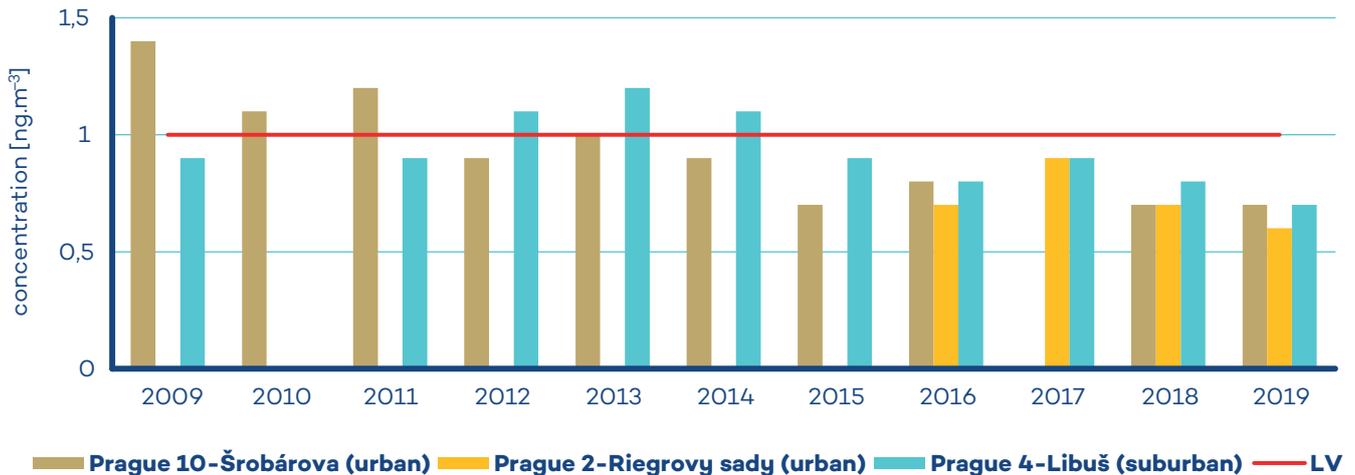
Fig. V.1.4 Annual average concentration of benzo[*a*]pyrene in 2018 and variation of concentrations in 2009–2019
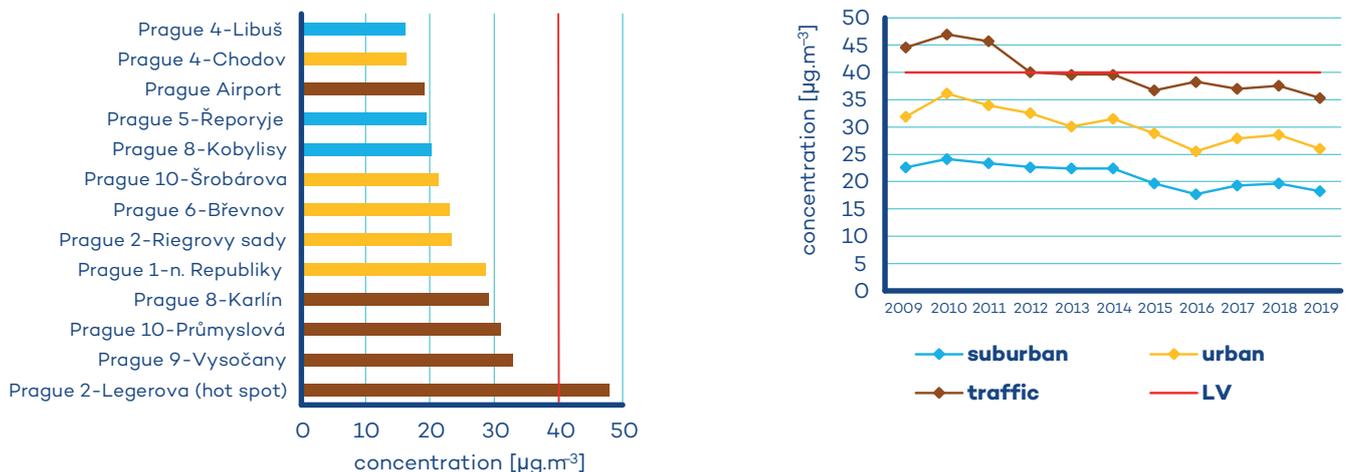
Fig. V.1.5 Annual average NO₂ concentration in 2019 and variation of concentrations in 2009–2019

in the evaluated period 2009–2019. The reason is, similarly to the concentrations of suspended particulates, the occurrence of abnormally high temperatures in the winter months and mostly good dispersion conditions at the end of 2019.

Nitrogen dioxide

The hourly pollution limit value for NO_2 (200 µg.m⁻³) was not exceeded in 2019 at any of 13 stations relevant for evaluation. The pollution limit value was neither exceeded at any station in Prague (the permitted number of cases exceeding the limit is 18). The highest hourly concentration of 145.6 µg.m⁻³ was measured at the Prague 2-Legerova (hot spot) traffic site at the end of summer holidays on 30 August 2019. Second highest average hourly concent-

ration (143.5 µg.m⁻³) was measured at the Prague 10-Průmyslová traffic site at the beginning of Easter on 17 April 2019.

The annual pollution limit level for NO_2 (40 µg.m⁻³) was exceeded at a single station in the Prague agglomeration (Fig. V.1.5). These concerned the traffic station at Prague 2-Legerova (hot spot) where the annual average concentration reached 48 µg.m⁻³). This traffic station, together with the Prague 5-Smíchov station, experienced exceeding the limit value also in the past years. The Prague 5-Smíchov station could not be included in the assessment of air pollution by NO_2 in the Prague agglomeration in 2019 due to the lack of valid data (measurements at the station were interrupted in April 2019 due to technical reasons)[1]. Nevertheless, it can be assumed that above-limit concentrations of NO_2 may appear

1   http://portal.chmi.cz/files/portal/docs/uoco/web_generator/locality/pollution_locality/loc_ASMI_CZ.html
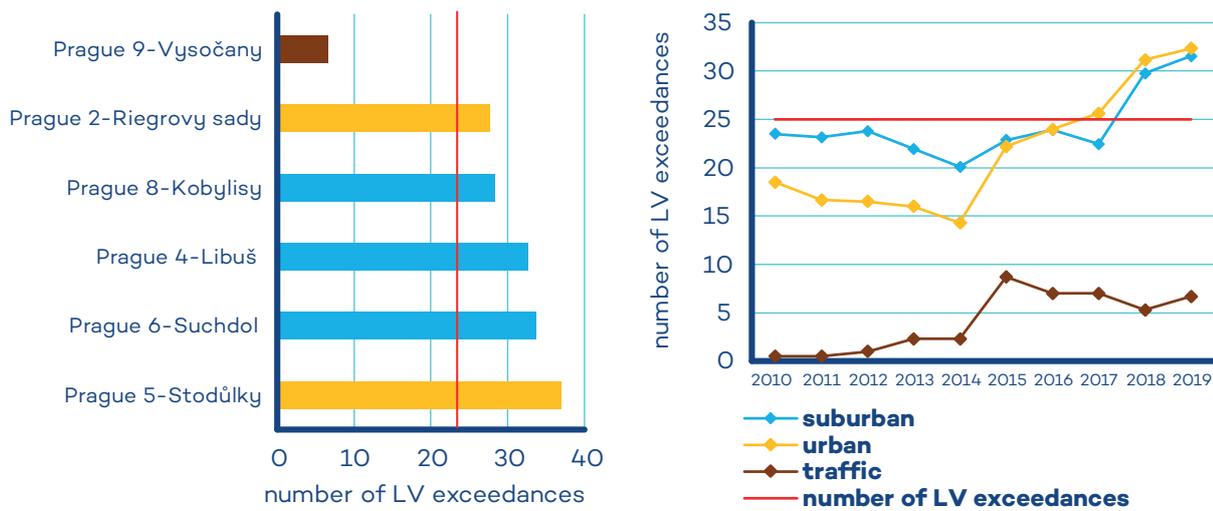
Fig. V.1.6 Number of cases exceeding the pollution limit of O_3 in the average for three years, 2010–2019

also at other exposed traffic locations in the Prague agglomeration equipped with monitoring stations.

The main emission source of nitrogen oxides in Prague is traffic (Fig. V.1.7), which is also reflected in the significantly higher average NO_2 concentrations at traffic sites in comparison with the levels at urban background and at suburban background locations (Fig. V.1.5). In the evaluated period, concentrations reached the peaks at all types of localities in 2010. At traffic locations, the annual average NO_2 concentrations have been gradually decreasing since 2010, and since 2015 their levels have remained below the limit value. In urban and suburban localities, a decrease can be observed between 2010 and 2016, then a slight increase in 2017 and 2018. In 2019, annual average concentrations decreased at all types of stations, at traffic stations they reached the minimum in the period under review. At suburban and city stations, 2019 is the second year with the lowest annual average concentration after 2016.

Ground-level ozone

In 2019, ground-level ozone was measured in 6 localities in the Prague agglomeration. On average in 3 years, 2017–2019, the limit value for ground-level ozone was exceeded at five locations: Prague 5-Stodůlky (37 times), Prague 6-Suchdol (33.7 times), Prague 4-Libuš (32.7 times), Prague 8-Kobylisy (28.3 times) and Prague 2-Riegrovy sady (27.7 times), while the permitted number of cases exceeding the limit value is 25 (Fig. V.1.6). Since 2010, when complete time series of cases exceeding the pollution limit at these sites can be assessed, the limit value was exceeded at the highest number of sites in 2019. In 2018, cases exceeding the limit value were observed at four stations, in 2016–2017 at three stations, in 2010, 2011, 2013 and 2015 only at one, in 2014 even at none. From the point of view of the time variation of the number of cases exceeding the ozone limit value, a stagna-

ting or slightly decreasing trend can be observed from 2010 to 2014, which was interrupted by 2015, when the number of cases exceeding the ozone limit value increased in the average per locality. The upward trend in the following years continued and reached its maximum currently in 2019. In 2015–2019, the increase in ozone pollution characteristics was predominantly due to the above-normal temperature in summer months. Especially 2018 was characterised by temperature above-normal to extremely above-normal and precipitation below-normal in summer months (ČHMÚ 2019), i.e. conditions favourable for creation of ground-level ozone. The year 2019, after 2018, is the second warmest year observed in a series of average values since 1961 (Chap. III). The lowest concentrations are measured in the long-term at the Prague 9-Vysočany traffic station, which corresponds to the ground-level ozone chemistry and fluctuation of its concentration (see Chap. IV.4.3).

Other substances

For other atmospheric pollutants set forth in the legislation (CO, SO_2, benzene, heavy metals), the Prague agglomeration has long been able to meet the pollution limits. After 2000, above-limit average annual arsenic concentration levels were recorded at the Prague 5-Řeporyje locality, for the last time in 2011. Nonetheless, the concentrations of these substances are also affected by the predominant meteorological and dispersion conditions, so that an increase in some pollution level characteristics for these pollutants was recorded, e.g. in 2003, 2006, 2010, 2011 and 2017.

TZL

REZZO 1+2   REZZO 3   REZZO 4

REZZO 1+2   REZZO 3   REZZO 4

SO$_2$

REZZO 1+2   REZZO 3   REZZO 4

REZZO 1+2   REZZO 3   REZZO 4

NO$_X$

REZZO 1+2   REZZO 3   REZZO 4

REZZO 1+2   REZZO 3   REZZO 4

2008
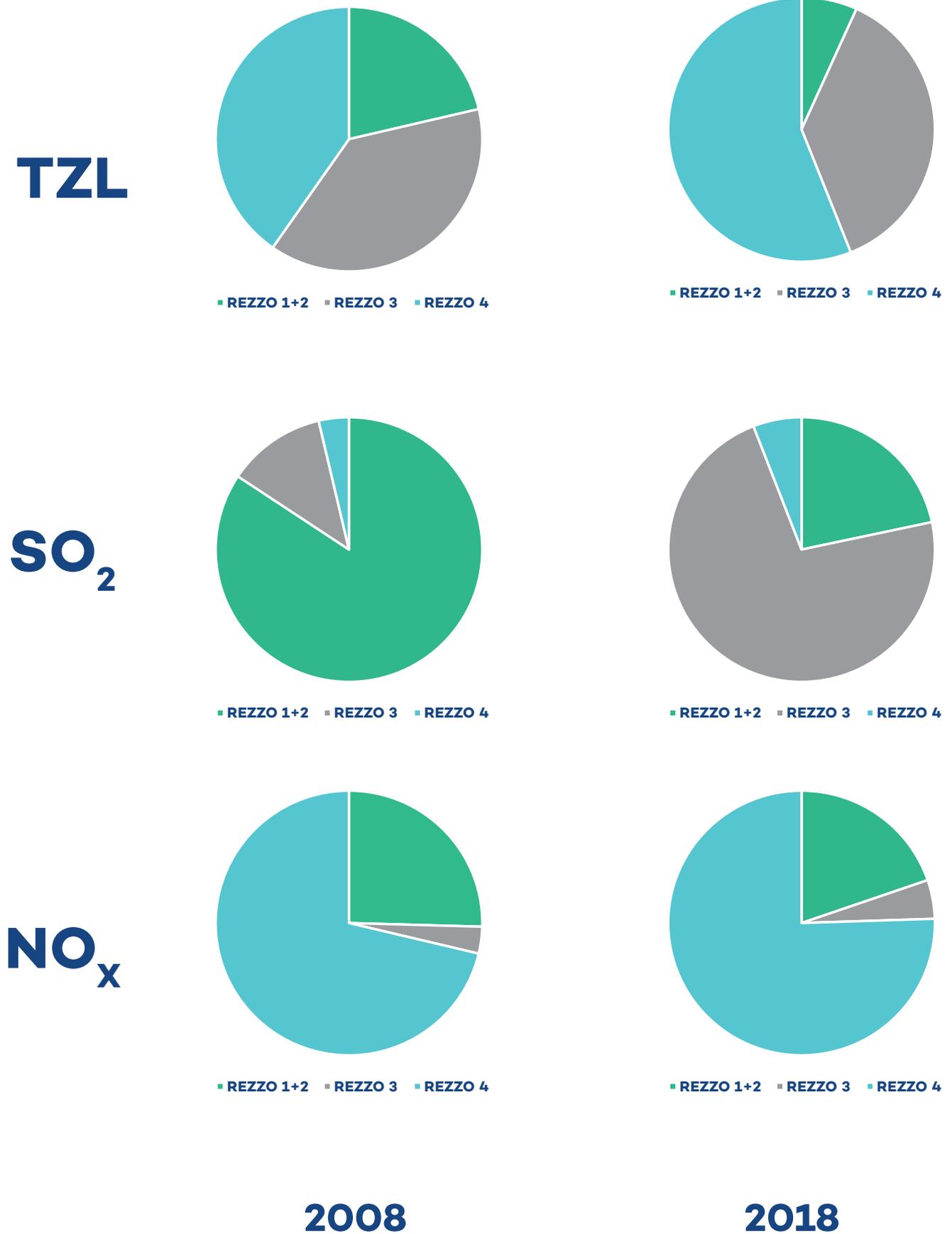
2018

Fig. V.1.7 Emissions of selected pollutants classified according to REZZO, agglomeration of Prague, 2018

V.1.2 Emissions in the Prague agglomeration

At the present time, approx. 1940 places of operation of sources of air pollution included in the REZZO 1 and REZZO 2 databases are individually registered in the territory of the Prague agglomeration. However, only several of them have a substantial effect on overall emissions. These are primarily the Cementárna Radotín, ZEVO Malešice (Pražské služby, a. s.), and other industrial enterprises, such as MITAS, a. s. or Kámen Zbraslav, located at the boundary between Prague and the Central Bohemian region. The sources of TSP also include recycling lines of construction wastes operated either directly at a given location (KARE, Praha, s.r.o., Chodovská) or at other locations of operation, for example, demolitions. Emissions from electricity generation by co-generation units (e.g. WWTP PVaK) continue to increase. Since 2015, the fraction of emissions from the largest heating plants of the Pražská teplárenská, a.s. company in Malešice and Michle decreased substantially, operating only gas-burning boilers already. According to the outputs of SLDB 2011, central heating sources predominate in heating households (52% of households), followed by gas boilers and local gas boilers (together 31% of households). The fraction of heating by electrical energy is significant (approx. 5%), as is that from difficult-to-classify other means (relatively high fraction of approx. 10%). Coal, wood or coke is used as a fuel in only a small part of the housing fund, primarily at the periphery of the city. Similar to housing, there is a prevalence of buildings of the communal sphere connected to central heating sources or having their own gas boilers.

There was a decrease in nearly all monitored emissions at the above-mentioned significant sources in the 2018–2019 period. The only exceptions are NO_x emissions from cement production (Cementárna Radotín). There was a slight increase in reported SPM emissions related primarily to entry into force of the obligation to report emissions from source category 5.11. (production of building materials, recycling lines, etc.), for the first time in 2019. In reality, however, emissions occurred throughout the operation of sources.

The emission load of Prague is rather specific nationwide. Point and areal sources operated in its territory are, with a few exceptions, minor. Following Fig. V.1.7 compiled from data for the year 2018, the greatest share of SPM and SO_2 emissions originates from household heating and of NO_x emissions from traffic. According to the amount of emissions of particular pollutants in 2016 (output of the PZKO processing) in relation to the size of the evaluated area, the Prague agglomeration ranked first in the case of NO_x, VOCs and benzene, second in the case of PM_{10} and lead, third in the case of $PM_{2.5}$, benzo[a]pyrene, arsenic, cadmium and nickel, and in seventh place for SO_2.

V.1.3 Summary

The Prague agglomeration is an area where many people are exposed to above-limit air pollution. In the Prague agglomeration, the 24-hour limit values for suspended particulate matter PM_{10} and the annual limit value for nitrogen dioxide have long been exceeded, especially at traffic locations. In the winter months, the limit value for the average 24-hour PM_{10} concentration is often exceeded. The above-limit annual average concentration for benzo[a]pyrene in the Prague agglomeration was observed last in 2014 at the Prague 4-Libuš station. Most cases exceeding the pollution limit values correspond to the significant traffic load of the capital city, while local household heating contributes to air pollution during the heating season. In 2019, in contrast to previous years, the 24-hour pollution limit value was not exceeded for the first time in the evaluated period and the annual average concentrations of PM_{10}, $PM_{2.5}$, NO_2 and benzo[a]pyrene decreased. The favourable situation in terms of air quality in 2019 is due to mild temperature conditions in the winter months and the occurrence of mostly good dispersion conditions. The renewal of the vehicle fleet and the ongoing replacement of boilers in households also contribute to the improvement of the situation in the Prague agglomeration.

Air pollution by ground-level ozone has a different character — the pollution limit value for ground-level ozone is usually exceeded in the suburban areas of Prague; in 2019 (on average over three years) the limit value was exceeded at five stations out of six, which is so far most in the period since 2010. Smog situations and regulations due to high concentrations of suspended particulate matter PM_{10}, nitrogen dioxide NO_2 and sulphur dioxide SO_2 and smog situations and alerts due to high concentrations of ground-level ozone O_3 were not declared in the Prague agglomeration in 2019 (for details see Chap. V.). In the Prague agglomeration (in 2018), mobile sources account for about 56% of total solid pollutants emissions excluding resuspension, and for about 75% of total nitrogen oxides (NO_x) emissions.

V.2 The Brno agglomeration

The Brno agglomeration lies in the centre of the Southern Moravian region and is identical with the administrative territory of the City of Brno. There are several important sources affecting air quality in the city. The impact of these sources varies significantly in particular parts of Brno, depending on, for example, the type of heating or traffic load in a given locality.

Like other large cities, Brno, as the second largest city in the Czech Republic, faces a significant share of traffic affecting air quality, especially in nitrogen oxides. There is still no main city traffic circuit and this fact greatly reduces traffic flow in some parts of the city and in the city centre. Local heating is the most important source of particulate matter.

In 2019, construction activities were also intensively carried out in several places which may lead to a very high share of air pollution temporarily and locally, especially near the Brno-Zvonařka station and temporarily also Brno-Úvoz (hot spot). In addition to pollution from the building activity itself (building material heaps, demolitions, loading and unloading or moving material, movement of construction machinery, etc.), construction work often also leads to disruptions in traffic flow and traffic jams. Subsequent resuspension is also important.

The effect of long-distance pollution transport cannot be neglected either. Especially in the north-east flow, pollution from the Moravian-Silesia region or even across the border from Poland can reach the Brno area via the Zlín region through the Moravská brána territorial area. Particularly, if such a situation occurs during temperature inversion, high concentrations of pollutants appear and, possibly, a smog situation can be announced. However, in 2019 no smog situation was announced in the territory of Brno agglomeration, similar to the previous year. However, this is primarily related to the meteorological conditions which were relatively good in both years.

Tab. V.2.1 The territory of the Brno agglomeration with the exceeded limit values of the individual pollutants

Year	PM_{10} annual average	PM_{10} 24h	$PM_{2.5}$ annual average	NO_2 annual average	Benzo[a]pyrene annual average	O_3
2012	–	27.7 %	3.04 %	2.45 %	45.03 %	4.02 %
2013	–	2.49 %	–	2.02 %	28.89 %	46.94 %
2014	–	0.54 %	0.43 %	–	0.43 %	–
2015	–	–	–	–	–	12.2 %
2016	–	–	–	0.87 %	1.85 %	0.01 %
2017	–	15.05 %	–	–	0.57 %	9.16 %
2018	–	13.17 %	–	–	13.64 %	37.17 %
2019	–	–	–	–	0.68 %	72.26 %
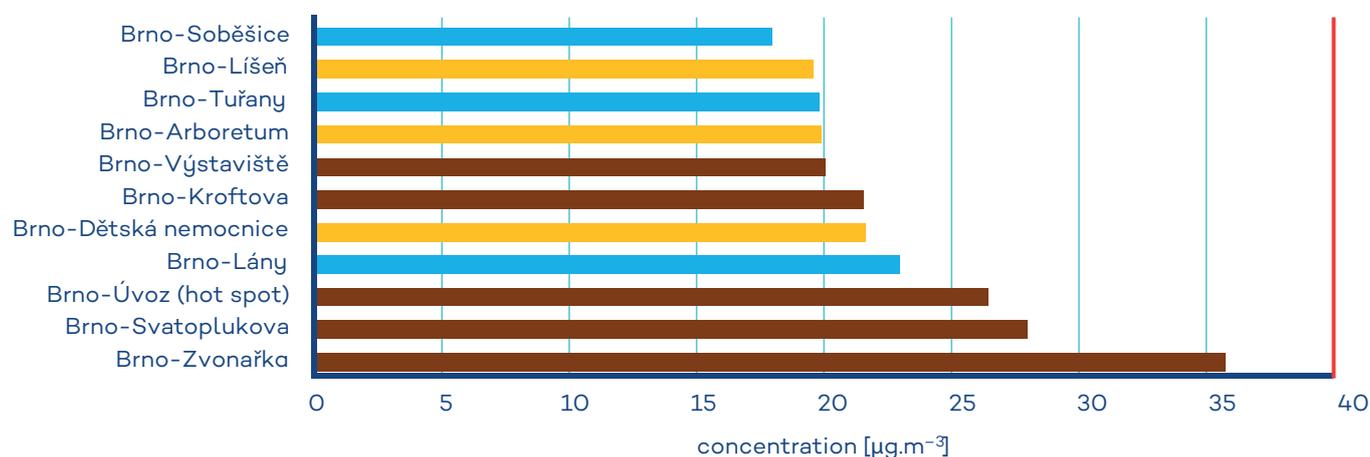
Fig V.2.1 Annual average PM_{10} concentrations in 2019, Brno agglomeration

At the Brno-Zvonařka station, verified data for the period from January to March 2019 were not delivered in time, therefore it was not possible to calculate the appropriate averages and number of exceedances of the limit for this station. At the time of creating this part of the yearbook, only preliminary data were available and individual averages were calculated; however, it still represents operational data that may not completely reflect the final value and at the same time this station is not included in the tabular part which is created earlier. In the comparison the values 2010–2019, the data from the Brno-Zvonařka station were combined from two series for this station (traffic station until 31 August 2018 and industrial station from 1 September 2018).

V.2.1 Air quality in the Brno agglomeration

Suspended particulate matter PM$_{10}$ and PM$_{2.5}$

At two stations (Brno-Arboretum and Brno-Výstaviště), the monitoring equipment was renewed during April 2019 and replaced with a new one. Due to this change, complete data were not available at the time of closing the tabular section, and therefore annual averages are not included in this section. For the purposes of the yearbook, these averages were calculated (these numbers may differ in the final form), both stations met the condition of 90% data availability.

In 2019, as in the previous year, the pollution limit value for the annual average concentration of PM$_{10}$ fraction of suspended particles (40 µg.m^{-3}) was not exceeded at any station in the Brno agglomeration (Fig. V.2.1). Of the stations that met the condition of
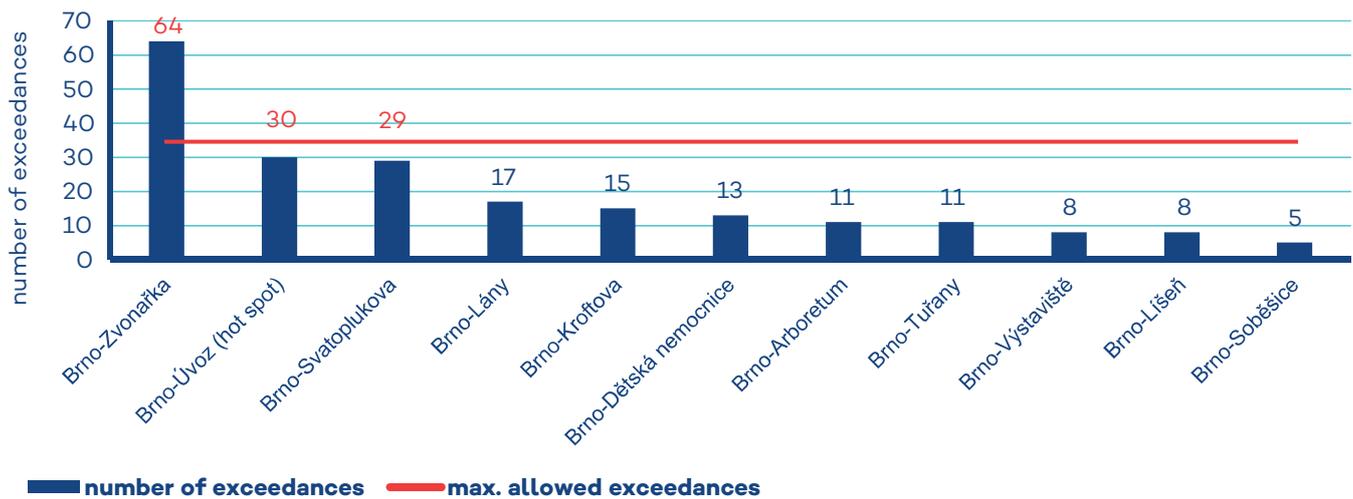
Fig V.2.2 Number of days with PM$_{10}$ concentration >50 µg.m^{-3} in the individual years, Brno agglomeration, 2019
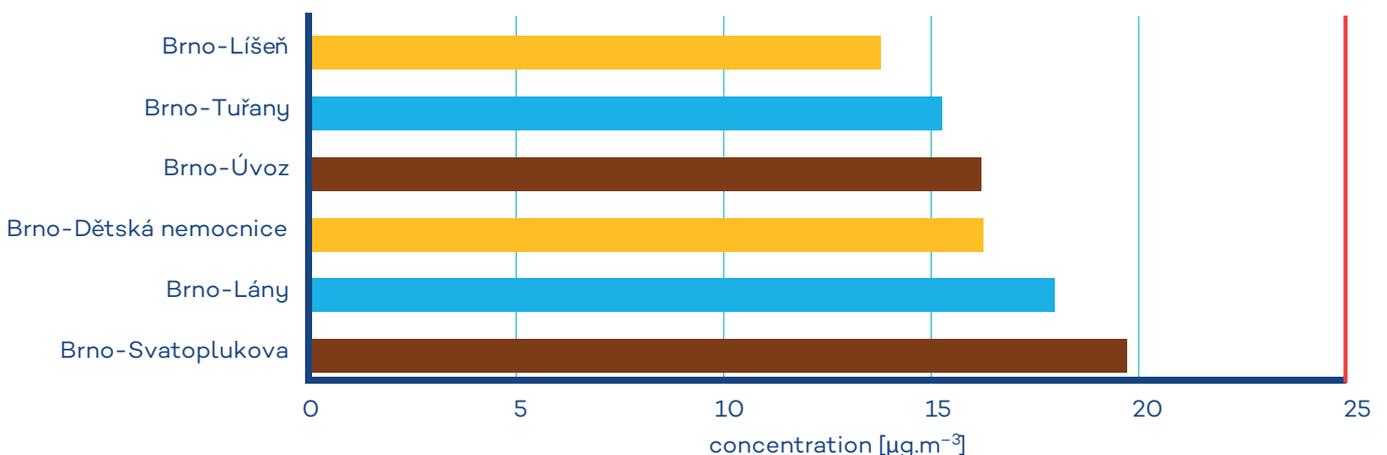
Fig V.2.3 Annual average PM$_{2,5}$ concentrations in 2019, Brno agglomeration

data availability (11 stations), the highest annual concentration of PM_{10} was observed at the Brno-Zvonařka station (35.8 µg.m⁻³). This is a station that was significantly affected in 2019 by extensive construction work in the immediate vicinity of the station. For this reason, the station was temporarily reclassified as industrial in September 2018, and this situation lasted throughout 2019.

In 2019, the 24-hour PM_{10} pollution limit value (50 µg.m⁻³) was exceeded only at the above-mentioned Brno-Zvonařka station (64x) (Fig. V.2.2), where due to construction works, including demolition of buildings, a very high level of pollution occurs, especially by larger PM_{10} particles. This issue was also elaborated within the CHMI extensive study for the regional office of the South Moravian region, in which the impact of construction works was demonstrated, and measures were recommended to reduce the impact of construction works on air quality in general. At no other station the permitted number of 35 cases exceeding the limit value per year was exceeded.

The pollution limit value for the annual average concentration of $PM_{2.5}$ fraction (25 µg.m⁻³) was not exceeded at any station in the agglomeration in 2019 (Fig. V.2.3). Of the stations for which data for the annual average are available, the highest concentration was reached at the Brno-Svatoplukova urban traffic station (19.7 µg.m⁻³). Even according to the newly adopted air pollution limit valid from 2020 (reduction to 20 µg.m⁻³), the annual air pollution limit for the annual concentration of $PM_{2.5}$ would not be exceeded at any station.

If we compare the course of average annual concentrations at the individual stations in recent years, we can say that the year 2019 was very good in terms of PM_{10} and $PM_{2.5}$ concentrations. The lowest annual average concentrations of PM_{10} since 2010 (or since the beginning of measurements at the given station, at the latest since 2016) were recorded at the vast majority of stations (Fig. V.2.4). For example, at the Brno-Arboretum station, for the first time since 2013, the annual average concentration was be-

low 20 µg.m⁻³ (19.9 µg.m⁻³, the earlier minimum of 2017 was 24.0 µg.m⁻³). The annual average was clearly the lowest since 2010 also at the stations Brno-Výstaviště, Brno-Lány, Brno-Svatoplukova, Brno-Tuřany, Brno-Soběšice and Brno-Kroftova. Data have been available at the Brno-Dětská nemocnice station only since 2014, and even here the value from 2019 was the lowest of all years. Exceptions are the Brno-Zvonařka station (for the above reasons) and the Brno-Úvoz station (hot spot) which were affected by construction activities in the immediate vicinity.

The situation is similar for smaller $PM_{2.5}$ particles. The lowest concentrations since 2010 were measured in 2019 at all stations with such a long time series (Brno-Lány, Brno-Svatoplukova — for the first time below 20 µg.m⁻³, Brno-Tuřany), at two other stations with available data and shorter time series, there were also the lowest concentrations in the history of $PM_{2.5}$ measurements (Brno-Líšeň and Brno-Dětská nemocnice).

Such a good situation can be explained by several factors. The first, there was a very warm winter and a generally warm year of 2019, which reduces the need for heating which is the main source of PM_{10} emissions and especially $PM_{2.5}$. Another factor was the above-average dispersion conditions in the year. We can also expect a gradual replacement of boilers in households with new ones and a gradual renewal of vehicle fleet with new cars producing fewer air pollutants.

Nitrogen dioxide (NO₂)

The main source of NO_2 in the Czech Republic is traffic. The highest concentrations of this pollutant occur in large cities, one of them being the Brno agglomeration. Clearly, the highest concentrations of NO_2 have long been observed at the stations most affected by traffic, such as the Brno-Svatoplukova station or the Brno-Úvoz station (hot spot).
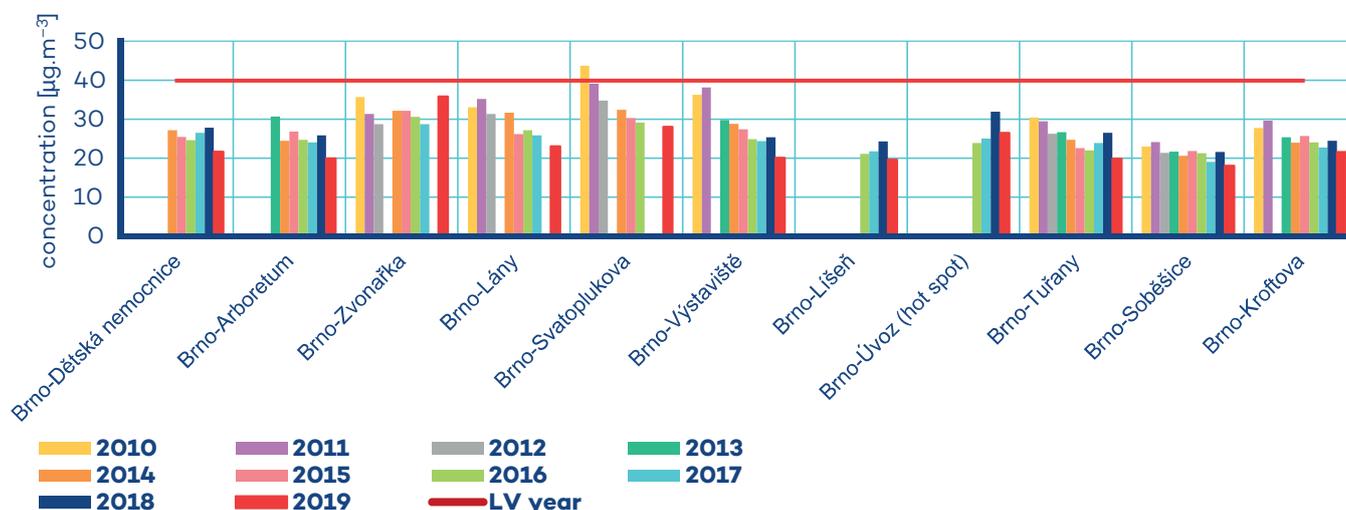
Fig V.2.4 Annual average PM_{10} concentrations between 2010 and 2019, Brno agglomeration
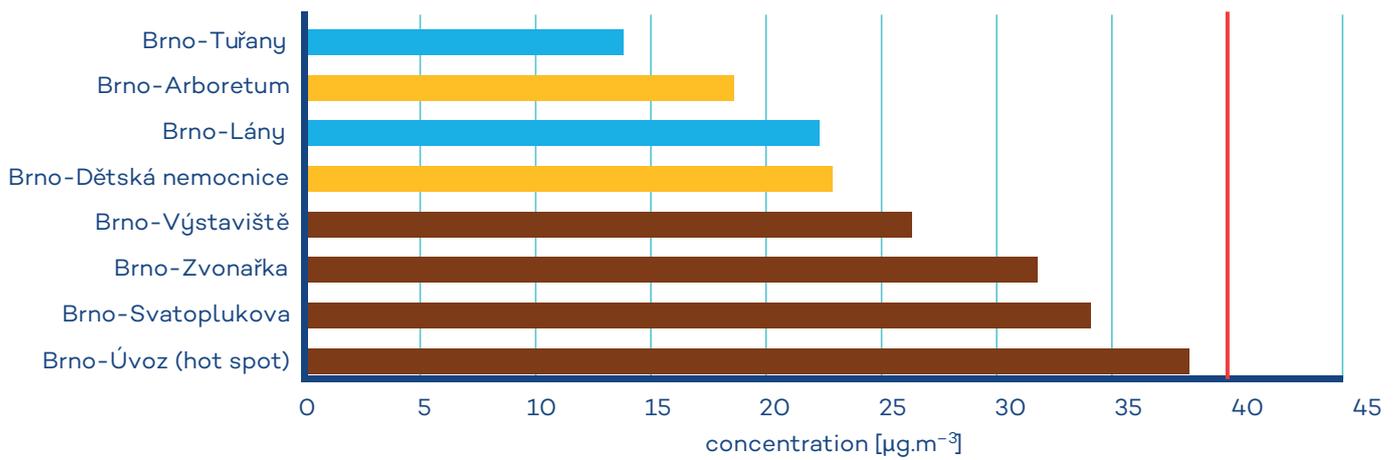
Fig V.2.5 Annual average NO$_2$ concentrations in 2019, Brno agglomeration
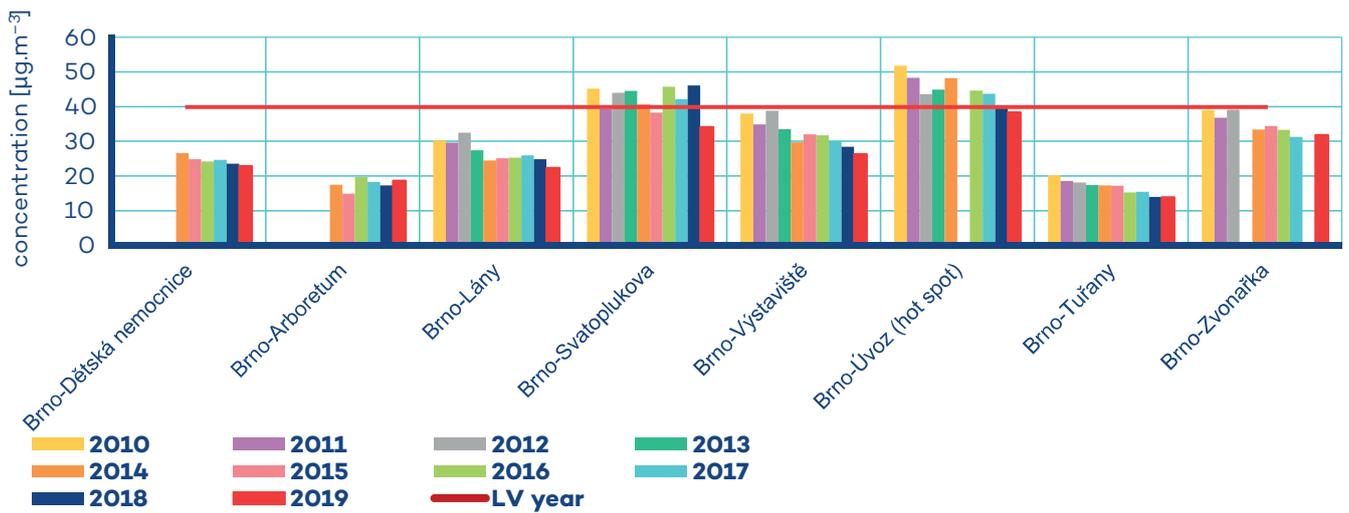
Fig V.2.6 Annual average NO$_2$ concentrations between 2010 and 2019, Brno agglomeration
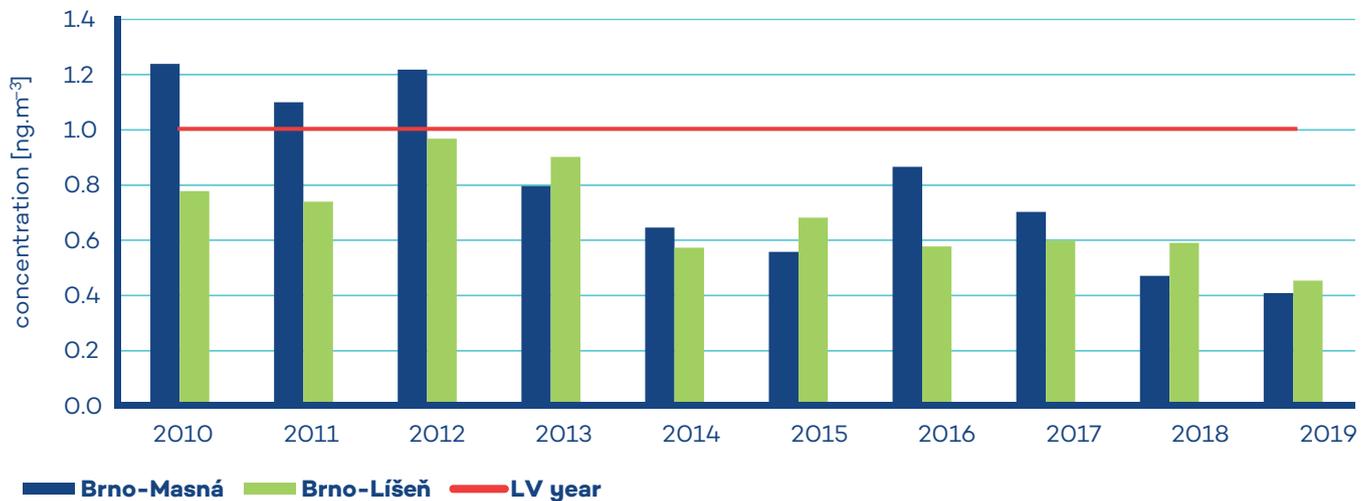
Fig V.2.7 Annual average benzo[a]pyrene concentrations between 2010 and 2019, Brno agglomeration

The annual NO$_2$ pollution limit value (40 µg.m^{-3}) was not exceeded in 2019 at any station with available data (8 stations) (Fig. V.2.5). Compared to the previous year, we can see a decrease in the annual average at all stations except for the Brno-Arboretum station (Fig. V.2.6) where there was a slight increase in the annual average by approximately 1 µg.m^{-3}. For example, at the Brno-Svatoplukova station, the most traffic affected station in the long-term with the highest annual NO$_2$ averages in Brno, the annual average decreased from 46.0 µg.m^{-3} (2018) to 34.1 µg. m^{-3} (2019). The highest average annual NO$_2$ concentration was measured at the Brno-Úvoz station (hot spot) (38.4 µg.m^{-3}).

The hourly pollution limit value for NO$_2$ (200 µg.m^{-3}) was not exceeded at any station in 2019.

As in the case of suspended particles, a significant contribution of good dispersion conditions in 2019 to the reduction of annual average concentrations can be assumed here as well. Gradually, however, the renewal of vehicle fleet in the Czech Republic is also evident, which contributes to the reduction of NO$_2$ and nitrogen oxide emissions in general.

Benzo[*a*]pyrene

Benzo[*a*]pyrene concentrations are monitored in Brno at two urban background stations – Brno-Masná and Brno-Líšeň. The pollution limit value for the annual average concentration of benzo[*a*]pyrene (1 ng.m^{-3}) was not exceeded in 2019 at any of these two stations. At both stations, the annual average ranged between 0.4 and 0.5 ng.m^{-3} and in both cases it was the lowest value in the ten-year evaluation period 2010–2019 (Fig. V.2.7). However, it should be noted that benzo[*a*]pyrene monitoring is affected by the highest level of uncertainty countrywide. Its main source is local heating and, as some project measurements have shown, short-term concentrations of benzo[*a*]pyrene were measured to be much higher in small settlements around Brno. It is therefore possible that benzo[*a*]pyrene concentrations are higher in districts with a higher proportion of solid fuel heating. Nevertheless, a gradual decline has been observed in the last decade, which is probably related to the renewal of solid fuel boilers in households. The year-on-year decrease is rather due to meteorological conditions, especially duration of the heating season and the duration of periods with very low temperatures and thus a high extent of heating.

Ground-level ozone (O$_3$)

Data on ground-level ozone concentrations for 2019 are available for three Brno stations, namely Brno-Tuřany, Brno-Lány and Brno-Dětská nemocnice. In all cases, these are urban or, in the case of Brno-Tuřany, suburban background stations where the concentrations of O$_3$ are higher than at traffic stations.

In the 2017–2019 period, the allowed number of instances exceeding the pollution limit value was higher only at the Brno-Tuřany station (35.0 times), as in the last year. At the Brno-Dětská nemocnice station there were exactly 22 instances of exceeding the limit value and at the Brno-Lány station 24 instances (Fig. V.2.8). The cause of higher ground-level ozone concentrations at the Brno-Tuřany station is its location outside the city and also its location in a completely open space of the airport runway with direct sunlight.

The variation of ozone concentrations is very closely linked to air temperatures and the intensity of solar radiation in a given year. In recent years, which are characterised by above-average and sometimes even highly above-average temperatures in summer, the number of cases with concentrations of ground-level ozone exceeding the limit value increased.

Other substances

The concentrations of heavy metals (As, Pb, Ni, Cd) in the territory of the agglomeration have long been below the limit value, in some cases by two orders of magnitude (for example Pb at the Brno-Líšeň station, for which the annual limit value is set at 500 ng.m^{-3}, reached only 3.3 ng.m^{-3} in the annual average of 2019).

Sulphur dioxide (SO$_2$) and benzene concentrations have long been below the limit values, same as concentrations of carbon monoxide (CO).
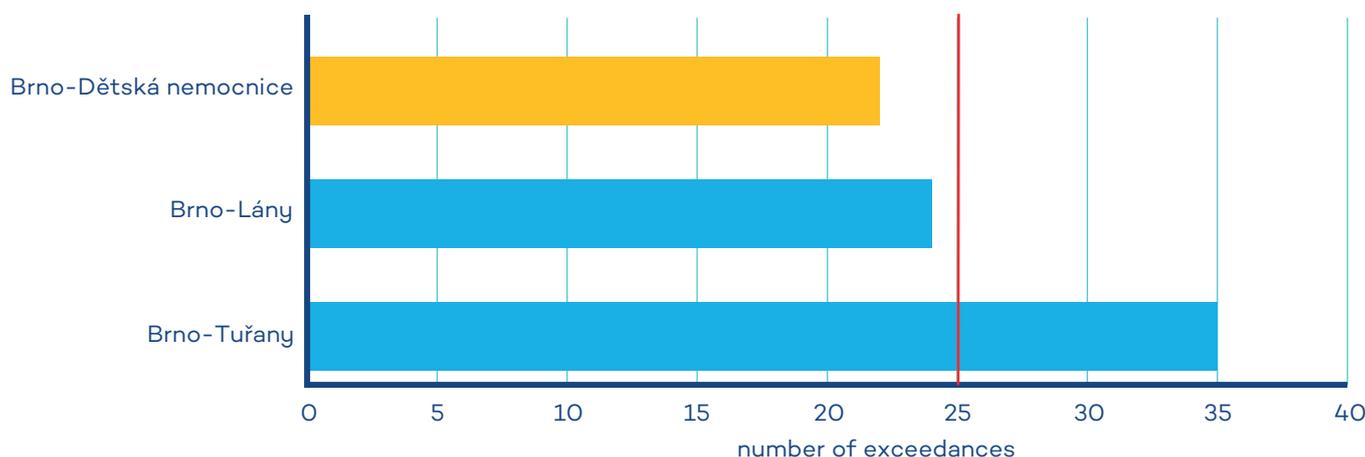
Fig V.2.8 Numbers of exceedances of the limit value of O$_3$ in the average for three years in 2017–2019

TZL
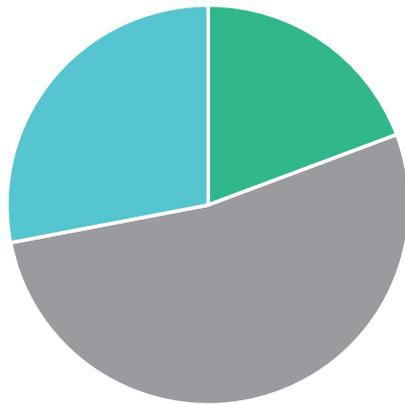
REZZO 1+2 **REZZO 3** **REZZO 4**
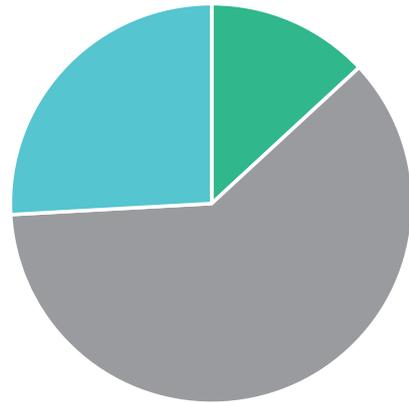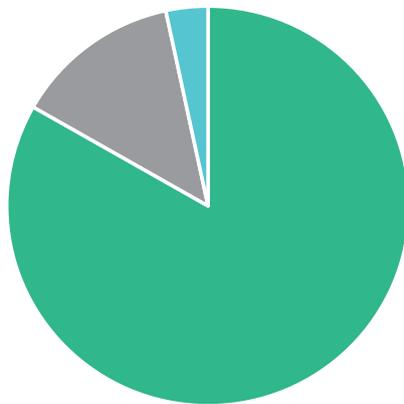
REZZO 1+2 **REZZO 3** **REZZO 4**

SO$_2$

REZZO 1+2 **REZZO 3** **REZZO 4**

REZZO 1+2 **REZZO 3** **REZZO 4**

NO$_X$
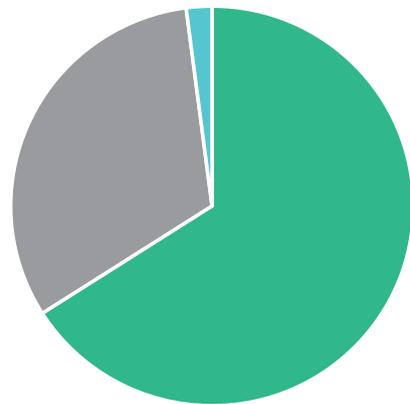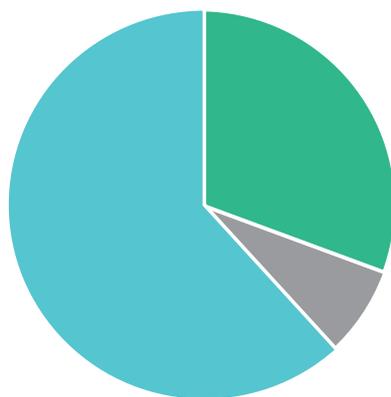
REZZO 1+2 **REZZO 3** **REZZO 4**
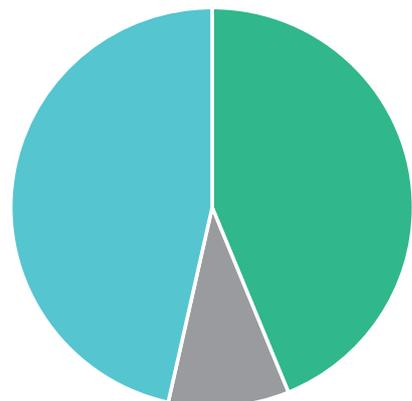
REZZO 1+2 **REZZO 3** **REZZO 4**

2008

2018

Fig. V.2.9 Emissions of selected pollutants listed according to REZZO, agglomeration of Brno, 2008 and 2018

V.2.2 Emissions in the Brno agglomeration

At the present time, approx. 590 sites of operation of sources of air pollution included in the REZZO 1 and REZZO 2 databases are individually registered in the territory of the Brno agglomeration. Only several dozen of them have a substantial effect on the overall emissions. These are primarily heating sources (Teplárny Brno, a. s.), communal waste incinerators (SAKO Brno, a. s.) and a few sites of operation of the processing industry (Eligo, a. s., Slévárna REMET foundry, s.r.o., or Brněnská obalovna, s.r.o. – Chrlice). The sources of SPM include also recycling lines of construction waste being operated both at a given location (e.g. Setra Brno-Černovice) and at other places where the activities are undergoing, for example, demolitions. According to the outputs of SLDB 2011, central heating sources predominate in heating households (54% of flats), followed by gas boilers and local gas boilers (together 37% of flats). Coal, wood or coke is used as a fuel in only a small part of the households, primarily at the periphery of the city. Similarly, a large portion of the buildings of the communal sphere are connected to central heating sources or have their own gas boilers.

There was a decrease in monitored emissions at the individually registered sources in the 2018–2019 period. For reported SPM emissions, there was a slight increase, especially in Eligo food production (by approx. 3 t to a total of 34.3 t) and also due to the general validity of the obligation to report emissions from category 5.11 sources. (production of building materials, recycling lines, etc.) for the first time in 2019. In reality, however, these emissions were being produced throughout the operation of the sources. Another significant source of SPM emissions are foundry operations (e.g. Slévárna HEUNISCH Brno) for which, in addition to reported SPM emissions, a certain fraction of difficult-to-identify fugitive emissions can also be expected. A decisive share of SO_2 emissions originates from the SAKO Brno, a.s., municipal waste incinerator, which, in addition to district heating sources, also plays a significant role in the production of NO_X emissions.

Countrywide, the emission load of Brno is rather specific. The point sources operating at its territory are minor, with some exceptions, and significant amount of the emissions originates from traffic or local household heating (Fig. V.2.9). According to a detailed evaluation of the variation of emissions between 2008 and 2016 prepared for the update of the Air Quality Improvement Program in 2018, transport accounts for more than 45% of NO_X emissions.

V.2.3 Summary

The main problem of the air quality in the territory of the Brno agglomeration is the high concentration of suspended particulates PM_{10} and nitrogen dioxide (NO_2) at some stations in the city. Compared to previous years, 2019 was a very good year in terms of air pollution.

For suspended particles, a decrease in the annual average concentration by tens of percent was observed at most stations compared to 2018. The only exception is the Brno-Zvonařka station, which, in 2019, was significantly locally affected by the surrounding extensive construction work (reconstruction of the Plotní/Dornych crossroads, demolition of buildings and their replacement by office complexes). The annual limit of PM_{10} was not exceeded at any station, neither the annual limit of $PM_{2.5}$. The total of 35 permitted cases exceeding the 24-hour limit value in a year was not met only at the Brno-Zvonařka station, where, according to so far operational data, 64 cases occurred. This is indeed a very high number, but it must be considered in the overall context. At the nearby Brno-Výstaviště station, which is also located at a busy crossroads of four-lane roads, there were only 8 cases. This indicates a very local increase in concentrations at Zvonařka due to temporary effects.

In 2019, no station in Brno exceeded the annual or hourly limit value for NO_2, which is also an improvement compared to 2018.

In both cases, the overall improvement of the situation in 2019 was due to good dispersion conditions and above-average temperatures, however, the gradual renewal of solid fuel boilers in households and the renewal of the vehicle fleet probably also have a certain effect.

The pollution limit value for benzo[a]pyrene was not exceeded either in 2019 at any of the two measuring stations; the annual average concentration at both of them was even the lowest in the evaluated ten-year period 2010–2019. Again, good dispersion conditions and above-average temperatures in the winter months of 2019 have their effect, and to some extent the renewal of solid fuel boilers may also play a role, as local household heating is almost the only source of benzo[a]pyrene emissions in the Czech Republic.

For the whole of 2019, no smog situation was announced in the territory of the Brno agglomeration, same as in the previous year.

V.3 The Ostrava/ Karviná/Frýdek-Místek agglomeration

The character and area of the Ostrava/Karviná/Frýdek-Místek agglomeration (O/K/F-M) differ significantly from the other two agglomerations of the Czech Republic (Prague and Brno). Since the agglomeration covers an area of three whole districts, not only urban areas, the air quality in the territory is represented by all basic types of localities, i.e. besides urban and suburban or transport localities, also sites with industrial, rural, and regional character located from lowlands to mountain areas. The area has been historically burdened with extensive industrial activity in the Upper Silesia basin. The key factors influencing the resulting air quality

are high concentration of industrial production, high density of built-up areas with local heating by solid fuels and dense transport infrastructure (Chap. IV) on both sides of the Czech-Polish border. Municipalities in most areas of the agglomeration are directly interconnected (called the Silesia type of built-up area) and industrial sites are part of municipalities. In order to monitor long-term above-limit concentrations of pollutants in the air and their trends, the area is covered by a dense network of more than twenty permanent measuring stations of various organizations supplemented by specialized temporary measurements.

An important factor contributing to the resulting reduced air quality in the agglomeration is the rate and nature of cross-border and inter-regional transport of pollution along the most frequent wind directions. In the area of the Czech-Polish border, it is most typical in the south-west – north-east axis. In the agglomeration (and not only in the immediate vicinity of the Karviná region border), air

Tab. V.3.1 The territory of the Ostrava/Karvinná/Frýdek-Místek agglomeration with the exceeded limit values of individual pollutants

Year	PM$_{10}$ annual average	PM$_{10}$ 24h	PM$_{2.5}$ annual average	NO$_2$ annual average	Benzo[a]pyrene annual average	O$_3$
2012	31.05 %	85.38 %	67.04 %	–	87.91 %	16.28 %
2013	27.12 %	77.38 %	58.55 %	–	100.00 %	26.51 %
2014	15.88 %	69.28 %	50.15 %	–	88.66 %	5.23 %
2015	0.77 %	53.96 %	28.73 %	–	100.00 %	27.15 %
2016	–	46.32 %	20.50 %	–	97.92 %	7.55 %
2017	1.00 %	65.54 %	34.88 %	–	83.02 %	11.66 %
2018	4.68 %	57.88 %	40.86 %	–	77.13 %	3.33 %
2019	–	9.91 %	1.57 %	–	70.55 %	9.16 %
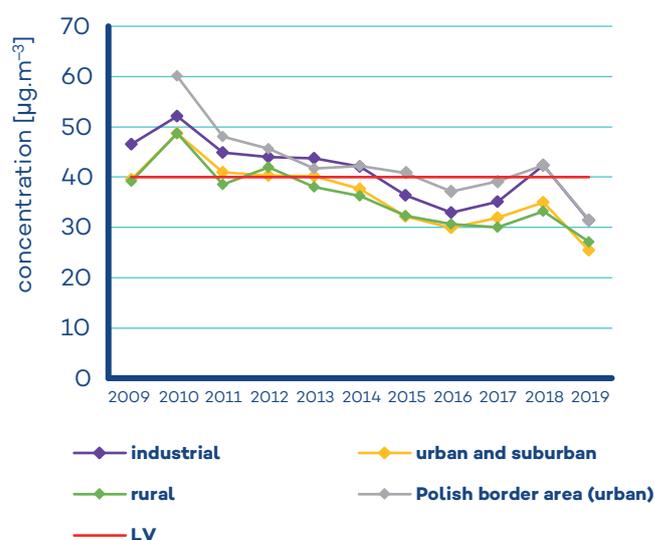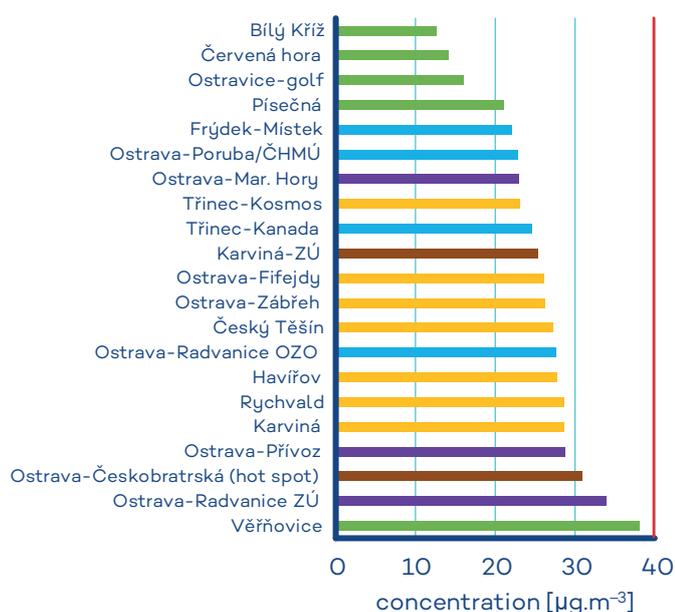
Fig. V.3.1 Annual average concentration of PM$_{10}$ in 2019 and variation of concentrations in 2009–2019, agglomeration of Ostrava/Karviná/Frýdek-Místek

quality is also significantly affected (during certain meteorological situations even principally) by cross-border emissions and air pollution contributions originating in the territory of the Republic of Poland. Possibilities of dispersion or transport of pollutants in the atmosphere are also modified by other meteorological factors (Chap. III). Not only in the lowland plane of the Ostrava basin, but also in the mountain valleys of the agglomeration, the inverse character of the weather with steady atmosphere and subsequent worsening dispersion conditions often occur which also significantly contribute to increasing concentrations of pollutants in the air. The most frequent smog episodes with above-limit threshold concentrations of suspended PM_{10} particles within the agglomeration appear in the Olše and Odra river floodplain areas with the centre of occurrence from December to February.

V.3.1 Air quality in the Ostrava/Karviná/Frýdek-Místek agglomeration

Suspended particulate matter PM_{10} and $PM_{2.5}$

In 2019, the limit annual average concentration of PM_{10} (40 μg.m^{-3}) was not exceeded in the agglomeration (Fig. V.3.1, Tab. V.3.1). Between 2010 and 2019, except for 2017 and 2018, there was a gradual decrease in concentrations at all types of localities, including the most polluted part of the agglomeration, the Polish border area. Average annual concentrations in 2019 were the lowest in the last ten years. Compared to the ten-year maxima (2010), PM_{10} concentrations at almost all types of agglomeration sites were approximately half in 2019; there was a lower decrease in some industrial localities. This positive result was mainly due to the nature of the prevailing meteorological conditions (Chapter III) which contri-

buted favourably, additionally to the effect of gradual reduction of emissions (Chapter V.3.2). A similar trend was observed in Polish and Czech localities in the border area which have long dominated air pollution surveys.

In 2019, the legally permitted number of 35 days with above-limit daily PM_{10} concentration was exceeded in 2019, unlike in previous years, only in localities of the Karviná area near the Czech-Polish border (Věřňovice, Rychvald, Karviná) and in some Ostrava localities directly affected by significant industrial or traffic sources of pollution (the Ostrava-Radvanice ZÚ and Ostrava-Přívoz industrial stations, traffic hot spot Ostrava-Českobratrská) (Fig. V.3.2). The most cases exceeding the daily PM_{10} limit value (50 μg.m^{-3}) were recorded in January. In the last ten-day period of this month, particularly poor dispersal conditions caused the emergence and announcement of a smog situation and regulation due to high concentrations of PM_{10} in both parts of the O/K/F-M agglomeration, i.e. without the Třinec area and in the Třinec area (Chapter VI). A higher number of days with above-limit concentrations also occurred in February and March, as well as in October and November. In the opposite, the only month in the year when no day with above-limit concentration was recorded in the agglomeration was August (Fig. V.3.3). The share of stations at which the daily limit value was exceeded in the agglomeration decreased dramatically year-on-year. For the first time in the last decade, the limit has not been exceeded in most urban areas of the agglomeration. The share of localities exceeding the limit value has fallen from earlier 90% to one third.

In 2019, the average annual $PM_{2.5}$ concentrations ranged above the limit (the limit value is 25 μg.m^{-3}) at two stations in the agglomeration (out of the total of 15 with a sufficient number of measurements). These concerned the Ostrava-Radvanice ZÚ industrial station and the Věřňovice station, which represent the background rural area of the most polluted part of the Czech-Polish border in the Karviná area. The pollution limit value (20 μg.m^{-3}), in force
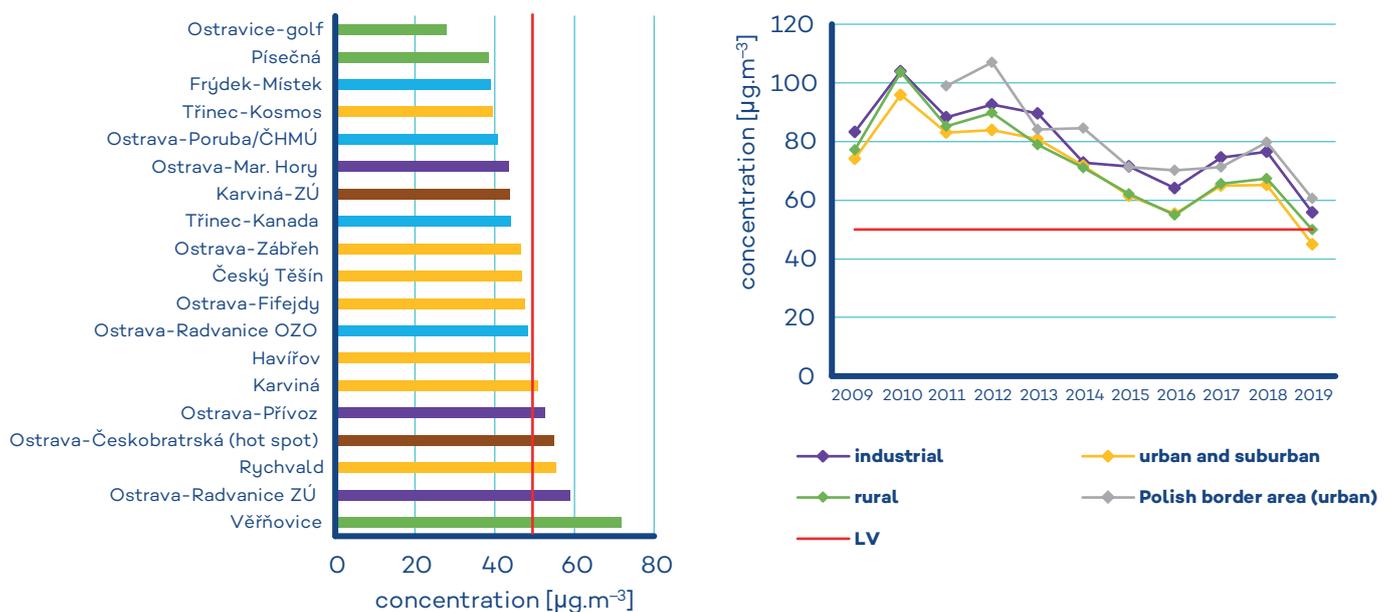
Fig. V.3.2 36th highest 24-hour PM_{10} concentrations in 2019 and variation of concentrations in 2009–2019, agglomeration of Ostrava/Karviná/Frýdek-Místek
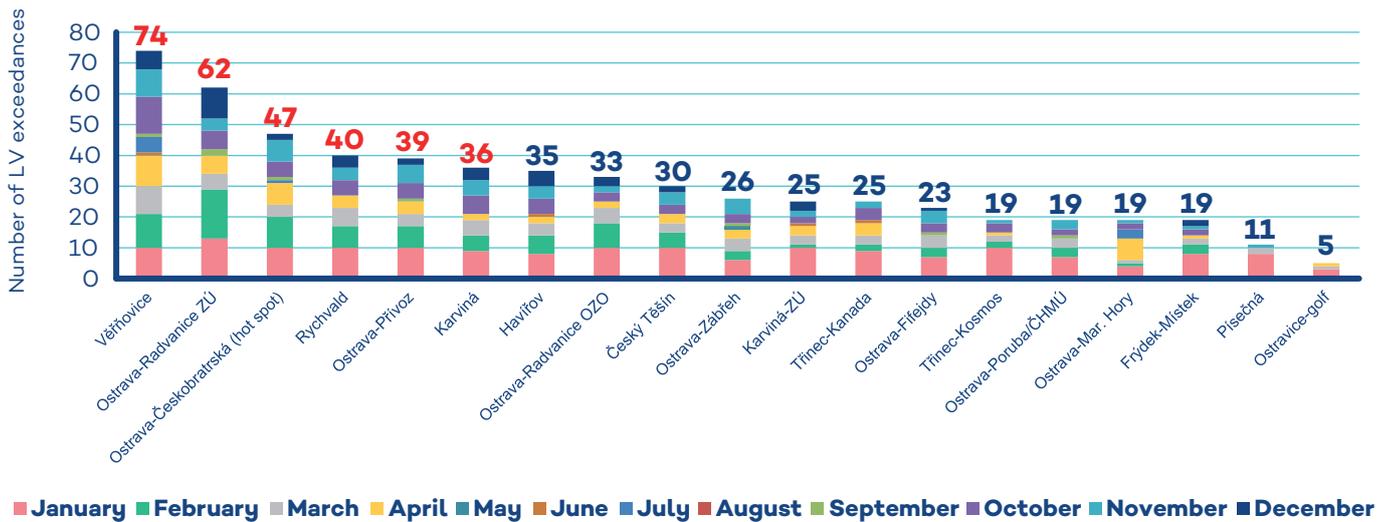
Fig. V.3.3 Number of days with concentrations of PM$_{10}$ > 50 μg.m^{-3} by months, including total number of cases exceeding the pollution limit, agglomeration of Ostrava/Karviná/Frýdek-Místek, 2019
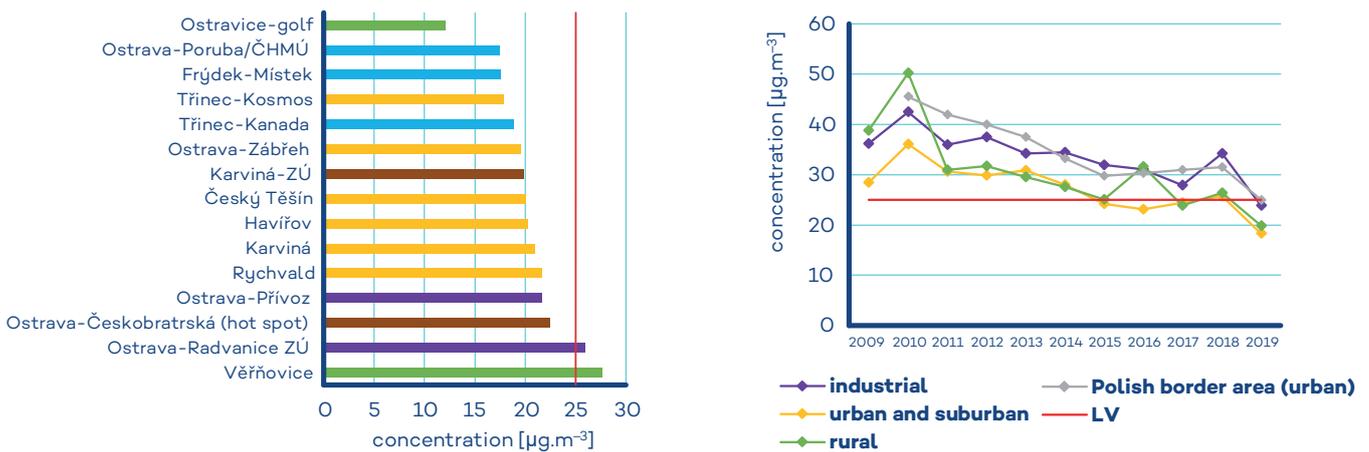
Fig. V.3.4 Annual average concentration of PM$_{2.5}$ in 2019 and variation of concentrations in 2009–2019, agglomeration of Ostrava/Karviná/Frýdek-Místek

from 2020, would be exceeded at approximately half of the stations with measurements available for this pollutant (Annex II). Nevertheless, this is the most favourable situation recorded in the agglomeration since the beginning of the measurement of this pollutant. The course of concentrations since 2009 (Fig. V.3.4) has been similar to that of PM$_{10}$, with PM$_{2.5}$ showing an even greater decrease in pollution in rural areas than PM$_{10}$.

Benzo[a]pyrene

The level of pollution by benzo[a]pyrene, an indicator of the contamination of the air by carcinogenic organic substances, is a very serious problem posing health risks in the entire cross-border area of Silesia and Moravia. Compared to the average concentration in the Czech Republic, several-times higher content of this pollutant

is permanently measured in suspended particulates in the O/K/F-M agglomeration. Also in 2019, the annual average concentration of benzo[a]pyrene in PM$_{10}$ mostly exceeded the limit value of 1 ng.m^{-3} several times in the agglomeration. The annual variation of concentration exhibits maximum benzo[a]pyrene values in the colder parts of the year while summer concentrations are substantially lower. However, in industrial locations of the O/K/F-M agglomeration, daily concentrations higher than 1 ng.m^{-3} occur persistently even in the warm part of the year which indicates the year-round effect of benzo[a]pyrene industrial emissions in these areas. As in previous years, in 2019, the highest annual average concentration of benzo[a]pyrene (8.7 ng.m^{-3}) was measured at the Ostrava-Radvanice ZÚ industrial station. So, the pollution limit value was exceeded there more than eight times. High values of benzo[a]pyrene can, however, be anticipated in the Czech-Polish border area (Chap. VIII) because of high concentrations measured in the south of the
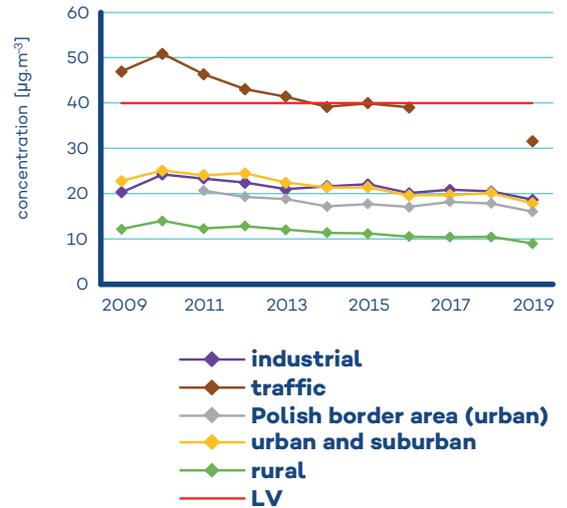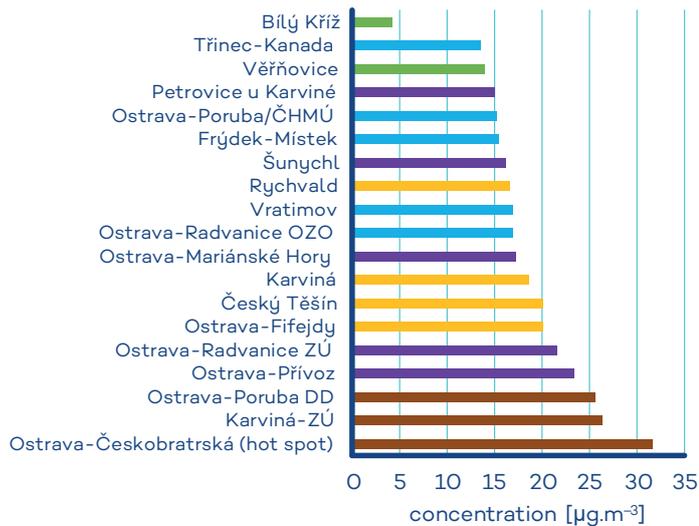
Fig. V.3.5 Annual average concentration of NO$_2$ in 2019 and variation of concentrations in 2009–2019, agglomeration of Ostrava/Karviná/Frýdek-Místek
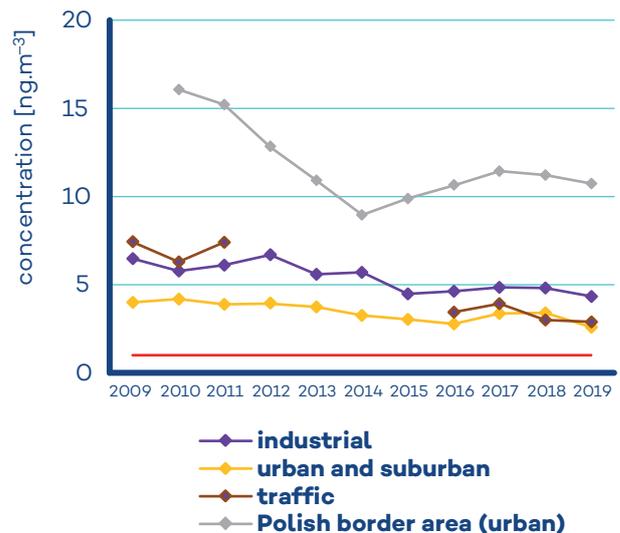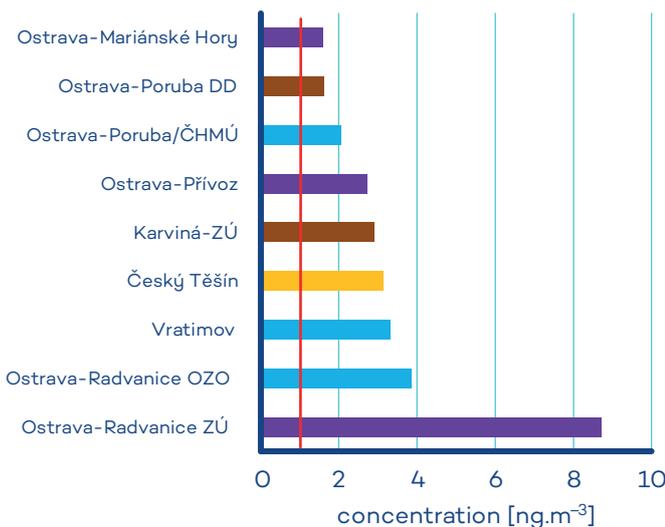
Fig. V.3.6 Annual average concentration of benzo[a]pyrene in 2019 and variation of concentrations in 2009–2019, agglomeration of Ostrava/Karviná/Frýdek-Místek

Republic of Poland (Fig. V.3.6). The amount of emissions of hydrocarbons released in the territory of Poland ranks, so far, among the highest within EU and a proportion of households with solid fuel heating is much higher at the Polish border area than at the Czech side of the border (VŠB-TU Ostrava 2018). Above-limit values can be expected also in other municipalities and urban areas of the agglomeration with a higher share of solid fuel heating of households where benzo[a]pyrene is not routinely measured in the long term. An example can be the above-limit value at the Vratimov station (3.3 ng.m^{-3}) where the observation was subsidized in 2019 from the budget of the Moravian-Silesia region. Historically, below the limit concentration of benzo[a]pyrene in the agglomeration was measured only in 2017 at the Bílý Kříž rural background mountain locality in the Moravian-Silesia Beskydy. The average annual con-

centrations of benzo[a]pyrene have rather been fluctuating in the last ten years (Fig. V.3.6). In 2019, in view of year-on-year changes, a decrease was recorded at almost all stations compared to 2018. The exception was the Ostrava-Radvanice ZÚ industrial station where the average annual concentration increased from 7.7 ng.m^{-3} in 2018 to 8.7 ng.m^{-3}.

Nitrogen dioxide

The annual average NO$_2$ concentrations in the agglomeration were below the limit values in all monitored localities with sufficient number of measurements in 2019. The value of the hourly limit for NO$_2$ at 200 μg.m^{-3} was not exceeded at any of the stations (the
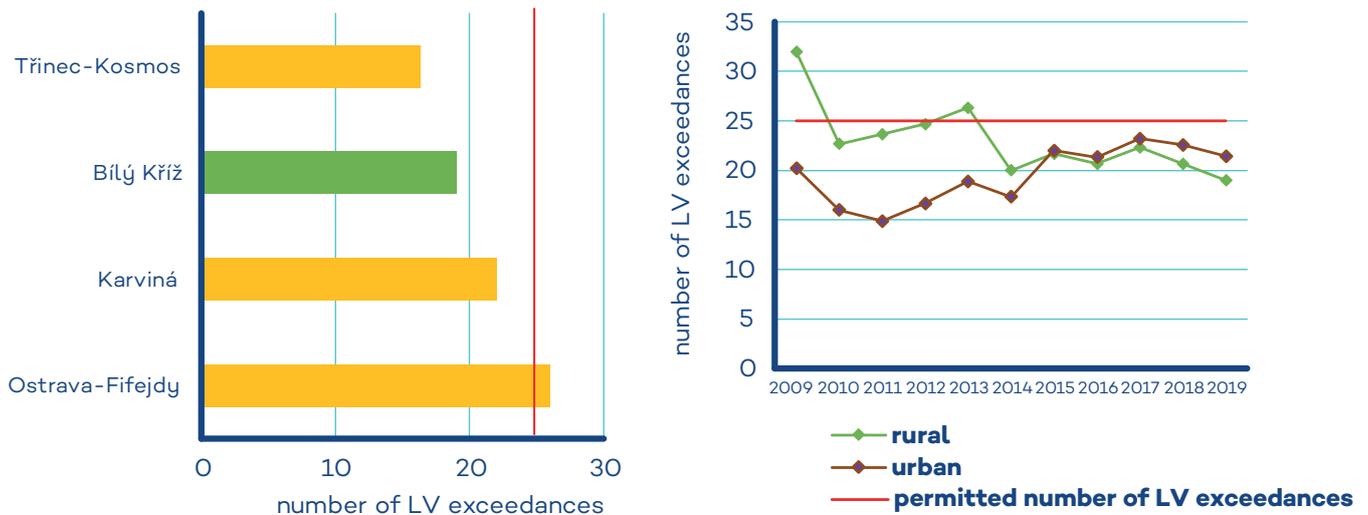
Fig. V.3.7 Number of cases exceeding the pollution limit of O$_3$ in the average for three years in 2010–2019, agglomeration of Ostrava/Karviná/Frýdek-Místek

maximum hourly concentration of 128.2 µg.m^{-3} was measured at the Ostrava-Poruba, DD traffic station). Within the agglomeration, the highest average concentrations occur at the Ostrava-Českobratrská (hot spot) station. It is focused on monitoring pollution originating primarily from traffic in the Ostrava city narrow street area where the concentration level in the past oscillated close to the annual pollution limit value of 40 µg.m^{-3}, or exceeded it. The variation of NO$_2$ concentrations over a ten-year time series shows only a slow decrease. There has been a year-on-year decrease in concentrations at all types of localities (Fig. V.3.5).

Ground-level ozone

In 2019, the number of instances exceeding the pollution limit level for ground-level ozone (maximum 8-hour daily average) on an average over three years surpassed the permitted limit of 25 days at three Ostrava stations (Ostrava-Fifejdy, Ostrava-Mariánské Hory, Ostrava-Radvanice OZO). In the O/K/F-M agglomeration, ozone was measured at 7 stations. The number of cases exceeding the limit value decreased year-on-year (Fig. V.3.7). No smog situation was announced for O$_3$ in the agglomeration in 2019 (Chapter VI).

Other substances

In 2019, there was a year-on-year decrease in benzene concentrations. The highest average concentration was observed at the Ostrava-Přívoz industrial station (4.2 µg.m^{-3}). Unlike in 2018, the limit value of 5 µg.m^{-3} was not exceeded there. In this locality, the limit value was being exceeded in the past. Screening measurements (Krejčí and Černikovský, 2013) in 2011–2012 confirmed the well-known position of the most important large sources producing benzene emissions in the city of Ostrava (chemical production at BorsodChem MCHZ, Ltd., and coking plants) situated at the axis

of prevailing air flow direction towards the monitoring station. It cannot be ruled out that emissions resulting from the remediation work carried out at the old ecological burden on the Ostrava waste lagoons of the Ostramo processing plant could also contribute to the resulting concentration in 2018. The occurrence of short-term extreme peak benzene values in this part of Ostrava is, however, necessary to monitor systematically. None of other localities in the agglomeration exceeded the pollution limit value, nor has it occurred in the long term.

In 2018, intensive remediation activities were carried out in removal of the so called over-the-amount sludge from oil lagoons formed by deposition of waste from refinery production and use of lubricating oils at the former Ostramo processing plant in Ostrava. In relation to this activity, peaks of extreme hourly SO$_2$ concentrations occurred at some Ostrava air quality monitoring stations, similarly to 2011. In 2019, similar extreme air pollution concentrations no longer occurred. The average annual SO$_2$ concentrations decreased year-on-year in all types of localities in the whole agglomeration.

Carbon monoxide concentrations in the Czech Republic have long been below the limit. In relation to higher emissions from industrial sources, higher values are persistently observed at the Ostrava localities in the agglomeration than in other areas of the Czech Republic.

In the O/K/F-M agglomeration in the last decade, concentration of metals in PM$_{10}$ suspended particulates mostly decreased. In 2019, annual average concentrations of all metals followed the year-on-year trend apparent for suspended particulates and, in comparison of 2018/2019, a slight decrease of annual average concentrations occurred in all types of localities. The pollution limit values (adopted for nickel, arsenic, cadmium and lead) were not exceeded in 2019 in the O/K/F-M agglomeration.

TSP

REZZO 1+2   REZZO 3   REZZO 4

SO₂

REZZO 1+2   REZZO 3   REZZO 4

NOₓ

REZZO 1+2   REZZO 3   REZZO 4

2008   **2018**
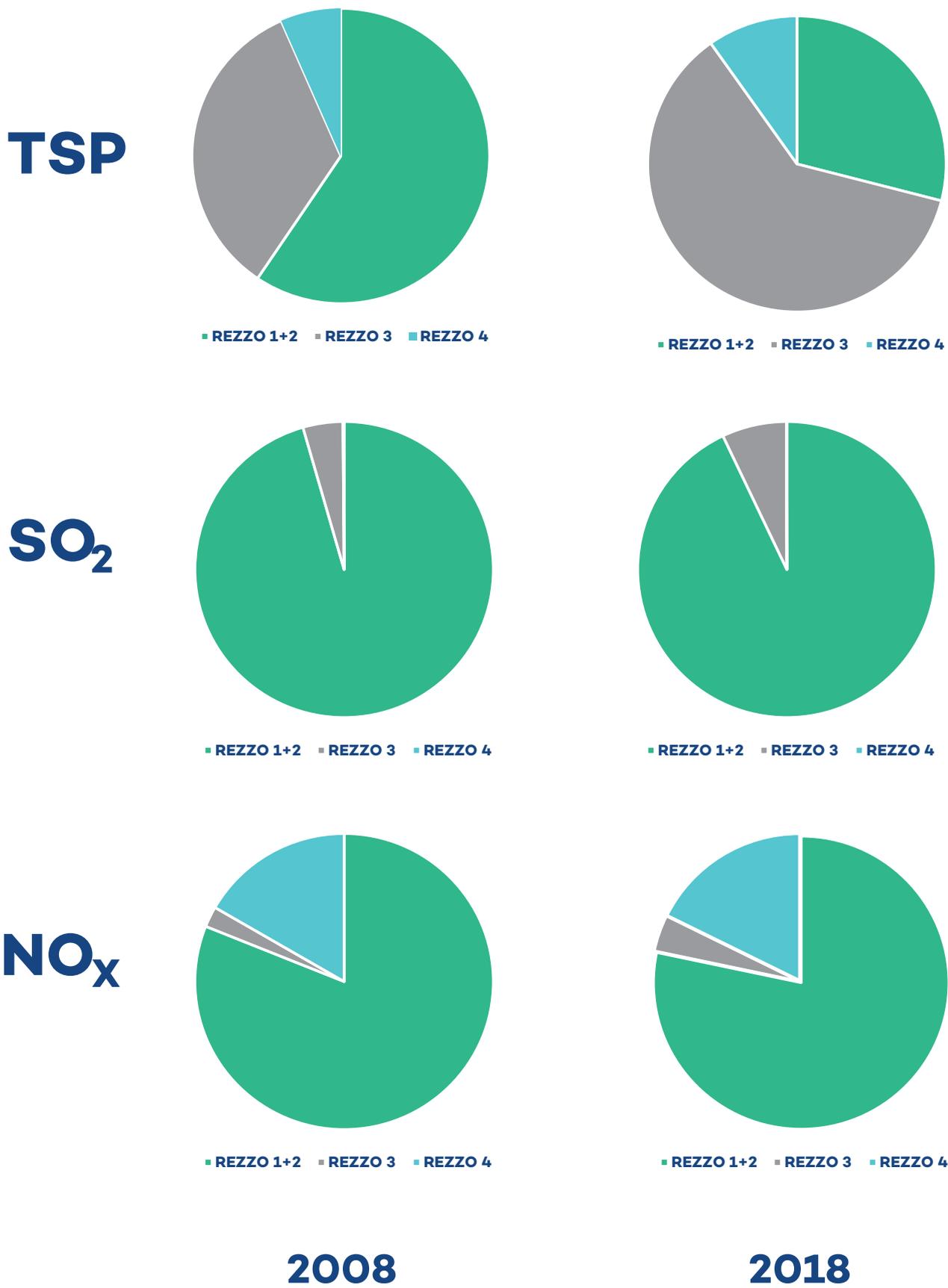
Fig. V.3.8 Emissions of selected pollutants classified according to REZZO, agglomeration of Ostrava/Karviná/Frýdek-Místek, 2018

V.3.2 Emissions in the Ostrava/Karviná/Frýdek-Místek agglomeration

The particular categories of emission sources have different proportion in the O/K/F-M agglomeration than in other parts of the Czech Republic (Fig. V.3.8). According to a detailed assessment of the course of emissions in 2008–2016 prepared for update of the programme for improving air quality in 2018, the share of industrial sources and the energy sector in the emissions of the main pollutants is still decreasing. According to preliminary data for 2019, significant metallurgical complexes together with coking plants, energy sector and other specifically monitored sources produced about 725 t of SPM emissions which was again less (by about 18%) than in the previous year. Further reductions were also recorded for SO_2 emissions (by 16.5%) and NO_X emissions (by 16.3%). The most significant reduction in SPM emissions (by more than 80t) took place at the steel and crude iron production plants of Liberty Ostrava, a.s. (successor of ArcelorMittal). In addition to further greening of the operation, a reduction by 20% in production capacity from mid-July 2019 also contributed to this result. A decrease in SP emissions by about 10t was also recorded at the production of Třinecké železárny, a.s. For benzo[a]pyrene, the share of emissions from local heating predominates and the year-on-year changes therefore occur mainly due to variable parameters of the heating period. Approximately 2% of benzo[a]pyrene emissions are attributable to individually monitored sources, mainly coke production (Liberty Ostrava, a.s., TŘINECKÉ ŽELEZÁRNY, a.s. and OKK Koksovny, a.s.) and iron production — especially the processing of iron ore into agglomerates.

Currently, approx. 770 places of operation of sources of air pollution included in the REZZO 1 and 2 databases are specifically registered in the territory of the agglomeration. Only several dozen of them have a substantial effect on overall emissions. In a total of SPM, SO_2 and NO_X emissions the highest amounts are produced by power plants and enterprise energy generation (e.g. TAMEH Czech s.r.o. – heating plant of the enterprise, Veolia Energie ČR, a.s. – Třebovice power plant, and Dětmarovice power plant). For technological sources, these are metallurgical production facilities, primarily ore agglomeration and production of crude iron (Liberty Ostrava a.s. – Plant 12 Blast Furnaces and TŘINECKÉ ŽELEZÁRNY, a.s. – Production of pig iron), but also some other sources such as Viadrus, a.s. in Bohumín or VÍTKOVICE HEAVY MACHINERY a.s., Plant 3. Approximately fifteen of the most important facilities produce annually 90% of all SPM, SO_2 and NO_X emissions of individually monitored sources and their share on equal type of emissions of all categories of sources is above 65%. This proportion does not include difficult-to-estimate fugitive SP emissions produced, for example, from landfills, handling of bulk materials and halls with dusty operations.

According to the output of SLDB 2011, central heating sources predominate in heating households (approx. 59% of flats), followed by gas boilers and local gas boilers (together approx. 25% of flats). The greatest differences can be found in the evaluated territory stemming primarily from the character of households in the districts. While in the Frýdek-Místek district the fraction of flats heated locally with solid fuels is close to 20%, this fraction equals only approx. 8% in the Karviná district and only 4% in the Ostrava district. This fact, exacerbated in addition by the higher average altitude of settlements in the Frýdek-Místek district and the greater average size of flats, is manifested primarily in emissions that have a substantial portion in the REZZO 3 category, i.e. SP and particulates, VOC, benzene and especially emissions of benzo[a]pyrene.

V.3.3 Summary

In the O/K/F-M agglomeration, some limit values for the concentrations of suspended particles and the benzo[a]pyrene bound thereto are still exceeded. Concentrations measured at the localities in the agglomeration are among the highest in the Czech Republic. The maximum values of average annual concentrations of PM_{10} and $PM_{2.5}$ measured there occur not only in the vicinity of large industrial sites but also near the Czech-Polish border. Pollutant concentrations below the limit values are more frequently measured in the southern part of the agglomeration in the background and rural localities in the Moravian-Silesia Beskydy mountains and their foothills. Air pollution by suspended particles is not only a problem in the agglomeration in the cold half of the year. The $PM_{2.5}/PM_{10}$ concentration ratio is highest at industrial sites of the O/K/F-M agglomeration (Fig. IV.1.16). Although the limit values for the protection of human health are exceeded on both sides of the Czech-Polish border, the concentration level of suspended particles and the benzo[a]pyrene adsorbed on them is different in the Czech and Polish localities in the border area of interest. Particularly in the case of benzo[a]pyrene concentrations, pollution in the adjacent Polish part of southern Silesia clearly dominates. The impact of transborder pollution transmission is most noticeable in the concentration levels measured in the valley localities of the border water streams, which are often comparable with industrial sites in Ostrava.

There is a specific sharing of particular categories of primary emission sources in the O/K/F-M agglomeration; REZZO 1 sources dominate in all the registered categories except for benzo[a]pyrene. The resulting effect of a complicated emission profile and mesoclimate conditions of the area, and also of mutual trans-boundary transport of polluting substances and their precursors between the Czech Republic and the Republic of Poland, is above the limit pollution concentration of pollutants in the air demonstrated by increased risks for the population.

The benefits of the measures implemented to reduce emissions released into the air in the agglomeration area were accompanied in 2019 by a positive effect of the prevailing improved meteorological conditions. In the O/K/F-M agglomeration, the average concentrations of the vast majority of pollutants decreased year-on-year. The most significant improvement occurred regarding suspended particulates. Despite this, smog situations were announced in the agglomeration in January due to high concentrations of PM_{10}. There was an increase in benzo[a]pyrene concentrations only at one industrial station in Ostrava, in other cases a decrease was also recorded for this pollutant.

In the warm part of the year, the above-limit level of pollution was reached by exceeding the permitted number of 25 days with a maximum daily 8-hour average of ground-level ozone concentration averaged over three years in Ostrava localities.

V.4 Air quality index in cities

The new air quality index (AQI) was designed by the CHMI Air Quality Department in cooperation with the National Institute of Public Health (SZÚ) and has been available on the CHMI website[1] since November 2019. For the purposes of evaluating the year-round situation, the AQI was recalculated using the same methodology for the entire year 2019. The AQI is also embedded in the Air Quality Information System (AQIS). The calculation of the air quality index has changed[2] due to a more accurate assessment of the current state of air quality and related health implications.

The calculation of the index is based on the simultaneous evaluation of 3-hour moving average concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and suspended particles (PM_{10}). In the summer period (1 April to 30 September), 3-hour moving average concentrations of ground-level ozone (O_3) are also evaluated. According to the National Institute of Public Health (SZÚ), the 3-hour moving average better describes the potential impact of polluted air on the health of the population. The advantage of the new air quality index is the basic three-level colour indication of the index, including specific advice and recommendations of the SZÚ to ensure the protection of human health (Table V.4.1)[3]. These health recommendations are based on the World Health Organization (WHO) evaluations. The air quality index at city stations in 2019 is shown in Fig. V.4.1.

Tab. V.4.1 Recommendation of the SZÚ for reducing the expositure of the population to air pollutants and protection of the health

Level	Index range	Air quality	Sensitive and vulnerable groups	General population
1A	< 0,34	Very good to good	Ideal conditions for outdoor activities.	Ideal conditions for outdoor activities.
1B	≥ 0,34 – 0,67		Outdoor activities without restrictions.	Outdoor activities without restrictions.
2A	≥ 0,67 – 1,00	Moderate	There might be a slight risk of inconvenience to a very small number of persons who are extremely sensitive to air pollution. No need to change your usual outdoor activities if you do not notice symptoms such as coughing and throat irritation.	Outdoor activities without restrictions.
2B	≥ 1,00 – 1,50		Consider reducing or postponing/moving intense outdoor activities, notably if your health condition aggravates or you experience symptoms such as coughing and throat irritation.	No need to change your usual outdoor activities.
3A	≥ 1,50 – 2,00	Poor to very poor	Reduce intense activities, particularly outdoors, notably if your health condition aggravates or symptoms such as coughing and throat irritation occur. Asthmatics and persons with chronic disease may need to use a relief medicine more often. All older people and children should limit their physical activity.	Consider reducing or postponing/moving intense outdoor activities if you experience symptoms such as coughing and throat irritation occur.
3B	≥ 2,00		Shorten your stay outdoors and avoid physical activities. Asthmatics and persons with chronic disease may need to use a relief medicine more often.	Reduce or postpone intense outdoor activities, notably if you experience any discomfort and symptoms such as irritation in the throat, eye irritation, coughing, etc.

1   www.chmi.cz/files/portal/docs/uoco/web_generator/actual_3hour_data_CZ.html
2   Until 2019, the calculation of the air quality index was based on hourly concentrations.
3   www.chmi.cz/files/portal/docs/uoco/web_generator/d_szu.pdf

At the Plzeň-Doubravka and Plzeň-Lochotín stations of the Plzeň region, indices at 1A and 1B levels (very good to good air quality) were reached with frequencies higher than 65% of the situations, and in more than 32% of situations the air quality was moderate (AQI at 2A and 2B level).

In Sokolov in the Karlovy Vary region, the highest frequency (over 63%) was achieved by the categories of very good to good air quality and less than 37% by the moderate air quality.

At the Most, Ústí nad Labem-city and Ústí nad Labem-Kočkov stations (Ústí nad Labem region), air quality indices 1A and 1B (very good to good) ranged with frequency between 52% and 55%. Moderate air quality indices (2A and 2B) reached frequencies of 44 and 47%.

At the Liberec-Rochlice station in the Liberec region, the most frequent situations were with very good to good air quality (60%) and about 40% of moderate air quality situations.

At the stations Mladá Boleslav and Kladno (Central Bohemian region) in 2019, the incidence of air quality indices 1A and 1B was 57–64 %, 2A and 2B 36–43 %.

In 2019, air quality in Prague was very good to good in most cases (Prague-Libuš 60%, Prague-Riegrovy sady and Prague-Kobylisy 56%). The frequency of moderate air quality in Prague-Libuš was 40%, and 44% in the Prague-Riegrovy sady and Praha-Kobylisy stations.

At the stations České Budějovice and Prachatice (South Bohemian region), the air quality level in 2019 was very good to good in 66 to 70% of situations. In 30 to 34% of situations, a moderate air quality index was reached.

In the Vysočina region at the Jihlava station, very good to good air quality was reached with frequency of 64% and the category of moderate air quality with frequency of 36%.

In Hradec Králové of the Hradec Králové region, the frequency of situations with air quality indices 1A and 1B was 61% and with 2A and 2B levels nearly 39%.

In Pardubice (Pardubice region) in 2019, air quality was most often very good to good (67% frequency), and further moderate (33%).
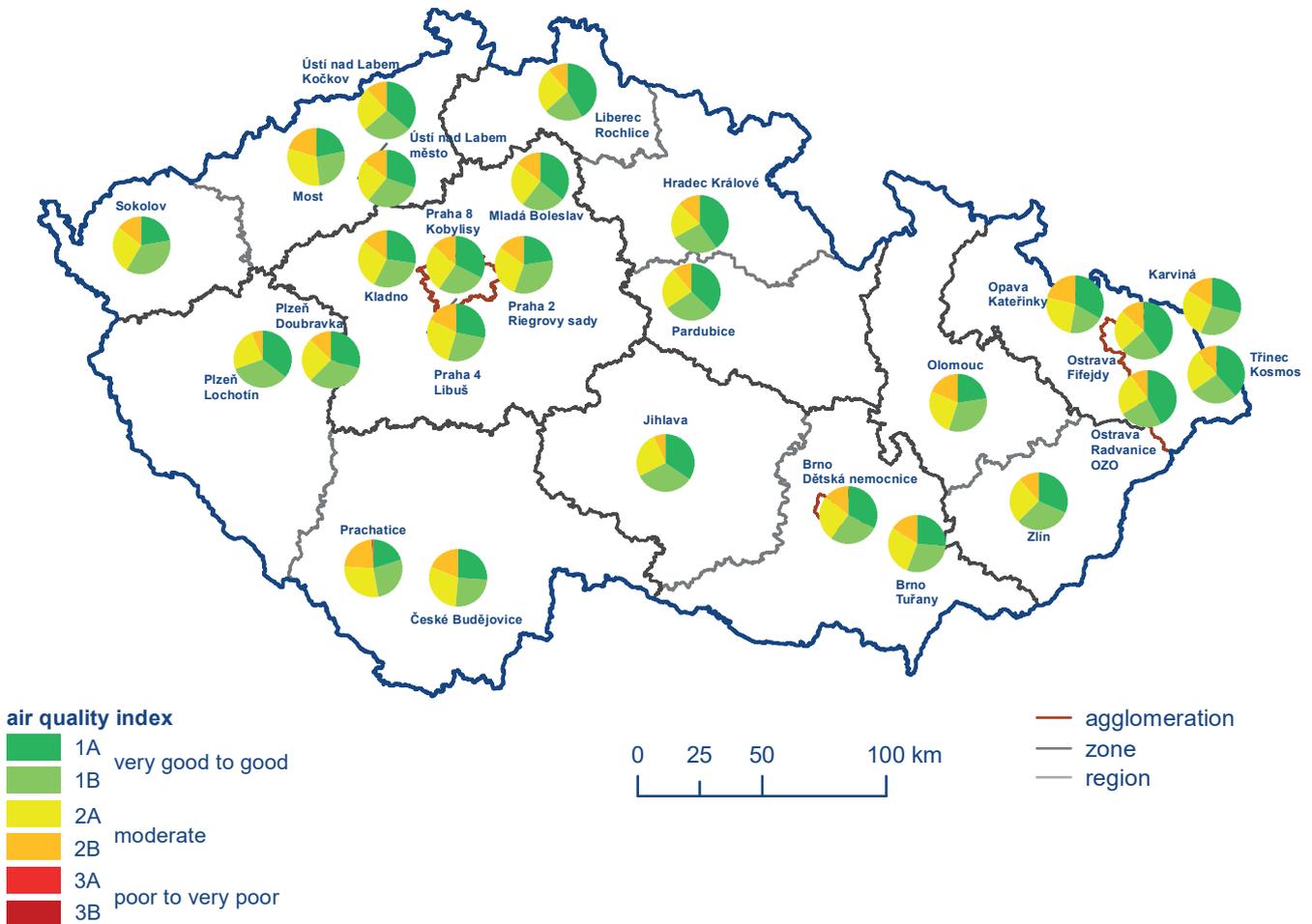
Fig. V.4.1 Proportional representation of the air quality index at selected urban and suburban stations, 2019

At the Brno-Dětská nemocnice station of the South Moravian region, air quality index 1A and 1B was achieved in 59% of cases, index 2A and 2B in 41% cases. Mostly very good to good air quality (62%) and moderate air quality in 38% of cases was reached at the Brno-Tuřany station.

At the Olomouc-Hejčín station of the Olomouc region, the air quality was mostly very good to good (55% frequency) in 2019. Situations with the index of the moderate level was reached with frequency of approx. 44%.

At the Zlín station of the Zlín region, the highest frequency of air quality was very good to good (62%). The index of the moderate level reached the frequency of 37%.

At the stations in the Moravian-Silesia region, the Karviná and Ostrava-Radvanice OZO stations reached the highest frequency of 2A and 2B index of moderate air quality (51 and 52%). Index 1A and 1B was achieved in 48% of cases at the Karviná station and 47% in the Ostrava-Radvanice OZO. In Ostrava-Fifejdy, index 1A and 1B was achieved in 51% and 2A and 2B in 48% of cases. The difference in the frequency of indices for very good to good and moderate air quality in Opava-Kateřinky reached almost 20% when index 2A and 2B was achieved in about 40% of cases. In Třinec-Kosmos, this difference reached almost 30%, of which about 64% related to index 1A and 1B.

In 2019, the frequency of the index 3A and 3B (poor to very poor air quality) was low at all evaluated urban stations and did not reach even 2%. The highest frequency of these indices was reached in the Moravian-Silesia region at the Karviná and Ostrava-Radvanice OZO stations (1.6%) and at the Ostrava-Fifejdy station (1.2%).

VI. SMOG WARNING AND REGULATION SYSTEM

With credentials issued by the Ministry of the Environment, the CHMI operates the Smog Warning and Regulation System (SWRS). Information provided through this system serves both for issuing warnings of extreme levels of air pollution (smog situations) and for regulating (reducing) release of pollutants from selected sources significantly affecting ambient air quality in the respective area. The monitored pollutants include the PM_{10} suspended particles, sulphur dioxide SO_2, nitrogen dioxide NO_2 and ground-level (tropospheric) ozone O_3.

Since 1 September 2012, the SWRS has been regulated by Act No. 201/2012 Coll., on air protection, and Decree No. 330/2012 Coll., as amended. Its rules are summarized in Tab. VI.1.

The current list of areas and representative stations for PM_{10}, SO_2 and NO_2 (Fig. VI.1, Fig. VI.3, and Fig. VI.4) is specified by the Bulletin of the Ministry of the Environment and, for O_3 (Fig. VI.2), by the CHMI

Director's Directive. From the beginning of 2019, a list published in the MoE Bulletin No. 7/2018 (MŽP 2018) applied for PM_{10}, SO_2 and NO_2 and a list published in the MoE Bulletin No. 5/2019 (MŽP 2019) applies from October 2019. For O_3, the list specified by the CHMI Director's Directive No. 2015/01 was in force throughout the year. As of 1 October 2019, the following changes took place in the representative SWRS stations: Košetice (JKOSA) - representativeness extended for PM_{10}, NO_2 and SO_2 substances to the Central Bohemian and South Bohemian zones and for O_3 to the Central Bohemian zone[1], Bělotín (MBELA) – representativeness extended for PM_{10} to the Moravian-Silesian zone, Rožďalovice-Rusá (SRORA) – representativeness extended for PM_{10} to the Hradec Králové and Pardubice regions and for SO_2 and NO_2 to the Northeast zone, and Ostrava-Poruba/CHMI (TOPOA) – a new representative station for SO_2 and NO_2 for the Ostrava/Karviná/Frýdek-Místek (O/K/F-M) agglomeration and for PM_{10} for the O/K/F-M agglomeration without the Třinec area.
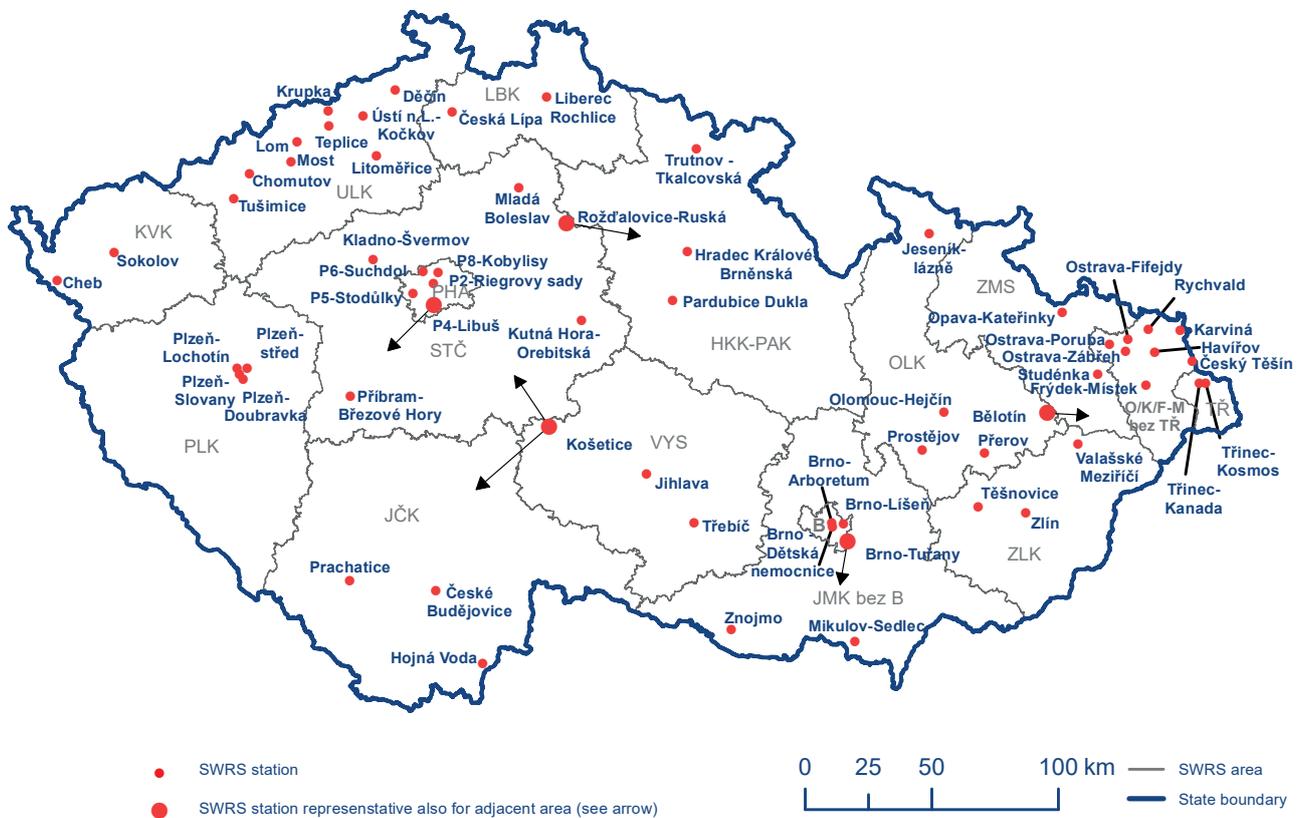
Fig. VI.1 SWRS areas and representative stations for PM_{10} as of 1 October 2019

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1   This extension for ozone was confirmed retrospectively by CHMI Director's Directive No. 2019/12 for the implementation of the Smog Warning and Regulation System, issued on 9 January 2020.

Tab. VI.1 The rules for the announcement and cancellation of smog situations and regulations (alerts)

Substance	Threshold value			Exceedance duration	Number of stations*	Supplementary condition
	Abbreviation	µg.m^{-3}	Interval			
Announcement of smog situation						
PM$_{10}$	IPH	100	12 h	1 h	50 % (two stations if there are just two of them)	Based on an evaluation of the forecast of meteorological conditions and pollution situation no decrease of the concentration below the informative threshold value can be expected during next 24 hours.
NO$_2$		200	1 h	3 h	1 station	
SO$_2$		250				
O$_3$		180		1 h		---
Announcement of regulation						
PM$_{10}$	RPH	150	12 h	1 h	50 % (two stations if there are just two of them)	Based on an evaluation of the forecast of meteorological conditions and pollution situation no decrease of the concentration below the informative threshold value can be expected during the next 24 hours.
NO$_2$		400	1 h	3 h		
SO$_2$		500				
Announcement of alert						
O$_3$	VPH	240	1 h	1 h	1 station	---
NO$_2$	RPH	400		3 h		
SO$_2$	RPH	500				
Cancellation						

The smog situation terminates and the regulation is revoked if no measuring site representative for the pollution level in an area of minimum 100 km^2 reports the concentration of polluting substances above the corresponding threshold value and this state lasts continuously for at least 12 hours and no recurrent instance of exceeding the informative, regulatory or warning threshold value can be expected in the next 24 hours based on the meteorological forecast.

12-hour time interval is being reduced up to 3 hours in a case when meteorological conditions cannot be assessed as leading to the smog situation and recurrent instance of exceeding the informative, regulatory or warning value can almost be excluded in the next 24 hours in accordance with the meteorological forecast.

* Station must be representative for the pollution level in an area of minimum 100 km^2.
Note: **IPH** – information threshold value, **RPH** – regulatory threshold value, **VPH** – alert threshold value. The requirements for the number of stations are related to the representative stations for the given SWRS area.
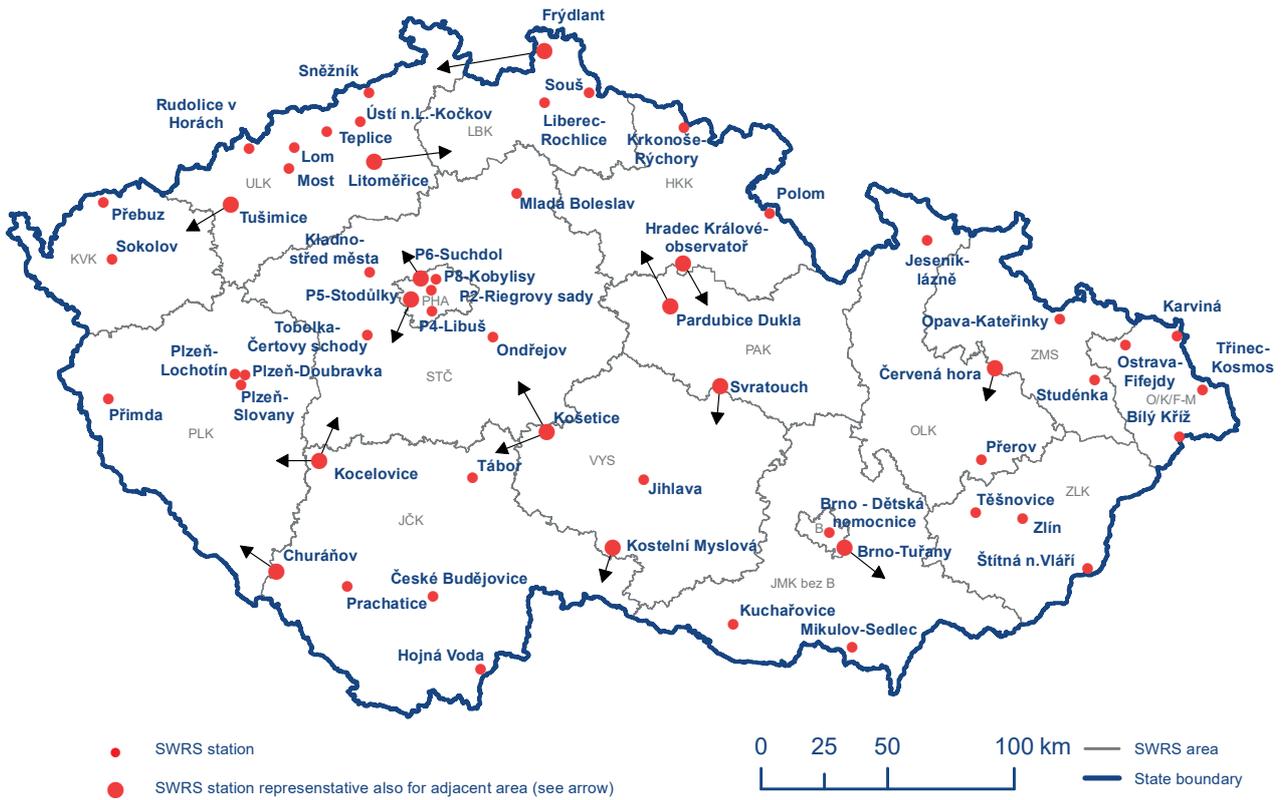
Fig. VI.2 SWRS areas and representative stations for O₃ as of 1. 10. 2019
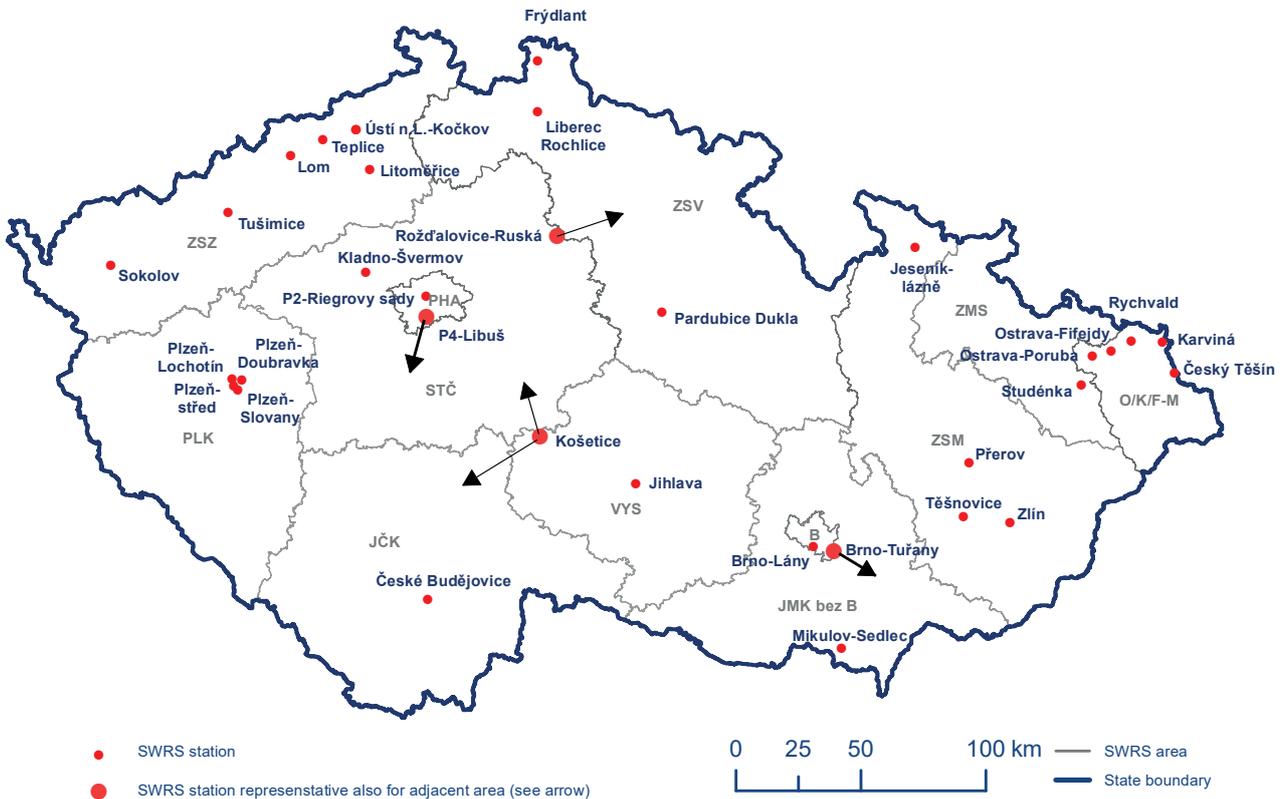
Fig. VI.3 SWRS areas and representative stations for SO₂ as of 1 October 2019

SWRS station

SWRS station represenstative also for adjacent area (see arrow)

0   25   50   100 km

SWRS area

State boundary
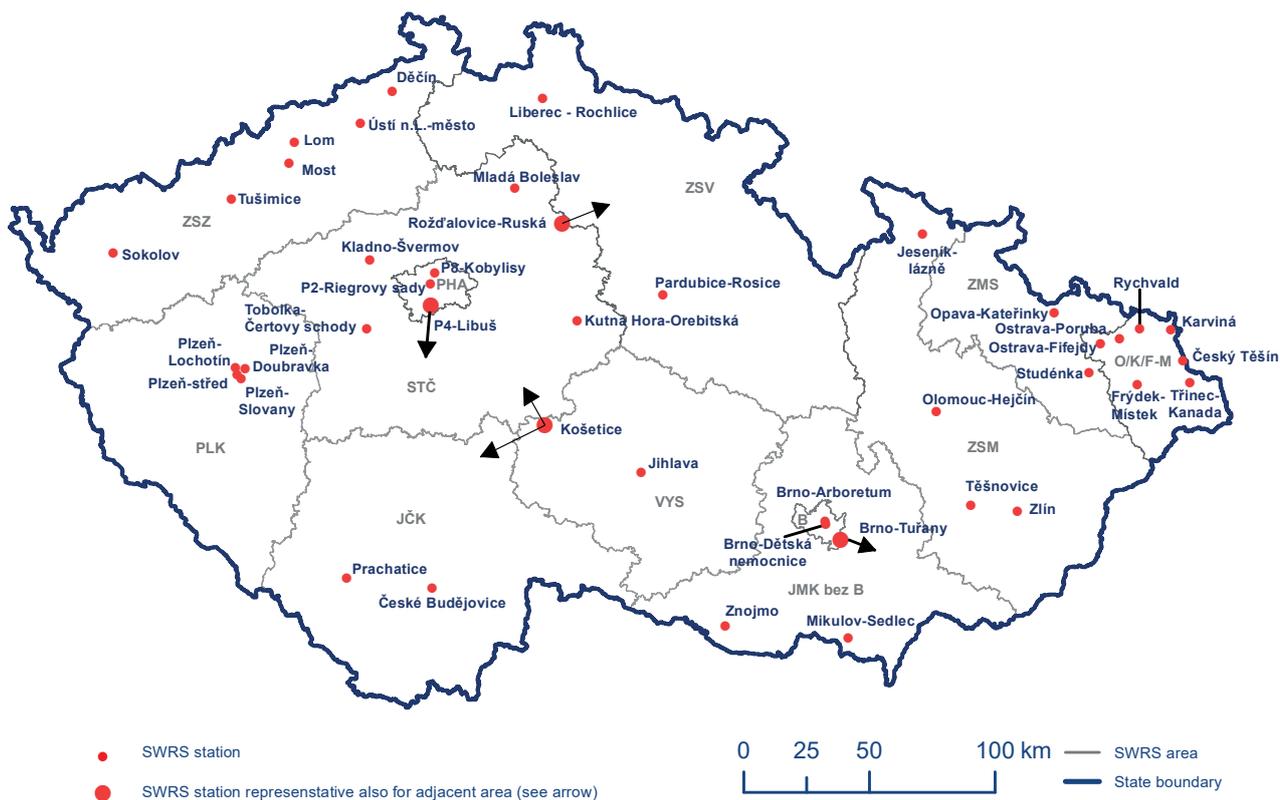
Fig. VI.4 SWRS areas and representative stations for NO$_2$ as of 1 October 2019

Smog situations

Smog situations   **Regulation**
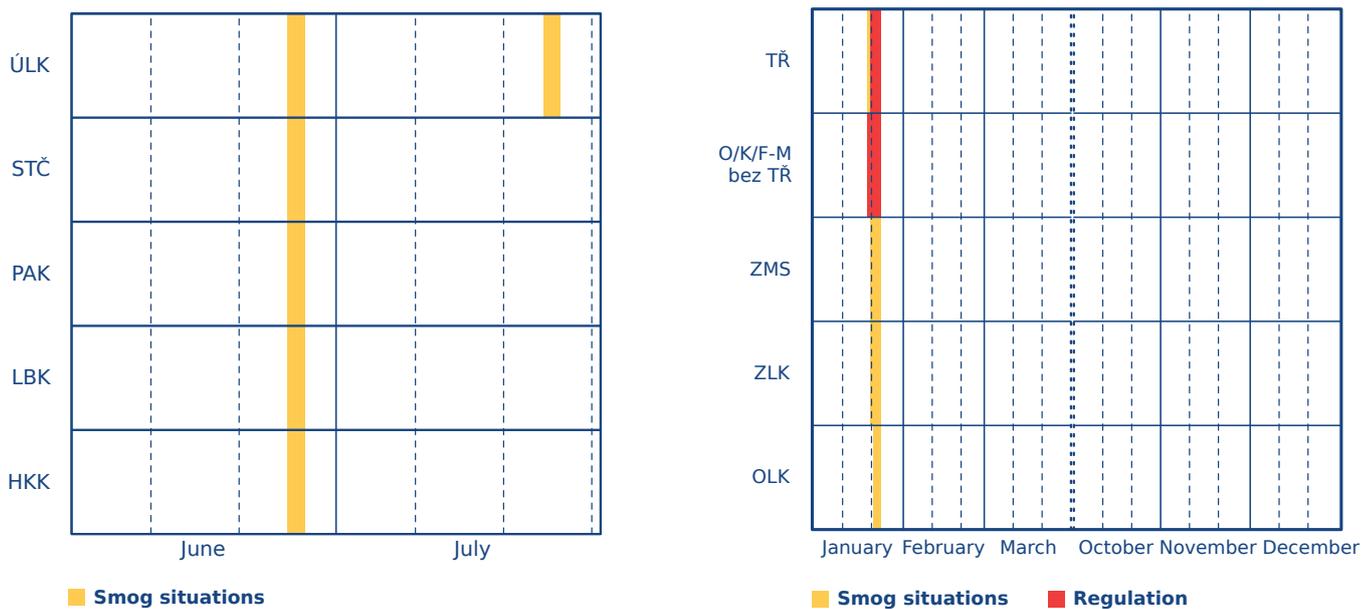
Fig. VI.5 Smog situations and regulations (alerts) for PM$_{10}$ (right) and O$_3$ (left) in the SWRS areas in which at least one smog situation was annouced, 2019

Announced smog situations and regulations (warnings)

In 2019, smog situations were announced due to exceeding the threshold values for PM_{10} and ground-level ozone O_3. The threshold values for NO_2 were not exceeded at representative SWRS stations during 2019. In the case of SO_2, the warning threshold was exceeded at one representative SWRS station (Sokolov, SKOMA), but other conditions necessary for the declaration of a smog situation were not met.

Due to the high concentrations of suspended PM_{10} particles, 5 smog situations were announced with a total duration of 385 h (approx. 16 days) and 2 regulations with a total duration of 162 h (approx. 7 days; Tab. VI.2). All smog situations and regulation occurred in January, in 5 out of the 16 SWRS areas (Fig. VI.5). Smog situations were announced in the territory of the O/K/F-M agglomeration without the Třinec area, further in the Třinec area, in the Moravian-Silesian zone and in the Zlín and Olomouc regions.

6 smog situations were announced for ground-level ozone O_3 with an overall duration of 90 h (approx. 4 days; Tab VI.4). Smog situations were announced mainly in the third decade of June 2019 (5 situations) and, in the Ústí nad Labem region, also at the end of July (Tab. VI.5). The warning threshold was not exceeded at any representative SWRS station in 2019.

Tab. VI.2 Smog situations and regulations for PM_{10} – number and duration, 2019

SWRS Area	Number of announcement		Duration [h]	
	Smog situation	Regulation	Smog situation	Regulation
Agglomeration of O/K/F-M without Třinec area	1	1	94	84
Třinec area	1	1	90	78
Moravia-Silesia zone	1	x	75	x
Zlín region	1	x	73	x
Olomouc region	1	x	53	x
Czech Republic in total	**5**	**2**	**385**	**162**

Note: Included only the SWRS areas in which at least one smog situation was announced. The duration of the smog situation includes also the duration of the regulation, if announced.

Tab. VI.3 Smog situations and regulations for PM_{10} – dates and times of announcement, 2019

Announcement		Cancellation		Duration	
Smog situation	Regulation	Regulation	Smog situation	Smog situation	Regulation
day and hour CET				[h]	
Agglomeration of O/K/F-M without Třinec area					
20.01.2019 11:32	20.01.2019 14:02	24.01.2019 02:08	24.01.2019 09:58	94	84
Třinec area					
20.01.2019 21:23	21.01.2019 01:54	24.01.2019 08:09	24.01.2019 15:43	90	78
Moravia-Silesia zone					
21.01.2019 02:01	x	x	24.01.2019 04:49	75	x
Zlín region					
21.01.2019 07:45	x	x	24.01.2019 08:46	73	x
Olomouc region					
22.01.2019 00:24	x	x	24.01.2019 05:16	53	x

Note: CET – local time, i.e. Central European Time. The duration of the smog situation includes also the duration of the regulation, if announced.

Synoptic situation during selected smog situations

19 – 24 January 2019

During the 18 and 19 January, the pressure high advanced through Central Europe to the east. The Czech Republic was thus affected by the back of this pressure high with the south-eastern flow. During 20 January, further pressure low was gradually restored over Central Europe, advancing slowly to the east with a weak south-eastern flow resuming over the Czech Republic on 22 January. At the same time, the pressure low over the western Mediterranean deepened and its edge affected the weather in our territory. Throughout the period, the air was cold in Central Europe, and the temperature at 850 hPa ranged from −12 to −5 °C. Occasionally, the cloud cover decreased, and with a mostly weak south-east wind, temperature inversions with unfavourable dispersion conditions occurred, especially at night. It was not until 25 January that the flow changed to the north-west with the extension of the higher air pressure ridge from the west, and the dispersion conditions improved.

26 – 27 June 2019

Between the pressure high above Eastern Europe and the area of air pressure low above Germany and southwestern Europe, warm air flowed over our territory from the south to the south-west. In mostly sunny weather on 26 June, the air temperatures reached 31 to 37 °C. On 27 June, a cold front crossed our territory to the south-east and ended the influx of very warm air.

Tab. VI.4 Smog situations and alerts for O_3 – number and duration, 2019

SWRS area	Number of announcement		Duration [h]	
	Smog situation	**Alert**	**Smog situation**	**Alert**
Hradec Králové region	1	x	13	x
Pardubice region	1	x	12	x
Liberec region	1	x	12	x
Ústí nad Labem region	2	x	40	x
Central Bohemia zone	1	x	13	x
Czech Republic in total	**6**	**x**	**90**	**x**

Note: Included only the SWRS areas in which at least one smog situation was announced. The duration of the smog situation includes also the duration of the regulation, if announced.

Tab. VI.5 Smog situation and alerts for O_3 – dates and times of announcement, 2019

Announcement		Cancellation		Duration	
Smog situation	**Alert**	**Alert**	**Smog situation**	**Smog situation**	**Alert**
day and hour CEST				[h]	
Hradec Králové region					
26.06.2019 21:03	x	x	27.06.2019 09:47	13	x
Liberec region					
26.06.2019 18:36	x	x	27.06.2019 07:02	12	x
Pardubice region					
26.06.2019 21:03	x	x	27.06.2019 08:34	12	x
Ústí nad Labem region					
26.06.2019 13:27	x	x	27.06.2019 03:20	14	x
25.07.2019 16:28	x	x	26.07.2019 18:46	26	x
Central Bohemia zone					
26.06.2019 18:36	x	x	27.06.2019 07:32	13	x

Note: CEST – local time, i.e. Central European Summer Time. The duration of the smog situation includes also the duration of the regulation, if announced.

VII. AREAS WHERE THE POLLUTION LIMIT VALUES ARE EXCEEDED

VII.1 Areas where the pollution limit values for protection of human health are exceeded

Annually, areas are defined where the pollution limit values are exceeded overall for all the pollutants that are monitored from the aspect of human health. The map of areas where at least one pollution limit value[1], not including ground-level ozone, is exceeded provides comprehensive information on ambient air quality in the Czech Republic. In 2019, 8.4% of the territory of the Czech Republic, inhabited by approx. 27.5% of the population, was designated as an area where the pollution limit values were exceeded (Fig. VII.1.1; Tab. VII.1.1). Assignment of these areas is, in the vast majority of cases, a result of exceeding the annual pollution limit values for benzo[a]pyrene (Tab. VII.1.1). To a lesser degree, assignment of a territory to these areas in 2019 was a result of exceeding the daily pollution limit value for suspended particulates PM_{10} and the annual pollution limit value

for $PM_{2.5}$. The areas exceeding the limit values were the most extent in the Ostrava/Karviná/Frýdek-Místek agglomeration (71%), and in the Moravian-Silesia (49%) and Central Moravia (29%) zones (Tab. VII.1.2). In the year-on-year comparison 2018/2019, the area of territories where at least one pollution limit value was exceeded, except for ozone, decreased. Figures VII.1.2 and VII.1.3 show a comparison of the territory with exceeded limit values in 2019 with that in 2018 and with the five-year average for the period 2014 to 2018. Based on the year-on-year comparison it can be stated that the most significant reduction of the above-limit concentration area took place in the Kladno area, the Ústí nad Labem and Zlín districts, and the Brno municipality where the area with exceeded pollution limit values for benzo[a]pyrene and PM_{10} suspended particulates decreased between years (Chap. VII.1 and Chap. VII.2). The longer-term comparison (Fig. VII.1.3) shows that in 2019 the delimited above-limit concentration area is of a lower extent than in the five-year average 2014−2018 and that the territories of the Moravian-Silesia, Olomouc, and Zlín regions remain the most affected. The identified area with at least one pollution limit value exceeded in 2019, except for ozone, is the smallest within the evaluation period between 2012 and 2019 (Fig. VII.1.4). The improvement in the situation can be attributed to a combination of factors.

Tab. VII.1.1 Percentage of the area exceeding the pollution limit (%) and percentage of population resident in areas exposed to above-limit values (%) in the Czech Republic, 2019

	Pollutants specified in Annex 1 to Act No. 201/2012 Coll., as amended						
	Item 1 of the Annex			Item 3 of the Annex		Item 4 of the Annex	
	PM_{10} 36th max. 24-h average > 50 µg.m⁻³	$PM_{2.5}$ annual average > 25 µg.m⁻³	Total LV exceedances	BaP annual average > 1 ng.m⁻³	Total exceedances, ozone excluded	O_3 26. highest values max. daily 8-h runing average (in the three−year average) > 120 µg.m⁻³	Total exceedances, including ozone
Inhabitants	0.9	0.1	0.9	27.5	27.5	56.9	75.6
Area	0.3	0.04	0.3	8.4	8.4	70.5	77.1

1   The annual pollution limit values for PM_{10}, $PM_{2.5}$, benzo[a]pyrene, NO_2, lead, cadmium, arsenic, nickel and benzene, the pollution limit value for CO (max. daily 8-hour moving average), the daily pollution limit values for PM_{10} and SO_2, the hourly pollution limit value for SO_2 and NO_2.

Tab. VII.1.2 Limit value (LV) exceedances in the zones/agglomerations, regions and municipalities with extended competencies of the Czech Republic, % of the area of the administrative unit, 2019

Zone / agglomeration	Region	Pollutants specified in Annex 1 to Act No. 201/2012 Coll., as amended						
		Item 1 of the Annex			Item 3 of the Annex		Item 4 of the Annex	
		PM$_{10}$	PM$_{2.5}$		BaP		O$_3$	
		36th max. 24–h average > 50 µg.m^{-3}	annual average > 25 µg.m^{-3}	Total LV exceedances	annual average > 1 ng.m^{-3}	Total exceedances, including ozon	26. highest values max. daily 8–h runing average (in the three–year average) > 120 µg.m^{-3}	Total exceedances, including ozon
Agglomeration of Prague	Prague	–	–	–	0.22	0.22	99.8	99.8
Central Bohemia zone	Central Bohemia region	0.01	–	–	1.59	1.59	98.79	98.79
South–western zone	South Bohemia region	–	–	–	0.29	0.29	57.4	57.69
	Plzeň Region	–	–	–	0.25	0.25	91.16	91.34
		–	–	–	0.27	0.27	71.99	72.23
	Karlovy Vary region	–	–	–	–	–	99.12	99.12
North–western zone	Ústí nad Labem region	0.04	–	0.04	2.1	2.14	99.96	99.96
		0.02	–	0.02	1.3	1.32	99.64	99.64
	Liberec region	–	–	–	1.42	1.42	97.47	97.69
North–eastern zone	Hradec Králové region	–	–	–	9.63	9.63	70.37	77.9
	Pardubice region	–	–	–	0.64	0.64	36.1	36.67
	Vysočina region	–	–	–	4.28	4.28	64.8	67.75
		–	–	–	0.03	0.03	53.58	53.61
South–eastern zone	South Moravia region without agglomeration of Brno	–	–	–	0.07	0.07	91.73	91.74
Agglomeration of Brno		–	–	–	0.04	0.04	73.33	73.34
		–	–	–	0.87	0.87	64.88	65.32
Central Moravia zone	Olomouc region	–	–	–	34.31	34.31	36.94	63.09
	Zlín region	–	–	–	21.57	21.57	41.07	60.16
		–	–	–	28.84	28.84	38.71	61.83
Moravia–Silesia zone		0.35	–	0.35	49.68	49.68	24.84	65.41
Agglomeration of Ostrava/Karviná/Frýdek–Místek	Moravia–Silesia region	10.14	1.63	10.14	70.13	70.13	8.97	72.9
		3.77	0.57	3.77	56.82	56.82	19.3	68.03

area with LV exceedances   8.4 %

0   25   50   100 km

agglomeration
zone
region
municipality over 30K inhab.

Fig. VII.1.1 Areas with exceeded air pollution limits for health protection excluding ground-level ozone, 2019

LV exceedances

	without LV exceedances	86.1 %
	2018	5.4 %
	2019	1.2 %
	2018;2019	7.2 %

0   25   50   100 km

agglomeration
zone
region
municipality over 30K inhab.

Fig. VII.1.2 Comparison of areas with exceeded air pollution limits for health protection excluding ground-level ozone in 2019 and 2018

The year 2019 was extremely above normal in terms of temperature and normal in terms of precipitation. In addition, in 2019, compared with the ten-year average, there were significantly improved dispersion conditions. These factors lead to lower emissions from heating and better dispersion of emissions from various sources. At the end of the year — in November and December — poor dispersion conditions did not occur, as usual in comparison with other years (for more details see Chap. III). The decrease in concentrations can also be attributed to measures already implemented to improve air quality (particularly the replacement of boilers), the continuing renewal of the vehicle fleet and measures taken at places of large sources (see Chapters II and IV.1.3).

After including ground-level ozone, the areas where at least one pollution limit value was exceeded in 2019 corresponded to 77.1% of the territory of the Czech Republic (Fig. VII.1.5) with approximately 75.6% of population (Tab. VII.1.1). In the year-on-year comparison 2018/2019 there was a decrease by 10% of the area exceeding at least one limit value, including ozone, however, this is still the second largest area with above-limit concentrations in the evaluated period 2012–2019 (Fig. VII.1.4). The graph shows an increase in the extent of the above-limit concentration area in the last three years in relation to increasing ozone concentrations (Chap. IV.4).

LV exceedances		
	without LV exceedances	84.2 %
	2014–2018	7.4 %
	2019	0.7 %
	2014–2018;2019	7.7 %

agglomeration
zone
region
municipality over 30K inhab.
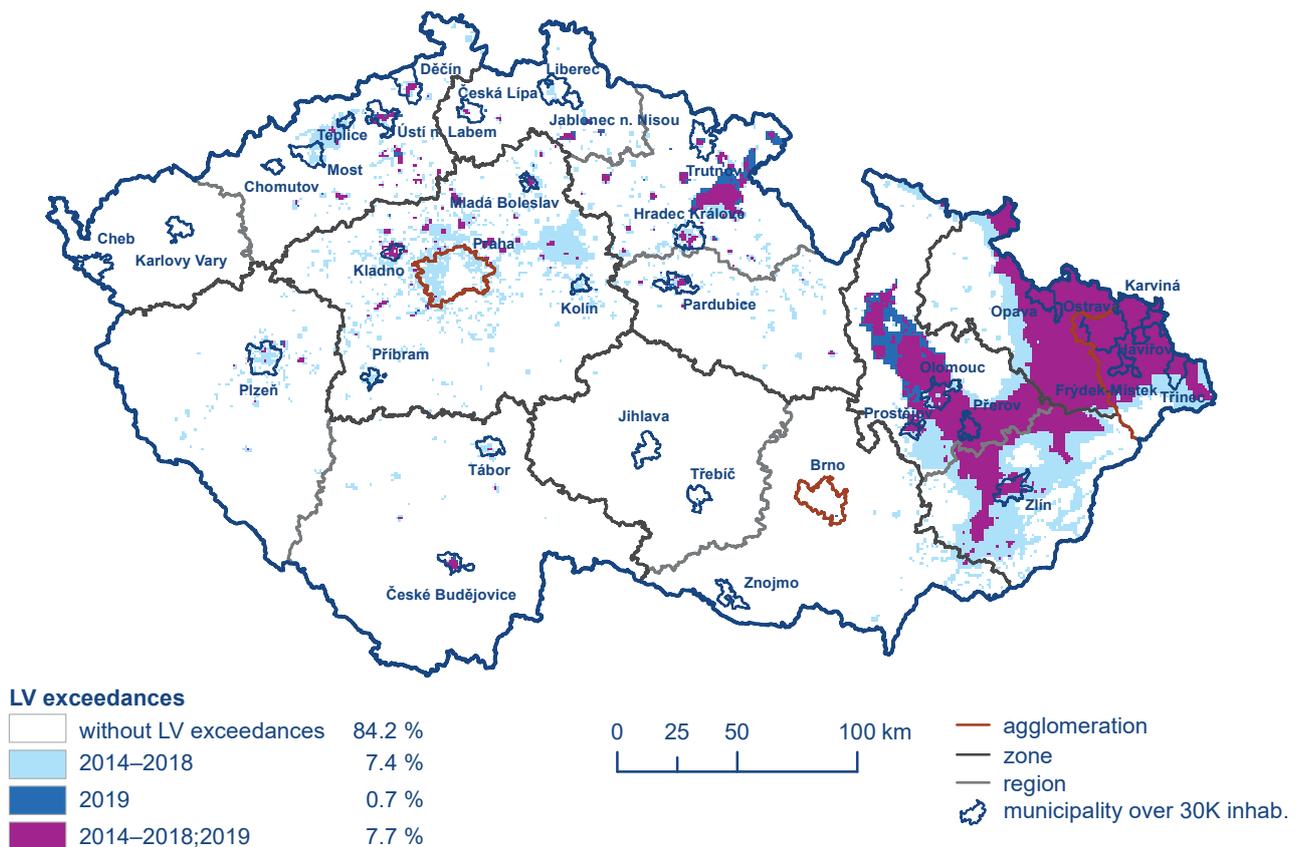
Fig. VII.1.3 Comparison of areas with exceeded air pollution limits for health protection excluding ground-level ozone in 2019 and in the five-year average 2014–2018

■ **Areas of exceedances of LV, O_3 excluded** ■ **Areas of exceedances of LV, O_3 included**
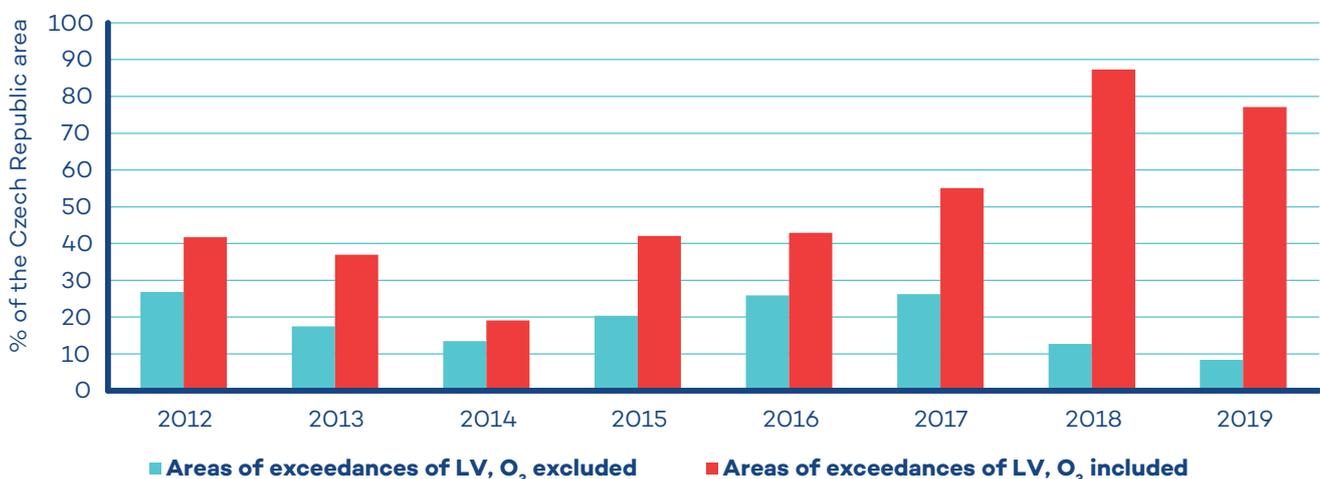
Fig. VII.1.4 Exceeded air pollution limit in the Czech Republic, percentage of the area, 2012–2019
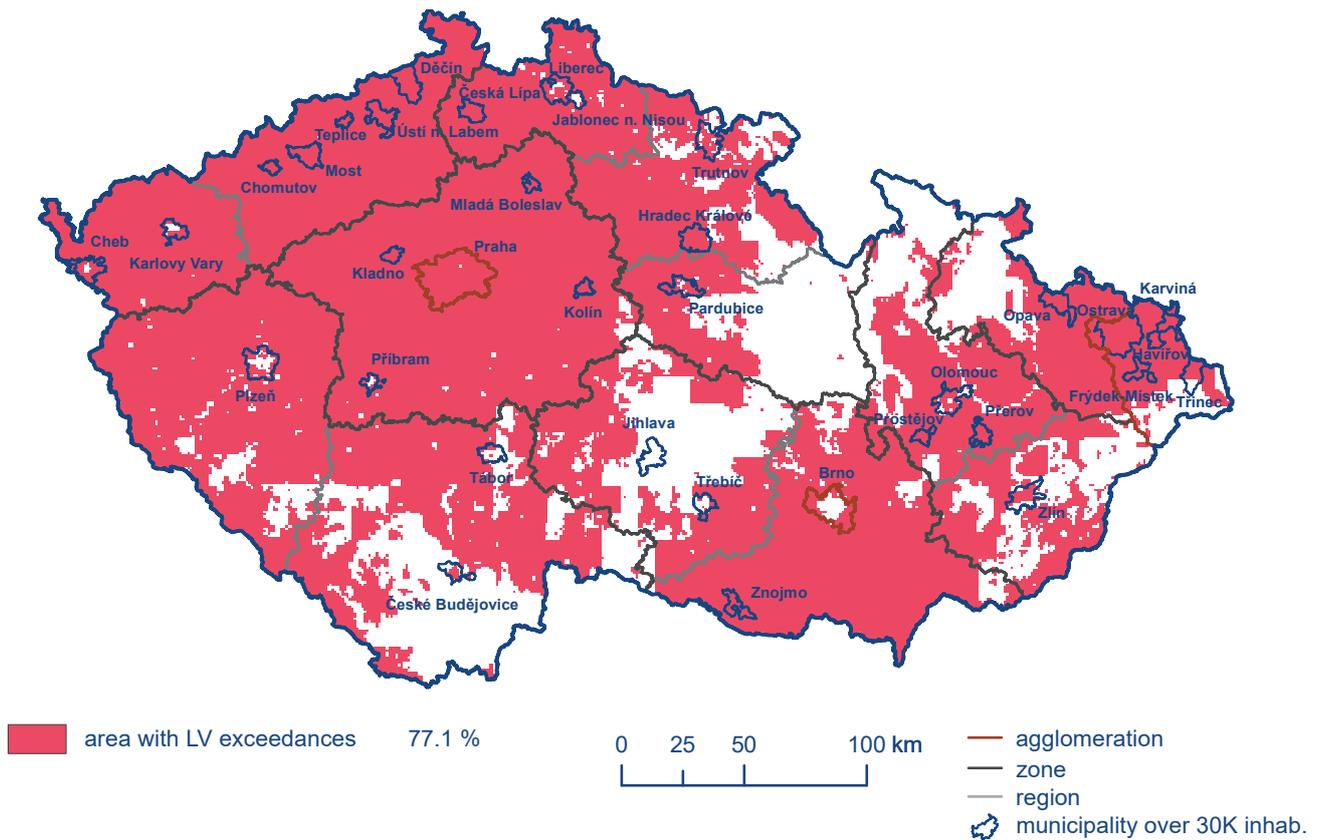
Fig. VII.1.5 Areas with exceeded air pollution limits for health protection including ground-level ozone, 2019

Regional differences in terms of air quality in the Czech Republic

As part of the population exposure assessment, the average population-weighted concentrations were calculated for PM_{10} and $PM_{2.5}$ suspended particulates and NO_2 for municipalities with population over 30,000 inhabitants (Fig. VII.1.6). In simple terms, the value represents a pollutant concentration that a person living in a given municipality is exposed to. This characteristic, classified according to Member States, is published in the framework of the European air quality assessment (ETC/ACM, 2018).

A comparison of the population-weighted concentration in large cities of the Czech Republic shows that population exposed to the highest concentrations of suspended PM_{10} and $PM_{2.5}$ particles are in the cities of the Moravian-Silesia and Olomouc regions which are the regions with the highest pollution exposure in terms of air quality country-wide in the long-term (Chap. V.3). In 2019, the weighted average concentrations of suspended PM_{10} and $PM_{2.5}$ particles did not exceed the pollution limit value. The Cheb, Karlovy Vary, Jablonec nad Nisou and Příbram cities are among the purest cities in terms of the evaluation of suspended particles concentrations. Relatively low concentration levels in cities located in the Karlovy Vary and South Bohemia regions are related to the local low regional background concentrations of suspended particles. Unlike the most heavily exposed regions, long-range transport of air pollution is not as important here and the landscape character allows good ventilation (especially in the South

Bohemia area). The low emission load of these areas is also a not negligible factor.

The situation is somewhat different in terms of assessing the air exposure to NO_2 concentrations. This is mainly due to different major emission sources than that for suspended particles where those include public energy, heat generation and road transport. In connection with intensive traffic and restrained traffic flow, the population exposed to the highest NO_2 concentrations belong to three most populous cities of the Czech Republic, i.e. in Prague, Brno and Ostrava where there is also higher regional pollution due to the presence of large pollution sources. In 2019, within large cities, population in the Jablonec nad Nisou, Trutnov, Třebíč, Příbram and Tábor cities was exposed to the lowest NO_2 values. Relatively low NO_2 concentrations occur in cities with a lower population and associated lower traffic intensity and in areas with lower regional background concentrations of NO_2 caused by lower emissions from large sources of pollution and less significant long-range pollution transport (the South Bohemia, Karlovy Vary, Vysočina and Liberec regions). Average weighted NO_2 concentration levels in the Czech Republic do not exceed the pollution limit value, however, following long-term measurements of NO_2 in some traffic localities, particularly in sites with high traffic intensity experiencing poor ventilation (dense build-up areas) and frequent restrictions of traffic flow, instances exceeding the pollution limit values in the immediate vicinity of heavily busy roads can be assumed.

PM₁₀ – annual average

PM₁₀ – max. 36ᵗʰ concen.

PM₂.₅ – annual average

NO₂ – annual average
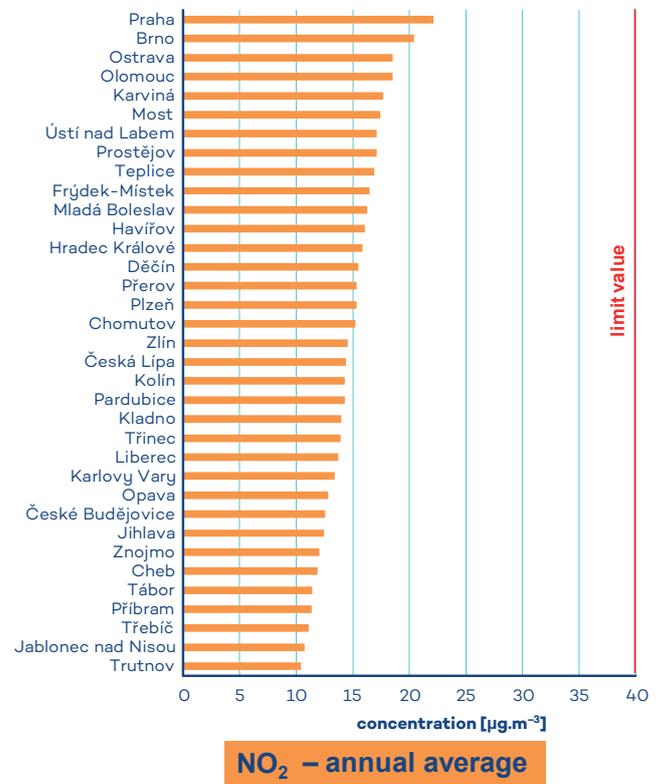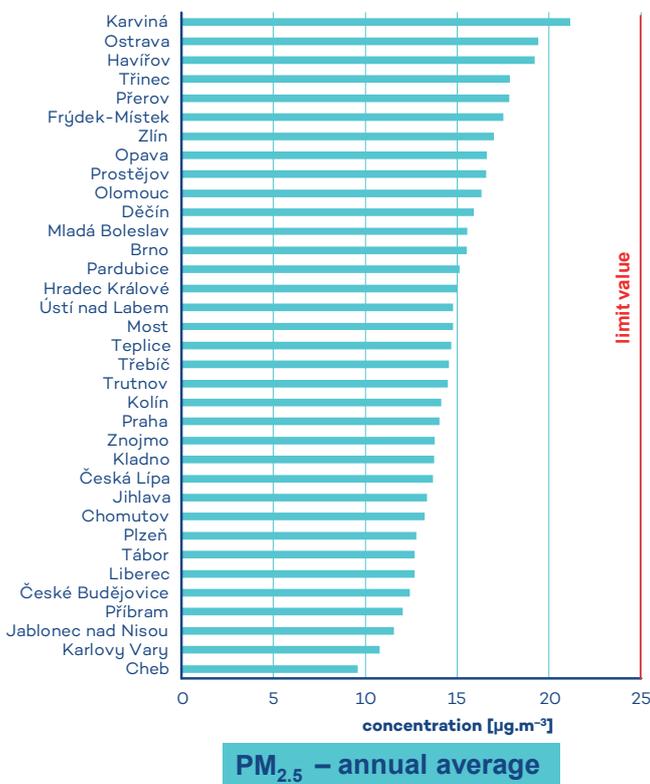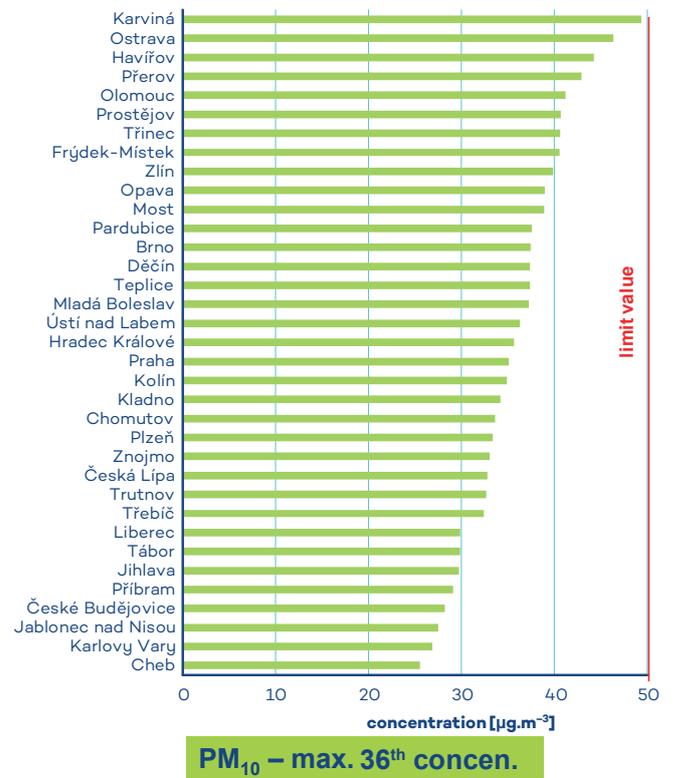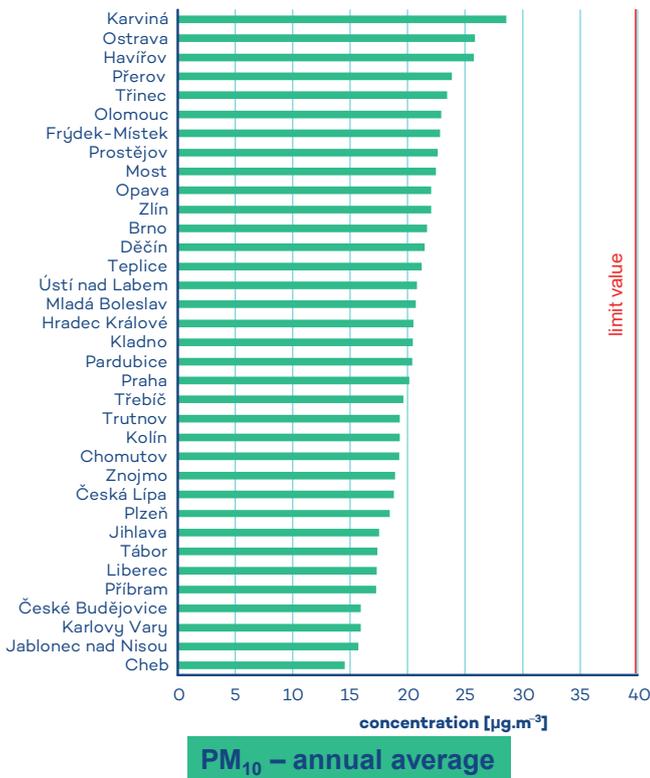
Fig. VII.1.6 Average population-weighted concentrations of pollutants in municipalities with more than 30,000 inhabitants, 2019
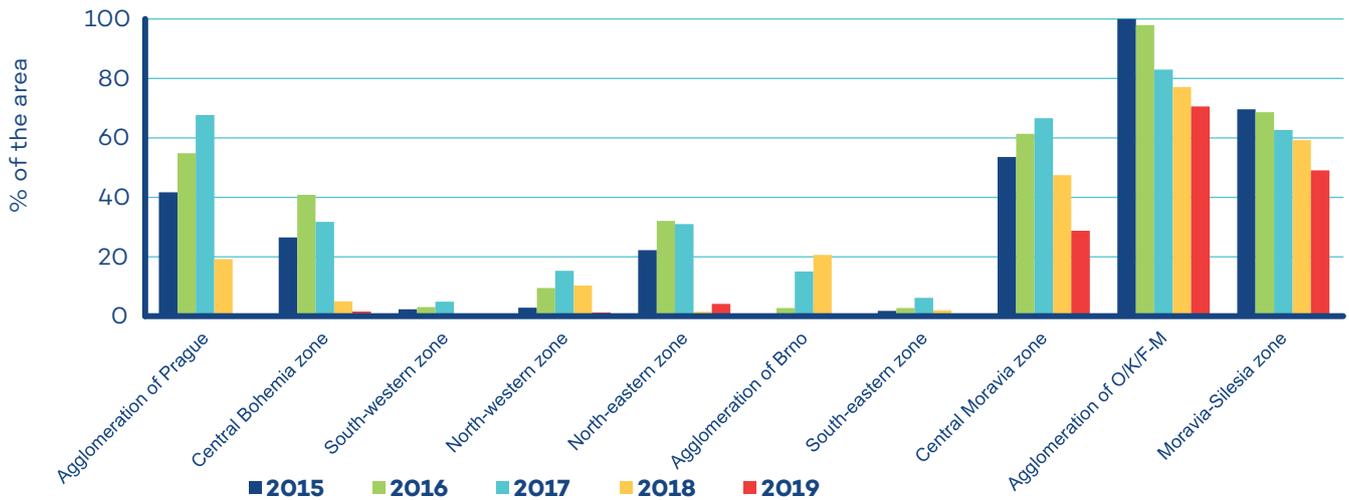
Fig. VII.1.7 Exceeded air pollution limit in the zones and agglomerations of the Czech Republic, percentage of the area, 2015–2019

Within the Czech Republic, there are considerable regional differences in terms of air quality as shown in Fig. VII.6 presenting variation of the area of territories with above-limit concentrations except for ozone in zones and agglomerations in the last five-year period 2015–2019. The most affected regions in terms of air quality have long been the O/K/F-M agglomeration and the Moravian-Silesia and Central Moravia zones. Regions with deteriorated air quality include the Prague and Brno agglomerations and the Central Bohemia, Northeast and Northwest zones. On the other hand, in the Southwest and Southeast zones the pollution limit values are exceeded only in very small areas. In 2019, the area with above-limit concentrations decreased most significantly due to a decrease in benzo[a]pyrene and PM_{10} suspended particulates concentrations in the Prague and Brno agglomerations and in the Central Moravia zone.

VII.2 Areas where the pollution limit values for protection of ecosystems and vegetation are exceeded

From the viewpoint of protection of the most valuable natural locations of the Czech Republic, exceeding of the pollution limit values for the protection of ecosystems and vegetation[2] in the territory of NPs and PLAs is also evaluated (Tab. VII.2.1). In 2019, at least one of these limit values was exceeded over nearly 79% of the territory of NPs and PLAs (Fig. VII.2.1).

Above-limit NO_X concentrations occur particularly around transport roads; the pollution limit value for NO_X for the most valuable natural parts of the Czech Republic was exceeded over only a very small area of several PLAs (Tab. VII.2.1, Fig. VII.2.2).

In 2019, all NPs and PLAs except for Poodří and Jeseníky PLAs were exposed to the above-limit ozone concentrations (Tab. VII.2.1).

The pollution limit value for the annual and winter average concentration of SO_2 was not exceeded in 2019 in the territory of any PLA or NP, similar to the previous years.

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2   Limit values for the annual and winter average concentrations of SO_2. Limit value for the annual average concentration of NO_X and the pollution limit value for O_3 expressed as the AOT40 exposure index.

area with LV exceedances   78.7 %

protected landscape areas

national parks

source: NCA CR

0   25   50   100 km

agglomeration

zone

region

municipality over 30K inhab.
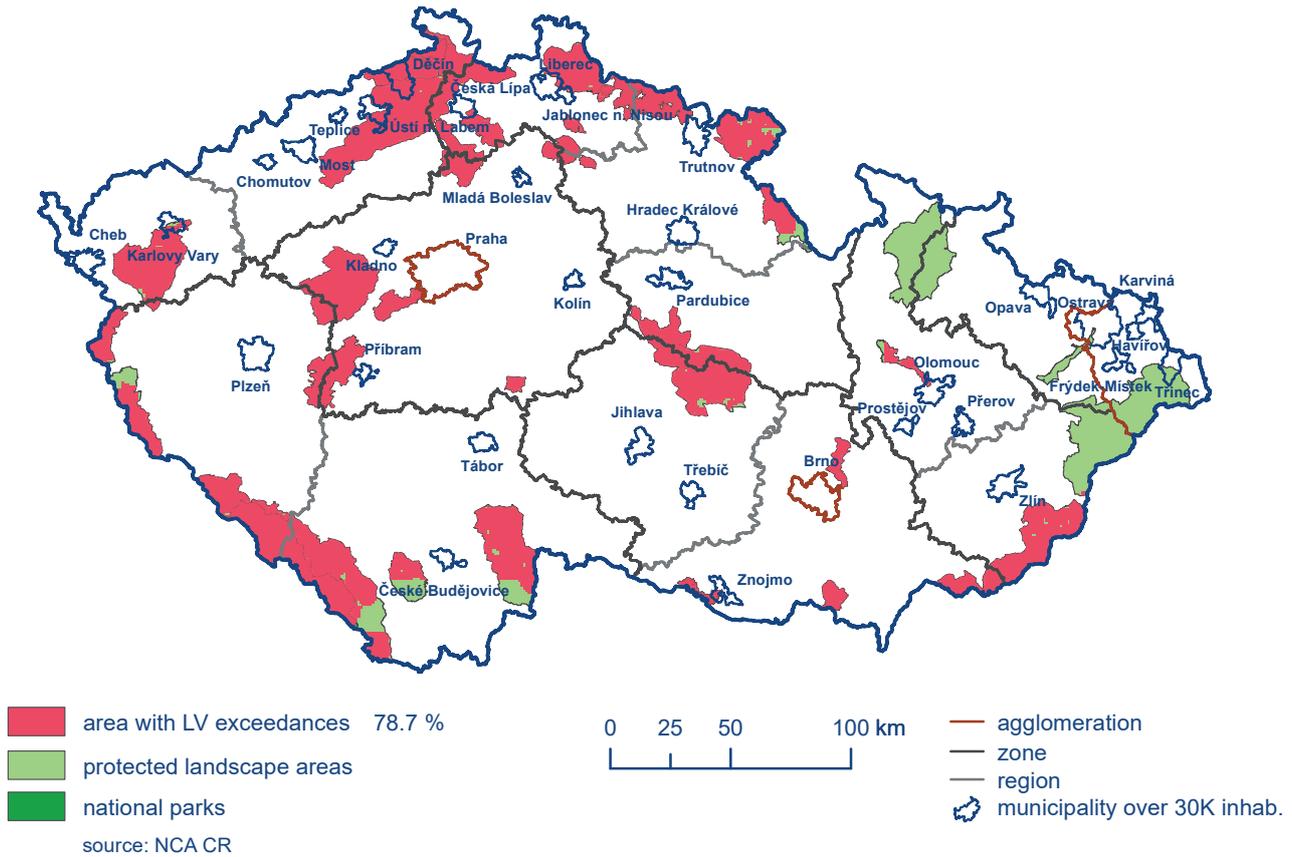
Fig. VII.2.1 Areas with exceeded air pollution limits for ecosystems and vegetation in national parks and protected landscape areas including ground-level ozone, 2019

area with LV exceedances   0.05 %

protected landscape area

national parks

source: NCA CR

0   25   50   100 km

agglomeration

zone

region

municipality over 30K inhab.
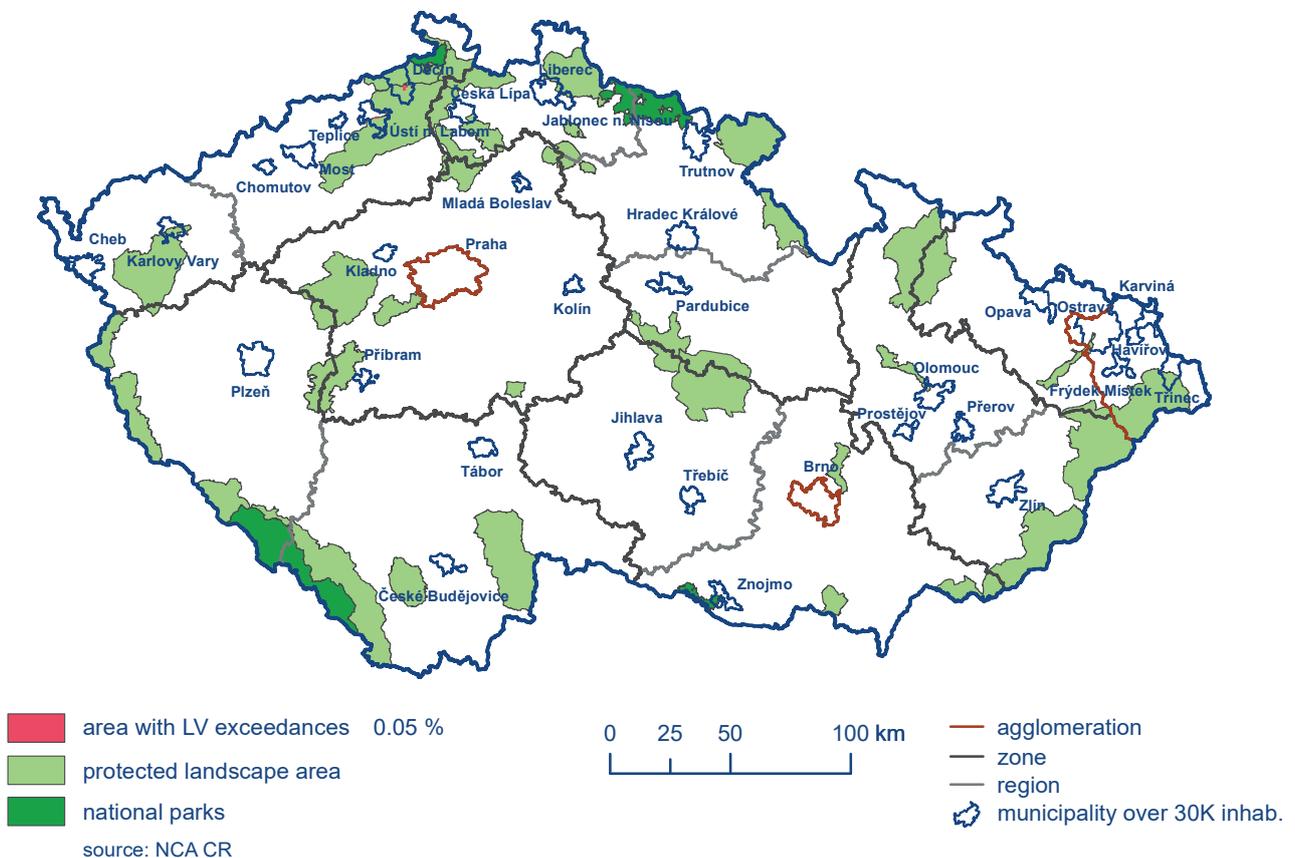
Fig. VII.2.2 Areas with exceeded air pollution limits for ecosystems and vegetation in national parks and protected landscape areas excluding ground-level ozone, 2019

Tab. VII.2.1 Exceedances of the limit value (NO$_x$ and AOT40) for the protection of ecosystems and vegetation within NP and CHKO, % of the territory of NP and CHKO, 2019

National park and protected landscape area	NO$_x$ Annual average > 30 µg.m^{-3}	O$_3$ AOT 40 > 18000 µg.m^{-3}.h	Sum
NP České Švýcarsko	–	100	100
Krkonošský národní park	–	99.9	99.9
NP Podyjí	–	100	100
NP Šumava	–	99.5	99.5
CHKO Beskydy	–	0.3	0.3
CHKO Bílé Karpaty	–	98.5	98.5
CHKO Blaník	–	100	100
CHKO Blanský les	–	52.6	52,6
CHKO Brdy	–	100	100
CHKO Broumovsko	–	90.4	90.4
CHKO České středohoří	0.4	99.8	99.8
CHKO Český kras	1	100	100
CHKO Český les	–	82.8	82.8
CHKO Český ráj	–	100	100
CHKO Jeseníky	–	–	–
CHKO Jizerské hory	–	98.2	98.2
CHKO Kokořínsko - Máchův kraj	–	100	100
CHKO Křivoklátsko	–	100	100
CHKO Labské pískovce	–	99.7	99.7
CHKO Litovelské Pomoraví	0.1	81.5	81.6
CHKO Lužické hory	–	99.1	99.1
CHKO Moravský kras	–	100	100
CHKO Orlické hory	–	70.9	70.9
CHKO Pálava	–	100	100
CHKO Poodří	–	–	–
CHKO Slavkovský les	–	97.1	97.1
CHKO Šumava	–	86.1	86.1
CHKO Třeboňsko	–	82.5	82.5
CHKO Žďárské vrchy	–	95.5	95.5
CHKO Železné hory	–	99.6	99.6

VIII. EUROPEAN CONTEXT

Air pollution in large industrial areas has been one of the serious environmental problems in Europe since roughly the middle of the last century. The well-known episodes of the "London smog" forced not only the UK, but also other Western European countries to gradually adopt national laws to reduce air pollution.

In the 1960s, it became apparent that the problem could only be solved through international cooperation. Studies within a program for investigation of long-range transmission of air pollution carried out under the auspices of the Organisation for Economic Cooperation and Development (OECD) in 1971–1977 have shown that acidification of rivers and lakes in Scandinavia is a result of so-called acid rain caused by pollutants released into the atmosphere in continental Europe. Consequently, the first internationally binding document was adopted to resolve problems connected with air pollution at a broad regional level, namely the Convention on Long-Range Transboundary Air Pollution (CLRTAP) which was adopted by the UN Economic Commission for Europe in 1979.

Measures introduced both under CLRTAP and later under European Union (EU) legislation, in particular, resulted in significant improvement of air quality in Europe in recent decades. Emissions of many pollutants have suitably been reduced, but pollution from suspended particulate matter and ozone still poses serious risks. A considerable part of the European population and ecosystems continues to be exposed to higher concentrations of pollutants than the legislatively stipulated limit levels and values recommended by the World Health Organisation (WHO).

Despite these improvements, air pollution is one of the highest-risk environmental factors causing premature death, increasing the incidence of a wide range of diseases, damaging vegetation and ecosystems and leading to a loss of biodiversity in Europe. All these factors also lead to significant economic losses. A further improvement will require measures and cooperation on a global, continental, national and local level in most branches of the economy with public participation. The measures must include technological development, structural changes including optimisation of the infrastructure and territorial planning, as well as a change in behaviour. The protection of natural capital, the promotion of economic prosperity, human well-being and social development are part of the European Union 2050 vision, set out in the 7th EU Environmental Action Programme (EU 2013).

Emissions of pollutants and greenhouse gases within Europe

Emissions of the main pollutants released into the ambient air in Europe have decreased since 1990. Nonetheless, this reduction has not been sufficient in all the sectors and the emissions of some pollutants have even increased. For example, there has not been a sufficient reduction in NO_X emissions from mobile sources and therefore air pollution limits are not complied with in many cities. In the past decade, $PM_{2.5}$ and benzo[*a*]pyrene emissions have also increased in the EU as a result of incomplete combustion of coal and biomass in households and in private and public buildings. These sources now make the greatest contribution to emissions of particulates and benzo[*a*]pyrene in the EU (Fig. VIII.1).

Greenhouse gas emissions are declining, particularly CO_2, CH_4 and N_2O emissions (Fig. VIII.2). On the contrary, there is an increase in fluorocarbon emissions in recent years. This is due to the longer retention of these substances in the equipment in which they are used. Overall, however, there are international obligations to reduce greenhouse gas emissions based on the requirements of both the UN Framework Convention on Climate Change and the related regulations of the European Union. Reducing emissions of fluorinated gases and limiting their use is also required by the Montreal Protocol.

Air quality monitoring in Europe

Long-term monitoring of air quality is at a high level in Europe which is, together with North America, a continent with the highest density of measuring stations. The national air quality monitoring networks are operated by the individual countries in accordance with the EU legislation, but practical provisions for these networks differ in the countries. In some, they are managed centrally by environmental agencies or meteorological institutes, in others by regional authorities. The central European database of pollutant concentrations measured at air quality monitoring stations (AQ e-reporting database) is operated by the European Environment Agency (EEA). Each year, individual countries transmit data measured within their monitoring networks to the EEA on the basis of EU legislation.

In addition to the national networks, long-term pan-European projects are being implemented, whose main goals include detecting long-term trends in air quality in a European-wide context. These programmes are implemented under CLRTAP (EMEP and the group for evaluating the impacts of long-range transboundary air pollution), within the World Meteorological Organization (WMO) GAW programme, and in the framework of European

research infrastructures (ACTRIS, ICOS). Long-range transport of pollutants across the continent and beyond is addressed by the CLRTAP convention under the EMEP program. The program was established in 1977 and one of its main goals is to monitor long-term trends in air quality on a regional scale, based on measurements at selected background locations.

Current state of air quality in Europe

From the viewpoint of damage to human health in Europe, the greatest problems are caused by concentration levels of particulate matter (PM), ground-level ozone (O_3), nitrous oxide (NO_2) and carcinogenic benzo[a]pyrene. Polluted air causes serious health problems especially for inhabitants of cities and municipalities. Damage to ecosystems is most extensively induced by O_3, and, in addition, increased concentrations of nitrogen oxides (NO_x) contribute to nitrogen deposition causing eutrophication.

It has been estimated that, in the three-year 2016–2018 period, 13–17% of the urban population in the EU Member States were exposed to above-limit 24-hour PM_{10} concentrations, 4–8% to above-limit annual $PM_{2.5}$ concentrations, 15–22% to annual benzo[a]pyrene concentrations over the target value, 12–34% to O_3 concentrations greater than the target value and 4–7% to above-limit annual NO_2 concentrations (EEA 2020).
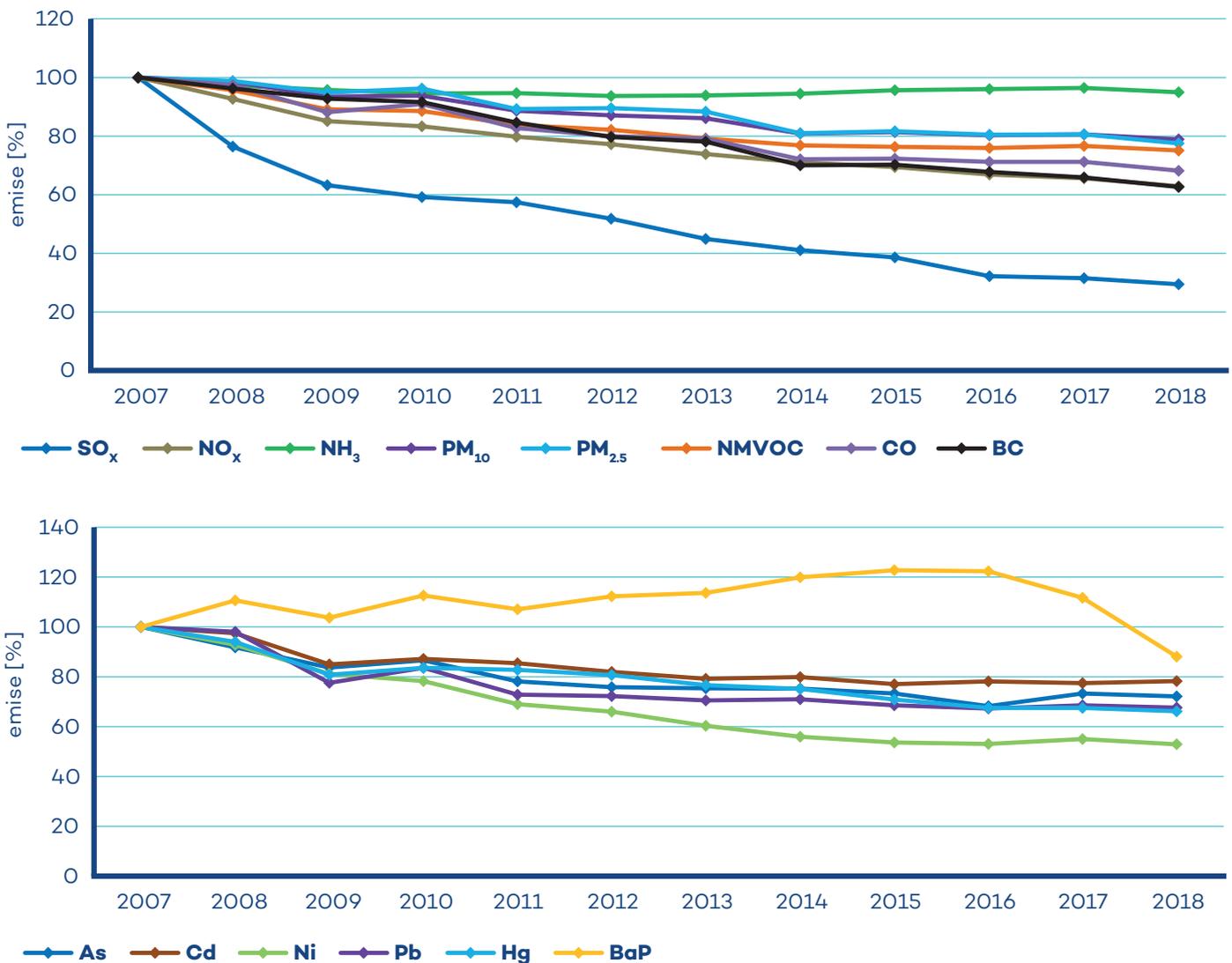
Pozn.: Emise jsou vyjádřeny podílem vůči emisím roku 2007. Údaje o využívání půdy, změny ve využívání půdy a lesnictví jsou k dispozici do roku 2012. Předávání zpráv o emisích BC je dobrovolné, nejsou tedy zahrnuty všechny státy.

Data viz National emissions reported to the Cenvention on Long-range Transboundary Air Pollution (LRTAP Convention)
https://www.eea.europa.eu/data-and-maps/dashboards/air-pollutant-emissions-data-viewer-3

Zdroj dat: EEA

Fig. VIII.1 Air pollutant emissions of 28 Member States of the European Union, 2007–2018

The estimate of the percentage of urban population exposed to concentrations higher than the values recommended by WHO was even greater, namely 43–48% concerning annual concentration of PM_{10}, 74–78% concerning annual concentration of $PM_{2.5}$, 75–90% concerning annual concentration of benzo[a]pyrene, 96–99% concerning O_3, 4–7% concerning annual concentration of NO_2, and 19–29% concerning 24-hour concentration of SO_2 (EEA 2020).
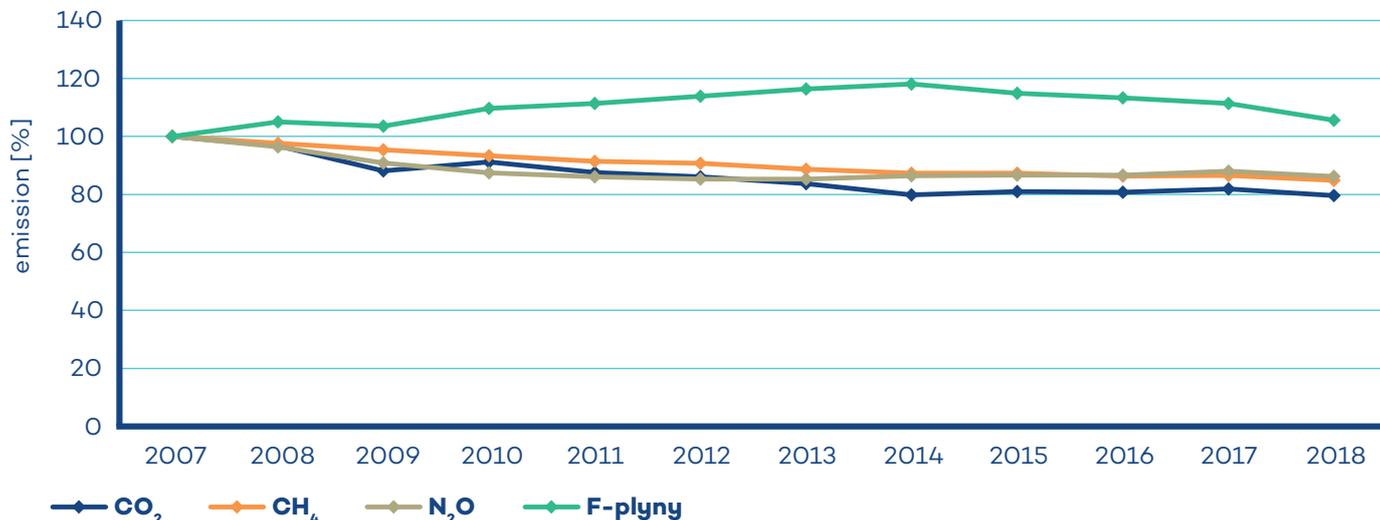
Pozn.: Emise jsou vyjádřeny podílem vůči emisím roku 2007. Emise jsou uvedeny včetně emisí ze sektoru využívání území, změny ve využívání území a lesnictví.

Data viz National inventory of greenhouse gas emissions 2020 (UNFCCC)
https://unfccc.int/ghg-inventories-annex-i-parties/2020

Zdroj dat: UNFCCC

Fig. VIII.2 Greenhouse gas emissions of 28 Member States of the European Union, 2007–2018
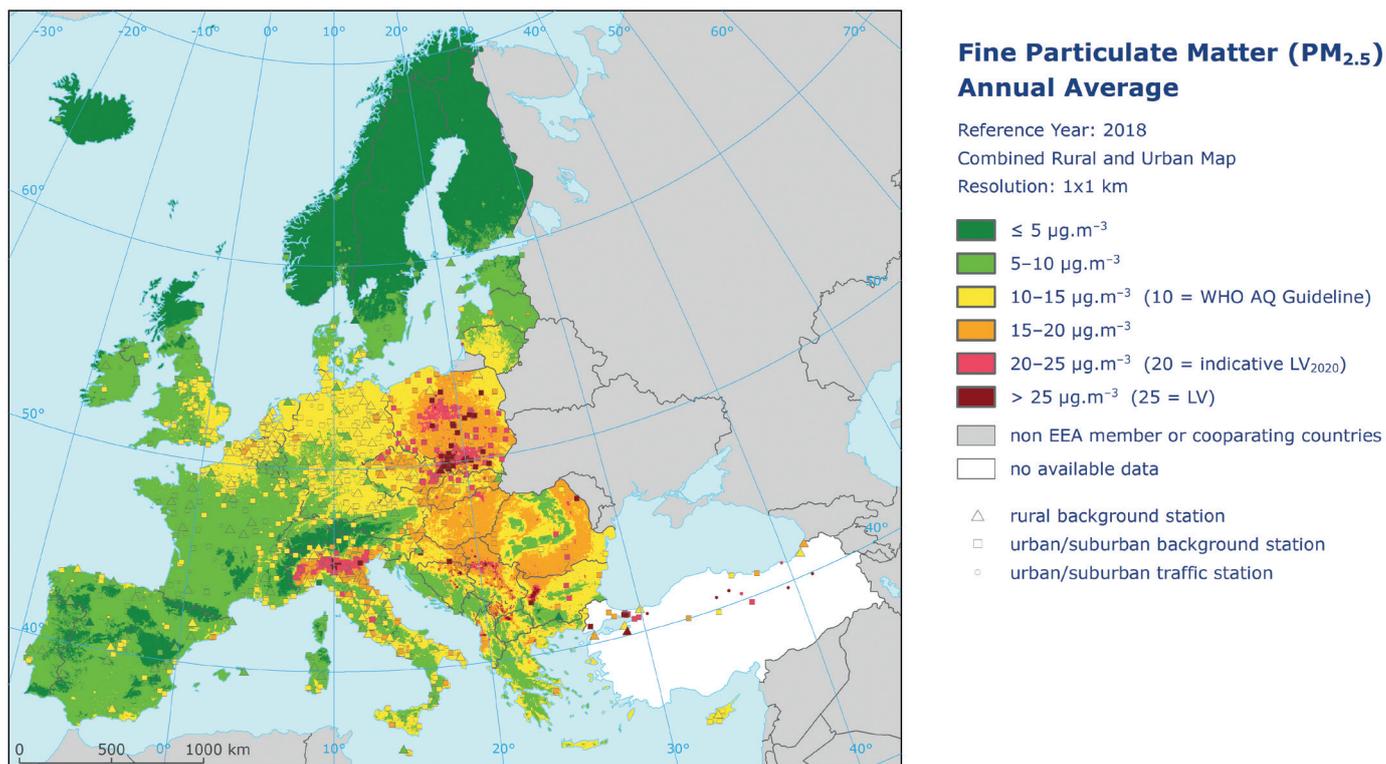
Fig. VIII.3 Field of annual average concentration of $PM_{2.5}$ in Europe, 2018

**Benzo[*a*]pyrene
Annual Average**

Reference Year: 2013
Combined Rural and Urban Background Map
Resolution: 1x1 km

≤ 0.12 ng.m⁻³
0.12–0.4 ng.m⁻³
0.4–0.6 ng.m⁻³
0.6–1 ng.m⁻³
1–1.5 ng.m⁻³ (1 = TV)
> 1.5 ng.m⁻³

non EEA member or cooparating countries
no available data

△ rural background station
□ urban/suburban background station
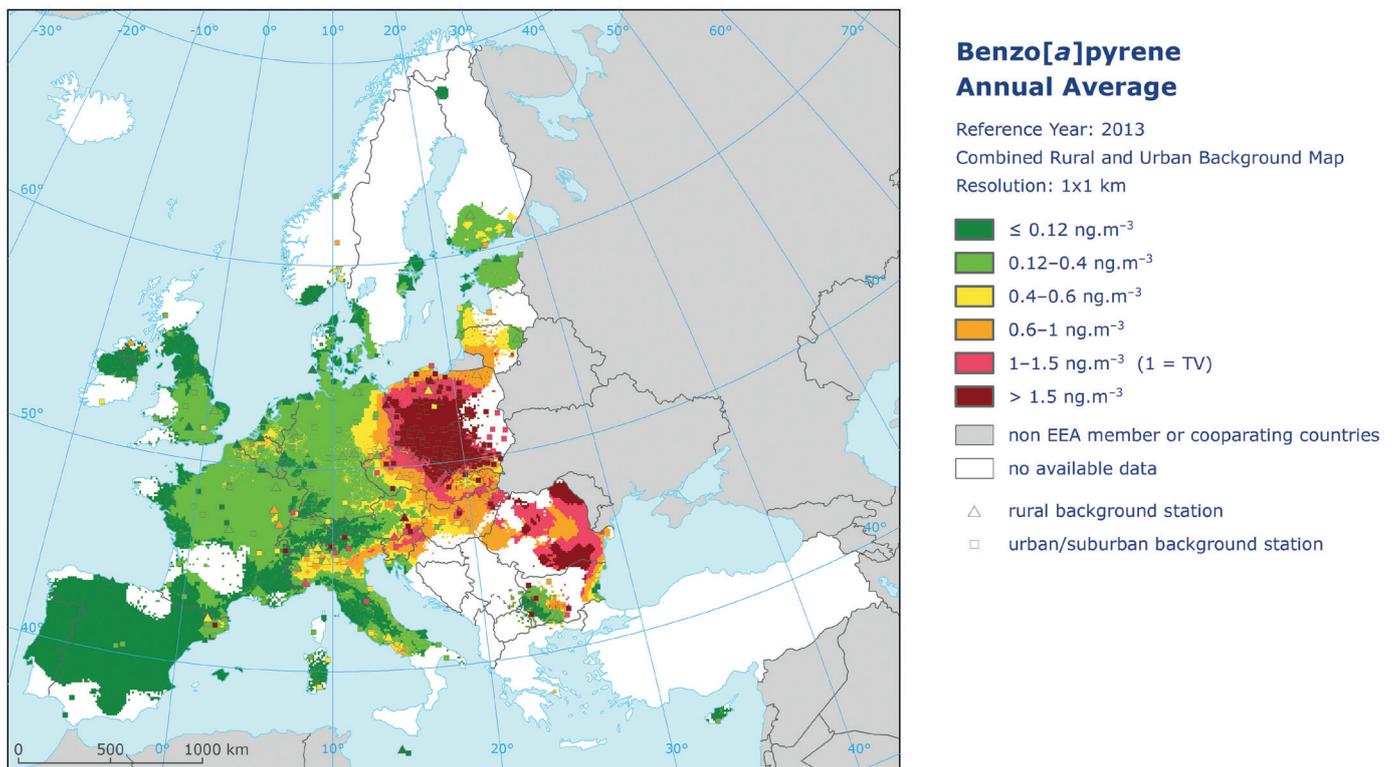
Fig. VIII.4 Field of annual average concentration of benzo[*a*]pyrene in Europe, 2018

**Nitrogen Dioxide (NO₂)
Annual Average**

Reference Year: 2018
Combined Rural and Urban Map
Resolution: 1x1 km

≤ 10 µg.m⁻³
10–20 µg.m⁻³
20–30 µg.m⁻³
30–40 µg.m⁻³
40–45 µg.m⁻³ (40 = LV)
> 45 µg.m⁻³

non EEA member or cooparating countries
no available data

△ rural background station
□ urban/suburban background station
◦ urban/suburban traffic station
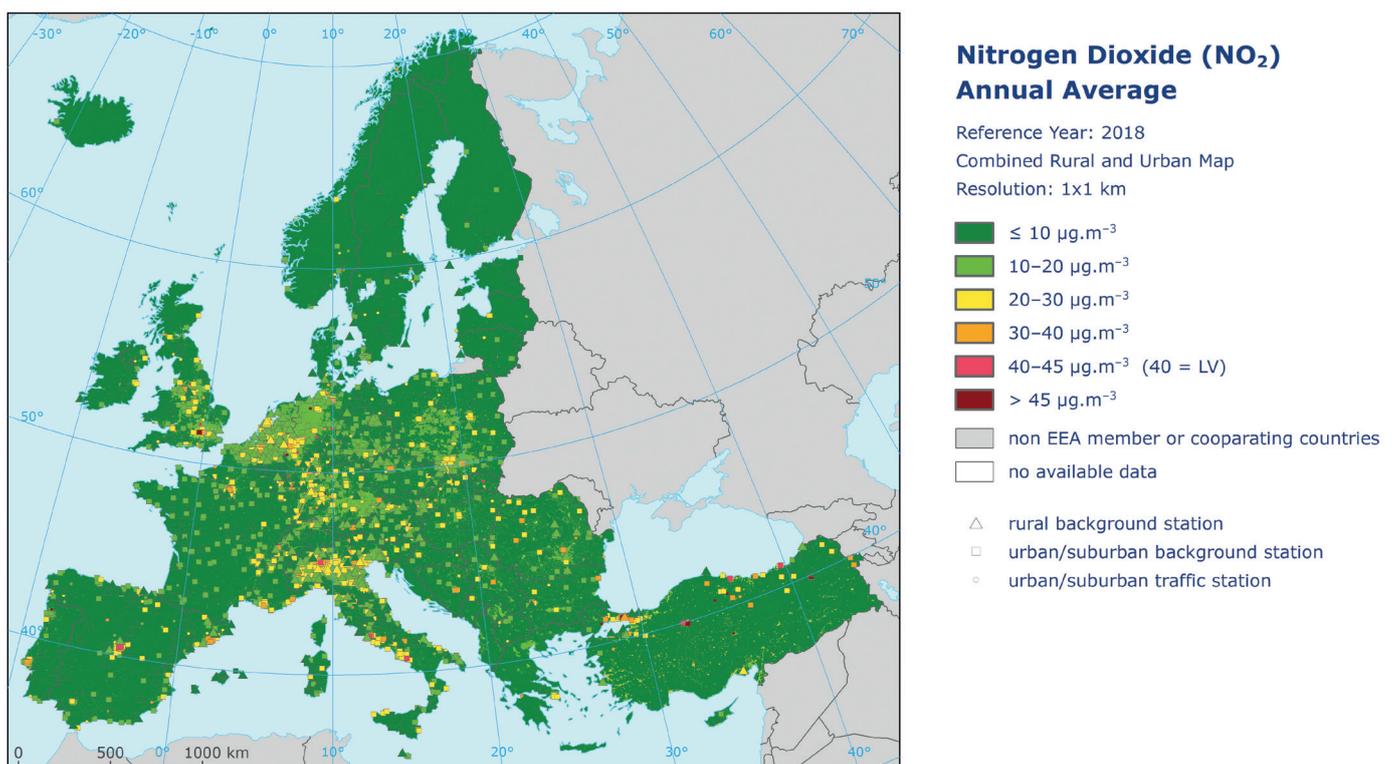
Fig. VIII.5 Field of annual average concentration of NO₂ in Europe, 2018
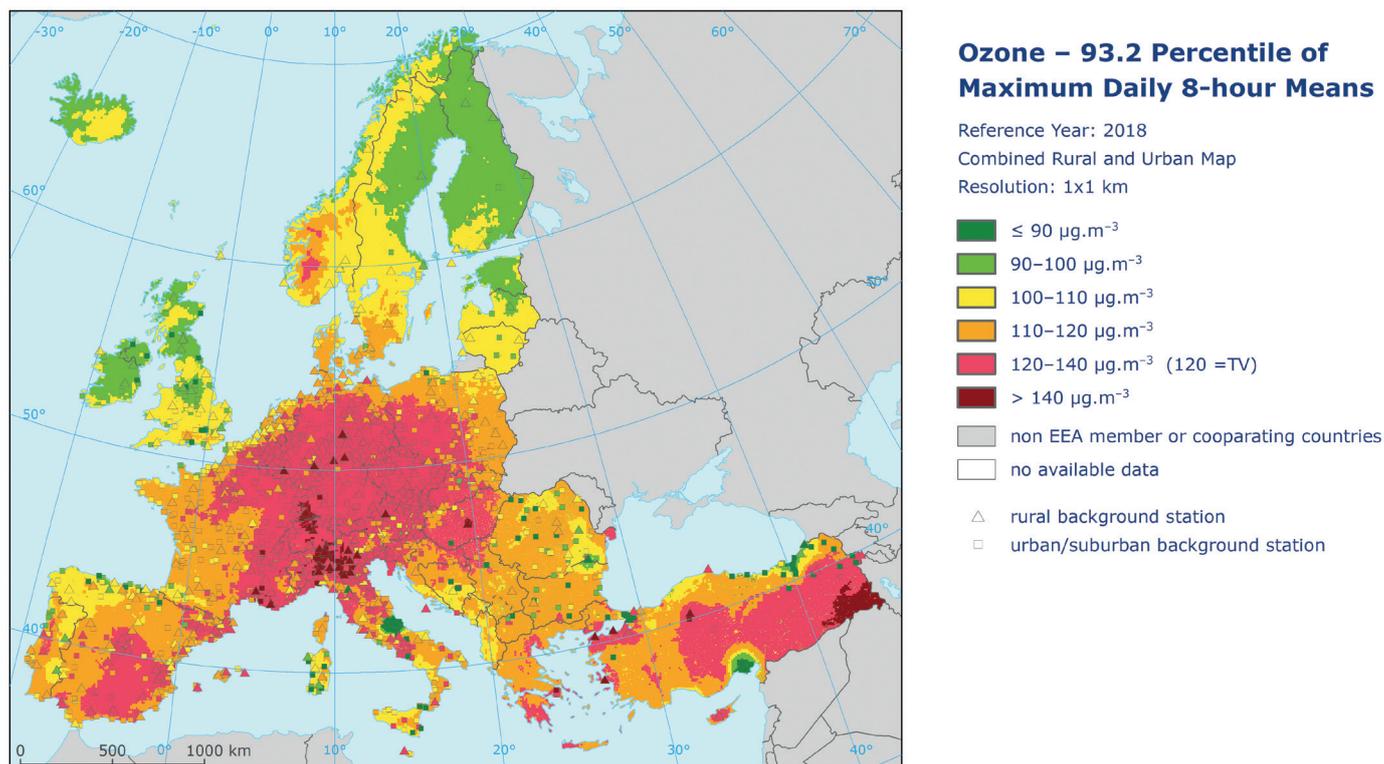
Fig. VIII.6 Field of 93.2 percentile of daily maximum 8-hour O$_3$ concentrations in Europe, 2018

Estimates of health impacts of the effect of polluted air indicate that long-term exposure to fine particulates PM$_{2.5}$ in Europe in 2018 contributed to approx. 417 thousand premature deaths, long-term exposure to high NO$_2$ concentrations to 55 thousand and short-term exposure to concentrations of O$_3$ to approx. 21 thousand premature deaths (EEA 2020).

The inhabitants of Central and Eastern Europe, including the Balkan Peninsula, suffer from the greatest exposure to above-limit concentrations of suspended particulates and benzo[a]pyrene, while the areas with the most widespread pollution also include the Po Valley in northern Italy (Fig. VIII.3, Fig. VIII.4).

Limit NO$_2$ concentrations are exceeded especially in areas affected by transportation (Fig. VIII.5). The occurrence of above-limit concentrations can also be anticipated in countries where these pollutants are monitored only at a limited number of sites or are not monitored at all or this data is not provided to EEA.

The primary pollutants that are derived from local and other emission sources are also accompanied by air pollution by secondary aerosol (Chap. IV.2.3, Chap. IV.9.3) and ground level ozone. In relation to the mechanism of its formation (Chap. IV.4.3), the ground level ozone concentrations increase from low values in northern Europe to the highest values especially in countries around the Mediterranean Sea (Fig. VIII.6).

Air quality of the Czech Republic in the European context

The pollution levels in various parts of the Czech Republic differ substantially. On the one hand, there are areas with very low pollution levels, in which the air quality is similar to that in the continuously unpopulated regions of Europe and the pollutant concentrations are well below the pollution limit levels. The data from the Czech EMEP background stations are comparable with the concentrations measured at similarly located Central European stations. On the other hand, the O/K/F-M agglomeration, together with the adjacent areas in the Republic of Poland, is among the most highly polluted regions of Europe, both from the standpoint of the extent and from the level of concentrations (Chap. IV.3). Transmission of pollutants across the border between the Czech Republic and neighbouring countries is the most intense in the Silesia area (for more details, see Chap. V.3 and Blažek et al. 2013). Obviously, polluted air flows across the state borders in other areas, but the mutual transboundary effect is much lower and its quantification or even an estimate of probable impact is mostly not available. In addition to the Silesia area, the share of various sources to the air pollution level has only been described in the Czech-Slovak boundary area of the Moravian-Silesia and Žilina regions (VŠB-TU Ostrava 2014).

Regarding the level of average concentrations per capita, in terms of suspended particulate matter PM$_{2.5}$, PM$_{10}$ and benzo[a]pyrene, the Czech Republic belongs to the above-average polluted countries, in terms of ozone, to the average to above-average polluted countries, and in terms of NO$_2$, to the average polluted countries (EEA 2019).

IX. ATMOSPHERIC DEPOSITION IN THE TERRITORY OF THE CZECH REPUBLIC

Atmospheric deposition refers to the flux of substances from the atmosphere to the surface of the Earth (Braniš, Hůnová 2009). This is an important process contributing to self-purification of the air; on the other hand, however, it is responsible for input of pollutants into other components of the environment. Atmospheric deposition has both wet and dry components. The wet component is connected with the occurrence of atmospheric precipitation (vertical deposition: rain and snow, and horizontal deposition: fog and rime) and is thus episodic in character. The dry component corresponds to the deposition of gases and particles by various mechanisms and occurs continuously.

The atmospheric deposition of most monitored substances in Europe has decreased substantially over the past twenty years but still remains a problem in a number of regions (EEA 2011). In the Czech Republic, the chemical composition of atmospheric precipitation and atmospheric deposition has been monitored for a long time at a relatively large number of localities.

In 2019, data on the chemical composition of atmospheric precipitation were provided to the Air Quality Information System (AQIS) from 38 locations in the Czech Republic (Fig. IX.1, Tab. IX.4). In the Czech Republic, measurements are provided by CHMI (14 localities), CGS (10 localities), VÚLHM (9 localities), HBÚ AV ČR (2 localities), and ÚH AV ČR, ÚVGZ AV ČR and GLÚ AV ČR (1 locality each).

The substances presented in the atmospheric deposition chapter have no limit values set by legislation as in the case of pollution. Therefore, another colour scale has been chosen to improve clarity of the depositions maps. More detailed information on atmospheric deposition, sampling, measurement and quantification of its components and specifications for preparation of maps are available at CHMI (2020d).
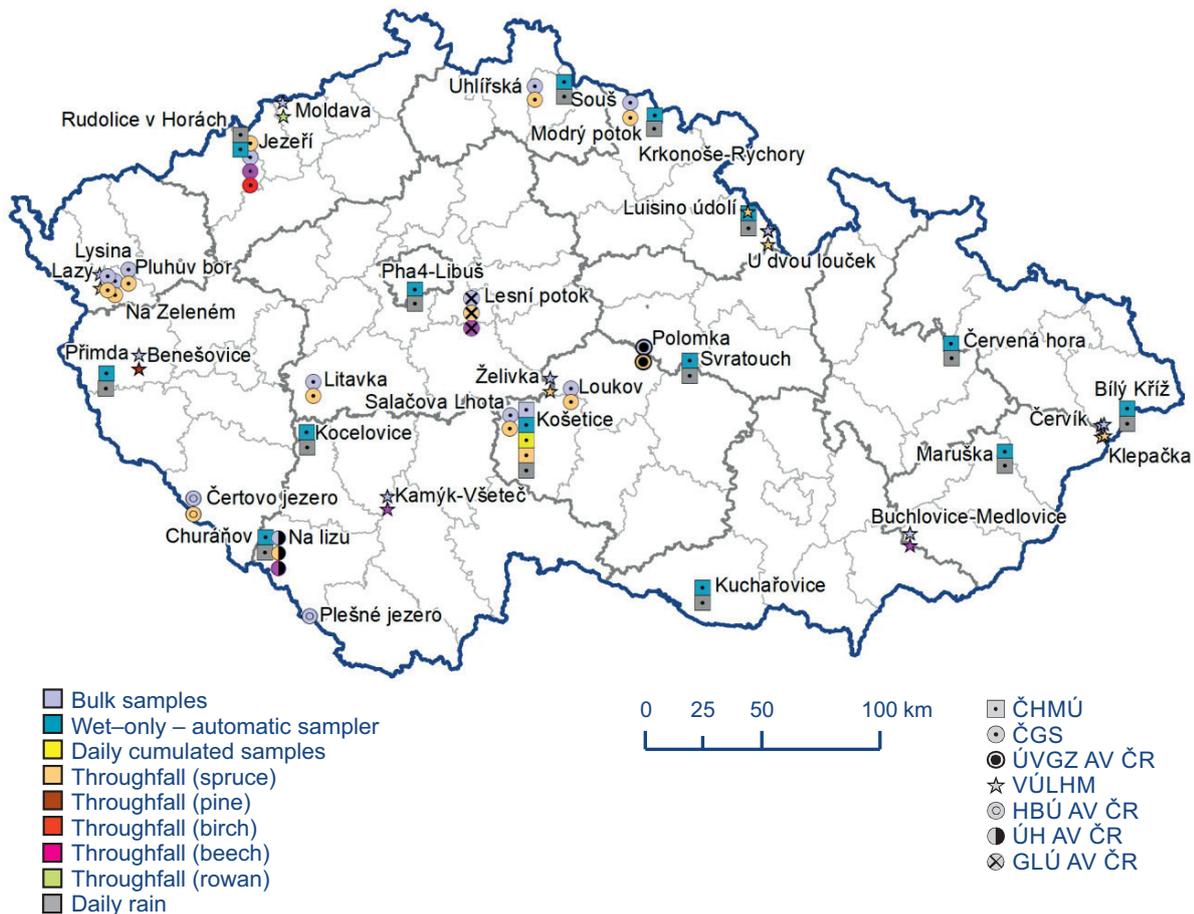
Fig. IX.1 Station networks monitoring atmospheric precipitation quality and atmospheric deposition, 2019

Bulk samples
Wet–only – automatic sampler
Daily cumulated samples
Throughfall (spruce)
Throughfall (pine)
Throughfall (birch)
Throughfall (beech)
Throughfall (rowan)
Daily rain

ČHMÚ
ČGS
ÚVGZ AV ČR
VÚLHM
HBÚ AV ČR
ÚH AV ČR
GLÚ AV ČR

Results

The year 2019 was normal in terms of precipitation. The average annual precipitation of 634 mm represents 92% of the long-term normal 1981–2010 (for more see Chapter III). Higher precipitation totals compared to 2018 (518 mm) resulted in an increase in wet deposition of reduced forms of nitrogen ($N\_NH_4^+$), total wet deposition of nitrogen and wet deposition of cadmium.

Deposition of sulphur

The field of total sulphur deposition represents the total level of sulphur deposition on the area of the Czech Republic. Its quantification is based on concentrations of SO_4^{2-} measured in atmospheric precipitation and SO_2 air pollution concentrations. In 2019, this value was 33,032 t (Table IX.2), compared to 2018, when the value of total sulphur deposition was 34,581 t. Total sulphur deposition exhibits maxima in the Krušné hory and Ostrava areas (Fig. IX.4).

The partial components of sulphur deposition also reached lower values. Wet deposition of sulphur ($S\_SO_4^{2-}$) reached the value of 13,657 t in 2019, while in 2018 the value was 14,682 t. The highest values of the wet component were then reached in the mountain areas, namely in the Moravian-Silesian Beskydy, Jeseníky, Krkonoše and in the Bohemian-Moravian Highlands (Fig. IX.2). In 2019, the dry deposition of sulphur (S_SO_2) amounted to 19,365 t, while in 2018 it was 19,899 t. The highest values of the dry component were reached in the Krušné hory and the Moravian-Silesian Beskydy (Fig. IX.3).

In 2019, throughfall deposition of sulphur ($S\_SO_4^{2-}$) in forested areas of the Czech Republic attained a value of 10,707 t with maximum values occurring in the mountain areas (Fig. IX.5). Map view of the throughfall sulphur deposition was prepared for forested areas on the basis of the sulphur concentration fields for throughfall precipitation and from the verified precipitation field, modified by the percentage amount of precipitation measured under vegetation at the individual stations in the range of 55% (Košetice) to 102% (U dvou louček) of the total precipitation in open areas in 2019. Throughfall deposition generally includes wet vertical and horizontal deposition (from fogs, low clouds and rime) and dry deposition of particles and gases in forests.

deposition flux [g.m⁻².year⁻¹]	
≤ 0.15	34.1 %
(0.15–0.20>	42.6 %
(0.20–0.25>	16.6 %
(0.25–0.35>	6.3 %
(0.35–0.50>	0.4 %

ČHMÚ
ČGS
ÚVGZ AV ČR
VÚLHM
ÚH AV ČR
GLÚ AV ČR

— region

0 25 50 100 km
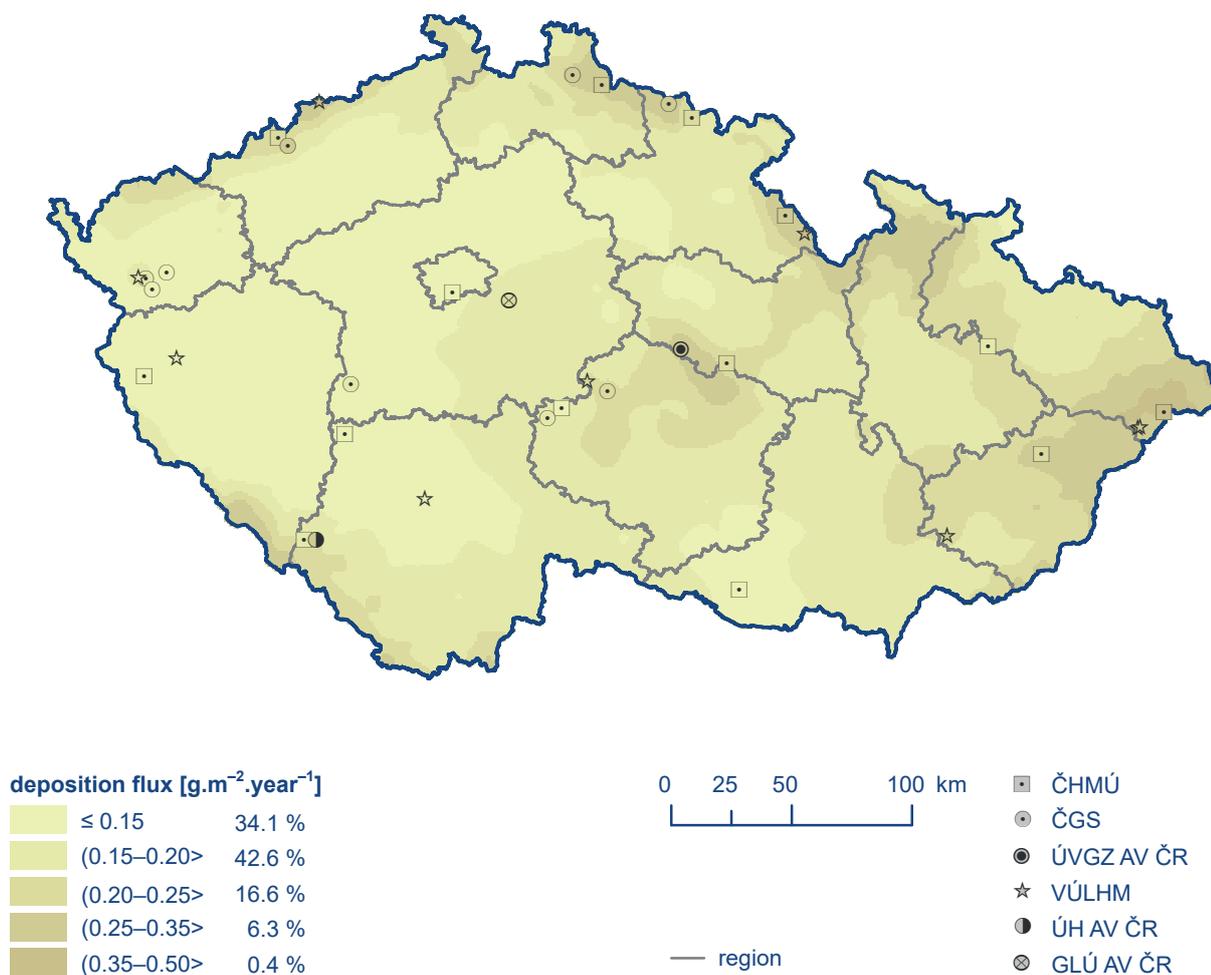
Fig. IX.2 Field of annual wet deposition of sulphur (S_SO₄²⁻), 2019

deposition flux [g.m^{-2}.year^{-1}]

≤ 0.15	12.2 %			
(0.15–0.20>	35.8 %		(0.50–1.0>	2.4 %
(0.20–0.25>	13.2 %		(1.0–1.5>	0.03 %
(0.25–0.35>	23.7 %		(1.5–2.0>	0.001 %
(0.35–0.50>	12.7 %		(2.0–3.0>	0.001 %
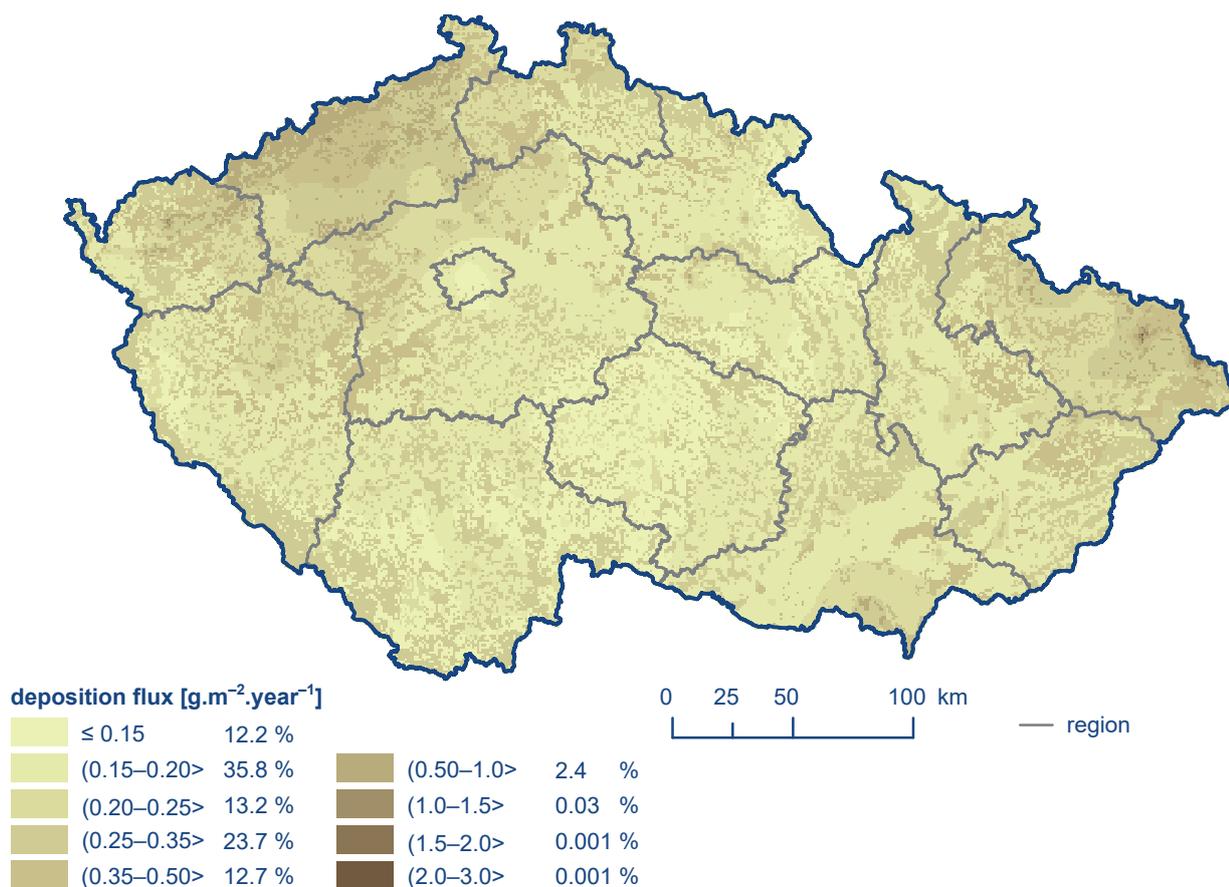
Fig. IX.3 Field of annual dry deposition of sulphur (S_SO$_2$), 2019

deposition flux [g.m^{-2}.year^{-1}]

≤ 0.15				
(0.15–0.20>			(0.50–1.0>	23.0 %
(0.20–0.25>	0.2 %		(1.0–1.5>	0.1 %
(0.25–0.35>	38.4 %		(1.5–2.0>	0.01 %
(0.35–0.50>	38.3 %		(2.0–3.0>	0.001 %
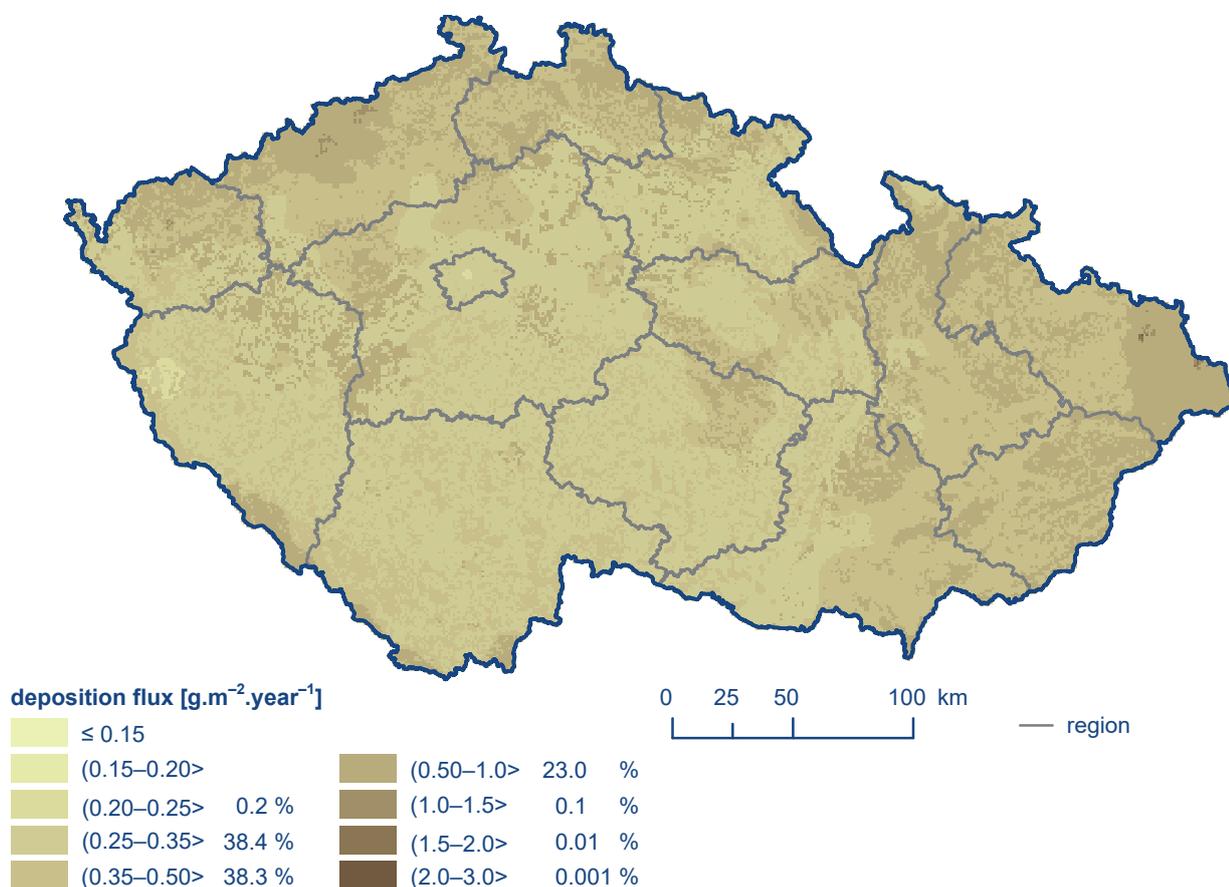
Fig. IX.4 Field of annual total deposition of sulphur, 2019

deposition flux [g.m⁻².year⁻¹]

≤ 0.15	
(0.15–0.20> 0.7 %	(0.50–1.0> 19.0 %
(0.20–0.25> 10.2 %	(1.0–1.5> 0.5 %
(0.25–0.35> 29.6 %	(1.5–2.0> 0.05 %
(0.35–0.50> 40.0 %	unforested area

0 25 50 100 km

region

- ČHMÚ
- ČGS
- ÚVGZ AV ČR
- VÚLHM
- ÚH AV ČR
- GLÚ AV ČR
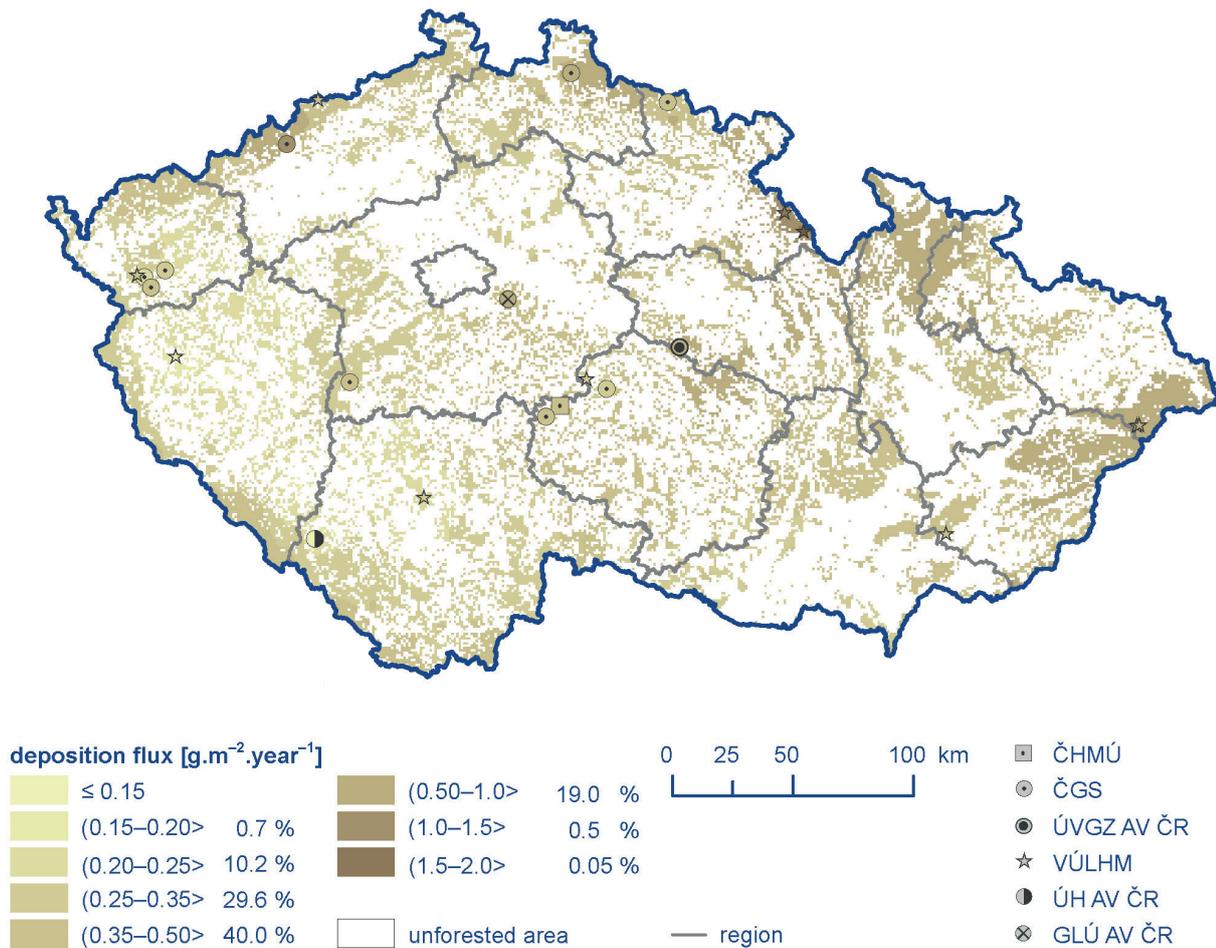
Fig. IX.5 Field of annual throughfall deposition of sulphur, 2019

Tab. IX.1 Average deposition fluxes of S, N and H in the Czech Republic, 2019

Element	Deposition	g.m⁻².year⁻¹	keq.ha⁻¹.year⁻¹
S (SO₄²⁻)	wet	0.173	0.108
S (SO₂)	dry	0.246	0.153
S	total	0.419	0.261
N (NO₃⁻)	wet	0.201	0.143
N (NH₄⁺)	wet	0.310	0.221
N (NOₓ)	dry	0.184	0.131
N	total	0.694	0.496
H (pH)	wet	0.004	0.036
H (SO₂, NOₓ)	dry	0.028	0.282
H	total	0.032	0.319

Tab. IX.2 Estimate of the wet, dry and total annual deposition of the given elements on the area of the Czech Republic (78,841 sq. km) in tonnes, 2019

	Deposition [t]		
	wet	**dry**	**total**
S	13,657	19,365	33,032
N (ox)	15,815	14,497	30,312
N (red)	24,437		
N (ox + red)	40,252		54,749
H+	290	2,245	2,535
Pb	31	18	
Cd	1.6	1.1	

Tab. IX.3 Estimate of the total and throughfall annual deposition of sulphur on the forested area of the Czech Republic (26,428 sq. km) in tonnes, 2001–2019

	Deposition [t]	
	total	throughfall
2001	27,894	36,899
2002	25,984	31,011
2003	21,306	26,818
2004	23,247	32,835
2005	22,855	26,461
2006	21,975	25,660
2007	17,445	29,279
2008	15,528	30,197
2009	16,590	26,193
2010	17,621	27,944
2011	15,118	18,691
2012	15,311	19,079
2013	16,530	19,723
2014	16,810	12,836
2015	13,294	16,044
2016	12,625	19,724
2017	14,621	12,608
2018	14,870	14,002
2019	13,133	10,707

Deposition of nitrogen

The total nitrogen deposition on the area of the Czech Republic in 2019 equalled 54,749 t (Tab. IX.2). As with sulphur deposition, there was a decrease compared to 2018 when the value was 57,674 t. The highest values of total nitrogen deposition were reached in the Jeseníky, Moravian-Silesian Beskydy, Orlické Mountains, Šumava and Novohradské Mountains (Fig. IX.10).

Some partial components of nitrogen deposition also reached somewhat lower values. Wet deposition of oxidized forms of nitrogen (N_NO$_3^-$) reached the value of 15,815 t in 2019 (Fig. IX.6), while in 2018 the value was 16,073 t. On the contrary, wet deposition of reduced forms (N_NH$_4^+$) increased in 2019 to value of 24,437 t (Fig. IX.7) compared to 2018, when the value was 23,892 t. The total wet deposition of nitrogen (sum of wet deposition of N_NO$_3^-$ and N_NH$_4^+$) in 2019 was equal to 40,252 t, while in 2018 to only 39,965 t. The highest values of total wet nitrogen deposition were recorded in the Šumava, Krkonoše, Jizerské Mountains, Orlické Mountains, Bohemian-Moravian Highlands, Jeseníky and Moravian-Silesian Beskydy (Fig. IX.8).

The value of dry deposition of oxidized forms of nitrogen (N_NO$_x$) reached the value of 14,497 t in 2019, while in 2018 it was up to 17,709 t. The highest values were reached in the territory of larger cities and along important roads (Fig. IX.9).

deposition flux [g.m^{-2}.year^{-1}]

	≤ 0.20	52.5 %
	(0.20–0.25>	35.4 %
	(0.25–0.35>	11.1 %
	(0.35–0.50>	1.0 %

0   25   50   100 km

— region

- ▫ ČHMÚ
- ⊙ ČGS
- ◉ ÚVGZ AV ČR
- ☆ VÚLHM
- ◑ ÚH AV ČR
- ⊗ GLÚ AV ČR
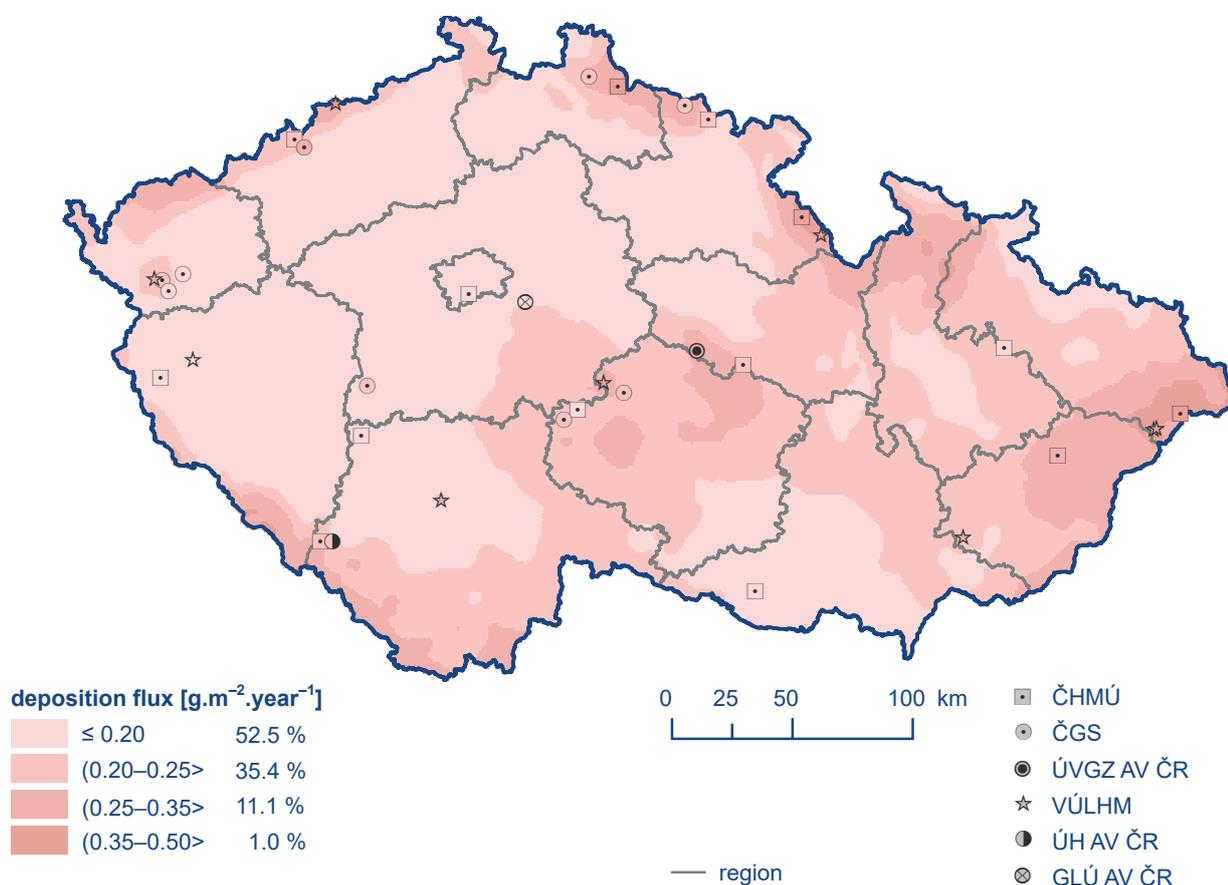
Fig. IX.6 Field of annual wet deposition of nitrogen (N_NO$_3^-$), 2019

deposition flux [g.m⁻².year⁻¹]

≤ 0.20	4.9 %
(0.20–0.25>	17.2 %
(0.25–0.35>	54.4 %
(0.35–0.50>	19.8 %
(0.50–0.75>	3.4 %

(0.75–1.00>	0.3 %
(1.00–1.50>	0.002 %

0   25   50   100 km

— region

⊡ ČHMÚ
⊙ ČGS
◉ ÚVGZ AV ČR
☆ VÚLHM
◑ ÚH AV ČR
⊗ GLÚ AV ČR
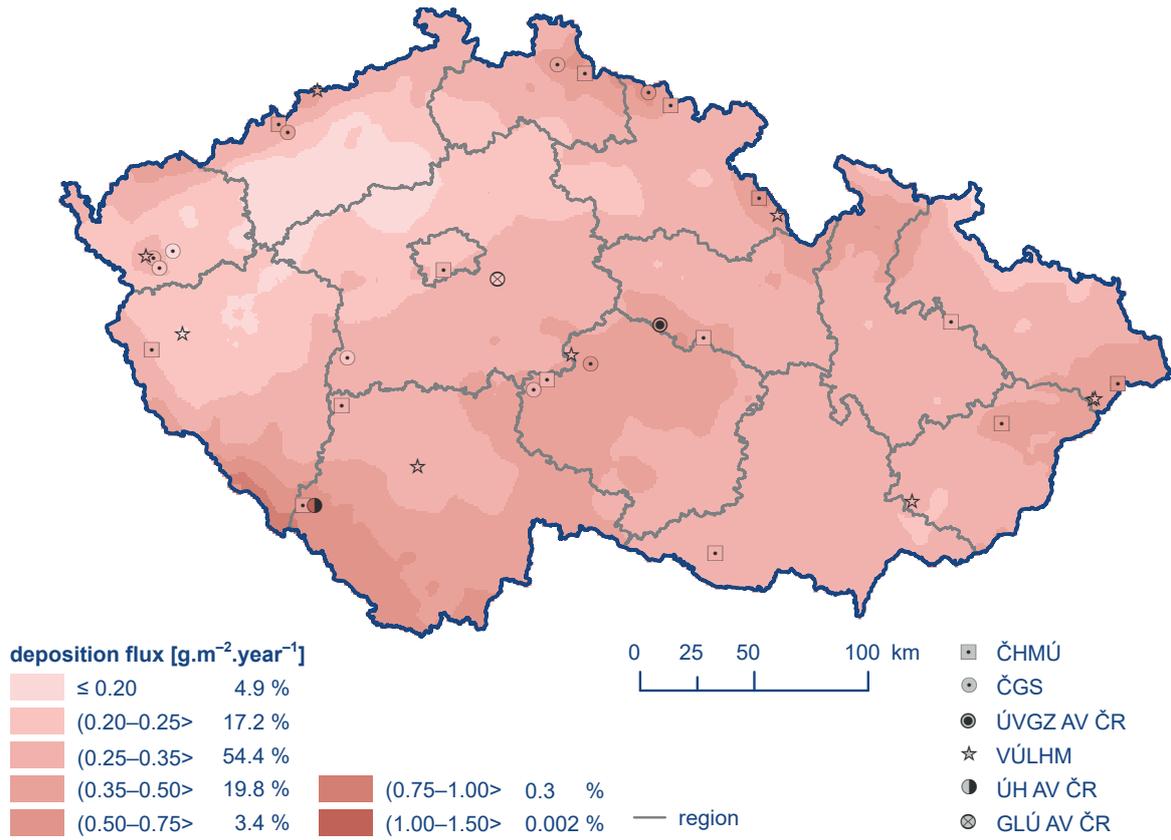
Fig. IX.7 Field of annual wet deposition of nitrogen (N_NH₄⁺), 2019

deposition flux [g.m⁻².year⁻¹]

≤ 0.20	
(0.20–0.25>	
(0.25–0.35>	6.8 %
(0.35–0.50>	45.1 %
(0.50–0.75>	42.9 %

(0.75–1.00>	
(1.00–1.50>	
(1.50–2.00>	4.6 %
(2.00–3.00>	0.6 %

0   25   50   100 km

— region
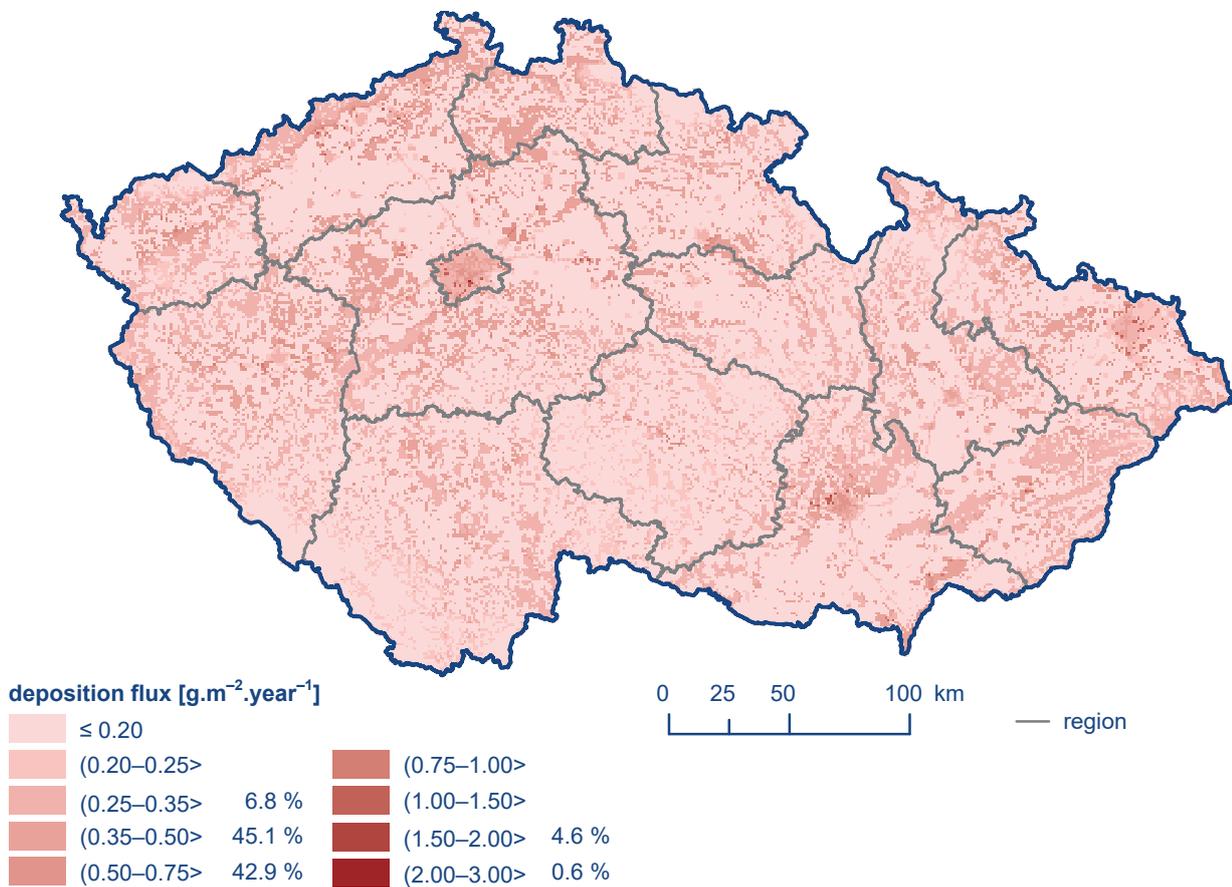
Fig. IX.8 Field of annual total wet deposition of nitrogen, 2019

deposition flux [g.m^{-2}.year^{-1}]

≤ 0.20	67.2 %			
(0.20–0.25>	5.9 %	(0.75–1.00>	0.2 %	
(0.25–0.35>	14.9 %	(1.00–1.50>	0.1 %	
(0.35–0.50>	10.0 %	(1.50–2.00>	0.003 %	
(0.50–0.75>	1.7 %	(2.00–3.00>	0.001 %	

0   25   50   100 km

—— region
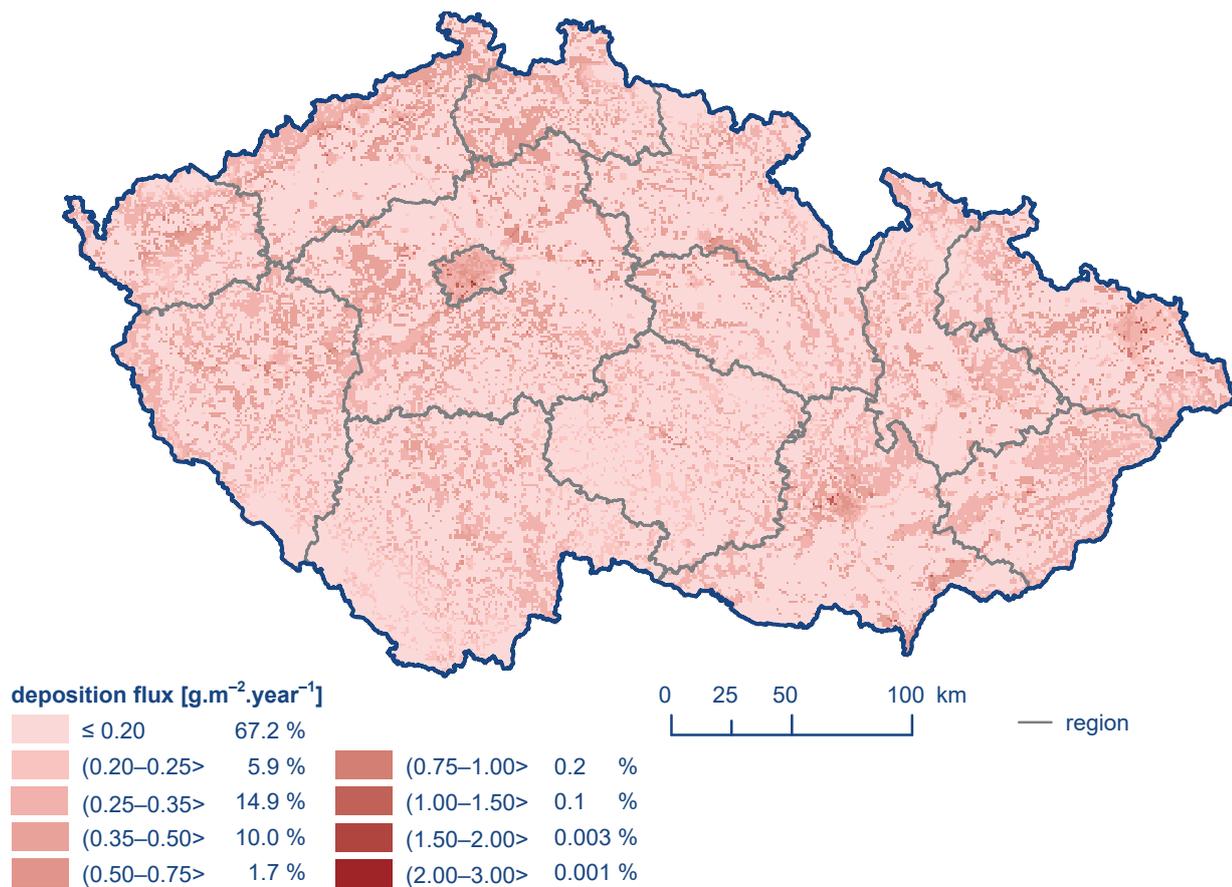
Fig. IX.9 Field of annual dry deposition of nitrogen (N_NO$_x$), 2019

deposition flux [g.m^{-2}.year^{-1}]

≤ 0.20				
(0.20–0.25>				
(0.25–0.35>		(0.75–1.00>	30.5 %	
(0.35–0.50>	9.6 %	(1.00–1.50>	4.4 %	
(0.50–0.75>	55.5 %	(1.50–2.00>	0.03 %	
		(2.00–3.00>	0.01 %	

0   25   50   100 km

—— region
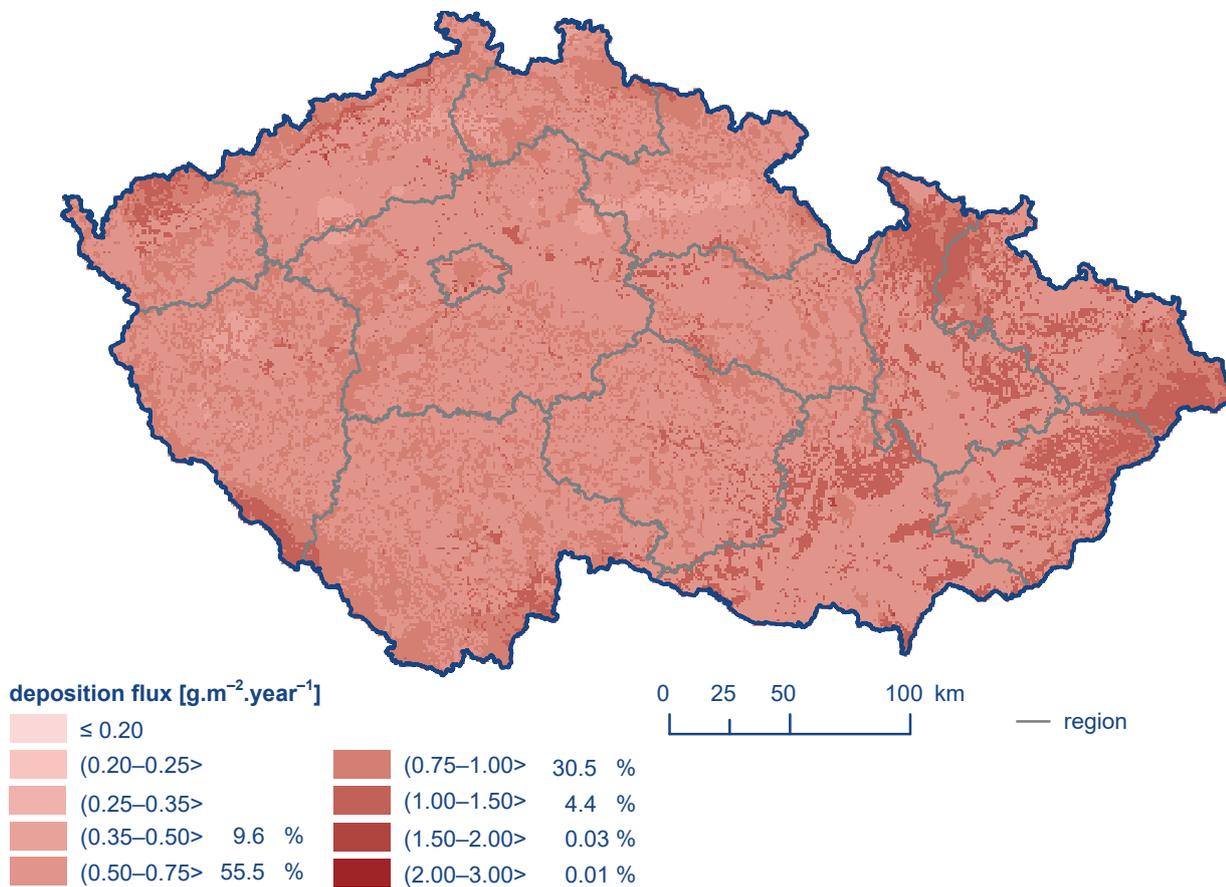
Fig. IX.10 Field of annual total deposition of nitrogen, 2019

Deposition of hydrogen, lead, cadmium, nickel and chloride ions

The total deposition of hydrogen ions on the area of the Czech Republic in 2019 was equal to 2,535 t (Table IX.2, Fig. IX.13). Compared to 2018 (2,805 t), this is a slight decrease. The wet component of hydrogen ion deposition reached 290 t in 2019 (Fig. IX.11) which is comparable to 2018 when the value was 296 t. In contrast, the dry component in 2019 was equal to 2,245 t (Fig. IX.12) and compared to 2018 (2,509 t) it is therefore a slight decrease. The deposition of hydrogen ions in the Šumava, Krušné Mountains, Jizerské Mountains, Orlické Mountains, the Hrubý Jeseník and Moravian-Silesian Beskydy reached the highest values.

Lead wet deposition in 2019 (31 t) was lower than in 2018 (37 t). The highest values were reached in the area of the Jizerské Mountains, Orlické Mountains, Jeseníky Mountains and the Moravi-an-Silesian Beskydy (Fig. IX.15). Dry deposition of lead showed a more significant decrease, reaching 18 t in 2019, while 28 t in 2018. The highest values were reached in the Ostrava, Moravian--Silesian Beskydy and Brdy regions (Fig. IX.16).

Wet deposition of cadmium reached 1.6 t in 2019 which means a year-on-year increase compared to 2018 (1.3 t). On the contrary, dry deposition was lower in 2019 (1.1 t) compared to 2018 (1.3 t). In the long run, cadmium deposition reaches the highest values in the Jablonec nad Nisou district (Fig. IX.17, Fig. IX.18).

Annual wet deposition of nickel ions reaches the highest values in the Uhlířská, Modrý potok, Polomka and U dvou louček localities (Fig. IX.19). Wet deposition of chloride ions attains, similarly to other monitored pollutants, higher values in mountain areas in the Czech Republic (Fig. IX.14).

deposition flux [mg.m^{-2}.year^{-1}]	
≤ 2.5	6.7 %
(2.5–5>	84.5 %
(5–7.5>	7.3 %
(7.5–10>	1.4 %
(10–25>	0.1 %

0   25   50   100 km

— region

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ČGS
ÚVGZ AV ČR
VÚLHM
ÚH AV ČR
GLÚ AV ČR
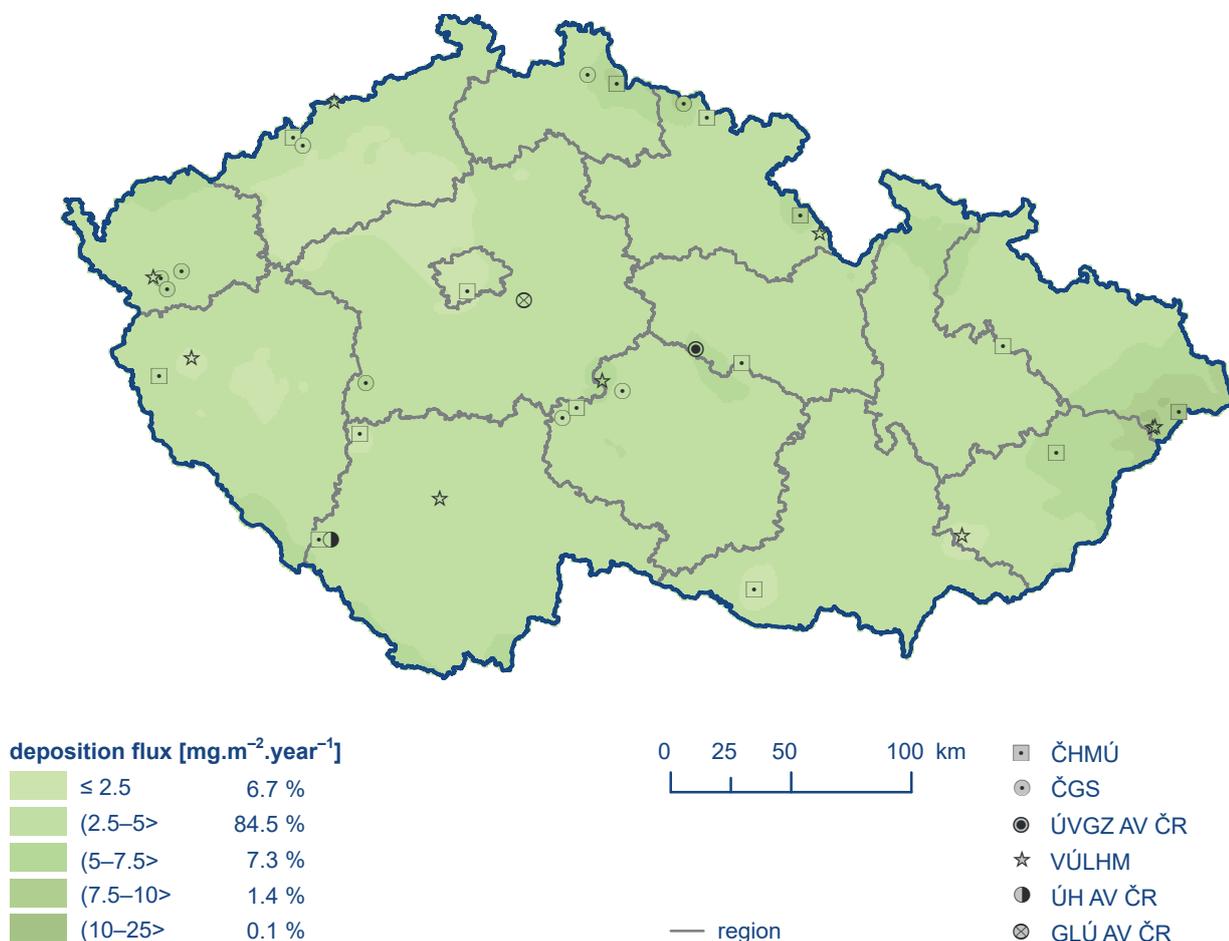
Fig. IX.11 Field of annual wet deposition of hydrogen ions, 2019

deposition flux [mg.m^{-2}.year^{-1}]

	≤ 2.5				
	(2.5–5>			(25–50>	33.1 %
	(5–7.5>			(50–100>	9.8 %
	(7.5–10>	0.04 %		(100–150>	0.2 %
	(10–25>	56.9 %		(150–250>	0.01 %

0   25   50   100 km

— region
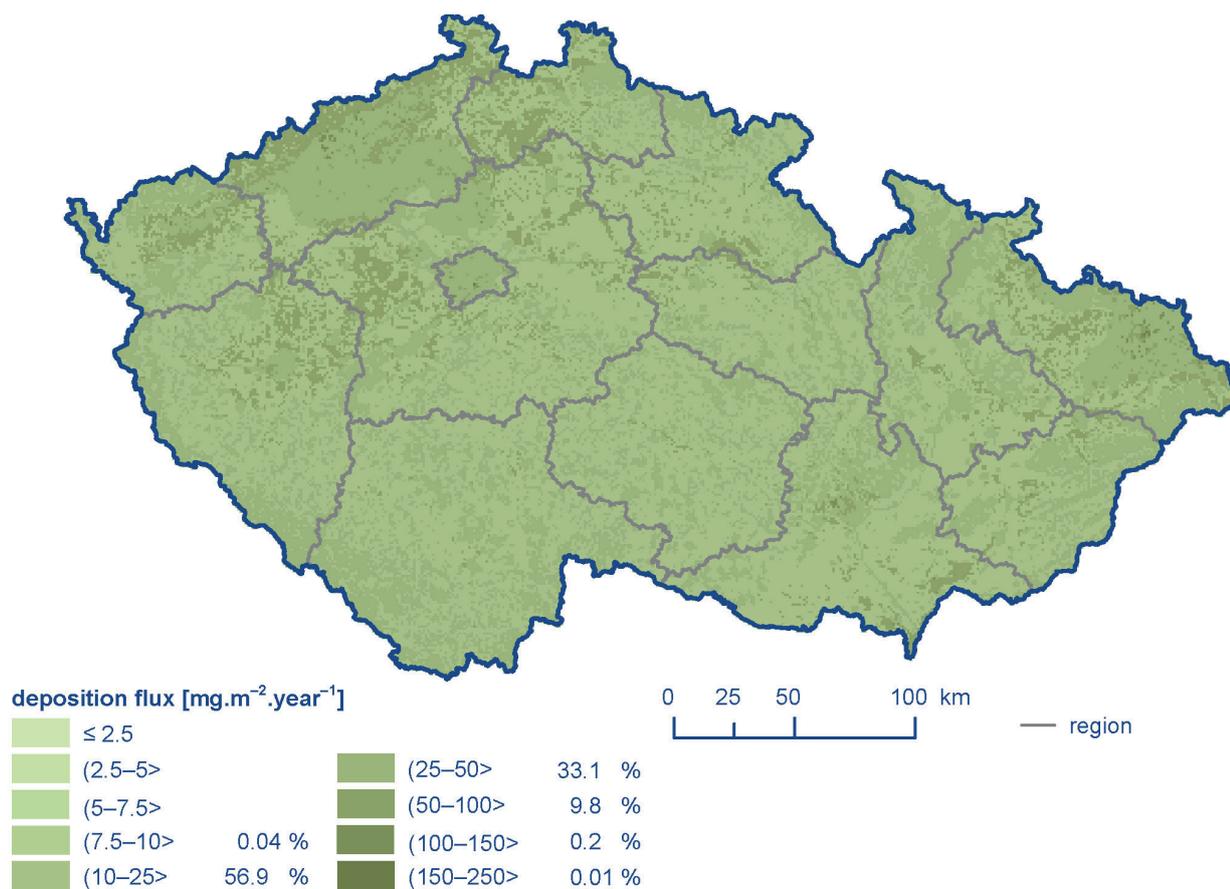
Fig. IX.12 Field of annual dry deposition of hydrogen ions corresponding to SO$_2$ and NO$_x$ gas deposition, 2019

deposition flux [mg.m^{-2}.year^{-1}]

	≤ 2.5				
	(2.5–5>			(25–50>	37.8 %
	(5–7.5>			(50–100>	13.4 %
	(7.5–10>			(100–150>	0.2 %
	(10–25>	48.6 %		(150–250>	0.01 %

0   25   50   100 km

— region
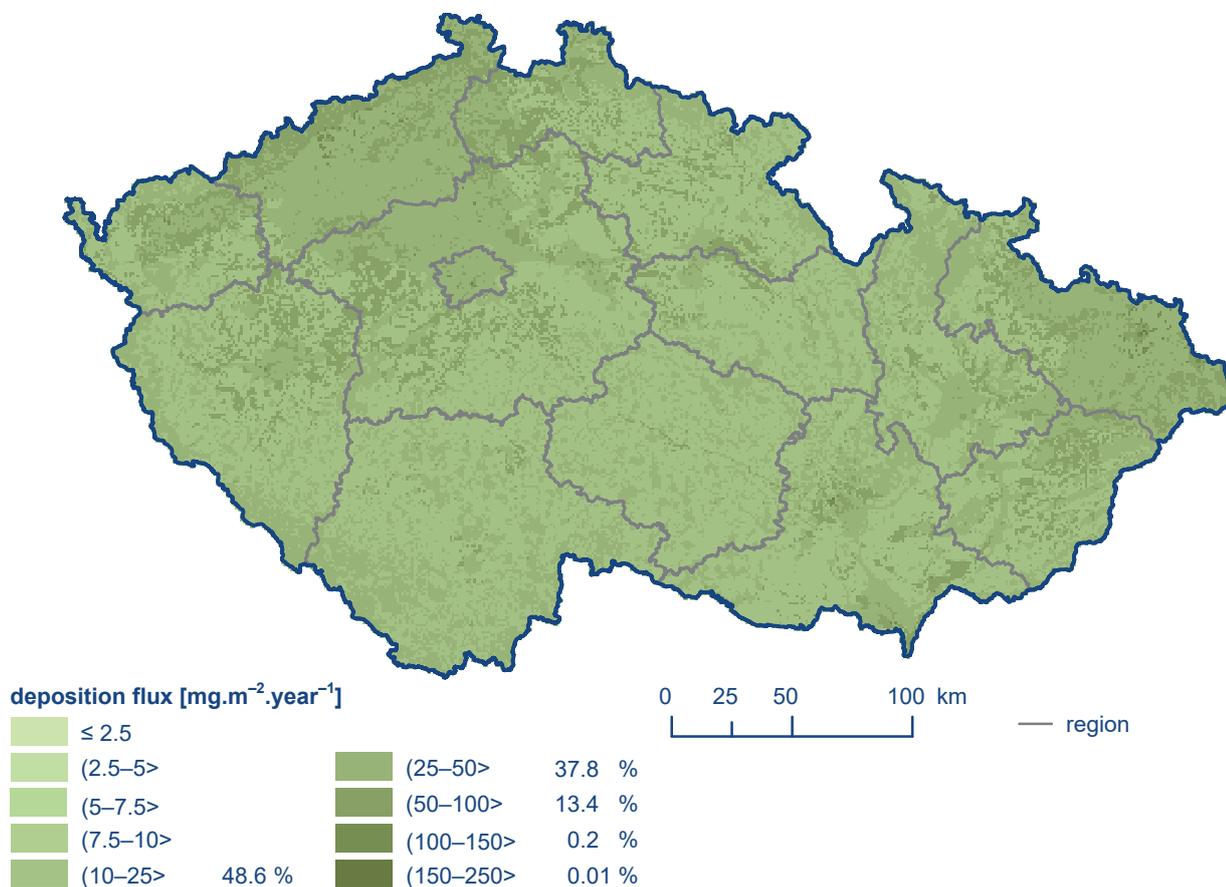
Fig. IX.13 Field of annual total deposition of hydrogen ions, 2019

deposition flux [g.m⁻².year⁻¹]

≤ 0.10	1.7 %	
(0.10–0.15>	34.7 %	
(0.15–0.20>	41.1 %	
(0.20–0.25>	11.7 %	(0.35–0.50> 1.8 %
(0.25–0.35>	8.9 %	(0.50–0.75> 0.1 %

region

0   25   50   100 km

◻ ČHMÚ
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◉ ÚVGZ AV ČR
☆ VÚLHM
◑ ÚH AV ČR
⊗ GLÚ AV ČR
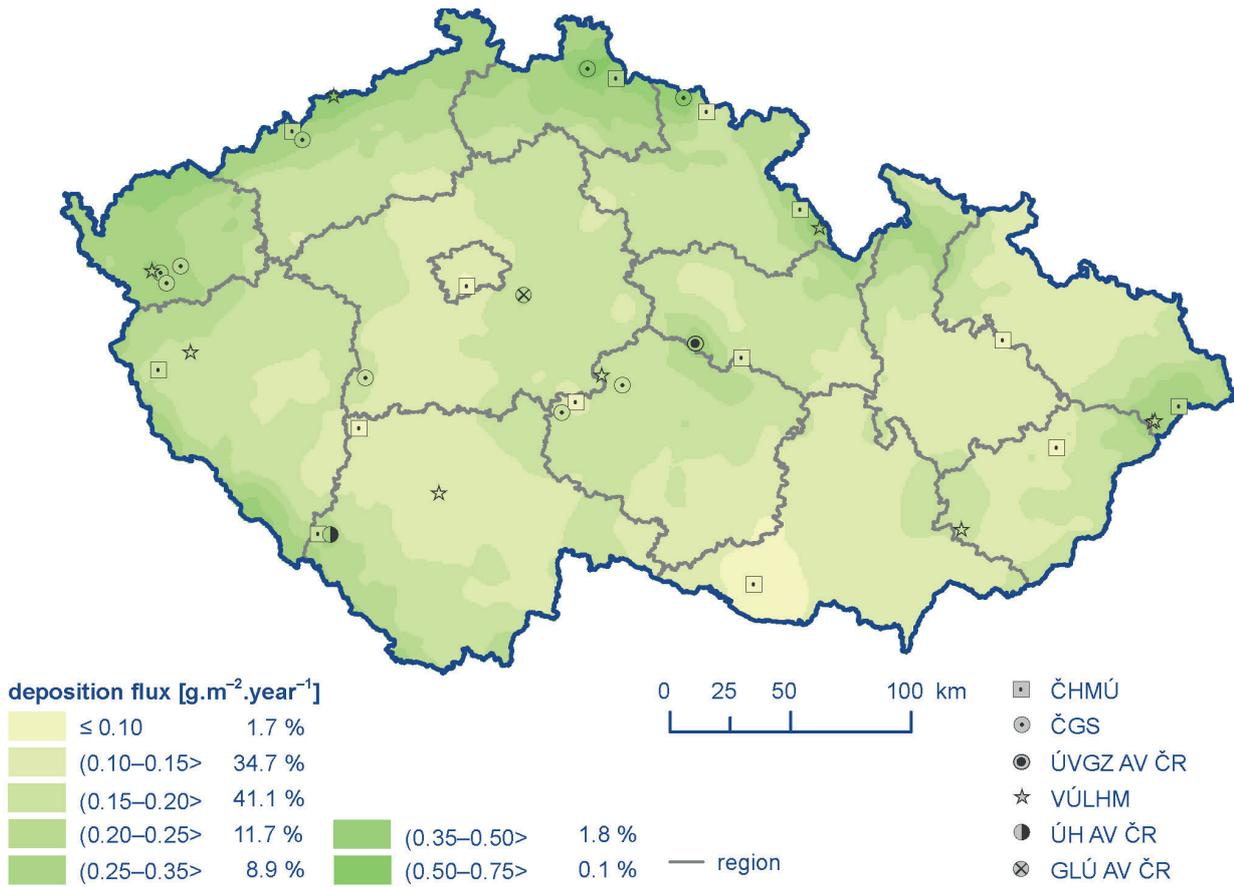
Fig. IX.14 Field of annual wet deposition of chloride ions, 2019

deposition flux [mg.m⁻².year⁻¹]

≤ 0.1		
(0.1–0.3>	23.9 %	
(0.3–0.5>	57.8 %	
(0.5–0.7>	14.4 %	(1.0–1.5> 0.4 %
(0.7–1.0>	3.5 %	(1.5–3.0> 0.001 %

region

0   25   50   100 km

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◉ ČGS
◉ ÚVGZ AV ČR
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◑ ÚH AV ČR
⊗ GLÚ AV ČR
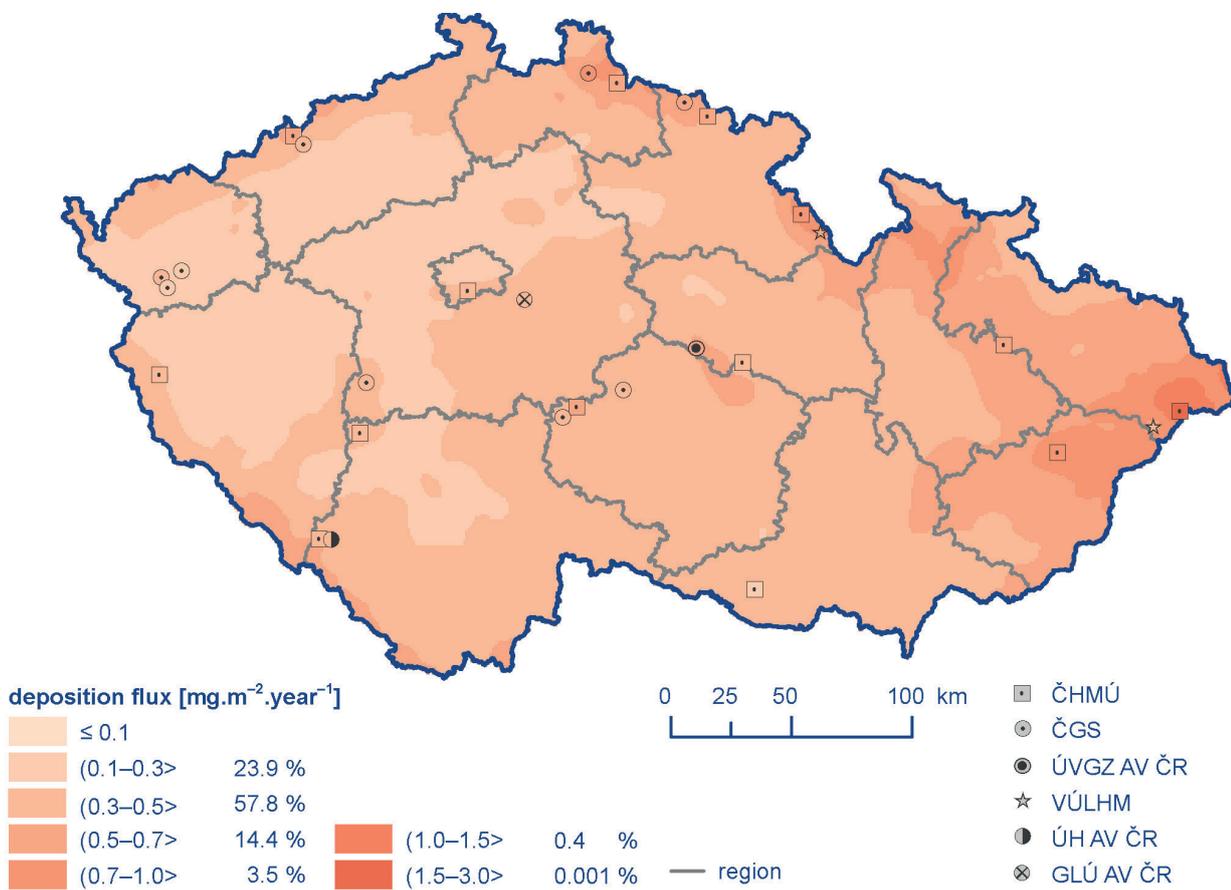
Fig. IX.15 Field of annual wet deposition of lead ions, 2019

deposition flux [mg.m⁻².year⁻¹]

≤ 0.1	14.3 %		
(0.1–0.3>	60.1 %		
(0.3–0.5>	19.4 %	(1.0–1.5>	0.3 %
(0.5–0.7>	4.5 %	(1.5–3.0>	0.1 %
(0.7–1.0>	1.3 %	(3.0–5.0>	0.01 %
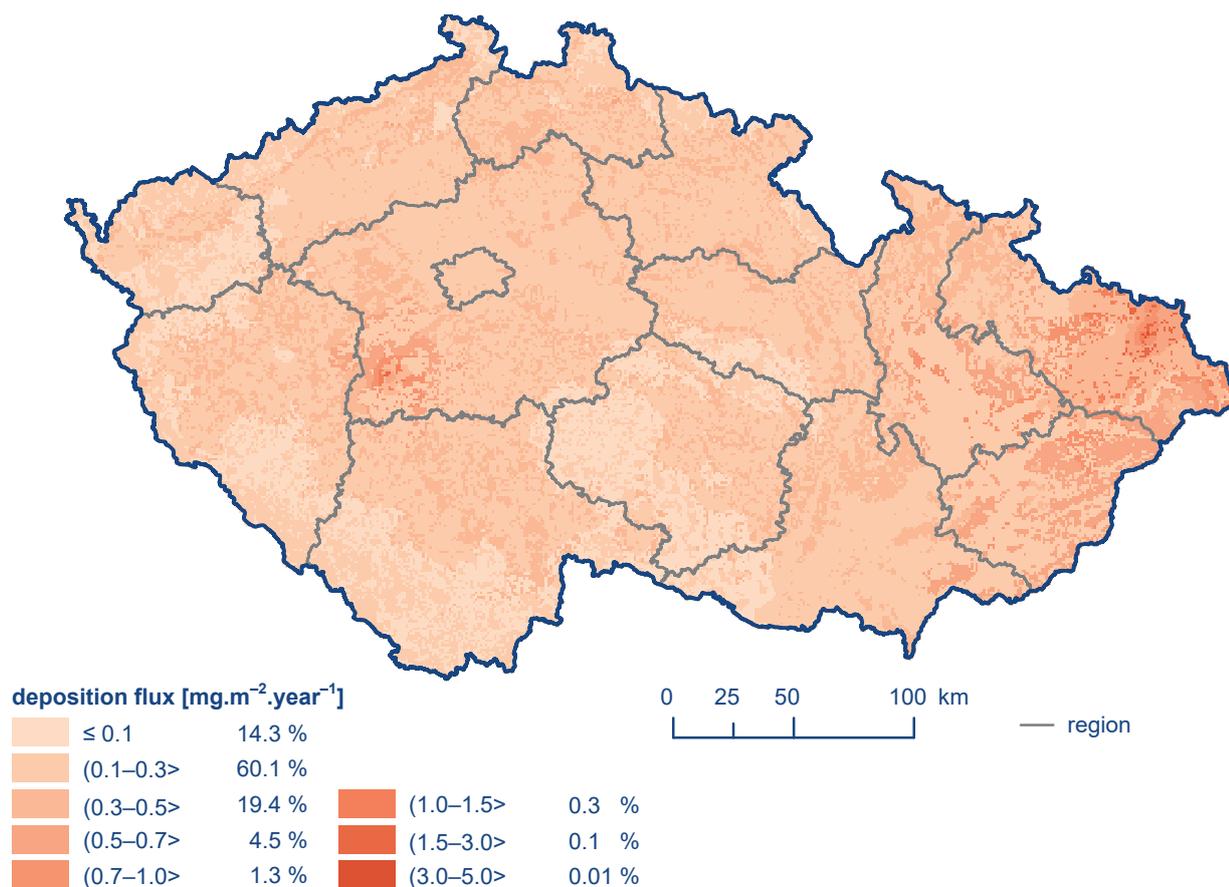
Fig. IX.16 Field of annual dry deposition of lead, 2019

deposition flux [mg.m⁻².year⁻¹]

≤ 0.015	20.1 %		
(0.015–0.20>	38.2 %	(0.040–0.050>	0.6 %
(0.020–0.025>	27.2 %	(0.050–0.075>	0.3 %
(0.025–0.030>	8.6 %	(0.075–0.100>	0.1 %
(0.030–0.040>	4.9 %	(0.100–0.150>	0.02 %

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GLÚ AV ČR
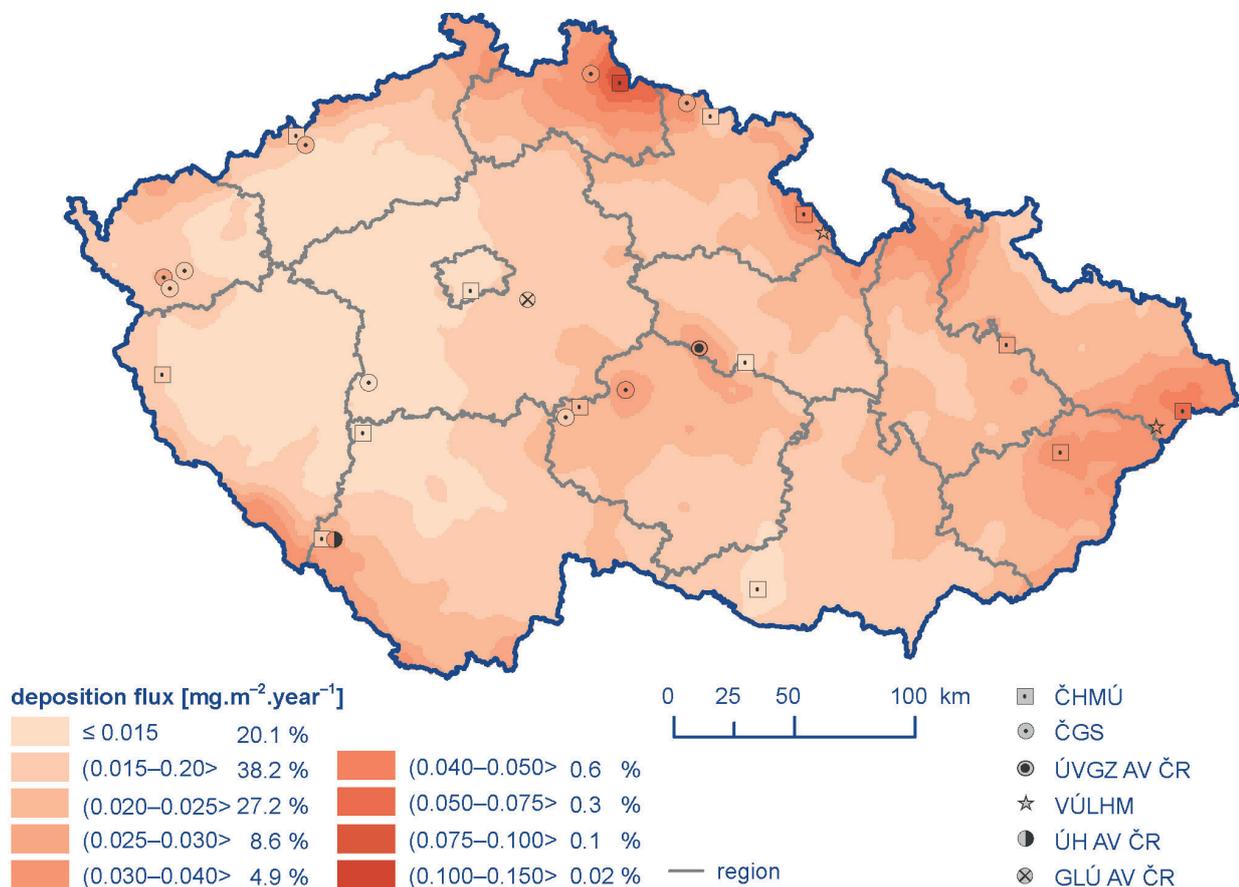
Fig. IX.17 Field of annual wet deposition of cadmium ions, 2019

deposition flux [mg.m^{-2}.year^{-1}]

≤ 0.015	69.3 %		(0.040–0.050>	1.3 %
(0.015–0.020>	12.9 %		(0.050–0.075>	1.9 %
(0.020–0.025>	8.5 %		(0.075–0.100>	0.8 %
(0.025–0.030>	2.5 %		(0.100–0.250>	0.4 %
(0.030–0.040>	2.4 %		> 0.250	0.01 %

0   25   50   100 km

— region
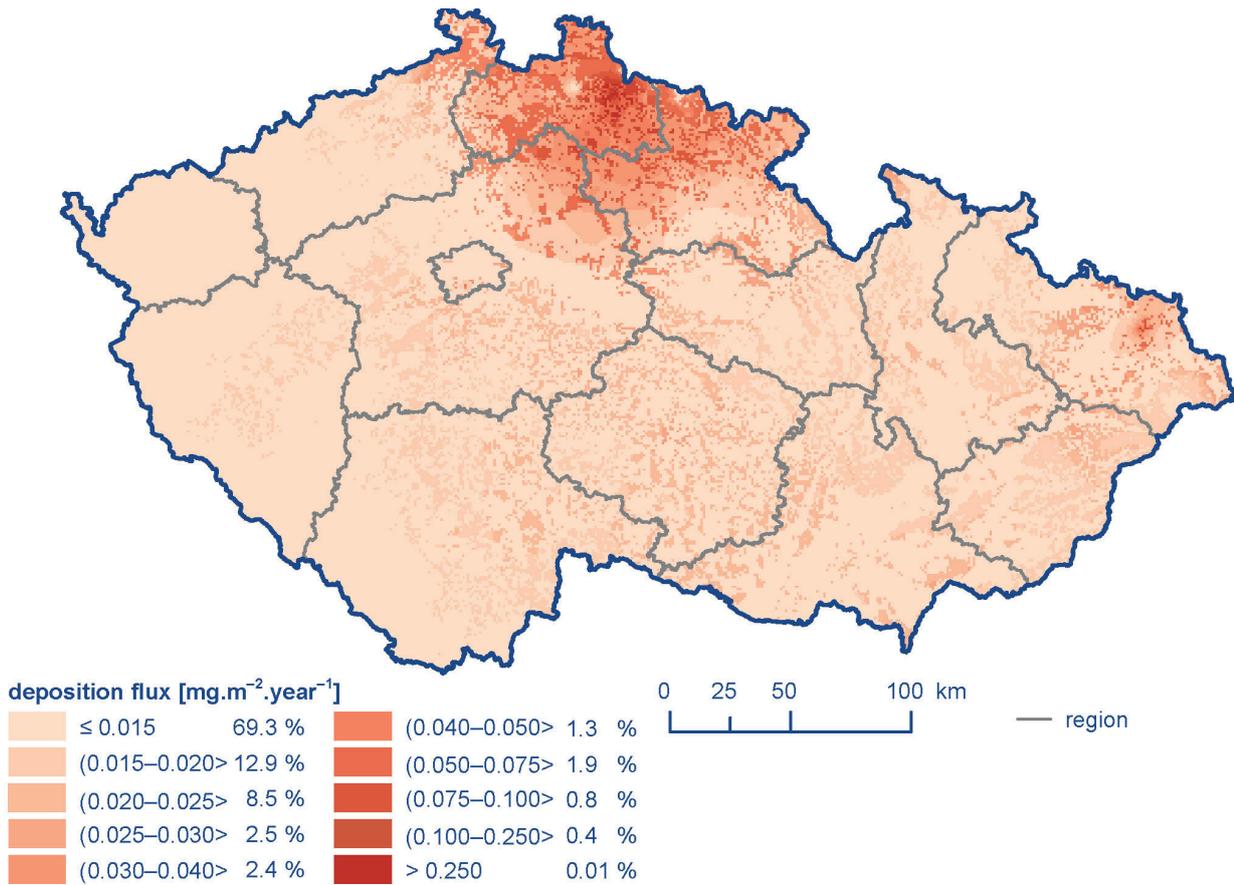
Fig. IX.18 Field of annual dry deposition of cadmium, 2019

deposition flux [mg.m^{-2}.year^{-1}]

≤ 0.25	0.5 %			
(0.25–0.35>	10.8 %		(1.0–1.5>	4.3 %
(0.35–0.50>	25.8 %		(1.5–2.0>	0.6 %
(0.50–0.75>	40.4 %		(2.0–3.0>	0.3 %
(0.75–1.0>	17.3 %		(3.0–5.0>	0.05 %

0   25   50   100 km

— region

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☆ VÚLHM
◑ ÚH AV ČR
⊗ GLÚ AV ČR
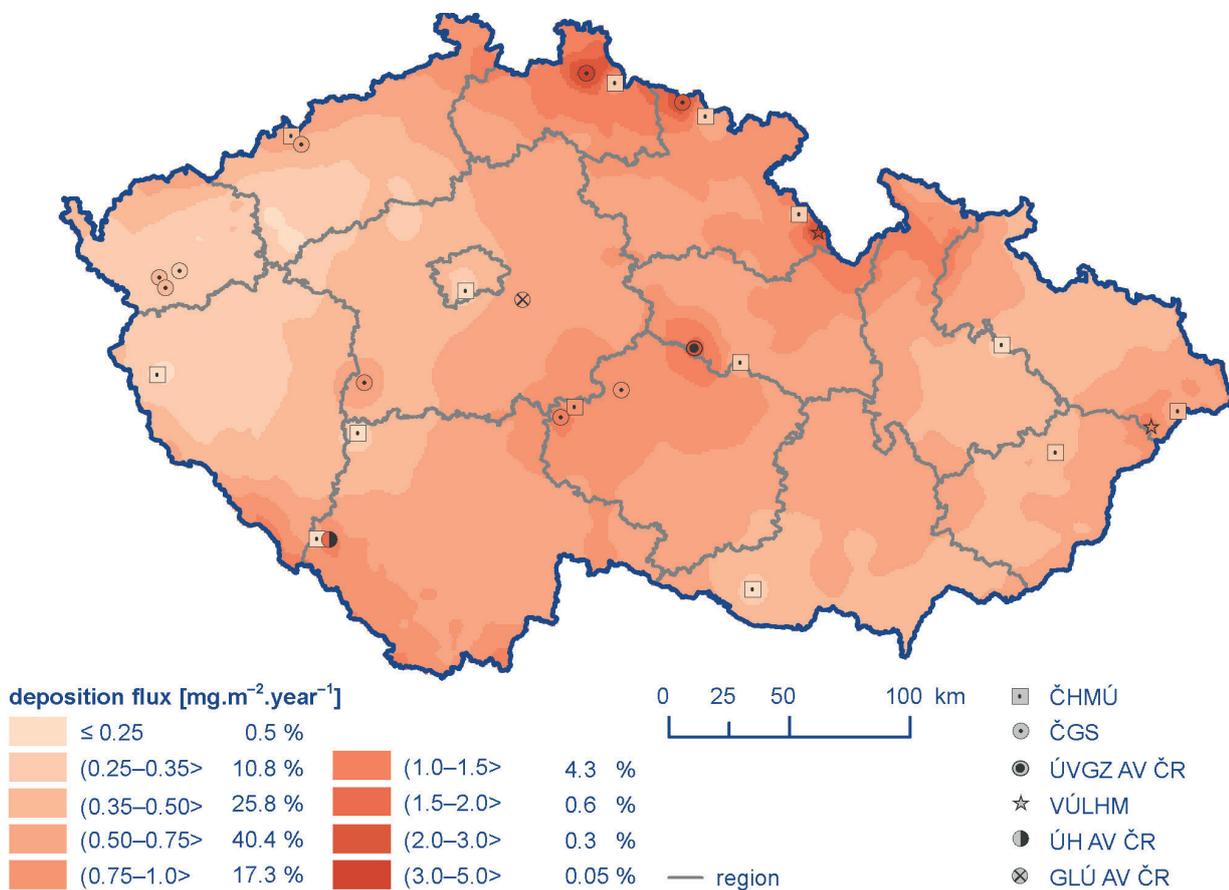
Fig. IX.19 Field of annual wet deposition of nickel ions, 2019

Trends in deposition

In the 1990s, the values of the total annual sulphur deposition were significantly higher than 100,000 t. Since 2000, a declining trend can be observed (Fig. IX.21). In 2000–2006, the value of total deposition remained in the range of approx. 65,000–75,000 t, except for 2003, which was significantly subnormal in terms of precipitation (516 mm, i.e. 77% of the long-term normal). Since 2011, the values of annual sulphur deposition have not reached 50,000 t, since 2015 they have fallen below 40,000 t on the area of the Czech Republic. The values of wet deposition of sulphur in 2000–2007 ranged from 30,000 to 50,000 t, except lower deposition in 2003 (19,128 t). Since 2008, depositions have not exceeded 30,000 t, after 2015 the downward trend below 20,000 t continues. The values of dry deposition are around 30,000 t until 2006, in 2007 and 2008 there was a significant decrease to values below 20,000 t. After an increase in deposition between 2009 and 2014, steady to slightly decreasing values can be observed in the last five years, in accordance with the level of sulphur dioxide concentration in the ground atmosphere.

Since 2001, the annual deposition of sulphur on the forested area of the Czech Republic (26,428 km^2) has shown a rather declining trend (Table IX.3). The value of total deposition in 2019 is the second lowest after 2016; the value of sub-crown deposition is the lowest since 2001. In some mountain areas in the country, the long-term throughfall deposition values are higher than the values of total sulphur deposition determined as the sum of wet (vertical only) and dry deposition from SO$_2$. This increase can be attributed to the contribution from deposition from fog, low clouds and rime (horizontal deposition) which is not included in the total deposition because of its uncertainty.

Total annual nitrogen deposition has ranged from 40,000 to 50,000 t since 2000. Since 2013, a declining trend can be observed, except for 2017 (Fig. IX.22). No significant trend has been observed since 2000 for wet or dry deposition of oxidized forms of nitrogen. Fluctuations in annual deposition values are related to air pollution concentrations of NO$_X$ in the troposphere.

Together with the variation of deposition of sulphur and nitrogen, a variation can be followed in the mutual ratio of these two elements in atmospheric precipitation related to trends in emissions of particular compounds (Fig. IX.20). A slight, although not steady, increase in the ratio of nitrates to sulphates can be observed at some stations since 2000 (Hůnová et al., 2017).

Since 2000, no trend of hydrogen ion deposition has been observed. The values of total deposition range between 2,500 and 4,500 t per year (Fig. IX.23). Since 2015, the total deposition of hydrogen ions does not exceed 3,000 t.

In the second half of the 1990s, there was a decrease in the wet deposition of some substances at selected stations in the Czech Republic (mainly SO$_4^{2-}$, H$^+$ and Pb$_2^+$). Since 2000, the values have rather stagnated, after 2010 there is a slight decrease in some substances again. These are, for example, H$^+$ at all stations, NO$_3^-$ especially at the Souš, and slightly also at the Svratouch, Košetice and Přimda localities (Fig. IX.24).
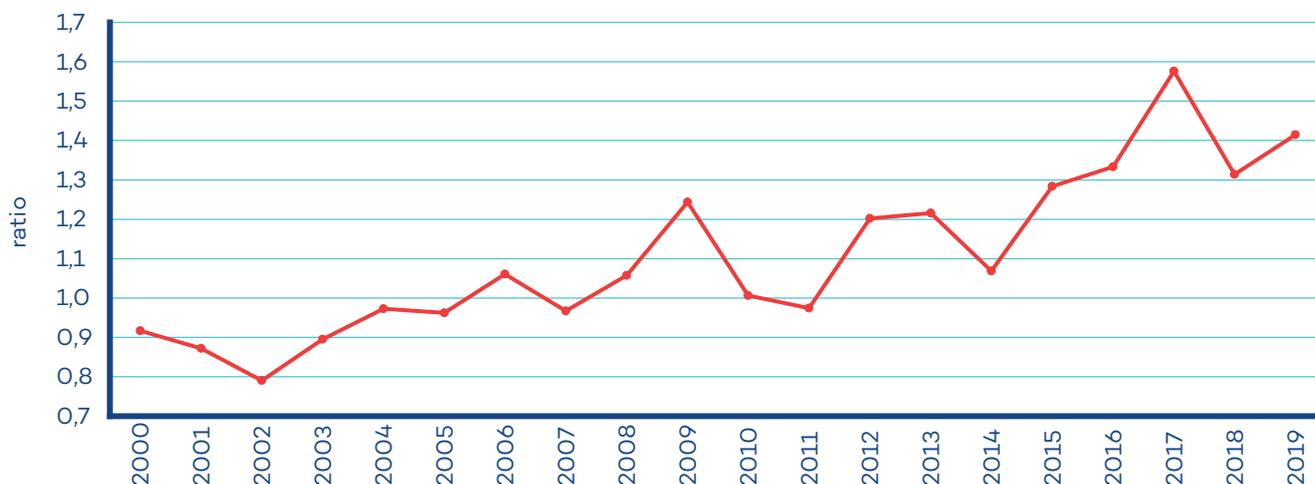
Fig. IX.20 Ratio of nitrate to sulphate concentrations in atmospheric deposition (expressed as μeq.l^{-1}) at the CHMI localities, 2000–2019
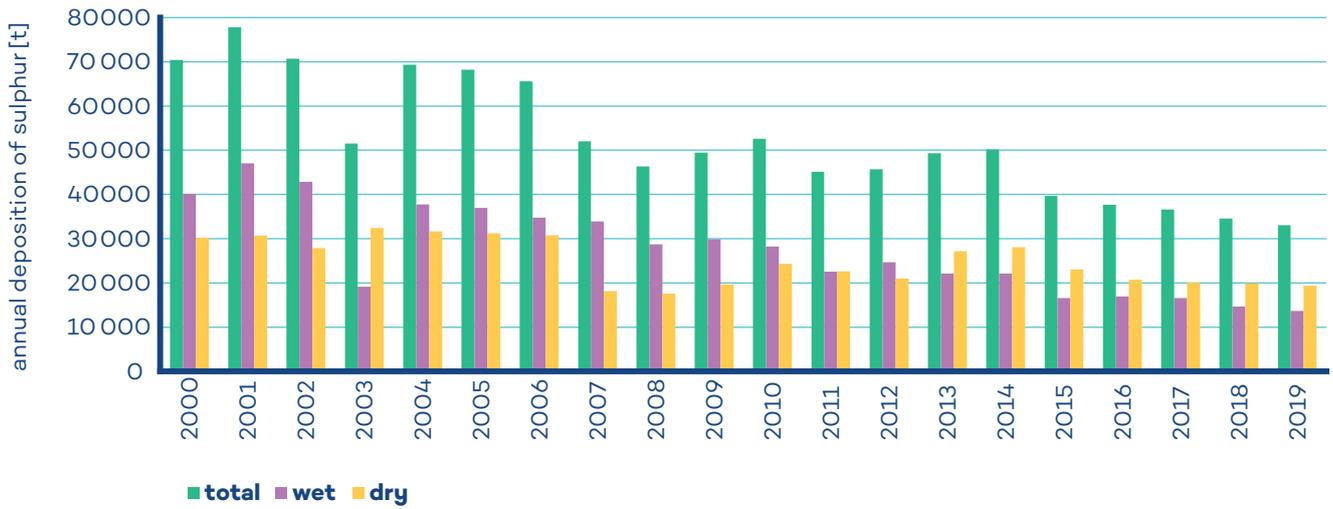
Fig. IX.21 Annual deposition of sulphur (S_SO$_4^{2-}$, S_SO$_2$) on the area of the Czech Republic, 2000–2019
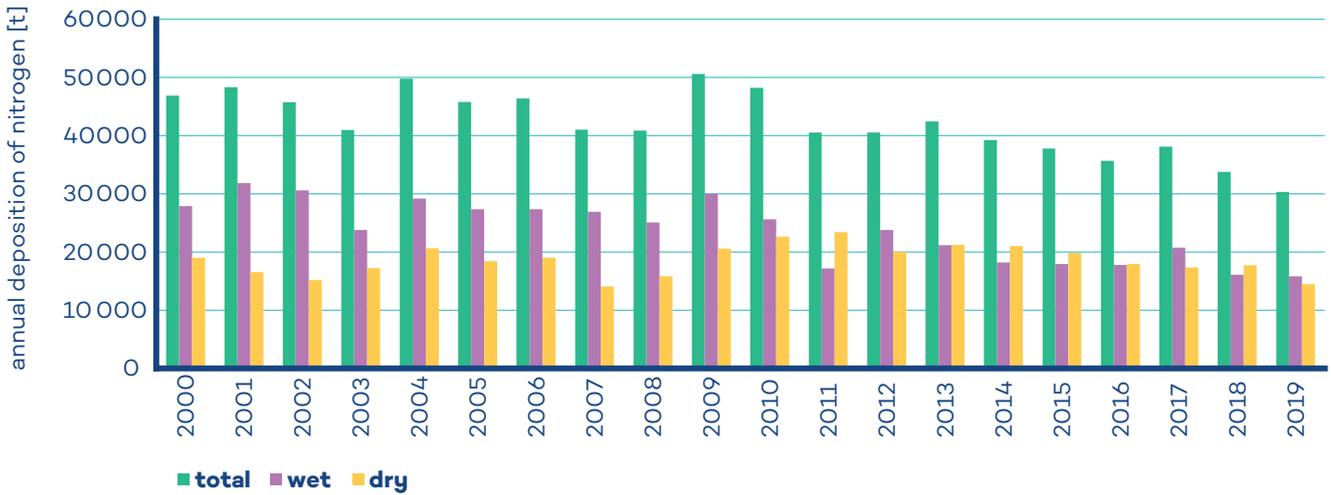
Fig. IX.22 Annual deposition of oxidized forms of nitrogen (N_NO$_3^-$, N_NO$_x$) on the area of the Czech Republic, 2000–2019

Fig. IX.23 Annual deposition of hydrogen ions on the area of the Czech Republic, 2000–2019
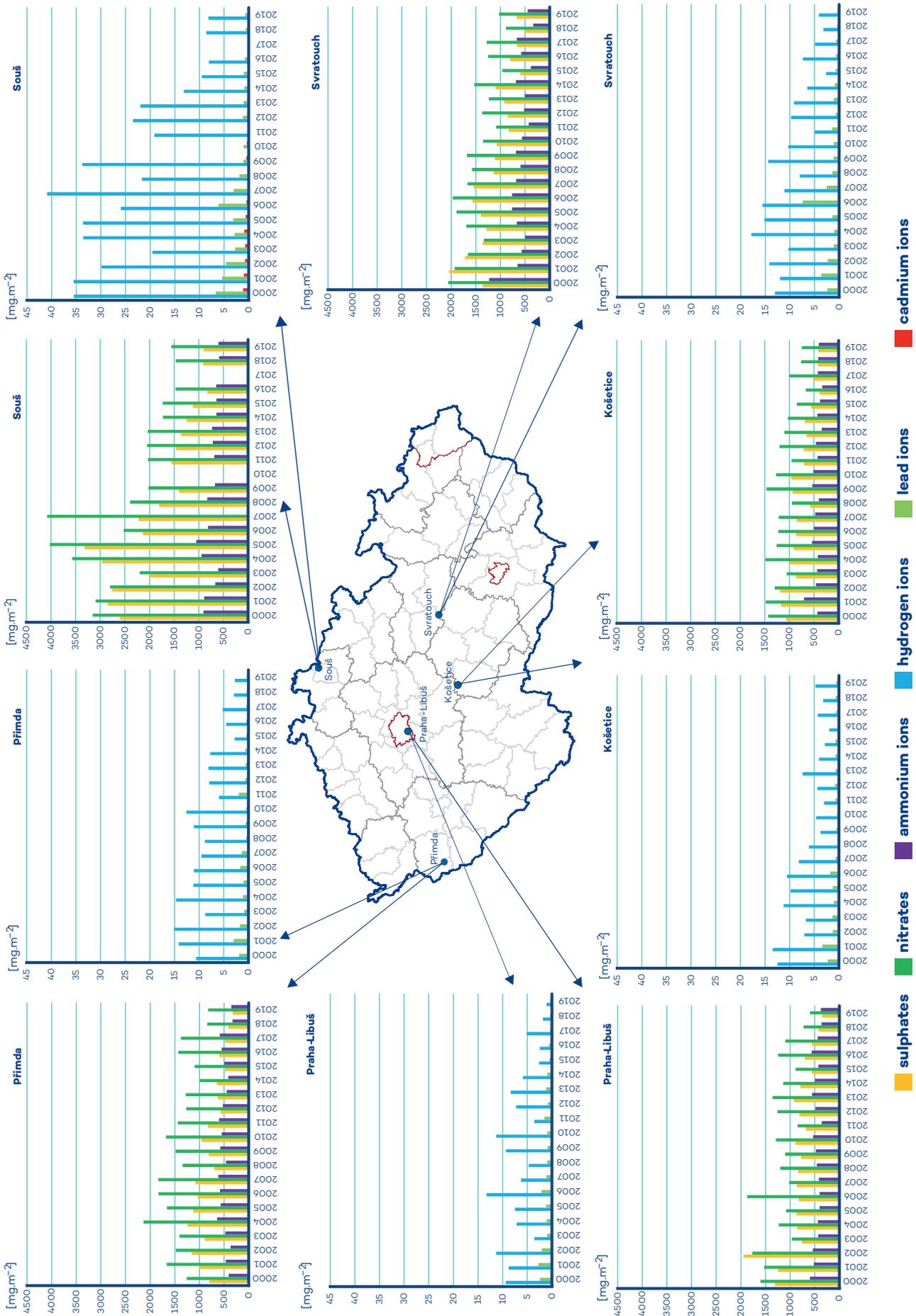
Fig. IX.24 Annual wet deposition at selected stations, 2000–2019

Tab. IX.4 Station networks monitoring atmospheric precipitation quality and atmospheric deposition, 2019

Code	Station	Region/country	District	Owner	Data supplier	Altitude [m]	Sampling
ALIB	Praha 4 – Libuš	Prague	Praha 4	CHMI	CHMI	301	W1(HM)
BKUC	Kuchařovice	South Moravian	Znojmo	CHMI	CHMI	334	W1(HM)
CCHU	Churáňov	South Bohemian	Prachatice	CHMI	CHMI	1 118	W1(HM)
CKAM	Kamýk–Všeteč	South Bohemian	České Budějovice	VÚLHM	VÚLHM	593	M2(HM), M4(HM)_bu
CKOC	Kocelovice	South Bohemian	Strakonice	CHMI	CHMI	519	W1(HM)
CLIZ	Na lizu	South Bohemian	Prachatice	ÚH AV ČR	CGS	828	M2(HM), M4(HM)_sm, M4(HM)_bu
CPL1						1 087	F2
CPL2	Plešné jezero	South Bohemian	Prachatice	HBÚ AV ČR	HBÚ AV ČR	1 122	F2
CPL3						1 334	F2
EPOM	Polomka	Pardubice	Chrudim	ÚVGZ AV ČR	CGS	512	M2(HM), M4(HM)_sm
ESVR	Svratouch	Pardubice	Chrudim	CHMI	CHMI	735	W1(HM)
HKRY	Krkonoše–Rýchory	Hradec Králové	Trutnov	CHMI	CHMI	1 001	W1(HM)
HLUD	Luisino údolí	Hradec Králové	Rychnov n. Kn.	CHMI	CHMI	875	W1(HM)
HLUU	Luisino údolí	Hradec Králové	Rychnov n. Kn.	VÚLHM	VÚLHM	940	M4(HM)_sm
HMOP	Modrý potok	Hradec Králové	Trutnov	CGS	CGS	1 010	M2(HM), M4(HM)_sm
HUDL	U dvou louček	Hradec Králové	Rychnov n. Kn.	VÚLHM	CGS	880	M2(HM), M4(HM)_sm, M4(HM)_bu
JKOS	Košetice	Vysočina	Pelhřimov	CHMI	CHMI CGS	535	D1(HM) (POPS,PAHs), M2(HM), M4(HM)_sm
JLKV	Loukov	Vysočina	Havlíčkův Brod	CGS	CGS	500	M2(HM), M4(HM)_sm
JSAL	Salačova Lhota	Vysočina	Pelhřimov	CGS	CGS	557	M2(HM), M4(HM)_sm
JZEL	Želivka	Vysočina	Havlíčkův Brod	VÚLHM	VÚLHM	440	M2(HM), M4(HM)_sm
KLAZ	Lazy	Karlovy Vary	Cheb	VÚLHM	VÚLHM	875	M2(HM), M4(HM)_sm
KLY1	Lysina	Karlovy Vary	Cheb	CGS	CGS	867	M2(HM)
KLY2						836	M4(HM)_sm
KNZ1	Na Zeleném	Karlovy Vary	Cheb	CGS	CGS	773	M2(HM)
KNZ2						750	M4(HM)_sm
KPB1	Pluhův bor	Karlovy Vary	Cheb	CGS	CGS	753	M2(HM)
KPB2						714	M4(HM)_sm

Code	Station	Region/country	District	Owner	Data supplier	Altitude [m]	Sampling
LSOU	Souš	Liberec	Jablonec n.N.	CHMI	CHMI	771	W1(HM)
LUHL	Uhlířská	Liberec	Liberec	CGS	CGS	780	M2(HM), M4(HM)_sm
PBEN	Benešovice	Plzeň	Tachov	VÚLHM	VÚLHM	385	M2(HM), M4_bo
PCJ1	Čertovo jezero	Plzeň	Klatovy	HBÚ AV ČR	HBÚ AV ČR	1 180	F2
PCJ2						1 057	F4_sm
PPRM	Přimda	Plzeň	Tachov	CHMI	CHMI	740	W1(HM)
SLES	Lesní potok	Central Bohemian	Kolín	GLÚ AV ČR	CGS	400	M2(HM), M4(HM)_sm, M4(HM)_bu
SLI1	Litavka	Central Bohemian	Příbram			700	M2(HM)
SLI2				CGS	CGS	710	M4(HM)_sm
TBKR	Bílý Kříž	Moravian-Silesian	Frýdek-Místek	CHMI	CHMI	890	W1(HM)
TCER	Červená hora	Moravian-Silesian	Opava	CHMI	CHMI	749	W1(HM)
TCRV	Červík	Moravian-Silesian	Frýdek-Místek	CGS	CGS	640	M2(HM), M4(HM)_sm
TKLE	Klepačka	Moravian-Silesian	Frýdek-Místek	VÚLHM	VÚLHM	650	M2(HM), M4(HM)_sm
UJEZ	Jezeří	Ústí nad Labem	Chomutov	CGS	CGS	820	M2(HM), M4(HM)_sm, M4(HM)_bu, M4(HM)_br
UMOD	Moldava	Ústí nad Labem	Teplice	VÚLHM	VÚLHM	805	M2(HM), M4(HM)_je
URVH	Rudolice v Horách	Ústí nad Labem	Chomutov	CHMI	CHMI	840	W1(HM)
ZBUC	Buchlovice-Medlovice	Zlín	Uherské Hradiště	VÚLHM	VÚLHM	350	M2(HM), M4(HM)_du
ZMAR	Maruška	Zlín	Vsetín	CHMI	CHMI	664	W1(HM)

Explanatory notes:

M2 – monthly bulk samples
M4 – monthly throughfall
W1 – tweekly wet-only – autom. sampler
D1 – daily wet-only – autom. sampler
F1 – wet-only– irregular samples
F2 – bulk– irregular samples
F4 – throughfall– irregular samples
(HM) – heavy metals analysis in mentioned sampling (POPs, PAHs) – POPs and PAHs analysis
_sm – spruce
_bu – beech
_bo – pine
_du – oak
_br – birch
_je – rowan

X. GREENHOUSE GAS EMISSIONS

Greenhouse gases form a part of the Earth's atmosphere and contribute to the so-called greenhouse effect. They are produced both by natural processes in nature, but also by human activities. Monitoring of these so-called anthropogenic greenhouse gas emissions is carried out within the inventory of greenhouse gas emissions and removals. For more on the processing methodology and reporting obligations, see CHMI 2020a.

Total greenhouse gas emissions including their removals from the Land use, land use change and forestry (LULUCF) sector, expressed in carbon dioxide equivalent (CO_2 eq.), decreased in the Czech Republic from 193 million tonnes in 1990 to 134 million tonnes in 2018 (Tab. X.1). Emissions alone (excluding LULUCF) decreased from 199 million tonnes to 128 million tonnes, making a decrease of 36% compared to the 1990 reference year. Share of individual sectors in total emissions in CO_2 eq. over the years is shown in Fig. X.1.

The share of CO_2 emissions in total greenhouse gas emissions in CO_2 equivalent (excluding LULUCF) was 82% in 2018, the share of CH_4 emissions reached 10% and the share of N_2O emissions 5%. The share of fluorocarbons in CO_2 equivalent in 2018 was 3% (CHMI 2020b).

As already mentioned, the emissions trading system is an important part of data sources in the preparation of background data for the inventory of greenhouse gas emissions (CHMI 2020a). Emissions reported in the EU ETS in 2018 reached 66.9 Mt CO_2, which is less than 64% of the total CO_2 emissions of the Czech Republic (Tab. X.2).

Energy   **Industrial processes**   **Agriculture**   **Land use, land use change and forestry**   **Waste**
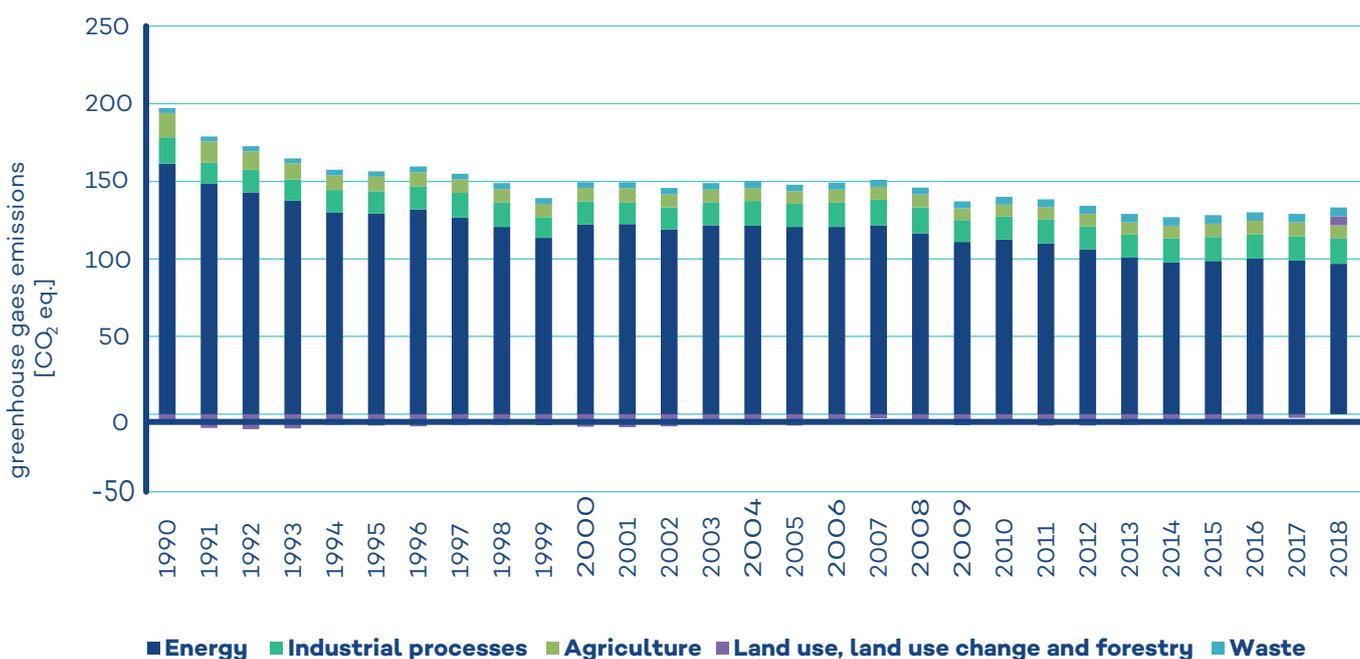
Fig. X.1 Share of individual sectors on total greenhouse gas emissions for 1990–2018 time-series

Tab. X.1 Trend in greenhouse gas emissions for 1990–2018 time-series

	CO$_2$ incl. net CO$_2$ from LULUCF	CO$_2$ incl. net CO$_2$ from LULUCF	CH$_4$	N$_2$O	F-gases	Sum emissions incl. LULUCF	Sum emissions excl. LULUCF
	Mt	Mt	Mt	Mt	Mt	Mt (CO$_2$ eq.)	Mt (CO$_2$ eq.)
1990	158.43	164.20	23.57	9.43	0.08	193.38	199.07
1991	139.92	148.89	21.99	8.08	0.08	171.74	180.65
1992	134.96	144.62	20.66	7.24	0.09	164.52	174.10
1993	129.34	138.64	19.76	6,50	0.09	157.22	166.44
1994	125.34	132.38	18.64	6.38	0.09	151.93	158.89
1995	124.14	131.61	18.21	6.67	0.10	150.57	157.96
1996	127.10	134.96	18.08	6.44	0.17	153.20	160.96
1997	123.81	130.73	17.68	6.42	0.27	149.56	156.37
1998	118.31	125.32	16.98	6.30	0.34	143.26	150.18
1999	109.39	116.62	16.25	6.09	0.40	133.37	140.52
2000	118.95	127.07	15.42	6.52	0.53	142.59	150.63
2001	118.55	126.96	15.18	6.76	0.68	142.30	150.63
2002	115.86	123.90	14.76	6.37	0.84	138.90	146.85
2003	120.83	127.38	14.78	5.91	1.00	143.58	150.03
2004	121.10	128.11	14.36	6.59	1.09	144.14	151.07
2005	118.25	125.67	14.73	6.40	1.20	141.64	148.97
2006	121.34	126.45	14.97	6.28	1.49	145.19	150.19
2007	125.39	128.26	14.55	6.35	1.89	149.24	151.98
2008	116.84	122.94	14.66	6.41	2.18	141.13	147.12
2009	108.03	115.19	14.30	5.56	2.26	131.12	138.19
2010	111.16	117.50	14.50	5.44	2.55	134.64	140.88
2011	107.74	115.06	14.50	6.06	2.78	132.05	139.32
2012	103.47	110.96	14.49	5.92	2.89	127.68	135.12
2013	99.59	106.43	13.90	5.69	3.01	123.01	129.80
2014	97.33	104.05	13.91	5.80	3.16	121.00	127.67
2015	98.94	104.82	13.98	6.20	3.37	123.28	129.09
2016	101.92	106.63	13.49	6.52	3.52	126.21	130.90
2017	103.30	105.64	13.29	6.43	3.72	127.46	129.78
2018	110.16	104.41	13.18	6.09	3.81	133.93	128.14

Tab. X.2 Trend in greenhouse gas emissions in emission trading scheme for 2010–2018 time-series

	Combustion of fuels	Refining of mineral oil	Production of pig iron or steel	Production of cement clinker, lime, or calcination of dolomite/ magnesite	Manufacture of glass and mineral wool	Manufacture of ceramics	Production of pulp, paper and cardboard	Total CO$_2$ in EU ETS	Total CO$_2$ in the Czech Republic	Share of CO$_2$ from EU ETS
	Mt CO$_2$	Mt CO$_2$	Mt CO$_2$	Mt CO$_2$	Mt CO$_2$	Mt CO$_2$	Mt CO$_2$	Mt CO$_2$	Mt CO$_2$	%
2010	62.05	1.05	6.08	3.37	0.66	0.43	0.65	75.58	118.48	63.79
2011	60.63	0.99	5.92	3.75	0.63	0.47	0.59	74.19	116.02	63.94
2012	56.25	0.95	5.86	3.42	0.65	0.45	0.59	69.31	111.87	61.96
2013	54.56	0.82	5.92	3.14	0.63	0.43	0.50	67.71	107.24	63.14
2014	53.24	0.91	5.90	3.37	0.67	0.40	0.48	66.70	104.86	63.60
2015	53.28	0.93	5.70	3.49	0.73	0.40	0.48	66.63	105.60	63.09
2016	53.87	0.71	6.06	3.72	0.73	0.40	0.46	67.52	107.39	62.87
2017	53.61	1.00	5.45	3.82	0.81	0.41	0.46	66.98	106.36	62.97
2018	52.96	0.92	5.79	4.15	0.80	0.42	0.48	66.91	105.10	63.67

Carbon dioxide

CO_2 emissions originate mainly from combustion of fossil fuels. Other contributing processes include, in particular, desulphurisation, decomposition of carbonates in production of lime, cement and glass, and metallurgical and chemical production. Emissions and removals (CO_2 absorption) occur in the LULUCF sector. As can be seen from Fig. X.2, CO_2 removals from LULUCF predominated until 2017, however in 2018, emissions already predominate. This situation is caused by excessive drought and bark beetle calamity which require logging in forests that would otherwise capture CO_2. In other areas, such as industrial processes, CO_2 capture is not yet performed in the Czech Republic. The combustion of solid fuels contributes the most to CO_2 emissions from combustion processes, and to a lesser extent also the combustion of liquid and gaseous fuels. In the last five years, there have been changes in the structure of fuels used, the share of natural gas and biomass combustion has been increasing, while the use of solid fuels has been declining. Even so, solid fuels predominate in the Czech Republic (CHMI 2020b) (Fig. X.3).

Between 1990 and 2018, CO_2 emissions decreased by 30% (Fig. X.2), mainly due to a decrease in the Energy sector - in the production of electricity and heat for production plants and services, households and other consumers. The decrease in combustion emissions in manufacturing companies in the early 1990s was a result of the slowdown and restructuring of some industries; at the end of the period, the decrease in emissions was reached by savings and the introduction of new technologies. Reductions in emissions from services and households can be attributed to more economical use of energy (increasing energy efficiency, especially thermal insulation of buildings, and more economical energy management). On the contrary, the opposite trend is evident in transport, namely in increase of emissions. However, it has been halted in recent years and emissions tend to fluctuate, which is due to the generally more efficient options for burning fuels and also to the change in the composition of fuels burned. As already mentioned above, since 2018, the Land use and land use change and forestry sector (CHMI 2020b) has also had its share in CO_2 emissions.
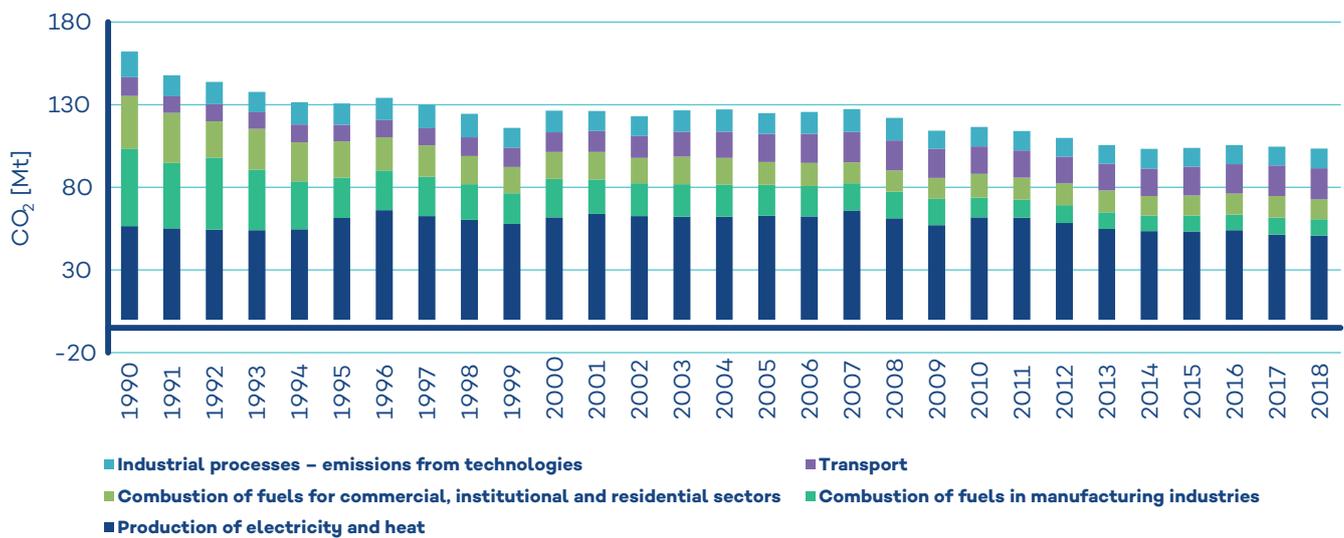
Fig. X.2 Share of individual sectors on total CO_2 emissions for 1990–2018 time-series
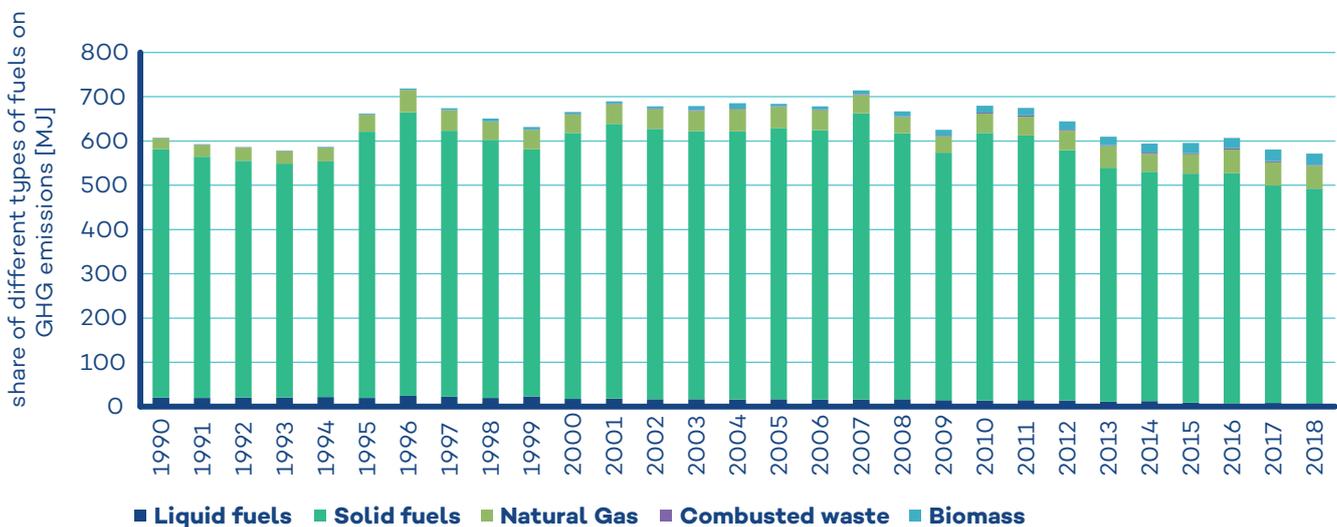
Fig. X.3 Share of different types of fuels combusted for 1990–2018 time-series

Methane

Methane is the second most important greenhouse gas in terms of production in the Czech Republic. Anthropogenic emissions of methane (CH_4) in the Czech Republic come mainly from the extraction and mining, treatment and distribution of fuels; these types of emissions are classified as fugitive emissions (emissions freely escaping into the atmosphere). Animal breeding, anaerobic decomposition of biological waste in landfills and wastewater treatment are further important sources of CH_4 emissions. In the breeding of animals, this gas is generated during digestive processes (especially in cattle) and decomposition of excrements of animal origin. Changes in these areas are also reflected in trends in methane emissions; in recent years, for example, there has been a noticeable change in fugitive emissions from the extraction and processing of fuels in connection with the closure of some mines in the Ostrava region (CHMI 2020b).

In the 1990–2018 period, CH4 emissions were reduced by 44% (Fig. X.4), particularly as a consequence of reduction of coal mining and livestock numbers and, to a lesser extent, by reduced solid fuel consumption in households. The increase in emissions in the Waste sector was reduced by utilisation of landfill gases and biogas for energy production purposes.

Nitrous oxide

The greatest amounts of emissions of nitrous oxide (N_2O) originate from agricultural activities, especially denitrification of nitrogen added to the soil in the form of artificial fertilizers or organic material. The production of nitric acid and other chemical industries, to a lesser extent, also transport (vehicles with catalytic converters) are also important sources (CHMI 2020b).

There was a reduction in N_2O emissions by 35% in the 1990–2018 period (Fig. X.5), particularly as a consequence of reduced use of artificial fertilizers in agriculture, a reduction in livestock numbers and, recently, also as a result of targeted introduction of technologies to eliminate nitrous oxide emissions in the production of nitric acid.

Fluorinated gases

Emissions of fluorinated gases increased from 102 kt CO_2 equiv. in 1995 to 3811 kt CO_2 equiv. in 2018 (Fig. X.6). Consequently, the contribution of fluorinated gases to the total aggregate emissions from industrial processes also increased (from 0.72% in 1995 to 23.4% in 2018). These substances are not manufactured in the Czech Republic and their total use is covered by import. They are used especially in refrigeration technology (namely HFCs), in electrical engineering (namely SF_6 and newly, since 2010, also NF_3) as well as in a number of other areas (e.g. in plasma etching, filling of fire extinguishers, aerosol propellants, and blowing agents). The emissions are generated mainly by releases from the facilities in which they are used. The increase in these emissions is caused by their use in replacing substances depleting the Earth's ozone layer (CFC, HCFC — mainly as refrigerants), greater use of modern technologies (air conditioning) and the manufacturing focus of the Czech Republic (production of cars and air conditioning units). The rapid increase of F-gases emissions in the context of their high potential of the global warming (GWP, Global Warming Potential) lead globally to the increased attention to monitoring of the level of emissions and consequently to regulation of F-gases use. These regulations deal mainly with applications for which there are available alternative technologies, more effective in terms of economy and having lower or no impact to the Earth climate system. The effect of the legislative measures has already been demonstrated, for example, in the use of fluorinated gases as inter-window insulation, blowing agents, or as refrigerants to refrigeration technologies designed for households, where these gasses are not used any more. In recent years, fluorinated gases with high GWP have been replaced by gases with low GWP. Nevertheless, their emissions to the atmosphere still appear due to long lifetime of the related equipment

Fugitive emissions from fuels mining and handling ■ **Agriculture** ■ **Waste** ■ **Combustion of fuels and industry**
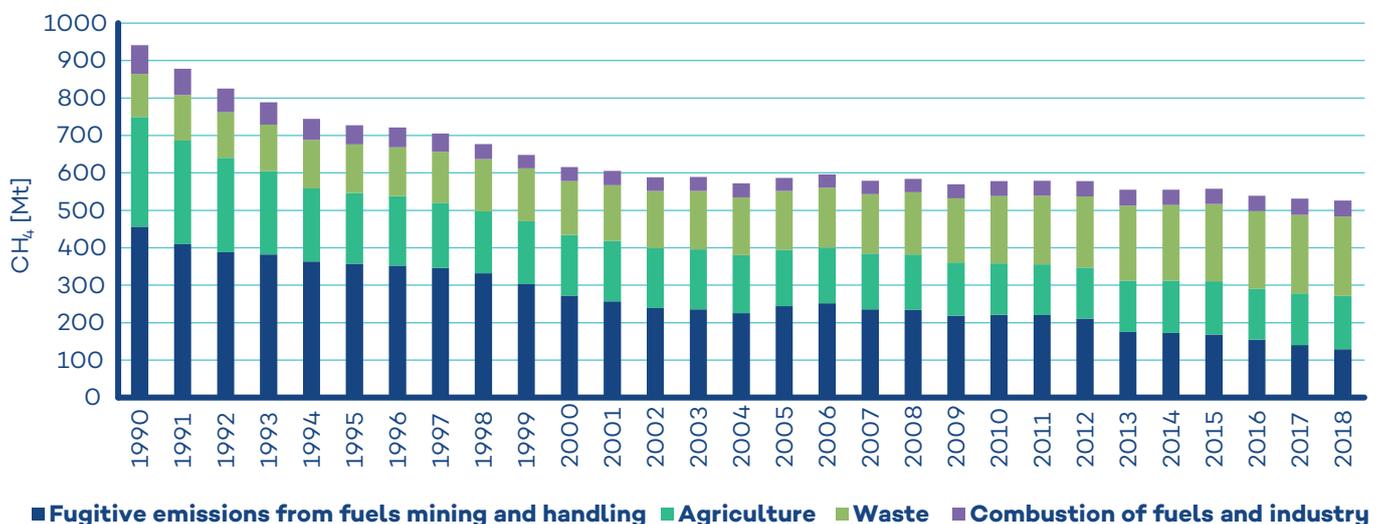
Fig. X.4 Share of individual sectors on total CH_4 emissions for 1990–2018 time-series

Agriculture ■ **Waste** ■ **Combustion of fuels** ■ **Industrial processes – emissions from technologies**
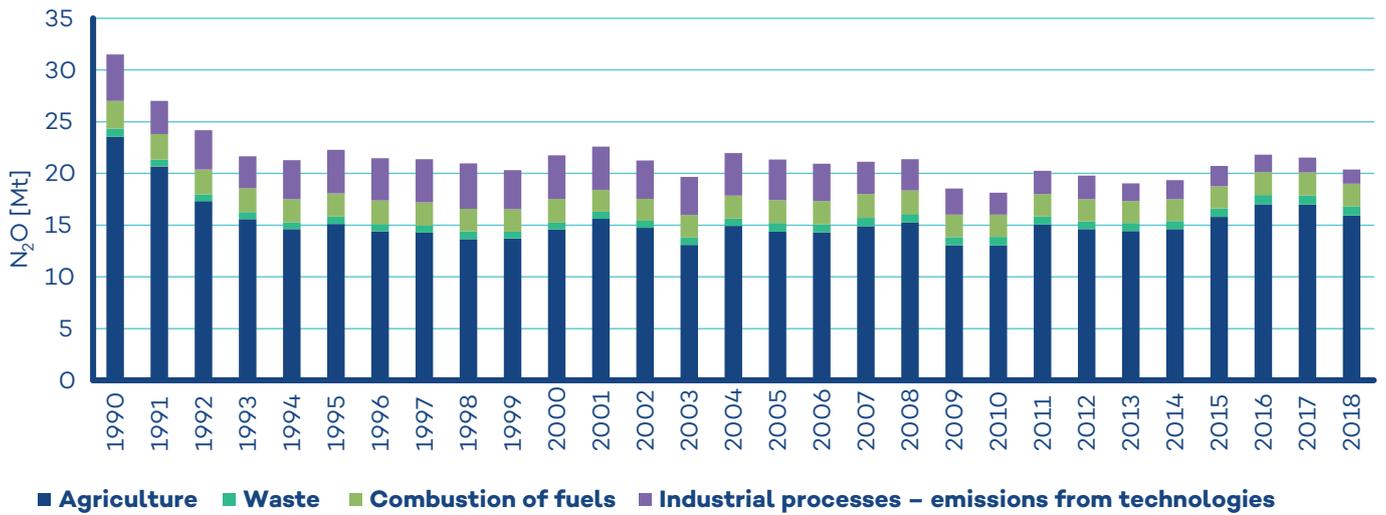
Fig. X.5 Share of individual sectors on total N$_2$O emissions for 1990–2018 time-series

■ **Electrotechnics and Other Uses of SF$_6$ and NF$_3$**
■ **Uses of HFCs and PFCs except of Refrigerantion and Air Conditionig Use**
■ **Refrigeration and Air conditioning**
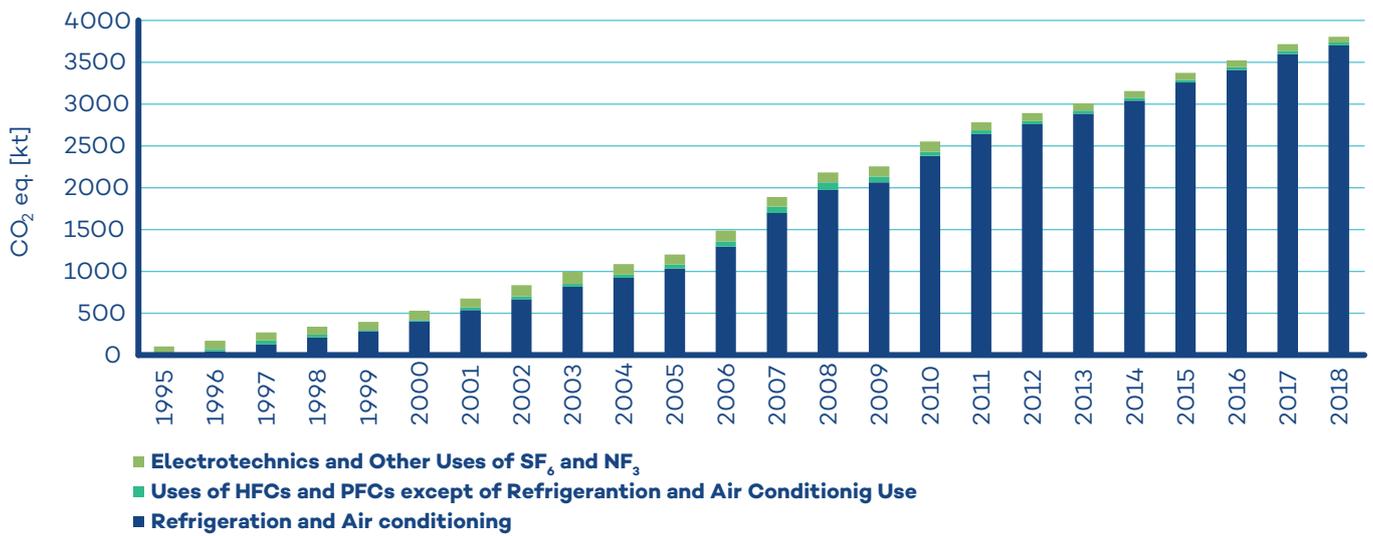
Fig. X.6 Share of individual sectors on total F-gas emissions for 1995–2018 time-series

XI. TABLES

Tab. XI.1 Stations with the highest numbers of exceedances of the 24-hour limit value of PM$_{10}$

KMPL	Station	District	Owner	Measuring method	Classi-fication	pLV	Max. 24-hour concen-tration [µg.m⁻³]	36th highest 24-hour concentration [µg.m⁻³]
TVERA	Věřňovice	Karviná	CHMI	RADIO	B/R/AI-NCI	**74**	**218.5**	71.8
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	OPEL	I/S/IR	**62**	**187.7**	58.9
TOCBA	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	OPEL	T/U/CR	**47**	**260.8**	54.8
TRYCA	Rychvald	Karviná	CHMI	RADIO	B/U/R	**40**	**217.6**	55.3
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	RADIO	I/U/IR	**39**	**181.3**	52.6
TKARA	Karviná	Karviná	CHMI	RADIO	B/U/R	**36**	**233.3**	50.9
SKLSA	Kladno-Švermov	Kladno	CHMI	RADIO	B/U/RI	**36**	**128.3**	50.6
THARA	Havířov	Karviná	CHMI	RADIO	B/U/R	35	185.3	48.9
ULOMA	Lom	Most	CHMI	RADIO	B/R/IN-NCI	35	133.5	50.0
TOROK	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	RADIO	B/S/R	33	188.5	48.4
MPHRA	Hranice	Přerov	MHRA	OPEL	B/U/RC	31	118.3	49.3
TCTNA	Český Těšín	Karviná	CHMI	RADIO	B/U/R	30	209.7	46.7
USTEA	Štětí	Litoměřice	MSTE	OPEL	B/U/R	30	120.8	48.5
BBNVA	Brno-Úvoz (hot spot)	Brno-město	CHMI	OPEL	T/U/R	30	107.5	48.0
ZZZSA	Zlín - ZŠ Kvítkova	Zlín	MZLI	RADIO	B/U/R	29	140.1	47.2
PPLRA	Plzeň-Roudná	Plzeň-město	ZÚ Ústí nL	OPEL	B/U/R	29	108.2	47.3
BBMSA	Brno-Svatoplukova	Brno-město	SMBrno	OPEL	T/U/R	29	92.4	47.4
AVRSA	Praha 10-Vršovice	Praha 10	CHMI	RADIO	T/U/R	28	113.3	45.3
MOLJA	Olomouc-Hejčín	Olomouc	CHMI	RADIO	B/U/R	27	118.7	45.7
MLOSA	Loštice	Šumperk	OLOŠ	OPEL	B/R/A-NCI	27	96.7	43.2
TOZRA	Ostrava-Zábřeh	Ostrava-město	CHMI	RADIO	B/U/R	26	170.5	46.5
ZUHRA	Uherské Hradiště	Uherské Hradiště	CHMI	RADIO	T/U/RC	26	125.1	44.2
ZOTMA	Otrokovice-město	Zlín	MOTRO	OPEL	T/U/RIC	26	123.5	46.5
MPRRA	Přerov	Přerov	CHMI	RADIO	B/U/CR	26	111.5	43.9
TKAOK	Karviná-ZÚ	Karviná	ZÚ-Ostrava	OPEL	T/U/R	25	186.2	43.8
TTRKA	Třinec-Kanada	Frýdek-Místek	SMTř.	RADIO	B/S/RN	25	159.6	43.9

KMPL	Station	District	Owner	Measuring method	Classi-fication	pLV	Max. 24-hour concen-tration [µg.m⁻³]	36th highest 24-hour concentration [µg.m⁻³]
ALEGA	Praha 2-Legerova (hot spot)	Praha 2	CHMI	OPEL	T/U/RC	25	107.9	43.9
TOFFA	Ostrava-Fifejdy	Ostrava-město	CHMI	RADIO	B/U/R	23	176.8	47.6
TSTDA	Studénka	Nový Jičín	CHMI	RADIO	B/R/A-NCI	23	145.2	41.5
EMTPA	Moravská Třebová - Piaristická	Svitavy	CHMI	RADIO	B/U/R	23	115.8	44.0
MPSTA	Prostějov	Prostějov	CHMI	RADIO	B/U/R	21	114.0	40.7
ARERA	Praha 5-Řeporyje	Praha 5	ZÚ Ústí nL	OPEL	B/S/RA	21	105.1	41.2
TTROA	Třinec-Kosmos	Frýdek-Místek	CHMI	RADIO	B/U/R	19	164.1	39.5
THAOA	Havířov	Karviná	ZÚ, SMHa	TEOM	B/U/R	19	160.3	40.3
TOMHK	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	TEOM	I/U/IR	19	156.2	43.5
TFMIA	Frýdek-Místek	Frýdek-Místek	CHMI	RADIO	B/S/R	19	146.0	39.1
SBERA	Beroun	Beroun	CHMI	RADIO	T/U/RCI	19	120.0	40.2
TOPOM	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	GRV	B/S/R	19	119.6	40.8
MBELA	Bělotín	Přerov	CHMI	RADIO	B/R/A-NCI	19	106.9	42.2
UULDA	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	OPEL	T/U/RC	19	101.3	41.8
UULMA	Ústí n.L.-město	Ústí nad Labem	CHMI	RADIO	B/U/RC	19	97.3	40.2
UDCMA	Děčín	Děčín	CHMI	RADIO	B/U/R	19	93.0	41.3
AREPA	Praha 1-n. Republiky	Praha 1	CHMI	RADIO	B/U/C	19	86.1	43.1
SKRPA	Kralupy nad Vltavou-sportoviště	Mělník	ZÚ Ústí nL	OPEL	I/U/RCI	18	114.8	41.4
UUDIA	Ústí n. L.-Prokopa Diviše	Ústí nad Labem	ZÚ Ústí nL	OPEL	I/U/RCI	18	89.7	41.7
UMOMA	Most	Most	CHMI	RADIO	B/U/R	18	85.3	41.1
TOVKA	Opava-Kateřinky	Opava	CHMI	RADIO	B/U/R	17	105.6	39.4
AKALA	Praha 8-Karlín	Praha 8	CHMI	RADIO	T/U/C	17	94.4	44.3
MDSTM	Dolní Studénky	Šumperk	CHMI	GRV	B/R/A-NCI	17	89.5	38.8
BBMLA	Brno-Lány	Brno-město	SMBrno	OPEL	B/S/RN	17	89.5	40.4
APRUA	Praha 10-Průmyslová	Praha 10	CHMI	RADIO	T/U/IC	17	85.5	38.3
CTABA	Tábor	Tábor	CHMI	RADIO	T/U/RC	17	77.9	39.2
ZVMZA	Valašské Meziříčí	Vsetín	CHMI	RADIO	B/U/R	16	157.3	40.5
AVYNA	Praha 9-Vysočany	Praha 9	CHMI	RADIO	T/U/CR	16	98.5	41.1
UTPMA	Teplice	Teplice	CHMI	RADIO	B/U/R	16	86.4	35.9

KMPL	Station	District	Owner	Measuring method	Classi-fication	pLV	Max. 24-hour concen-tration [µg.m⁻³]	36th highest 24-hour concentration [µg.m⁻³]
ZZLNA	Zlín	Zlín	CHMI	RADIO	B/S/RN	15	123.9	35.9
BBNFM	Brno-Kroftova	Brno-město	CHMI	GRV	T/U/R	15	85.9	37.1
ALERA	Letiště Praha	Praha 6	Letiště Pr	RADIO	T/S/C	14	94.0	40.6
SBRLM	Brandýs n. Labem	Praha-východ	CHMI	GRV	B/S/R	14	90.0	38.0
ULTTA	Litoměřice	Litoměřice	CHMI	RADIO	B/U/R	14	85.5	37.8
ZTNVA	Těšnovice	Kroměříž	CHMI	RADIO	B/R/A-REG	13	110.4	34.5
BBDNA	Brno - Dětská nemocnice	Brno-město	CHMI	RADIO	B/U/RC	13	97.3	36.9
SCELM	Čelákovice	Praha-východ	Stř. kraj	GRV	B/U/R	13	97.0	41.0
BHODA	Hodonín	Hodonín	ZÚ-Ostrava	OPEL	B/U/R	12	96.5	38.5
UDOKM	Doksany	Litoměřice	CHMI	GRV	B/R/NA-NCI	12	85.0	34.0
TPISM	Písečná	Frýdek-Místek	CHMI	GRV	B/R/AN-NCI	11	131.7	38.4
BBNYA	Brno-Tuřany	Brno-město	CHMI	RADIO	B/S/R	11	102.3	34.9
EPAUA	Pardubice Dukla	Pardubice	CHMI	RADIO	B/U/R	11	83.8	37.1
HHKSA	Hr.Král.-Sukovy sady	Hradec Králové	ZÚ Ústí nL	OPEL	T/U/RCI	11	79.8	35.9
SMBOA	Mladá Boleslav	Mladá Boleslav	CHMI	RADIO	B/U/R	11	76.0	37.0
ZVSHM	Vsetín - hvězdárna	Vsetín	CHMI	GRV	B/S/RN	10	123.7	36.4
HHKBA	Hradec Králové-Brněnská	Hradec Králové	CHMI	RADIO	T/U/RC	10	88.5	34.9
ASUCA	Praha 6-Suchdol	Praha 6	CHMI	RADIO	B/S/R	10	86.6	33.3
UTUSA	Tušimice	Chomutov	CHMI	RADIO	B/R/IA-NCI	10	84.9	35.4
AKOBA	Praha 8-Kobylisy	Praha 8	CHMI	RADIO	B/S/R	10	83.5	34.0
LCLMA	Česká Lípa	Česká Lípa	CHMI	RADIO	B/U/R	10	79.3	31.6
HHKTM	Hradec Králové – tř. SNP	Hradec Králové	CHMI	GRV	B/U/R	10	77.5	34.1
ABREA	Praha 6-Břevnov	Praha 6	CHMI	RADIO	B/U/RN	10	72.3	30.0
UKOSA	Kostomlaty pod Mileš.	Teplice	ČEZ	OPTO-RADIO	I/R/A	9	94.5	30.0
BVYSM	Vyškov	Vyškov	CHMI	GRV	B/S/RA	9	86.0	33.3

Tab. XI.2 Stations with the highest values of annual average concentrations of PM$_{10}$

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [μg.m^{-3}]
TVERA	Věřňovice	Karviná	CHMI	RADIO	B/R/AI-NCI	38.1
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	OPEL	I/S/IR	33.9
TOCBA	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	OPEL	T/U/CR	30.9
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	RADIO	I/U/IR	28.8
TKARA	Karviná	Karviná	CHMI	RADIO	B/U/R	28.7
TRYCA	Rychvald	Karviná	CHMI	RADIO	B/U/R	28.7
BBMSA	Brno-Svatoplukova	Brno-město	SMBrno	OPEL	T/U/R	28.0
THARA	Havířov	Karviná	CHMI	RADIO	B/U/R	27.8
TOROK	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	RADIO	B/S/R	27.7
TCTNA	Český Těšín	Karviná	CHMI	RADIO	B/U/R	27.3
PPLRA	Plzeň-Roudná	Plzeň-město	ZÚ Ústí nL	OPEL	B/U/R	27.2
BBNVA	Brno-Úvoz (hot spot)	Brno-město	CHMI	OPEL	T/U/R	26.5
ULOMA	Lom	Most	CHMI	RADIO	B/R/IN-NCI	26.5
MPHRA	Hranice	Přerov	MHRA	OPEL	B/U/RC	26.3
TOZRA	Ostrava-Zábřeh	Ostrava-město	CHMI	RADIO	B/U/R	26.3
USTEA	Štětí	Litoměřice	MSTE	OPEL	B/U/R	26.2
TOFFA	Ostrava-Fifejdy	Ostrava-město	CHMI	RADIO	B/U/R	26.1
AKALA	Praha 8-Karlín	Praha 8	CHMI	RADIO	T/U/C	25.7
MOLJA	Olomouc-Hejčín	Olomouc	CHMI	RADIO	B/U/R	25.6
ALEGA	Praha 2-Legerova (hot spot)	Praha 2	CHMI	OPEL	T/U/RC	25.5
AVRSA	Praha 10-Vršovice	Praha 10	CHMI	RADIO	T/U/R	25.4
SKLSA	Kladno-Švermov	Kladno	CHMI	RADIO	B/U/RI	25.4
TKAOK	Karviná-ZÚ	Karviná	ZÚ-Ostrava	OPEL	T/U/R	25.4
ZOTMA	Otrokovice-město	Zlín	MOTRO	OPEL	T/U/RIC	25.4
ZUHRA	Uherské Hradiště	Uherské Hradiště	CHMI	RADIO	T/U/RC	25.4
AREPA	Praha 1-n. Republiky	Praha 1	CHMI	RADIO	B/U/C	24.8
TTRKA	Třinec-Kanada	Frýdek-Místek	SMTř.	RADIO	B/S/RN	24.7
ZZZSA	Zlín - ZŠ Kvítkova	Zlín	MZLI	RADIO	B/U/R	24.7
THAOA	Havířov	Karviná	ZÚ, SMHa	TEOM	B/U/R	24.5
EMTPA	Moravská Třebová - Piaristická	Svitavy	CHMI	RADIO	B/U/R	24.3
ALERA	Letiště Praha	Praha 6	Letiště Pr	RADIO	T/S/C	24.2
MLOSA	Loštice	Šumperk	OLOŠ	OPEL	B/R/A-NCI	24.2
MPRRA	Přerov	Přerov	CHMI	RADIO	B/U/CR	24.1
TSTDA	Studénka	Nový Jičín	CHMI	RADIO	B/R/A-NCI	23.7
UULDA	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	OPEL	T/U/RC	23.7
UMOMA	Most	Most	CHMI	RADIO	B/U/R	23.6
ARERA	Praha 5-Řeporyje	Praha 5	ZÚ Ústí nL	OPEL	B/S/RA	23.5
MBELA	Bělotín	Přerov	CHMI	RADIO	B/R/A-NCI	23.4
UDCMA	Děčín	Děčín	CHMI	RADIO	B/U/R	23.4
APRUA	Praha 10-Průmyslová	Praha 10	CHMI	RADIO	T/U/IC	23.2

Tab. XI.3 Stations with the highest values of annual average concentrations of PM$_{2.5}$

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [μg.m^{-3}]
TVERA	Věřňovice	Karviná	CHMI	RADIO	B/R/AI-NCI	**27.6**
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	OPEL	I/S/IR	**26.0**
TOCBA	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	OPEL	T/U/CR	22.5
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	RADIO	I/U/IR	21.7
TRYCA	Rychvald	Karviná	CHMI	RADIO	B/U/R	21.6
TKARA	Karviná	Karviná	CHMI	RADIO	B/U/R	20.9
ZOTMA	Otrokovice-město	Zlín	MOTRO	OPEL	T/U/RIC	20.6
THARA	Havířov	Karviná	CHMI	RADIO	B/U/R	20.3
MPHRA	Hranice	Přerov	MHRA	OPEL	B/U/RC	20.1
TCTNA	Český Těšín	Karviná	CHMI	RADIO	B/U/R	20.0
TKAOK	Karviná-ZÚ	Karviná	ZÚ-Ostrava	OPEL	T/U/R	19.9
USTEA	Štětí	Litoměřice	MSTE	OPEL	B/U/R	19.9
BBMSA	Brno-Svatoplukova	Brno-město	SMBrno	OPEL	T/U/R	19.7
TOZRA	Ostrava-Zábřeh	Ostrava-město	CHMI	RADIO	B/U/R	19.6
ZZZSA	Zlín - ZŠ Kvítkova	Zlín	MZLI	RADIO	B/U/R	19.0
EMTPA	Moravská Třebová - Piaristická	Svitavy	CHMI	RADIO	B/U/R	18.9
TTRKA	Třinec-Kanada	Frýdek-Místek	SMTř.	RADIO	B/S/RN	18.9
MLOSA	Loštice	Šumperk	OLOŠ	OPEL	B/R/A-NCI	18.6
BBMLA	Brno-Lány	Brno-město	SMBrno	OPEL	B/S/RN	18.0
TSTDA	Studénka	Nový Jičín	CHMI	RADIO	B/R/A-NCI	18.0
MPRRA	Přerov	Přerov	CHMI	RADIO	B/U/CR	17.9
MOLJA	Olomouc-Hejčín	Olomouc	CHMI	RADIO	B/U/R	17.8
TTROA	Třinec-Kosmos	Frýdek-Místek	CHMI	RADIO	B/U/R	17.8
UDCMA	Děčín	Děčín	CHMI	RADIO	B/U/R	17.8
MBELA	Bělotín	Přerov	CHMI	RADIO	B/R/A-NCI	17.7
TFMIA	Frýdek-Místek	Frýdek-Místek	CHMI	RADIO	B/S/R	17.6
TOPOM	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	GRV	B/S/R	17.4
ALEGA	Praha 2-Legerova (hot spot)	Praha 2	CHMI	OPEL	T/U/RC	17.3
ZVMZA	Valašské Meziříčí	Vsetín	CHMI	RADIO	B/U/R	17.3
ARERA	Praha 5-Řeporyje	Praha 5	ZÚ Ústí nL	OPEL	B/S/RA	17.0
TOVKA	Opava-Kateřinky	Opava	CHMI	RADIO	B/U/R	16.8
SKRPA	Kralupy nad Vltavou-sportoviště	Mělník	ZÚ Ústí nL	OPEL	I/U/RCI	16.7
BBDNA	Brno - Dětská nemocnice	Brno-město	CHMI	RADIO	B/U/RC	16.3
UULDA	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	OPEL	T/U/RC	16.3
BBNVA	Brno-Úvoz (hot spot)	Brno-město	CHMI	OPEL	T/U/R	16.2
UUDIA	Ústí n. L.-Prokopa Diviše	Ústí nad Labem	ZÚ Ústí nL	OPEL	I/U/RCI	16.2
ZZLNA	Zlín	Zlín	CHMI	RADIO	B/S/RN	16.2
MDSTM	Dolní Studénky	Šumperk	CHMI	GRV	B/R/A-NCI	15.8
PPLRA	Plzeň-Roudná	Plzeň-město	ZÚ Ústí nL	OPEL	B/U/R	15.6
SBERA	Beroun	Beroun	CHMI	RADIO	T/U/RCI	15.6

Tab. XI.4 Stations measuring PM$_1$ in the ambient air with the values of annual average and maximum 24-hour concentrations

KMPL	Station	District	Owner	Measuring method	Classification	Max. 24-hour concentration [μg.m^{-3}]	Annual concentration [μg.m^{-3}]
TOCBA	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	OPEL	T/U/CR	235.3	19.9
ZOTMA	Otrokovice-město	Zlín	MOTRO	OPEL	T/U/RIC	109.6	18.9
USTEA	Štětí	Litoměřice	MSTE	OPEL	B/U/R	108.8	17.9
BBMSA	Brno-Svatoplukova	Brno-město	SMBrno	OPEL	T/U/R	76.5	17.4
TTRKA	Třinec-Kanada	Frýdek-Místek	SMTř.	RADIO	B/S/RN	140.8	17.0
BBMLA	Brno-Lány	Brno-město	SMBrno	OPEL	B/S/RN	79.6	16.2
ALEGA	Praha 2-Legerova (hot spot)	Praha 2	CHMI	OPEL	T/U/RC	75.6	15.2
ARERA	Praha 5-Řeporyje	Praha 5	ZÚ Ústí nL	OPEL	B/S/RA	81.2	15.2
SKRPA	Kralupy nad Vltavou-sportoviště	Mělník	ZÚ Ústí nL	OPEL	I/U/RCI	100.4	14.9
UUDIA	Ústí n. L.-Prokopa Diviše	Ústí nad Labem	ZÚ Ústí nL	OPEL	I/U/RCI	75.6	14.2
UULDA	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	OPEL	T/U/RC	80.5	14.1
BBNVA	Brno-Úvoz (hot spot)	Brno-město	CHMI	OPEL	T/U/R	81.0	14.0
PPLRA	Plzeň-Roudná	Plzeň-město	ZÚ Ústí nL	OPEL	B/U/R	55.5	13.2
PKLSA	Klatovy soud	Klatovy	ZÚ Ústí nL	OPEL	T/U/R	53.7	12.2
PPLEA	Plzeň-střed	Plzeň-město	MPI	OPEL	T/U/RC	50.3	12.2
PPLLA	Plzeň-Lochotín	Plzeň-město	MPI	OPEL	B/U/R	53.3	12.2
ASROA	Praha 10-Šrobárova	Praha 10	ZÚ Ústí/SZÚ	OPEL	B/U/RC	55.5	10.7
PPLAG	Plzeň-Slovany	Plzeň-město	MPI	OPEL	T/U/RC	50.0	10.1
CCBTA	Čes. Budějovice-Třešň.	České Budějovice	ZÚ Ústí nL	OPEL	B/U/R	42.1	9.0

Tab. XI.5 Overview of localities with the exceedance of the limit value for annual average PM$_{10}$ concentration, 2015-2019

KLOK	Station	District	Owner	Classification	2015	2016	2017	2018	2019
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	I/U/IR	36.3	32.9	35.1	**40.8**	28.8
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	I/S/IR	**42.2**	**41.0**	**43.9**	**44.0**	33.9
TVERA	Věřňovice	Karviná	CHMI	B/R/AI-NCI	**41.6**	39.7	**40.1**	**43.6**	38.1
ZZLTK	Zlín-Svit	Zlín	MZLI	T/U/CR	**41.7**	-	-	-	-

Tab. XI.6 Stations with the highest values of annual average concentrations of benzo[*a*]pyrene in the ambient air

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [ng.m⁻³]
TOREP	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	HPLC	I/S/IR	**8.7**
TOROP	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	HPLC	B/S/R	**3.9**
TVRTP	Vratimov	Ostrava-město	ZÚ, MSK	HPLC	I/S/RI	**3.3**
SKLSP	Kladno-Švermov	Kladno	CHMI	GC-MS	B/U/RI	**3.2**
TCTNP	Český Těšín	Karviná	CHMI	GC-MS	B/U/R	**3.1**
TKAOP	Karviná-ZÚ	Karviná	ZÚ-Ostrava	HPLC	T/U/R	**2.9**
TOPRP	Ostrava-Přívoz	Ostrava-město	CHMI	GC-MS	I/U/IR	**2.7**
TSTDP	Studénka	Nový Jičín	CHMI	GC-MS	B/R/A-NCI	**2.2**
ZVMZP	Valašské Meziříčí	Vsetín	CHMI	GC-MS	B/U/R	**2.1**
TOPOP	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	GC-MS	B/S/R	**2.0**
SBRLP	Brandýs n. Labem	Praha-východ	CHMI	GC-MS	B/S/R	**1.7**
TOMHP	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	HPLC	I/U/IR	**1.6**
TOPDP	Ostrava-Poruba, DD	Ostrava-město	ZÚ, SMOva	HPLC	T/U/R	**1.6**
TKRVP	Krnov-úpravna vody	Bruntál	CHMI, MSK	GC-MS	B/R/AN-NCI	**1.4**
CCBAP	Č.Budějovice-Antala Staška	České Budějovice	CHMI	GC-MS	B/S/R	**1.2**
MOLJP	Olomouc-Hejčín	Olomouc	CHMI	GC-MS	B/U/R	**1.2**
SCELP	Čelákovice	Praha-východ	Stř. kraj	GC-MS	B/U/R	**1.2**
TBRMP	Brumovice MŠ	Bruntál	ZÚ, MSK	HPLC	B/R/RA	**1.1**
ZZLNP	Zlín	Zlín	CHMI	GC-MS	B/S/RN	**1.1**
CCBTP	Čes. Budějovice-Třešň.	České Budějovice	ZÚ Ústí nL	GC-MS	B/U/R	1.0
EPAUP	Pardubice Dukla	Pardubice	CHMI	GC-MS	B/U/R	1.0
HHKTP	Hradec Králové – tř. SNP	Hradec Králové	CHMI	GC-MS	B/U/R	1.0
HVITP	Vítězná	Trutnov	CHMI	GC-MS	B/R/AN-NCI	1.0
PPLRP	Plzeň-Roudná	Plzeň-město	ZÚ Ústí nL	GC-MS	B/U/R	1.0
TBRSP	Bruntál-škola	Bruntál	CHMI,MSK	GC-MS	T/U/R	1.0
UDOKP	Doksany	Litoměřice	CHMI	GC-MS	B/R/NA-NCI	1.0
UUDIP	Ústí n. L.-Prokopa Diviše	Ústí nad Labem	ZÚ Ústí nL	GC-MS	I/U/RCI	1.0
MOLSP	Olomouc-Šmeralova	Olomouc	ZÚ-Ostrava	HPLC	B/U/R	0.9
SKRPP	Kralupy nad Vltavou-sportoviště	Mělník	ZÚ Ústí nL	GC-MS	I/U/RCI	0.9
THBEP	Horní Benešov MŠ	Bruntál	ZÚ, MSK	HPLC	B/S/R	0.9
PPLXP	Plzeň-Slovany	Plzeň-město	CHMI	GC-MS	T/U/RC	0.8
ALIBP	Praha 4-Libuš	Praha 4	CHMI	GC-MS	B/S/R	0.7
ASROP	Praha 10-Šrobárova	Praha 10	ZÚ Ústí/SZÚ	GC-MS	B/U/RC	0.7
LLILP	Liberec Rochlice	Liberec	CHMI	GC-MS	B/U/R	0.7
UTPMP	Teplice	Teplice	CHMI	GC-MS	B/U/R	0.7
ARIEP	Praha 2-Riegrovy sady	Praha 2	CHMI	GC-MS	B/U/NR	0.6
JZNZP	Žďár nad Sázavou	Žďár nad Sázavou	ZÚ-Ostrava	HPLC	B/U/RC	0.6
BBNIP	Brno-Líšeň	Brno-město	CHMI	GC-MS	B/U/R	0.5
BHODP	Hodonín	Hodonín	ZÚ-Ostrava	HPLC	B/U/R	0.5

Tab. XI.7 Stations with the highest values of the 19th and maximum hourly concentrations of NO$_2$

KMPL	Station	District	Owner	Measuring method	Classi-fication	pLV	Max. hourly concen-tration [µg.m^{-3}]	19th highest hourly con-centration [µg.m^{-3}]
AKALA	Praha 8-Karlín	Praha 8	CHMI	CHLM	T/U/C	0	155.3	92.8
CTABA	Tábor	Tábor	CHMI	CHLM	T/U/RC	0	148.1	116.1
ALEGA	Praha 2-Legerova (hot spot)	Praha 2	CHMI	CHLM	T/U/RC	0	145.6	125.7
APRUA	Praha 10-Průmyslová	Praha 10	CHMI	CHLM	T/U/IC	0	143.5	101.2
ABREA	Praha 6-Břevnov	Praha 6	CHMI	CHLM	B/U/RN	0	136.4	82.3
BBDNA	Brno - Dětská nemocnice	Brno-město	CHMI	CHLM	B/U/RC	0	134.9	102.0
BBMLA	Brno-Lány	Brno-město	SMBrno	CHLM	B/S/RN	0	133.7	94.3
ZOTMA	Otrokovice-město	Zlín	MOTRO	CHLM	T/U/RIC	0	133.5	114.4
BBMSA	Brno-Svatoplukova	Brno-město	SMBrno	CHLM	T/U/R	0	128.9	96.0
PPLAA	Plzeň-Slovany	Plzeň-město	MPI	CHLM	T/U/RC	0	128.5	79.8
TOPDA	Ostrava-Poruba, DD	Ostrava-město	ZÚ, SMOva	CHLM	T/U/R	0	128.2	93.9
MOLJA	Olomouc-Hejčín	Olomouc	CHMI	CHLM	B/U/R	0	128.0	88.4
BBNVA	Brno-Úvoz (hot spot)	Brno-město	CHMI	CHLM	T/U/R	0	123.8	96.2
ZUHRA	Uherské Hradiště	Uherské Hradiště	CHMI	CHLM	T/U/RC	0	123.8	86.1
AREPA	Praha 1-n. Republiky	Praha 1	CHMI	CHLM	B/U/C	0	123.6	89.1
ASROA	Praha 10-Šrobárova	Praha 10	ZÚÚstí/SZÚ	CHLM	B/U/RC	0	122.6	89.3
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	CHLM	I/U/IR	0	120.9	81.7
TOCBA	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	CHLM	T/U/CR	0	119.2	94.7
HHKSA	Hr.Král.-Sukovy sady	Hradec Králové	ZÚ Ústí nL	CHLM	T/U/RCI	0	117.6	83.4
AVYNA	Praha 9-Vysočany	Praha 9	CHMI	CHLM	T/U/CR	0	115.5	99.1
BBMVA	Brno-Výstaviště	Brno-město	SMBrno	CHLM	T/U/C	0	113.4	86.7
ARIEA	Praha 2-Riegrovy sady	Praha 2	CHMI	CHLM	B/U/NR	0	111.3	87.4
PPLEA	Plzeň-střed	Plzeň-město	MPI	CHLM	T/U/RC	0	106.9	73.1
UULDA	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	CHLM	T/U/RC	0	105.8	86.3
ZZZSA	Zlín - ZŠ Kvítkova	Zlín	MZLI	CHLM	B/U/R	0	102.0	81.5
TOMHK	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	CHLM	I/U/IR	0	101.4	69.4
SMBOA	Mladá Boleslav	Mladá Boleslav	CHMI	CHLM	B/U/R	0	100.6	75.9
ALERA	Letiště Praha	Praha 6	Letiště Pr	CHLM	T/S/C	0	99.3	81.7
TKAOK	Karviná-ZÚ	Karviná	ZÚ-Ostrava	CHLM	T/U/R	0	99.1	85.3
SBERA	Beroun	Beroun	CHMI	CHLM	T/U/RCI	0	96.4	84.0
ACHOA	Praha 4-Chodov	Praha 4	CHMI	CHLM	B/U/RN	0	95.8	71.5
AKOBA	Praha 8-Kobylisy	Praha 8	CHMI	CHLM	B/S/R	0	95.6	80.9
MSMSA	Šumperk - 5.ZŠ	Šumperk	MŠUM	CHLM	B/U/R	0	95.6	75.4
ARERA	Praha 5-Řeporyje	Praha 5	ZÚ Ústí nL	CHLM	B/S/RA	0	95.3	75.8
TCTNA	Český Těšín	Karviná	CHMI	CHLM	B/U/R	0	95.3	70.6
ALIBA	Praha 4-Libuš	Praha 4	CHMI	CHLM	B/S/R	0	94.9	78.8
SPBRA	Příbram-Březové Hory	Příbram	CHMI	CHLM	B/U/R	0	92.6	71.4
UMOMA	Most	Most	CHMI	CHLM	B/U/R	0	92.6	76.7
TOFFA	Ostrava-Fifejdy	Ostrava-město	CHMI	CHLM	B/U/R	0	92.4	79.2
UULMA	Ústí n.L.-město	Ústí nad Labem	CHMI	CHLM	B/U/RC	0	92.0	71.2

Tab. XI.8 Stations with the highest values of annual average concentrations of NO$_2$

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [µg.m⁻³]
ALEGA	Praha 2-Legerova (hot spot)	Praha 2	CHMI	CHLM	T/U/RC	**48.0**
BBNVA	Brno-Úvoz (hot spot)	Brno-město	CHMI	CHLM	T/U/R	38.4
BBMSA	Brno-Svatoplukova	Brno-město	SMBrno	CHLM	T/U/R	34.1
ZOTMA	Otrokovice-město	Zlín	MOTRO	CHLM	T/U/RIC	33.9
AVYNA	Praha 9-Vysočany	Praha 9	CHMI	CHLM	T/U/CR	33.0
TOCBA	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	CHLM	T/U/CR	31.6
APRUA	Praha 10-Průmyslová	Praha 10	CHMI	CHLM	T/U/IC	31.1
UULDA	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	CHLM	T/U/RC	31.0
AKALA	Praha 8-Karlín	Praha 8	CHMI	CHLM	T/U/C	29.2
AREPA	Praha 1-n. Republiky	Praha 1	CHMI	CHLM	B/U/C	28.7
SBERA	Beroun	Beroun	CHMI	CHLM	T/U/RCI	26.7
ZUHRA	Uherské Hradiště	Uherské Hradiště	CHMI	CHLM	T/U/RC	26.7
BBMVA	Brno-Výstaviště	Brno-město	SMBrno	CHLM	T/U/C	26.3
TKAOK	Karviná-ZÚ	Karviná	ZÚ-Ostrava	CHLM	T/U/R	26.3
TOPDA	Ostrava-Poruba, DD	Ostrava-město	ZÚ, SMOva	CHLM	T/U/R	25.5
JJIZA	Jihlava-Znojemská	Jihlava	ZÚ-Ostrava	CHLM	T/U/R	23.7
ARIEA	Praha 2-Riegrovy sady	Praha 2	CHMI	CHLM	B/U/NR	23.4
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	CHLM	I/U/IR	23.4
ABREA	Praha 6-Břevnov	Praha 6	CHMI	CHLM	B/U/RN	23.0
BBDNA	Brno - Dětská nemocnice	Brno-město	CHMI	CHLM	B/U/RC	22.9

Tab. XI.9 Stations with the highest values of annual average of NO$_x$ concentrations at rural stations

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [µg.m⁻³]
MLOSA	Loštice	Šumperk	OLOŠ	CHLM	B/R/A-NCI	22.9
TVERA	Věřňovice	Karviná	CHMI	CHLM	B/R/AI-NCI	19.7
UDOKA	Doksany	Litoměřice	CHMI	CHLM	B/R/NA-NCI	17.4
TSTDA	Studénka	Nový Jičín	CHMI	CHLM	B/R/A-NCI	16.3
ULOMA	Lom	Most	CHMI	CHLM	B/R/IN-NCI	14.2
TBRMA	Brumovice MŠ	Bruntál	ZÚ, MSK	CHLM	B/R/RA	13.8
UTUSA	Tušimice	Chomutov	CHMI	CHLM	B/R/IA-NCI	13.2
BMOCA	Sivice	Brno-venkov	Českomorav	CHLM	B/R/I-NCI	13.1
PKUJA	Kamenný Újezd	Rokycany	CHMI	CHLM	B/R/NA-NCI	12.7
STCSA	Tobolka-Čertovy schody	Beroun	VČs	CHLM	B/R/AN-NCI	10.2
USNZA	Sněžník	Děčín	CHMI	CHLM	B/R/N-REG	9.5
ZTNVA	Těšnovice	Kroměříž	CHMI	CHLM	B/R/A-REG	8.7
BMISA	Mikulov-Sedlec	Břeclav	CHMI	CHLM	B/R/A-REG	7.9
TCERA	Červená hora	Opava	CHMI	CHLM	B/R/N-REG	6.4
MJESA	Jeseník-lázně	Jeseník	CHMI	CHLM	B/R/N-NCI	6.1
KPRBA	Přebuz	Sokolov	CHMI	CHLM	B/R/AN-REG	5.3
TBKRA	Bílý Kříž	Frýdek-Místek	CHMI	CHLM	B/R/N-REG	5.0
JKOSA	Košetice	Pelhřimov	CHMI	CHLM	B/R/AN-REG	4.3
CCHUA	Churáňov	Prachatice	CHMI	CHLM	B/R/N-REG	2.9

Tab. XI.10 Stations with the highest values of maximum daily 8-hour running average concentrations of ozone

KMPL	Station	District	Owner	Measuring method	Classification	n	ppLVn 2017–2019	MAX8h–2019 [µg.m⁻³]	MAXx–n 2017–2019 [µg.m⁻³]	x	Valid years
HKRYA	Krkonoše–Rýchory	Trutnov	CHMI	UVABS	B/R/N–REG	2	70.5	180.9	127.5	51	2018–2019
URVHA	Rudolice v Horách	Most	CHMI	UVABS	B/R/N–REG	3	48.7	166.2	131.7	76	2017–2019
USNZA	Sněžník	Děčín	CHMI	UVABS	B/R/N–REG	3	47.0	163.9	130.1	76	2017–2019
UULKA	Ústí n.L.–Kočkov	Ústí nad Labem	CHMI	UVABS	B/S/RN	3	45.7	175.7	130.4	76	2017–2019
TCERA	Červená hora	Opava	CHMI	UVABS	B/R/N–REG	3	45.7	138.4	127.2	76	2017–2019
ESVRA	Svratouch	Chrudim	CHMI	UVABS	B/R/AN–REG	2	41.5	136.5	125.2	51	2018–2019
BKUCA	Kuchařovice	Znojmo	CHMI	UVABS	B/R/A–NCI	2	38.5	145.9	125.6	51	2018–2019
ZSNVA	Štítná n.Vláří	Zlín	CHMI	UVABS	B/R/N–REG	3	38.3	143.9	126.0	76	2017–2019
CCHUA	Churáňov	Prachatice	CHMI	UVABS	B/R/N–REG	2	37.5	–	125.2	51	2017–2018
UTPMA	Teplice	Teplice	CHMI	UVABS	B/U/R	3	37.3	167.9	126.0	76	2017–2019
ASTOA	Praha 5–Stodůlky	Praha 5	CHMI	UVABS	B/U/R	3	37.0	149.9	127.5	76	2017–2019
HPLOA	Polom	Rychnov nad Kněžnou	CHMI	UVABS	B/R/N–REG	3	36.3	163.6	126.6	76	2017–2019
PPRMA	Přimda	Tachov	CHMI	UVABS	B/R/N–REG	3	36.3	147.2	125.8	76	2017–2019
BBMAA	Brno–Arboretum	Brno–město	SMBrno	UVABS	B/U/RN	1	35.0	154.2	125.6	26	2019
BBNYA	Brno–Tuřany	Brno–město	CHMI	UVABS	B/S/R	3	35.0	152.2	124.6	76	2017–2019
ASUCA	Praha 6–Suchdol	Praha 6	CHMI	UVABS	B/S/R	3	33.7	150.3	125.4	76	2017–2019
KPRBA	Přebuz	Sokolov	CHMI	UVABS	B/R/AN–REG	3	33.7	155.8	124.3	76	2017–2019
SKLMA	Kladno–střed města	Kladno	CHMI	UVABS	B/U/R	3	33.3	155.5	125.4	76	2017–2019
UTUSA	Tušimice	Chomutov	CHMI	UVABS	B/R/IA–NCI	3	33.0	157.8	124.2	76	2017–2019
ALIBA	Praha 4–Libuš	Praha 4	CHMI	UVABS	B/S/R	3	32.7	160.3	125.4	76	2017–2019
TOROK	Ostrava–Radvanice OZO	Ostrava–město	ZÚ, SMOva	UVABS	B/S/R	3	32.3	161.9	123.1	76	2017–2019
UULMA	Ústí n.L.–město	Ústí nad Labem	CHMI	UVABS	B/U/RC	3	32.0	186.5	125.1	76	2017–2019
UDOKA	Doksany	Litoměřice	CHMI	UVABS	B/R/NA–NCI	3	32.0	171.8	123.2	76	2017–2019
LFRTA	Frýdlant	Liberec	CHMI	UVABS	B/R/N–REG	3	31.7	169.1	123.3	76	2017–2019
JKOSA	Košetice	Pelhřimov	CHMI	UVABS	B/R/AN–REG	3	31.7	135.1	122.4	76	2017–2019
TOMHK	Ostrava–Mariánské Hory	Ostrava–město	ZÚ, SMOva	UVABS	I/U/IR	3	31.3	162.4	123.6	76	2017–2019
CKOCA	Kocelovice	Strakonice	CHMI	UVABS	B/R/N–REG	3	31.3	148.0	122.8	76	2017–2019
UMOMA	Most	Most	CHMI	UVABS	B/U/R	3	31.0	162.5	124.3	76	2017–2019

KMPL	Station	District	Owner	Measuring method	Classification	n	ppLVn 2017–2019	MAX8h–2019 [µg.m⁻³]	MAXx-n 2017–2019 [µg.m⁻³]	x	Valid years
ULTTA	Litoměřice	Litoměřice	CHMI	UVABS	B/U/R	3	30.7	165.9	122.2	76	2017–2019
BMISA	Mikulov-Sedlec	Břeclav	CHMI	UVABS	B/R/A-REG	3	30.3	141.2	123.7	76	2017–2019
SONRA	Ondřejov	Praha-východ	CHMI	UVABS	B/R/N-REG	3	30.0	137.0	122.7	76	2017–2019
LSOUA	Souš	Jablonec nad Nisou	CHMI	UVABS	B/R/N-REG	3	29.7	165.7	123.6	76	2017–2019
HHKOK	Hradec Králové-observatoř	Hradec Králové	CHMI	UVABS	B/S/R	3	29.7	–	122.4	76	2017–2019
AKOBA	Praha 8-Kobylisy	Praha 8	CHMI	UVABS	B/S/R	3	28.3	150.5	122.1	76	2017–2019
ARIEA	Praha 2-Riegrovy sady	Praha 2	CHMI	UVABS	B/U/NR	3	27.7	147.2	121.7	76	2017–2019
USTEA	Štětí	Litoměřice	MSTE	UVABS	B/U/R	2	27.5	162.7	121.4	51	2018–2019
TOFFA	Ostrava-Fifejdy	Ostrava-město	CHMI	UVABS	B/U/R	3	26.0	156.2	120.3	76	2017–2019
LLILA	Liberec Rochlice	Liberec	CHMI	UVABS	B/U/R	3	25.7	156.7	120.4	76	2017–2019
KSOMA	Sokolov	Sokolov	CHMI	UVABS	B/S/R	3	25.3	159.1	120.1	76	2017–2019
SMBOA	Mladá Boleslav	Mladá Boleslav	CHMI	UVABS	B/U/R	3	25.0	168.8	120.0	76	2017–2019
JKMYA	Kostelní Myslová	Jihlava	CHMI	UVABS	B/R/A-NCI	3	24.7	140.4	119.6	76	2017–2019
BBMLA	Brno-Lány	Brno-město	SMBrno	UVABS	B/S/RN	3	24.0	146.3	118.9	76	2017–2019
TCTAA	Český Těšín-autobusové nádraží	Karviná	ZÚ, MSK	UVABS	T/U/RC	1	23.0	–	118.0	26	2017
CPRAA	Prachatice	Prachatice	CHMI	UVABS	B/S/R	3	22.7	146,7	118.7	76	2017–2019
ZTNVA	Těšnovice	Kroměříž	CHMI	UVABS	B/R/A-REG	3	22.7	135.9	118.0	76	2017–2019
JJIHA	Jihlava	Jihlava	CHMI	UVABS	B/U/RC	3	22.3	139.8	119.3	76	2017–2019
BBDNA	Brno - Dětská nemocnice	Brno-město	CHMI	UVABS	B/U/RC	3	22.0	137.9	118.8	76	2017–2019
TKARA	Karviná	Karviná	CHMI	UVABS	B/U/R	3	22.0	157.7	118.1	76	2017–2019
TOVKA	Opava-Kateřinky	Opava	CHMI	UVABS	B/U/R	3	21.3	133.0	118.0	76	2017–2019
MPRRA	Přerov	Přerov	CHMI	UVABS	B/U/CR	3	21.0	136.2	118.1	76	2017–2019

Note:

n ... number of valid years for the calculation

x ... xth max. daily 8-h concentration

ppLVn ... average number of LV exceedances for n valid years

MAX8h ... the highest max. daily 8-h concentration for the current year

MAXx-n ... the highest xth max. daily 8-h concentration for n valid years

Tab. XI.11 Stations with the highest AOT40 values of ozone at rural and suburban stations

KMPL	Station	District	Owner	Measuring method	Classification	n	AOT40* [µg.m⁻³.h]	Valid years
URVHA	Rudolice v Horách	Most	CHMI	UVABS	B/R/N-REG	5	23 055.4	2015–2019
BKUCA	Kuchařovice	Znojmo	CHMI	UVABS	B/R/A-NCI	4	22 598.8	2015, 2017–2019
HKRYA	Krkonoše-Rýchory	Trutnov	CHMI	UVABS	B/R/N-REG	4	22 344.4	2015–2016, 2018–2019
USNZA	Sněžník	Děčín	CHMI	UVABS	B/R/N-REG	5	22 317.8	2015–2019
BBNYA	Brno-Tuřany	Brno-město	CHMI	UVABS	B/S/R	5	21 759.0	2015–2019
TCERA	Červená hora	Opava	CHMI	UVABS	B/R/N-REG	5	21 272.5	2015–2019
JKOSA	Košetice	Pelhřimov	CHMI	UVABS	B/R/AN-REG	5	21 031.1	2015–2019
ASUCA	Praha 6-Suchdol	Praha 6	CHMI	UVABS	B/S/R	5	20 973.0	2015–2019
LSOUA	Souš	Jablonec nad Nisou	CHMI	UVABS	B/R/N-REG	5	20 912.5	2015–2019
ALIBA	Praha 4-Libuš	Praha 4	CHMI	UVABS	B/S/R	5	20 845.0	2015–2019
CKOCA	Kocelovice	Strakonice	CHMI	UVABS	B/R/N-REG	5	20 564.3	2015–2019
CCHUA	Churáňov	Prachatice	CHMI	UVABS	B/R/N-REG	5	20 542.9	2015–2019
UULKA	Ústí n.L.-Kočkov	Ústí nad Labem	CHMI	UVABS	B/S/RN	5	20 526.9	2015–2019
TOROK	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	UVABS	B/S/R	5	20 246.2	2015–2019
ZSNVA	Štítná n.Vláří	Zlín	CHMI	UVABS	B/R/N-REG	5	20 225.7	2015–2019
BMISA	Mikulov-Sedlec	Břeclav	CHMI	UVABS	B/R/A-REG	5	20 201.1	2015–2019
ESVRA	Svratouch	Chrudim	CHMI	UVABS	B/R/AN-REG	5	20 058.1	2015–2019
UDOKA	Doksany	Litoměřice	CHMI	UVABS	B/R/NA-NCI	4	19 730.3	2016–2019
HPLOA	Polom	Rychnov nad Kněžnou	CHMI	UVABS	B/R/N-REG	5	19 547.6	2015–2019
KPRBA	Přebuz	Sokolov	CHMI	UVABS	B/R/AN-REG	5	19 485.4	2015–2019
HHKOK	Hradec Králové-observatoř	Hradec Králové	CHMI	UVABS	B/S/R	5	19 244.2	2015–2019
SONRA	Ondřejov	Praha-východ	CHMI	UVABS	B/R/N-REG	5	19 129.2	2015–2019
LFRTA	Frýdlant	Liberec	CHMI	UVABS	B/R/N-REG	4	18 721.1	2016–2019
STCSA	Tobolka–Čertovy schody	Beroun	VČs	UVABS	B/R/AN-NCI	4	18 466.5	2015–2017, 2019
UTUSA	Tušimice	Chomutov	CHMI	UVABS	B/R/IA-NCI	5	18 133.6	2015–2019
ZTNVA	Těšnovice	Kroměříž	CHMI	UVABS	B/R/A-REG	4	17 766.3	2016–2019
JKMYA	Kostelní Myslová	Jihlava	CHMI	UVABS	B/R/A-NCI	5	17 468.6	2015–2019
CPRAA	Prachatice	Prachatice	CHMI	UVABS	B/S/R	5	17 439.1	2015–2019
PPRMA	Přimda	Tachov	CHMI	UVABS	B/R/N-REG	5	17 245.1	2015–2019
ZZLNA	Zlín	Zlín	CHMI	UVABS	B/S/RN	5	17 227.5	2015–2019
KSOMA	Sokolov	Sokolov	CHMI	UVABS	B/S/R	5	16 845.5	2015–2019
AKOBA	Praha 8-Kobylisy	Praha 8	CHMI	UVABS	B/S/R	5	15 450.3	2015–2019
CHVOA	Hojná Voda	České Budějovice	CHMI	UVABS	B/R/N-REG	5	14 770.5	2015–2019
ULOMA	Lom	Most	CHMI	UVABS	B/R/IN-NCI	5	14 432.3	2015–2019
TSTDA	Studénka	Nový Jičín	CHMI	UVABS	B/R/A-NCI	5	14 268.0	2015–2019
MJESA	Jeseník-lázně	Jeseník	CHMI	UVABS	B/R/N-NCI	5	13 376.7	2015–2019
BBMLA	Brno-Lány	Brno-město	SMBrno	UVABS	B/S/RN	3	13 368.0	2016, 2018–2019
TBKRA	Bílý Kříž	Frýdek-Místek	CHMI	UVABS	B/R/N-REG	5	13 306.4	2015–2019
PPLVA	Plzeň-Doubravka	Plzeň-město	CHMI	UVABS	B/S/A	5	12 891.4	2015–2019

Note:

n … number of years for the calculation (with the valid annual average)

* … average for n years

Tab. XI.12 Number of hours of the ozone information threshold exceedance (180 µg.m⁻³) per year at selected AIM stations, 2005–2019

Region	KMPL	Station	Owner	Classification	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Capital City of Prague	AKOBA	Praha 8-Kobylisy	CHMI	B/S/R	0	16	0	0	0	0	0	0	7	0	0	0	0	4	0
	ALERA	Letiště Praha	Letiště Pr	T/S/C	–	–	–	–	–	–	–	–	–	–	–	–	–	0	○
	ALIBA	Praha 4-Libuš	CHMI	B/S/R	4	10	5	0	0	0	0	6	3	2	29	0	0	3	0
	AREPA	Praha 1-n. Republiky	CHMI	B/U/C	0	○	○	0	0	0	○	–	–	–	–	–	–	–	–
	ARIEA	Praha 2-Riegrovy sady	CHMI	B/U/NR	–	–	–	–	–	0	0	1	3	0	11	0	0	4	0
	ASMIA	Praha 5-Smíchov	CHMI	T/U/RC	0	0	1	0	0	0	0	0	–	–	–	–	–	–	–
	ASTOA	Praha 5-Stodůlky	CHMI	B/U/R	0	19	4	0	0	2	0	6	0	0	30	0	1	4	0
	ASUCA	Praha 6-Suchdol	CHMI	B/S/R	1	24	10	0	0	3	0	2	9	1	28	0	0	3	0
	AVELA	Praha 6-Veleslavín	CHMI	B/S/R	0	12	8	0	0	0	0	–	–	–	–	–	–	–	–
	AVEXA	Praha 6-Veleslavín	CHMI	I/U/I	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–
	AVYNA	Praha 9-Vysočany	CHMI	T/U/CR	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	BBDNA	Brno – Dětská nemocnice	CHMI	B/U/RC	–	–	–	–	–	–	–	○	○	0	1	0	0	0	0
	BBMLA	Brno-Lány	SMBrno	B/S/RN	–	–	–	–	–	–	–	○	○	0	2	0	0	0	0
	BBMRA	Brno-Arboretum	SMBrno	T/U/RN	0	38	0	0	0	0	0	○	○	–	–	–	–	–	○
	BBMZA	Brno-Zvonařka	SMBrno	T/U/C	3	1	0	0	0	0	0	0	0	○	0	0	0	○	○
South Moravia	BBNDA	Brno-střed	CHMI	T/U/R	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–
	BBNYA	Brno-Tuřany	CHMI	B/S/R	0	12	6	0	0	1	0	0	1	0	11	0	0	0	0
	BHODA	Hodonín	ZÚ-Ostrava	B/U/R	0	1	16	0	1	–	–	–	–	–	–	–	–	–	–
	BKUCA	Kuchařovice	CHMI	B/R/A-NCI	0	8	7	0	0	0	0	0	5	0	12	0	0	0	0
	BMISA	Mikulov-Sedlec	CHMI	B/R/A-REG	2	7	3	0	0	0	0	0	1	0	5	0	0	0	0

Region	KMPL	Station	Owner	Classification	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
South Bohemia	CCBDA	České Budějovice	CHMI	B/U/R	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	CCHUA	Churáňov	CHMI	B/R/N-REG	0	0	0	0	0	0	0	0	43	0	0	0	0	0	0
	CHVOA	Hojná Voda	CHMI	B/R/N-REG	1	9	0	0	0	0	0	0	2	0	0	0	0	0	0
	CKOCA	Kocelovice	CHMI	B/R/N-REG	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	CPRAA	Prachatice	CHMI	B/S/R	○	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	CTABA	Tábor	CHMI	T/U/RC	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Pardubice	EPAOA	Pardubice-Rosice	CHMI	B/S/RI	3	14	2	0	0	5	0	0	-	-	-	-	-	-	-
	EPAUA	Pardubice Dukla	CHMI	B/U/R	1	5	0	0	0	0	0	0	0	0	5	0	0	0	0
	ESVRA	Svratouch	CHMI	B/R/AN-REG	0	○	0	0	0	0	0	0	0	0	1	0	0	0	0
Hradec Králové	HHKBA	Hradec Králové-Brněnská	CHMI	T/U/RC	2	13	4	0	0	0	0	0	-	-	-	-	-	-	-
	HHKOK	Hradec Králové-observatoř	CHMI	B/S/R	0	13	0	0	0	0	0	0	0	0	0	0	0	1	2
	HHKSA	Hr.Král.-Sukovy sady	ZÚ Ústí nL	T/U/RCI	0	0	0	0	0	0	0	0	0	0	0	○	-	-	-
	HKRYA	Krkonoše-Rýchory	CHMI	B/R/N-REG	○	1	0	0	0	0	0	0	0	0	1	0	0	0	5
	HOHZA	Orlické hory-Zakletý I	CHMI	B/R/N-REG	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	HPLOA	Polom	CHMI	B/R/N-REG		-	-	-	-	-	-	○	○	0	0	0	0	0	0
	HSERA	Šerlich	CHMI	B/R/N-REG	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-
Vysočina	JJIHA	Jihlava	CHMI	B/U/RC	0	5	7	0	0	0	0	0	0	0	0	0	0	0	0
	JKMYA	Kostelní Myslová	CHMI	B/R/A-NCI	0	9	5	0	0	0	0	0	0	0	3	0	0	0	0
	JKOSA	Košetice	CHMI	B/R/AN-REG	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
	JZNZA	Žďár nad Sázavou	ZÚ-Ostrava	B/U/RC	0	0	4	0	0	○	○	○	0	0	-	-	-	-	-
Karlovy Vary	KPRBA	Přebuz	CHMI	B/R/AN-REG	0	6	0	1	0	0	0	0	0	0	2	0	0	0	0
	KSOMA	Sokolov	CHMI	B/S/R	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0

Region	KMPL	Station	Owner	Classification	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Liberec	LFRTA	Frýdlant	CHMI	B/R/N-REG	–	–	–	–	–	–	–	–	–	○	○	●	●	5	●
	LFRUA	Frýdlant-Údolí	CHMI	B/R/AN-NCI	–	–	–	–	–	○	●	●	●	●	○	○	–	–	–
	LLILA	Liberec Rochlice	CHMI	B/U/R	–	–	–	–	–	–	–	–	–	○	3	●	●	●	●
	LLIMA	Liberec-město	CHMI	B/U/RC	●	2	●	●	●	●	●	●	●	●	○	○	–	–	–
	LSOUA	Souš	CHMI	B/R/N-REG	●	3	●	●	●	●	●	●	●	●	1	●	●	●	1
	MJESA	Jeseník-lázně	CHMI	B/R/N-NCI	●	2	3	●	●	●	●	●	●	●	●	●	●	●	●
Olomouc	MOLSA	Olomouc-Šmeralova	ZÚ-Ostrava	B/U/R	●	●	1	●	●	○	–	–	–	–	–	–	–	–	–
	MOLVK	Olomouc-Velkomoravská	MOLO	T/U/R	●	●	●	●	●	●	●	–	–	–	–	–	–	–	–
	MPHRA	Hranice	MHRA	B/U/RC	–	–	–	–	–	–	–	–	–	–	–	–	○	○	●
	MPRRA	Přerov	CHMI	B/U/CR	●	1	8	●	●	●	●	●	●	●	2	●	●	●	●
	MPSTA	Prostějov	CHMI	B/U/R	●	4	●	●	●	●	●	●	–	–	–	–	–	–	–
	MSMSA	Šumperk – 5.ZŠ	MŠUM	B/U/R	–	–	–	–	–	–	–	–	–	–	–	○	○	●	●
	MSMUK	Šumperk MÚ	MŠUM	B/U/R	●	●	●	●	●	●	●	●	●	●	●	○	●	–	–
	PKLSA	Klatovy soud	ZÚ Ústí nL	T/U/R	●	●	●	●	●	●	●	●	●	●	●	○	–	–	–
Plzeň	PPLAA	Plzeň-Slovany	MPI	T/U/RC	●	●	1	●	●	●	●	●	●	●	●	●	●	●	●
	PPLBA	Plzeň-Bory	MPI	B/U/R	●	1	●	●	●	1	●	●	●	●	●	○	○	–	–
	PPLLA	Plzeň-Lochotín	MPI	B/U/R	●	1	●	●	●	●	●	●	●	●	2	●	●	●	●
	PPLVA	Plzeň-Doubravka	CHMI	B/S/A	●	1	●	●	●	●	●	●	●	●	●	●	●	●	●
	PPRMA	Přimda	CHMI	B/R/N-REG	3	1	2	●	●	○	●	●	●	●	6	●	3	●	●
	SKLMA	Kladno-střed města	CHMI	B/U/R	2	12	1	●	●	●	●	●	●	●	14	●	●	●	●
Central Bohemian	SMBOA	Mladá Boleslav	CHMI	B/U/R	4	28	5	●	●	1	●	●	●	●	9	●	●	1	3
	SONRA	Ondřejov	CHMI	B/R/N-REG	●	●	7	●	●	●	●	●	●	●	5	●	●	●	●
	STCSA	Tobolka-Čertovy schody	VČs	B/R/AN-NCI	–	–	–	–	–	–	○	●	●	●	18	●	●	2	●

Region	KMPL	Station	Owner	Classification	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	TBILA	Bílovec	ZÚ, MSK	T/S/R	-	-	-	-	-	-	-	-	-	○	○	6	○	○	-
	TBKRA	Bílý Kříž	CHMI	B/R/N-REG	●	8	●	●	●	●	●	●	●	●	●	●	●	●	●
	TBOUA	Bohumín	ZÚ, MSK	T/S/R	-	-	-	-	-	-	-	-	-	○	○	●	○	○	-
	TBRNA	Bruntál	ZÚ, MSK	T/U/RC	-	-	-	-	-	-	-	-	○	●	○	-	-	-	-
	TCERA	Červená hora	CHMI	B/R/N-REG	●	●	8	2	●	●	●	●	●	●	8	●	●	●	●
	TCTAA	Český Těšín-autobusové nádraží	ZÚ, MSK	T/U/RC	-	-	-	-	-	-	-	-	-	-	○	○	●	○	○
	THLOA	Horní Lomná	ZÚ, MSK	B/R/N	-	-	-	-	-	-	-	-	-	○	-	○	○	-	-
	TKARA	Karviná	CHMI	B/U/R	●	14	2	●	●	7	●	●	●	●	2	●	●	2	1
	TKSTA	Karlova Studánka	ZÚ, MSK	B/R/RN-NCI	-	-	-	-	-	-	-	-	○	●	○	-	-	-	-
	TODRA	Odry	ZÚ, MSK	B/S/R	-	-	-	-	-	-	-	-	-	○	31	○	○	-	-
	TOFFA	Ostrava-Fifejdy	CHMI	B/U/R	●	3	8	●	●	2	●	●	1	3	7	●	●	●	●
Moravian-Silesian	TOMHK	Ostrava-Mariánské Hory	ZÚ, SMOva	I/U/IR	-	-	-	-	●	5	●	●	5	1	12	●	●	3	●
	TONVA	Ostrava Nová Ves-areál OVak	ZÚ, MSK	T/U/IAN	-	-	-	-	-	-	-	-	○	-	○	○	○	○	○
	TOPRA	Ostrava-Přívoz	CHMI	I/U/IR	●	○	-	-	-	-	-	-	-	-	-	-	-	-	-
	TOREK	Ostrava-Radvanice ZÚ	ZÚ, SMOva	I/S/IR	-	-	5	-	●	●	●	●	5	1	10	●	●	●	●
	TOROK	Ostrava-Radvanice OZO	ZÚ, SMOva	B/S/R	-	-	-	-	-	-	-	○	4	3	11	●	●	●	●
	TOSTA	Ostravice	ZÚ, MSK	B/R/NR-NCI	-	-	-	-	-	-	-	-	○	2	○	-	-	-	-
	TOUZA	Opava-univerzitní zahrada	ZÚ, MSK	T/U/R	-	-	-	-	-	-	-	-	-	○	○	○	○	○	○
	TOVKA	Opava-Kateřinky	CHMI	B/U/R	-	-	-	●	●	-	●	●	●	●	7	●	●	●	●
	TRYMA	Rýmařov	ZÚ, MSK	B/U/R	-	-	-	-	-	-	-	-	-	○	●	○	○	-	-
	TSTDA	Studénka	CHMI	B/R/A-NCI	●	1	5	●	●	2	●	2	1	●	7	●	●	●	●
	TTROA	Třinec-Kosmos	CHMI	B/U/R	●	12	1	●	●	2	●	●	●	2	3	●	●	●	●
	TVITA	Vítkov	ZÚ, MSK	B/S/RN	-	-	-	-	-	-	-	-	-	○	○	1	○	○	-

Region	KMPL	Station	Owner	Classification	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ústí nad Labem	UDOKA	Doksany	CHMI	B/R/NA-NCI	-	-	-	-	-	-	-	-	-	○	4	0	1	0	3
	ULOMA	Lom	CHMI	B/R/IN-NCI	2	21	5	0	3	3	0	0	0	0	15	0	0	0	0
	ULTHK	Litoměřice-ZÚ	ZÚ	B/U/RC	6	32	0	-	-	-	-	-	-	-	-	-	-	-	-
	ULTTA	Litoměřice	CHMI	B/U/R	2	21	2	0	0	6	0	0	4	0	7	0	0	0	0
	UMOMA	Most	CHMI	B/U/R	2	6	0	2	0	6	0	0	1	0	18	0	0	3	2
	URVHA	Rudolice v Horách	CHMI	B/R/N-REG	7	43	8	3	0	0	0	0	1	0	37	0	0	1	0
	USNZA	Sněžník	CHMI	B/R/N-REG	0	14	0	0	0	4	0	0	4	0	30	0	0	6	0
	USTEA	Štětí	MSTE	B/U/R	-	-	-	-	-	-	-	-	-	-	-	○	○	0	0
	UTPMA	Teplice	CHMI	B/U/R	2	17	1	○	3	7	0	0	7	0	23	0	3	3	1
	UTUSA	Tušimice	CHMI	B/R/IA-NCI	6	10	0	0	0	2	1	0	0	0	14	0	0	1	0
	UULKA	Ústí n.L.-Kočkov	CHMI	B/S/RN	0	11	7	0	0	0	0	0	3	0	29	0	0	5	2
	UULMA	Ústí n.L.-město	CHMI	B/U/RC	0	2	0	0	0	2	0	0	1	0	2	0	0	3	5
	UVALA	Valdek	CHMI	B/R/AN-NCI	0	11	0	0	0	1	-	-	-	-	-	-	-	-	-
	UZAZA	Žatec	SŠZE Žatec	B/S/R	-	1	3	2	○	0	○	○	○	0	○	○	-	-	-
Zlín	ZSNVA	Štítná n.Vláří	CHMI	B/R/N-REG	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
	ZTNVA	Těšnovice	CHMI	B/R/A-REG	-	-	-	-	-	-	-	-	-	○	○	0	0	0	0
	ZZLNA	Zlín	CHMI	B/S/RN	0	6	1	0	0	0	0	0	0	0	0	0	0	0	0
	ZZLTK	Zlín-Svit	MZLI	T/U/CR	0	0	0	0	0	0	0	0	0	0	4	○	-	-	-
	ZZZSA	Zlín – ZŠ Kvítkova	MZLI	B/U/R	-	-	-	-	-	-	-	-	-	-	-	○	○	0	0

Note:
Bold figures show data for the station / year with the fulfilled condition for the calculation for the valid annual arithmetic average.

Tab. XI.13 Stations with the highest values of annual average concentrations of benzene

KMPL	Station	District	Owner	Measuring method	Classification	Annual con-centration [µg.m⁻³]
TOPRD	Ostrava-Přívoz	Ostrava-město	CHMI	GC-FID	I/U/IR	4.2
TOREV	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	GC-FID	I/S/IR	3.1
TOFFD	Ostrava-Fifejdy	Ostrava-město	CHMI	GC-FID	B/U/R	2.6
TOROV	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	GC-FID	B/S/R	2.4
TOCBD	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	GC-FID	T/U/CR	2.3
TOMHV	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	GC-FID	I/U/IR	2.1
ZVMZD	Valašské Meziříčí	Vsetín	CHMI	GC-FID	B/U/R	2.1
TVRTV	Vratimov	Ostrava-město	ZÚ, MSK	GC-FID	I/S/RI	1.9
TVERD	Věřňovice	Karviná	CHMI	GC-FID	B/R/AI-NCI	1.8
TOPOD	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	GC-FID	B/S/R	1.5
TOVKD	Opava-Kateřinky	Opava	CHMI	GC-FID	B/U/R	1.4
TTROD	Třinec-Kosmos	Frýdek-Místek	CHMI	GC-FID	B/U/R	1.4
UULDD	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	GC-FID	T/U/RC	1.4
BBNVD	Brno-Úvoz (hot spot)	Brno-město	CHMI	GC-FID	T/U/R	1.3
MOLJD	Olomouc-Hejčín	Olomouc	CHMI	GC-FID	B/U/R	1.3
ALEGD	Praha 2-Legerova (hot spot)	Praha 2	CHMI	GC-FID	T/U/RC	1.2
AREPD	Praha 1-n. Republiky	Praha 1	CHMI	GC-FID	B/U/C	1.2
ZZLND	Zlín	Zlín	CHMI	GC-FID	B/S/RN	1.2
EPAOD	Pardubice-Rosice	Pardubice	CHMI	GC-FID	B/S/RI	1.1
UMOMD	Most	Most	CHMI	GC-FID	B/U/R	1.1
UULMD	Ústí n.L.-město	Ústí nad Labem	CHMI	GC-FID	B/U/RC	1.1
ALIBD	Praha 4-Libuš	Praha 4	CHMI	GC-FID	B/S/R	1.0
BBDND	Brno - Dětská nemocnice	Brno-město	CHMI	GC-FID	B/U/RC	1.0
HHKBD	Hradec Králové-Brněnská	Hradec Králové	CHMI	GC-FID	T/U/RC	1.0
PPLXD	Plzeň-Slovany	Plzeň-město	CHMI	GC-FID	T/U/RC	1.0
EPAUD	Pardubice Dukla	Pardubice	CHMI	GC-FID	B/U/R	0.9
JJIHD	Jihlava	Jihlava	CHMI	GC-FID	B/U/RC	0.9
SKLMD	Kladno-střed města	Kladno	CHMI	GC-FID	B/U/R	0.9
TBRMV	Brumovice MŠ	Bruntál	ZÚ, MSK	GC-FID	B/R/RA	0.9
THBEV	Horní Benešov MŠ	Bruntál	ZÚ, MSK	GC-FID	B/S/R	0.9
KSOMD	Sokolov	Sokolov	CHMI	GC-FID	B/S/R	0.8
LLILD	Liberec Rochlice	Liberec	CHMI	GC-FID	B/U/R	0.8
UTUSD	Tušimice	Chomutov	CHMI	GC-FID	B/R/IA-NCI	0.8
BMISD	Mikulov-Sedlec	Břeclav	CHMI	GC-FID	B/R/A-REG	0.7
KCHMD	Cheb	Cheb	CHMI	GC-FID	B/S/R	0.7
URVHD	Rudolice v Horách	Most	CHMI	GC-FID	B/R/N-REG	0.6

Tab. XI.14 Stations with the highest values of annual average concentrations of lead in the ambient air

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [ng.m^{-3}]
TORE0	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	ICP-MS	I/S/IR	51.9
TORO0	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	ICP-MS	B/S/R	24.6
SPBR0	Příbram-Březové Hory	Příbram	CHMI	ICP-MS	B/U/R	20.4
TKAO0	Karviná-ZÚ	Karviná	ZÚ-Ostrava	ICP-MS	T/U/R	17.2
TVRT0	Vratimov	Ostrava-město	ZÚ, MSK	ICP-MS	I/S/RI	15.0
TOMH0	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	ICP-MS	I/U/IR	14.6
TOPR0	Ostrava-Přívoz	Ostrava-město	CHMI	ICP-MS	I/U/IR	14.6
TCTN0	Český Těšín	Karviná	CHMI	ICP-MS	B/U/R	14.3
TOPR5	Ostrava-Přívoz	Ostrava-město	CHMI	ICP-MS	I/U/IR	12.1
MOLJ0	Olomouc-Hejčín	Olomouc	CHMI	ICP-MS	B/U/R	9.3
MOLS0	Olomouc-Šmeralova	Olomouc	ZÚ-Ostrava	ICP-MS	B/U/R	9.3
BBNA0	Brno-Masná	Brno-město	ZÚ-Ostrava	ICP-MS	B/U/CR	7.2
LTAS0	Tanvald-školka	Jablonec nad Nisou	CHMI	ICP-MS	B/U/R	7.2
UUDI0	Ústí n. L.-Prokopa Diviše	Ústí nad Labem	ZÚ Ústí nL	ICP-MS	I/U/RCI	7.2
TOPO0	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	ICP-MS	B/S/R	6.9
BHOD0	Hodonín	Hodonín	ZÚ-Ostrava	ICP-MS	B/U/R	6.7
TOPO5	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	ICP-MS	B/S/R	6.0
JJIZ0	Jihlava-Znojemská	Jihlava	ZÚ-Ostrava	ICP-MS	T/U/R	5.8
TBRM0	Brumovice MŠ	Bruntál	ZÚ, MSK	ICP-MS	B/R/RA	5.8
THBE0	Horní Benešov MŠ	Bruntál	ZÚ, MSK	ICP-MS	B/S/R	5.7

Tab. XI.15 Stations with the highest values of annual average concentrations of cadmium in the ambient air

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [ng.m^{-3}]
LTAS0	Tanvald-školka	Jablonec nad Nisou	CHMI	ICP-MS	B/U/R	4.0
TORE0	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	ICP-MS	I/S/IR	1.4
LSOU0	Souš	Jablonec nad Nisou	CHMI	ICP-MS	B/R/N-REG	1.0
SBUS0	Buštěhrad	Kladno	ZÚ Ústí nL	ICP-OES	B/U/R	1.0
TORO0	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	ICP-MS	B/S/R	0.6
ALIB0	Praha 4-Libuš	Praha 4	CHMI	ICP-MS	B/S/R	0.5
TKAO0	Karviná-ZÚ	Karviná	ZÚ-Ostrava	ICP-MS	T/U/R	0.4
TOMH0	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	ICP-MS	I/U/IR	0.4
TOPR0	Ostrava-Přívoz	Ostrava-město	CHMI	ICP-MS	I/U/IR	0.4
TOPR5	Ostrava-Přívoz	Ostrava-město	CHMI	ICP-MS	I/U/IR	0.4
TVRT0	Vratimov	Ostrava-město	ZÚ, MSK	ICP-MS	I/S/RI	0.4
ALIB5	Praha 4-Libuš	Praha 4	CHMI	ICP-MS	B/S/R	0.3
BBNA0	Brno-Masná	Brno-město	ZÚ-Ostrava	ICP-MS	B/U/CR	0.3
BHOD0	Hodonín	Hodonín	ZÚ-Ostrava	ICP-MS	B/U/R	0.3
JJIH0	Jihlava	Jihlava	CHMI	ICP-MS	B/U/RC	0.3
JJIZ0	Jihlava-Znojemská	Jihlava	ZÚ-Ostrava	ICP-MS	T/U/R	0.3
JZNZ0	Žďár nad Sázavou	Žďár nad Sázavou	ZÚ-Ostrava	ICP-MS	B/U/RC	0.3
LJIZ0	Jizerka	Jablonec nad Nisou	CHMI	ICP-MS	B/R/AN-REG	0.3
LLIL0	Liberec Rochlice	Liberec	CHMI	ICP-MS	B/U/R	0.3
TCTN0	Český Těšín	Karviná	CHMI	ICP-MS	B/U/R	0.3

Tab. XI.16 Stations with the highest values of annual average concentrations of arsenic in the ambient air

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [ng.m^{-3}]
SKLS0	Kladno-Švermov	Kladno	CHMI	ICP-MS	B/U/RI	3.3
ARER0	Praha 5-Řeporyje	Praha 5	ZÚ Ústí nL	ICP-MS	B/S/RA	2.9
SKLC0	Kladno-Vrapice	Kladno	ZÚ Ústí nL	ICP-OES	B/S/I	2.6
SSTE0	Stehelčeves	Kladno	ZÚ Ústí nL	ICP-OES	B/S/R	2.6
TBRS0	Bruntál-škola	Bruntál	CHMI,MSK	ICP-MS	T/U/R	2.5
LTAS0	Tanvald-školka	Jablonec nad Nisou	CHMI	ICP-MS	B/U/R	2.3
ULOM0	Lom	Most	CHMI	ICP-MS	B/R/IN-NCI	2.1
PPLR0	Plzeň-Roudná	Plzeň-město	ZÚ Ústí nL	ICP-MS	B/U/R	2.0
SBUS0	Buštěhrad	Kladno	ZÚ Ústí nL	ICP-OES	B/U/R	2.0
TOMH0	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	ICP-MS	I/U/IR	2.0
PKLS0	Klatovy soud	Klatovy	ZÚ Ústí nL	ICP-MS	T/U/R	1.9
SKRP0	Kralupy nad Vltavou-sportoviště	Mělník	ZÚ Ústí nL	ICP-MS	I/U/RCI	1.8
TORO0	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	ICP-MS	B/S/R	1.8
TORE0	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	ICP-MS	I/S/IR	1.7
TVRT0	Vratimov	Ostrava-město	ZÚ, MSK	ICP-MS	I/S/RI	1.7
UUDI0	Ústí n. L.-Prokopa Diviše	Ústí nad Labem	ZÚ Ústí nL	ICP-MS	I/U/RCI	1.7
THBE0	Horní Benešov MŠ	Bruntál	ZÚ, MSK	ICP-MS	B/S/R	1.6
TOPR0	Ostrava-Přívoz	Ostrava-město	CHMI	ICP-MS	I/U/IR	1.6
TKAO0	Karviná-ZÚ	Karviná	ZÚ-Ostrava	ICP-MS	T/U/R	1.5
UDOK0	Doksany	Litoměřice	CHMI	ICP-MS	B/R/NA-NCI	1.5

Tab. XI.17 Stations with the highest values of annual average concentrations of nickel in the ambient air

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [ng.m^{-3}]
TOMH0	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	ICP-MS	I/U/IR	4.0
TOPR0	Ostrava-Přívoz	Ostrava-město	CHMI	ICP-MS	I/U/IR	3.6
TORE0	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	ICP-MS	I/S/IR	2.6
TORO0	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	ICP-MS	B/S/R	2.2
TVRT0	Vratimov	Ostrava-město	ZÚ, MSK	ICP-MS	I/S/RI	1.9
TBRM0	Brumovice MŠ	Bruntál	ZÚ, MSK	ICP-MS	B/R/RA	1.8
BBNA0	Brno-Masná	Brno-město	ZÚ-Ostrava	ICP-MS	B/U/CR	1.7
TOPR5	Ostrava-Přívoz	Ostrava-město	CHMI	ICP-MS	I/U/IR	1.6
MOLJ0	Olomouc-Hejčín	Olomouc	CHMI	ICP-MS	B/U/R	1.5
THBE0	Horní Benešov MŠ	Bruntál	ZÚ, MSK	ICP-MS	B/S/R	1.3
ASRO0	Praha 10-Šrobárova	Praha 10	ZÚÚstí/SZÚ	ICP-MS	B/U/RC	1.1
MOLS0	Olomouc-Šmeralova	Olomouc	ZÚ-Ostrava	ICP-MS	B/U/R	1.1
TKAO0	Karviná-ZÚ	Karviná	ZÚ-Ostrava	ICP-MS	T/U/R	1.1
JZNZ0	Žďár nad Sázavou	Žďár nad Sázavou	ZÚ-Ostrava	ICP-MS	B/U/RC	1.0
TCTN0	Český Těšín	Karviná	CHMI	ICP-MS	B/U/R	1.0
BHOD0	Hodonín	Hodonín	ZÚ-Ostrava	ICP-MS	B/U/R	0.9
ARIE0	Praha 2-Riegrovy sady	Praha 2	CHMI	ICP-MS	B/U/NR	0.8
HHKT0	Hradec Králové - tř. SNP	Hradec Králové	CHMI	ICP-MS	B/U/R	0.8
JJIZ0	Jihlava-Znojemská	Jihlava	ZÚ-Ostrava	ICP-MS	T/U/R	0.7
SBUS0	Buštěhrad	Kladno	ZÚ Ústí nL	ICP-OES	B/U/R	0.7

Tab. XI.18 Stations with the highest values of the 25th and maximum hourly concentrations of SO$_2$

KMPL	Station	District	Owner	Measuring method	Classifi-cation	pLV	Max. hourly concentra-tion [µg.m⁻³]	25th highest hourly concen-tration [µg.m⁻³]
TOPOA	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	UVFL	B/S/R	0	315.6	35.7
TBRMA	Brumovice MŠ	Bruntál	ZÚ, MSK	UVFL	B/R/RA	0	271.1	37.0
KSOMA	Sokolov	Sokolov	CHMI	UVFL	B/S/R	0	254.3	55.7
TSTDA	Studénka	Nový Jičín	CHMI	UVFL	B/R/A-NCI	0	219.2	28.8
USNZA	Sněžník	Děčín	CHMI	UVFL	B/R/N-REG	0	203.5	65.0
UKRUA	Krupka	Teplice	CHMI	UVFL	B/R/N-NCI	0	193.3	88.9
TCTNA	Český Těšín	Karviná	CHMI	UVFL	B/U/R	0	192.8	127.8
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	UVFL	I/U/IR	0	191.2	49.8
ULTTA	Litoměřice	Litoměřice	CHMI	UVFL	B/U/R	0	191.2	38.9
UMLAA	Milá	Most	ČEZ	UVFL	I/R/A	0	187	35.0
TOFFA	Ostrava-Fifejdy	Ostrava-město	CHMI	UVFL	B/U/R	0	178.2	45.0
UNVDA	Nová Víska u Domašína	Chomutov	ČEZ	UVFL	I/R/N	0	172	51.0
UMEDA	Měděnec	Chomutov	CHMI	UVFL	B/R/ANI-NCI	0	161.1	55.9
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	UVFL	I/S/IR	0	148.6	98.0
ULOMA	Lom	Most	CHMI	UVFL	B/R/IN-NCI	0	137.4	66.8
TVRTA	Vratimov	Ostrava-město	ZÚ, MSK	UVFL	I/S/RI	0	132.9	52.7
TKARA	Karviná	Karviná	CHMI	UVFL	B/U/R	0	124.6	70.0
PPLAA	Plzeň-Slovany	Plzeň-město	MPI	UVFL	T/U/RC	0	123.3	21.6
TOROK	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	UVFL	B/S/R	0	119.8	68.7
UULKA	Ústí n.L.-Kočkov	Ústí nad Labem	CHMI	UVFL	B/S/RN	0	117.2	53.3

Tab. XI.19 Stations with the highest numbers of exceedances of the 24-hour limit value of SO$_2$

KMPL	Station	District	Owner	Measuring method	Classifi-cation	pLV	Max. 24-hour con-centration [µg.m⁻³]	4th highest 24-hour con-cen tration [µg.m⁻³]
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	UVFL	I/S/IR	0	69.5	51.5
TCTNA	Český Těšín	Karviná	CHMI	UVFL	B/U/R	0	64.9	51.6
USNZA	Sněžník	Děčín	CHMI	UVFL	B/R/N-REG	0	58.7	42.5
TPEKA	Petrovice u Karviné	Karviná	ČEZ	UVFL	I/S/C	0	49.0	37.8
UKOSA	Kostomlaty pod Mileš.	Teplice	ČEZ	UVFL	I/R/A	0	46.0	35.8
TOPOA	Ostrava-Poruba/CHMI	Ostrava-město	CHMI	UVFL	B/S/R	0	44.7	18.7
UKRUA	Krupka	Teplice	CHMI	UVFL	B/R/N-NCI	0	44.1	32.2
TVERA	Věřňovice	Karviná	CHMI	UVFL	B/R/AI-NCI	0	41.2	26.7
TOFFA	Ostrava-Fifejdy	Ostrava-město	CHMI	UVFL	B/U/R	0	41.1	22.3
TSUNA	Šunychl	Karviná	ČEZ	UVFL	I/S/A	0	40.3	28.1
TOROK	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	UVFL	B/S/R	0	38.0	33.0
ULTTA	Litoměřice	Litoměřice	CHMI	UVFL	B/U/R	0	36.4	20.6
TOMHK	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	UVFL	I/U/IR	0	36.1	23.7
TRYCA	Rychvald	Karviná	CHMI	UVFL	B/U/R	0	36.1	25.9
TKARA	Karviná	Karviná	CHMI	UVFL	B/U/R	0	35.6	30.9
UULKA	Ústí n.L.-Kočkov	Ústí nad Labem	CHMI	UVFL	B/S/RN	0	34.0	28.7
THBEA	Horní Benešov MŠ	Bruntál	ZÚ, MSK	UVFL	B/S/R	0	33.6	28.9
UMEDA	Měděnec	Chomutov	CHMI	UVFL	B/R/ANI-NCI	0	33.0	24.5
TBRMA	Brumovice MŠ	Bruntál	ZÚ, MSK	UVFL	B/R/RA	0	31.9	28.5
TOPRA	Ostrava-Přívoz	Ostrava-město	CHMI	UVFL	I/U/IR	0	31.9	26.6

Tab. XI.20 Stations with the highest values of annual average concentrations of SO$_2$

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [µg.m⁻³]
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	UVFL	I/S/IR	14.9
TOROK	Ostrava-Radvanice OZO	Ostrava-město	ZÚ, SMOva	UVFL	B/S/R	12.9
TCTNA	Český Těšín	Karviná	CHMI	UVFL	B/U/R	11.2
TVRTA	Vratimov	Ostrava-město	ZÚ, MSK	UVFL	I/S/RI	9.3
TPEKA	Petrovice u Karviné	Karviná	ČEZ	UVFL	I/S/C	9.0
UKRUA	Krupka	Teplice	CHMI	UVFL	B/R/N-NCI	9.0
TSUNA	Šunychl	Karviná	ČEZ	UVFL	I/S/A	8.6
UKOSA	Kostomlaty pod Mileš.	Teplice	ČEZ	UVFL	I/R/A	8.6
UMLAA	Milá	Most	ČEZ	UVFL	I/R/A	8.6
THBEA	Horní Benešov MŠ	Bruntál	ZÚ, MSK	UVFL	B/S/R	8.2
TOMHK	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	UVFL	I/U/IR	7.6
ULOMA	Lom	Most	CHMI	UVFL	B/R/IN-NCI	7.6
UDROA	Droužkovice	Chomutov	ČEZ	UVFL	I/R/A	7.,3
TKARA	Karviná	Karviná	CHMI	UVFL	B/U/R	7.2
UNVDA	Nová Víska u Domašína	Chomutov	ČEZ	UVFL	I/R/N	7.2
UHVRA	Havraň	Most	ČEZ	UVFL	I/R/A	6.9
TBRMA	Brumovice MŠ	Bruntál	ZÚ, MSK	UVFL	B/R/RA	6.8
UBLZA	Blažim	Most	ČEZ	UVFL	I/R/A	6.7
UTPMA	Teplice	Teplice	CHMI	UVFL	B/U/R	6.5
UULKA	Ústí n.L.–Kočkov	Ústí nad Labem	CHMI	UVFL	B/S/RN	6.2

Tab. XI.21 Stations with the highest values of annual averages of SO$_2$ concentrations at rural stations

KMPL	Station	District	Owner	Measuring method	Classification	Annual concentration [µg.m⁻³]
UKRUA	Krupka	Teplice	CHMI	UVFL	B/R/N-NCI	9.0
ULOMA	Lom	Most	CHMI	UVFL	B/R/IN-NCI	7.6
TBRMA	Brumovice MŠ	Bruntál	ZÚ, MSK	UVFL	B/R/RA	6.8
UMEDA	Měděnec	Chomutov	CHMI	UVFL	B/R/ANI-NCI	6.0
BMISA	Mikulov-Sedlec	Břeclav	CHMI	UVFL	B/R/A-REG	5.5
TVERA	Věřňovice	Karviná	CHMI	UVFL	B/R/AI-NCI	5.5
TSTDA	Studénka	Nový Jičín	CHMI	UVFL	B/R/A-NCI	5.0
USNZA	Sněžník	Děčín	CHMI	UVFL	B/R/N-REG	5.0
UDOKA	Doksany	Litoměřice	CHMI	UVFL	B/R/NA-NCI	3.6
LFRTA	Frýdlant	Liberec	CHMI	UVFL	B/R/N-REG	3.5
PKUJA	Kamenný Újezd	Rokycany	CHMI	UVFL	B/R/NA-NCI	3.4
UTUSA	Tušimice	Chomutov	CHMI	UVFL	B/R/IA-NCI	3.4
TBKRA	Bílý Kříž	Frýdek-Místek	CHMI	UVFL	B/R/N-REG	3.0
ZTNVA	Těšnovice	Kroměříž	CHMI	UVFL	B/R/A-REG	3.0
MJESA	Jeseník-lázně	Jeseník	CHMI	UVFL	B/R/N-NCI	2.4
CCHUA	Churáňov	Prachatice	CHMI	UVFL	B/R/N-REG	2.1
KPRBA	Přebuz	Sokolov	CHMI	UVFL	B/R/AN-REG	1.9
JKOSA	Košetice	Pelhřimov	CHMI	UVFL	B/R/AN-REG	1.1

Tab. XI.22 Stations with the highest values of winter averages of SO$_2$ concentrations at rural stations, 2018/2019

KMPL	Station	District	Owner	Measuring method	Classification	Winter average concentration [μg.m⁻³]
UKRUA	Krupka	Teplice	CHMI	UVFL	B/R/N-NCI	10.0
ULOMA	Lom	Most	CHMI	UVFL	B/R/IN-NCI	9.7
USNZA	Sněžník	Děčín	CHMI	UVFL	B/R/N-REG	7.1
TVERA	Věřňovice	Karviná	CHMI	UVFL	B/R/AI-NCI	6.2
TSTDA	Studénka	Nový Jičín	CHMI	UVFL	B/R/A-NCI	5.6
UMEDA	Měděnec	Chomutov	CHMI	UVFL	B/R/ANI-NCI	5.2
BMISA	Mikulov-Sedlec	Břeclav	CHMI	UVFL	B/R/A-REG	3.9
UDOKA	Doksany	Litoměřice	CHMI	UVFL	B/R/NA-NCI	3.8
UTUSA	Tušimice	Chomutov	CHMI	UVFL	B/R/IA-NCI	3.8
ZTNVA	Těšnovice	Kroměříž	CHMI	UVFL	B/R/A-REG	3.5
SRORA	Rožďalovice-Ruská	Nymburk	CHMI	UVFL	B/R/A-NCI	3.4
PKUJA	Kamenný Újezd	Rokycany	CHMI	UVFL	B/R/NA-NCI	3.1
LFRTA	Frýdlant	Liberec	CHMI	UVFL	B/R/N-REG	3.0
CCHUA	Churáňov	Prachatice	CHMI	UVFL	B/R/N-REG	2.5
MJESA	Jeseník-lázně	Jeseník	CHMI	UVFL	B/R/N-NCI	2.4
TBKRA	Bílý Kříž	Frýdek-Místek	CHMI	UVFL	B/R/N-REG	2.4
KPRBA	Přebuz	Sokolov	CHMI	UVFL	B/R/AN-REG	2.1
JKOSA	Košetice	Pelhřimov	CHMI	UVFL	B/R/AN-REG	1.1

Tab. XI.23 Stations with the highest values of maximum 8-hour running average concentrations of CO

KMPL	Station	District	Owner	Measuring method	Classification	Max.8-h concentration [μg.m⁻³]
TOREK	Ostrava-Radvanice ZÚ	Ostrava-město	ZÚ, SMOva	IRABS	I/S/IR	3 656.2
STCSA	Tobolka-Čertovy schody	Beroun	VČs	IRABS	B/R/AN-NCI	2 469.8
TOCBA	Ostrava-Českobratrská (hot spot)	Ostrava-město	CHMI	IRABS	T/U/CR	2 347.3
SBERA	Beroun	Beroun	CHMI	IRABS	T/U/RCI	2 092.5
TVRTA	Vratimov	Ostrava-město	ZÚ, MSK	IRABS	I/S/RI	2 030.0
TOMHK	Ostrava-Mariánské Hory	Ostrava-město	ZÚ, SMOva	IRABS	I/U/IR	1 966.6
ZUHRA	Uherské Hradiště	Uherské Hradiště	CHMI	IRABS	T/U/RC	1 893.9
TSTDA	Studénka	Nový Jičín	CHMI	IRABS	B/R/A-NCI	1 777.0
CTABA	Tábor	Tábor	CHMI	IRABS	T/U/RC	1 769.6
HHKBA	Hradec Králové-Brněnská	Hradec Králové	CHMI	IRABS	T/U/RC	1 678.3
ALEGA	Praha 2-Legerova (hot spot)	Praha 2	CHMI	IRABS	T/U/RC	1 650.0
ALIBA	Praha 4-Libuš	Praha 4	CHMI	IRABS	B/S/R	1 455.4
ZOTMA	Otrokovice-město	Zlín	MOTRO	IRABS	T/U/RIC	1 411.0
BBMLA	Brno-Lány	Brno-město	SMBrno	IRABS	B/S/RN	1 397.9
THBEA	Horní Benešov MŠ	Bruntál	ZÚ, MSK	IRABS	B/S/R	1 329.6
UULDA	Ústí n.L.-Všebořická (hot spot)	Ústí nad Labem	CHMI	IRABS	T/U/RC	1 266.8
TBRMA	Brumovice MŠ	Bruntál	ZÚ, MSK	IRABS	B/R/RA	1 255.0
BBNVA	Brno-Úvoz (hot spot)	Brno-město	CHMI	IRABS	T/U/R	1 250.1
PPLAA	Plzeň-Slovany	Plzeň-město	MPI	IRABS	T/U/RC	1 246.2
JJIHA	Jihlava	Jihlava	CHMI	IRABS	B/U/RC	1 117.0
JKOSA	Košetice	Pelhřimov	CHMI	IRABS	B/R/AN-REG	422.9

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LIST OF ABBREVIATIONS

a. s.	joint-stock company
ACTRIS	Aerosols, Clouds and Trace gases Research InfraStructure Network
AIM	Automated Air QualityMonitoring
AOT40	Accumulated Ozone Exposure over a Threshold of 40 ppb
AQI	Air Quality Index
AQIS	Air Quality Information System
ASKPCR	Association of the Glass and Ceramic Industry of the Czech Republic
ATEM	Studio of Ecological Models
AV ČR	Czech Academy of Sciences
BaP	benzo[a]pyrene
BC	black carbon
CDV	Transport Research Centre
CENIA	Czech Environmental Information Agency
CET	Central European Time
CEZ	Czech Energetic Work
CFC	chlorofluorocarbon
CGS	Czech Geological Survey
CLRTAP	Convention on Long-range Transboundary Air Pollution
Coll.	Collection of Laws
CR	Czech Republic
CSO	Czech Statistical Office
CZT	Central heat supply
DC	dispersion conditions
DMR	digital elevation model
DMÚ	digital terrain model
EC	elemental carbon
EC	elemental carbon
EC	elemental carbon
EEA	European Environment Agency
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmissions of Air Pollutants in Europe
EoI	Council Decision 97/101/EC on exchange of information
ESFRI	European Strategy Forum on Research Infrastructures
ETC/ACM	European Topic Centre for Air pollution and Climate change Mitigation
ETS	Emission Trading Scheme
EU	European Union
GAW	Global Atmosphere Watch
GIOS	Leadership of Chief Inspectorate Of Environmental Protection
GWP	Global Warming Potential
HBÚ AV ČR	Institute of Hydrobiology of the Academy of Sciences of the Czech Republic
HCB	hexachlorbenzene
HCFC	hydrochlorofluorocarbons
HFC	hydrofluorocarbons
CHMI	Czech Hydrometeorological Institute
IARC	International Agency for Research on Cancer
ICOS	Integrated carbon observation systém
IPCC	Intergovernmental Panel on Climate Change
IPH	Informative threshold value
IPR	Prague Institute of Planning and Development
ISPOP	System of the Fulfilling Reporting Obligations

LfULG	Saxon State Office for the Environment Agriculture and Geology
LRTAP	Convention on Long-range Transboundary Air Pollution
LTO	long-term objective
LULUCF	Land Use, Land-Use Change and Forestry
LV	limit value
MHMP	Prague City Hall
MOE	Ministry of Environment
NAO	National Atmospheric Observatory
NFR	Nomenclature for Reporting Codes
NMVOC	non-methane volatile organic compounds
NP	national park
O/K/F-M	Ostrava/Karviná/Frýdek-Místek
OC	organic carbon
OECD	Organisation for Economic Cooperation and Development
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PCDD	polychlorinated dibenzo-p-dioxins
PLA	protected landscape area
PM_{10}	particulate matter fraction < 10 μm
$PM_{2.5}$	particulate matter fraction < 2.5 μm
POP	persistent organic pollutants
PVaK	Prague Water Supply and Sewerage company
PZKO	Air Quality Improvement Program
REZZO	Register of Air Pollution Emissions Sources
RPH	Regulátory threshold value
SELČ	Central European Summer Time
SEM	scanning electron microscope
SLDB	Census of persons, houses and apartments
SMPS	scanning mobility particle size scanner
SPE	summary operating records
SPM	suspended particulate matter
SWRS	Smog Warning and Regulation System
SZÚ	National Institute of Public Health
TAČR	Technology Agency of the Czech Republic
TSP	total suspended particulates
UCR	Hodnota jednotkového rizika
UFIREG	Ultrafine Particles – an evidence based contribution to the development of regional and European environmental and health policy
ÚCHP AV ČR	Institute of Chemical Process Fundamentals of the CAS
UN	United Nations
UN-ECE	United Nations Economic Commission for Europe
UTC	Coordinated Universal Time
ÚVGZ AV ČR	Global Change Research Institute CAS
v. v. i.	public research institution
VI	ventilation index
VOC	volatile organic compounds
VPH	Alert threshold value
VŠB TU	Technical University of Ostrava
VÚLHM	Forest Management and Gamekeeping Research Institute
VÚZT	The Agricultural Technology Research Institute
WaM	without additional measures
WHO	World Health Organization
WM	with additional measures
WMO	World Meteorological Organization
WWTP	Waste Water Treatment Plant
ZABAGED	Fundamental Base of Geographic Data of the Czech Republic
ZÚ	Institute of Public Health

ANNEX I

Detailed specification of the presented pollution level maps

Spatial maps are constructed from the results of measurements at the individual locations using and combining a wide range of information (ČHMÚ 2020d). Uncertainties of individual maps depend mainly on the density of the network of monitoring stations and the uniformity of coverage of the territory of the Czech Republic by stations, as well as on the uncertainties of individual measurements, model inputs, model calculations and a way used in constructing the spatial maps. Maps have the least uncertainty near measuring stations. Although the uncertainties of some particular maps are quite high, these relate to estimates of the air pollution field that adequately correspond to the background data used and the state of current knowledge. The uncertainties of maps must be taken into account when interpreting them.

The following paragraphs describe the background sources used for construction of the air pollution maps for 2019 and the specifications of the individual maps presented in this yearbook.

1. Data employed

a. **Measured air pollution data**; The annual characteristics of the measured data from the AQIS database are used.

b. **Outputs from the dispersion models**; Outputs from the following models are used

CAMx — Eulerian model, resolution 2.3 x 2.3 km, 2019:

• meteorology: ALADIN 2019 model in 2.3 x 2.3 km resolution

• anthropogenic emissions for the territory of the Czech Republic: REZZO 1 and 2 stationary sources — reporting for 2018 updated by reporting for 2019 available as of 4 February 2020; REZZO 3 areal sources — local heating (background data 2018, degree-days 2019), agriculture — breeding and agriculture activities (2018), surface brown coal mines (2018), black coal mines (2017), quarries — surface mining (2017), fugitive emissions

from production of coke, iron and steel, foundries and other resources in 2017, landfills (2018), construction activities (2018), use of solvents (2018); REZZO 4 mobile sources — road transport according to the Road and Motorway Directorate census (2016), off-road transport (2017), Václav Havel Airport in Prague (2016)

• anthropogenic emissions for the territory of Poland: detailed emissions for 2015 provided under the LIFE-IP MAŁOPOL-SKA[1] project by GIOS (Główny Inspektorat Ochrony Środowiska) — area sources and KOBiZE (Krajowy Ośrodek Bilansowania i Zarządzania Emisjami) — point sources

• anthropogenic emissions for the rest of the territory: basic substances — CAMS-REG-AP v3.11[2] for 2016 (Granier 2019); benzo[*a*]pyrene (2017) (EMEP/CEIP 2019)

• biogenic VOC emissions from plants and NO from soil: the MEGAN v2.1 model (GUENTER et al. 2012)

• boundary conditions — minimum values from the CAMx model

CAMS ensemble forecast[3] — median of nine Euler models, resolution 0.1 x 0.1°, year 2019 (meteorology: ECWMF 2019, emission: CAMS-REG-AP v2.2.1 2015; see METEO-FRANCE (2019) for details)

SYMOS — Gaussian model, resolution 1 x 1 km (reference points in 250 x 250 m grid in a built-up area and 500 x 500 m grid outside a built-up area averaged into a grid of 1 x 1 km), 2019 (meteorology: wind roses 2019 from the ALADIN model in the 2.3 x 2.3 km grid and four altitude levels, anthropogenic emissions: for the Czech Republic as for the CAMx model (emissions from construction activities were not included); outside the Czech Republic CAMS-REG-AP v3.1);

The latest outputs that were available from the particular models at the time of preparing the yearbook were always used.

c. **Emissions from traffic**: resolution 1 x 1 km, source: the Road and Motorway Directorate census (2016)

d. **Elevation**: resolution 1 x 1 km, source: ZABAGED, SALSC.

e. **Population density**: resolution 1 x 1 km, source: CSO.

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1   Project LIFE14 IPE/PL/000021. WWW: https://powietrze.malopolska.pl/en/life-project/
2   https://permalink.aeris-data.fr/CAMS-REG-AP
3   https://www.regional.atmosphere.copernicus.eu/

2. Estimate of uncertainty

The uncertainty in relation to the relevant map was assessed using the cross-validation method, see Horálek et al. (2007). Estimation of the concentrations at the measuring sites is always created by leaving out the given measurement using the other data, thus objectively estimating the quality of the map outside the measuring site. This approach was used repeatedly for all the measuring sites. The estimated values were compared with the measured values using the **root-mean-square error (RMSE)** or the **relative root-mean-square error (RRMSE)**.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{Z}(s_i) - Z(s_i))^2} \qquad RRMSE = \frac{RMSE}{\frac{1}{N}\sum_{i=1}^{N}Z(s_i)}.100$$

where

$Z(s_i)$ is the measured value of the concentration at the ith point,
$\hat{Z}(s_i)$ is the estimate at the ith point using the other data,
N is the number of monitoring stations.

For calculation reasons, the estimate of the uncertainty was calculated only for interpolation of the residuals; thus the overall uncertainty of the map is somewhat greater. It should also be noted that this is the median uncertainty of the whole map; the spatial distribution of the uncertainty was not estimated.

3. Parameters of the individual maps

For the maps of the individual pollutants, the Tab. 1–8 below present the supplementary quantities used in the linear regression model and their parameters (c, a1, a2, …), the interpolation parameters using kriging (range, nugget, partial sill) and the inverse distance values (IDW — inverse distance weighted) and, for most maps, the root-mean-square of the error (RMSE) in the map is also given. These parameters are always given for the individual pollution layers (rural, urban, traffic).

a. Suspended particulate matter PM$_{10}$: The maps were constructed using 55 rural (without distinguishing background and industrial), 88 urban and suburban background and 25 traffic stations. The results of measurements at seven urban and suburban industrial stations were taken into account only in their immediate vicinity (Tab. 1, Annex 1).

b. Suspended particulate matter PM$_{2.5}$: The maps were constructed using 26 rural (without distinguishing background and industrial), 52 urban and suburban background and 18 traffic stations. The results of measurements at four urban and suburban industrial stations were taken into account only in their immediate vicinity. The uncertainty in the map was not calculated because of the mapping methodology (Tab. 2, Annex I). This is because PM$_{10}$ maps were used as supplementary quantities — due to strong regression relation between PM$_{10}$ and PM$_{2.5}$ the uncertainty estimates would be underestimated.

c. Benzo[a]pyrene: The maps were constructed using 11 rural, and 36 urban and suburban background and traffic stations. The results of measurements at six industrial stations were taken into account only in their immediate vicinity. Due to the lack of measuring stations in small settlements, the estimation of uncertainty in rural areas is only indicative (Tab. 3, Annex I).

d. Nitrogen dioxide and nitrogen oxides: The maps for NO$_2$ were constructed using 25 rural (without distinguishing background and industrial), 45 urban and suburban background and 21 traffic stations. The results of measurements at 8 urban and suburban industrial stations were taken into account only in their immediate vicinity. The maps for NO$_X$ were constructed using 24 rural, 45 urban and suburban background and 21 traffic stations (Tab. 4, Annex I).

e. Tropospheric ozone: The maps of the 26th highest maximum daily 8-hour running average were constructed on the basis of 24 rural and 31 urban and suburban stations. The maps for AOT40 were constructed using 23 rural and 25 urban and suburban background stations (Tab. 5, Annex I).

f. Benzene: The maps were constructed using 6 rural, and 22 urban and suburban background stations. The results of measurements at 4 industrial and 7 traffic stations were taken into account only in their immediate vicinity (Tab. 6, Annex 1).

g. Heavy metals: The maps for arsenic were constructed using 14 rural and 44 urban and suburban stations (without distinguishing between background, traffic and industrial stations). The cadmium map was constructed using 58 stations (without distinguishing according to type). The uncertainty in the cadmium map was estimated without the Tanvald municipality and its immediate vicinity because the high absolute values at this location would cause distortion of the overall uncertainty of the map. The high relative uncertainty of the cadmium map is related to the low cadmium values over most of the territory (Tab. 7, Annex I).

h. Sulphur dioxide: The map of the 4th highest 24-hour concentration was constructed using 25 rural (without distinguishing background and industrial) and 27 urban and suburban background stations. The results of measurements at 2 traffic and 7 industrial stations were taken into account only in their immediate vicinity. The maps of the annual or winter averages were constructed using 27 and 25, respectively, rural (without distinguishing background and industrial) and 28 and 25, respectively urban and suburban background stations. The results of measurements at 2 traffic stations and 7 and 4, respectively, industrial stations were taken into account only in their immediate vicinity (Tab. 8, Annex I).

The numbers of stations also include foreign (German and Polish) stations that were used in the creation of some maps.

Tab. 1 PM$_{10}$ map parameters

Linear regression model + interpolation of residuals	Annual average			36th highest daily average		
	rural areas	urban background	traffic	rural areas	urban background	traffic
c (constant)	7.2	19.7	11.0	8.4	35.0	19.5
a1 (model CAMx)	1.73	0.54	1.13	1.65	0.49	0.95
a2 (altitude)	–0,0053	–0.0136		–0.0054	–0.0276	
range [km]	26	18	25	34	28	0
nugget	0	3.6	0	0	17	19
partial sill	3.6	5.6	5.8	12	7	9
weight IDW		1			1	
RMSE [µg.m^{-3}]	**1.8**	**2.6**	**1.8**	**4.1**	**5.2**	**4.1**
relat. RMSE [%]	**11**	**13**	**8**	**14**	**14**	**11**

Tab. 2 PM$_{2.5}$ map parameters

Linear regression model + interpolation of residuals	Annual average		
	rural areas	urban background	traffic
c (constant)	–0.2	–1,1	0.9
a1 (rural map of PM$_{10}$)	0.55		
a2 (urban background map of PM$_{10}$)		0.79	
a3 (traffic map of PM$_{10}$)			0.66
a4 (model CAMx)	0.56		
range [km]	90	110	150
nugget	0.7	0.7	0
partial sill	0.0	0.2	3.2
weight IDW	1	1	

The urban and rural layers were combined using the limits of the classification intervals (ČHMÚ 2020d): α1 = 200 inhabitants per km^2, α2 = 1000 inhabitants per km^2. The background and traffic layers were combined using the limits of the classification intervals (ČHMÚ 2020): τ1 = 3 tonnes p.a. per km^2, τ2 = 8 tonnes p.a. per km^2 (for PM$_{10}$ and PM$_{2.5}$ maps), or τ1 = τ2 = 10 tonnes p.a. per km^2 (for NO$_2$ and NO$_X$ maps), where the PM$_{10}$ and PM$_{2.5}$ maps were based on SPM emissions, while the NO$_2$ and NO$_X$ maps were based on NO$_X$ emissions[4].

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4   For the spatial maps of NO$_2$ and NO$_X$, the traffic layer was used only in cities, while outside of cities in territories with NO$_X$ > 10 tonnes p.a. per km^2 the layers were used from all the urban, suburban, rural and traffic stations.

Tab. 3 Benzo[*a*]pyrene map parameters

Linear regression model + interpolation of residuals	Annual average	
	rural areas	urban background
c (constant)	-0.5	-2.4
a1 (urban map of $PM_{2.5}$)		0.17
a2 (model CAMx)	1.76	0.71
a3 (model SYMOS – local heating emission only)		0.73
range [km]	70	8
nugget	0	0
partial sill	0.12	0.2
weight IDW		
RMSE [µg.m⁻³]	**> 0.3**	**0.5**
relat. RMSE [%]	**> 40**	**43**

Tab. 4 NO_2 and NO_x map parameters

Linear regression model + interpolation of residuals	NO_2 – annual average			NO_x – annual average		
	rural areas	urban background	traffic	rural areas	urban background	traffic
c (constant)	8.4	18	21.5	11.1	28.6	87.5
a1 (model SYMOS NO_2)	4.5	2.1				
a2 (model SYMOS NO_2 – REZZO 4)			4.2			
a3 (model SYMOS NO_x)				1.9	0.9	
a3 (model SYMOS NO_x – REZZO 4)						34.9
a4 (altitude)	-0.01	-0.02		-0.01	-0.03	
weight IDW	1	1	1	1	1	1
RMSE [µg.m⁻³]	**1.3**	**3.1**	**6.1**	**2.2**	**7.1**	**18,4**
relat. RMSE [%]	**15**	**19**	**22**	**20**	**28**	**34**

Tab. 5 Ground-level ozone map parameters

Linear regression model + interpolation of residuals	26th highest maximum daily 8-hour average		AOT40 exposure index	
	rural areas	urban background	rural areas	urban background
c (constant)	-5.3	32.2	10 915	11 238
a1 (model CAMS)	1,2	0.9	0.7	0.5
weight IDW	1	1	1	1
RMSE [µg.m⁻³]	**4.1**	**3.4**	**2 789**	**2 939**
relat. RMSE [%]	**3**	**3**	**15**	**17**

Tab. 6 Benzene map parameters

Linear regression model + interpolation of residuals	Annual average	
	rural areas	urban background
c (constant)	0.3	–0.1
a1 (model CAMx)	4.3	9.8
weight IDW	1	1
RMSE [µg.m⁻³]	0.3	0.3
relat. RMSE [%]	29	25

Tab. 7 Arsenic and cadmium map parameters

Linear regression model + interpolation of residuals	Arsenic – annual average		Cadmium – annual average
	rural areas	urban background	whole map
c (constant)	–0.6		
a1 (rural map of PM$_{10}$)	0.094		
range [km]	320	15	15
nugget	0	0	0
partial sill	0.1	0.5	0.3
weight IDW			
RMSE [µg.m⁻³]	0.2	0.6	0.2
relat. RMSE [%]	23	41	92

Tab. 8 SO$_2$ map parameters

Linear regression model + interpolation of residuals	4th highest daily average		Annual average		Winter average	
	rural areas	urban background	traffic	rural areas	urban background	traffic
c (constant)	10.1	5.8	2.6	2.6	2.8	2.1
a1 (model CAMx)	0.4	0.5	0.6	0.5	0.6	0.5
weight IDW	3	2	1	1	2.4	1.6
RMSE [µg.m⁻³]	7.9	6.9	2	1.7	2.1	1.6
relat. RMSE [%]	45	41	42	33	40	30

ANNEX II

## Evaluation of PM$_{2.5}$ Concentrations in Relation to the Limit Value Valid From 2020

concentration [μg.m^{-3}]	
≤ 12.0	57.78 %
12.1–17.0	39.69 %
17.1–20.0	2.10 %
20.1–25.0	0.39 %
> 25.1	0.04 %

agglomeration
zone
region
municipality over 30K inhab.
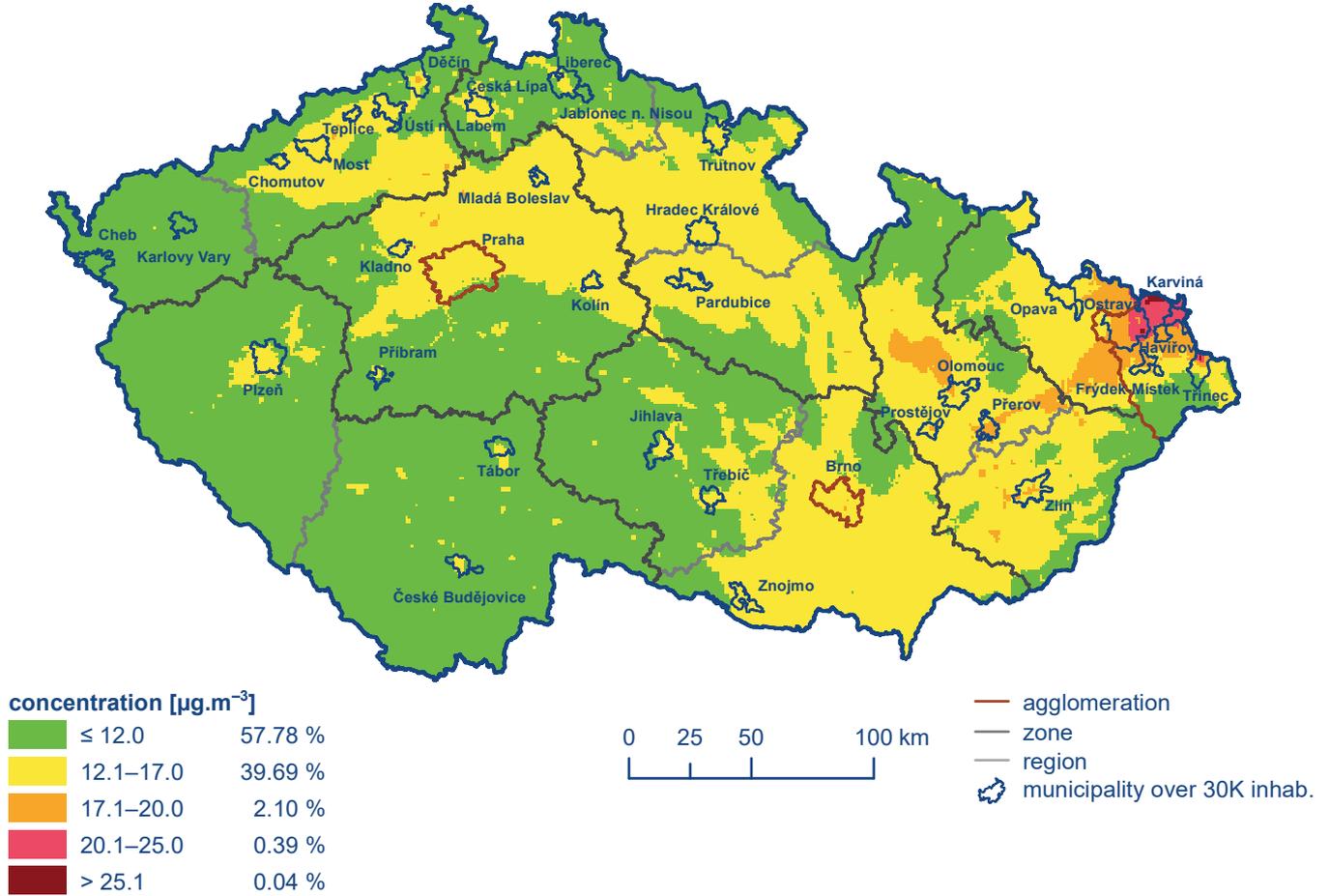
Fig. 1 Field of annual average concentration of PM$_{2.5}$ in 2019 indicating limit value valid from 2020

current annual LV   **annual LV to be in force from 2020**
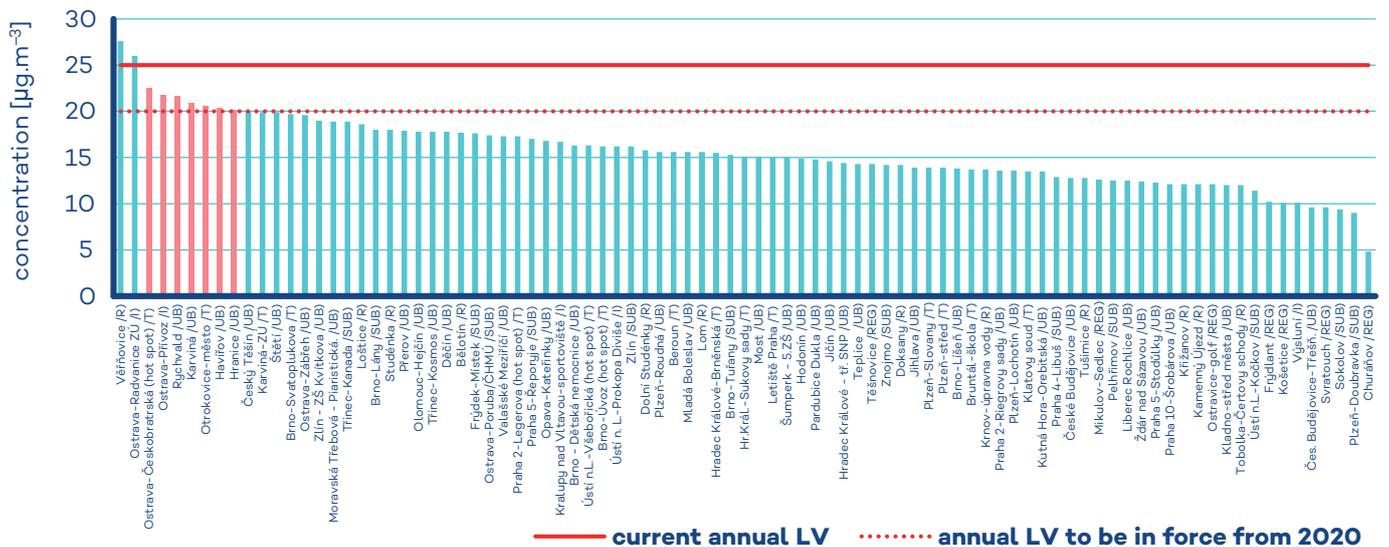
Fig. 2 Annual average concentrations of PM$_{2.5}$ in 2019 with LV to be in force from 2020