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Data collection, processing and evaluation systems in 2021

Air pollution and quality
Atmospheric deposition
Greenhouse gases

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Introduction

This document presents methodological material that describes the system of work in the Czech Hydrometeorological Institute (CHMI) for data collection and processing, divided according to professional subject matters. Furthermore, the current methodology used to assess air quality is also described.

The document describes methodological procedures for collecting data on areas covered by the CHMI Air Quality Division: air pollution and air quality, atmospheric deposition, greenhouse gases, emissions, and other phenomena affecting our ambient air and climate. There is also a description of the presentation and reporting of data for each area.

This document is accompanying material to the CHMI tabular and graphic yearbook. The graphic yearbook "Air Pollution in the Czech Republic in 2021" (CHMI 2022a), together with the electronically published data yearbook "Summary Tabular Survey" (CHMI 2022b), is a comprehensive overview of information on air quality in the Czech Republic in a given year. The tabular yearbook presents verified measured air pollution data and data on the chemical composition of atmospheric precipitation from individual localities including aggregated data, while the graphic yearbook provides commented summary information in overview maps, graphs and tables.

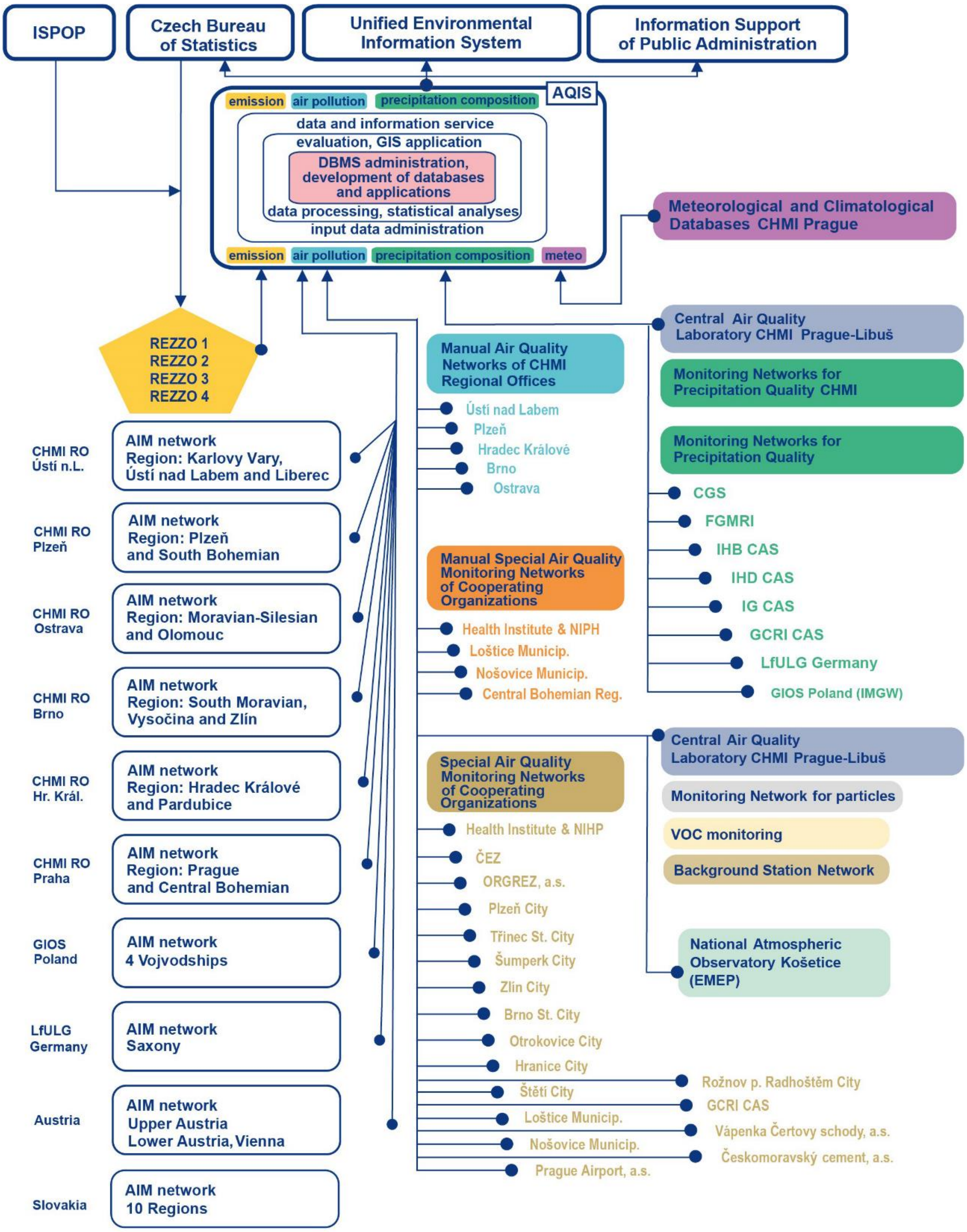
1 Data collection and processing

The "Air Quality Information System" Department (hereinafter referred to as the "AQIS Department") is responsible for the collection, processing and archiving of data in the CHMI. The AQIS Department also cooperates with individual specialized sections to fulfil these activities. The AQIS database (hereinafter referred to as "AQIS") is operated using the Oracle database system.

The AQIS Department was established in 1990. It was created by transforming the former "Air Pollution Information System" (IIS), which was formerly part of the "Meteofond" and "Air Quality" Departments that dealt with emissions, transmissions (transport and dispersion) and air quality.

AQIS is operated on the basis of the Air Protection Act, currently Act No. 201/2012 Coll., as amended. The operation of the system is entrusted by the Ministry of the Environment (MoE) to the Czech Hydrometeorological Institute (CHMI).

AQIS is continuously developed and operated using current information technologies as an integrated system for countrywide comprehensive assessments of the state and development of air pollution; it encompasses the collection, archiving and processing of data from automated and manual monitoring networks in the Czech Republic (CR) (an air pollution database and database of chemical composition of precipitation) as well as the storage and processing of data on emissions and sources of air pollution (an emissions database). In recent years, ISKO has also included the National Inventory System for Greenhouse Gases. Along with the air pollution data, the air pollution database also stores accompanying meteorological data, which in large part are collected by CHMI automated air pollution stations, and are used for the evaluation of air pollution-meteorological relationships (Fig. 1).



Explanations:

AQIS	Air Quality Information System
DBMS	Database Management System
GIS	Geographic Information System
CHMI RO	CHMI Regional Office
NIPH	National Institute of Public Health
FGMRI	Forestry and Game Management Research Institute
AIM	Automated Air Quality Monitoring
ISPOP	Integrated System of Compliance with Reporting Duty in Environmental Areas
REZZO	Register of emissions and stationary sources
CGS	Czech Geological Survey
IHB CAS	Institute of Hydrobiology of the Czech Academy of Sciences
IHD CAS	Institute of Hydrodynamics of the Czech Academy of Sciences
IG CAS	Institute of Geology of the Czech Academy of Sciences
GCRI CAS	Global Change Research Institute of the Cz. Acad. of Sc.
LfULG	Landesamt für Umwelt, Landwirtschaft und Geologie Dresden, FRG
GIOS	Główny Inspektorat Ochrony Środowiska, Poland
IMGW	Institute of Meteorology and Water Management, Wroclaw, Poland

Fig. 1 Ties of the AQIS to data sources and co-operating systems, 2021

1.1 Air pollution – emissions

The terms “air pollution” and “emissions” encompass a range of processes that lead to the release of pollutants into the air. Air pollution sources are of natural or anthropogenic origin, and the difference between these two types is not always unambiguous. Natural sources include volcanic activity, forest fires, and substances produced by plants. Anthropogenic sources involve human activities. Primary air pollution is understood as a release of pollutants into the air directly from their sources, while secondary pollutants are formed as a result of physical-chemical reactions in the atmosphere (ozone, secondary aerosol particles, most NO_2, etc.). A specific process that is closely related to primary pollution is the swirling of fine and coarse dust particles deposited on the Earth's surface, which occurs during the movement of road vehicles and agricultural machinery, or during stronger winds. This process, called resuspension, involves dust particles but also re-introduces substances into the air that are bound to them, such as heavy metals and POPs.

The CHMI evaluates the level of air pollution for primary pollutants of anthropogenic origin under authorisation by the Ministry of the Environment. The basic background material for this evaluation consists of the “emission inventory”, which combines the direct collection of data reported by operators of sources with model data calculations either 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.[1]

There is a wide range of pollutants that sources release into the air. Regular emission inventories related to the concept of air pollution are performed for dust particles (SPM, PM_{10} and $PM_{2.5}$ fractions), acidifying gases (SO_X and NO_X), carbon monoxide, volatile organic compounds (VOCs) and ammonia. Other monitored pollutants are selected heavy metals, some of which also have set air quality limits (arsenic, cadmium, nickel and lead), polycyclic aromatic hydrocarbons (the monitored air pollutant being benzo[*a*]pyrene), and also e.g., PCDD/F and PCBs. Emission inventories are also performed for other substances, e.g., benzene, NO_2, carbon particles, etc.

1.1.1 Collection of emission data

From the viewpoint of methods for monitoring emissions, air pollution sources are divided into individually monitored sources and collectively monitored sources. In connection with the categorization of sources according to Annex No. 2 of the Air Protection Act 201/2012 Coll. and the method of reporting the data of the summary operational records according to Annex No. 11 to Decree No. 415/2012 Coll., the following breakdown of resources is used (Tab. 1).

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[1] The methodology and results of emission inventories are available at: http://portal.chmi.cz/files/portal/docs/uoco/oez/emisnibilance_CZ.html

Tab. 1 Classification of air pollution sources according to the method of emission monitoring

Type of sources	Specified stationary sources	Unspecified stationary sources	Mobile sources
Category	REZZO 1, REZZO 2	REZZO 3	REZZO 4
Included	Stationary combustion plants for combustion of fuels with a total nominal heat consumption higher than 0.3 MW, waste incinerators, other sources (technological combustion processes, industrial production etc.).	Stationary combustion plants for combustion of fuels with a total nominal heat consumption up to 0.3 MW. Unnamed stationary technological sources and other activities producing emissions (see below).	Road, railway, water and air transport of persons and freight, for road transport also tyre and brake wear, road abrasion** and evaporation from fuel systems of vehicles using petrol, operation of off-road vehicles and machines used in maintenance of green spaces in parks and forests etc.
Data origin	Reported emission data except for the simple reports* pursuant to Annex No. 11 to the Decree No. 415/2012 Coll.	Calculated emissions from activity data, obtained e.g. from the Census, production and energy statistical surveys, road traffic census and the register of vehicles etc., and emission factors.	
Recording method	Individually monitored sources • REZZO 1 – reported emissions • REZZO 2 – emissions calculated from the reported data on fuel consumption and emission factors.	Sources monitored collectively.	Sources monitored collectively.

* the operator reports only the consumption of fuels and distribution of petrol

** resuspension of dust particles from road surfaces is not included in the inventory

The sources listed in Annex No. 2 of the Act No. 201/2012 on 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, as well as 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) introduced by Act No. 25/2008 Coll., on the integrated register of environmental pollution and the integrated system of compliance with environmental reporting obligations and on the amendment of certain acts. ISPOP data are then collected in the REZZO 1 and REZZO 2 databases. An exception holds for movable stationary sources (mainly those sources included under code 5.11. of Annex No. 2 to the Act on Air Protection – Operation of recycling lines for building materials), for which the location of their operation may change during the year. Emissions from these sources are reported collectively for operations over the entire region. Collection of data for the previous year takes place from January to the end of March. Reported data are available at the beginning of April, and the processing of submitted reports then takes place in the following months. The processes introduced by the AQIS emission data management operating rules also include extensive inspections of the reported data, calculations of emissions not ascertained by the notifier, the completion of unreported parameters and corrections of erroneous data.[2]

Collectively monitored sources incorporated in REZZO 3 include emissions from unspecified combustion sources (i.e., of a total nominal heat consumption up to 0.3 MW), construction and agricultural activities, surface use of organic solvents, filling stations, coal mining, car and building fires, waste and waste-water treatment, use of fireworks, cigarettes, shoe cleaners, etc. Emissions from these sources are determined using data collected by national statistical surveys and emission factors. The group of unspecified combustion sources includes the highly significant household heating sector, for which a specific methodology for the determination of emissions is used. Other sectors encompass services, commerce, authority offices, educational and medical institutions, and also the armed forces (since 2017, neither SPE data nor military sources included in Annex 2 of the Air Protection Act are included in the reported data).

The data used for the evaluation of emissions from collectively monitored combustion sources include, in particular, the outputs of the 2011 National Census, regularly updated by data on housing construction provided by the Czech Statistical Office. Furthermore, there are climatic data, data on the calorific value and quality of fuels supplied to households, and the results of extensive measurements performed to determine the emission factors of all major groups of combustion sources, classified by the type of combustion equipment and type of fuel. An estimate of the share of a particular type of household combustion equipment on fuel consumption has been based on results of the ENERGO 2015 statistical survey, the National Census, and statistics of sales of boilers, fireplaces and heaters.

For most other collectively monitored stationary sources, methodologies are used for which summary statistical data are regularly collected, either broken down by individual regions or countrywide only. These include livestock statistics, production of selected products and fuel extraction, aggregate data for construction, fires, sales of selected commodities (fertilizers, organic solvent products, fireworks,

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[2] For the mechanisms of summary operating records (SPE), see:
http://portal.chmi.cz/files/portal/docs/uoco/oez/emise/evidence/aktual/spe_uvod_cz.html

cigarettes), data on landfills, and wastewater treatment plants, as well as others. GIS information is also used for some methodologies.

Data from mobile sources are also monitored collectively (REZZO 4) and include emissions from road traffic (including NMVOC emissions from vehicle fuel system petrol evaporation and emissions from brake, tyre and road abrasion), rail, water and air transport, and the operation of off-road machinery and mechanisms (agricultural, forest and construction machinery, military vehicles, greenery maintenance, etc.). An inventory of emissions from mobile sources is maintained by CDV Brno, p. r. i. and VÚZT Praha, p. r. i. Road traffic emission estimates are prepared using the international COPERT methodology. Transport statistics, data on fuel sales, data on the composition of the vehicle fleet according to the Register of Vehicles of the CR, and data on the annual mileage of vehicles according to the output of registers of the Technical Inspection Stations are used to determine the proportional involvement of a particular group of vehicles on fuel consumption. Data from the Register of Vehicles and from the Technical Inspection Stations are also used for model evaluation of emissions of agricultural machinery (especially tractors). For other groups of mobile sources, fuel sale statistics and transport statistic information (rail, water and air transport) are used. In accordance with legislative provisions, some emissions from transport are not added to the total assessed emissions. In the CR, this applies to the air transport sector, which only includes emissions from the landing and take-off cycle. This means that emissions from the flight phase (approximately above 1 km of flight altitude) and emissions from aircraft flying over the territory of the CR are excluded.

The methodological development and annual countrywide processing and management of the emission database archive are provided by the CHMI in cooperation with external suppliers (CDV Brno, p. r. i., VÚZT Prague, p. r. i., SVÚOM Prague). The scheme of data processing for individually and collectively monitored sources is shown in Fig. **2**. The time series, starting around 1984, incorporates the reported annual emission data and accompanying technical data of the most important group of operator facilities (formerly the especially large and large sources referred to as REZZO 1) within the AQIS emission data. Since the 1990s, the database also includes data on sources classified by previous legislation as so-called medium sources of air pollution (formerly REZZO 2 sources). Data from collectively monitored sources are archived in the form of expert reports with accompanying tabular data.

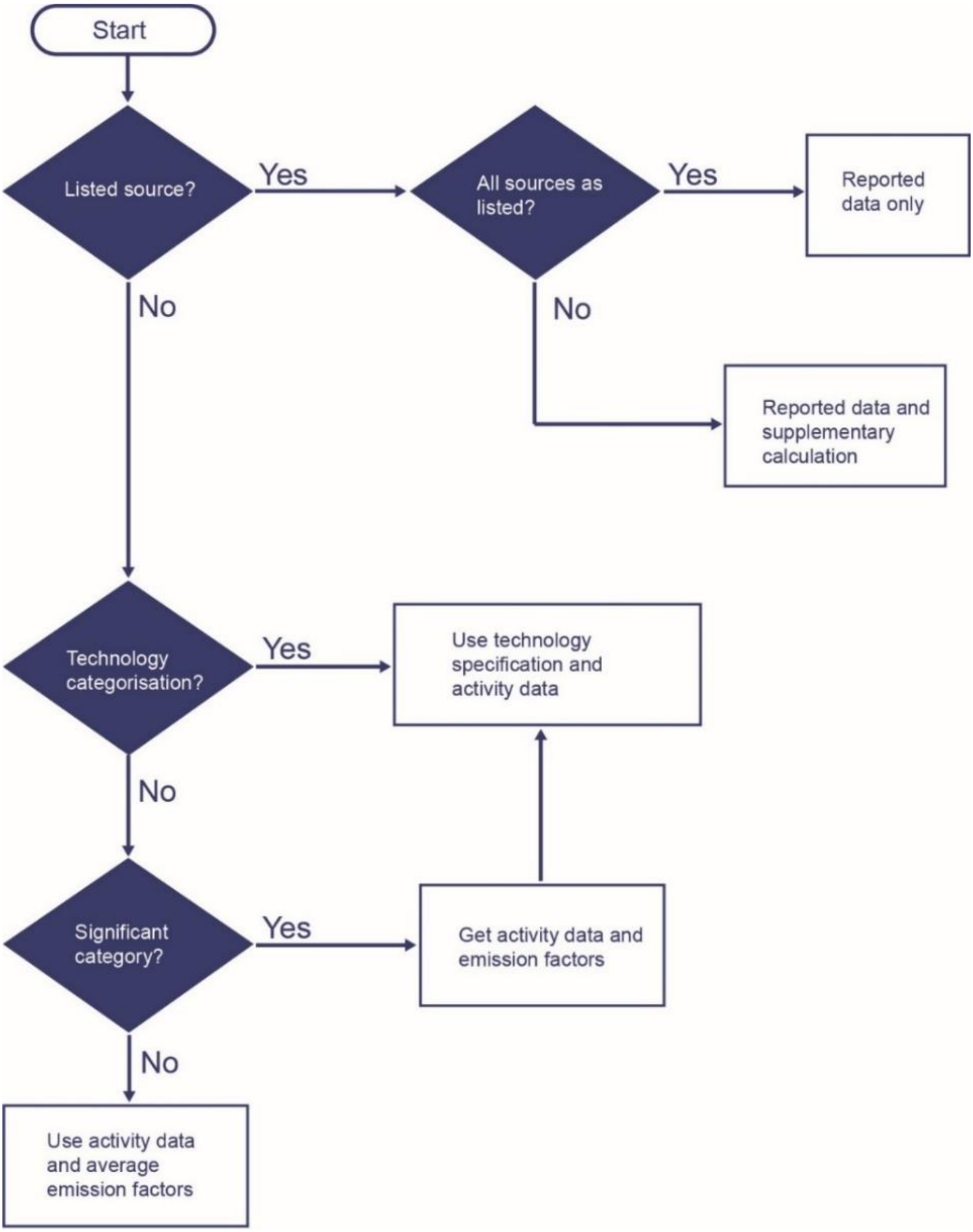

Fig. 2 The scheme of data processing for individually and collectively monitored sources

1.1.2 Processing and presentation of emission data

The processing of REZZO 1 and 2 emission data takes place partly automatically within the emissions section of the AQIS database, and mainly includes the uploading of reporting files, lists of facilities and operators, the recording of system information, and the automated calculation of necessary parameters and emissions. It is then possible to export the on-line data from specific reports, control map previews, multi-annual overviews for tracing trends and other outputs, particularly necessary for the control of reported data. For the needs of international reporting and modelling of air quality, emissions of pollutants that operators are not obliged to measure are calculated within the emission section of the AQIS database on the basis of reported activity data and emission factors. Emission factors for stationary combustion sources are differentiated according to the type of furnace and heat output, based on fuel consumption data. For other sources, emission factors depend on the type of technological process, the type and quantity of product, and the methods in which emissions are reduced. To determine the emissions of PM_{10} and $PM_{2.5}$, the percentages of the given PM fraction in the total emissions of SPM are used. If the source is equipped with a separator to reduce SPM emissions, the share of the SPM fraction depends on the separation principle of this device. For combustion sources without a separator the fractions are determined according to the type of fuel, and for other sources the method of formation of SPM is a key factor (Hnilicová 2012).

REZZO 3 data processing takes place in the MS Excel spreadsheet with manual input of the required new data, particularly statistical data. REZZO 4 data processing takes place at external suppliers by similar means (specialized applications and MS Excel), and the outputs are delivered to the CHMI directly in the format required for emission inventories.

The standard outputs of emission inventories are countrywide and regional balances, determined mainly for basic pollutants. For the needs of modelled evaluations of air quality, detailed lists for pollutants with established air pollution limits are created. These data are prepared in a form for either point emissions (chimneys, exhausts, fugitive leaks) or emissions assigned to a defined area depending on the attribution possibilities (basic settlement units, municipalities, regions).

The so-called sectoral breakdown of sources given by the Nomenclature for Reporting Codes (NFR) is used for the international reporting of aggregated emission data. The main groups of sources are combustion sources including transport (NFR 1), technological sources without combustion, so-called processes emissions (NFR 2), sources using solvents (NFR 2D), agricultural activities including livestock breeding (NFR 3) and waste management. (NFR 5). The method of conducting the emission inventory is described in detail in a document (CHMI 2022c) submitted annually as part of the emission data reported in accordance with the requirements for international reporting (European Parliament and Council Directive (EU) 2016/2284 and CLRTAP Convention). The Informative Inventory Report (IIR) presents the results of emission inventories since 1990. Emissions can be continuously updated, for example on the basis of recommendations in the detailed inventory review (most recently in 2015) or specific evaluations carried out annually by an international team of experts under responsibility of the European Commission.

In addition to the already mentioned emission balances, the CHMI portal also presents data on individual emission sources in the REZZO 1 Source list and specific information on thermal recovery and waste incineration (e.g. a list of waste incinerators and waste co-incineration plants and a registry of waste incineration and co-incineration permits).

1.2 Air quality

Air quality is characterized by concentrations of harmful substances in the ambient air. A pollutant in the air comes into contact with a recipient (human, plant, animal, material) and produces a negative effect. Air pollution occurs after the physical-chemical conversion of emissions released to the air. Air pollution concentrations in the CR are most often reported in $\mu g \cdot m^{-3}$ or $ng \cdot m^{-3}$, while in other countries air pollution concentrations are sometimes given in units of ppb or ppm.

A pollutant is any substance that, by its presence in the air, has or may have harmful effects on human health or the environment, or has an irritating odour (Act No. 201/2012 Coll., on air protection). Emission concentrations are measured directly at the source, while air pollution concentrations are measured in the area around the source. The level of air pollution load is determined by measurements at air pollution monitoring stations.

The pollution limit value means the highest permissible level of concentration of a given substance set by Act No. 201/2012 on air protection, as amended. Air pollution limits represent values of the maximum permitted air pollution concentrations of individual pollutants in the air with differing averaging intervals. For selected substances, the maximum allowed number of instances exceeding the limit value is also set. The pollution limit value is then defined for specified substances using three criteria. The first criterion is the limit value, the second represents the time averaging interval, and the third is the maximum number of cases exceeding the limit value.

In addition to substances for which an air pollution limit is set (SO_2, NO_2, CO, benzene, PM_{10}, $PM_{2.5}$, benzo[*a*]pyrene, Pb, As, Cd, Ni, O_3, NO_X), many other substances that are important for environmental protection are also measured within the National Air Quality Monitoring Network (ammonia, some ions, elemental and organic carbon, a group of aromatic hydrocarbons, volatile organic compounds, persistent organic compounds, etc.).

1.2.1 Collection of air quality data

Concentrations measured at monitoring stations form the basis for air quality assessments (Fig. 3). The measuring network is the densest in areas with the highest concentrations of pollutants, but it covers the entire CR. The backbone network of monitoring stations is the National Air Quality Monitoring Network (NAQMN) which is operated by the CHMI. It includes both automated monitoring stations (AIM) and manual air pollution stations (MIM), from which the samples are analysed in CHMI laboratories. The National Air Quality Monitoring Network is supplemented by monitoring stations of other organizations, and these measurements are also used in air quality assessments. The AQIS also includes information from the border areas of Germany, Poland, Austria, and Slovakia, which is obtained through reciprocal data exchange.

An important basis for air quality assessments and for the creation of maps of air pollution characteristics is the classification of measuring stations for information exchange – EoI (EC 1997, Larssen et al. 1999). This represents a part of the database that contains so-called metadata or descriptive data. Metadata form an integral part of the data collection. The official European classification was applied to all stations in the CR registered in the AQIS database. The complete EoI classification of stations consists of three key letters separated by a slash, which indicate the type of station, the type of area and the characterization of the area. The third column only includes examples of combinations of area characteristics, in fact any logical combination is possible, with the first letter having the highest priority (Tab. 2). Further information on the classification of stations, including legislation, is provided in the Summary Tabular Survey for 2021 (CHMI 2022b).

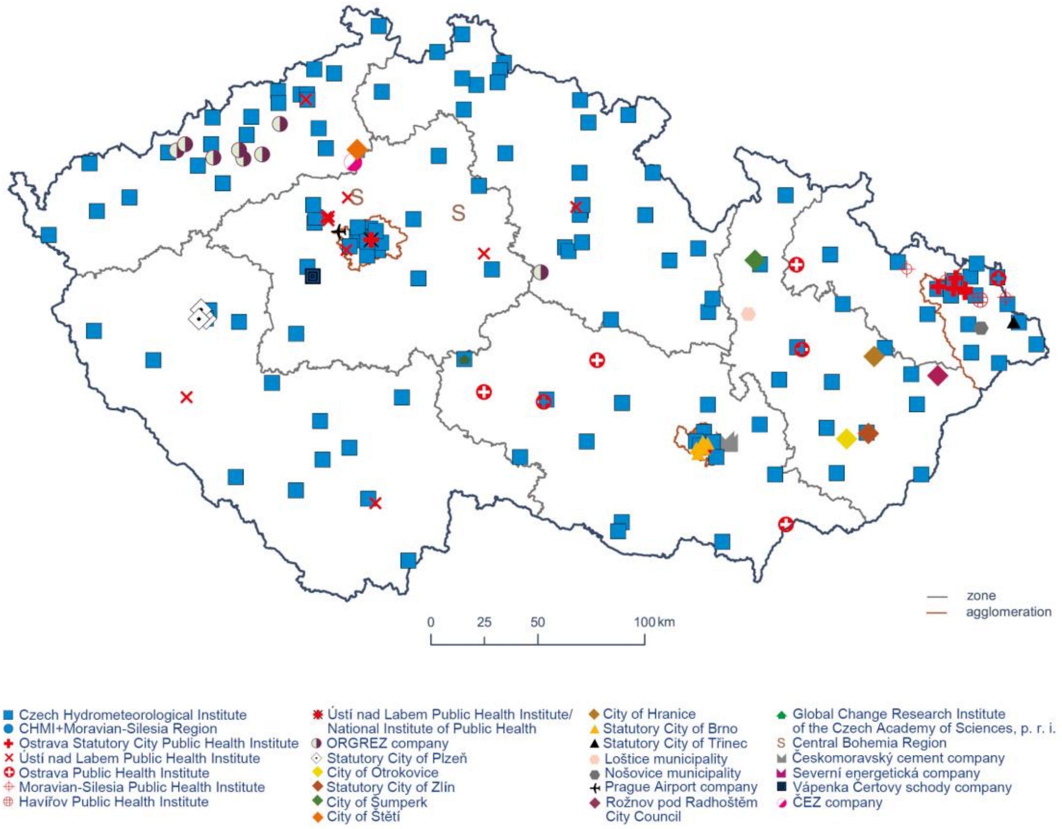

Fig. 3 Station networks of ambient air quality monitoring in the Czech Republic, 2021

Tab. 2 Exchange of Information (EoI) station classification

Type of station		Type of area		Characterisation of area	
Traffic	(T)	Urban	(U)	Residential	(R)
Industrial	(I)	Suburban	(S)	Commercial	(C)
Background	(B)	Rural	(R)	Industrial	(I)
				Agricultural	(A)
				Natural	(N)
				Residential/Commercial	(RC)
				Commercial/Industrial	(CI)
				Industrial/Residential	(IR)
				Residential/Commercial/Industrial	(RCI)
				Agricultural/Natural	(AN)

The NAQMN also includes four hot spot stations, commonly used to monitor sites or areas with high air pollution. In AQIS, this type of station represents those focused exclusively on monitoring the impact of traffic on air pollution (paragraph A.2 of Annex No. 3 to Decree No. 330/2012 Coll.). The CHMI monitoring hot spot stations are located in heavily congested localities in Prague (Fig. 4), Brno, Ostrava and Ústí nad Labem.

Fig. 4 Prague 2-Legerova hot spot AIM station (Photo: CQL Prague-Libuš)

The number of air pollution monitoring stations of basic pollutants from selected organizations, with data stored in AQIS, has changed continuously since 1969. The most stations were operating in the 1980s and 1990s.

In 2015, a substantial innovation took place in the National Air Quality Monitoring Network (NAQMN), the largest since the establishment of the countrywide automated air pollution monitoring in the first half of the 1990s. Within the framework of the Operational Program on the Environment, the CHMI implemented a project of comprehensively renewing technology for the monitoring and evaluation of air quality throughout the CR. In addition to the instrumentation itself, automated station containers, including masts for meteorological sensors, were also updated. The monitored localities and scope of measurements were selected in accordance with the applicable legislation, especially with regard to the need for a comprehensive national air quality assessment. This measuring network optimization led to either the reduction or cancellation of measurements in some localities, as well as the relocation or construction of 10 measuring locations at places where continuous air quality monitoring have been lacking and where air quality mapping and evaluation was needed. At five localities, the measuring program was changed from manual to automatic, which in addition to more detailed information on air quality also brought about an improvement in the population's awareness of current air pollution. The NAQMN upgrade was launched in mid-February and was completed by 30 September 2015.

Within the project, 98 automated measuring stations were updated (e.g. Fig. 5 and Fig. 6). At another 27 localities, new samplers were installed separately for sampling designated for detailed laboratory analysis (Fig. 7). 14 automatic precipitation collectors were also installed for the subsequent chemical analysis of precipitation. In total, almost 500 devices were replaced. Analytical instruments were provided to air quality laboratories, which increased the accuracy and reliability of laboratory analyses. One noteworthy example is the laboratory for determining PAH concentrations (Fig. 8).

Fig. 5 Hradec Králové-Brněnská AIM station (Photo: CHMI Regional Office in Hradec Králové)

Fig. 6 Ostrava-Poruba AIM station (Photo: CHMI Regional Office in Ostrava)

Fig. 7 Vyškov MIM station – sampler (photo: CHMI Regional Office in Brno)

Fig. 8 Laboratory for determination of PAHs concentrations (photo: CHMI Regional Office in Ústí nad Labem)

The successful implementation of the project enabled the CHMI to continue to maintain a high level of monitoring and evaluation of air quality in the CR and to further refine and develop key activities in this area.

Even after 2015, when the development of the National Air Quality Monitoring Network (NAQMN) undertook a substantial innovation, further implementations for renewal and modernization of the network continued (and still continue).

As part of the project "Supply of equipment for air quality monitoring vehicles", the measuring equipment of the vehicles was renewed, but not the car body of these vehicles themselves. For measurement, CHMI mobile stations use measuring containers placed on special vehicles (Fig. 9 and Fig. 10). However, the purchased measuring containers were installed on cars that had reached the end of their service life, so it was necessary to renew these cars. As the containers are made with certain specific features, they can only be placed on vehicles that have been correspondingly modified. The basis of the project "Acquisition of special vehicles and installation of measuring modifications of CHMI" was therefore to acquire car body configurations and assembly of measuring modifications – vehicles modified in this way are used mainly in special-purpose campaigns for various types of measurements and for surveying. The measuring car of the van type with equipment was purchased for the Moravian-Silesia region and thus the whole of Moravia, so that borrowing from Prague or Ústí nad Labem does not have to take place. The car is equipped with SO_2, NO_x, O_3, $PM_{2.5}$ and PM_{10} analysers, and its purchase has improved the possibility of implementing targeted measurements in sensitive locations.

Fig. 9

Fig. 10

Monitoring vehicles with equipment for measuring air quality in the NAQMN (Photo: CQL Prague Libuš)

The implementation of the project Air Quality Monitoring System – Innovation and Development (SIMIR 1-4) within the framework of the Operational Program Environment (OPE), renewed the special measuring equipment of the CHMI in 2017–2018. The Ambient Air Quality Calibration Laboratory (QCL) was equipped with a set of SO_2, NO-NO_x, CO and O_3 analysers. Sets of sensitive SO_2 and NO-NO_x analysers were purchased for selected background stations and the EMEP stations throughout the Czech Republic because at selected measuring points the concentrations of SO_2 and NO_x, especially in the summer months, are very low and close to the detection limits. Furthermore, the network was expanded with gas particle analysers and a particle counter for measurement while moving, including accessories.

In 2018–2019 (within the SIMIR 2 project), the laboratory equipment for the determination of organic substances was renewed. A gas chromatograph for the determination of volatile organic compounds (VOCs) with FID detection, including thermal desorption, which is used to determine ground-level ozone precursors (Fig. 11), and also an HR-ICP-MS analyzer were purchased for the Central Ambient Air Quality Laboratory (CQL). Within the SIMIR 3 project, meteorological equipment (SODAR) was also renewed.

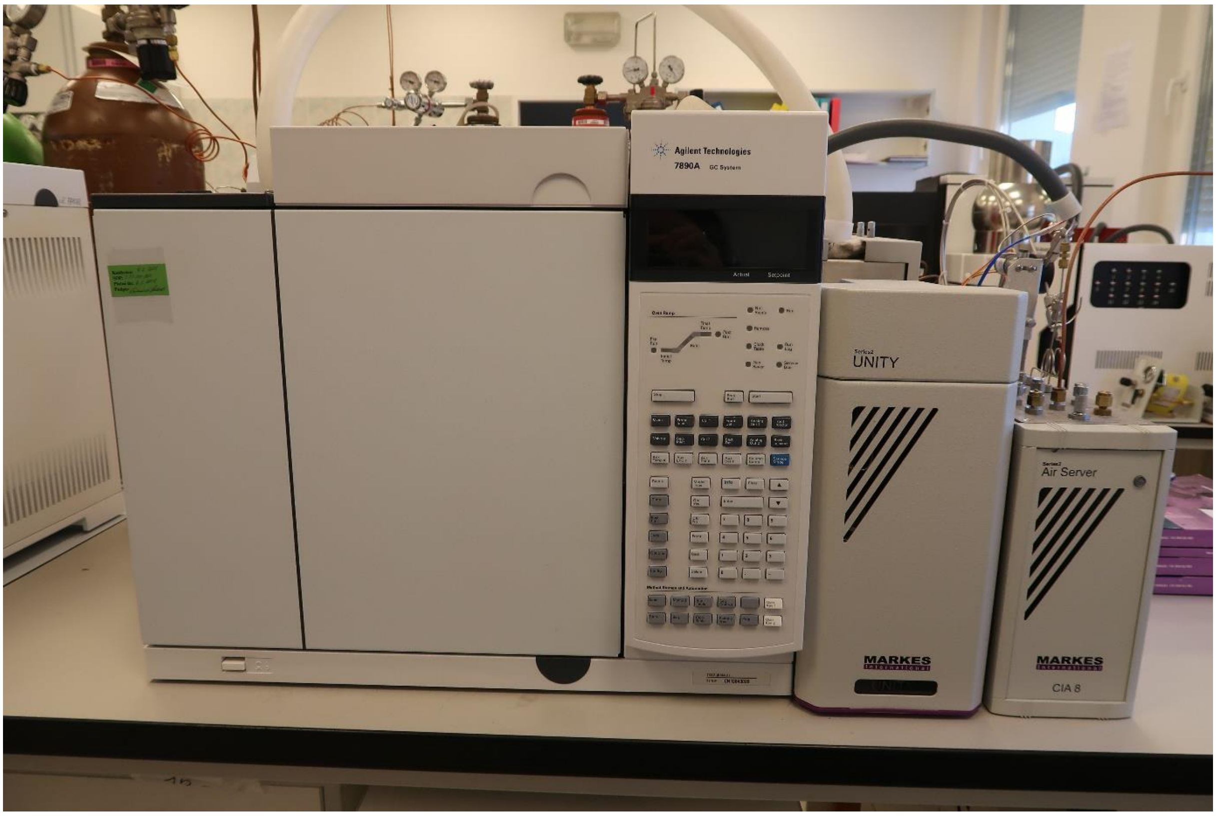

Fig. 11 Gas chromatograph with FID detector for determination of volatile organic compounds (VOCs) in outdoor air (Photo: CQL Prague Libuš)

Because at many places in the Czech Republic, the limit value for polycyclic aromatic hydrocarbons (PAHs) is exceeded and their determination is one of the conditions for the identification of sources, a GC-MS analyser for PAHs was purchased to the CHMI Regional Office in Ústí nad Labem – it replaced there the existing equipment for measuring benzo[*a*]pyrene and other PAHs. As part of the renewal of the technique for ensuring calibrations for the measurement of pollutants, the QCL was retrofitted with an infrared spectrometer with Fourier transform with accessories measuring CO concentrations and sums of total hydrocarbons at the order of nmol/mol.

The OPE SIMIR 3 project aim enabled the renewal of special equipment for measuring air pollution in the NAQMN in 2018–2019. An automatic station for diluting samples and standards was placed in the CQL at the Prague-Libuš station which, in conjunction with the ICP-MS, reduces the uncertainty of the accredited method for the analysis of so-called heavy metals (HMs) in the ambient air. It is also used in the analysis of HMs in atmospheric precipitation to determine deposition and facilitates the preparation of standards. The tandem analyser of the size concentration of particles SMPS + APS at the Prague-

Libuš station enables online measurement of particles in the air in the range of 5 nm to 10 µm – the data can be used to model the processes of particle formation that take place in the atmosphere.

The existing equipment for measuring the amount of organic and elemental carbon in the air from exposed filters was also replaced, and the NAQMN was also equipped with new samplers to expand the measurement of HMs and PAHs.

The acquired drone with sufficient load capacity serves as a carrier for instruments for measuring air quality (Fig. 12). With its help, it is possible to measure the vertical profiles of pollutant concentrations and the size distribution of suspended particles. The use of a suitable flight mode allows mapping the distribution of concentrations in horizontal and vertical areas. The particle counter using a drone can be used to detect changes in the mass concentrations of suspended particles, as well as possible changes in the size spectrum of particles with altitude and their distribution in vertical and horizontal areas. These measurements, extended to the third dimension, provide hitherto unknown information on changes in concentration fields (spatial and temporal) under different meteorological conditions. By using the thermal camera it is possible to make remote temperature measurement in smoke trails of sources or in trails from cooling towers; it can be used for stationary mounting in long-term monitoring mode, as well as expedition and measurements while moving, especially in combination with a drone and it also can be used in diagnostics of measuring instruments in the CQL.

Fig. 12 Dron serving as a carrier of instruments for measuring air quality (Photo: Tušimice Observatory)

The aim of the project Air Quality Monitoring – Infrastructure for Ultrafine Particles (IM – UFP) in 2018–2019 was to build the necessary infrastructure for future measurements of aerosol particles up to 1 µm, including three stations for measuring these particles (e.g.Fig. 5). This not only meant acquiring and building the stations, but also establishing a system ensuring metrological consistency of the standards, gauges and analysers used to ensure the reliability of the measured results. This makes it possible to assess the state of ambient air pollution by pollutants that were previously of minor importance. The acquisition of the station container and accessories for ultrafine particle measurements has created a completely new infrastructure – the PM analyser (particle spectrometer) is essential for determination and measurement of the size concentration of aerosol particles in the air. It uses varying electrical mobility of aerosols dependent, among other things, on their size. The mixed aerosol in the air can thus be identified and the size concentration of each size fraction can then be determined. The PM analyser –total particle counter was acquired to continuously check the total size concentration of aerosol particles from the particle spectrometer; it detects total aerosol particle concentrations. Since ultrafine particle stations are also intended to evaluate health effects, measurement of the black carbon (BC) parameter is recommended. To determine the ambient air concentration of BC (in its PM_1 mass fraction), a BC analyser was acquired – this complements the information on the size concentrations with the total mass concentration of aerosol particles. This analyser has found use, for example, in identifying traffic pollution sources. A set of instrumentation has been purchased to ensure the correctness of the measurements for the metrological verification and to ensure correct reference to standards.

Assurance of measurement quality was previously only performed via the CQL. In 2019–2020, the air pollution measurement network technology was renewed. It was necessary to equip the AIM stations at the CHMI regional offices with so-called calibration benches – in case of problems with the analysers, NAQMN staff can immediately carry out metrological rectification. SO_2, NO_2, CO and O_3 analysers and dilution units with reference gas sources make a component of these calibration benches. As no spare instruments were acquired during the renewal of the NAQMN through the NAQMN Innovation Project and it is necessary to have backup instruments in case of a failure, SO_2, NO_2, CO and O_3 gas analysers, dust meters for PM_{10}/$PM_{2.5}$ measurement, PM_{10}/$PM_{2.5}$ sequential samplers and equipment for remote monitoring of the instrument status were purchased allowing to intervene immediately and ensure the time yield of the measurements so that the sampling is carried out within the agreed timeframe, since special measurements are, in principle, always carried out under time pressure.

In addition, a benzene sampler was acquired, as the technical improvement of benzene samplers reduces sampling uncertainty, increases the fluency of the sampling, improves the indication of the sample taken and ensures the possibility of informing NAQMN technicians about the status of the sampler. A wet-only collector was purchased to collect wet-only deposition; it is an automatic sampling device of the box type. A new traffic station was established in Pilsen – the basic condition for its installation was a container with accessories. It is equipped with a dust meter for PM_{10} and $PM_{2.5}$, NO_2 and CO analysers and a sampler for benzene. The population is thus informed in real time about air pollution from transport vehicles.

In 2019–2020, laboratory equipment for measuring air pollution was renewed. An ion chromatograph with a conductivity detector was acquired for the determination of cations in ambient air (mainly in the $PM_{2.5}$ aerosol fraction) – it provides measurements in the NAQMN of the Czech Republic for reporting to the European air pollution database and for determining the origin of pollution. As various plastic components are used in the NAQMN which wear out in time and need to be renewed, a 3D printer was acquired for the manufacturing of these components which serves as an alternative to purchasing original spare parts from manufacturers which are often characterised by high prices. Sample registering has changed from paper to electronic version, thus avoiding now the possibility of an error, which was most often the human factor.

The renewal of the network and laboratory equipment in 2020 meant the acquisition of sampling equipment for long-term sampling of volatile organic compounds (VOCs), which include ozone precursors, aldehydes, ketones, and halogenated hydrocarbons (Fig. 13). These are special stainless steel canisters enabling the collection of these substances for subsequent GC/FID and GC/MS analysis. This increases the representativeness of VOC measurements at optimal time intervals and allows the use of measured data from project measurements. Sampling equipment for long-term VOC sampling on sorption tubes allows timing and flow control as required, thus increasing the informative value of VOC measurements; it is possible to use the measured data for comparison with routine sampling and analyses by other chemical analytical methods (Fig. 14). In addition to project measurements, it is also used in the standard NAQMN. The gas chromatograph with mass detection with preconcentration unit represents a VOC measurement device enabling the subsequent determination of light and standard VOC compounds and making use of the measured data provided especially within air pollution project measurements.

Fig. 13 GCMS analyser for determination of volatile organic compounds (VOCs) collected in canisters (Photo: CQL Prague Libuš)

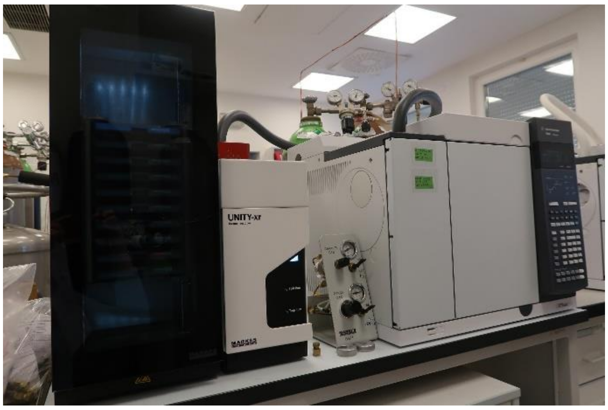

Fig. 14 Gas chromatograph for determination of benzene from sorption tubes (Photo: CQL Prague Libuš)

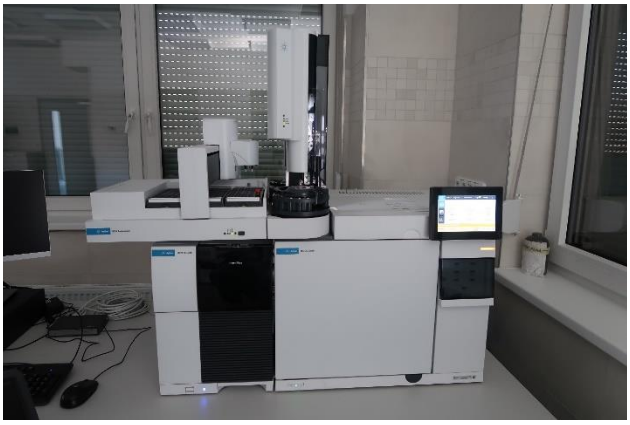

Fig. 15 Gas chromatograph with chemical ionization, on which a method for determination of nitro-PAH is being developed (CHMI Regional Office in Ústí nad Labem)

To test the efficiency of filter capture, which is a requirement of the ČSN EN 12341 standard on Air quality – Reference gravimetric method for determining the mass concentration of aerosol fractions of PM_{10} and $PM_{2.5}$, the Filter Test Ring is used. For a special type of measurements in which the purpose is to separate the aerosol before subsequent chemical-analytical methods by size, samplers equipped with cascade impactor are used. An automated analyser is used for online measurements of aerosol composition to determine selected elements in the PM_{10} and $PM_{2.5}$ fractions in the ambient air – it works on the principle of an energy dispersive X-ray fluorescence spectrometer that can evaluate the sampled aerosol for the composition of some elements pseudo-online. It is designed for special measurements in NAQMN and operated simultaneously with automatic PM analysers. A sequential low-volume sampler for off-line aerosol sampling of the PM_1 fraction was acquired at the Košetice Observatory – this extended the existing measurements of $PM_{2.5}$ and PM_{10} aerosol particles by the manual method and the measurement results allow a more detailed study of the influence of local pollution and long-range transport at the background site.

During the renewal of special meteo-technology, specialised measuring equipment was acquired at the Tušimice Observatory to measure vertical fluxes and deposition rates of pollutants near the Earth's surface (eddy covariance measurement system). Modelling of vertical transport of pollutants and other scalar quantities (e.g. sensible and latent heat, or momentum) has a major impact on the success of numerical prediction models and advanced pollution models. The data obtained also allow improving models of fugitive emissions and resuspension of dust particles from the Earth's surface. A specialised measurement technique, the portable automatic scanning aerosol Lidar, is used to monitor the spatial temporal distribution of dust particle concentration and size spectra, enabling continuous monitoring of the spatial structure of aerosol layers in the lower atmosphere, and concentration and particle size distribution at different altitude levels. The information provided is essential for smog situation cause analysis and prediction, as well as more detailed air pollution modelling with more advanced models. It finds its use in field measurements, monitoring of fugitive particulate emission sources and detection of transboundary transport of pollution.

In the ACTRIS project, which involves the Košetice Observatory, a Doppler Lidar is used – an instrument for measuring the vertical profile of aerosol particles in the atmosphere and other superstructure parameters such as the extinction coefficient (reduction of incident solar radiation by the presence of aerosol particles), the height of the atmospheric boundary layer, the temperature profile of the atmosphere, etc. The Košetice Observatory is located in the main air corridor, therefore a Doppler type of Lidar operating on the principle of elastic light scattering is required.

The laboratories at the CHMI Regional Office in Ústí nad Labem were expanded. The air quality department has a relatively large representation at this branch, which is given by the extent of the monitoring area, its pollution and also the specialization of laboratories for PAH determination, gravimetric determination of dust aerosol, and measurement of ultrafine particles (UFPs). In addition to analysing all PAH samples taken by the CHMI in the Czech Republic, the laboratory at this branch also serves for projects and development in the field of PAHs and other organic substances analysed by gas chromatography (Fig. 15). At present, samples from 29 stations are analysed here (the original number of stations was 10); and it is for this reason that the decision was made to expand the premises at this branch and to build a new workplace; primarily, the new laboratory building is intended for measuring PAH in NAQMN, there are also laboratories focused on testing and further development of existing methods, the use of new instruments to ensure measurement quality and work on projects in which the branch is actively involved. PAH determinations are extended by hopanes and other organic substances, which are mainly used to identify combustion sources. It is also worth mentioning the determination of nitro-PAHs and other substances in the air, the source of which is, for example, transport – these are substances with an order of magnitude higher toxicity than PAHs and thus with a greater impact on public health.

There is also a laboratory for ultrafine particles, which currently provides measurements from six stations. In this monitoring network it is possible to determine the spectrum of ultrafine aerosol particles. The laboratory is equipped with two gas chromatographs with a mass detector (GCMS) for the determination of PAHs and hopanes, as well as a gas chromatograph with chemical ionization, on which a method for the determination of nitro-PAHs is being developed; To ensure the quality of UFP measurements, there are, for example, SMPS (Scanning Mobility Particle Sizer) and CPC (Condensation Particle Counter) devices. The output of determinations performed in the laboratory includes resulting data sets, which are provided, after verification, to the user, which is mainly AQIS (Air Quality Information System). The results of benzo[*a*]pyrene (BaP) measurements can then be found in the air pollution yearbooks available on the CHMI website. It is also possible to monitor the BaP load in a given area; the trend of pollution is then monitored in the graphic yearbooks. As this analyte is one of the main emission sources of combustion in local heating plants, the results can also be used in this area.

All renewed and newly acquired equipment in the National Air Quality Monitoring Network (not only in the Operational Programme Environment) is regularly and repeatedly assessed; decisions are made on its further renewal, preservation and its additional necessary expansion.

1.2.2 Processing and presentation of air quality data

Concentrations measured by air pollution monitoring stations are stored in the AQIS air quality database. Data have been archived in the AQIS since the beginning of measurement, concentrations of sulphur dioxide and suspended particles from CHMI station networks in northern Bohemia, Prague and in the O/K/F-M agglomeration since 1969, and ozone concentrations in Hradec Králové since 1957. Detailed descriptive data on measurement sites, measurement programs and methods, classification and measurement quality are also managed in the AQIS.

Verification of air pollution data takes place in two steps. The employees of the CHMI regional office (CLI), i.e. the administrator of the measuring network and the expert in charge of control and verification are responsible for the first verification. They are responsible for measuring, collecting, checking and also the subsequent verification of data. The second verification of air pollution data is performed in the AQIS Department continuously throughout the year with using the database application (Fig. 16).

After uploading air pollution data, software verification is automatically initiated, which creates a file of “suspicious data”. The data from this file are assessed for credibility by an authorized expert. Using further software tools (AQIS2), all newly uploaded data to the AQIS database are checked.

Based on the results of the verification, the expert in charge of checking the data contacts the supplier to address the problematic data. Verification of suspicious data is requested. In the event the supplier considers the data to be incorrect, the supplier provides the corrected data to the AQIS data administrator, who stores the data in the database.

At the end of the annual data collection, the expert in charge of checking the accuracy of the data also checks the reliability of all measured and calculated (aggregated) air pollution data.Further information on the verification of air pollution data is provided in the Summary Tabular Survey 2021 (CHMI 2022b).

A selection of information, tables, graphs and map presentations is part of the tabular and graphic yearbooks available on the CHMI website (http://www.chmi.cz), where other overviews, including graphic representations related to air pollution are also available.

The Air Quality Tab also provides current measurement data after just a short delay from CHMI automated monitoring stations and from other organizations in tables, as the air quality index (AQI), in graphs, and as estimates of the spatial distribution of PM_{10}, SO_2, NO_2 and O_3 concentrations, including a separate map of the air quality index. These maps are also available in a newly developed CHMI+ mobile application for the Android and iOS operation systems. Currently, an up to date overview of data from the Polish and Austrian automated stations is also available; in the case of Polish stations the data are delayed by two hours due to operational reasons.

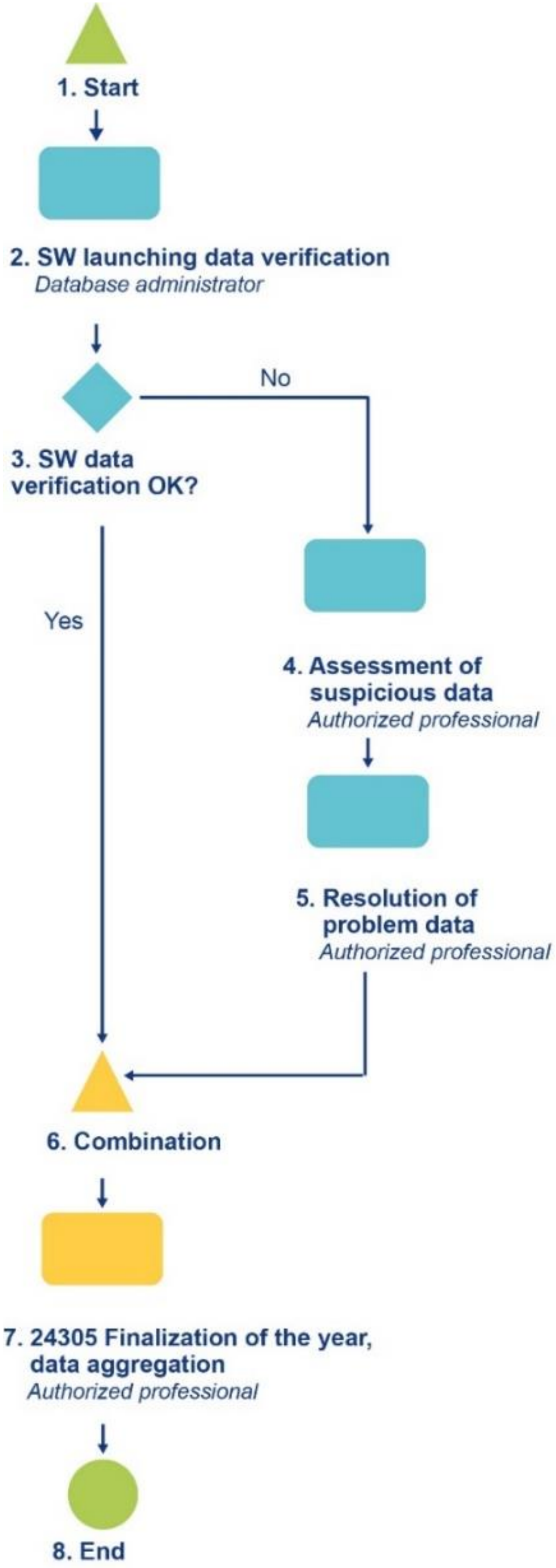

Fig. 16 Diagram of the verification of air pollution data in the AQIS

1.3 Atmospheric deposition

Atmospheric deposition refers to the flux of substances from the atmosphere to the Earth's surface. This is an important process contributing to self-cleaning of the air; on the other hand, however, it is responsible for the input of pollutants into other components of the environment (hydrosphere, pedosphere, cryosphere, biosphere). Atmospheric deposition consists of both wet and dry components. The wet component is associated with the occurrence of atmospheric precipitation, both vertical (rain, snow) and horizontal (fog, rime). The dry component corresponds to the deposition of gases and particles by various mechanisms, and involves the direct transfer of substances from the air to vegetation, the Earth's surface or the oceans. Unlike wet deposition, which is an episodic phenomenon due to its dependence on precipitation, dry deposition is slower, but continuous (Braniš, Hůnová 2009).

The quantification of total atmospheric deposition is very important for studying its impact on the natural environment. Determination of the individual components differs substantially in relation to the difficulty of the method and reliability of the obtained results. The CHMI has long been focused on improving the measurement of deposition fluxes in order to achieve results as close as possible to actual deposition (Hůnová et al. 2016). One of the goals is to identify areas permanently affected by the high atmospheric deposition of selected substances (Hůnová et al. 2019a).

1.3.1 Wet vertical deposition

It is relatively easiest to measure wet vertical deposition (Krupa 2002) that is associated with vertical, i.e., falling precipitation (rain, snow). Three methods are used for sampling. The “wet-only” method samples “net precipitation”, where the sampling device is exposed only for the duration of precipitation (Fig. 17). If the sampling device is exposed continuously and the sample includes, in addition to vertical precipitation, an undefined proportion of dry deposition, this is a “bulk” sampling method (Fig. 18). The best possible estimate of the total atmospheric deposition is considered to be from the “throughfall” method, which samples precipitation under a forest canopy (Fig. 19). The crowns of trees very effectively “catch” the dry deposition, which then, together with the wet component, enters the sampling containers (Braniš, Hůnová 2009). However, this only applies to those pollutants that are not subject to significant exchange between the atmosphere and the ecosystem, such as sulphur, but not for nitrogen.

In the CR, the Czech Hydrometeorological Institute (CHMI), the Czech Geological Survey (CGS), the Forest Management and Gamekeeping Research Institute (VULHM) and the Academy of Sciences of the CR, specifically the Institute of Hydrobiology (HBU AS CR), the Global Change Research Institute (ÚVGZ AS CR) and the Institute of Geology (GLÚ AS CR) provide measurements of the chemical composition of atmospheric precipitation, and thus wet vertical deposition. The CHMI stations measure net precipitation (“wet-only”) at weekly intervals. An exception is the Košetice National Atmospheric Observatory, where "bulk" and "throughfall" precipitation are also measured. At the localities of other organizations, measurements are measured in monthly (or irregular) intervals of concentrations in bulk precipitation in open areas, or in througfall samples. Heavy metal analyses are also performed at all stations (Fig. 20). An up-to-date overview of stations and sampling types is given in CHMI (2022a).

Fig. 17 Automated "wet-only" sampler, Prague-Libuš station (Photo: E. Svobodová)

Fig. 18 "Bulk" sampler, Prague-Libuš station (Photo: E. Svobodová)

Fig. 19 "Throughfall" sampling, forest stream catchment area of the Košetice observatory (Photo: J. Svobodová)

To check the data on precipitation quality a calculation of the ion balance is routinely used, performed by the respective laboratory analysing the collected precipitation sample. The difference between the amount of cations and the amount of anions in the sample must meet the permitted criteria, which varies slightly from organization to organization. Furthermore, a control is done by comparing the calculated and measured conductivity, which must also meet permitted criteria. A control is also performed by the analysis of blank laboratory samples, and site samples are continuously monitored and evaluated, which enables checking the performance during sampling and monitoring ongoing changes due to transport, handling, storage and treatment of samples before chemical analysis.

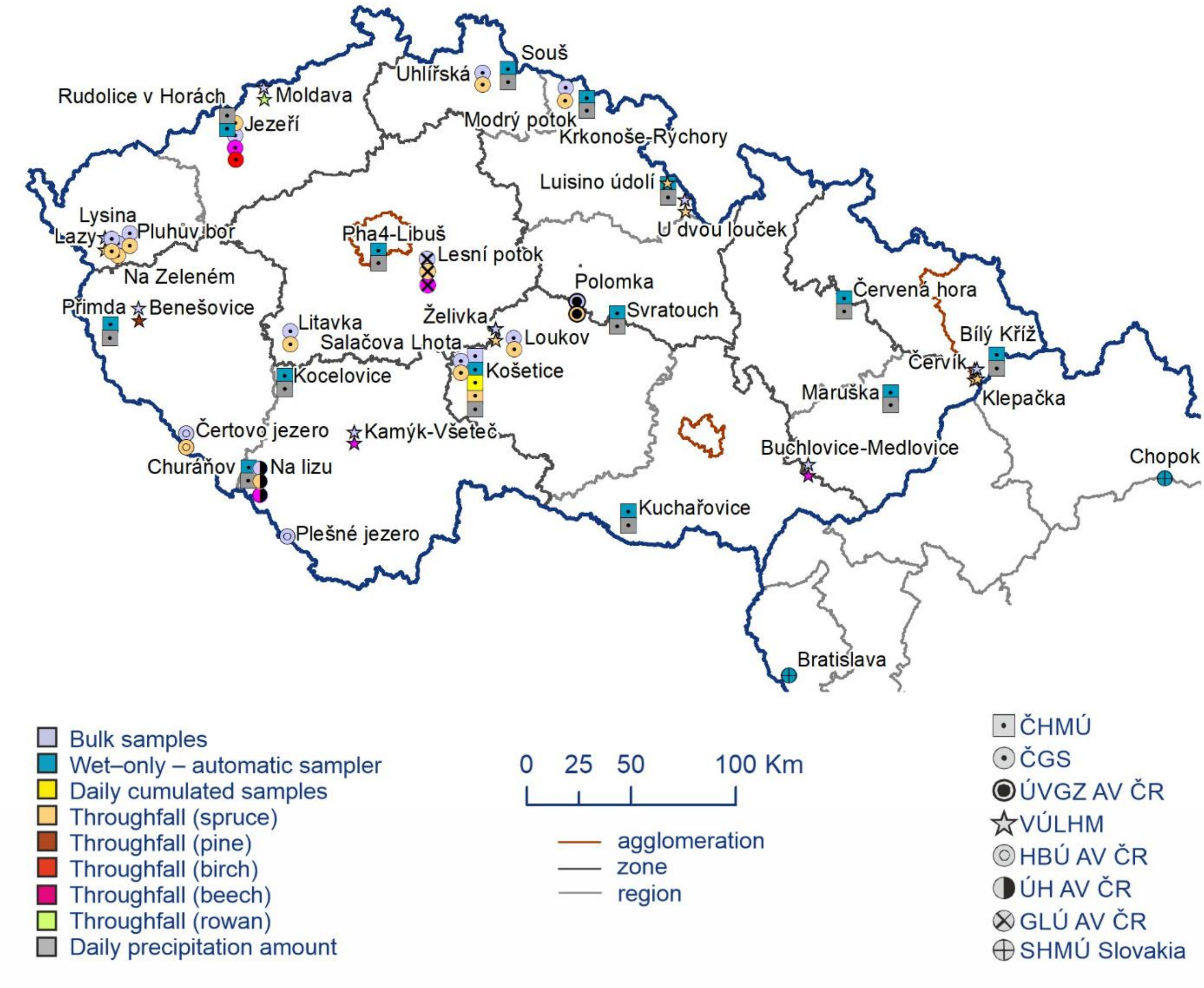

Fig. 20 Station networks monitoring atmospheric precipitation quality and atmospheric deposition, 2021

1.3.2 Wet horizontal deposition

The horizontal component of wet deposition is the most difficult to measure component of the total atmospheric deposition (e.g. Krupa 2002; Klemm, Wrzesinsky 2007). Direct sample collection is very complicated. This component is therefore measured only exceptionally, and usually significantly underestimates the actual deposition (Bridges et al. 2002; Hůnová et al. 2011).

1.3.3 Dry deposition

A method for the direct measurement of dry deposition is not available, so it must be estimated using various, usually relatively complicated approaches (Wesely, Hicks 2000; Kumar et al. 2008). In the CHMI, the so-called inferential method is used, where the dry deposition of the relevant substance is calculated as the product of its average air pollution concentration and the relevant deposition rate (Wesely, Hicks 2000). While the air pollution concentration data of a substance are relatively reliable, the deposition rate depends on a number of factors (environmental and meteorological) and carries considerable uncertainties (Braniš, Hůnová 2009).

1.4 Greenhouse gas emissions

1.4.1 Data collection

Greenhouse gases (i.e. gases that contribute to the greenhouse effect) have always been present in the atmosphere, but in recent history the concentrations of many have increased as a result of human activities. Over the last century, human activities have increased atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and halogenated hydrocarbons, i.e., greenhouse gases. Greenhouse gases prevent heat from radiating back into space and cause the climate to warm. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2014), CO_2 concentrations in the atmosphere have increased by 40%, mainly from fossil fuel combustion emissions and secondarily from emissions from land use changes. CH_4 concentrations have increased by 150% and N_2O concentrations by 20% compared to the pre-industrial period. Ground-level ozone also contributes to the greenhouse effect. The amount of ozone generated in the lower atmosphere has increased due to emissions of nitrogen oxides, hydrocarbons and carbon monoxide.

Relatively new man-made greenhouse gases entering the atmosphere have caused a further intensification of the greenhouse effect. This includes in particular a number of fluorine-containing substances (F-gases), including HFCs (hydrofluorocarbons). HFCs are used instead of ozone-depleting CFCs in refrigerators and other applications, and their emissions are increasing rapidly. Compared to carbon dioxide, all other greenhouse gases occur at low (CH_4, N_2O) or very low concentrations (F-gases). On the other hand, these substances are more effective (per molecule) as greenhouse gases than carbon dioxide, the main greenhouse gas.

As a result of scientific findings that human activities affect the climate and following growing public awareness of regional and global environmental issues, climate change became part of the political agenda in the mid-1980s. The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988, and two years later concluded that anthropogenic climate change is a global threat that requires an international agreement to address it. The UN began negotiations on a United Nations Framework Convention on Climate Change (UNFCCC), which entered into force in 1994. The long-term goal was to stabilize greenhouse gas emissions in the atmosphere at a level that would prevent harmful climate change for the planet and humanity. A key annex to the Convention is Annex I, which specifies countries that are required to report an annual inventory of greenhouse gas emissions and removals. The basic goal of the Convention was to create conditions for the timely stabilization of global concentrations of greenhouse gases in the atmosphere at levels that would prevent the dangerous interference of anthropogenic influences with the Earth's climate system. The Parties of the Convention meet annually at member conferences to review the progress made so far and, where appropriate, approve strategies to achieve adopted and possibly future objectives.

The most important amendment to the Convention was signed in 1997 in Kyoto, Japan. The Kyoto Protocol (KP) committed industrialized countries to reducing their total greenhouse gas emissions, individually or jointly, by at least 5% during the first monitoring period (2008-2012) compared to 1990. The reductions concerned emissions and sinks of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), partially (HFC), and completely fluorinated hydrocarbons (PFC) and sulphur hexafluoride (SF_6), expressed as aggregated CO_2 emissions. In the case of the CR, this represented a commitment to reduce total greenhouse gas emissions by 8% compared to the reference year 1990 (for HFCs, PFCs, SF_6 and NF_3, 1995 was set as the base year). In December 2012, an amendment was approved at the 18th Conference of the Parties (COP-18) in Doha, Qatar, confirming the continuation of the KP and its second commitment period, which was set to eight years (2013–2020). Within the second commitment period, some Parties committed to reducing their greenhouse gas emissions by at least 18% below the 1990 levels. A commitment to reduce emissions by 20% has been set for the CR, as well as other EU member states. The EU will fulfil its commitment to the Convention and the KP at the Community level.

The Paris Agreement was adopted at the 21st Conference of the Parties in 2015 in Paris. It regulates the basic principles of climate protection measures that should be applied after 2020. In 2021, specific elements of greenhouse gas emissions and sink reporting requirements were agreed in Glasgow under the rules of the Paris Agreement specified in Decisions 18/CMA.1 and 5/CMA.3. However, reporting under the new rules will not begin until 2024. Until then, the preparation of the national inventory report will be governed by Decision 24/CP.19 "Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention" of the 19th Conference of the Parties, which sets out reporting requirements.

As one of the parties to the UN Framework Convention on Climate Change, the CR has an obligation to prepare and regularly update national inventories of greenhouse gas emissions and sinks. In addition, membership of the European Union imposes additional requirements on the CR, such as compliance with the obligations specified in Article 7 of EU Regulation No. 525/2013.

Following these international requirements, the EU has created its own emissions trading system. In the CR, there are two interconnected systems in force - the European Emissions Trading System (ETS), and flexible KP mechanisms: the Clean Development Mechanism, Joint Implementation Projects and International Emissions Trading. The expiry of the flexible KP mechanisms is provided for in Regulation (EU) No. 525/2013 of the European Parliament and of the Council. For CHMI, as the coordinator of the inventory of emissions and sinks of greenhouse gases, the mutual interaction of the national inventory and the EU ETS system is essential. The national inventory provides background data for the calculation of emissions from relevant processes. And conversely, when processing the national inventory, for example, precisely measured emission factors in the EU ETS or data on emission sources of specific polluters are used.

The collection of data on activities from which greenhouse gas emissions arise is generally based on official data from the Czech Statistical Office (CzSO) that are published annually, with the most representative being the Czech Statistical Yearbook. The Czech Statistical Yearbook is usually published at the end of November, but some data are not available until later. Data from emissions trading, data from specific industrial associations, and data from the Czech Land Surveying and Cadastre Administration are also used.

In the case of industrial processes, production data are generally not available in statistics if there are less than four related enterprises in the whole country. In such cases, inventory experts conduct specific detailed investigations in the given area.

The deadline for collecting all data is 15 November. In some cases, however, CzSO makes corrections to the data, which are available later. In such cases, it is not possible to include the updated data in the reporting for the EU that is submitted by 15 January and which must be considered as preliminary output of the Czech national greenhouse gas inventory. However, all revised data are included in the final submission to the UNFCCC by 15 April (which is also submitted to the EU).

All data, both the so-called activity data and the resulting calculations, go through detailed quality control, which takes its place throughout the inventory processing. Settings of control procedures and internal audits are also the subject of international reviews, and if these procedures are found to be insufficient, the inventory system is marked as non-functional and the entire process of emissions trading for the country may be suspended, with major impacts on the economy. The scheme of inventory preparation is shown in Fig. 21.

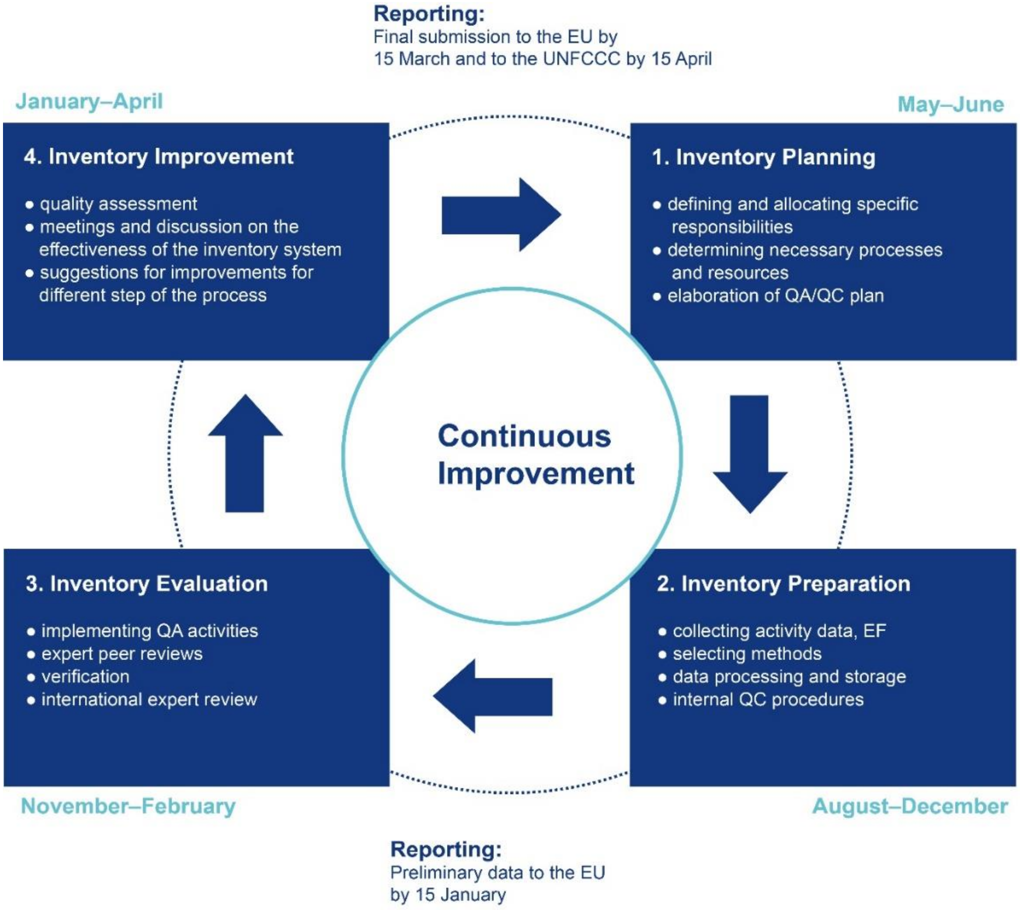

Fig. 21 Scheme of inventory preparation

1.4.2 Data processing and presentation

The national inventory report along with official reporting tables (CRF - Common Reporting Format) and all required amendments are submitted to the European Commission by 15 March each year and to the Secretariat of the United Nations Framework Convention on Climate Change by 15 April. Responsibility for the proper functioning of the National Inventory System (NIS) in the CR lies with the Ministry of the Environment, which has appointed the CHMI to be the institution responsible for the compiling and coordinating of GHG inventories and required data and text outputs that are then published on the Convention portal (https://unfccc.int), similarly to reporting from other Parties. The main tasks of the CHMI are inventory management, general and cross-cutting issues, control procedures (QA/QC), communication with relevant UNFCCC and EU bodies, etc. The Czech national inventory system has long included a number of research institutions that are responsible for compiling the emission inventories in the sectors from which greenhouse gases are emitted. The functioning of the national inventory system is also subject to reviews conducted by the UNFCCC as well as the work of the sectoral experts. The resulting official inventory is then prepared by the CHMI and approved by the Ministry of the Environment and other governmental organs. Fig. 22 shows a diagram of the functioning of the national inventory system in the CR.

One of the basic requirements of the Convention, the KP and other amendments is the timely, accurate, transparent, consistent and internationally comparable systematic monitoring of greenhouse gas emissions. These are the relevant principles of so-called TACCC - transparency, accuracy, completeness, comparability, and consistency.

The inventory includes anthropogenic emissions of not only the direct greenhouse gases CO_2, CH_4, N_2O, HFC, PFC, SF_6, NF_3, but also the indirect greenhouse gases NO_X, CO, NMVOC and SO_2. Indirect means that they do not directly contribute to the greenhouse effect, but that their presence in the atmosphere can affect the climate in various ways. As mentioned above, ozone (O_3) is also a greenhouse gas that is produced by the chemical reactions of its precursors: nitrogen oxides, hydrocarbons and/or carbon monoxide.

The inventory of greenhouse gas emissions and sinks is prepared in accordance with the methodological guidelines of the Intergovernmental Panel on Climate Change, IPCC 2006 Guidelines. In addition, great emphasis is placed on improving the accuracy of these internationally valid methodologies taking country-specific conditions into account as much as possible. In such cases of improved methodological procedures, there is often a need to recalculate the reported emissions for the whole time series. This maintains a time-series consistent approach to emissions reporting.

Data from all sectors are then processed according to UNFCCC requirements into official reporting tables and the reporting document. Each chapter must contain a description of the activities from which the emissions of greenhouse gases arise, a detailed description of methodological procedures, results, possible recalculations, and last but not least, information on the control procedures performed and possible uncertainties in emission estimates. All this must be carried out in great detail and is inspected annually by both the UNFCCC and the EU. If a major problem is found, it must be corrected immediately and the entire inventory resubmitted.

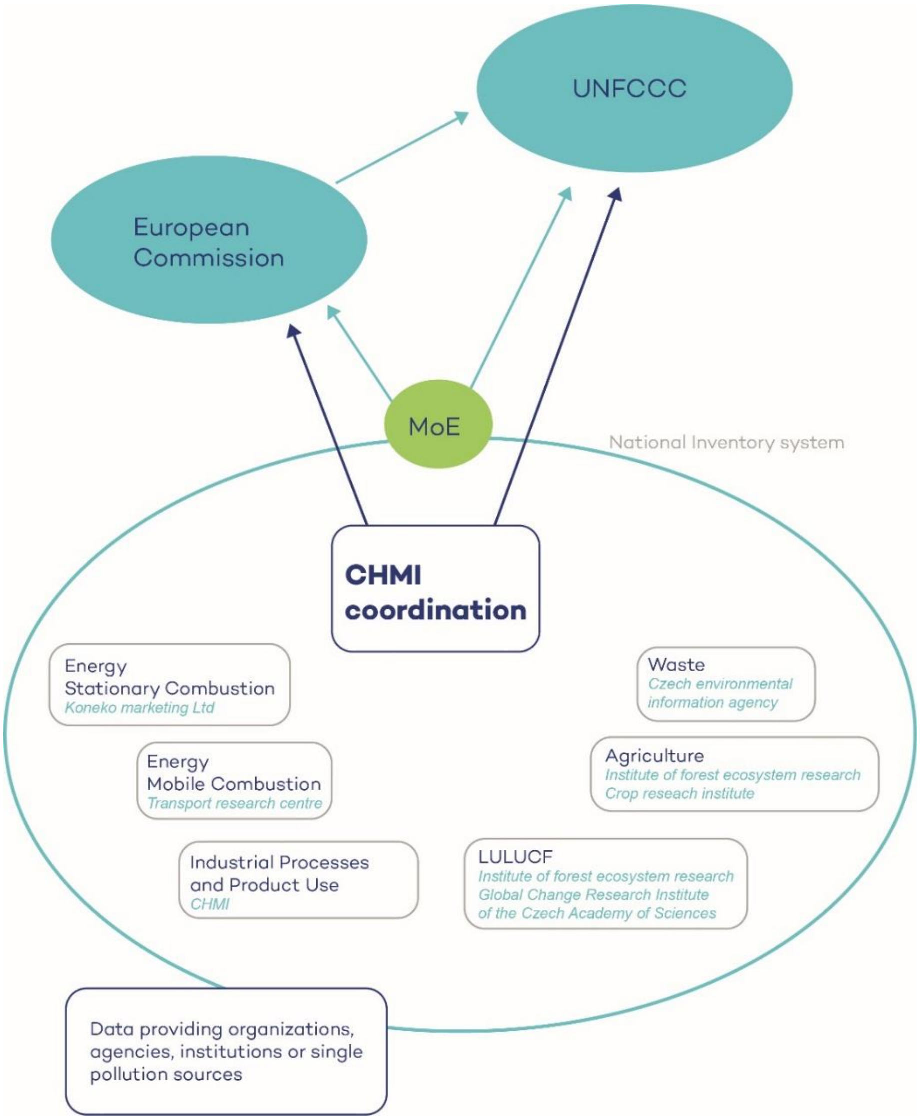

Fig. 22 Diagram of the functioning of the national inventory system in the CR

2 Evaluation

This chapter defines the tools used to assess air quality. These include meteorological and dispersion conditions that significantly affect both emissions and air pollution concentrations. Furthermore, there is a description of the methodology for creating areal maps that present the areal distribution of concentration estimates.

2.1 Meteorological and dispersion conditions

The degree of air pollution does not depend only on the amount of pollutants in the atmosphere. Other important factors include the geography of the area, location of the pollution sources and meteorological conditions for the dispersion of pollutants (dispersion conditions). These factors affect the amount of emissions from anthropogenic and natural sources, the formation of secondary pollutants and the rate of their removal from the air.

The level of air pollution is mainly affected by air temperature, precipitation, horizontal flow and vertical mixing. Air temperature and vertical flow affect the stability of the atmosphere and, together with horizontal flow, affect the dispersion conditions. Precipitation then contributes to the leaching of air pollutants.

2.1.1 Meteorological conditions

The climatological normal is used to evaluate meteorological conditions. The normal means a characteristic obtained from long-term observations, whereas standard climatological normals are set as 30-year averages (1931–1960, 1961–1990, etc.). Due to the ongoing climate change, the World Meteorological Organization (WMO) recommends the calculation of so-called interim climatological standards, always for the last thirty years (e.g. 1981–2010). In February 2022, the CHMI switched to the 1991–2020 climatological normal (ČMeS 2017, Škáchová 2021). Territorial temperatures and territorial precipitation in the Czech Republic are available on the CHMI website, including normals[3].

2.1.2 Dispersion conditions

Dispersion conditions describe the ability of the atmosphere to disperse pollutants. Dispersion is affected not only by the stability of the atmosphere and the flow of air in the atmosphere, but also by the state of pressure systems, i.e., the weather (synoptic) situation. Categorisation of weather situations divides situations into 28 types, of which 13 are defined as anticyclonic and 15 as cyclonic (CHMI 2022d). Anticyclonic situations are more problematic in terms of air quality, as descending air movements and low air velocity often lead to stabilization of the temperature stratification of the atmosphere and thus to the formation of temperature inversions (Škáchová 2021).

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[3] https://www.chmi.cz/historicka-data/pocasi/uzemni-teploty
https://www.chmi.cz/historicka-data/pocasi/uzemni-srazky

As already mentioned, the dispersion of substances in the air is affected by the stability of the boundary layer of the atmosphere[4], depending on the alteration of temperature with height. In the layer of the atmosphere adjacent to the Earth's surface (troposphere), the temperature usually decreases with height by about 0.65 °C/100 m. If the temperature decreases faster with height, it is an unstable stratification, which manifests itself in an ordered thermal convection and thermal turbulence (Bednář 2008) and thus conditions suitable for the dispersion of pollutants occur. However, if the temperature rises with height, it is a temperature inversion and the atmosphere stabilizes. Vertical mixing is reduced and there is an accumulation of pollutants in the atmosphere and thus an increase in their concentrations.

One of the ways in which dispersion conditions can be expressed numerically is in terms of the ventilation index (VI), which is defined as the product of the depth of the mixing layer and the average wind speed within it (Ferguson 2001). Under conditions in the CR, the ventilation index expressed in this way generally attains values from hundreds up to tens of thousands $m^2 \cdot s^{-1}$, with values above 3,000 $m^2 \cdot s^{-1}$ designated as good dispersion conditions, values between 1,100 and 3,000 $m^2 \cdot s^{-1}$ considered moderately poor, and values below 1,100 $m^2 \cdot s^{-1}$ as poor. Situations with poor dispersion conditions do not necessarily mean the occurrence of high pollutant concentrations. Important factors also include the duration of the situation, the starting level of pollution, the distribution of sources, and their emissions to a layer under an inversion. However, the substantial and extensive exceeding of pollution level limits occurs almost exclusively under moderately poor and poor dispersion conditions. The occurrence frequency of various types of dispersion conditions strongly depends on the time of day and season of the year (Škáchová 2020).

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[4] The boundary layer of the atmosphere is the layer where the influence of the earth's surface on the field of meteorological elements is evident (ČMeS, 2017).

2.1.3 Effects on emissions

Anthropogenic emissions from heating depend on the air temperature, in the cold half of the year the emissions are higher than in the warm half of the year. Long-distance heating supply is regulated by Decree1 No. 194/2007 Coll. Households with their own heating behave differently. Heating emissions are determined on the basis of the number of heating days and the temperatures that occurred during them. For the purposes of this yearbook, heating days are defined as days with an average daily temperature below +13 °C. Temperature conditions in the heating season (January–May, September–December) are characterized by degree-days. This is the sum of differences between the reference indoor temperature and the average daily outdoor temperature on heating days.

$$D_{t_{ref}} = \sum_{\substack{heating \\ days}} \left(t_{ref} - t_d\right)$$

where D_{tref} are degree-days, t_{ref} is the reference temperature of indoor air (21 °C), and t_d is the average daily temperature on the individual heating days.

Lower temperatures can lead to increases in combustion emissions from motor vehicles, especially during cold starts (ATEM 2012; Chan et al. 2013; Vojtíšek 2013). Emissions of volatile organic compounds (VOCs) from solvents and the storage and distribution of petrol are also dependant on temperature. In addition, temperature and photosynthetically active components of solar radiation affect biogenic emissions of non-methane volatile organic compounds (e.g. isoprene and terpenes), which act as precursors for secondary organic aerosols and tropospheric ozone. Emissions from forested areas are especially important (e.g. Bednář et al. 2013; Zemánková et al. 2010). Wind speeds above approximately $4\ \text{m}\cdot\ \text{s}^{-1}$ can cause resuspension, i.e., the eddying and repeated lifting of previously settled particles back into the air. Meteorological conditions also affect the degree and rate of evaporation of persistent organic substances from the soil, where they were deposited mainly through agricultural activities.

2.1.4 Effects of meteorological conditions on the formation of secondary pollutants and the atmospheric chemistry

Meteorological conditions, especially temperature, relative air humidity and solar radiation, directly affect the chemical and physical processes taking place among the pollutant substances in the air (e.g. Baek et al. 2004). Meteorological conditions can also have indirect impacts, e.g., intense mixing can lead to the dilution of emitted substances and thus to a reduction in reaction rates. Photochemical reactions are dependent on solar radiation. In the summer, high temperatures and especially intense solar radiation contribute to high tropospheric ozone concentrations (Blažek et al. 2013).

2.2 Creation of ambient air pollution and atmospheric deposition maps

2.2.1 Ambient air pollution maps

Directive No. 2008/50/EC on ambient air quality and cleaner air for Europe, which is implemented into the Czech legislation (i.e. Decree No. 330/2012 Coll.), requires that air quality be evaluated in all zones and agglomerations of each member state. It further requires that the primary source of the evaluation be the results of stationary measurements. In the creation of air pollution maps, measured concentrations may be supplemented by modelling and indicative measurements, so that the resultant estimates provide sufficient information on the spatial distribution of pollutant concentrations in the air. The requirement to use stationary measurements as primary sources of information is applicable primarily for areas in which pollutant concentrations exceed the upper assessment threshold. To ensure uniformity in the map creation methodology, this requirement is applied to the whole territory of the CR.

The basic source of data for the creation of air pollution maps are therefore the concentrations of pollutants measured at individual monitoring stations. There are only a limited number of monitoring stations. Therefore, in addition to the measured (primary) data, various additional (secondary) data are used for preparation of the maps, which provide comprehensive information about the entire territory and simultaneously exhibit a regression relation with the measured data. The main secondary source of information consists of models of pollution transport and dispersion, based on data from emission inventories and meteorological data. In the CR, mainly the CAMx Eulerian chemical dispersion model is used, supplemented by the SYMOS Gaussian model and the European EMEP Eulerian model. In addition, for individual pollutants, data on the altitude and population density are used; for details, see Annex I in the graphic yearbook (CHMI 2022a). The combination of primary and secondary data takes advantage of both the precision of the primary measured data and the comprehensive coverage of the entire territory by the secondary data. In regular map creation for the yearbook, the linear regression model is used with subsequent interpolation of its residuals. Kriging and IDW models are used as interpolation methods; for details, see Annex I in the graphic yearbook (CHMI 2022a).

Urban and rural types of air pollution differ in character; in general, urban pollution is affected by emissions and is generally higher than rural air pollution. One exception is ground-level ozone pollution, which exhibits the opposite behaviour. Thus, urban and rural map layers are created independently and the resultant map is a product of the combination of urban and rural maps using the grid of population density. For certain pollutants (PM_{10}, $PM_{2.5}$, NO_2, NO_x), a traffic map layer is considered in addition to the urban and rural map layers. This layer is merged with the urban and rural background layers using the grid of traffic emissions. The measured air pollution data from background rural stations are used as primary data for the construction of rural maps. Air pollution data from urban and suburban background stations are used for urban maps. Data from traffic stations are used for the traffic layers. Simultaneously, individual stations are classified according to the AQIS database.

The maps are created using geographic information systems (GIS). The main data sources are the AQIS relational database of measured emissions and the chemical compositions of atmospheric precipitation. The maps are constructed with spatial resolution of 1x1 km, in the WGS 1984 UTM Zone 33N projection. Annex I in graphic yearbook (CHMI 2022a) gives detailed mapping specifications for individual pollutants.

Since 1994, the digital DMÚ 200, DMR-2, DMÚ25 and later the ZABAGED layers are used as the basis for basic geographic and thematic layers in the standard projection (WGS 1984 UTM Zone 33N projection). The data provided by CSO are used for updated layers of administrative classifications.

2.2.1.1 Mapping of rural and urban (or traffic) layers

Maps of rural and urban background pollution (and, where applicable, traffic pollution) are prepared separately, constructed using combinations of primary (measured) and secondary (model and other supplementary) data (Horálek et al. 2007). The methodology employed consists of a linear regression model with spatial interpolation of its residuals. This methodology enables the use of supplementary data for the entire mapped territory. Where there are no suitable supplementary data, simple interpolation of the measured data is used. The estimate is calculated using the relationship

$$\hat{Z}(s_0) = c + a_1.X_1(s_0) + a_2.X_2(s_0) + \dots + a_p.X_p(s_0) + \eta(s_0), \qquad (1)$$

where $\hat{Z}(s_0)$ is the estimated concentration value at point s_0,
$X_i(s)$ are the various supplementary parameters at point s_0 for $i = 1, 2, \dots, p$,
$c, a_1, a_2, \dots$ are the parameters of the linear regression model,
$\eta(s_0)$ is the spatial interpolation of the residuals of the linear regression model at point s_0, calculated using the residuals at the points of measurement.

The interpolation is performed using either the inverse distance weighting method (IDW) or ordinary kriging (specifications for individual pollutants are given in Annex I in the graphic yearbook (CHMI 2022a). The IDW method is a simple deterministic method, with the weight of the individual measuring stations in the interpolation depending only on their distance from the estimated point. On the other hand, kriging is a more advanced geostatistical method taking into account the structure of the air pollution field. However, the IDW method has the advantage that the interpolation respects the measured values in the points of the measuring stations. Kriging does not, in general, respect these measured values. A solution lies in interpolation using kriging, and then applying IDW to its residuals at the measuring sites.

Interpolation of residuals using IDW is calculated using the relationship

$$\hat{R}(s_0) = \frac{\sum_{\mathrm{i}=1}^{N} \frac{R(s_i)}{d_{0\mathrm{i}}}}{\sum_{\mathrm{i}=1}^{N} \frac{1}{d_{0\mathrm{i}}\beta}}, \qquad (2)$$

where $\hat{R}(s_0)$ is the estimate of the field of residuals at point s_0,
$R(s_i)$ is the residual of the linear regression model at the measuring site s_i,
N is the number of surrounding stations used in the interpolation,
d_{0i} is the distance between points s_0 and s_i,
β is the weight.

For ordinary kriging, the interpolation of the residuals is calculated using the relationship

$$\hat{R}(s_0) = \sum_{\mathrm{i}=1}^{N} \lambda_i R(s_i), \qquad (3)$$

where $R(s_i)$ is the residual of the linear regression model at the measurement site s_i,
$\lambda_1, \dots, \lambda_N$ are the weights derived using the theory of spatial statistics (see Cressie 1993) from the system of $N + 1$ equations for the unknowns λ_i and m:

$$\sum_{j=1}^{N} \lambda_j \cdot \gamma(d_{ij}) + \gamma(d_{0i}) - m = 0 \quad \text{for} \quad i = 1, \dots N, \qquad (4)$$
$$\sum_{i=1}^{N} \lambda_i = 1,$$

where $\gamma(d_{ij})$ is the value of the estimated variogram (see below) for the distance d_{ij},
d_{ij} is the distance between sites s_i a s_j,
m is the so-called Lagrange multiplier allowing the sum of weights λi to be equal to one.

The variogram is a measure of spatial correlation, and expresses the dependence of the inter-point variability on the distance between the points (e.g. Cressie 1993). The estimated variogram is created by fitting the spherical curve to an empirical residual field variogram (cluster of points), which is calculated using the relationship

$$2\gamma_v(h) = \frac{1}{n} \sum_{i,j;d_{ij}=h\pm\delta} \left(R(s_i) - R(s_j)\right)^2 \qquad (5)$$

where n is the number of pairs of stations s_i and s_j, whose mutual distance $h \pm \delta$
δ is tolerance

The spherical curve and the variogram range, nugget and sill are illustrated in Fig. 23. The difference between the sill and the nugget is called a partial sill.

The calculated urban and rural (and, as appropriate, also traffic) layers are subsequently merged.

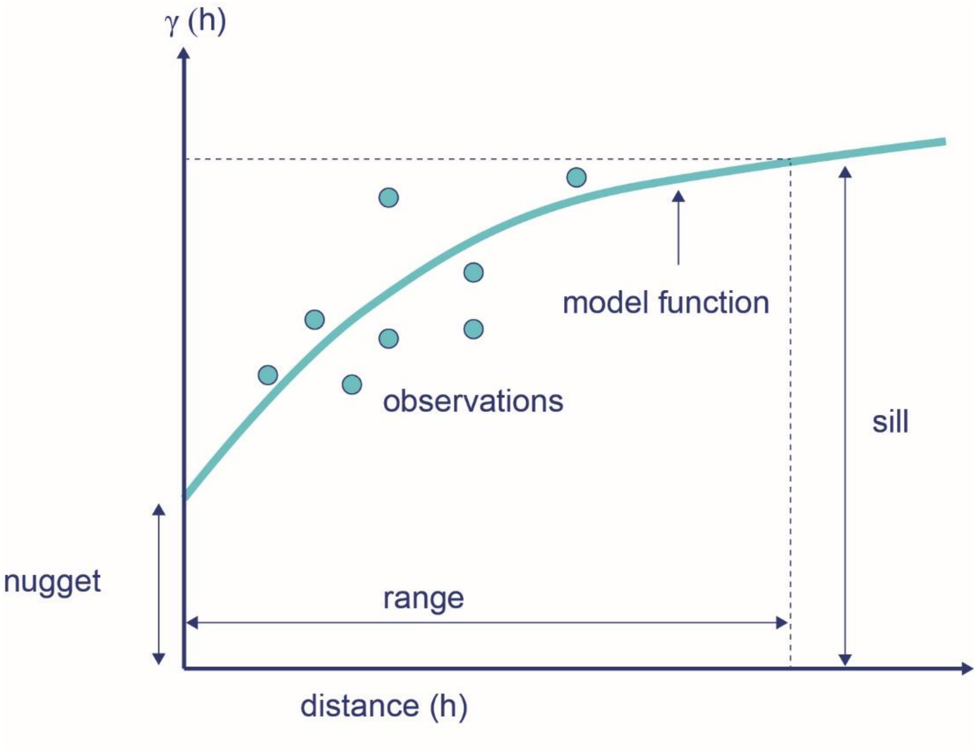

Fig. 23 Diagram showing the variogram parameters and fitted spherical curve

Merging of urban and rural (and, as appropriate, traffic) layers

The population density layer is used for merging the urban and rural layers (Horálek et al. 2007; De Smet et al. 2011). Merging is carried out using the relationship

$$
\begin{aligned}
\hat{Z}(s_0) &= \hat{Z}_r(s_0) && \text{for } \alpha(s_0) \le \alpha_1 \\
&= \frac{\alpha_2 - \alpha(s_0)}{\alpha_2 - \alpha_1} \cdot \hat{Z}_r(s) + \frac{\alpha(s_0) - \alpha_1}{\alpha_2 - \alpha_1} \cdot \hat{Z}_u(s_0) && \text{for } \alpha_1 < \alpha(s_0) < \alpha_2 \qquad (6) \\
&= \hat{Z}_u(s_0) && \text{for } \alpha(s_0) \ge \alpha_2
\end{aligned}
$$

where $\hat{Z}(s_0)$ is the final estimate of the concentration at point s_0,
$\hat{Z}_r(s_0)$, $\hat{Z}_u(s_0)$ is the concentration at point s_0 for the rural or urban map,
$\alpha(s_0)$ is the population density at point s_0,
α_1, α_2 are the classification intervals corresponding to the population density (Annex I in the graphic yearbook (CHMI 2021a).

The entire concept of separate mapping for rural and urban pollution is based on the assumption that $\hat{Z}_r(s_0) \le \hat{Z}_u(s_0)$ for all common pollutants except for ozone, and $\hat{Z}_r(s_0) \ge \hat{Z}_u(s_0)$ for ozone. For areas where this assumption is not fulfilled, a layer created similarly to the urban and rural layers is used, created on the basis of all the background stations without distinguishing between urban and rural stations.

If traffic pollution is also mapped for the relevant pollutant, the traffic layer is added to the background (merged urban and rural) layer using the grid of traffic emissions:

$$
\begin{aligned}
\hat{Z}(s_0) &= \hat{Z}_b(s_0) && \text{for } \tau(s_0) \le \tau_1 \\
&= \frac{2}{3}.\hat{Z}_b(s_0) + \frac{1}{3}.\left(\frac{\tau_2 - \tau(s_0)}{\tau_2 - \tau_1} \cdot \hat{Z}_b(s) + \frac{\tau(s_0) - \tau_1}{\tau_2 - \tau_1} \cdot \hat{Z}_t(s_0) \right) && \text{for } \tau_1 < \tau(s_0) < \tau_2 \qquad (7) \\
&= \frac{2}{3}.\hat{Z}_b(s_0) + \frac{1}{3}.\hat{Z}_t(s_0) && \text{for } \tau(s_0) \ge \tau_2
\end{aligned}
$$

where $\hat{Z}(s_0)$ is the final estimate of the concentration at point s_0,
$\hat{Z}_b(s_0)$ is the concentration at point s_0 for the background layer,
$\hat{Z}_t(s_0)$ is the concentration at point s_0 for the traffic layer,
$\tau(s_0)$ are the emissions from traffic at point s_0,
τ_1, τ_2 are classification intervals corresponding to emissions from traffic given in Annex I in the graphic yearbook (CHMI 2022a).

The above function is based on the assumption that $\hat{Z}_b(s_0) \le \hat{Z}_t(s_0)$ for common pollutants except ozone, and $\hat{Z}_b(s_0) \ge \hat{Z}_t(s_0)$ for ozone. For areas where this assumption is not met, the background layer $\hat{Z}_b(s_0)$ is used.

2.2.2 Atmospheric deposition maps

Maps of the total annual deposition for sulphur, nitrogen and hydrogen ions, and maps of wet deposition for sulphur, nitrogen, hydrogen ions, lead, cadmium, chloride and nickel ions, are regularly prepared for the publication Air Pollution in the CR. Dry deposition maps are also presented for sulphur, nitrogen, hydrogen ions, lead and cadmium.

Maps of the wet deposition of individual ions are created from the fields of ion concentrations in precipitation (based on annual mean weighted concentrations calculated from measured values) and from the fields of total annual precipitation on the basis of data from CHMI precipitation gauging stations, taking into account the effect of altitude on the amount of precipitation. In creating the fields of wet deposition, the results of wet-only samples at individual stations are preferred over bulk samples, and weekly sampling is preferred over monthly sampling. Data from the network of stations with measurements performed by CGS, VÚLHM and GIOS, based on monthly bulk sample collection, are modified for the preparation of wet deposition maps by empirical coefficients expressing the ratios of individual ions in wet-only and bulk samples (values for the individual ions range from 0.74 for NH_4^+ to 1.06 for H^+). The fact that the ratio is greater than 1 for the H^+ ion can be explained by the fact that solid particles contained in bulk samples react with hydrogen cations, reducing their concentrations (Ranalli et al. 1997).

The dry deposition of sulphur and nitrogen is calculated using the fields of annual mean concentrations of SO_2 and NO_x for the CR and rates in forested or treeless areas of 0.7 cm·s^{-1} or 0.35 cm·s^{-1}, respectively, for sulphur dioxide, and of 0.4 cm·s^{-1} or 0.1 cm·s^{-1}, respectively, for nitrogen oxides (Dvořáková et al. 1995). For the yearbook presenting an assessment of air pollution since 2019, an updated layer of forested areas in 1 × 1 km grid is prepared on the basis of vector data of forest areas from the SALSC ZABAGED geodatabase (Hůnová et al. 2019b).

By summing the maps of wet and dry deposition of sulphur and nitrogen, maps of total deposition are created.

The map of wet deposition of hydrogen ions is created on the basis of measured pH values in precipitation. The map of dry deposition of hydrogen ions corresponds to the deposition of SO_2 and NO_x gases on the basis of stoichiometry, assuming their acidic reaction in the environment. The map of total hydrogen ion deposition is created by the sum of wet and dry deposition maps.

The fields of dry deposition of lead and cadmium contained in aerosol are prepared from the concentration fields of these metals in the air (or on the basis of pollution value fields for the annual average PM_{10} concentrations and the values of the IDW interpolation of the fraction of individual metals in dust). For the deposition rate of cadmium contained in aerosol, values of 0.27 cm·s^{-1} for forests and 0.1 cm·s^{-1} for treeless terrain are used, and for lead 0.25 cm·s^{-1} for forests and 0.08 cm·s^{-1} for treeless terrain are used (Dvořáková et al. 1995).

2.2.2.1 Throughfall deposition of sulphur

The map of the throughfall deposition of sulphur is created for places with vegetation based on the field of sulphur concentrations in throughfall precipitation and from the verified precipitation field modified in percentage by the amount of precipitation measured under vegetation at individual stations (this value is usually in the range of 50-90% of the precipitation total in the open area). Throughfall deposition generally includes wet vertical and horizontal deposition (from fog, low clouds and rime) and dry deposition of particles and gases. For sulphur, for which the internal cycle in vegetation is negligible, it should be a good estimate of the total deposition.

In some mountain areas of the country, the long-term throughfall deposition values are higher than the values of total sulphur deposition determined as the sum of wet (only vertical) and dry deposition from SO_2. This increase can be attributed to deposition contributions from fog, low clouds and rime (horizontal deposition), which are not included in the total deposition because of their uncertainty. Rime and fog are usually very concentrated, and in mountain areas and areas with a frequent occurrence of fogs (valley fogs, fogs close to water courses and lakes) can contribute substantially to the deposition of sulphur and other elements. The locally highly variable character of this deposition is also a problem, as extrapolation over a larger area can lead to inaccuracies. For mountain areas, sulphate deposition from fog and rime is considered to correspond to 50–90% of the bulk deposition on average over a longer period lasting several years (Tesař et al. 2000; Tesař et al. 2005). In some independently evaluated years, the ratio sulphates from fog and rime deposition compared to bulk deposition even exceeded 100%.

Throughfall deposition further includes a contribution of the dry deposition of S from SO_4^{2-} contained in particulate aerosols. As an example, the year 2014 is given here, when, based on the data on sulphate concentrations in aerosol from two stations (Churáňov and Košetice) and applying a deposition rate of 0.25 $cm \cdot s^{-1}$ (Dvořáková et al. 1995), the dry deposition of S from SO_4^{2-} attained an average value of 0.04 $g \cdot m^{-2}$ per year for forested areas (Churáňov = 0.026 $g \cdot m^{-2}$ per year, Košetice = 0.058 $g \cdot m^{-2}$ per year). Because of the limited number of locations where sulphate concentrations in aerosol are monitored, this is only a very rough estimate.

The map of throughfall deposition can be considered illustrative of values that total sulphur deposition (including horizontal deposition and dry deposition of S from SO_4^{2-} in particulate aerosol) can attain, because unlike other pollutants, internal circulation of sulphur in vegetation is negligible (Draaijers et al. 1997).

For the graphic yearbooks during the 2008-2018 period, throughfall deposition was calculated using the forested areas layer of the SALSC ZABAGED database with a finer grid (500x500 m), where the total forest area is 26,428 km^2. For this reason, total throughfall deposition values since 2001 were recalculated with this forest layer in order to be comparable with data after 2007. For the yearbook presenting the air pollution assessment since 2019, an updated layer of forested areas in the 1x1 km grid was prepared based on vector data of forest areas from the SALSC ZABAGED geodatabase (Hůnová et al. 2019b).

3 Glossary of terminology

Air quality
Air quality is characterised by the concentrations of harmful substances in the ambient air. The pollutant contained in the air comes into contact with a recipient (human, plant, animal, material) and produces a negative effect. Air pollution occurs after the physical-chemical conversion of emissions released into the air.

Atmospheric deposition
The flux of substances from the atmosphere to the Earth's surface. This is an important process contributing to self-cleaning of the air; on the other hand, it is responsible for the input of pollutants into other components of the environment.

Boundary layer
The boundary layer refers to the part of the atmosphere adjacent to the Earth's surface in which mechanical and thermal turbulence develops as a result of interactions with the Earth's surface, and in which there is an intense vertical transfer of momentum, heat, water vapour and polluting substances.

“Bulk” sampling
Sampling of precipitation collecting, in addition to “wet-only“ precipitation, an undefined part of the dry deposition in continuously exposed containers, usually for a period of a week or a month.

Chemical transport model
Method for estimating concentrations in an area based on emissions and meteorological inputs, taking into account the physical and chemical properties of individual substances and their transport in the atmosphere.

Emissions
The release of pollutants or greenhouse gases into the air and atmosphere.

F-gases
Fluorinated greenhouse gases; hydrocarbons whose molecule contains a fluorine atom.

Greenhouse gas
A gas that contributes to the Earth's greenhouse effect.

IDW
A simple method of interpolation, where the weight of individual measuring stations is a measure corresponding to the inverse of the distance to the point of interest.

Interpolation
An estimation of a quantity (e.g. air pollution concentration) in an area on the basis of known values of this quantity at a limited number of points (e.g. measuring localities).

Kriging

An interpolation method using spatial correlation to determine the weight of individual measuring stations.

Linear regression model

A method of estimating one quantity on the basis of other quantities using their statistical interrelationships.

Mixing layer

Mixing layer means the layer of air between the Earth's surface and the lower boundary of the lowest holding temperature layer.

“Throughfall” sampling

The sampling of precipitation under the tree canopy (below-canopy deposition) performed in a forested area in regularly or irregularly placed continuously exposed sampling containers for a period of usually one month. This sampling is considered to be the best estimate of the total exposure.

“Wet-only” sampling

The collection of net precipitation using an automatic sampler exposed only for the duration of the precipitation episode.

Resuspension

The resuspension of particles (also secondary dusting), i.e. particles originally deposited that are subsequently re-released by swirling into the air by wind or by the effect of turbulent flow caused by a passing vehicle.

4 List of abbreviations

AIM	Automated Air Quality Monitoring
AQI	Air Quality Index
AQIS	Air Quality Information System
ATEM	Studio of Ecological Models
CAMx	Comprehensive Air Quality Model with Extensions
CDV	Transport Research Centre
CFC	Chlorofluorocarbon
CGS	Czech Geological Survey
CLI	Central Laboratories of Ambient Air Quality Monitoring
CR	Czech Republic
CRF	Common Reporting Format
CSO	Czech Statistical Office
DMÚ	digital terrain model
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
GIS	Geographic Information System
HBÚ AV ČR	Institute of Hydrobiology of the Academy of Sciences of the CR
HFC	hydrofluorocarbons
CHMI	Czech Hydrometeorological Institute
IDW	Inverse Distance Weighing
IIR	Report on the implementation of emission inventories
IPCC	Intergovernmental Panel on Climate Change
ISPOP	System of the Fulfilling Reporting Obligations
KP	Kyoto Protocol
LRTAP	Convention on Long-range Transboundary Air Pollution
MIM	Manual Air Quality Monitoring
MOE	Ministry of Environment
NAQMN	National Air Quality Monitoring Network
NFR	Nomenclature for Reporting Codes
NIS	National Inventory System

NMVOC	non-methane volatile organic compounds
PCB	polychlorinated biphenyls
PCDD/F	polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans
PFC	perfluorocarbons
POPs	persistent organic pollutants
QA / QC	Quality assurance and quality control
REZZO	Register of Air Pollution Emissions Sources
SALSC	State Administration of Land Surveying and Cadastre
SLDB	Census of persons, houses and apartments
SP	solid pollutants
SPE	summary operating records
SPM	suspended particulate matter
STK	Technical Inspection Station
SVÚOM	National Research Institute for the Protection of Materials
SYMOS	System for Modelling of Stationary Sources
TSP	total suspended particulates
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
ÚVGZ AV ČR	Global Change Research Institute CAS
VOC	volatile organic compounds
VÚLHM	Forest Management and Gamekeeping Research Institute
VÚZT	The Agricultural Technology Research Institute
ZABAGED	Fundamental Base of Geographic Data of the CR
ZSJ	basic settlement unit

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