I. INTRODUCTION

Polluted air has a demonstrable detrimental impact on human health. Pollutants can cause a wide range of health problems from less serious to grave diseases, and 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 an increased incapacity for work. Pollutants adversely affect vegetation, including influencing growth and resulting in decreased yields of agricultural crops and forests. In addition, they lead to the eutrophication and acidification of soils and aquatic ecosystems, and subsequently to changes in species diversity and a reduction in the number of plant and animal species. Many pollutants cumulate in the environment, with a detrimental impact on ecosystems, and enter into the food chain. Pollutants are transported in the atmosphere and can thus affect air quality both in the immediate vicinity of the pollution source and in more distant areas. In addition, some of them directly or indirectly affect the climate system of the Earth. The damage caused by atmospheric

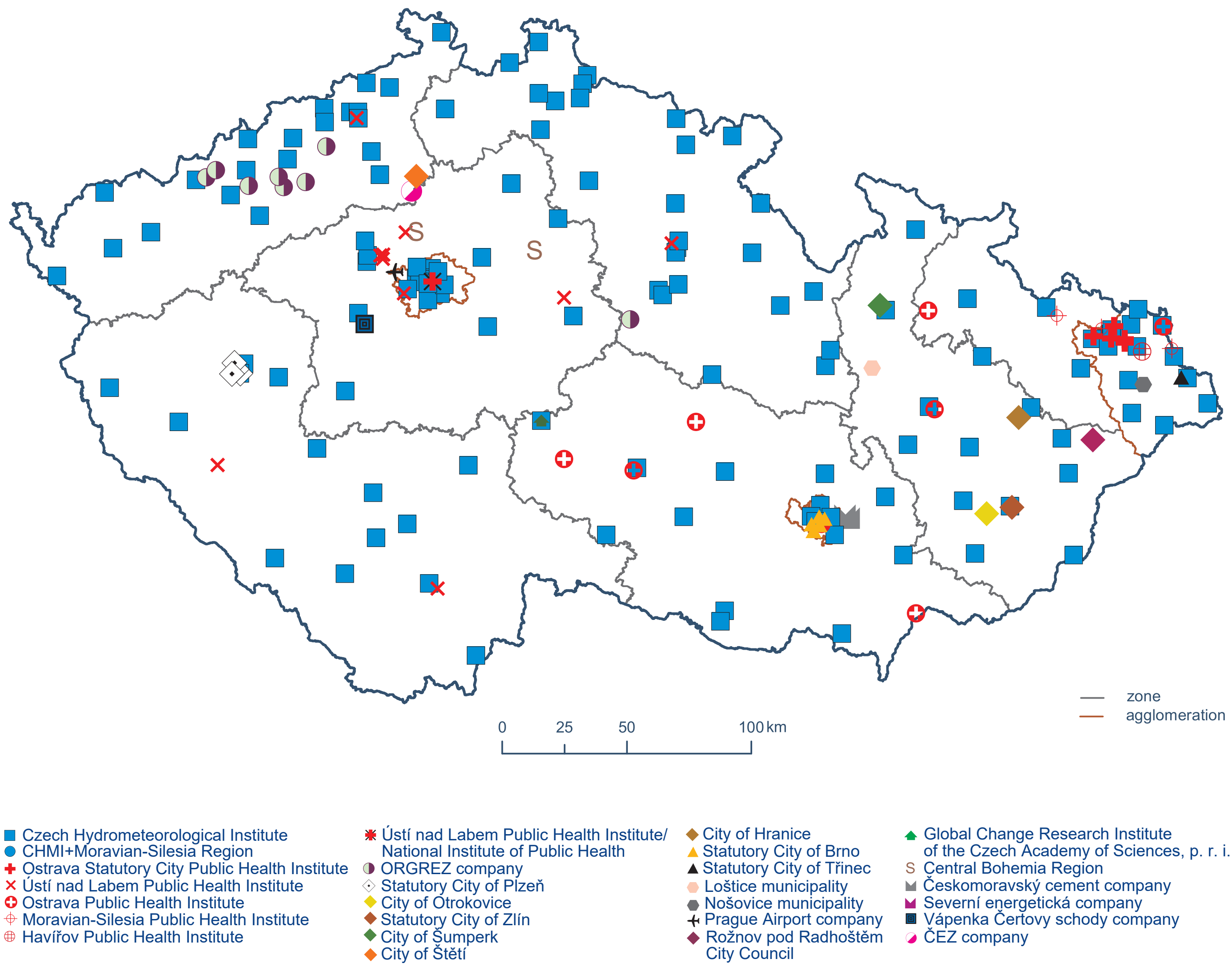

Fig. I.1 Station networks of ambient air quality monitoring in the Czech Republic, 2021

pollutants to materials and buildings, which are frequently historically important, must also be mentioned. Efforts to limit the effects of these impacts also incur 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 over the past years, particular sources produce emissions levels 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 particles and polycyclic aromatic hydrocarbons bound to them. In the spring and summer, 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 the transfer of pollutants from other areas. The level of air pollution is objectively determined by means of a network of measuring stations that monitor concentrations of pollutants of the ambient air (air pollution) in the ground layer of the atmosphere (Fig. I.1). Based on a mandate from the Ministry of the Environment (MoE), the Czech Hydrometeorological 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.

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 [μg·m^{-3}]		Limit value [μg·m^{-3}]
		Lower assessment threshold	Upper assessment threshold	
SO_2	1 hour	—	—	**350** max. 24/year
	24 hours	**50** max. 3×/year	**75** max. 3×/year	**125** max. 3×/year
NO_2	1 hour	**100** max. 18×/year	**140** max. 18×/year	**200** max. 18×/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. 35×/year	**35** max. 35×/year	**50** max. 35×/year
	calendar year	**20**	**28**	**40**
$PM_{2.5}$	calendar year	**12**	**17**	**20**[a)]
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**[b)] 25× in 3-year average

a) In 2020, in the context of EU legislation, a stricter limit value of 20 μg·m^{-3} for the annual average concentration of $PM_{2.5}$ entered into force. Until 2019, the limit value of 25 μg·m^{-3} applied.

b) If the maximum permitted number of cases exceeding the limit value in a zone or agglomeration is observed, it is necessary to strive to achieve a zero number of such cases (averaging period is one year).

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 in particular are 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, an overview of their emission sources and their impacts are given in Tab. I.5.

Pollution limit levels comply with recommended values set by the World Health Organization (WHO) following a number of epidemiological studies. In the case of substances without a set limit, the levels are derived 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 related to 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, pollution limit levels set by the legislation may be higher, but processes directed towards meeting the WHO guideline values must be generally supported (WHO 2013).

The WHO has been issuing recommended air quality values in view of health protection on a regular basis since 1987 to help governments and civil society reduce human exposure to air pollution and its adverse effects. Other WHO recommended values for air quality were published in 2006 (WHO 2006). This global update has had a significant impact on global air pollution mitigation guidelines. More than 15 years have passed since the guidelines were issued in 2006. Since then, there has been a significant increase in the quality and amount of evidence pointing to the adverse effects of air pollution on human health. The update of WHO air quality values was launched in 2016 based on significant scientific progress and the global importance of these values. In September 2021, the WHO issued new recommended values for air quality for six pollutants (so-called classical pollutants, i.e., PM_{10}, $PM_{2.5}$, NO_2, O_3, SO_2 and CO; Tab. I.3), for which knowledge on effects on human health advanced the most (WHO 2021).

Following the European Green Deal, air quality directives are currently being revised. The aim of the revision is to align air pollution limits more closely with scientific knowledge, including the latest WHO recommendations, to improve the legislative framework for air quality and to strengthen monitoring and modelling of air quality and air quality programmes (EC 2022).

I.1 The political and legislative framework for 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 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/

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 [$\mu g \cdot m^{-3}$]
		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[a)]	–	–	[$\mu g \cdot m^{-3} \cdot h$] 18 000[b)] average for 5 years

a) Note: AOT40 is the sum of differences between the hourly concentration higher than 80 $\mu g \cdot m^{-3}$ (= 40 ppb) and the value 80 $\mu g \cdot m^{-3}$ in the given period by using only hourly values measured every day between 8:00 and 20:00 CET.

b) If the limit value in the zone or agglomeration of 18 000 $\mu g \cdot m^{-3} \cdot h$ is complied with, it is necessary to strive to reach the limit value of 6 000 $\mu g \cdot m^{-3} \cdot h$ (averaging period is one year).

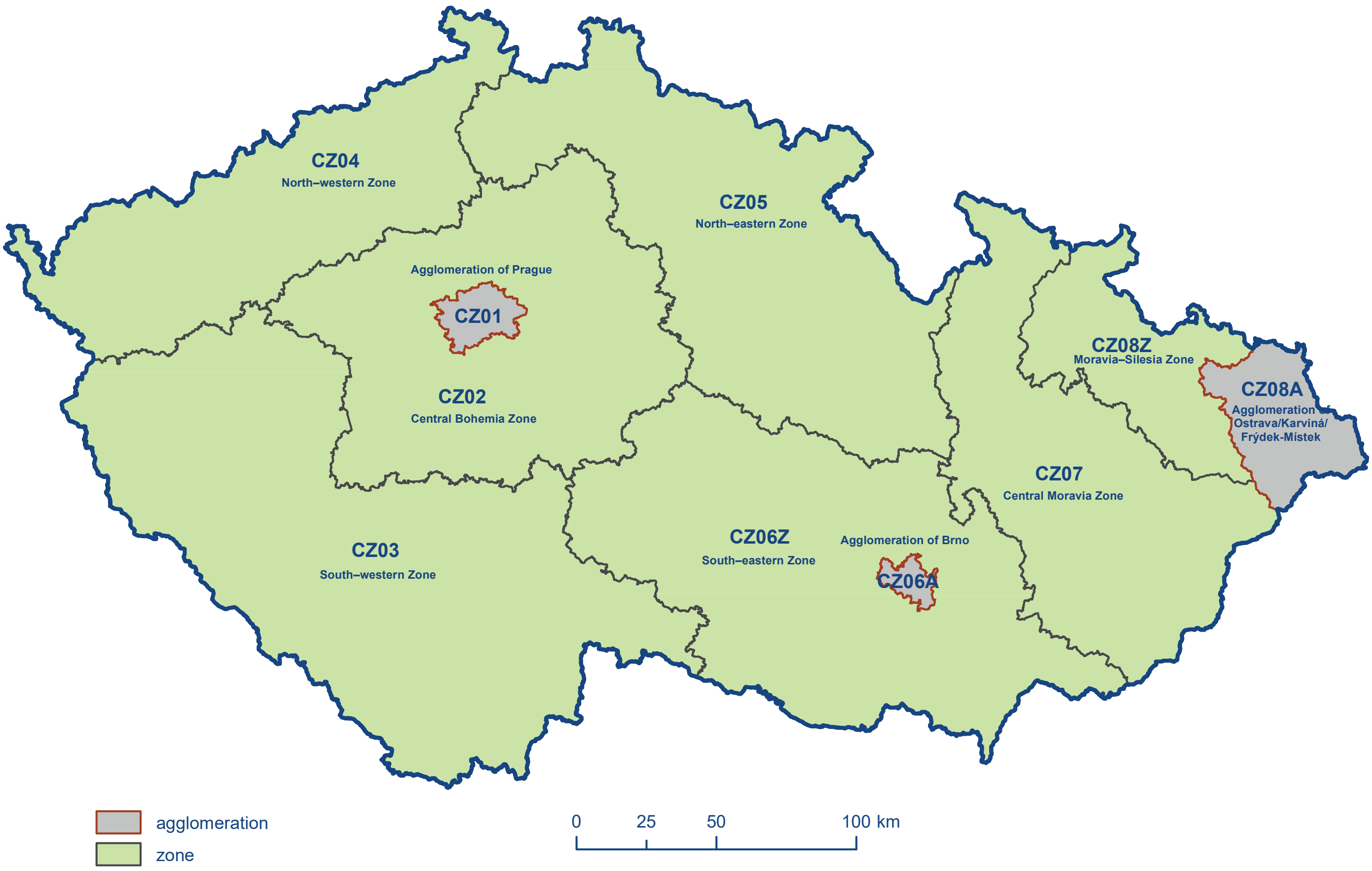

Fig. I.2 The zones and agglomerations for ambient air quality assessment and evaluation of ambient air pollution level according to the Act No. 201/2012 Col/. on Clean Air Protection, as amended

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 2010/75/EU on industrial emissions (integrated pollution prevention and control). It is also EU Commission Decree 2015/1480 of 28 August 2015 amending 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 the location of sampling sites for assessing ambient air quality.

The national legislation on air quality evaluation in the Czech Republic (CR) is also based on the European legislation. The basic legislative norm in the CR is 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. The zone is a territory specified by the MoE for monitoring and managing the air quality; the 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 further specified by Decree No. 330/2012 Coll., on the method of assessing and evaluating pollution levels and on the extent of informing the public on the level of pollution and in smog situations.

Based on the requirement of the European Commission to prepare a coherent approach to air quality control in the CR, a Medium-Term Strategy (up to 2020) for improving air quality in the CR had been prepared. This conceptual document was approved in December 2015, and summarizes the outputs of basic strategic documents for improving air quality – the 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 CR has been updating this document continuously since 2004, and its main purpose is to ensure a reduction in the overall production of pollutants and levels of air pollution in the CR. The working group, of which CHMI was also an acti-

Tab. I.3 WHO Air Quality Guidelines for the protection of public health (WHO 2000, WHO 2005, WHO 2021)

Pollutant	Averaging time	Air quality guideline level until 2020	Air quality guideline level since 2021
PM_{10}	calendar year	20 $\mu g \cdot m^{-3}$	15 $\mu g \cdot m^{-3}$
	24 hours[c)]	50 $\mu g \cdot m^{-3}$	45 $\mu g \cdot m^{-3}$
$PM_{2.5}$	calendar year	10 $\mu g \cdot m^{-3}$	5 $\mu g \cdot m^{-3}$
	24 hours[c)]	25 $\mu g \cdot m^{-3}$	15 $\mu g \cdot m^{-3}$
benzo[*a*]pyrene[a)]		not specified	not specified
NO_2	calendar year	40 $\mu g \cdot m^{-3}$	10 $\mu g \cdot m^{-3}$
	24 hours[c)]		25 $\mu g \cdot m^{-3}$
	1 hour	200 $\mu g \cdot m^{-3}$	200 $\mu g \cdot m^{-3}$
O_3	max. daily 8-h running average[c)]	100 $\mu g \cdot m^{-3}$	100 $\mu g \cdot m^{-3}$
	peak season[d)]		60 $\mu g \cdot m^{-3}$
benzene[a)]		not specified	not specified
Pb	calendar year	0.5 $\mu g \cdot m^{-3}$	
Cd[a, b)]		not specified	not specified
As[a)]		not specified	not specified
Ni[a)]		not specified	not specified
SO_2	24 hours[c)]	20 $\mu g \cdot m^{-3}$	40 $\mu g \cdot m^{-3}$
	10 minutes	500 $\mu g \cdot m^{-3}$	500 $\mu g \cdot m^{-3}$
CO	15 minutes	100 000 $\mu g \cdot m^{-3}$	100 000 $\mu g \cdot m^{-3}$
	1 hour	30 000 $\mu g \cdot m^{-3}$	35 000 $\mu g \cdot m^{-3}$
	8 hours	10 000 $\mu g \cdot m^{-3}$	10 000 $\mu g \cdot m^{-3}$
	24 hours[c)]		4 000 $\mu g \cdot m^{-3}$

a) These are carcinogenic substances for human health. Therefore, no-effect level of the substance exposure cannot be established. The WHO recommended level is not specified. For more information on carcinogenic risks, see WHO (2000). The WHO only determines the unit risk factors for non-threshold carcinogenic substances. Unit risk factor values for 1 $\mu g \cdot m^{-3}$ lifetime risk exposure are as follows: 6×10^{-6} for benzene, 8.7×10^{-2} for benzo[*a*]pyrene, 4.9×10^{-4} for Cd, 3.8×10^{-4} for Ni, and 1.5×10^{-3} for As.

b) The recommended value for cadmium in outdoor air to prevent further accumulation of this element in agricultural soils is 0.005 $\mu g \cdot m^{-3}$.

c) Determined as 99th percentile.

d) The average of daily 8-hour O_3 maximum concentrations for six consecutive months with the highest six-month moving average O_3 concentration.

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

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. The aim of the programme is to set out measures to achieve the required air quality in the shortest possible time. PZKOs set measures mainly at the regional and local level.

PZKOs 2020+ for individual zones and agglomerations were published in the Bulletin of the Ministry of the Environment (MŽP 2020, MŽP 2021). Following the amendment to the Air Protection Act of 2018 (No. 172/2018 Coll.), PZKOs 2020+ replace the previous air quality improvement programs of 2016. PZKOs 2020+ stipulate binding measures to achieve air pollution limits. These measures were determined on the basis of an analysis of the causes of air pollution and on the basis of air pollution projections of air quality developments, taking into account existing measures. In addition to these binding measures, PZKOs 2020+ also stipulate so-called Support measures. Support measures represent good practice in air quality management at all levels and in all parts of public administration.

I.2 Objectives of the publication

The "Air Pollution in the Czech Republic in 2021" yearbook, together with the published "Summary Table Survey" data yearbook (CHMI 2022e), and with the methodological material "Data collection, processing and evaluation system" (CHMI 2022d), provides a comprehensive annual overview of information on the ambient air quality in the territory of the CR for the relevant year. The evaluation of air quality is based on 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 individual locations, including aggregated data, while the graphic yearbook provides a commented summary of information in the form of overview maps, graphs and tables.

The summary and introductory chapter of the yearbook contains the most important information on air quality in a given year and general information on the issue. The following chapters contain detailed elaborations of individual topics related to emissions of polluting substances, and evaluations of air quality in the CR and the situation in Europe. The publication also contains information on greenhouse gas emissions and atmospheric deposition.

Ambient air quality yearbooks are intended for authorities and organizations dealing with and managing issues related to the environment and air protection in the CR as well as to the professional and wider public. The yearbooks are publicly available on the CHMI websites www.chmi.cz and info.chmi.cz. The publication is the fundamental information document on air quality in the CR. Its aim is to evaluate the air quality in a broader context based on the available data and information.

The yearbook presents an air quality evaluation in 2021 pursuant to the requirements of the Czech legislation on air quality protection. 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). In 2020, in the context of EU legislation, a stricter limit value of 20 μg·m^{-3} for the annual average concentration of $PM_{2.5}$ entered into force. Until 2019, the limit value of 25 μg·m^{-3} applied.

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

	Averaging interval	Vegetation category	Guideline value
NO_x	calendar year		30 μg·m^{-3}
	24 hours		75 μg·m^{-3}
SO_2	year and winter period	agricultural crops	30 μg·m^{-3}
	year and winter period	forests and natural vegetation	20 μg·m^{-3}
	calendar year	lichens	10 μg·m^{-3}
O_3	AOT40, calculated from 1-hour values between May and July	agricultural crops	6 000 μg·m^{-3}
	AOT40, calculated from 1-hour values between April and October	forests	20 000 μg·m^{-3}
	AOT40, calculated from 1-hour values between May and July	semi-natural vegetation	6 000 μg·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 2013). 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 ≤ 2.5 µm) and coarse mode (particles ≥ 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, 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 ≤ 10 micrometers) and $PM_{2.5}$ (particles with a diameter ≤ 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 2015). 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 2015). 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 2013).

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 CR.	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 2013).
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 CR are road transport and public energy production.	As concerns the impact on human health, the most significant nitrogen oxide is NO_2 (WHO 2005). 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 2013, 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 2005), 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 2013, 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 2013). 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 2013). 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 2013).
Benzene Benzene is present in the air mainly due to anthropogenic activities. Benzene emissions are released into the air by exhaust gases and evaporating from vehicle fuel systems. A significant amount of benzene emissions arises from the combustion of solid fuels in households, surface use of organic solvents, or fuel extraction.	Benzene ranks among human carcinogens (IARC 2020). At high concentrations, it can have haematotoxic, genotoxic and immunotoxic effects (SZÚ 2015).	Benzene can bioaccumulate; it can damage leaves of agricultural crops and kill plants (EEA 2013).

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 CR include the production of iron and steel, road transport (tyre and brake abrasion), households, 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 2013). 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 2013).
Cadmium Cadmium is bound mainly to the particles with aerodynamic diameter of up to 2.5 μm (EC 2001b). The main sources in the CR include households (heating, water heating, cooking), public energy and heat production, iron and steel production, and glass 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 2013).
Arsenic Arsenic occurs largely in particles with aerodynamic diameter up to 2.5 μm (EC 2001b). The main sources in the CR include households (heating, water heating, cooking), public energy and heat production, and glass production.	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 2013).
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 CR include public energy and heat production, and combustion processes in industry, construction activities and households.	Nickel can affect the respiratory and immune systems in humans (WHO 2000, EEA 2013). 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 CR 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 2013).
Carbon monoxide Carbon monoxide (CO) is a gas emitted due to incomplete combustion of fossil fuels. The largest sources of CO emissions in the CR 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 2013). 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 2013, 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).