

2025

AIR QUALITY REPORT OF THE SLOVAK REPUBLIC



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FOREWORD

Dear members of the professional community and the general public, we are pleased to present the Air Quality Report for 2025.

Air is a fundamental component of the environment, and its quality is one of the key factors affecting both human health and the condition of ecosystems. It is a complex and dynamic system in which the effects of natural processes continuously interact with the consequences of human activity. Its composition varies over time and across locations, influenced not only by the amount of emitted pollutants but also, to a significant extent, by the meteorological and geographical characteristics of a given area.

Air pollution arises from a variety of sources. In Slovakia, the main anthropogenic sources include road transport, residential heating, the energy sector, and industry. Natural processes also play an important role, including windblown dust, pollen seasons, wildfires, and the long-range transport of particles, such as Saharan dust, which can temporarily affect air quality thousands of kilometres from its source. The combination of these influences makes air quality highly variable both spatially and temporally.

Air quality assessment is based on measuring the concentrations of selected air pollutants. The most significant include particulate matter (PM₁₀ and PM_{2.5}), nitrogen oxides, ground-level ozone, and benzo(a)pyrene. Monitoring these pollutants is essential because it enables the assessment of air quality and its impacts on human health and the environment. In the event of a significant increase in pollutant concentrations, it also allows for timely warnings to affected populations. Furthermore, monitoring provides important information for identifying pollution sources, tracking long-term trends, and evaluating the effectiveness of measures aimed at reducing air pollution. In 2025, a slight improvement in the average concentrations of several air pollutants was observed compared with the previous period. From a long-term perspective, a positive trend can also be seen across all assessed zones.

Meteorological conditions played a significant role throughout the year in contributing to episodes of poorer air quality. In 2025, episodes of long-range transport of Saharan dust were less intense than in the previous year and affected only a limited number of monitoring stations. During the winter period, particularly in February, prolonged temperature inversions were the main cause of temporarily elevated pollutant concentrations, especially in areas with higher emissions resulting from residential heating.

Long-term assessments show that air quality in Slovakia continues to improve, particularly with regard to particulate matter and nitrogen dioxide concentrations. This favourable trend is the result of a combination of legislative measures, technological modernisation, gradual emission reductions in key sectors of the economy, as well as the replacement of residential heating systems and the transition to cleaner heating technologies. Nevertheless, local challenges remain, particularly those associated with emissions from household heating in Banská Bystrica and Košice Regions, heavy traffic in the largest regional cities, and, in Košice agglomeration, the impact of a major industrial source. This industrial facility changed ownership and has announced plans to modernise its production processes. If these planned measures are successfully implemented, further improvements in air quality can be expected in the region.

In some regions, improving air quality remains a long-term challenge. This is due not only to specific geographical and meteorological conditions that limit the dispersion of air pollutants, but also to the socio-economic circumstances of part of the population, particularly low-income households, which make the transition to more modern and environmentally friendly heating systems more difficult.

The assessment also reflects the requirements of the new European Ambient Air Quality Directive, which introduces stricter limit values for several air pollutants after 2030 and aims to align them more closely with the recommendations of the World Health Organization (WHO). As part of this assessment, evaluations of compliance with the future limit values were carried out to better estimate preparedness for the forthcoming legislative changes. The results indicate that, although air quality is gradually improving, achieving the new limit values in some locations will require additional targeted measures to further reduce emissions.

Emissions and Air Quality Division



SUMMARY FOR THE GENERAL PUBLIC

■ Monitoring Air Quality

Air quality depends on a combination of several factors – local emissions, meteorological conditions, and the long-range transport of pollutants. For an objective assessment of air quality, it is essential not only to carry out systematic measurements of pollutant concentrations but also to use modelling simulations, which help provide additional information on the spatial distribution of pollutant concentrations in areas where direct measurements are not available.

Emissions released into the atmosphere from various sources disperse and can be transported by wind over long distances. During this transport, they undergo chemical transformations and, under the influence of gravity, gradually settle onto the Earth's surface or vegetation.

Precipitation, such as rain or snow, represents an effective mechanism for removing pollutants from the atmosphere. During precipitation, a process known as wet deposition occurs, whereby emissions are captured by water droplets and subsequently transferred to the Earth's surface. This process significantly contributes to reducing the concentrations of certain pollutants in the atmosphere.

At monitoring stations, concentrations of pollutants are recorded to characterise air quality in a given location. Measurements of pollutant concentrations in ambient air are carried out by the Slovak Hydrometeorological Institute at stations belonging to the National Air Quality Monitoring Network (NMSKO). [Fig. 1](#) shows the three basic types of automatic monitoring stations (AMS):

- *Urban traffic station,*
- *Urban background station,*
- *Rural (regional) background station.*

At several AMS stations, in addition to air quality, the chemical composition of atmospheric precipitation is also monitored. In areas where monitoring stations are not available, mathematical modelling is used to determine pollutant concentrations in the atmosphere.



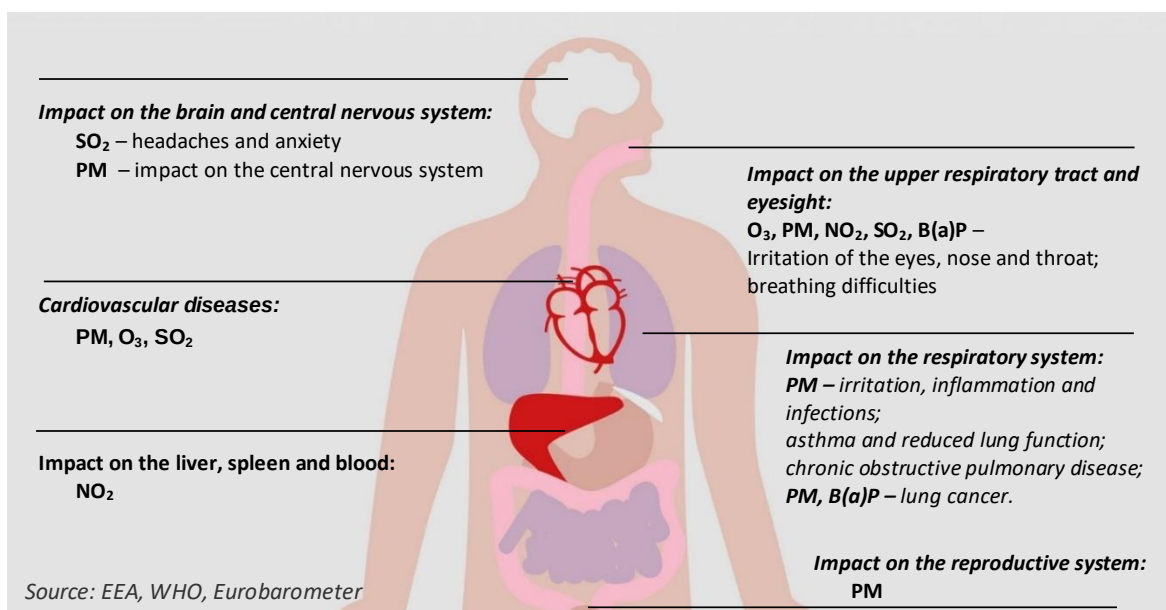
Fig. 1 Main types of automatic monitoring stations of the National Air Quality Monitoring Network.



The monitored pollutants, whose measurement is required by legislation, have proven adverse effects on human health and vegetation. In addition, chemical substances present in the atmosphere can participate in reactions that produce further compounds, which are often more toxic. For this reason, regular measurement of their concentrations in ambient air is essential.

Air pollution does not affect everyone equally – the most vulnerable groups include older people, individuals with chronic illnesses, pregnant women, and young children (Fig. 2).

Fig. 2 Impacts of air pollution on human health.



Another important objective of air quality monitoring and modelling is to improve our understanding of the processes taking place in the atmosphere. These are influenced by the characteristics of pollution sources (e.g. stack heights), the properties of emissions (such as their temperature and exit velocity), as well as meteorological conditions (wind, precipitation and temperature stratification) and the characteristics of the surrounding terrain.

Slovak legislation, European Union legislation and the guidelines of the World Health Organization (WHO) establish limit values, target values and guideline values for concentrations of air pollutants in ambient air, with the aim of protecting human health from the long-term effects of air pollution. Brief characteristics of the main air pollutants:

PM₁₀, PM_{2,5}	consists of tiny solid particles and liquid droplets with an aerodynamic diameter of less than 10 µm and 2.5 µm, respectively. The abbreviation PM stands for <i>particulate matter</i> and includes both solid and liquid particles. PM _{2,5} represents the fine particle fraction. Airborne PM forms part of the atmospheric aerosol.
<i>Health effects</i>	The smaller the particles, the deeper they can penetrate into the respiratory system. Their health effects depend not only on particle size but also on their chemical composition. Long-term exposure may have adverse effects on both the respiratory and cardiovascular systems.
<i>Main sources</i>	PM ₁₀ and PM _{2,5} originate from a variety of natural sources (e.g. soil dust) as well as anthropogenic sources resulting from human activities, including road transport, industry and residential heating. In Slovakia, the most significant source of particulate matter is residential heating using solid fuels, which substantially deteriorates air quality, particularly during the winter months. The problem is further exacerbated by unfavourable atmospheric dispersion conditions, especially temperature inversions in mountainous and basin areas, which inhibit the dispersion of pollutants and cause them to accumulate near ground level.
Benzo(a)pyrene [B(a)P]	belongs to the group of polycyclic aromatic hydrocarbons (PAHs). It is formed during incomplete combustion and is associated with the fine fraction of atmospheric aerosol. Tobacco smoking is also a significant source of human exposure.
<i>Health effects</i>	Benzo(a)pyrene has carcinogenic and mutagenic effects.
<i>Main sources</i>	The most significant source of B(a)P emissions in Slovakia is residential heating using solid fuels (see PM), followed by road transport. Among large industrial sources, coke production is a major contributor to benzo(a)pyrene emissions.
Ozone (O₃)	is a triatomic molecule consisting of three oxygen atoms. While stratospheric ozone plays an important role in protecting against harmful ultraviolet radiation from the Sun, tropospheric (ground-level) ozone has adverse effects on human health, vegetation and buildings, and is therefore classified as an air pollutant.
<i>Health effects</i>	It can cause eye irritation and breathing difficulties. Long-term exposure may lead to inflammatory diseases of the respiratory tract and, at high concentrations, can contribute to the development of chronic obstructive pulmonary disease.
<i>Main sources</i>	Ozone in the atmosphere is formed through photochemical reactions involving precursor substances, including nitrogen oxides, carbon monoxide (CO) and volatile organic compounds (VOCs). Transport from higher layers of the atmosphere is particularly significant at higher mountain elevations.

Heavy metals	The definition of this group is based on the density of the substance and its effects on living organisms; therefore, arsenic is also included. In ambient air, concentrations of lead, cadmium, nickel, arsenic and mercury are monitored. Heavy metals are mainly present in the fine fraction of atmospheric aerosol.
<i>Health effects</i>	The most significant pathway by which heavy metals enter the human body is through food intake, while inhalation represents a less frequent but relevant form of exposure. They have the ability to bioaccumulate – that is, to accumulate in the human body. Long-term exposure to these substances can lead to serious chronic health disorders, such as: Neurotoxic effects: especially lead, which damages the nervous system, with the most severe effects occurring in children; Nephrotoxic effects: mercury, cadmium and lead can negatively affect kidney function; Carcinogenicity: nickel, cadmium and arsenic are classified as proven carcinogens; Respiratory damage: arsenic is associated with inflammatory changes in the respiratory tract and chronic lung diseases.
<i>Main sources</i>	Metallurgy, to a lesser extent the energy sector and coal-fired residential heating.
Benzene (C ₆ H ₆)	Belongs to the group of volatile organic compounds. Under normal conditions, it is in a liquid state, does not mix with water and has a characteristic odour.
<i>Health effects</i>	Benzene is a carcinogenic substance.
<i>Main sources</i>	Road transport, petrochemical industry.
Sulphur dioxide (SO ₂)	It is a colourless reactive gas with a strong irritating odour at higher concentrations.
<i>Health effects</i>	It has an irritating effect on the respiratory tract and the conjunctiva of the eyes; long-term exposure may cause respiratory diseases, particularly in children.
<i>Main sources</i>	Combustion processes in industry and the energy sector, or residential heating using coal with a high sulphur content.
Nitrogen oxides (NO _x)	In the context of air quality, the term nitrogen oxides refers collectively to nitrogen dioxide (NO ₂) and nitric oxide (NO). NO ₂ is a yellowish-brown toxic gas, while NO is a reactive gas that rapidly oxidises to NO ₂ . Nitrogen oxides, carbon monoxide and volatile organic compounds participate in reactions that affect ground-level ozone concentrations and are therefore referred to as O₃ precursors .
<i>Health effects</i>	Exposure to nitrogen oxides (NO _x), particularly nitrogen dioxide (NO ₂), can irritate the respiratory tract and contribute to respiratory symptoms. Long-term exposure to NO ₂ may contribute to inflammation of the respiratory tract, impaired lung function and an increased risk of respiratory diseases and infections.
<i>Main sources</i>	Road transport, combustion processes in industry and the energy sector.
Carbon monoxide (CO)	It is a colourless, odourless, toxic gas that is produced during incomplete or inefficient combustion.
<i>Health effects</i>	It prevents oxygen from being transported in the blood. Chronic effects – long-term exposure may cause tissue damage; people suffering from cardiovascular diseases are particularly at risk.
<i>Main sources</i>	Road transport and combustion processes in industry and the energy sector.

DESCRIPTION OF THE TERRITORY OF THE SR WITH REGARD TO AIR QUALITY

Pollutants have different physical and chemical properties and are released into the atmosphere from natural sources or as a result of human activities. Air quality (AQ) depends on several factors:

- the amount of emissions,
- the spatial distribution of air pollution sources,
- meteorological conditions,
- the characteristics of the surrounding terrain.

Processes affecting the behaviour of pollutants in the atmosphere include transport in the horizontal direction (advection) and vertical direction (convection), chemical reactions (for example, the oxidation of NO to NO₂ or the formation of ozone), phase changes (e.g. condensation during the cooling of hot flue gases released from chimneys), and dry, wet and occult deposition. Dry deposition represents the capture of pollutants on the Earth's surface or vegetation. Wet deposition is the removal of pollutants dispersed in the atmosphere by precipitation. Precipitation is highly effective in reducing atmospheric pollution and enables the transfer of pollutants into other environmental compartments – water, soil and sediments. Occult deposition is the capture of fog (or cloud) droplets on various surfaces, particularly on vegetation. It plays a more significant role in forest areas and mountainous regions.

The complexity of terrain affects the speed and direction of air flow and is one of the characteristics determining the conditions for pollutant dispersion, which are unfavourable in Slovakia particularly in enclosed mountain basins. Frequent temperature inversions in these areas hinder the dispersion of pollutants in the atmosphere and are one of the reasons for the occurrence of high pollutant concentrations during the winter period. Potential long-range transport of pollutants also depends on wind conditions, as some pollutants can remain in the atmosphere for several days. The following text provides a brief description of the territory of the Slovak Republic in terms of terrain characteristics and meteorological parameters that have the greatest influence on air quality.

■ Wind conditions

The direction of air flow in Central Europe is mainly influenced by general atmospheric circulation and the landscape relief. In Slovakia, westerly and north-westerly air flow prevails; however, this does not apply in some locations, particularly in mountain passes, valleys and basins, due to the influence of terrain. In the Záhorie region, southeasterly winds prevail over north-westerly winds, while the opposite is true in the Danubian Lowland. Northerly air flow dominates in the central Váh region, the Nitra region and eastern Slovakia.

In the lowlands of western Slovakia, the average annual wind speed at a height of 10 metres above the surface ranges from 3 to 4 m·s⁻¹, while in eastern Slovakia it ranges from 2 to 3 m·s⁻¹.

Well-ventilated areas may be characterised by lower concentrations of pollutants, despite the presence of nearby air pollution sources.

In basins, wind conditions depend on their position and openness to the prevailing air flow. The average annual wind speed in more open basins (e.g. the Váh Valley, the Podtatra Basin and the Košice Basin) ranges from 2 to 3 m·s⁻¹. In more enclosed basins, where temperature inversions also occur most frequently (e.g. the Zvolen Basin, the Žiar Basin and the Žilina Basin), it ranges from 1 to 2 m·s⁻¹. In enclosed basins (e.g. the Brezno Basin, the Rožňava Basin and the western part of the Liptov Basin – in

the Ružomberok area), calm conditions occur more frequently and average wind speeds are often even lower.

In mountain areas, the average annual wind speed reaches 4 to 8 m·s⁻¹. Even at lower elevations, there are locations (Košice, Bratislava) with higher annual average wind speeds exceeding 4 m·s⁻¹, with Bratislava being among the windiest cities in Central Europe.

■ Atmospheric precipitation

The amount of precipitation in Slovakia generally increases with altitude by approximately 50–60 mm per 100 m of elevation. The annual precipitation total ranges from around 500 mm (the eastern part of Žitný ostrov, the areas of Galanta and Senec) to 2,000 mm (the High Tatras).

Relatively low precipitation totals occur in the so-called rain shadow of mountain ranges. This applies, for example, to the Spiš basins, which are relatively dry and protected from the southwest to northwest by the High and Low Tatras and from the south by the Slovak Ore Mountains.

The highest amounts of precipitation occur from June to August (40% – with June or July being the wettest months), while spring accounts for 25%, autumn for 20% and winter for 15% of annual precipitation. The lowest precipitation totals occur from January to March.

The high variability of precipitation throughout the year causes frequent and sometimes prolonged periods of drought, especially in lowland areas, creating conditions for increased erosion of soil not covered by vegetation. Among the driest regions is the Danubian Lowland, which is the warmest and relatively windiest area of Slovakia.

1.1 Division of the territory into agglomerations and zones

Air pollution sources are unevenly distributed across the country. For the effective assessment of air quality, the territory of Slovakia is divided into zones and agglomerations in accordance with Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe, as well as Slovak legislation (Decree of the Ministry of the Environment of the Slovak Republic No. 250/2023 Coll. on air quality).

The division of the territory into zones and agglomerations is published in Annex No. 11 to the Decree of the Ministry of the Environment of the Slovak Republic No. 250/2023 Coll. on air quality and is available on the *website* of the Slovak Hydrometeorological Institute (SHMÚ).

1.1.1 Division of the territory into zones and agglomerations for SO₂, NO₂, NO_x, PM₁₀, PM_{2,5}, benzene, polycyclic aromatic hydrocarbons and CO

For the purpose of monitoring and regulating air quality, Slovakia is divided into zones and agglomerations. Zones generally correspond to individual regions, while a separate category consists of cities with populations exceeding 250,000 inhabitants, which are defined as agglomerations. In Slovakia, this criterion is met by Bratislava and Košice.

Agglomerations:

- Agglomeration Bratislava – the territory of the capital city of the Slovak Republic, Bratislava,
- Agglomeration Košice – the territory of the city of Košice and the municipalities of Bočiar, Haniska, Sokoľany and Veľká Ida.

Zones:

- Banská Bystrica region
- Bratislava region¹
- Košice region²
- Nitra region
- Prešov region
- Trenčín region
- Trnava region
- Žilina region

Detailed information on the zones and agglomerations is provided in the Appendices to this Report.

Tab. 1.1 contains information on the area and population of individual regions based on data available on the *website* of the Statistical Office of the Slovak Republic (SO SR).

Tab. 1.1 *Area and population of individual regions of the Slovak Republic*

	Area [km ²]	Population*
Bratislava region	2 053	739 635
Trnava region	4 146	565 462
Trenčín region	4 502	562 536
Nitra region	6 344	661 995
Žilina region	6 809	684 190
Banská Bystrica region	9 454	607 581
Prešov region	8 973	810 075
Košice region	6 754	777 933

* Status as of 31. 12. 2025

Source: Statistical Office of SR

1.1.2 Division of the territory into zones and agglomerations for lead, arsenic, cadmium, nickel, mercury and ozone

The territory of the Slovak Republic is divided into two zones for lead, arsenic, cadmium, nickel, mercury and ozone:

Agglomeration: Agglomeration Bratislava

Zone: Slovakia

The reason is the nature of these pollutants and the results of long-term air quality assessment.

Concentrations of lead, arsenic, cadmium, nickel and mercury in Slovakia have remained below limit values or target values for a long time, and there are no extensive areas with deteriorated air quality.

The occurrence of tropospheric ozone is predominantly regional in character. Its concentrations are significantly influenced by transboundary transport, photochemical formation from precursors emitted over long distances, and natural sources of volatile organic compounds.

Although the ozone target value for the protection of human health is exceeded, this is not a problem associated with specific urban or industrial areas, but rather a regional phenomenon affecting large areas. For this reason, a more detailed division of the territory into multiple zones is not applied for ozone.

¹ Does not include the territory of Bratislava

² Does not include the territory of agglomeration Košice



AIR QUALITY MONITORING NETWORK

The monitoring of air pollutants in Slovakia dates back to the second half of the 1950s. Systematic monitoring began in 1967, when the first air protection legislation came into force (Act No. 35/1967 Coll. on measures against air pollution). Measurements, which initially included only SO₂ and dust deposition in Bratislava, Košice and the surrounding areas, were gradually expanded to include additional pollutants and locations. Over time, legislation has changed – the range of monitored pollutants has been extended and limit values have been tightened. An example of such an adjustment is the reduction of the limit value for the annual average concentration of PM_{2,5}, which was lowered to 20 µg·m⁻³ from 2020 onwards (from the original 25 µg·m⁻³). The current form of air quality legislation in Slovakia represents the implementation of EU legislation.

On 23 October 2024, Directive (EU) 2024/2881 of the European Parliament and of the Council on ambient air quality and cleaner air for Europe was adopted, setting ambitious objectives for 2030. This legislation replaced Directives 2004/107/EC and 2008/50/EC.

The aim of air quality monitoring is to assess the level of air pollution and population exposure. Monitoring stations are located to represent areas influenced by major emission sources, urban background environments, as well as regional background conditions. Regional background stations enable the monitoring of long-range transport of pollutants and long-term air quality trends.

Pollutants can remain in the atmosphere for several days. Their persistence depends on various properties, such as sedimentation rate and chemical reactivity. Due to air circulation, these substances can be transported over considerable distances, a process known as long-range transport. As a result, even seemingly clean mountain areas can be affected by high concentrations of pollutants.

The monitoring station network – the **National Air Quality Monitoring Network (NMSKO)** – began to be established in the former Czechoslovakia in 1991. Currently, it includes continuous measurements using automatic instruments and manual sampling, with samples analysed in the SHMÚ Testing Laboratory and other external laboratories. Precipitation quality is monitored at regional AMS stations within the EMEP monitoring programme.

A detailed list of monitoring instruments and methods is provided in “**Annex A – National Air Quality Monitoring Network, List of Stations – 2025.**”

In 1979, the **UNECE Convention on Long-range Transboundary Air Pollution** (hereinafter referred to as the Convention) was signed in Geneva. To date, eight protocols have been adopted under the Convention. The first of these was the **Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)** (Geneva, 1984).

The aim of EMEP is to monitor, model and assess the long-range transport of pollutants in Europe and to provide a basis for emission reduction strategies at the international level. The EMEP monitoring network currently includes approximately 180 regional stations, including four Slovak EMEP stations, which are part of NMSKO. The first EMEP station in Slovakia was established at Chopok near the SHMÚ meteorological observatory at an altitude of 2,008 m. Air quality measurements at this site began as early as 1977.

The monitoring programme of the EMEP network has been gradually expanded at the stations. Measurements of sulphur compounds and precipitation analyses were supplemented by nitrogen oxides, nitrates, ammonium ions in the air, particulate matter, ozone and volatile organic compounds. Later, measurements of heavy metals and, from autumn 2020, organic and elemental carbon (EC/OC) in ambient air were also incorporated into the programme.

The monitoring programme of air quality stations within the NMSKO network is presented in Table 2.1. The table contains information on air quality monitoring stations belonging to NMSKO according to agglomerations and zones:

- **the characteristics of the station according to the dominant sources of air pollution** (traffic, background, industrial), the type of area monitored by the station (urban, suburban, rural/regional), and geographical coordinates;
- **the monitoring programme.** Automatic continuous monitoring instruments provide hourly average concentrations of PM₁₀, PM_{2,5}, nitrogen oxides, sulphur dioxide, ozone, carbon monoxide, benzene and mercury. The SHMÚ Testing Laboratory analyses heavy metals and polycyclic aromatic hydrocarbons as part of manual monitoring, with results provided as 24-hour average values. The exception are EMEP stations, for which the monitoring programme is described in [Tab. 2.2](#) and [Tab. 2.3](#)



Tab. 2.1 National Air Quality Monitoring Network (NMSKO).

AGGLOMERATION zone	Monitoring station	Type		Continuous							Manual	
		area types	stations	PM ₁₀	PM _{2,5}	Nitrogen oxide NO, NO ₂ , NO _x	Sulphur dioxide, SO ₂	Ozone, O ₃	Carbon monoxide CO	Mercury	Heavy metals As, Cd, Ni, Pb	Polycyclic aromatic hydrocarbons (PAHs) – B(a)P
BRATISLAVA	Bratislava, Kamenné nám	U	B	x	x							
	Bratislava, Trnavské mýto	U	T	x	x	x			x		x	x
	Bratislava, Jeséniova	S	B	x	x	x	x	x			x	x
	Bratislava, Mamateyova	U	B	x	x	x	x	x				
	Bratislava, Púchovská	U	T	x	x	x	x		x			x
	In total: 5 stations			5	5	4	3	2	2		2	3
KOŠICE	Košice, Amurská	U	B	x	x							
	Košice, Štefánikova	U	T	x	x	x	x		x			
	Košice, Ďumbierska	S	B					x				
	Veľká Ida, Letná	S	I	x	x				x		x	x
	In total: 4 stations			3	3	1	1	1	2		1	1
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	U	T	x	x	x	x		x		x	x
	Banská Bystrica, Zelená	U	B	x	x	x		x				x
	Jelšava, Jesenského	U	B	x	x	x		x			x	x
	Hnúšťa, Hlavná	U	B	x	x							
	Lučenec, Gemerská cesta	U	T	x	x	x		x	x			
	Žiar nad Hronom, Jilemnického	U	B	x	x							
	Žarnovica, Dolná	S	B	x	x	x						x
	Zvolen, J. Alexyho	U	B	x	x							
	In total: 8 stations			8	8	5	1	3	2		2	4
Bratislava region	Pezinok, Obrancov mieru	U	B	x	x	x		x				
	Rovinka	S	B									x
	Rohožník, Senická	S	T	x	x	x	x		x			
	Senec, Boldocká	U	T	x	x	x		x	x			
	In total: 4 stations			3	3	3	1	2	2		0	1
Košice region	Kojšovská hoľa	R	B			x		x				
	Trebišov, T. G. Masaryka	S	B	x	x	x		x				
	Strážske, Mierová	U	B	x	x							
	Krompachy, SNP	U	T	x	x	x	x		x			x
	In total: 4 stations			3	3	3	1	2	1		0	1
Nitra region	Nitra, Štúrova	U	T	x	x	x	x		x			x
	Nitra, Janíkovce	S	B	x	x	x		x				
	Komárno, Vnútoraná Okružná	U	B	x	x	x		x				
	Plášťovce	S	B	x	x	x		x				x
	In total: 4 stations			4	4	4	1	3	1		0	2
Prešov region	Humenné, Nám. Slobody	U	B	x	x	x		x				
	Stará Lesná, AÚ SAV, EMEP	R	B	x	x	x		x			x	x
	Gánovce, Meteo. st.	R	B			x		x				
	Poprad, Železničná	S	B	x	x	x						
	Prešov, Arm. gen. L. Svobodu	U	T	x	x	x			x			
	Starina, Vodná nádrž, EMEP	R	B			x		x		x	x	x
	Vranov nad Topľou, M. R. Štefánika	U	B	x	x		x					
	Kolonické sedlo	R	B	x	x							
	Bardejov, Pod Vinbargom	S	B	x	x	x		x				
	In total: 9 stations			7	7	7	1	5	1	1	2	2
Trenčín region	Prievidza, Malonecpalská	U	B	x	x	x	x	x			x	x
	Bystričany, Rozvodňa SSE	S	B	x	x		x					
	Handlová, Morovnianska cesta	U	B	x	x		x					

AGGLOMERATION zone	Monitoring station	Type		Continuous							Manual			
		area types	stations	PM ₁₀	PM _{2,5}	Nitrogen oxide NO, NO ₂ , NO _x	Sulphur dioxide, SO ₂	Ozone, O ₃	Carbon monoxide CO	Mercury	Heavy metals As, Cd, Ni, Pb	Polycyclic aromatic hydrocarbons (PAHs) – B(a)P		
	Trenčín, Hasičská	U	T	x	x	x	x		x					
	Púchov, 1. mája	S	B	x	x	x	x		x		x	x		
	In total: 5 stations			5	5	3	5	1	2		2	2		
Trnava region	Topoľníky, Aszód, EMEP	R	B	x	x	x	x	x		x	x			
	Senica, Hviezdoslavova	U	T	x	x		x							
	Trnava, Kollárova	U	T	x	x	x			x			x		
	Sereď, Vinárska	U	B	x	x	x					x			
	In total: 4 stations			4	4	3	2	1	1	1	2	1		
Žilina region	Chopok, EMEP	R	B			x		x			x			
	Martin, Jesenského	U	T	x	x	x			x			x		
	Ružomberok, Riadok	U	B	x	x	x	x	x	x		x	x		
	Žilina, Obežná	U	B	x	x	x		x	x			x		
	Oščadnica	S	B	x	x	x	x	x				x		
	Liptovský Mikuláš, Školská	U	B	x	x	x	x							
	In total: 6 stations			5	5	6	3	4	3		2	4		
NMSKO In total: 53 monitoring stations*						47	47	39	19	24	17	2	13	21

Area type: U – urban, S – semi urban, R – rural (regional)

Station type: B – background, T – traffic, I – industrial

*Note: The AMS station in Rovinka was out of operation for most of 2025 due to technical reasons. At the AMS in Rovinka, only BaP was measured in 2025.

The air quality monitoring programme at EMEP stations in 2025 (Table 2.2) defines the following sampling intervals:

- **ozone:** measured by a continuous analyser,
- **heavy metals:** every three days in Topoľníky and Stará Lesná, weekly at Starina and Chopok,
- **VOC:** weekly sampling interval,
- **other substances:** 24-hour sampling interval.

Tab. 2.2 EMEP Station Monitoring Programme – Ambient Air.

Monitoring station	Ozone O ₃	Sulphur dioxide SO ₂	Nitrogen oxide NO _x	Sulphates SO ₄ ²⁻	Nitrates NO ₃ ⁻	Nitric acid HNO ₃	Chlorides Cl	Ammonia, ammonium ions NH ₃ , NH ₄ ⁺	Alkali ions K ⁺ , Na ⁺ , Ca ²⁺ , Mg ²⁺	VOC	PM ₁₀ / TSP*	EC/OC	Lead, Pb	Arsenic, As	Cadmium, Cd	Nickel, Ni	Chromium, Cr	Copper, Cu	Zinc, Zn	Mercury, Hg**
Chopok	x	x	x	x	x	x	x				x*		x	x	x	x	x	x	x	
Topoľníky	x										x		x	x	x	x	x	x	x	x
Starina	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Stará Lesná	x										x	x	x	x	x	x	x	x	x	

* TSP – total suspended particles in ambient air

** Mercury is monitored outside the EMEP monitoring programme.

Precipitation quality (pH, conductivity, sulphates, nitrates, chlorides, ammonium ions and alkali metal cations) is analysed from samples collected at EMEP stations according to the monitoring programme presented in Table 2.3.

Sampling intervals for precipitation analysis of heavy metals are monthly, with the exception of the EMEP station Starina, where samples are collected weekly. Two types of precipitation collectors are used for precipitation sampling: “wet-only” and “bulk”.

Tab. 2.3 Precipitation Monitoring Programme at EMEP Stations and at Bratislava, Jeséniova Station.

	pH	Conductivity	Sulphates (SO ₄ ²⁻)	Nitrates (NO ₃ ⁻)	Chlorides (Cl ⁻)	Ammonium ions (NH ₄ ⁺)	Alkali ions (K ⁺ , Na ⁺ , Ca ²⁺)	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
Chopok	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Topoľníky	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Starina	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Stará Lesná	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bratislava, Jeséniova	x	x	x	x	x	x	x	x	x	x	x	x	x	x

2.1 MONITORING STATIONS OF OTHER OPERATORS

Tab. 2.4 Monitoring stations of other operators of large stationary sources of air pollution (VZZO).

Zone	District	Station name*	Type		Geographical		Altitude [m]
			area	station	length	width	
BRATISLAVA	Bratislava II	Bratislava, Vlčie Hrdlo (Slovnaft, a.s.)	S	I	17°10'13"	48°07'41"	134
		Bratislava, Pod. Biskupice (Slovnaft, a.s.)	U	B	17°13'01"	48°07'42"	132
Bratislava region	Senec	Rovinka (Slovnaft, a.s.)	S	B	17°13'34"	48°06'05"	133
Nitra region	Šaľa	Trnovec nad Váhom (Duslo, a.s.)	S	B	17°55'43"	48°08'60"	117
Žilina region	Ružomberok	Ružomberok (Mondi a.s. - Supra)	U	I	19°19'12"	49°04'43"	478
KOŠICE	Košice II	Košice, Haniska (U.S. Steel, s.r.o.)	S	I	21°15'07"	48°36'54"	212
		Košice, Poľov (U.S. Steel, s.r.o.)	R	B	21°11'54"	48°39'40"	271
Košice region	Košice - surroundings	Veľká Ida (U.S. Steel, s.r.o.)	S	I	21°10'12"	48°33'35"	208

* The owner of the station is indicated in parentheses in the station name.

Area type: U – urban, S – semi urban, R – rural (regional)

Station type: B – background, T – traffic, I – industrial



3.1 INTRODUCTION

The assessment of air quality according to the requirements of Section 4 of Act No. 146/2023 Coll. on Air Protection and on Amendments and Supplements to Certain Acts (hereinafter referred to as the Air Protection Act) is carried out by SHMÚ using monitoring and mathematical modelling.

Chapter 3 presents the processed results of air quality monitoring. The assessment of air quality using mathematical modelling is presented in *Chapter 4*.

Chapter 3.3 evaluates the results of air quality measurements at monitoring stations according to limit values and target values for the protection of human health. *Chapter 3.4* presents the results of measurements from monitoring stations with the EMEP programme according to limit values for the protection of vegetation. The EMEP programme also includes the analysis of atmospheric precipitation quality.

3.1.1 Meteorological Conditions – Ventilation Index

Air quality is determined not only by emission sources themselves but also by meteorological conditions, such as dispersion conditions and precipitation.

Dispersion conditions can be assessed using the ventilation index, which is the product of the mixing layer height and the average wind speed within the mixing layer. The mixing layer is the part of the atmosphere where mechanical and thermal air mixing takes place. As the intensity of turbulent mixing increases, the height of the mixing layer also increases. The higher the value of the ventilation index, the better the dispersion conditions.

The ventilation index at locations with monitoring stations in individual regions was calculated from outputs of the ALADIN meteorological model with a spatial resolution of 2×2 km. Ventilation index values vary over time – see the difference between values in February ([Fig. 3.1](#)) – and spatially, depending on orography, built-up areas, and other factors. A simplified version of the CHMI methodology was used for the assessment.

Fig. 3.1 Index as an Indicator of Dispersion Conditions in 2024 and 2025.

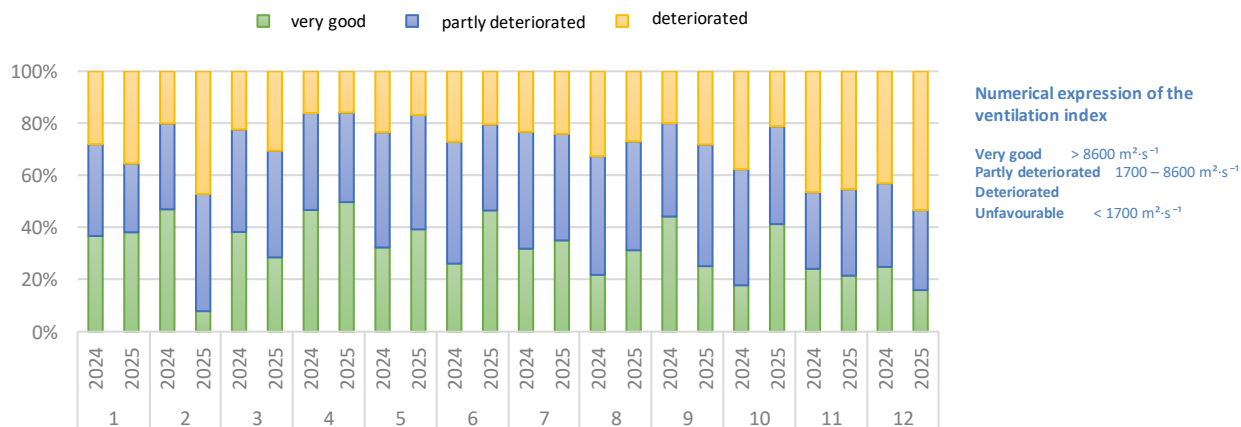
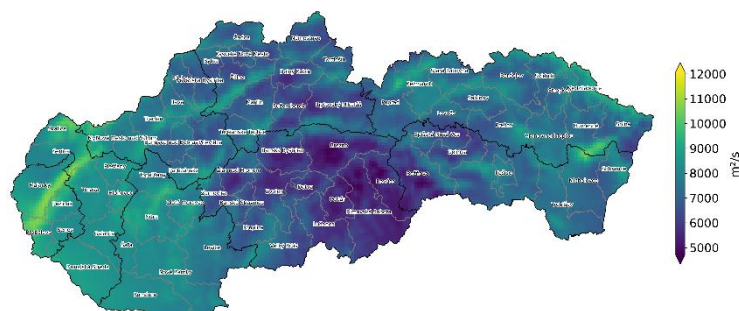


Fig. 3.2 Map of the average ventilation index in 2025.



The map of the ventilation index for 2025 shows significant regional differences in conditions for the dispersion of pollutants.

Very good ventilation conditions occurred mainly in the western part of Slovakia, in the Danubian Lowland, and locally also in mountainous and foothill areas of northern Slovakia. The lowest ventilation index values were recorded in basin areas of central Slovakia, particularly in the

southern part of the Banská Bystrica Region, where conditions favourable for the accumulation of pollutants occur more frequently. In most of Slovakia, the ventilation index fell within the category of **partly deteriorated dispersion conditions**.

3.2 CRITERIA FOR AIR QUALITY ASSESSMENT

Air quality (according to Section 3(4) of the Air Protection Act) is considered good if the level of air pollution is below the limit value, target value and exposure reduction commitment.

Tab. 3.1 presents limit values for the protection of human health and critical levels for the protection of vegetation, as well as upper and lower assessment thresholds for evaluating ambient air pollution levels for SO₂, NO₂, NO_x, PM₁₀, PM_{2,5}, Pb, CO and benzene. **Tab. 3.2** presents target values for the protection of human health and vegetation for As, Cd, Ni and benzo(a)pyrene [B(a)P]. The values in **Tab. 3.1** and **Tab. 3.2** are based on Slovak legislation (Annex No. 1 to Decree No. 250/2023 Coll.).

Tab. 3.1 Limit values for the protection of human health and critical levels for the protection of vegetation, upper and lower assessment thresholds for evaluating ambient air pollution levels for pollutants.

Pollutant	Receptor	Averaging period	Limit value* [µg·m ⁻³]		Assessment threshold [µg·m ⁻³]			
					Upper		Lower	
SO ₂	Human health	1h	350	(24)				
		24h	125	(3)	75	(3)	50	(3)
	Vegetation	1y, winter period	20	(-)	12	(-)	8	(-)
NO _x		1y	30	(-)	24	(-)	19,5	(-)
NO ₂	Human health	1h	200	(18)	140	(18)	100	(18)
		1y	40	(-)	32	(-)	26	(-)
O ₃	Human health	8h maximum**	120	(25)				
PM ₁₀		24h	50	(35)	35	(35)	25	(35)
		1y	40	(-)	28	(-)	20	(-)
PM _{2,5}		1y	20		17		12	
CO		8h maximum	10 000	(-)	7 000	(-)	5 000	(-)
Benzene		1y	5	(-)	3,5	(-)	2	(-)
Pb		1y	0,5		0,35	(-)	(-)	

* The permitted number of exceedances is indicated in brackets. ** on average over 3 years

Tab. 3.2 Target values for the protection of human health and vegetation for As, Cd, Ni and B(a)P.

	Assessment threshold [ng·m ⁻³]		Averaging period	Limit value [ng·m ⁻³]
	Upper	Lower		
As	3,6	2,4	Calendar year	6
Cd	3	2		5
Ni	14	10		20
B(a)P	0,4	0,6		1

As part of the **European Green Deal**, the European Union developed the **Zero Pollution Action Plan**, which sets out a vision for 2050. Its aim is to reduce air pollution by that year to a level that is no longer considered harmful to human health and natural ecosystems. The action plan includes new limit and target values for many pollutants.

Tab. 3.3 presents the limit, target and recommended values according to Slovak legislation (2023), the new limit and target values to be achieved by **1 January 2030**, and the **WHO recommendations (2021)**.

Tab. 3.3 Comparison of limit values, target values and WHO recommendations.

Pollutant	Averaging period	Limit value 250/2023 ^{a)}		New limit value as of 1. January 2030 ^{b)}		WHO recommendations (2021) ^{c)}	
		Concentration [µg·m ⁻³]	permitted number of exceedances per year	Concentration [µg·m ⁻³]	permitted number of exceedances per year	Concentration [µg·m ⁻³]	permitted number of exceedances per year
PM _{2,5}	24 h	-	-	25	(18)	15	(3–4)
	Calendar year	20	-	10	-	5	-
PM ₁₀	24 h	50	(35)	45	(18)	45	(3–4)
	Calendar year	40	-	20	-	15 ³	-
O ₃	Maximum daily 8-hour mean value	120	(25)*	120	(18)*	100	(3–4)
NO ₂	1 h	200	(18)	200	(3)	-	-
	24 h	-	-	50	(18)	25	(3–4)
	Calendar year	40	-	20	-	10	-
SO ₂	1 h	350	(24)	350	(3)	-	-
	24 h	125	(3)	50	(18)	40	(3–4)
	Calendar year	-	-	20	-	-	-
CO	Maximum daily 8-hour mean value	10 mg·m ⁻³	-	10 mg·m ⁻³	-	-	-
	24 h	-	-	4 mg·m ⁻³	(18)	4 mg·m ⁻³	(3–4)

^{a)} Decree n. 250/2023 Z. z.: <https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2023/250/20230701>

^{b)} https://eur-lex.europa.eu/resource.html?uri=cellar:2ae4a0cc-55f8-11ed-92ed-01aa75ed71a1.0009.02/DOC_2&format=PDF

^{c)} <https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines>

* Averaged over three years for the calendar year.

3.3 Air quality monitoring results: local air pollution

Tab. 3.4 Percentage of valid data in the National Air Quality Monitoring Network (NMSKO).

Zone	Pollutant	SO ₂	NO ₂	PM ₁₀	PM _{2,5}	CO	O ₃
BRATISLAVA	Bratislava, Kamenné nám.			99	99		
	Bratislava, Trnavské Mýto		96	98	98	95	
	Bratislava, Jeséniova	94	94	99	98		96
	Bratislava, Mamateyova	87	95	98	98		95
	Bratislava, Púchovská	95	96	99	99	96	
Bratislava region	Pezinok, Obrancov mieru		95	97	98		95
	Rohožník, Senická cesta	92	96	99	99	95	
	Senec, Boldocká		82	99	99	95	96
Trnava region	Senica, Hviezdoslavova	77		98	99		
	Trnava, Kollárova		95	99	99	96	
	Topoľníky, Aszód, EMEP	94	93	99	99		95
	Sereď, Vinárska		90	99	99		
Nitra region	Nitra, Janíkovce		96	99	99		91
	Nitra, Štúrova	96	92	99	99	98	
	Komárno, Vnúťorná Okružná		91	99	99		96
	Plášťovce		97	99	99		89
Trenčín region	Prievidza, Malonecpalská	53	94	99	99		95
	Bystričany, Rozvodňa SSE	96		98	99		
	Handlová, Morovniarska cesta	89		99	99		
	Púchov, 1.mája	94	92	99	99	96	
	Trenčín, Hasičská	90	93	98	98	95	
Banská Bystrica region	Banská Bystrica, Štefánikovo nám.	94	95	99	99	97	
	Banská Bystrica, Zelená		88	99	99		93
	Jelšava, Jesenského		90	99	99		93
	Hnúšťa, Hlavná			99	99		
	Lučenec, Gemerská cesta		95	98	98	95	94
	Zvolen, J. Alexyho			99	99		
	Žarnovica		96	99	99		
	Žiar nad Hronom, Jilemnického			99	99		
Žilina region	Chopok, EMEP		92				94
	Liptovský Mikuláš, Školská	94	96	98	99		
	Martin, Jesenského		94	99	99	96	
	Oščadnica	96	96	99	99		96
	Ružomberok, Riadok	96	95	100	99	96	96
	Žilina, Obežná		87	99	99	96	88
Prešov region	Gánovce, Meteo. st.		97	99			95
	Humenné, Nám. slobody		95	99	99		95
	Prešov, arm. gen. L. Svobodu		96	99	99	95	
	Vranov nad Topľ., M.R.Štefánika	94		98	98		
	Stará Lesná, AÚ SAV, EMEP		95	100	99		99
	Starina, Vodná nádrž, EMEP		96				94
	Kolonicke sedlo			98	98		
	Poprad, Železničná		93	99	99		
	Bardejov, Pod Vinbargom		90	99	99		97
KOŠICE	Košice, Štefánikova	96	95	99	99	96	
	Košice, Amurská			99	99		
	Košice, Ďumbierska						99
	Veľká Ida, Letná			99	99	97	
Košice region	Kojšovská hoľa		95	99			98
	Trebišov, T. G. Masaryka		99	99	99		98
	Strážske, Mierová			99	99		
	Krompachy, SNP	97	96	99	99	97	

≥ 90% valid measurements; benzene was assessed using mathematical modelling in 2025.

■ Gaseous pollutants, particulate matter PM

Tab. 3.5 Assessment of air pollution according to limit values for the protection of human health.

Agglomeration Zone	Pollutant	SO ₂		NO ₂		PM ₁₀		PM _{2.5}	Benzene	CO	O ₃
	Averaging period	1 h	24 h	1 h	1 year	24 h	1 year	1 year	1 year	8 h ¹⁾	8 h ²⁾
	Parameter	PP	PP	PP	P	PP	P	PP	P	P	P
	Limit value [µg·m ⁻³]	350	125	200	40	50	40	20	5	10 000	120
	Max number of exceedances	24	3	18		35					25
Bratislava	Bratislava, Kamenné nám.					4	18	13			
	Bratislava, Trnavské mýto			0	28	6	20	13	0,4*	731	
	Bratislava, Jeséniova	0	0	0	7	4	17	11			27
	Bratislava, Mamateyova	0	0	0	15	3	17	12			16
	Bratislava, Púchovská	0	0	0	12	5	19	11		657	
Bratislava region	Pezinok, Obrancov mieru			0	8	2	15	13			19
	Rohožník, Senická cesta	0	0	0	10	4	18	11		1476	
	Senec, Boldocká			0	16	5	19	11		1055	5
Trnava region	Senica, Hviezdoslavova	0	0			4	17	12			
	Trnava, Kollárova			0	25	10	20	11	0,6*	1030	
	Topoľníky, Aszód, EMEP	0	0	0	4	6	16	10			3
	Sereď, Vinárska			0	10	3	17	12			
Nitra region	Nitra, Janíkovce			0	9	2	16	12			27
	Nitra, Štúrova	0	0	0	21	5	19	12	0,3*	1104	
	Komárno, Vnúťomá Okružná			0	12	5	18	12			20
	Plášťovce			0	6	37	24	19			10
Trenčín region	Prievidza, Malonecpalská	0	0	0	13	0	15	11			4
	Bystričany, Rozvodňa SSE	0	0			1	19	12			
	Handlová, Morovianska cesta	0	0			2	16	11			
	Púchov, 1.mája	0	0	0	8	3	17	15		1093	
	Trenčín, Hasičská	0	0	0	18	8	21	13	0,6*	875	
Banská Bystrica region	Banská Bystrica, Štefánik. n.	0	0	0	22	19	23	16	0,5*	1498	
	Banská Bystrica, Zelená			0	6	1	14	10			3
	Jeľšava, Jesenského			0	6	39	27	19			3
	Hnúšťa, Hlavná					4	18	13			
	Lučenec, Gemerská cesta			0	12	19	21	17	0,4*	1217	4
	Zvolen, J. Alexyho					3	17	13			
	Žarnovica			0	10	14	22	17			
	Žiar n/H, Jilemnického					2	15	10			
Žilina region	Chopok, EMEP			0	1						41
	Liptovský Mikuláš, Školská	0	0	0	11	3	18	13			
	Martin, Jesenského			0	16	13	22	15	0,5*	1491	
	Oščadnica	0	0	0	7	3	18	15			9
	Ružomberok, Riadok	0	0	0	14	7	20	15	0,8*	1852	0
	Žilina, Obežná			0	16	8	20	15		1358	1
Prešov region	Gánovce, Meteo. st.			0	7						1
	Humenné, Nám. slobody			0	9	5	19	15			2
	Prešov, arm. gen. L. Svobodu			0	31	24	25	17	0,6*	1826	
	Vranov n/T, M. R. Štefánika	0	0			8	18	14			
	Stará Lesná, AÚ SAV, EMEP			0	4	0	9	7			6
	Starina, Vodná nádrž, EMEP			0	3						0
	Kolónické sedlo, Hvezdáreň					0	12	11			
	Poprad, Železničná			0	14	1	16	11			
	Bardejov, Pod Vinbargom			0	9	3	17	13			1

Agglomeration Zone	Pollutant	SO ₂		NO ₂		PM ₁₀		PM _{2.5}	Benzene	CO	O ₃
	Averaging period	1 h	24 h	1 h	1 year	24 h	1 year	1 year	1 year	8 h ¹⁾	8 h ²⁾
	Parameter	PP	PP	PP	P	PP	P	PP	P	P	P
	Limit value [µg·m ⁻³]	350	125	200	40	50	40	20	5	10 000	120
	Max number of exceedances	24	3	18		35					25
KOŠICE	Košice, Štefánikova	0	0	0	20	24	24	15	0,9*	1453	
	Košice, Amurská					13	21	15			
	Košice, Ďumbierska										7
	Veľká Ida, Letná					42	31	20		2011	
Košice region	Kojšovská hoľa			0	2						17
	Trebišov, T. G. Masaryka			0	10	10	20	15			3
	Strážske, Mierová					4	19	14			
	Krompachy, SNP	0	0	0	12	14	22	16	1,1*	1565	

≥ 90% valid measurements ¹⁾ Maximum 8-hour concentration; ²⁾ Number of days with a maximum daily 8-hour mean O₃ concentration above 120 µg/m³, averaged over three years * Benzene was assessed using the CMAQ mathematical model. P – average, PP – number of exceedances. Exceedances of the limit/target value are indicated in red.

The assessment of air pollution according to limit values (LV) for the protection of human health for SO₂, NO₂, PM₁₀, PM_{2,5}, CO and benzene is presented in **Tab. 3.5**.

The limit value for the daily average concentration of PM₁₀ was **exceeded in 2025 at two monitoring stations**:

- **zone Košice region:** Veľká Ida, Letná,
- **zone Banská Bystrica region:** Jelšava, Jesenského.

The AMS Plášťovce station recorded 37 exceedances; after subtracting the PM₁₀ contribution from natural sources, the daily limit value was met (35 exceedances). More information on the deduction of the contribution from natural sources is provided in Annex C.

The limit value for O₃ was also **exceeded in 2025 at three monitoring stations**:

- **agglomeration Bratislava:** Bratislava, Jeséniova,
- **Zone Slovakia:** Nitra, Janíkovce, Chopok.

The limit values for **SO₂, NO₂, CO a benzene were not exceeded at any AMS station in any zone**.

■ Heavy metals

Tab. 3.6 Average yearly concentrations of heavy metals.

Agglomeration Zone	Pollutant	[ng·m ⁻³]	As	Cd	Ni	Pb*
	Target value/ limit value		6.0	5	20	500
BRATISLAVA	Bratislava, Trnavské mýto		0.1	0.1	0.8	2.8
	Bratislava, Jeséniova		0.1	0.1	0.6	1.2
SLOVAKIA	Banská Bystrica, Štefánikovo nábrežie		0.1	0.2	0.6	6.8
	Jelšava, Jesenského		0.1	0.2	0.6	5.0
	Ružomberok, Riadok		0.1	0.1	0.9	2.3
	Veľká Ida, Letná		0.2	0.5	0.4	11.7
	Prievidza, Malonecpalská		0.1	0.1	0.4	1.9
	Sereď, Vinárska		0.1	0.1	0.6	11.3
	Púchov, 1. mája		0.1	0.1	0.6	2.1

Arsenic (As), Cadmium (Cd), Nickel (Ni), Lead (Pb)

Neither the limit value nor the target value for heavy metals was exceeded in any zone in 2025. The annual average concentrations of heavy metals measured at NMSKO stations are only a fraction of their respective target or limit values at all AMS stations.

The highest annual average concentrations of lead were measured at the monitoring stations in Veľká Ida and Sereď.

■ Benzo(a)pyrene

Tab. 3.7 presents the annual average concentrations of benzo(a)pyrene [B(a)P] in ambient air based on measurements from 2019–2025.

Tab. 3.7 Annual average concentrations of benzo(a)pyrene [$\text{ng}\cdot\text{m}^{-3}$] in 2019 – 2025.

Zone	Monitoring station	2019	2020	2021	2022	2023	2024	2025
BRATISLAVA	Bratislava, Jeséniova	0,2	0,2	0,3	0,3	*0,3	0,2	0,2
	Bratislava, Trnavské Mýto	0,4	0,5	0,5	0,5	0,3	0,5	0,3
	Bratislava, Púchovská			0,9	0,4	0,4	0,4	0,3
Bratislava region	Rovinka		0,4	0,6	0,5	0,4	0,5	0,4
Trnava region	Trnava, Kollárova	0,7	0,5	0,6	0,5	0,5	0,6	0,5
Nitra region	Nitra, Štúrova	0,8	0,6	0,8	0,6	0,5	0,5	0,5
	Plášťovce			2,2	2,4	2,6	*2,2	*1,9
Trenčín region	Prievidza, Malonecpalská	1,4	1,2	1,1	0,9	1,1	0,9	0,9
	Púchov, 1. mája			4,7	2,0	1,2	1,4	1,2
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	1,7	1,6	1,7	1,4	1,2	1,0	1,1
	Banská Bystrica, Zelená	1,1	1,2	1,3	0,9	0,9	0,7	0,7
	Jelšava, Jesenského	4,0	3,0	2,8	2,7	3,4	3,5	2,4
	Žarnovica			2,2	2,7	1,9	2,2	*2,1
Žilina region	Žilina, Obežná	2,0	1,9	1,9	1,9	1,2	1,3	*1,6
	Ružomberok, Riadok		4,5	2,3	2,2	2,0	1,7	1,4
	Oščadnica			12,0	2,5	1,9	2,1	1,6
	Martin, Jesenského						**1,0	1,1
Prešov region	Starina, Vodná nádrž, EMEP	0,4	0,3	0,4	0,2	0,3	0,2	0,3
	Stará Lesná, AÚ SAV, EMEP	0,4	0,3	0,4	0,3	0,2	0,2	0,2
KOŠICE	Veľká Ida, Letná	4,5	4,6	6,1	5,4	4,9	6,2	5,8
Košice region	Krompachy, SNP	2,7	2,1	2,2	2,2	2,1	1,8	2,0

≥ 90% valid measurements Exceedance of the target value is indicated in red.

* 80% valid measurements

** Martin, Jesenského – B(a)P measurements started in 2024.

The target value for B(a)P was exceeded at monitoring stations in the Slovakia zone:

- **Nitra region:** Plášťovce
- **Banská Bystrica region:** Banská Bystrica, Štefánikovo nábrežie; Jelšava; Žarnovica
- **Žilina region:** Oščadnica, Ružomberok, Žilina, Martin.
- **Trenčín region:** Púchov
- **Košice region:** Krompachy
- **Košice:** Veľká Ida

AMS Plášťovce, Žarnovica and Žilina did not meet the required proportion of valid data. Based on a qualified estimate, these locations are also classified as areas where the target value for B(a)P was exceeded.

The target value for B(a)P remains exceeded at more than half of the monitoring stations; however, the long-term development of concentrations indicates a gradual improvement of the situation in several zones. The most pronounced decrease in concentrations was recorded in the Banská Bystrica Region and Žilina Region zones.

In the Košice agglomeration and the Košice Region zone, no clear decreasing trend can be observed, and concentrations remain elevated in the long term.

In the Bratislava agglomeration and the Bratislava Region and Trnava Region zones, B(a)P concentrations have remained below the target value over the long term. In the Trenčín Region zone, most locations are at the level of the target value or only slightly above it.

Ozone

Decree of the Ministry of the Environment of the Slovak Republic No. 250/2023 Coll. on Air Quality establishes the target value for ozone for the protection of human health as follows: The maximum daily 8-hour mean value must not exceed $120 \mu\text{g}/\text{m}^3$ on more than 25 days per calendar year, averaged over three years. The number of days with exceedances of the target value for ground-level ozone is presented in **Tab. 3.8**.

Tab. 3.8 Number of days with a maximum daily 8-hour mean O_3 concentration above $120 \mu\text{g}\cdot\text{m}^{-3}$

Zone	Station	2023	2024	2025	Average 2023 – 2025
BRATISLAVA	Bratislava, Jeséniova	23	26	33	27
	Bratislava, Mamateyova	18	18	11	16
Bratislava region	Pezinok, Obrancov mieru	16	26	14	19
	Senec, Boldocká	3	3	10	5
Trnava region	Topoľníky, Aszód, EMEP	2	1	5	3
Nitra region	Nitra, Janíkovce	21	18	43	27
	Komárno, Vnútoraná Okružná	16	29	16	20
	Plášťovce	13	8	8	10
Trenčín region	Prievidza, Malonecpalská	4	3	6	4
Banská Bystrica region	Banská Bystrica, Zelená	0	1	8	3
	Jelšava, Jesenského	1	4	4	3
	Lučenec, Gemerská cesta	0	5	6	4
Žilina region	Chopok, EMEP	34	53	37	41
	Oščadnica	6	10	10	9
	Ružomberok, Riadok	1	0	0	0
	Žilina, Obežná	1	0	2	1
Prešov region	Gánovce, Meteo. st.	0	2	1	1
	Humenné, Nám. Slobody	2	0	5	2
	Stará Lesná, AÚ SAV, EMEP	*0	10	2	6
	Starina, Vodná nádrž, EMEP	1	0	0	0
	Bardejov, Pod Vinbargom	1	1	1	1
KOŠICE	Košice, Ďumbierska	4	15	2	7
Košice region	Kojšovská hoľa	*17	11	23	17
	Trebišov, T. G. Masaryka	3	1	5	3

≥ 90% of the required valid data

Red colour – exceedance of the target value

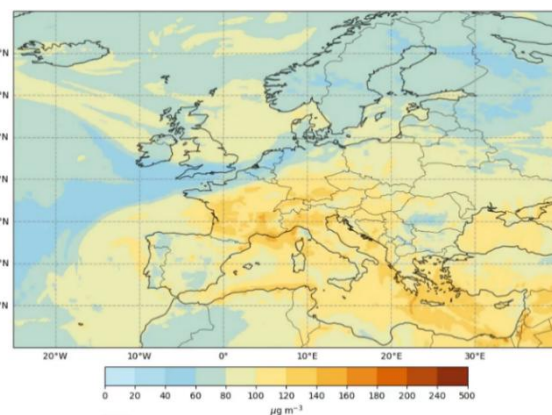
* the year was not included in the average due to insufficient data during the summer period.

Target value of O_3 was exceeded:

- **Agglomeration Bratislava:** BA Jeséniova
- **Zone Slovakia:** Chopok, Nitra Janíkovce

The highest number of ozone exceedances in Janíkovce was recorded in July (20), with an unusually high number (10) already occurring in June. The significant June episode originated in the Mediterranean region and gradually affected the whole of Europe (**Fig. 3.3**), including Slovakia. Conditions for local ozone formation in Janíkovce were similar to those at the Bratislava, Jeséniova station. The precursors were most likely provided mainly by road traffic (in this case, from Nitra), while the sufficient amount of sunlight is also reflected in the temperatures. During summer, maximum daily temperatures exceeding 35°C were recorded in Janíkovce, with a total of 33 tropical days with maximum temperatures above 30°C .

Fig. 3.3 Spatial distribution of ground-level ozone during the June 2025 episode.



Ground-level ozone AOT40 values for the protection of vegetation are presented in [Tab. 3.9](#). AOT40 is a specific indicator for the protection of plants, forests and natural ecosystems. It represents the cumulative dose (accumulated exposure) to which vegetation is exposed during the main growing season from May to July.

Tab. 3.9 Ground-level ozone AOT40 values for the protection of vegetation (May – July).
The AOT40 target value is 18,000 $\mu\text{g}\cdot\text{m}^{-3}\cdot\text{h}$.

Station	2021	2022	2023	2024	2025	Average 2021 – 2025
Bratislava, Jeséniova	19 274	23 763	20 177	*16339	18 704	20 480
Bratislava, Mamateyova	17 655	20 072	16 292	14 805	10 337	15 832
Senec, Boldocká*		14 893	8 930	9 467	*9569	11 097
Pezinok, Obrancov mieru		19 368	11 931	17 345	13 402	15 512
Topoľníky, Aszód, EMEP	13 176	16 686	12 739	8 267	4 374	11 048
Nitra, Janíkovce	18 931	24 322	18 824	11 372	32 509	21 192
Komárno, Vnútorná Okružná	*17 818	12 824	21 701	18 013	13 991	16 632
Plášťovce	*24 211	19 720	15 043	12 281	12 466	14 878
Prievidza, Malonecpalská	11 799	*15 529	8 582	9 164	*8002	9 848
Banská Bystrica, Zelená	15 869	*19 716	9 226	4 695	*9071	9 930
Jelšava, Jesenského	10 186	*17 622	10 530	10 085	*8817	10 267
Lučenec, Gemerská cesta		14 834	9 478	8 136	11 820	11 067
Chopok, EMEP	23 654	26 536	24 179	22 651	18 135	23 031
Oščadnica		14 893	8 930	16 058	9 792	12 418
Ružomberok, Riadok	*8 041	2 935	7 890	4 208	1 792	4 206
Žilina, Obežná	4 794	5 338	5 114	2 225	*3639	4 368
Košice, Ďumbierska	7 368	12 662	11 835	15 866	9 077	11 362
Kojšovská hoľa	13 260	19 435	13 249	10 471	13 942	14 071
Trebišov, T. G. Masaryka	12 369	15 806	10 425	11 341	11 422	12 273
Bardejov, Pod Vinbargom	10 607	12 711	7 413	11 139	5 750	9 524
Gánovce, Meteo. st.	6 707	11 317	4 596	10 524	8 582	8 345
Humenné, Nám. slobody	12 578	16 047	9 520	8 738	10 353	11 447
Stará Lesná, AÚ SAV, EMEP	2 491	6 210		12 855	9 587	7 786
Starina, Vodná nádrž, EMEP	11 737	9 560	5 857	7 810	*5980	8 741

* The year was not included in the average due to insufficient data during the summer period.
Red indicates an exceedance of the target value.

Ozone poses the greatest risk to vegetation in locations outside urban areas; therefore, this indicator is monitored primarily at rural and background stations. In urban areas, ozone is often depleted by other emissions (e.g. from road traffic), whereas in rural areas and at higher elevations its concentrations remain high.

The AOT40 target value was exceeded in two zones:

- **Agglomeration Bratislava:** Bratislava, Jeséniova,
- **Zone Slovakia:** Chopok, Nitra Janíkovce.

The PM₁₀ limit value was not exceeded at any industrial AMS station operated by other air quality monitoring network operators VZZO ([Tab. 3.10](#)).

Tab. 3.10 Assessment of air pollution according to limit values for the protection of human health in 2025 based on measurements from industrial stations of other operators.

AGGLOMERATION Zone	Pollutant Averaging period Limit value [$\mu\text{g}\cdot\text{m}^{-3}$] (Maximum number of exceedances)	SO ₂		NO ₂		PM ₁₀		CO
		1 h 350 (24)	24 h 125 (3)	1 h 200 (18)	1 year 40	24 h 50 (35)	1 year 40	8 h ¹⁾ 10 000
BRATISLAVA Bratislava region	Bratislava Pod. Biskupice, Slovnaft	0	0	0	16	4	19	969
	Bratislava Vlčie Hrdlo, Slovnaft	0	0	0	15	3	19	705
	Rovinka, Slovnaft	3	0	0	12	3	19	613
Nitra region	Trnovec nad Váhom	0	0	0	2	3	17	
Žilina region	Ružomberok, Supra SCP					21	22	
KOŠICE	USS Veľká Ida					31	28	
	USS Polov					6	15	
	USS Haniska					10	21	

¹⁾Max. 8-hour conc.; AMS Leles and Oslany (SE) ceased operation due to the termination of the operation of the VZZO.

3.3.1 Adjustment of PM₁₀ concentrations for the contribution of natural dust

EU legislation allows the contribution of natural sources of pollution to be taken into account when assessing air quality, particularly the transport of dust from the Sahara and other arid regions. Table 3.11 presents the daily contribution of natural dust in cases where its subtraction resulted in a reduction in the number of exceedances of the PM₁₀ daily limit value. Tab. 3.12 presents the number of exceedances of the PM₁₀ daily limit value after subtracting the contribution from natural sources.

Tab. 3.11 Subtraction of the contribution of natural dust from the average daily PM₁₀ concentrations in 2025.

Date	AMS	PM ₁₀ $\mu\text{g}\cdot\text{m}^{-3}$	PM _{10_s} $\mu\text{g}\cdot\text{m}^{-3}$	Difference	Source of dust
26.1.2025 20.12. 2025	Plášťovce	51.7 52.7	49.7 49.4	2.0 3.3	Sahara
8.3. 2025	Trnava, Kollárova	51.0	50.5	0.6	Arabian peninsula
10.3. 2025	Banská Bystrica, Štefánik. n.	52.2	48.4	3.8	Sahara, Arabian peninsula
10.3. 2025	Humenné, Nám. Slobody	50.8	48.7	2.2	Sahara, Arabian peninsula
10.3. 2025	Lučenec, Gemerská cesta	52.4	48.6	3.8	Sahara, Arabian peninsula
28.3. 2025 17.8. 2025 18.12. 2025	Veľká Ida, Letná	51.4 50.5 50.8	49.7 48.0 50.2	1.6 2.5 0.6	Sahara
19.12. 2025	Vranov nad Top., M.R.Štefánika	50.9	49.6	1.3	Sahara

Tab. 3.12 Change in the number of exceedances of the PM₁₀ daily limit value before and after subtracting the contribution of natural dust in 2025.

AMS	Number of exceedances DLV PM ₁₀	Number of exceedances DLV PM ₁₀ after the subtraction of natural dust	Difference
Veľká Ida, Letná	42	39	3
Plášťovce	37	35	2
Banská Bystrica, Štefánik. n.	19	18	1
Lučenec, Gemerská cesta	19	18	1
Trnava, Kollárova	10	9	1
Vranov nad Top., M. R. Štefánika	8	7	1
Humenné, Nám. slobody	5	4	1

3.3.2 Assessment based on upper and lower assessment thresholds

Air quality assessment is carried out by fixed measurements in agglomerations and zones where the concentration level of a pollutant is above the upper assessment threshold. Exceedances of the upper and lower assessment thresholds are determined based on concentrations measured over the previous five years.

The assessment threshold for air pollution levels is considered to have been exceeded if it is exceeded in at least three individual years out of the last five years.

In the period 2020–2025, the levels of SO₂, CO and benzene at all AMS stations were below the lower assessment threshold for air pollution levels.

If five years of data are not available, exceedances of the upper and lower assessment thresholds for air pollution levels may be determined by combining the results of short-term measurement campaigns carried out during one year at locations with the likely highest levels of air pollution with results obtained from emission inventories and modelling (Decree of the Ministry of the Environment of the Slovak Republic No. 250/2023 Coll. on Air Quality). The classification of monitoring stations according to the upper and lower assessment thresholds is presented in [Tab. 3.13](#) and [Tab. 3.15](#).

Tab. 3.13 Classification of AMS according to the upper (UAT) and lower (LAT) assessment thresholds for air quality assessment in the period 2021–2025.

AGGLOMERATION zone	Station	UAT and LAT with regard to the protection of human health									
		SO ₂	NO ₂			PM ₁₀		PM _{2.5}	CO	Benzene	
		24h Average	1h Average	Annual Average	24h Average	Annual Average	Annual Average	8h maximum	Annual Average		
		> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT	> UAT < UAT < LAT < LAT
BRATISLAVA	Bratislava, Kamenné nám.					x		x			
	Bratislava, Trnavské myto			x	x		x	x		x	x
	Bratislava, Jeséniova	x	x	x	x	x	x	x			
	Bratislava, Mamateyova	x	x	x	x	x	x	x			
	Bratislava, Púchovská	x	x	x	x	x	x	x		x	x
KOŠICE	Košice, Štefánikova	x		x	x		x	x		x	x
	Košice, Amurská				x		x	x			
	Veľká Ida, Letná				x	x	x			x	
Banská Bystrica region	Banská Bystrica, Štefánikovo n.	x		x	x		x	x		x	x
	Banská Bystrica, Zelená		x	x		x	x	x			
	Zvolen, J. Alexyho				x		x	x			
	Jelšava, Jesenského		x	x	x		x	x			
	Hnúšťa, Hlavná				x		x	x			
	Žarnovica		x	x	x		x	x			
	Lučenec, Gemerská cesta		x	x	x		x	x		x	x
Bratislavský kraj	Žiar nad Hronom, Jilemnického					x	x	x			
	Pezinok	x	x	x	x		x	x		x	
	Rovinka	x	x	x	x		x			x	x
	Rohožník, Senická cesta	x	x	x	x		x		x	x	x
Košice region	Senec, Boldocká		x	x	x		x	x		x	
	Kojšovská hofa*		x	x							
	Strážske, Mierová				x		x	x			
	Krompachy, SNP	x	x	x	x		x	x		x	x
Nitra region	Trebišov, T. G. Masaryka		x	x	x		x	x			
	Nitra, Janíkovce		x	x	x		x	x			
	Nitra, J. Štúrova	x	x	x	x		x	x		x	x

AGGLOMERATION zone	Station	UAT and LAT with regard to the protection of human health											
		SO ₂	NO ₂			PM ₁₀			PM _{2,5}	CO	Benzene		
		24h Average	1h Average	Annual Average	24h Average	Annual Average	Annual Average	8h maximum	Annual Average	Annual Average	Annual Average	Annual Average	
		< UAT<LAT > UAT	< LAT > UAT	< UAT>LAT > UAT	< LAT > UAT	< UAT>LAT > UAT	< LAT > UAT	< UAT>LAT > UAT	< LAT > UAT	< UAT>LAT > UAT	< LAT > UAT	< UAT>LAT > UAT	
	Komárno, Vnúťorná Okružná			x		x	x		x	x			
	Plášťovce			x		x	x		x	x			
	Humenné, Nám. slobody			x		x	x		x	x			
Prešov region	Prešov, Arm. gen. L. Svobodu			x		x			x		x		x
	Gánovce, MS SHMÚ*			x		x							
	Starina, Vodná nádrž, EMEP*			x		x							
	Vranov n/Topľou, M. R. Štefánika		x				x		x	x			
	Stará Lesná, AÚ SAV, EMEP*			x		x		x		x			
	Kolónické sedlo, Hvezdáreň						x		x		x		
	Poprad, Železničná			x		x		x		x			
	Bardejov, Pod Vinbargom			x		x		x		x			
	Trenčín region	Prievidza, Malonecpalská		x		x		x		x		x	
		Bystričany, Rozvodňa SSE		x				x		x		x	
Handlová, Morovniarska cesta			x				x		x		x		
Púchov, 1. mája			x		x		x		x		x		
Trenčín, Hasičská			x		x		x		x		x		
Trnava region	Senica, Hviezdoslavova,		x				x		x		x		
	Trnava, Kollárova			x		x		x		x		x	
	Topoľníky, Aszód, EMEP*		x		x		x		x		x		
	Sereď, Vinárska			x		x		x		x			
Žilina region	Martin, Jesenského			x		x		x		x		x	
	Liptovský Mikuláš, Školská		x		x		x		x		x		
	Oščadnica		x		x		x		x		x		
	Chopok, EMEP*			x		x							
	Ružomberok, Riadok		x		x		x		x		x		
	Žilina, Obežná			x		x		x		x			

* Stations indicating the regional background level

Pollutant	Period	Lower threshold 250/2023 μg·m ⁻³ / *mg·m ⁻³	New threshold 2024/2880 μg·m ⁻³ / *mg·m ⁻³
PM ₁₀	24h/35x	35	x
	year	20	15
PM _{2.5}	year	12	5
	year	26	10
NO ₂	1h	100	-
	8-h. max	5*	
CO	24-h	-	4*
	24-h	50	40
Benzene	year	2	1,7
O ₃	8-h. daily max	x	100

Tab. 3.14 Comparison of the lower assessment threshold according to current legislation and the assessment thresholds under the EU Directive.

The assessment of upper and lower thresholds shows that, under the current system, the highest number of stations above the upper assessment threshold is recorded for the daily PM₁₀ concentration. However, the new EU Directive 2024/2881 replaces the system of upper and lower assessment thresholds with a single assessment threshold; below this threshold, mathematical modelling is sufficient for air quality assessment.

For the annual PM₁₀ concentration, the current lower assessment threshold is 20 μg·m⁻³, while the new assessment threshold under Directive 2024/2881 will be 15 μg·m⁻³. The difference is even more significant for PM_{2.5}: the current upper assessment threshold is 17 μg·m⁻³, whereas the new Directive introduces an assessment threshold of 5 μg·m⁻³.

Key changes in the assessment:

- **Abolition of the two-level system:** The system of lower and upper assessment thresholds is replaced by a single threshold. Exceeding this threshold (in at least 3 years out of the previous 5 years) triggers the obligation for fixed measurements.
- **Significant tightening of requirements:** For example, for $PM_{2,5}$, the threshold triggering mandatory measurements is reduced from the current $12 \mu\text{g}\cdot\text{m}^{-3}$ to $5 \mu\text{g}\cdot\text{m}^{-3}$. For NO_2 , the threshold decreases from $26 \mu\text{g}\cdot\text{m}^{-3}$ to $10 \mu\text{g}\cdot\text{m}^{-3}$.
- **Removal of daily thresholds:** For PM_{10} particulate matter, assessment thresholds are determined only as an annual mean concentration.
- **Ozone:** While ozone monitoring was previously linked to exceedances of long-term objectives, the new legislation introduces a fixed numerical threshold of $100 \mu\text{g}\cdot\text{m}^{-3}$ (maximum daily 8-hour mean; 3 exceedances).

After applying the new thresholds, the number of locations classified above the assessment threshold will therefore increase significantly, particularly for $PM_{2,5}$ and PM_{10} .

This means that air quality assessment under the new Directive will be stricter and more sensitive also to concentrations that, under the current system, are below the lower assessment threshold.

Tab. 3.15 Classification of monitoring stations measuring heavy metals and benzo(a)pyrene according to the upper (UAT) and lower (LAT) assessment thresholds in the period 2021–2025.

Station	As			Cd			Ni			Pb			B(a)P		
	> UAT	< UAT > LAT	< LAT	> UAT	< UAT > LAT	< LAT	> UAT	< UAT > LAT	< LAT	> UAT	< UAT > LAT	< LAT	> UAT	< UAT > LAT	< LAT
Bratislava, Jeséniova															x
Bratislava, Trnavské mýto			x			x			x			x		x	
Bratislava, Púchovská															x
Veľká Ida, Letná			x			x			x			x	x		
Banská Bystrica, Štefánikovo nábr.			x			x			x			x		x	
Banská Bystrica, Zelená													x		
Jelšava, Jesenského			x			x			x			x			
Žarnovica													x		
Rovinka														x	
Krompachy, SNP						x			x			x			
Nitra, Štúrova														x	
Plášťovce													x		
Starina, Vodná nádrž, EMEP															x
Stará Lesná, EMEP															x
Prievidza, Malonecpalská						x			x			x			
Púchov, 1. mája													x		
Trnava, Kollárova														x	
Žilina, Obežná													x		
Ružomberok, Riadok			x			x			x			x			
Oščadnica													x		
Martin, Jesenského															
Sereď, Vinárska			x			x			x			x			

Similarly, for the assessment of heavy metals and benzo(a)pyrene, the new EU Directive will replace the two-level system (upper and lower assessment thresholds) with a single assessment threshold, which will be stricter than the current thresholds in several cases. However, given that heavy metal levels in Slovakia are low, these changes will not result in any changes in the classification or assessment.

In the period 2021–2025, the levels of the monitored heavy metals at all AMS stations were below the lower assessment threshold for air pollution levels.

The new threshold for mandatory monitoring for B(a)P of $0.30 \text{ ng}\cdot\text{m}^{-3}$ will be set lower than the previous lower assessment threshold ($0.4 \text{ ng}\cdot\text{m}^{-3}$). For several locations, this will result in changes in the assessment regime for this pollutant.

3.3.3 Smog warning system

The smog warning system serves to protect public health during short-term and significant deterioration of air quality.

■ When a smog situation is declared

A smog situation is declared when the specified threshold is exceeded and, at the same time, the meteorological forecast does not indicate that the situation is expected to improve within the following 24 hours.

Two levels are distinguished:

- **Notification of the occurrence of a smog situation:** issued when the information threshold (IT) is exceeded.
- **Warning of a serious smog situation:** issued when the warning threshold (WT) is exceeded.

Tab. 3.16 Monitored pollutants and their smog threshold values.

Pollutant	Information threshold $\mu\text{g}\cdot\text{m}^{-3}$	Warning threshold $\mu\text{g}\cdot\text{m}^{-3}$	Averaging period
PM ₁₀	100	150	12-h. rolling average
O ₃	180	240*	1-h. / *3 consecutive hours
SO ₂	—	500	3 consecutive hours
NO ₂	—	400	3 consecutive hours

■ Legislative framework

Detailed rules for the implementation of the smog warning system and procedures for declaring smog situations are established in accordance with Act No. 146/2023 Coll. on Air Protection and Decree of the Ministry of the Environment of the Slovak Republic No. 250/2023 Coll. on Air Quality.

Notifications of the occurrence of a smog situation for PM₁₀ were issued for the following areas³:

- **Zone Banská Bystrica region:** Jelšava, Lučenec, Žarnovica
- **Zone Žilina region:** Čadca District, Liptovský Mikuláš, Ružomberok, Veľká Ida.
- **Zone Nitra region:** Galanta District, Levice District

A warning of a serious smog situation for PM₁₀ was issued for the area of:

- **Zone Banská Bystrica region:** Jelšava and its surrounding are for the period from 25.-26. 2. 2025.

Notifications of the occurrence of a smog situation for O₃ were issued for:

- **Agglomeration Bratislava:** 26. 6. 2025, 9. 8. 2025

The warning threshold for O₃ was not exceeded in Slovakia

Tab. 3.17 Duration of exceedance of the information threshold expressed in hours.

AMS/month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Veľká Ida, Letná		46	18								9		73
Jelšava, Jesenského	15	50											65
Liptovský Mikuláš, Školská	37												37
Ružomberok, Riadok	22											3	25
Plášťovce	8	16											24
Košice, Štefánikova			9										9
Martin, Jesenského	9												9
Žarnovica	5												5
Banská Bystrica, Štefánik. náb.	4												4
Oščadnica												1	1
Total	96	116	27								9	4	252

³ In cases where the threshold was exceeded, but an improvement in dispersion conditions could be expected within 24 hours based on the meteorological forecast or the nature of the pollution, a smog situation was not declared; however, the public was informed about the exceedance of the threshold value.

In 2024, due to an extreme Saharan dust transport episode on 1 April 2024, exceedances of the information threshold were recorded simultaneously at 50 monitoring stations. In 2025, simultaneous exceedances of the information threshold were recorded at a maximum of 3 stations, namely on New Year's Day in Jelšava, Liptovský Mikuláš and Ružomberok.

However, this does not mean that episodes of unfavourable air quality did not occur over larger areas; the situation at individual stations changed gradually depending on varying meteorological conditions.

3.3.4 National exposure reduction target for PM_{2,5} particulate matter

The health effects resulting from air pollution by PM particles depend on the size and composition of particulate matter, with smaller particles having a more direct impact on human health. Therefore, both European and Slovak legislation are shifting the focus towards PM_{2,5}.

The indicator used to express the trend in population exposure to PM_{2,5} concentrations is the Average Exposure Indicator (AEI) for PM_{2,5}.⁴

Tab. 3.18 shows the values of this indicator are presented from 2010, which is the reference year for the AEI. According to Annex No. 4 to Decree No. 250/2023 Coll., the national exposure reduction target for PM_{2,5} particles was set at 18 µg·m⁻³, to be achieved by 2020. This target was successfully achieved.

PM_{2,5} exposure concentration reduction commitment

Exposure concentration reduction commitment as of 2015	20 µg·m ⁻³
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Tab. 3.18 depicts the development of the PM_{2,5} Average Exposure Indicator over the last 16 years. Its further decrease in 2025 reflects lower annual average PM_{2,5} concentrations over the last 3 years, particularly in 2023 and 2025. The Slovak Republic has also met the PM_{2,5} exposure reduction target for 2025.

Tab. 3.18 Average Exposure Indicator (AEI) for PM_{2,5} in the period 2010–2025.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
AEI [µg·m ⁻³]	24,4	24,4	23,1	22,6	20,4	19,9	18,7	19	18,4	18,1	16,5	15,7	15,9	15,2	14,2	13,6

PM_{2,5} Average Exposure Reduction Commitments after 2030

The new European legislation introduces a fundamental shift in the approach to air quality standards. In addition to compliance with limit values at specific locations, the concept of the Average Exposure Indicator (AEI) is also being strengthened. The AEI reflects the overall level of pollution in urban environments, where the impact on public health is most significant.

⁴ The AEI is defined as a three-year moving average of annual average PM_{2,5} concentrations from selected urban and suburban background stations. For example, the AEI for 2025 is calculated as the average of the annual mean concentrations measured at these stations in 2023, 2024 and 2025.

Key changes and new goals:

- **Inclusion of NO₂:** While this concept previously applied only to PM_{2,5} particles, the new Directive introduces an exposure reduction commitment also for NO₂. The target Average Exposure Concentration value that Member States aim to achieve for this pollutant will be **10 µg·m⁻³**. The exposure reduction commitment for **2030 will be 11.5 µg·m⁻³**.
- **PM_{2,5} exposure reduction commitment:** For the Slovak Republic, the key commitment for PM_{2,5} particles will be a **25% reduction commitment**. This target applies to areas where the initial level (10 years earlier, i.e. in 2020) exceeded **12 µg·m⁻³**. The long-term objective will be to achieve an **Average Exposure Concentration of 5 µg·m⁻³**. The exposure reduction commitment for **2030 will be 12.0 µg·m⁻³**.

3.3.5 Comparison of air quality monitoring results with the requirements of the new EU Directive

The new Directive of the European Parliament and of the Council (EU) 2024/2881 on ambient air quality and cleaner air for Europe introduces, from 2030, significantly stricter limit values for several pollutants. From 2027, EU Member States will be required to carry out a parallel assessment of air quality according to both the current and the new legislative requirements, enabling continuous evaluation of preparedness to meet future limit values. Therefore, the Slovak Hydrometeorological Office has already carried out a preliminary assessment of monitoring results according to the requirements of the new Directive as part of the 2025 assessment.

The new Directive introduces not only stricter limit values but, in some cases, also changes the assessment approach. For PM₁₀, compliance will be assessed against a lower daily limit value (45 µg·m⁻³ instead of 50 µg·m⁻³), while the permitted number of exceedance days per year will simultaneously be reduced from 35 to 18 days.

■ PM₁₀ a PM_{2,5}

The annual average PM₁₀ concentrations in 2025 were within the lower half of the range of values observed during the reference period 2017–2025 at most AMS stations. Several stations reached concentrations close to or below the 10th percentile of the long-term distribution compared with the average values of previous years.

However, from the perspective of the new Directive (EU) 2024/2881, the situation remains less favourable. The future annual average limit value for PM₁₀ (20 µg·m⁻³) would be exceeded at 12 AMS stations in seven zones ([Fig. 3.4](#)).

Fig. 3.4 Annual average PM_{10} concentrations compared with the reference period (median, 10th–90th percentile).

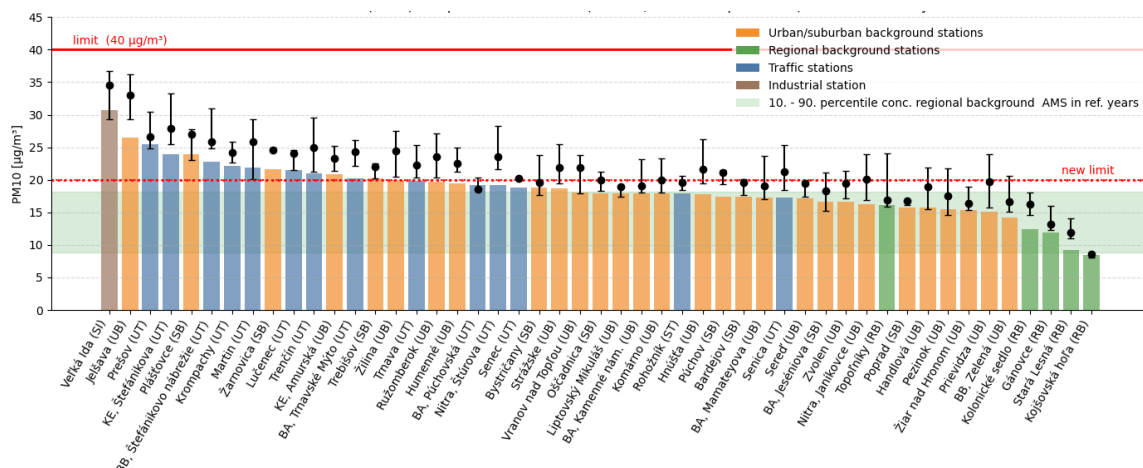


Fig. 3.5 (left) the table lists monitoring stations with exceedances of the new annual PM_{10} limit value; the map (right) shows the spatial distribution of PM_{10} concentrations at AMS stations and provides an overview of the zones that would not comply with the future annual PM_{10} limit value at the current level of pollution.

Fig. 3.5 AMS stations with exceedances of the annual limit value for PM_{10} according to the new EU Directive (left); Map of annual average PM_{10} concentrations (right).

AMS	zone	Concentration $\mu g/m^3$
Trenčín	TNSK	21
Plášťovce	NSK	24
BB, Štefánik. n.		23
Jelšava	BBSK	27
Lučenec		22
Zarnovica		22
Martin	ZSK	22
KE, Amurská		21
KE, Štefánikova	KE	24
Veľká Ida		31
Krompachy	KSK	22
Prešov	PSK	25

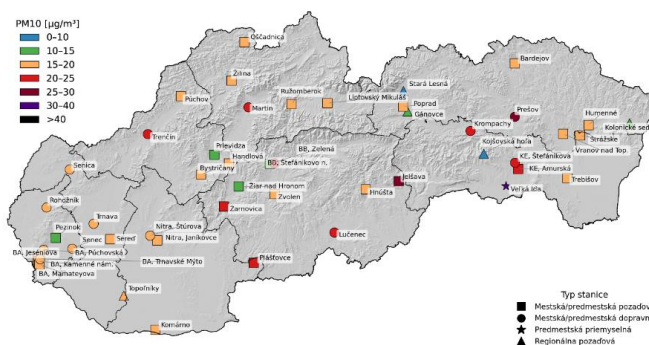
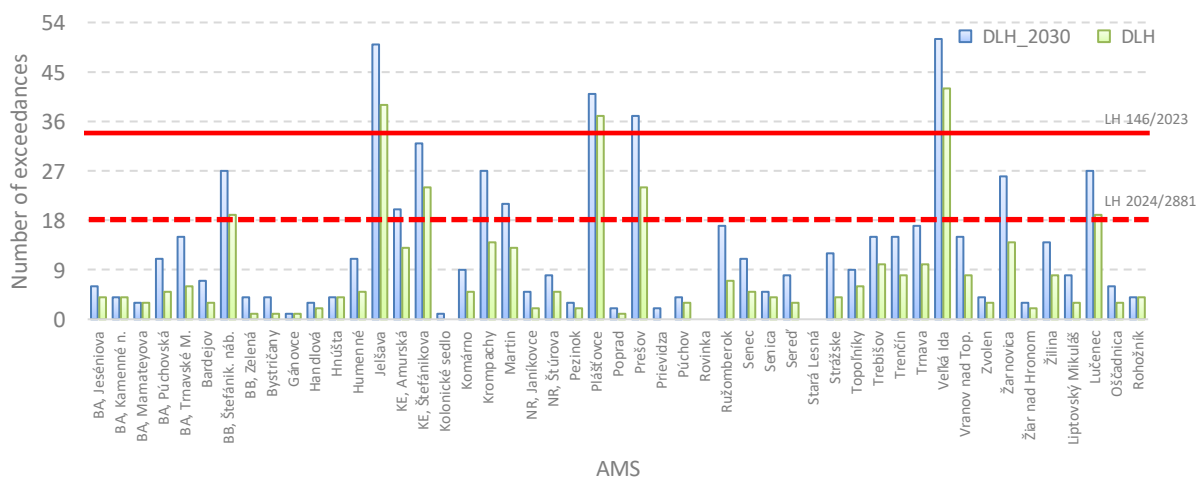


Fig. 3.6 Comparison of the number of exceedances of the daily limit value for PM_{10} under the current and new EU legislation.



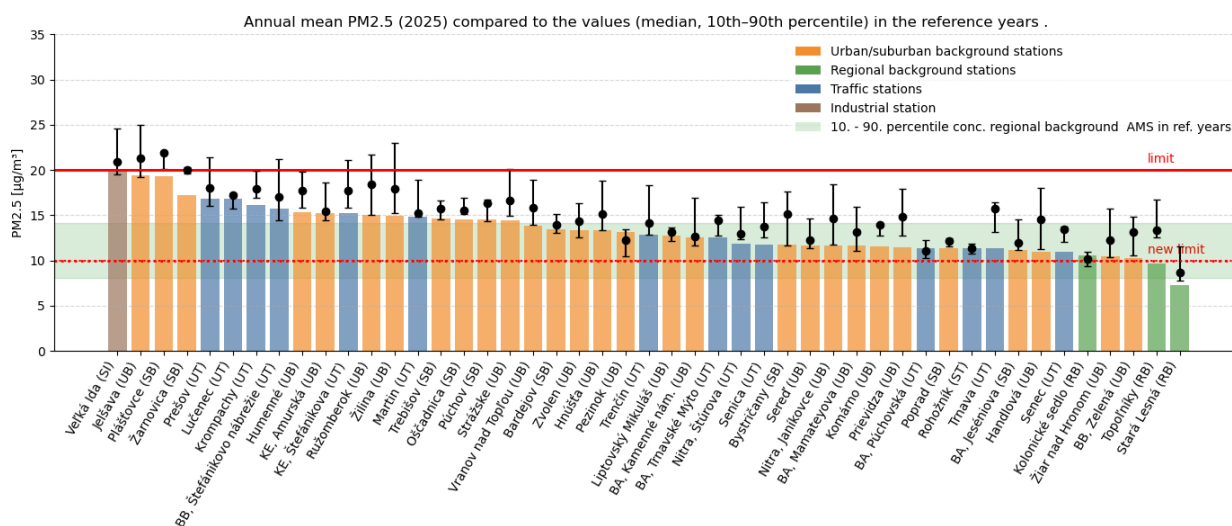
The new daily PM₁₀ limit value (45 µg·m⁻³) would be exceeded at **11 AMS stations in six zones.**

Tab. 3.19 Number of exceedances of the new limit value (LV) by AMS stations and zones.

AMS	zone	Number of exceedances of the new LV/current LV
Plášťovce	NSK	41 (37)
BB, Štefánik. n.	BBSK	27
Jelšava		50 (39)
Lučenec		27
Žarnovica		26
Martin	ZSK	21
KE, Amurská	KE	20
KE, Štefánikova		32
Veľká Ida		51 (42)
Krompachy	KSK	27
Prešov	PSK	37

The comparison of the number of exceedances of the daily PM₁₀ limit value (Fig. 3.6) under the current and the new EU legislation demonstrates the significant impact of the stricter assessment criteria. As a result of lowering the limit value to 45 µg·m⁻³ and tightening the compliance criteria (18 permitted exceedances), the 2025 data indicate that an additional 11 monitoring stations would no longer meet the requirements of the new Directive. These results confirm that the new requirements will be considerably more sensitive to the occurrence of short-term episodes of elevated PM₁₀ concentrations.

Fig. 3.7 Annual average PM_{2,5} concentrations compared with the reference period (median, 10th–90th percentile).

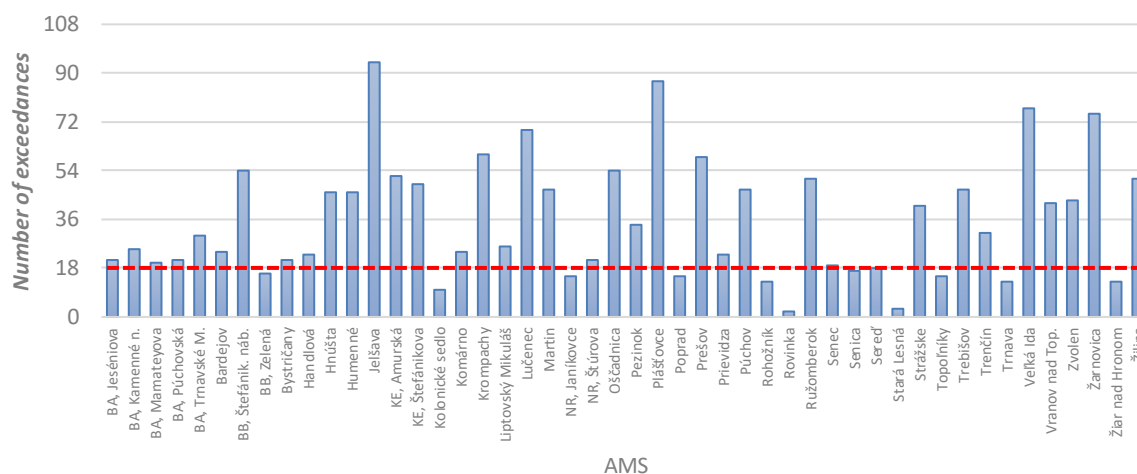


The annual average PM_{2,5} concentrations in 2025 were within the lower half of the range of values observed during the reference period at most monitoring stations, with several locations recording some of the lowest concentrations since monitoring began. Despite this favourable trend, the majority of monitoring stations exceeded the new annual limit value of 10 µg·m⁻³ established by Directive (EU) 2024/2881.

The new annual limit value would not be exceeded only at the AMS stations in the Banská Bystrica region (Banská Bystrica, Zelená and Žiar nad Hronom) and at the regional background stations Kolonické sedlo, Stará Lesná and Topoľníky.

The new annual PM_{2,5} limit value (10 µg·m⁻³) lies close to the lower bound of the concentration range observed at regional background stations (Fig. 3.7, green line) during the reference period. This indicates that achieving this value in the short term will be challenging even at locations with minimal influence from local emission sources.

Fig. 3.8 Number of days with daily mean $PM_{2.5}$ concentrations above $25 \mu g/m^3$. The new EU legislation permits 18 exceedances.

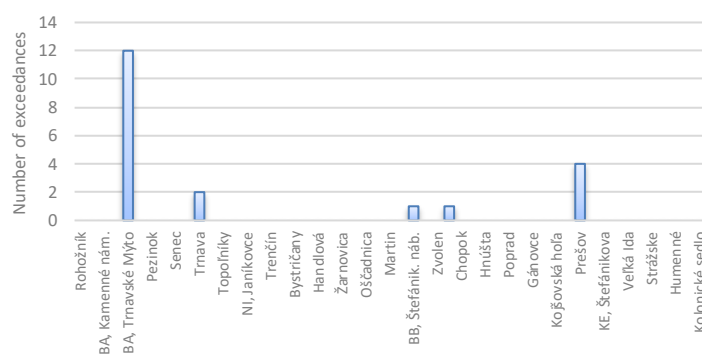


The number of daily $PM_{2.5}$ exceedances according to the new Directive (EU) 2024/2881 exceeded the permitted threshold of 18 days at 33 AMS stations. The highest numbers of exceedances would occur in the Banská Bystrica region, Košice region, Prešov region and Žilina region, as well as in the Košice agglomeration. This limit value would be exceeded in all zones, including the Bratislava agglomeration (Fig. 3.8).

The results confirm that the daily $PM_{2.5}$ limit value is among the most demanding requirements of the new Directive, and achieving compliance will require a significant reduction in concentrations, particularly during the heating season.

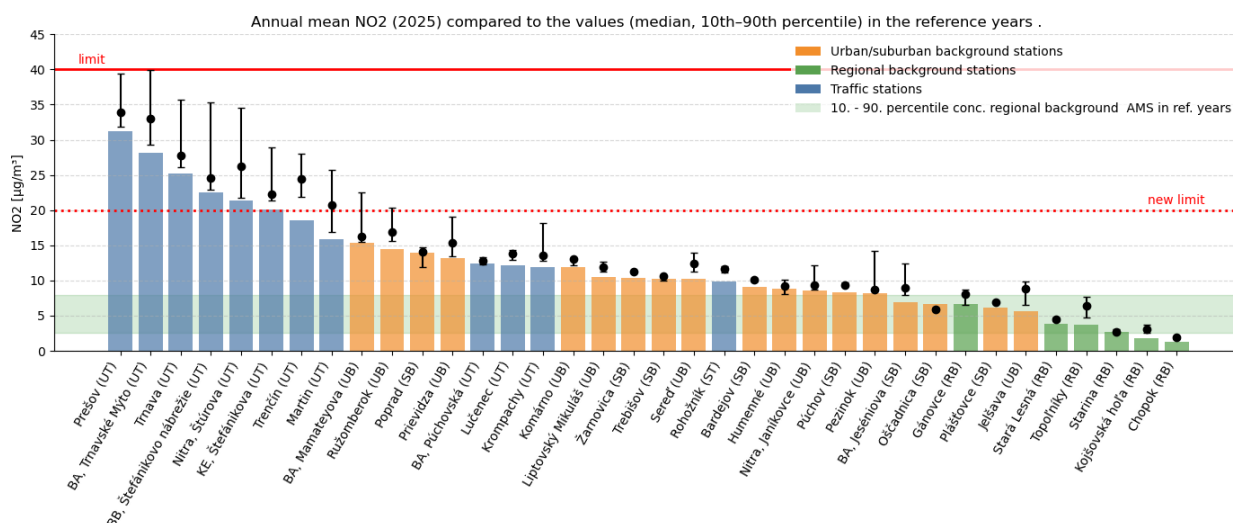
Nitrogen dioxide

Fig. 3.9 Number of exceedances of the new daily limit value for NO_2 .



In 2025, the annual limit value of $20 \mu g \cdot m^{-3}$ for nitrogen dioxide (NO_2) was not exceeded at any monitoring station. The most recent exceedances were recorded in 2018 at the monitoring stations Prešov, Arm. gen. L. Svobodu and Bratislava, Trnavské Mýto.

Fig. 3.10 Annual average concentrations of NO₂ compared with the reference period (median, 10th–90th percentile).



The annual average NO₂ concentrations in 2025 would exceed the new limit value of 20 µg·m⁻³ at five monitoring stations. All traffic stations outside regional capitals, as well as several traffic stations in regional capitals, were below the new limit value.

Exceedances of the annual limit value would occur in the following zones:

- **agglomeration Bratislava:** Bratislava Trnavské mýto
- **agglomeration Košice:** Košice, Štefánikova
- **zone Prešov region:** Prešov, arm. Gen. L. Svobodu
- **zone Banská Bystrica region:** Banská Bystrica, Štefánikovo nábr.
- **zone Trenčín region:** Trenčín.

Concentrations at regional background stations were well below the new limit value and were also within the lower part of the range of values observed during the reference years. The regional background level of NO₂ in Slovakia therefore already meets the requirements of the new Directive with a sufficient margin.

The situation would also be favourable with regard to the new Average Exposure Indicator (AEI) for population exposure, for which the target value is set at 10 µg·m⁻³. Most urban background stations are approaching or already meeting this level, indicating that the reduction of population exposure to NO₂ is progressing well in Slovakia. The main challenge will be achieving compliance with the new limit values in the most traffic-affected locations in Prešov, Bratislava and Trnava.

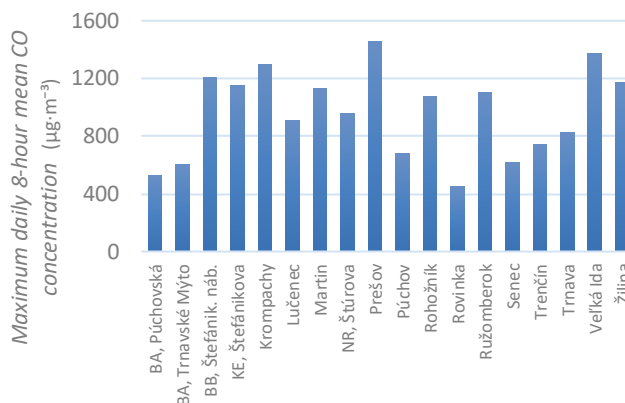
The stricter hourly limit value for NO₂ would not be exceeded at any AMS. The new daily limit value would likewise not be exceeded at any AMS. The highest number of exceedances (12) would be recorded at the Bratislava Trnavské mýto AMS (Fig. 3.12).

Carbon monoxide

For carbon monoxide (CO), the new Directive (EU) 2024/2881 does not change the limit value for the maximum daily 8-hour mean concentration, which remains at $10,000 \mu\text{g}\cdot\text{m}^{-3}$. At the same time, it introduces a new 24-hour limit value of $10,000 \mu\text{g}\cdot\text{m}^{-3}$, which must not be exceeded more than 18 times per calendar year.

The assessment of data for the period 2017–2025 shows that no exceedances of this value were recorded at the monitoring stations. The highest 24-hour CO concentration was measured in 2017 at the Trenčín, Hasičská monitoring station and reached $3,350 \mu\text{g}\cdot\text{m}^{-3}$, remaining below the new limit value. CO concentrations in Slovakia have remained at a low level over the long term and meet the requirements of the new Directive with a sufficient margin.

Fig. 3.11 Maximum daily 8-hour mean CO concentration at monitoring stations.



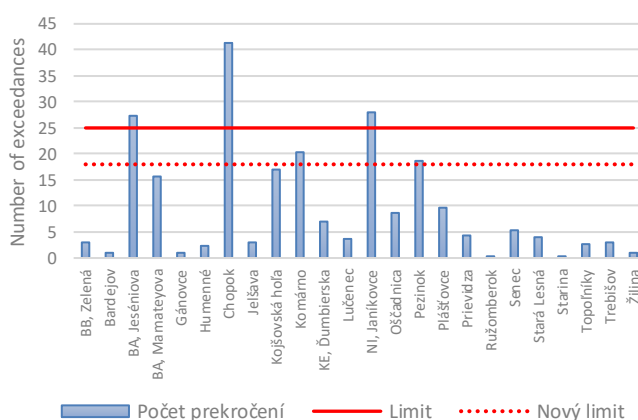
Ozone

The new Directive (EU) 2024/2881 introduces a limit value for ozone based on the maximum daily 8-hour mean concentration indicator, with compliance assessed according to the number of days exceeding $120 \mu\text{g}\cdot\text{m}^{-3}$. Compared with the current legislation, the requirements are tightened by reducing the maximum permitted number of exceedance days from 25 to 18 days per calendar year, evaluated as an average over three consecutive years.

According to the 2025 data, five AMS stations would not meet the new requirement:

- Bratislava, Jeséniova
- Pezinok
- Nitra Janíkovce, Komárno,
- Chopok

Fig. 3.12 Number days with the maximum daily 8-hour mean ozone (O_3) concentration above $120 \mu\text{g}\cdot\text{m}^{-3}$.



The results highlight the sensitivity of the stricter ozone assessment, particularly in southwestern Slovakia at the locations of Pezinok, Nitra and Komárno. This is related to favourable conditions for the photochemical formation of ground-level ozone, including high solar radiation intensity in these areas, higher temperatures during the summer period, and the availability of ozone precursors originating from transport and other anthropogenic sources.

■ Benzene

The new Directive (EU) 2024/2881 tightens the annual limit value for benzene from $5 \mu\text{g}\cdot\text{m}^{-3}$ to $3.4 \mu\text{g}\cdot\text{m}^{-3}$. Modelling results for 2025 show that benzene concentrations across the entire territory of Slovakia remain well below this value. The highest modelled concentrations were recorded in the vicinity of significant industrial and traffic sources, with only local areas exceeding the level of $1 \mu\text{g}\cdot\text{m}^{-3}$.

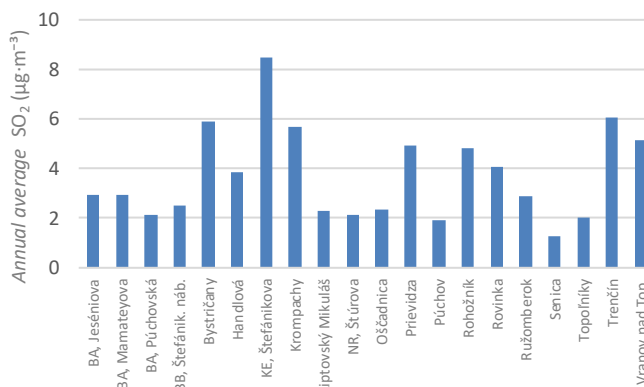
From the perspective of the new legislation, benzene therefore does not currently represent a problematic pollutant, and even after the tightening of the limit value, a sufficient margin for compliance remains across most of Slovakia.

■ Sulphur dioxide

The new Directive (EU) 2024/2881 introduces significant tightening of the assessment requirements for sulphur dioxide (SO_2) by reducing the daily limit value from $125 \mu\text{g}\cdot\text{m}^{-3}$ to $50 \mu\text{g}\cdot\text{m}^{-3}$ and limiting the number of permitted exceedances of the hourly limit value.

At the same time, it introduces a new annual limit value of $20 \mu\text{g}\cdot\text{m}^{-3}$ for the protection of human health. The annual average SO_2 concentrations in 2025 at monitoring stations ranged from 1 to $8 \mu\text{g}\cdot\text{m}^{-3}$. The monitoring results confirm that the annual, daily and hourly limit values according to the new Directive were not exceeded at any AMS in 2025.

Fig. 3.13 Annual average SO_2 concentration.



3.4 REGIONAL MONITORING

Regional air pollution represents pollution in the atmospheric boundary layer above natural areas located at a sufficient distance from local, industrial and urban emission sources. The atmospheric boundary layer is the lowest part of the atmosphere, extending from the Earth's surface to an altitude of approximately 1,000 metres, where vertical mixing of pollutants takes place.

In remote areas, unlike urbanised or industrial regions, emissions of pollutants are generally more evenly distributed throughout the entire volume of this layer, resulting in lower ground-level concentrations of pollutants.

The following text presents measurement results from regional monitoring stations of the EMEP network. [Chapter 3.4.1](#) focuses on air quality monitoring, while [Chapter 3.4.2](#) analyses the quality of atmospheric precipitation.

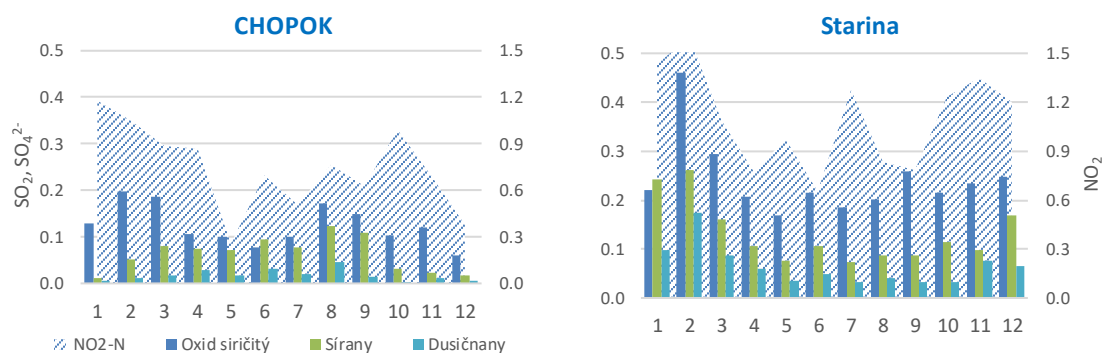
3.4.1 Air

■ Sulphur dioxide, sulphates

SO₂ concentrations at the EMEP stations Chopok and Starina remained at low levels in 2025 and, with a large margin, met the critical levels for the protection of vegetation for both the calendar year and the winter period (0.34 µg·m⁻³ at Chopok and 0.44 µg·m⁻³ at Starina). A summary of the average SO₂ and sulphate concentrations is provided in [Tab. 3.20](#).⁵ illustrates the monthly variation of sulphur and nitrogen compounds. Sulphates accounted for 2.4% of the total aerosol at Chopok and 6.9% of PM₁₀ at Starina. The values are recalculated as sulphur and nitrogen mass equivalents.

[Fig. 3.14](#) illustrates the monthly variation of sulphur and nitrogen compounds. Sulphates accounted for 2.4% of the total aerosol at Chopok and 6.9% of PM₁₀ at Starina. The values are recalculated as sulphur and nitrogen mass equivalents.

Fig. 3.14 Monthly variation of sulphur and nitrogen compounds.



Tab. 3.20 Annual average concentrations of monitored ions [µg·m⁻³] in ambient air at EMEP stations.

	SO ₂	SO ₄ ²⁻	NO ₂	NO ₃ ⁻	HNO ₃	Cl ⁻	NH ₃	NH ₄ ⁺	Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺
Chopok	0,12	0,06	0,73	0,02	0,08	0,01	-	-	-	-	-	-
Starina	0,13	0,24	1,09	0,06	0,10	0,02	0,73	0,26	0,12	0,11	0,03	0,20

SO₂, SO₄²⁻ – recalculated as sulphur; NO_x, NO₃⁻, HNO₃, NH₃, NH₄⁺ – recalculated as nitrogen.

⁵ Limit values are set by Annex No. 1 of the Decree of the Ministry of the Environment of the Slovak Republic No. 250/2023 Coll. on Air Quality.

■ Nitrogen oxides, nitrates

For nitrogen oxides (NO_x), a critical level is established for the protection of vegetation and natural ecosystems (an air quality standard equivalent to a limit value), representing the sum of NO and NO_2 .

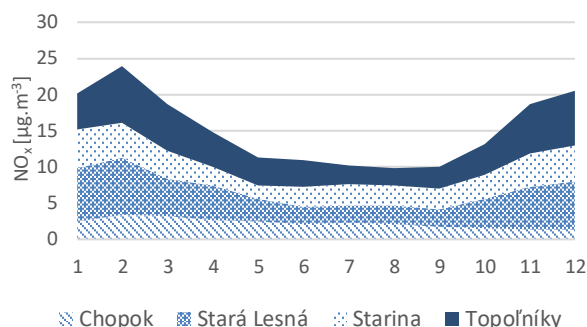
The critical level is set at $30 \mu\text{g}\cdot\text{m}^{-3}$ for the calendar year. Based on the data for 2025, the annual average concentrations were calculated at regional stations:

- Chopok $2,2 \mu\text{g}\cdot\text{m}^{-3}$
- Stará Lesná $4,6 \mu\text{g}\cdot\text{m}^{-3}$
- Starina $3,5 \mu\text{g}\cdot\text{m}^{-3}$
- Topoľníky $4,8 \mu\text{g}\cdot\text{m}^{-3}$

The limit value was not exceeded. The graph in Fig. 3.15 shows the monthly average NO_x concentrations. Monthly concentrations did not show a significant trend; the maximum was reached in February, with $25 \mu\text{g NO}_x\cdot\text{m}^{-3}$ at Topoľníky. This value is below the critical level for the protection of vegetation for the calendar year. Annual average concentrations of nitrogen dioxide and nitrates are presented in Tab. 3.20.

Nitrates and nitric acid are among the important nitrogen compounds in the atmosphere and contribute to the formation of secondary inorganic aerosol. In 2025, nitrates were again more prevalent in the gaseous than in the particulate form ($\text{NO}_3^-(\text{s})/\text{HNO}_3(\text{g})$) and accounted for 6.1% of total TSP at Chopok and 6.9% of PM_{10} at Starina.

Fig. 3.15 Average monthly concentrations of NO_x in the air.



■ Ammonia, ammonium ions and alkali metal ions

Detailed qualitative composition of ambient air in accordance with the EMEP monitoring strategy has been carried out since 2007 at the regional monitoring station Starina. Concentrations of ammonia, ammonium cations, sodium, potassium, calcium and magnesium ions are monitored in the air on a daily basis. The average concentrations of these components (NH_3 and NH_4^+ recalculated as nitrogen) are presented in Tab. 3.20. The annual concentration of ammonium ions was $0.26 \mu\text{g N}\cdot\text{m}^{-3}$, while the annual concentration of ammonia was $0.73 \mu\text{g N}\cdot\text{m}^{-3}$. Together with sodium, potassium, magnesium and calcium ions, they accounted for approximately 7.7% of the PM_{10} mass. Among the basic aerosol components, the ammonium ion was the most abundant; it is formed through the neutralisation of acidic sulphur and nitrogen compounds in the atmosphere.

■ Atmospheric aerosol and heavy metals

The concentrations of PM_{10} and TSP (measured at Chopok), as well as more detailed characteristics of particulate matter composition at EMEP stations, including the proportions of lead, copper, cadmium, nickel, chromium, zinc, arsenic, elemental carbon and organic carbon in PM_{10} /TSP for 2025, are presented in Tab. 3.21.

Tab. 3.21 Annual average concentrations of PM_{10} , TSP, OC/EC [$\mu\text{g}\cdot\text{m}^{-3}$] and heavy metals [$\text{ng}\cdot\text{m}^{-3}$] in ambient air.

	$\text{PM}_{10}/\text{TSP}^1$	Pb	Cu	Cd	Ni	Cr	Zn	As	OC/EC
Chopok ¹	7	0,67	0,59	0,03	0,65	0,62	8,24	0,10	-
Topoľníky	13	2,51	1,18	0,09	0,37	0,52	12,27	0,09	-
Starina	11	1,40	0,50	0,08	0,37	0,26	7,71	0,09	-
Stará Lesná	9	1,91	0,80	0,08	0,29	0,41	8,914	0,10	2,6/0,36

¹ TSP – total suspended particles, measured at Chopok; PM_{10} results are based on gravimetric determination.

■ Volatile organic compounds

Volatile organic compounds C₂–C₈ (so-called light hydrocarbons) have been sampled at the Starina station since 1994. The concentrations of individual compounds show different seasonal patterns throughout the year. Lower hydrocarbons (ethane, ethene, propane and propene) exhibit seasonal variation, with higher values occurring in winter. In contrast, the highest isoprene concentrations are measured during the summer months. This is due to the fact that isoprene is a chemical compound with biogenic emissions, produced by plants. Isoprene emissions increase with increasing temperature. Benzene and its derivatives do not show a seasonal pattern, and their concentrations remain constant throughout the year.

Tab. 3.22 Annual average concentrations of volatile organic compounds [ppb] at the EMEP Starina station.

ethane	ethene	ethyne	propane	propene	i-butane	butane
2.08	0.98	0.02	0.74	0.15	0.32	0.42
butene	pentane	pentene	hexane	isoprene	benzene	toluene
0.06	0.12	PDL	0.15	0.03	0.25	0.27

* BDL – below the detection limit of the analytical method.

3.4.2 Atmospheric precipitation

The chemical composition of atmospheric precipitation is regularly monitored not only at EMEP stations but also at the urban background station Bratislava, Jeséniova.

Tab. 3.23 Annual volume-weighted average concentrations of pollutants in atmospheric precipitation.

	precipitation [mm]	pH	conductivity [μS·cm ⁻¹]	SO ₄ ²⁻ [mg·l ⁻¹]	NO ₃ ⁻ [mg·l ⁻¹]	NH ₄ ⁺ [mg·l ⁻¹]	Cl ⁻ [mg·l ⁻¹]	Na ⁺ [mg·l ⁻¹]	K ⁺ [mg·l ⁻¹]	Mg ²⁺ [mg·l ⁻¹]	Ca ²⁺ [mg·l ⁻¹]
Chopok	1060	5,41	7,0	0,237	0,176	0,367	0,161	0,212	0,174	0,042	0,279
Topoľníky	400	5,65	10,4	0,303	0,246	0,592	0,173	0,279	0,169	0,069	0,498
Starina	376	5,23	8,6	0,300	0,307	0,560	0,238	0,196	0,466	0,070	0,401
Stará Lesná	423	5,28	7,9	0,233	0,184	0,387	0,186	0,166	0,180	0,044	0,334
BA, Jeséniova	606	5,59	10,8	0,338	0,318	0,487	0,178	0,236	0,246	0,078	0,557

SO₄²⁻ – recalculated as sulphur, NO₃⁻, NH₄⁺ – recalculated as nitrogen.

■ Main ions, pH, conductivity

In 2025, the annual average precipitation amount recorded at regional stations was within the standard range compared with previous years.

The precipitation water reaction (pH) was slightly acidic at all EMEP stations. The measured pH values showed very low variability across all stations. The highest pH value of 5.65 was measured at Topoľníky, indicating neutralisation of acidity by alkaline substances and the influence of emissions from anthropogenic sources. In Bratislava, the pH reached 5.59, corresponding to an increased load in an urbanised area (Tab. 3.23, Fig. 3.15).

Electrical conductivity of atmospheric precipitation, as an indicator of the total content of dissolved ions, was highest at Topoľníky (10.4 μS·cm⁻¹), a location with more intensive agricultural land use. Outside the EMEP sites, the highest conductivity was recorded in Bratislava (10.8 μS·cm⁻¹), corresponding to a high degree of urbanisation. In contrast, the lowest conductivity was measured at Chopok (7.0 μS·cm⁻¹), where low ion concentrations typical of a less polluted mountain environment are observed.

Sulphates (SO_4^{2-}) and nitrates (NO_3^-), the main inorganic acidic components, showed the lowest concentrations at Chopok, with values of $0.237 \text{ mg}\cdot\text{l}^{-1}$ and $0.176 \text{ mg}\cdot\text{l}^{-1}$, respectively. Their highest values at EMEP stations were recorded at Topoľníky for sulphates ($0.303 \text{ mg}\cdot\text{l}^{-1}$) and at Starina for nitrates ($0.307 \text{ mg}\cdot\text{l}^{-1}$), as well as in Bratislava, where anthropogenic influence is higher (transport, fuel combustion and agriculture) (Tab. 3.23, Fig. 3.16).

Ammonium ions (NH_4^+), which contribute to the neutralisation of acidic components, reached the highest concentration at Topoľníky ($0.592 \text{ mg}\cdot\text{l}^{-1}$), corresponding to the more intensive agricultural use of the surrounding area. At Chopok, their concentration was $0.367 \text{ mg}\cdot\text{l}^{-1}$, representing the lowest value among the monitored sites, but higher than in previous years.

Basic cations, particularly calcium (Ca^{2+}) and magnesium (Mg^{2+}), which neutralise acidic components, showed the highest Ca^{2+} concentrations at Topoľníky ($0.498 \text{ mg}\cdot\text{l}^{-1}$) and Bratislava ($0.557 \text{ mg}\cdot\text{l}^{-1}$). Mg^{2+} concentrations were relatively low at all locations compared with previous years.

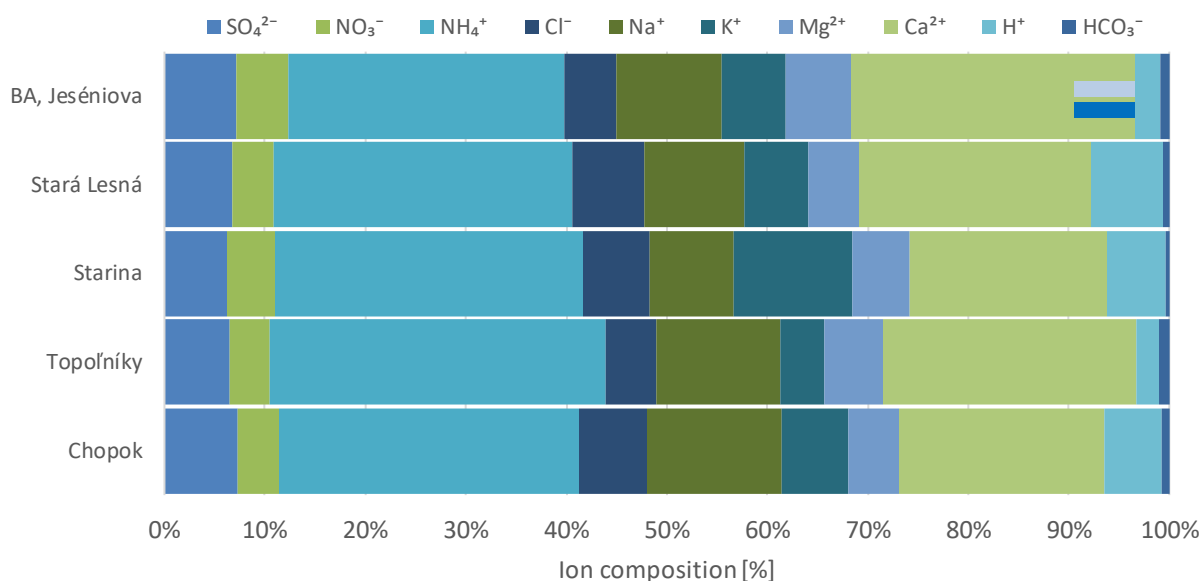
In 2025, higher potassium (K^+) concentrations were recorded mainly at Starina ($0.466 \text{ mg}\cdot\text{l}^{-1}$). Potassium is considered an indicator of biomass combustion, but it can also originate from resuspended soil material and vegetation.

Chlorides (Cl^-) and sodium (Na^+) are natural components of atmospheric deposition. Their main source is the long-range transport of aerosol particles; however, local sources and resuspended dust may also contribute to their concentrations. The highest average Cl^- concentrations were recorded at Starina ($0.238 \text{ mg}\cdot\text{l}^{-1}$), while the highest Na^+ concentrations were measured at Topoľníky ($0.279 \text{ mg}\cdot\text{l}^{-1}$) and Bratislava ($0.236 \text{ mg}\cdot\text{l}^{-1}$).

The relative equivalent ratios of ions in precipitation show that ammonium ions together with Ca^{2+} formed the dominant part of the cation component, while sulphates and nitrates dominated among the anions. Compared with acidic components, sufficient concentrations of neutralising cations were present at all locations, which was reflected in pH values above 5.

When interpreting relative equivalent ion ratios, it is necessary to consider that H^+ values and derived HCO_3^- concentrations were calculated from pH measurements, which were not available for all precipitation samples. Therefore, the ion balance may not be completely closed, and the resulting ratios represent an indicative assessment of the chemical composition of precipitation.

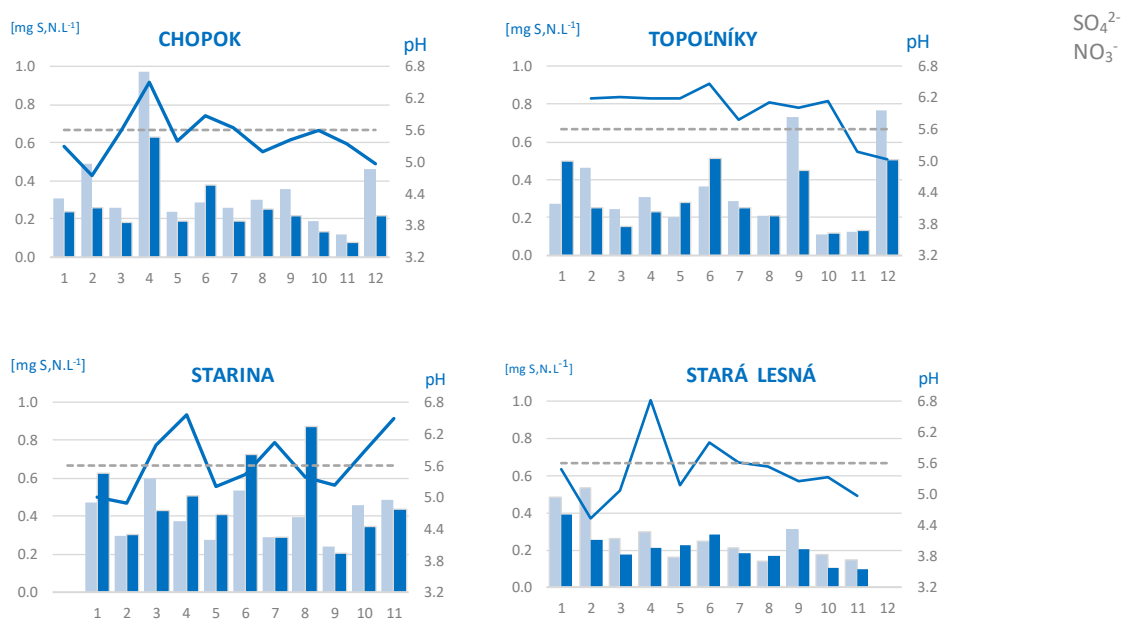
Fig. 3.16 Relative equivalent ratios of the main ions in precipitation (%).



■ Heavy metals in atmospheric precipitation

Monitoring of heavy metals in precipitation in Slovakia is carried out in accordance with the CCC EMEP (Chemical Coordinating Centre of EMEP) monitoring strategy. At first-level stations, the following heavy metals are monitored: lead (Pb), copper (Cu), cadmium (Cd), nickel (Ni), chromium (Cr), zinc (Zn) and arsenic (As). The same monitoring scope is applied at the Bratislava, Jeséniova station.

Fig. 3.17 Concentrations of sulphates and nitrates in atmospheric precipitation.



The results of annual volume-weighted average concentrations of heavy metals in atmospheric precipitation for 2025 are presented in [Tab. 3.24](#). The development of lead concentrations in precipitation indicates a decreasing trend continuing after 2020, which is related to the gradual

reduction of emissions from industry and energy production, including the reduction or closure of significant sources such as the Vojany and Nováky thermal power plants. A more pronounced decrease in concentrations has been observed particularly since 2023. In 2025, lead concentrations were low at all monitored stations (0.32–0.89 $\mu\text{g}\cdot\text{l}^{-1}$).

Zinc concentrations in precipitation show significant year-to-year variability. In 2025, concentrations increased at most monitored locations compared with the previous year. The highest values were recorded at Chopok (46.9 $\mu\text{g}\cdot\text{l}^{-1}$) and Starina (42.5 $\mu\text{g}\cdot\text{l}^{-1}$). These are among the highest concentrations observed in the last decade; in the long term, the highest zinc concentrations have mainly been recorded at the Chopok and Starina stations. A slight increase was also observed in nickel concentrations. The highest value was recorded at the Starina station (1.29 $\mu\text{g}\cdot\text{l}^{-1}$), which has long ranked among the locations with higher nickel concentrations in precipitation.

In 2025, the highest copper concentration in precipitation was recorded at the Bratislava, Jeséniova station (3.34 $\mu\text{g}\cdot\text{l}^{-1}$). Compared with the previous two years, this represents a significant increase. Elevated copper concentrations in urban environments are often associated mainly with traffic emissions, particularly brake system wear, as well as with other anthropogenic sources within the agglomeration (Tab. 3.24).

Tab. 3.24 Annual volume-weighted average concentrations of heavy metals in atmospheric precipitation.

	Precipitation [mm]	Pb [$\mu\text{g}\cdot\text{l}^{-1}$]	Cd [$\mu\text{g}\cdot\text{l}^{-1}$]	Cr [$\mu\text{g}\cdot\text{l}^{-1}$]	As [$\mu\text{g}\cdot\text{l}^{-1}$]	Cu [$\mu\text{g}\cdot\text{l}^{-1}$]	Zn [$\mu\text{g}\cdot\text{l}^{-1}$]	Ni [$\mu\text{g}\cdot\text{l}^{-1}$]
Chopok	1003	0.55	0.03	0.16	0.07	1.34	46.9	0.55
Topoľníky	469	0.32	0.03	0.15	0.07	1.40	19.3	0.69
Starina	565	0.65	0.05	0.24	0.11	1.40	35.4	1.29
Stará Lesná	688	0.69	0.05	0.12	0.01	1.19	26.3	0.79
BA, Jeséniova	624	0.89	0.05	0.20	0.12	3.34	25.2	0.80

RESULTS OF MATHEMATICAL AIR QUALITY MODELLING

The Air Protection Act No. 146/2023 Coll. establishes procedures for the assessment and criteria of air quality in full compliance with EU directives and allows the assessment of air quality to be based not only on measurements from monitoring stations but also on mathematical modelling. The fundamental basis for air quality assessment in Slovakia is provided by the results of pollutant concentration measurements carried out by SHMÚ at NMSKO stations. In addition to measurements, mathematical modelling methods are used for the spatial assessment of air quality.

Air quality assessment calculations using mathematical modelling were carried out using modified versions of the RIO and CMAQ models. These models have been used for air quality assessment since 2020, and their outputs have been regularly presented in Air Quality Reports since then.

4.1 Brief characterisation of the models used

■ Chemical transport model CMAQ v5.3

The Community Multiscale Air Quality Modeling System (CMAQ) modelling system is developed and supported by the EPA National Exposure Research Laboratory at the Research Triangle Park, NC development centre. CMAQ represents a third-generation air quality model, meaning that it is capable of modelling multiple pollutants simultaneously over large spatial scales, including areas covering entire continents. It is a three-dimensional Eulerian chemical transport model used to simulate ozone, atmospheric aerosols (PM), sulphur oxides, nitrogen oxides and other pollutants in the troposphere. Mathematically, CMAQ calculates changes in pollutant concentrations over time for each grid cell using the continuity equation. These concentration changes include processes such as emissions, advection, diffusion, chemical transformations of pollutants, and removal processes from the atmosphere, including dry and wet deposition to the Earth's surface. For air quality assessment, a simulation was performed with a horizontal resolution of 2×2 km using meteorological data from the ALADIN model. The model computational domain covers the area of Central Europe.

■ Interpolation-regression model RIO

The RIO model is an advanced interpolation-regression model. Its inputs are measured concentrations and various auxiliary spatial fields that are related to the spatial distribution of a given pollutant, such as elevation maps, traffic intensity, ventilation index, and gridded emissions from local heating sources. The set of these so-called drivers is specific to each pollutant. Spatial drivers may also include model results, for example from the CMAQ model, satellite observations, etc. Using the RIO model, higher spatial resolution concentration fields can be obtained. In the first step of the calculation, the model determines the spatial correlations between the given pollutant and individual potential spatial drivers at the locations of monitoring stations. In the next step, it optimises the so-called β parameter, which is obtained by combining selected spatial drivers that show the strongest correlation with the spatial distribution of the pollutant. The model calculates the β parameter that provides the best correlation with measured data. The differences between the values calculated using the β parameter at monitoring station locations and the actual measurements are then interpolated using the ordinary kriging method. These interpolated residuals are subsequently added to the values calculated using the β parameter for each grid point. For air quality assessment using the RIO model, a spatial resolution of 1×1 km was used.

■ IDW-R

The RIO interpolation model belongs to the group of so-called approximating interpolation methods, which means that it smooths the concentration field and does not necessarily reproduce the measured concentration values at monitoring station locations. Therefore, the outputs of the RIO or CMAQ models are further adjusted using the IDW-R (inverse distance weighting – regression) technique. In the first step of IDW-R, a linear regression curve is calculated between the measured data and the model outputs. In the second step, a standard IDW interpolation of the differences between the measured data and the values calculated using linear regression is performed, resulting in a 2D map of interpolated differences. This map is multiplied by rescaled input data with values ranging from 0 to 1 and subsequently added to the values calculated by regression. The technique can be repeated several times consecutively, with improving statistical indicators. For the final comparison of the model results with measurements, the root mean square error (RMSE) and systematic error (BIAS) were used.

4.2 RESULTS AND OUTPUTS

■ PM₁₀ modelling

The dominant source of PM₁₀ emissions is residential heating, particularly the use of solid fuels, which accounted for approximately 48% of total PM₁₀ emissions according to the reported data from the latest reporting year 2024. Another significant source is agriculture, contributing approximately 21% of total PM₁₀ emissions. Large and medium-sized industrial sources and energy production account for around 10% of PM₁₀ emissions, while waste combustion and waste handling contribute approximately 6%. Road transport represents around 10% of PM₁₀ emissions; nevertheless, its impact on air quality near heavily trafficked roads is not negligible.

The issue of PM modelling using chemical transport or dispersion models is complicated by the significant, although time-limited, influence of activities whose emissions are difficult to quantify and localise in space and time. These include, for example, construction and demolition activities, agricultural operations such as ploughing and harvesting, and illegal burning of agricultural residues and waste. The spatial distribution of PM₁₀ concentrations in Slovakia was calculated using the RIO model.

Auxiliary spatial data included outputs from the AtmoStreet Gaussian model (18%), the ventilation index from the ALADIN model with 1 km resolution (14%), and elevation data (68%). After subsequent adjustment of the results using the IDW-R method and comparison with measurements, RMSE = 0.3 $\mu\text{g}\cdot\text{m}^{-3}$ and BIAS = 0.0 $\mu\text{g}\cdot\text{m}^{-3}$ were obtained.

The resulting annual average PM₁₀ concentrations are shown in [Fig. 4.1](#). As can be seen, the limit value for the annual average concentration (40 $\mu\text{g}\cdot\text{m}^{-3}$) was not exceeded anywhere within the spatial resolution of the model. The highest PM₁₀ concentrations occur in valleys of central and north-western Slovakia, the Gemer, Šariš and Spiš regions, and in the vicinity of Košice.

[Fig. 4.2](#) shows the number of days during which the daily average limit value for PM₁₀ concentrations of 50 $\mu\text{g}\cdot\text{m}^{-3}$ was exceeded. This value must not be exceeded on more than 35 days per year. According to the modelling results, this requirement may not be met in valleys and basins in Gemer, around Jelšava and Rožňava, in the vicinity of Veľká Ida, in southern Slovakia around Plášťovce, and in smaller valley areas of north-western and central Slovakia, particularly Orava and Lower Liptov. Higher numbers of exceedances generally occur in poorly ventilated basin areas of Slovakia with a high share of solid fuels used for local heating.

Fig. 4.1 Annual average concentrations of PM_{10} [$\mu\text{g}\cdot\text{m}^{-3}$].

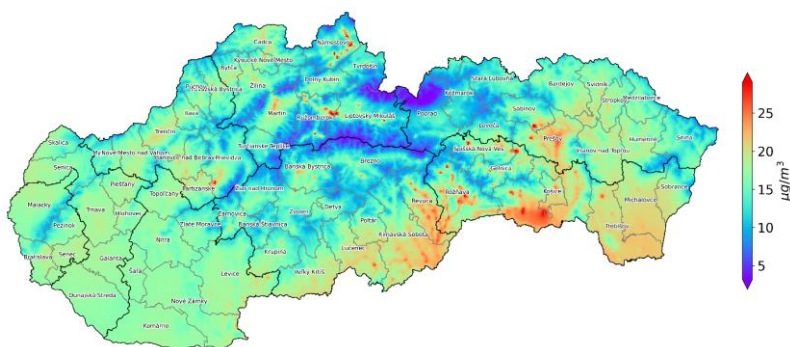
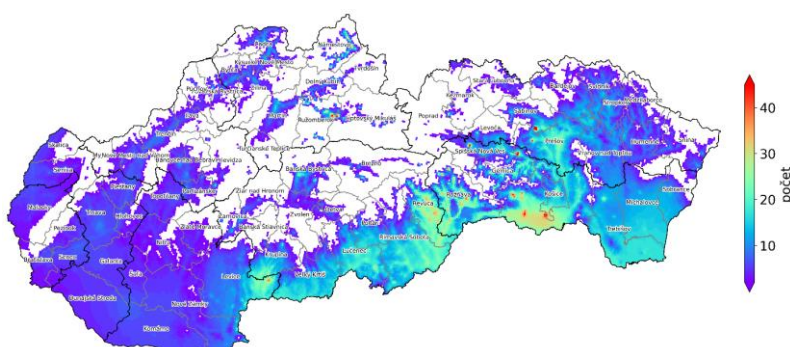


Fig. 4.2 Number of days with exceedances of the limit value for the 24-hour PM_{10} concentration [$\mu\text{g}\cdot\text{m}^{-3}$]. Only areas with a non-zero number of exceedances are shown.



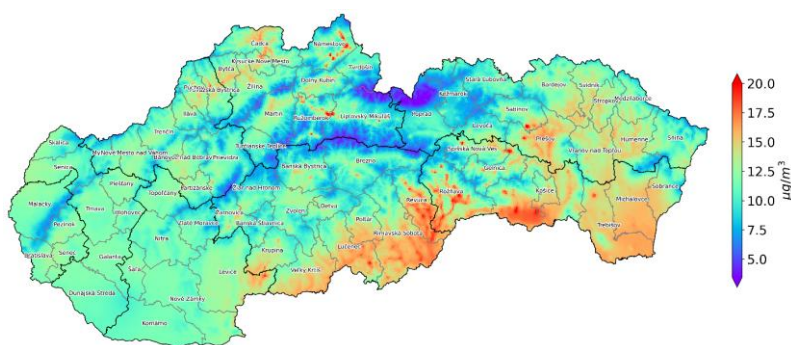
■ $PM_{2,5}$ modelling

The dominant source of $PM_{2,5}$ emissions is residential heating, mainly the use of solid fuels, which accounts for 67% of total $PM_{2,5}$ emissions according to officially reported data. More than 9% of $PM_{2,5}$ emissions originate from transport, while significant contributions also come from waste combustion and waste management (8%) and large and medium-sized industrial sources and energy production (8%).

The spatial distribution of $PM_{2,5}$ concentrations in Slovakia was calculated using the RIO model. Auxiliary spatial data included outputs from the AtmoStreet model (14%), the ventilation index (23%), and elevation data (63%). After subsequent adjustment of the RIO model output using the IDW-R method, comparison with measurements resulted in $RMSE = 0.1 \mu\text{g}\cdot\text{m}^{-3}$ and $BIAS = 0.0 \mu\text{g}\cdot\text{m}^{-3}$.

The resulting annual average $PM_{2,5}$ concentrations are shown in Fig. 4.3. The annual average limit value of $20 \mu\text{g}\cdot\text{m}^{-3}$ was not exceeded in 2025 at this spatial resolution. According to the modelling results, the highest $PM_{2,5}$ concentrations occurred in the valleys of the Gemer region, around Veľká Ida in the Abov region, in the vicinity of Prešov, Orava, Kysuce and Lower Liptov. As in the case of PM_{10} , the highest concentrations are found in locations with a high number of local solid-fuel heating sources, particularly in enclosed mountain valleys.

Fig. 4.3 Annual average concentrations of $PM_{2,5}$ [$\mu\text{g}\cdot\text{m}^{-3}$] in 2025.



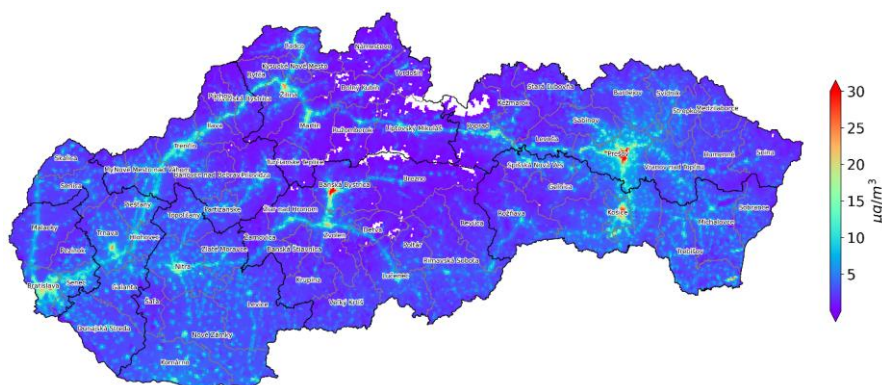
■ NO₂ modelling

Although road transport contributes approximately 33% of total NO_x emissions, the impact of road traffic near heavily trafficked roads on NO₂ concentrations is significantly greater than the influence of other source types. Emissions from other sources, released through chimneys at higher elevations, are effectively dispersed under typical meteorological conditions.

The spatial distribution of NO₂ concentrations in Slovakia was calculated using the RIO model. The following auxiliary spatial data were used: outputs from the AtmoStreet traffic model (43%), 2 m air temperature from the ALADIN model with a 1 km horizontal resolution (13%), and land use data (44%). After subsequent adjustment of the model output using the IDW-R method and comparison with measurements, RMSE = 1 $\mu\text{g}\cdot\text{m}^{-3}$ and BIAS = 0.0 $\mu\text{g}\cdot\text{m}^{-3}$ were obtained.

The resulting annual average NO₂ concentrations are shown in Fig. 4.4. The highest concentrations occur in the vicinity of large cities, i.e. in areas with increased road traffic intensity. The figure shows that, at the spatial resolution applied, the annual average limit value (40 $\mu\text{g}\cdot\text{m}^{-3}$) was not exceeded in 2025. Similarly, the hourly average limit value (200 $\mu\text{g}\cdot\text{m}^{-3}$, which must not be exceeded more than 18 times per calendar year) was not exceeded according to either measured or modelled concentration values.

Fig. 4.4 Annual average concentrations of NO₂ [$\mu\text{g}\cdot\text{m}^{-3}$].



■ O₃ modelling

The spatial distribution of ozone concentrations in Slovakia was calculated using the RIO model, with auxiliary spatial fields consisting of outputs from the AtmoStreet model considering only traffic sources (36%) and elevation data (64%). After subsequent adjustment of the calculated concentrations using the IDW-R method and comparison with measurements, RMSE = 1.1 $\mu\text{g}\cdot\text{m}^{-3}$ and BIAS = 0.0 $\mu\text{g}\cdot\text{m}^{-3}$ were obtained. The resulting annual average ozone concentrations are shown in Fig. 4.5. Fig. 4.6 illustrates the number of days on which the average eight-hour concentration of ground-level ozone exceeded 120

$\mu\text{g}\cdot\text{m}^{-3}$ (i.e. the target value for the protection of human health), showing the average number of days over the period 2023–2025. (This average number of days must not exceed 25.) The figure shows that more than 25 exceedances in the average over the period 2023–2025 occur in high-altitude mountain areas and in western Slovakia. **Fig. 4.7** presents average AOT40 values for the protection of vegetation for the period 2021–2025 (according to the Decree of the Ministry of the Environment of the Slovak Republic No. 250/2023 Coll. on Air Quality). The target value of 18,000 is also exceeded in high-mountain locations and in western Slovakia.

Fig. 4.5 Annual average ozone concentrations [$\mu\text{g}\cdot\text{m}^{-3}$].

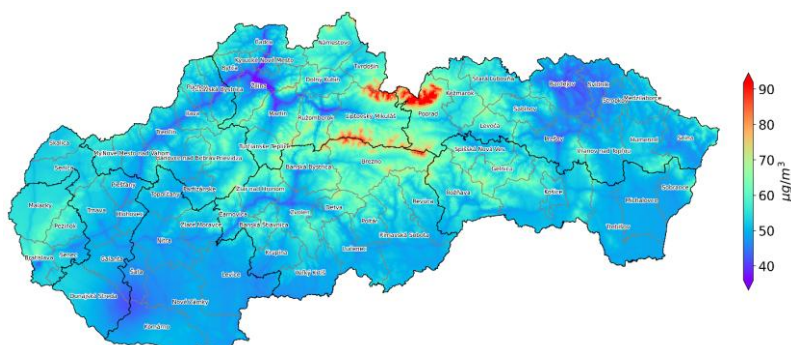


Fig. 4.6 Number of days on which the average eight-hour ground-level ozone concentration exceeded $120 \mu\text{g}\cdot\text{m}^{-3}$ (average over the years 2023–2025).

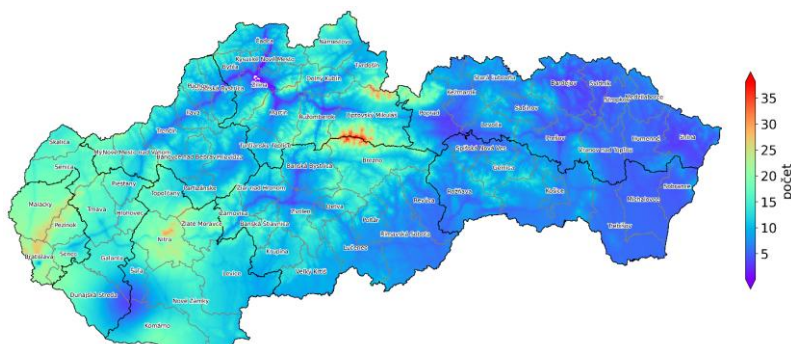
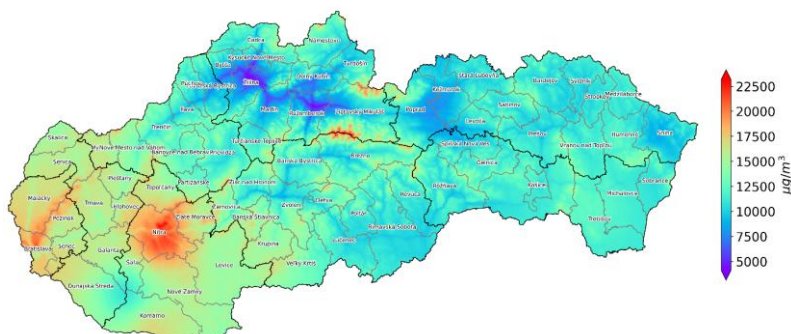


Fig. 4.7 Average AOT40 values over the five-year period (2021–2025).



Annual average ground-level ozone concentrations generally increase with altitude, which is caused by the penetration of stratospheric ozone into the upper layers of the troposphere. In 2025, similarly to previous years, the maximum values were measured at the highest-altitude locations, while the minimum values occurred at stations in city centres, where ozone is depleted by high concentrations of NO. Elevated ozone values are also observed in the peripheral areas of larger urban agglomerations and in industrial zones, where ozone is formed mainly through photochemical reactions involving nitrogen oxides, VOCs and CO. For a more detailed assessment of the spatial distribution of tropospheric ozone, it would be necessary to apply a high-resolution chemical transport model with reliable emission inputs for ozone precursors.

For improved model calibration, a denser monitoring network would be required, or a series of indicative measurements should be carried out to characterise various types of environments (locations directly influenced by road traffic, locations at different distances from urban centres or from ozone precursor sources). Therefore, the maps above do not represent the actual situation with sufficient accuracy.

■ SO₂ modelling

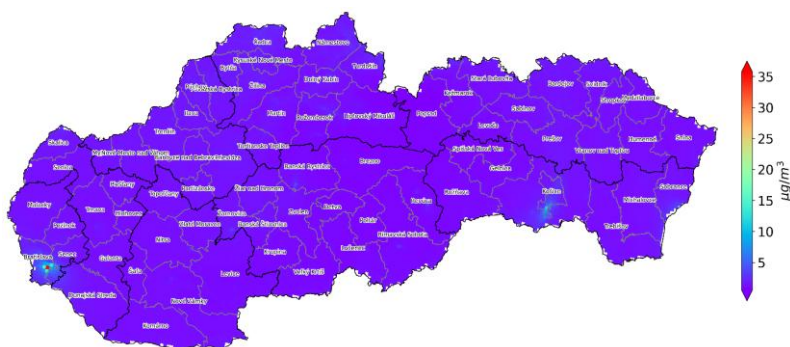
Unlike PM and benzo(a)pyrene, SO₂ emissions are mainly influenced by large industrial sources and the energy sector. High-stack sources (chimneys of industrial or energy facilities) currently contribute around 75% of total sulphur oxide emissions, while approximately 15% are fugitive emissions from industry. Residential heating accounts for around 8% of total emissions. Locally, the influence of small sources may be more pronounced in areas where coal is widely used for residential heating.

Sulphur oxide emissions show a significant decreasing trend. The latest reported emissions of 9.7 kt in 2024 are substantially lower than the 45.7 kt reported in 2014 (in 1990, reported emissions reached as much as 140 kt). The significant reduction over the last decade is associated with the reduction or closure of operations of two major historical SO₂ emission sources: the Slovalco, a.s. aluminium plant (Žiar nad Hronom) and the Nováky power plant.

The spatial distribution of SO₂ concentrations in Slovakia was calculated using the CMAQ model, using meteorological data from the ALADIN model. High-stack emission sources for the territory of Slovakia were obtained from the NEIS database (National Emission Information System). The calculation included SO₂ emissions from 892 of the most significant sources registered in the NEIS database. The most important SO₂ emission sources in 2025 were U. S. Steel Košice, s.r.o. and SLOVNAFT, a.s. (Bratislava).

The simulation also included SO₂ emissions from residential heating and road transport (which represent less than 1% of total SO₂ emissions). Outside the territory of Slovakia, emissions from the TNO-MAC III database were used. Another important characteristic required for air quality modelling is the seasonal variation of emissions throughout the year, which was determined according to the type and characteristics of the source (year-round operation, seasonal operation, energy production, residential heating, etc.). However, for large sources these changes are often sudden and substantial and cannot be reconstructed retrospectively with sufficient accuracy, which contributes to uncertainties in the modelled concentrations.

Fig. 4.8 Annual average concentrations of SO_2 [$\mu\text{g}\cdot\text{m}^{-3}$].



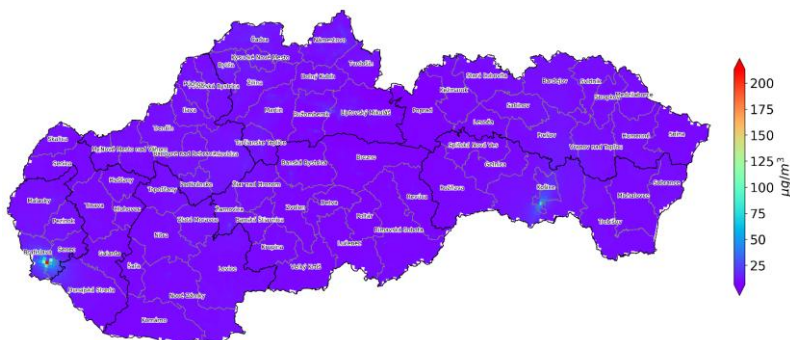
Measured annual average SO_2 concentrations have been low in recent years. At such low levels, the sensitivity threshold of SO_2 measuring devices (analysers) has been reached; therefore, for annual average SO_2 concentrations, the model is not calibrated against measured concentration values.

The resulting map of annual average SO_2 concentrations from modelling (**Fig. 4.8**) shows that the highest concentrations occur in locations directly affected by significant point sources. Higher concentrations are also found in areas where coal is still used for local heating, particularly in north-western Slovakia.

Hourly average SO_2 concentrations should not exceed $350 \mu\text{g}\cdot\text{m}^{-3}$ more than 24 times per calendar year. Therefore, the 99.7th percentile of hourly values is calculated (this percentile corresponds approximately to the 25th highest hourly concentration). Interestingly, in the case of the 99.7th hourly percentile, measurement results correlate relatively well with the CMAQ model results ($r = 0.77$). This suggests that measurements capture concentration maxima reasonably well.

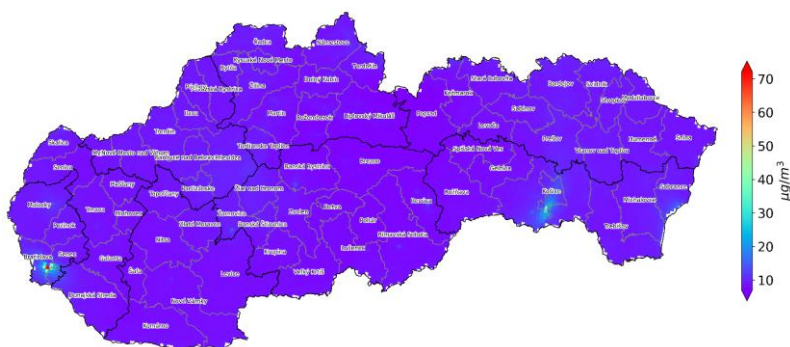
The SO_2 concentrations calculated by the CMAQ model were subsequently processed using the IDW-R method to achieve the best possible agreement with measurements ($\text{RMSE} = 3.1 \mu\text{g}\cdot\text{m}^{-3}$ and $\text{BIAS} = 0 \mu\text{g}\cdot\text{m}^{-3}$). The resulting 99.7th hourly percentile of SO_2 concentrations is shown in **Fig. 4.9**, indicating that the 25th highest hourly concentration was well below the limit value of $350 \mu\text{g}\cdot\text{m}^{-3}$.

Fig. 4.9 99,7 hour percentile [$\mu\text{g}\cdot\text{m}^{-3}$] of SO_2 concentrations.



The daily average SO_2 concentration should not exceed $125 \mu\text{g}\cdot\text{m}^{-3}$ more than three times in a calendar year. This is represented by the 99.2nd percentile of the daily average concentrations, which corresponds approximately to the fourth highest daily concentration. As in the previous case, the CMAQ model results were further processed using the IDW-R method ($\text{RMSE} = 2.4 \mu\text{g}\cdot\text{m}^{-3}$ and $\text{BIAS} = -0.3 \mu\text{g}\cdot\text{m}^{-3}$). The resulting 99.2nd percentile of the daily average SO_2 concentrations is shown in **Fig. 4.10**, demonstrating that the fourth highest daily average concentration remained well below the limit value of $125 \mu\text{g}\cdot\text{m}^{-3}$.

Fig. 4.10 99,2 percentile [$\mu\text{g}\cdot\text{m}^{-3}$] of average daily SO_2 concentrations.



■ CO modelling

The spatial distribution of CO concentrations in Slovakia was calculated using the CMAQ model, with meteorological data from the ALADIN model.

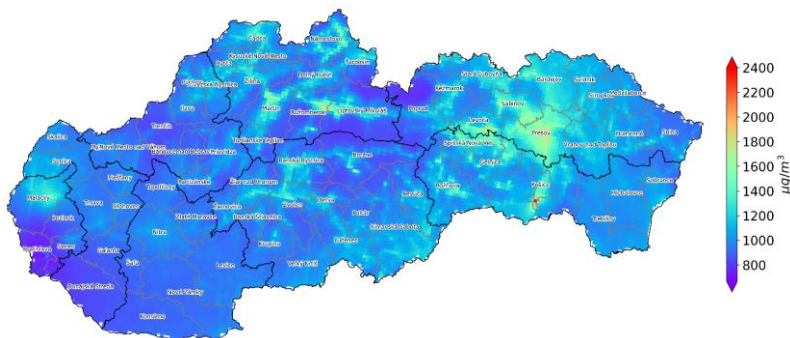
The most important sources of CO emissions are residential heating (approximately 41% of total emissions) and industrial point sources (more than 43% of total emissions). More than 1,200 of the most significant sources registered in the NEIS database were included in the calculation. The simulation also included emissions from road transport (approximately 20% of the total emission input) and agriculture (approximately 5% of the total emission input). Outside the territory of Slovakia, emissions from the TNO-MAC III database were used.

The maximum 8-hour rolling CO concentrations in 2025 shown in **Fig. 4.11** were obtained from the CMAQ model and subsequently processed using the IDW-R method. The limit value of $10,000 \mu\text{g}\cdot\text{m}^{-3}$ was not exceeded. Comparison of the model results with measurements yielded $\text{RMSE} = 108 \mu\text{g}\cdot\text{m}^{-3}$ and $\text{BIAS} = -2 \mu\text{g}\cdot\text{m}^{-3}$.

The figure shows that the highest CO concentrations occur in the vicinity of significant point sources, major roads and areas affected by local heating sources. Since CO is measured practically only at traffic and industrial stations, it is difficult to determine the true background concentration, also because CO is relatively chemically stable and remains in the atmosphere for a relatively long time.

This pollutant does not represent a problem in terms of exceedances of the limit value for the protection of human health.

Fig. 4.11 Maximum 8-hour rolling CO concentrations [$\mu\text{g}\cdot\text{m}^{-3}$].



■ Benzene modelling

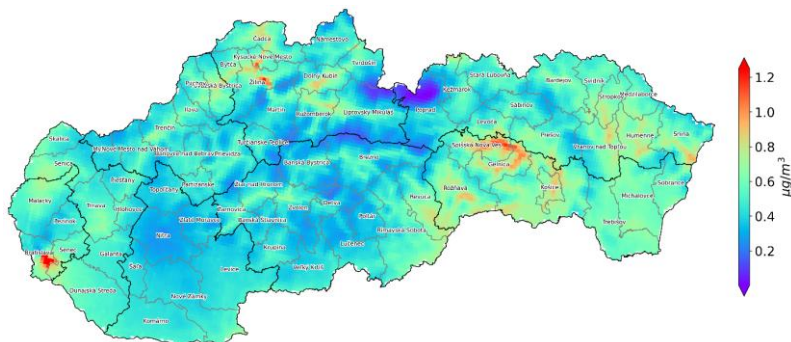
The spatial distribution of benzene concentrations in Slovakia was calculated using the CMAQ model, with meteorological inputs from the ALADIN model.

The largest contributions to the emission inputs for benzene modelling come from road transport (approximately 66%), residential heating (more than 19%) and industrial sources (more than 16%). The

most significant sources are SLOVNAFT, a.s. Bratislava and U. S. Steel Košice, s.r.o. Outside the territory of Slovakia, emissions from the TNO-MAC III database were used.

The annual average benzene concentrations in 2025 shown in Fig. 4.12 were obtained from the CMAQ model. Fig. 4.12 shows that the highest benzene concentrations occur in the vicinity of major roads, particularly in areas with unfavourable dispersion conditions, and in areas influenced by the two aforementioned industrial sources. Overall, however, benzene concentrations remain below the limit value of $5 \mu\text{g}\cdot\text{m}^{-3}$, even in the vicinity of the most significant emission sources.

Fig. 4.12 Annual average concentrations of benzene [$\mu\text{g}\cdot\text{m}^{-3}$].



■ Benzo(a)pyrene [B(a)P] modelling

The most significant source of B(a)P emissions, similarly to $\text{PM}_{2.5}$, is residential heating using solid fuels. According to the latest reported data from 2024, residential heating accounted for more than 70% of total B(a)P emissions, while waste combustion also represents an important source, contributing 19%. Among industrial sources, coke production has the most pronounced impact, as demonstrated by the high concentrations measured at the industrial monitoring station Veľká Ida, Letná. In 2025, this station again recorded the highest annual average B(a)P concentration among all monitoring stations in Slovakia, reaching $5.8 \text{ ng}\cdot\text{m}^{-3}$. It should be noted that this station is also located in a municipality with local heating sources.

Residential heating has a particularly strong impact on elevated B(a)P concentrations in mountain valleys with good availability of firewood, frequent unfavourable dispersion conditions and temperature inversions, especially during winter months. An example of a monitoring station located in such an area is Jelšava, Jesenského. The annual average B(a)P concentration at this station reached $2.4 \text{ ng}\cdot\text{m}^{-3}$ in 2025, while the target value is $1 \text{ ng}\cdot\text{m}^{-3}$.

For the assessment of spatial distribution, the RIO interpolation model and the IDW-R method were used, as the application of a chemical transport model for B(a)P is associated with substantial uncertainty in the spatial and temporal distribution of emissions. The situation is further complicated by complex chemical reactions that are still the subject of ongoing research. Due to the relatively small number of monitoring stations measuring this pollutant, performing a robust regression and interpolation using the RIO model is also challenging.

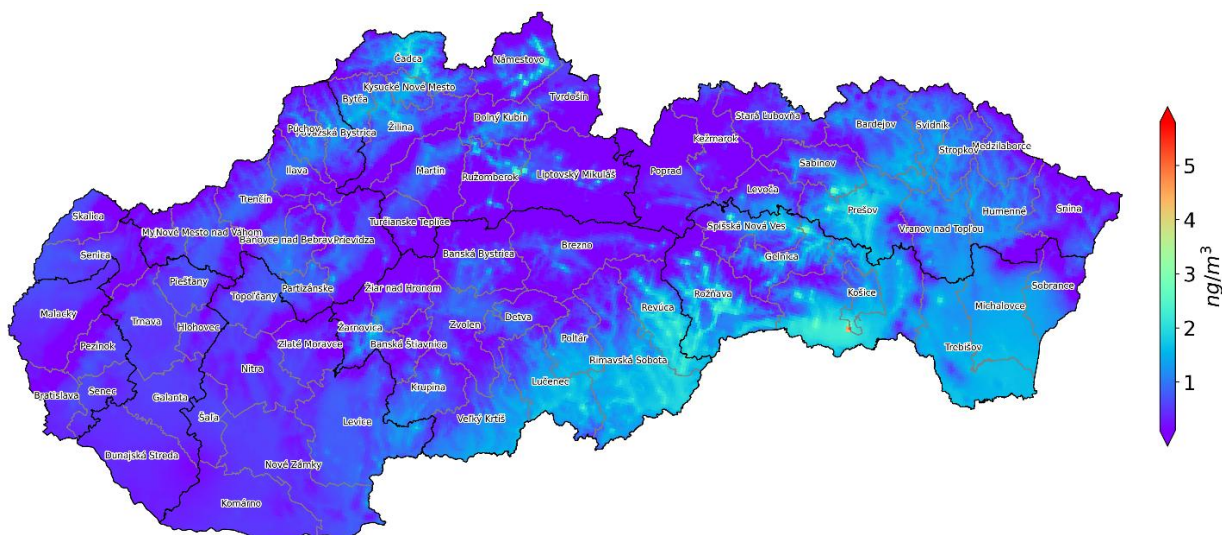
Since the correlation between measured B(a)P concentrations and the annual average $\text{PM}_{2.5}$ concentrations calculated at monitoring station locations using the combination of RIO and IDW-R is relatively high (correlation coefficient $r = 0.8$), the already calculated annual average $\text{PM}_{2.5}$ concentrations were used as input data for the IDW-R model. The resulting spatial distribution of annual average B(a)P concentrations across Slovakia is shown in Fig. 4.13.

Comparison with measurements resulted in $\text{RMSE} = 0.1 \text{ ng}\cdot\text{m}^{-3}$ and $\text{BIAS} = 0 \text{ ng}\cdot\text{m}^{-3}$. The target value for the annual average B(a)P concentration of $1 \text{ ng}\cdot\text{m}^{-3}$ was exceeded at many monitoring locations. The lowest concentrations were recorded at background stations Stará Lesná and Starina, as well as in towns

located in the Danubian Lowland. This pattern is also reflected in the modelling results, with the highest concentrations occurring in eastern Slovakia.

The model may overestimate B(a)P concentrations particularly in the vicinity of Košice, the East Slovak Lowland and the eastern part of the South Slovak Basin, because it is strongly influenced by the high annual average concentration measured at Veľká Ida. Together with Krompachy, Veľká Ida is one of only two stations in the Košice region where B(a)P is monitored.

Fig. 4.13 Annual average concentrations of benzo(a)pyrene [$\text{ng}\cdot\text{m}^{-3}$].



4.3 CONCLUSION

Mathematical models, regardless of their sophistication, represent only an approximation of reality, and their results are associated with a relatively high degree of uncertainty, which is strongly dependent on the quality of input data. The most important input data are meteorological fields and the spatial distribution of emissions. At present, for annual assessments, meteorological data can be considered considerably more reliable than emission data. Therefore, emission data can be regarded as the primary source of uncertainty in the outputs of mathematical air quality models.

Another factor that must be considered when assessing the spatial distribution of concentrations using regional-scale models is their spatial resolution. The models used in this analysis have a horizontal spatial resolution of 1 or 2 km. The calculated concentration should therefore represent the average concentration over an area of 1×1 km (or 2×2 km). However, within such an area, the spatial variability of concentrations is usually relatively large, particularly in built-up or human-influenced areas. A model with a resolution of 1×1 km therefore inevitably leads to smoothing of local maxima and overestimation of local minima. This is particularly relevant in areas with a high density of local heating sources or heavily trafficked roads within built-up areas, as these sources are located close to the ground surface and typically cause the strongest highly localised concentrations of PM and B(a)P.

For a more accurate representation of concentration distributions within individual cities and for identifying local maxima, high-resolution local models need to be applied. However, the accuracy of these models also strongly depends on the quality of input emission data, and their optimal use requires more detailed local emission inventories (local heating sources and traffic). Outputs from high-resolution local models are mainly used in air quality improvement programmes prepared for individual zones and agglomerations, including air quality management areas.

Similarly to previous years, the most significant air quality problems in 2025 were high concentrations of PM₁₀, PM_{2,5} and B(a)P, particularly during the colder part of the year (October–March). Residential heating using solid fuels has a substantial impact on these elevated concentrations. The most complicated situation occurs in mountain valleys, in areas with good availability of firewood and frequent unfavourable dispersion conditions, especially during the heating season. Financial constraints often prevent local residents from using natural gas for heating or purchasing modern low-emission heating appliances. This factor also contributes to reduced air quality in the above-mentioned areas.

PROPOSAL FOR THE DELINEATION OF AIR QUALITY MANAGEMENT AREAS IN 2026

It is the responsibility of SHMÚ, based on the assessment of air quality in zones and agglomerations for the period 2022–2025, in accordance with Section 8(3) of Act No. 146/2023 Coll. on Air Protection, as amended, to propose an update of the delineation of air quality management areas (AQMAs) in Slovakia for 2026.

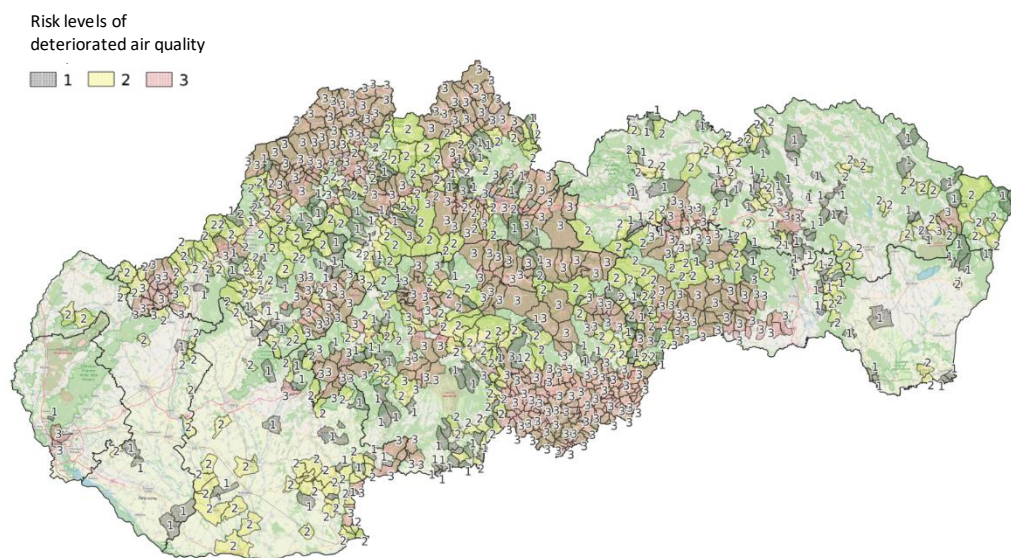
Monitoring results play a decisive role in air quality assessment. Since 2021, results of mathematical modelling have also been considered in the proposal for air quality management areas (AQMAs), as the complex terrain reduces the representativeness areas of individual monitoring stations and therefore it is not possible to cover the entire territory of Slovakia through measurements alone.

The methodology for identifying municipalities at risk of deteriorated air quality due to residential heating, based on the article *Determination of Risk Areas of Air Quality Threatened by PM₁₀ Particles from Local Heating in Slovakia*, was developed in 2021 and updated in 2022 using the results of the 2021 Population and Housing Census.

In 2023, the methodology was further updated based on the results of high-resolution modelling using the CALPUFF model in selected domains with a presumed risk of deteriorated air quality (Fig. 5.1).

Based on the assessment of the above-mentioned data sources according to the current methodology, municipalities are assigned risk levels from 0 to 3, where risk level 3 represents the highest risk of deteriorated air quality. Municipalities where exceedances of a limit value for any pollutant were identified either by high-resolution modelling or by measurements are automatically assigned risk level 3.

Fig. 5.1 Risk municipalities identified using the integrated assessment method for 2026.



Selected domains for high-resolution modelling are marked in black.

Zones and agglomerations containing at least one municipality with risk level 3 are required to prepare an Air Quality Improvement Programme. In this context, municipalities assigned risk level 3 correspond to air quality management areas (AQMAs). However, emission reduction measures must be

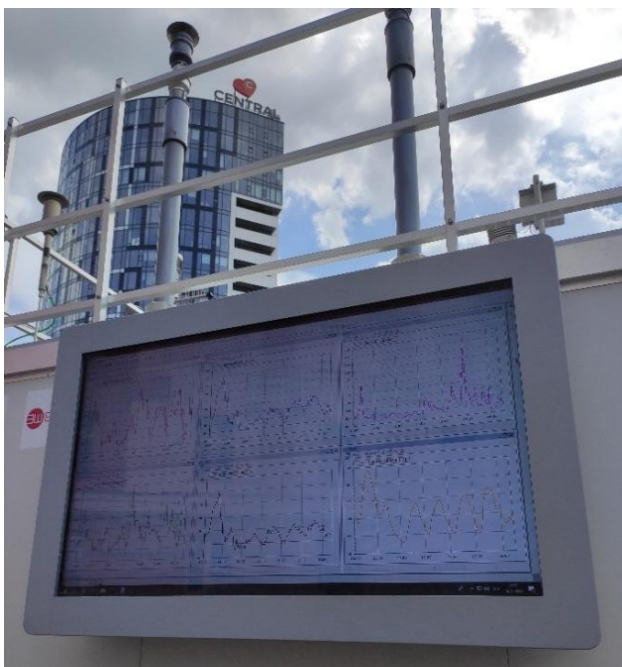
implemented within the designated zone in all municipalities with risk levels 2 or 3, and ideally also in municipalities with risk level 1.

Fig. 5.1 and the website contain the list of municipalities with assigned risk levels and the locations of domains where high-resolution air quality modelling was performed.

The list of risk municipalities will be updated if input data are refined, either at the national level or for individual regions or municipalities. Updates will be carried out at most once per year and at least once every five years. If necessary, the methodology itself may also be updated.

The currently proposed list of air quality management areas (AQMAs) remains unchanged compared with 2025.

SUMMARY



The assessment of air quality for 2025 confirms the continuation of the long-term trend of gradual improvement in most evaluated zones of Slovakia. In 2025, some of the lowest concentrations since the beginning of monitoring were recorded at several monitoring stations.

The Bratislava and Trnava regions continue to belong to areas with the most favourable long-term air quality, where limit values for most monitored pollutants have not been exceeded for many years and pollution levels show a decreasing trend. Positive development is also continuing in the Banská Bystrica region, where historically the lowest concentrations of particulate matter and benzo(a)pyrene were recorded at several monitoring stations in 2025. Nevertheless, the south-eastern part of the region remains among the areas with persistent air quality

problems caused mainly by residential heating.

In contrast, improvement is slower or stagnation is observed in some zones. In the Košice agglomeration, elevated concentrations of benzo(a)pyrene and particulate matter in the southern part of the agglomeration remain the most significant issue, with air quality strongly influenced by industrial activities. For PM_{10} concentrations, a rather stagnant trend was observed at most monitoring stations, while nitrogen dioxide concentrations at traffic monitoring stations continue to decrease over the long term.

Mathematical modelling provides valuable complementary information to the monitoring network and indicates that elevated concentrations of particulate matter and benzo(a)pyrene may also occur in locations outside the coverage of the monitoring network.

Despite the favourable development with regard to current legislation, meeting the requirements of the new European air quality directive will represent a significant challenge in all zones of Slovakia. The greatest difficulties can be expected in achieving the new limit values for $PM_{2,5}$ and, locally, also for nitrogen dioxide and benzo(a)pyrene. Further improvements in air quality will therefore require continued measures focused on the modernisation of residential heating systems, reduction of emissions from transport and industry, as well as support for measures in regions where improvements are hindered by unfavourable dispersion conditions and the socio-economic situation of the population.