

AIR QUALITY REPORT OF THE SLOVAK REPUBLIC

2025

ANNEX

AIR QUALITY ASSESSMENT IN THE BRATISLAVA AGGLOMERATION AND THE BRATISLAVA REGION ZONE

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1 DESCRIPTION OF THE BRATISLAVA AGGLOMERATION AND THE BRATISLAVA REGION ZONE IN TERMS OF AIR QUALITY

For the purposes of Air Quality Assessment, the territory of Slovakia is divided into zones and agglomerations. The the Bratislava Region comprises:

- **Bratislava agglomeration** – includes the territory of the capital city of the Slovak Republic, Bratislava;
- **Bratislava Region zone** – includes the Bratislava Region excluding the territory of the city of Bratislava.

According to data from the Statistical Office of the Slovak Republic, as of 31 December 2024, the Bratislava Region had the highest population density among all regions of Slovakia, at approximately **358 inhabitants per km²**. The highest population density is recorded in Bratislava I District, with approximately **4,954 inhabitants per km²**, whereas Malacky District has the lowest population density within the region, at approximately **84 inhabitants per km²**. The average population density in the Slovak Republic is approximately **105–117 inhabitants per km²**.

1.1 Bratislava Agglomeration

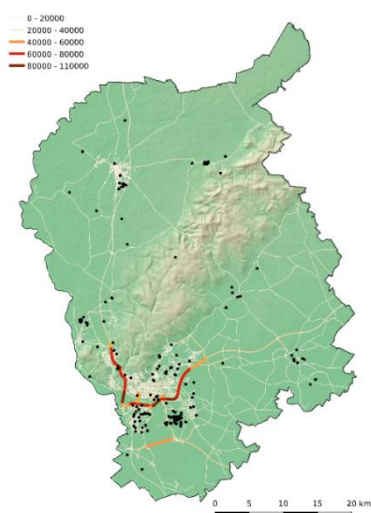
Bratislava is situated in a diverse terrain, with elevations ranging from 126 m a.s.l. (Čunovo) to 514 m a.s.l. (Devínska Kobyla). The Little Carpathians mountain range extends from the south-west to the north-east, with the western part of Bratislava lying within the Záhorie Lowland, while the eastern and south-eastern parts are located in the Danubian Lowland.

In the area of Devín Gate, which separates the Hainburg Hills and the Devín Carpathians, and in the Lamač Gate area between the Devín Carpathians and the Pezinok Carpathians, orographic conditions lead to increased wind speeds, which have a positive effect on the ventilation of the city. The River Danube flows through Bratislava and is used for inland waterway transport.

Air pollution sources in the Bratislava agglomeration

The dominant source of air pollution in the capital city is road transport (**Fig. 1.1**). Significant industrial emission sources in Bratislava also include the Slovnaft refinery, which is one of the largest point sources in the region. The busiest road sections in Bratislava, with the average number of vehicles per 24 hours based on the latest National Traffic Census conducted in 2022 and 2023, are as follows:

Fig. 1.1 Map of the busiest roads.



Tab. 1.1 Number of vehicles on the busiest roads in Bratislava (vehicle/day).

Motorway/ road	Number of vehicles	Heavy goods vehicles	Passenger cars
D1 JV obchvat BA II	101 407	18 284	82 817
D1 BA V. Incheba	74 008	15 154	58 639
D2 BA V. Lanfranconi	94 387	15 688	78 320
D4 obchvat Jarovce	20 127	3 533	16 533
n. 2 Patrónka vozidiel	40 395	3 694	36 293
n. 61 Bajkalská ulica	51 683	3 382	47 970
n. 572 Šancova ulica	34 466	3 444	30 744
R7 od prístavu na juh	42 722	5 098	37 487
n. 502 Račianska	26 074	1 512	24 165
n. 63 BA II	18434	1 784	16 650

1.2 Bratislava Region Zone

The Bratislava Region zone covers the area of the region excluding the Bratislava agglomeration. The Bratislava Region is the smallest region in terms of area among all regions of Slovakia. It includes the southern part of the Little Carpathians, the Záhorie Lowland and most of the Danubian Lowland. The elevation of the territory ranges from 126 m a.s.l. to 754 m a.s.l. (Vysoká Hill). The most populous towns are the district towns of Pezinok, Senec and Malacky. The average population density in Malacky District is significantly lower than in the other districts.

Air pollution sources in the Bratislava Region zone

A significant source of air emissions in the Bratislava Region is road transport, which is concentrated mainly along motorway routes. The busiest road sections in the region, with the average number of vehicles per 24 hours in individual districts, based on the latest National Traffic Census conducted in 2022 and 2023¹, are as follows:

Tab. 1.2 Number of vehicles on the busiest roads in Bratislava Region (vehicle/day).

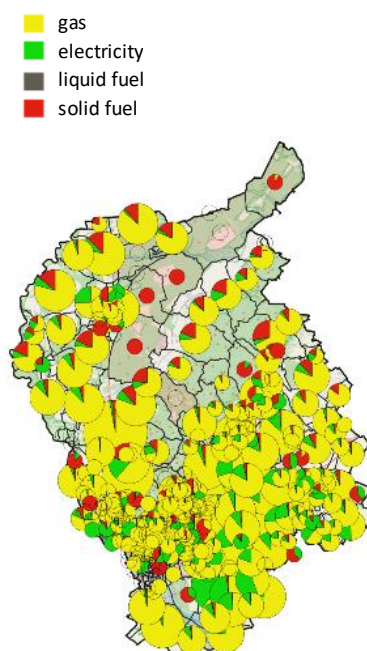
District	Motorway/ road	Number of vehicles	Heavy goods vehicles	Passenger cars
Malacky	D2 Malacky	32 452	13 002	19 350
	D4 Stupava	12 267	1 042	11 173
	n.2 Stupava	16 254	1 585	14 548
	n. 503 Malacky	16 420	1 345	14 997
	n. 2 Veľké Leváre	14 997	3 382	47 970
Senec	D1 Senec	59 067	8 968	49 958
	R7 Senec	21 236	2 883	18 286
	n. 503 Senec	19 126	2 760	16 247
	n. 62 Senec	15 556	3 137	12 323
	n. 63 Senec	14 904	1 456	13 273
Pezinok	n. 61 Senec	18 365	1 569	16 648
	502 Svätý Jur	19 439	1 727	17 428
	502 Pezinok	18 776	1 716	16 889

Industrial sources of air pollution, with the exception of cement plants (which may contribute mainly to increased concentrations of the coarse fraction of particulate matter), are of lesser importance in terms of local air pollution by basic pollutants.

Fig. 1.2 shows the shares of individual fuel types used for heating detached houses in municipalities (or basic settlement units) within the Bratislava Region.

The map indicates that the spatial distribution of fuel use is not geographically homogeneous – in many areas, heating with natural gas and electricity predominates. However, in the northern and north-eastern parts of the region, particularly in smaller and rural municipalities in the districts of Malacky and Pezinok, a higher share of solid fuel heating is evident. Overall, **natural gas heating was the predominant heating source in the Bratislava Region in 2021.**

Fig. 1.2 Distribution of Heating Fuels in Detached Houses in the Bratislava Region



2 AIR QUALITY MONITORING STATIONS IN THE BRATISLAVA AGGLOMERATION AND THE BRATISLAVA REGION ZONE

Tab. 2.1 and **Tab. 2.3** contain information on air quality monitoring stations in the Bratislava agglomeration and the Bratislava Region zone, including:

- the international Eol code, the characterisation of the station according to the dominant sources of air pollution (traffic, background, industrial), the type of area monitored by the respective 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 and benzene. The SHMÚ Testing Laboratory performs analyses of heavy metals and polycyclic aromatic hydrocarbons as part of manual monitoring. The results are reported as 24-hour average values.

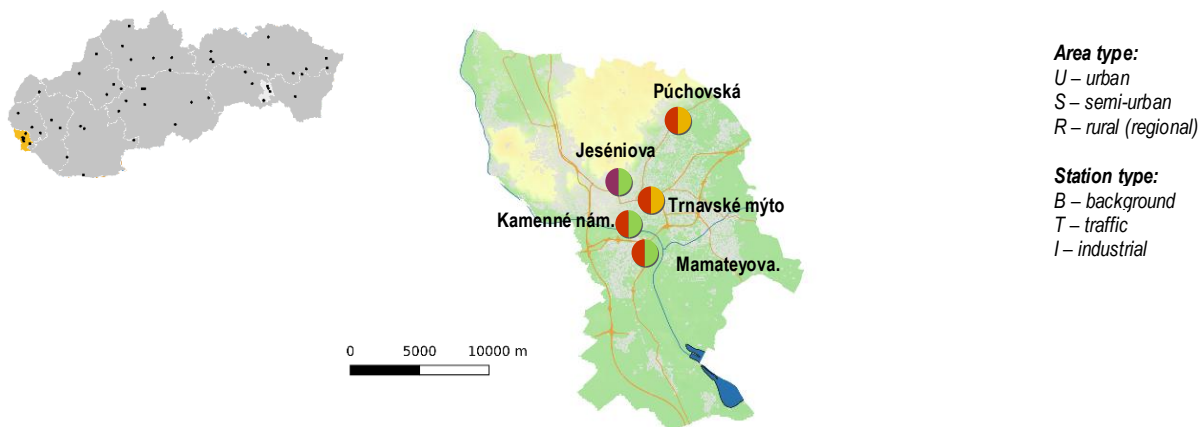
2.1 Bratislava Agglomeration

Air quality in Bratislava is monitored at five monitoring stations. Traffic monitoring stations are located at Trnavské mýto, which is an area characterised by high traffic intensity and a high concentration of pedestrians in the city, while another station is located in the **Rača district** on **Púchovská Street**.

Residential estate development is represented by the NMSKO station in Petržalka, located on Mamateyova Street. Other monitoring stations are situated in a residential area on Jeséniova Street in Koliba (monitoring background pollution levels in a suburban area) and directly in the city centre at Kamenné námestie (monitoring urban background levels).

Tab. 2.1 Air quality monitoring programme in the Bratislava agglomeration.

Agglomeration Bratislava								Monitoring programme									
District	Eol Code	Station name	Type		Geographical		altitude [m]	Continuous									
			area	station	length	width		PM ₁₀	PM _{2,5}	NO _x	SO ₂	O ₃	CO	Benzene	Hg	As, Cd, Ni, Pb	B(a)P
Bratislava I	SK0004A	Bratislava, Kamenné nám.	U	B	17°06'49"	48°08'41"	139										
Bratislava III	SK0002A	Bratislava, Trnavské mýto	U	T	17°07'44"	48°09'30"	136										
Bratislava III	SK0048A	Bratislava, Jeséniova	S	B	17°06'22"	48°10'05"	287										
Bratislava V	SK0001A	Bratislava, Mamateyova	U	B	17°07'31"	48°07'29"	138										
Bratislava III	SK0061A	Bratislava, Púchovská	U	T	17°09'29"	48°12'41"	145										
Total								5	5	4	3	2	2	2	0	1	3



At the Bratislava, Jeséniova monitoring station, precipitation quality is also analysed in addition to air quality monitoring. The monitoring programme of this station is presented in **Tab. 2.2**. The sampling period and sampling interval were two weeks.

Tab. 2.2 *Precipitation monitoring programme at the Bratislava, Jeséniova station.*

	pH	Conductivity	Sulphates (SO_4^{2-})	Nitrates (NO_3^-)	Chlorides (Cl^-)	Ammonium ions (NH_4^+)	Cations ($\text{K}^+, \text{Na}^+, \text{Ca}^{2+}, \text{Mg}^{2+}$)	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
Bratislava, Jeséniova	x	x	x	x	x	x	x	x	x	x	x	x	x	x

2.2 Bratislava Region Zone

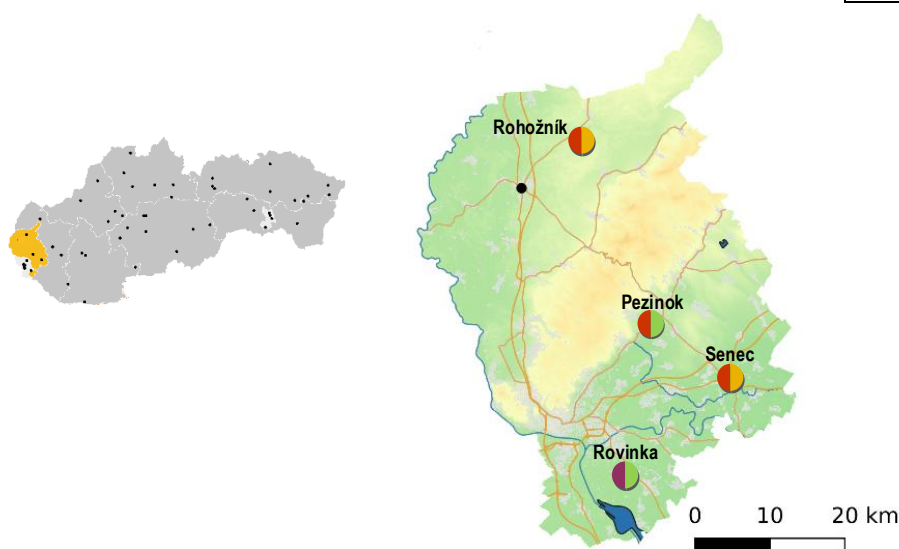
Air quality in the Bratislava Region zone (excluding the Bratislava agglomeration) is monitored at four NMSKO stations. The stations monitoring the impact of traffic are located in **Rohožník** and **Senec**. Both stations in these district towns are situated at traffic junctions with high levels of pedestrian movement.

Air pollution in residential areas outside the main transport routes is monitored by stations located in the district town of **Pezinok**, where the station is situated within a school grounds, and in the municipality of **Rovinka**. Air quality monitoring in this municipality is also carried out due to its proximity to the Slovnaft refinery.

Tab. 2.3 Air quality monitoring programme in Bratislava Region zone.

Bratislava Region zone (excluding Bratislava agglomeration)								Monitoring programme									
								Continuous								Manual	
District	Eol code	Station name	Type		Geographical		Altitude [m]	PM ₁₀	PM _{2,5}	NO, NO ₂	SO ₂	O ₃	CO	Benzene	Hg	As, Cd, Ni, Pb	B(a)P
			area	station	length	width											
Pezinok	SK0075A	Pezinok, Obrancov mieru.	U	B	17°15'35"	48°17'00"	150										
Rohožník	SK0077A	Rohožník, Senická cesta	U	T	17°10'17"	48°27'25"	201										
Rovinka	SK0076A	Rovinka*	S	B	17°13'50"	48°05'59"	129										
Senec	SK0068A	Senec, Boldocká	U	T	17°24'16"	48°13'23"	126										
Total								4	3	4	2	2	3	2	0	0	1

*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.



3 ASSESSMENT OF AIR QUALITY MONITORING RESULTS IN THE BRATISLAVA AGGLOMERATION AND THE BRATISLAVA REGION ZONE

This chapter provides an assessment of air quality in the Bratislava agglomeration and the Bratislava Region zone based on the results of monitoring carried out in 2025.

Tab. 3.1 Assessment of air pollution against limit values for the protection of human health and the PM₁₀ smog warning system in the Bratislava agglomeration and the Bratislava Region zone.

	Pollutant	Type	Protection of human health										IP ²⁾	VP ²⁾
			SO ₂		NO ₂		PM ₁₀		PM _{2,5}	CO	O ₃	Benzen e	PM ₁₀	PM ₁₀
	Averaging period	areas / stations	1 h	24 h	1 h	1 year	24 h	1 year	1 year	8 h ¹⁾	8 h ²⁾	1 year	12 h	12 h
	Parameter		number of exceedances	number of exceedances	number of exceedances	average	number of exceedances	average	average	average	average	average	duration of exceedance [h]	duration of exceedance [h]
	Limit value [µg·m ⁻³]		350	125	200	40	50	40	20	10 000	120	5	100	150
	Maximum number of exceedances		24	3	18		35							
BRATISLAVA	Bratislava, Kamenné nám.	UB					4	18	13				0	0
	Bratislava, Trnavské mýto	UT			0	28	6	20	13	731		0,4*	0	0
	Bratislava, Jeséniová	SB	0	0	0	7	4	17	11		27		0	0
	Bratislava, Mamateyova	UB	0	0	0	15	3	17	12		16		0	0
	Bratislava, Púchovská	UT	0	0	0	12	5	19	11	657			0	0
Bratislava Region	Pezinok, Obrancov mieru	UB			0	8	2	15	13		19		0	0
	Rohožník, Senická	UT	0	0	0	10	4	18	11	1476			0	0
	Senec, Boldocká	UT			0	16	5	19	11	1055	5		0	0

■ ≥ 90 % valid data

¹⁾ maximum 8-hour concentration

²⁾ IP, VP – duration of exceedance (in hours) of the information threshold (IP) and alert threshold (VP) for PM₁₀

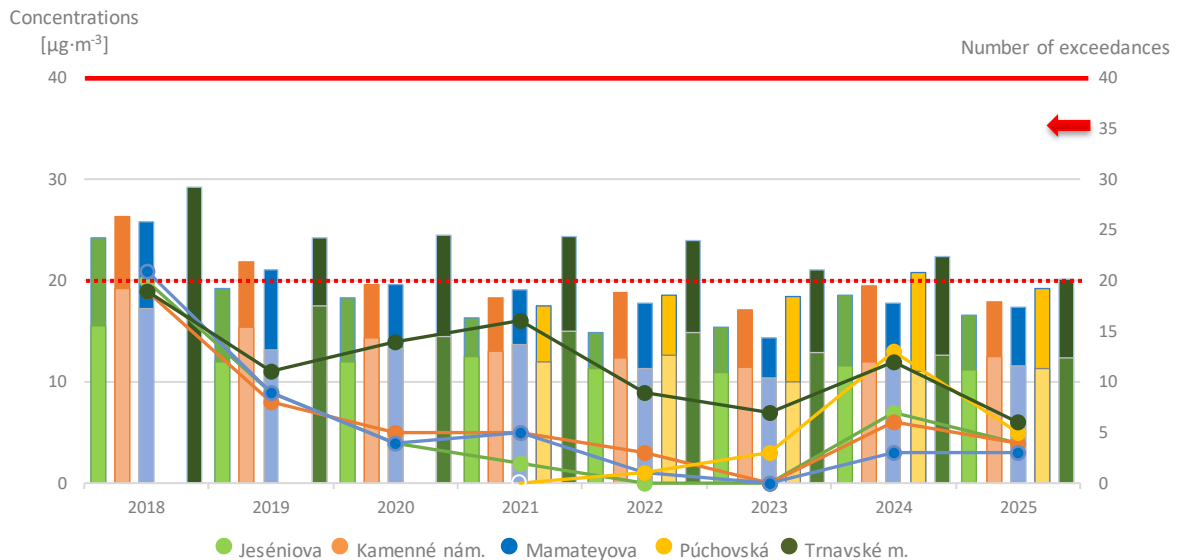
³⁾ Exceedance of the maximum daily 8-hour concentration of 120 µg·m⁻³, averaged over 3 calendar years

* output from the CMAQ model

3.1 Bratislava Agglomeration

3.1.1 PM₁₀ and PM_{2,5}

Fig. 3.1 Annual mean concentrations of PM₁₀ and PM_{2,5} and the number of exceedances of the PM₁₀ daily limit value.



PM₁₀ – dark-coloured bars, **PM_{2,5}** – light-coloured bars; number of exceedances – lines.

Red lines – annual limit values (LVs): **solid line** – PM₁₀ (40 µg·m⁻³); **dashed line** – PM_{2,5} (20 µg·m⁻³) and the new PM₁₀ LV.

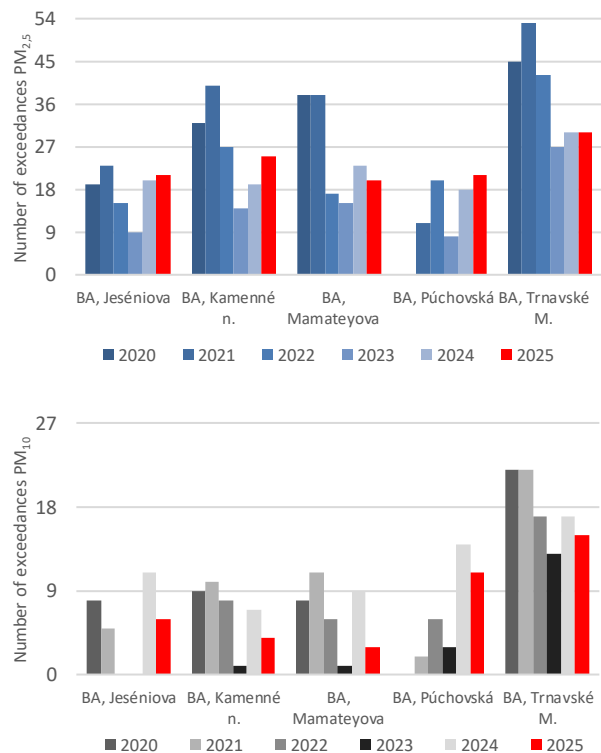
Red arrow – limit value for the number of exceedances (daily mean PM₁₀ concentration of 50 µg·m⁻³; maximum number of exceedances: 35 per calendar year).

Fig. 3.1 shows the annual mean concentrations of PM₁₀ and PM_{2,5} and the number of exceedances of the daily limit value (50 µg·m⁻³), based on measurement results from AMS in the Bratislava agglomeration during the period 2018–2025.

The limit values for the annual mean and daily mean concentrations of PM₁₀ and PM_{2,5} were not exceeded at any monitoring station in the Bratislava agglomeration.

The highest annual mean PM₁₀ concentration of 20 µg·m⁻³ was recorded at the traffic monitoring station Trnavské mýto. At the Púchovská traffic monitoring station, the annual mean concentration was 19 µg·m⁻³, representing a decrease of 2 µg·m⁻³ compared with 2024. The PM₁₀ pollution levels at urban background locations were lower in 2025 than in the

Fig. 3.2 Number of exceedances of the PM_{2,5} and PM₁₀ daily limit values applicable from 2030*



* The daily mean concentration of PM_{2,5} > 25 µg·m⁻³ and PM₁₀ > 45 µg·m⁻³ may be exceeded a maximum of 18 times per year; the limit value applies from 1 January 2030.

previous year. None of the monitoring stations exceeded the permitted number of exceedances (35) of the daily mean PM_{10} concentration ($50 \mu g \cdot m^{-3}$); the number of exceedances ranged from 3 to 6 (Fig. 3.1). The WHO recommendation (a maximum of 3–4 exceedances) would have been met only at the AMS on Mamateyova Street.

The Bratislava monitoring locations Jeséniova and Púchovská, situated near detached house areas, recorded fewer exceedances of the new $PM_{2,5}$ daily limit value compared with stations located in the wider city centre, despite the potential influence of local solid fuel heating, particularly occasional fireplace use.

The measurement results indicate that $PM_{2,5}$ concentrations in more densely urbanised locations (Kamenné námestie) are influenced to a greater extent by dust resuspension, construction activities and the overall level of urban dust. Therefore, measures aimed at reducing $PM_{2,5}$ concentrations should also focus on limiting dust emissions from construction activities, for example through thorough watering of construction sites and adjacent roads.

The highest number of exceedances was recorded at the Trnavské mýto traffic AMS, which is significantly affected by road transport and the resuspension of particles generated by brake and tyre wear.

Although the share of solid fuel heating in Bratislava is low, it may still have a negative impact on urban air quality during periods with unfavourable dispersion conditions.

■ Assessment of Compliance with the Requirements of the New Directive

As part of the European Green Deal, the European Union has developed a Zero Pollution Action Plan, which sets out a vision for 2050. Its objective is to reduce air pollution by that year to levels that are no longer considered harmful to human health and natural ecosystems. The Action Plan includes new EU limit values and target values for many pollutants. The greatest challenge for Slovakia will be achieving compliance with the limit values for $PM_{2,5}$. For $PM_{2,5}$, the Plan introduces a daily limit value of $25 \mu g \cdot m^{-3}$, which must not be exceeded more than 18 times per year (to be achieved by 1 January 2030).

The entire zone **would also comply with the stricter limits introduced by the new EU Directive** for the annual PM_{10} limit value ($20 \mu g \cdot m^{-3}$). However, **none** of the AMS would meet the annual $PM_{2,5}$ limit value ($10 \mu g \cdot m^{-3}$).

The graph in Fig. 3.2 shows exceedances of the new daily limit values for $PM_{2,5}$ and PM_{10} in 2025.

In the Bratislava agglomeration, the new $PM_{2,5}$ limit value would be **exceeded at all AMS**. The lowest number of exceedances was measured at the AMS Mamateyova (20 exceedances), while 30 exceedances were recorded at the AMS Trnavské mýto and 25 exceedances at the AMS Kamenné námestie.

All AMS would comply with the daily PM_{10} limit value.

In 2025, dispersion conditions were favourable and, for the first time during the assessment period, the entire agglomeration complied with the stricter PM_{10} limit values introduced by the new EU Directive 2024/2881, both for the annual and daily limit values.

Annual mean $PM_{2,5}$ concentrations at all monitoring stations ranged from 11 to $13 \mu g \cdot m^{-3}$, which is significantly below the current limit values; however, they still exceeded the stricter annual limit value introduced by the new Directive ($10 \mu g \cdot m^{-3}$). In addition, none of the automatic monitoring stations would meet the requirements of the $PM_{2,5}$ daily limit value applicable from 2030.

3.1.2 Nitrogen dioxide

Nitrogen dioxide monitoring is carried out at four stations in the Bratislava agglomeration. The annual limit value for NO₂ (40 µg·m⁻³) was not exceeded at any monitoring station.

At the Trnavské mýto traffic monitoring station, the second-highest annual mean NO₂ concentration in Slovakia was recorded again in 2025 (28 µg·m⁻³). This is related to the high traffic intensity at this location and the fact that road transport is the main source of NO₂ emissions.

Compared with the long-term average, NO₂ concentrations have gradually decreased (Fig. 3.3), with the most pronounced decline recorded at the AMS Trnavské mýto. At the Púchovská station, assessment of long-term trends is limited, as the available measurement series only dates back to 2021.

The box plots demonstrate a moderate seasonal pattern in NO₂ concentrations. The highest values were recorded at most stations during the winter months. The situation at the AMS Trnavské mýto was different, with the maximum concentration recorded in August (Fig. 3.4).

At the Jeséniova station, the annual mean NO₂ concentration was 7 µg·m⁻³, making it the only monitoring station in Bratislava to meet the WHO recommended guideline value for NO₂ (10 µg·m⁻³).

3.1.3 Ozone

Ozone monitoring in the capital city is carried out at two monitoring stations, Mamateyova and Jeséniova. The latter is located at a higher altitude in Koliba, at the foothills of the Malé Karpaty Mountains. Higher ozone concentrations are measured at this station compared with the Mamateyova station in Petržalka.

The box plots of O₃ concentrations show a typical seasonal pattern (Fig. 3.5), with an increase from spring onwards, maximum values during the summer period, and a decrease in autumn and winter. In 2025, the higher O₃ concentrations were also significantly influenced by an above-average number of sunshine hours, which promoted photochemical ozone formation. This effect was most pronounced at the BA Jeséniova station, which is not significantly affected by ozone titration by NO₂ from traffic emissions; the target value for the protection of human health was exceeded on 27 days at this location.

Fig. 3.3 Comparison of Annual NO₂ Concentrations with the Long-term Trend.

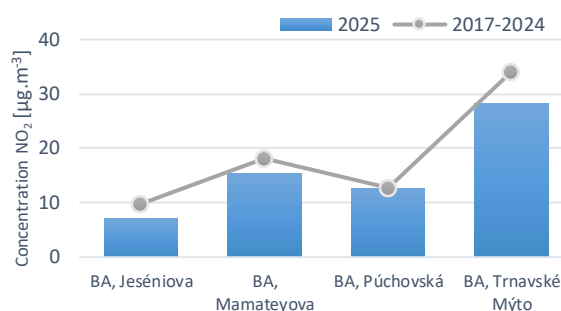


Fig. 3.4 Boxplots of daily NO₂ by months and AMS.

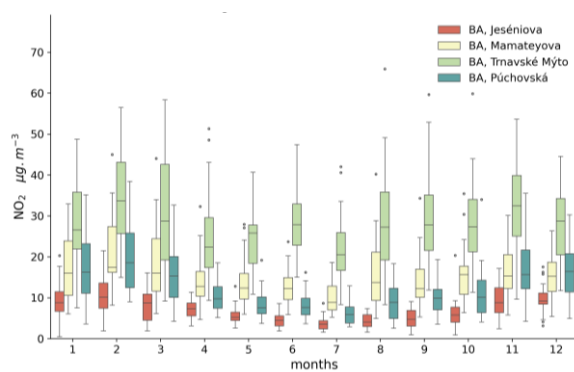
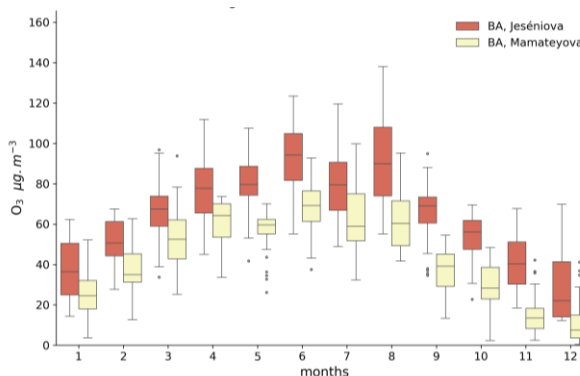


Fig. 3.5 Box plots of O₃ concentrations by months



The number of days with exceedances of the target value for ground-level ozone is presented in **Tab. 3.2**.

Tab. 3.2 Number of days with a maximum daily 8-hour mean O_3 concentration above $120 \mu\text{g}\cdot\text{m}^{-3}$

Station	2023	2024	2025	Average 2023 – 2025
Bratislava, Jeséniova	23	26	33	27
Bratislava, Mamateyova	18	18	16	19

■ $\geq 90\%$ required valid data

Exceedances of the target value are highlighted in red¹.

Ground-level O_3 is formed in the atmosphere in the presence of solar (UV-B) radiation through chemical reactions involving nitrogen oxides (NO and NO_2) and volatile organic compounds (VOCs) or carbon monoxide. The sources of nitrogen oxides are combustion processes; in urban agglomerations, the main source is road transport, while in the case of Bratislava the refinery also contributes. Sources of VOC emissions include transport, industrial sources and, during the vegetation period, plants.

The target value for the protection of human health for ozone was exceeded during the assessed period 2022–2025 in the Bratislava agglomeration at the Bratislava, Jeséniova monitoring station.

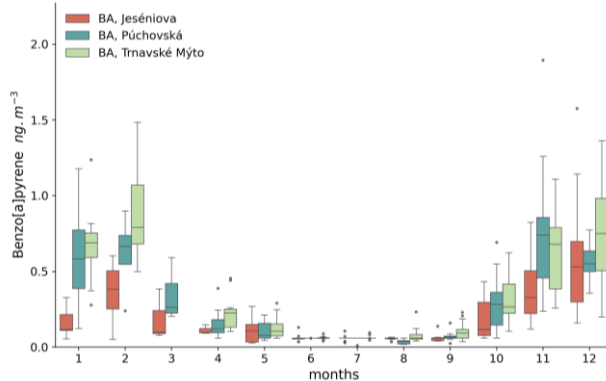
■ Assessment of Compliance with the Requirements of the New Directive

The target value for the protection of human health for ozone **would be exceeded** at both monitoring stations.

3.1.4 Benzo(a)pyrene

The pollutant benzo[a]pyrene is monitored at three monitoring stations in the Bratislava agglomeration – Jeséniova Street, Trnavské mýto and Púchovská Street (**Fig. 3.6**). None of the stations exceeded the target value for the annual mean concentration ($1 \text{ ng}\cdot\text{m}^{-3}$). Concentrations at all stations remained low, with a daily maximum value of $1.8 \text{ ng}\cdot\text{m}^{-3}$ recorded at the AMS Púchovská.

Fig. 3.6 Boxplots of B(a)P concentrations by months



Tab. 3.3 Annual mean concentrations of benzo(a)pyrene in years 2020 – 2025.

	2020	2021	2022	2023	2024	2025
Target value [$\text{ng}\cdot\text{m}^{-3}$]	1,0	1,0	1,0	1,0	1,0	1,0
Bratislava, Jeséniova	0,2	0,3	0,3	0,3*	0,2	0,2
Bratislava, Trnavské Mýto	0,5	0,5	0,5	0,3	0,5	0,3
Bratislava, Púchovská		0,9	0,4	0,4	0,4	0,3

■ $\geq 90\%$ valid data; * 60 % valid data

¹ Note: According to Decree of the Ministry of Environment of the Slovak Republic No. 250/2023 Coll. on Air Quality, the target value for the protection of human health for ground-level ozone is defined as follows: the maximum daily 8-hour mean concentration shall not exceed $120 \mu\text{g}\cdot\text{m}^{-3}$ on more than 25 days per calendar year, averaged over three years.

3.1.5 Chemical composition of precipitation

Precipitation quality in Bratislava is monitored at the Jeséniova station in Koliba. In 2025, precipitation amounts were unevenly distributed throughout the individual months. Below-average precipitation was recorded in February, March and April (data from the Jeséniova AMS), while above-average precipitation occurred during the autumn months.

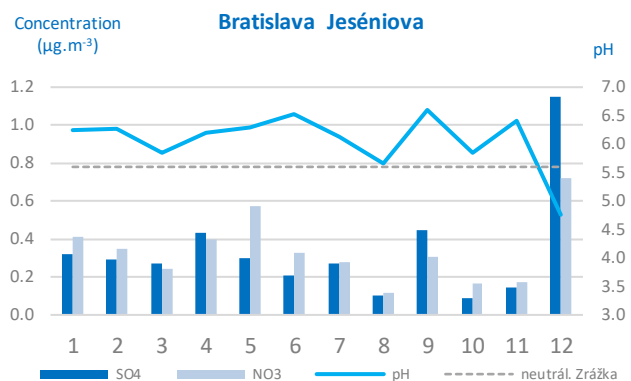
Throughout the year, with the exception of December, precipitation pH values were predominantly within the neutral to slightly alkaline range. In December, acidic precipitation was recorded, mainly associated with increased concentrations of sulphate ions in precipitation. The annual volume-weighted mean pH value of precipitation was 5.6 (Fig. 3.7)².

Ion concentrations in precipitation did not show a clear seasonal trend. Higher nitrate concentrations were recorded in May, while the highest overall concentrations occurred in December, which was also reflected in the pH value, indicating an acidic range.

Wet deposition of oxidised nitrogen in the form of NO_3^- -N reached 0.19 g N/m²/year, reduced nitrogen in the form of NH_4^+ -N reached 0.30 g N/m²/year, and sulphur in the form of SO_4^{2-} -S reached 0.21 g S/m²/year.

Wet deposition of lead was 5.6 g/ha/year. Detailed monitoring results are presented in *Chapter 3.4 Regional Monitoring of the Air Quality Report for 2025*.

Fig. 3.7 Monthly values of ion concentrations and pH in precipitation



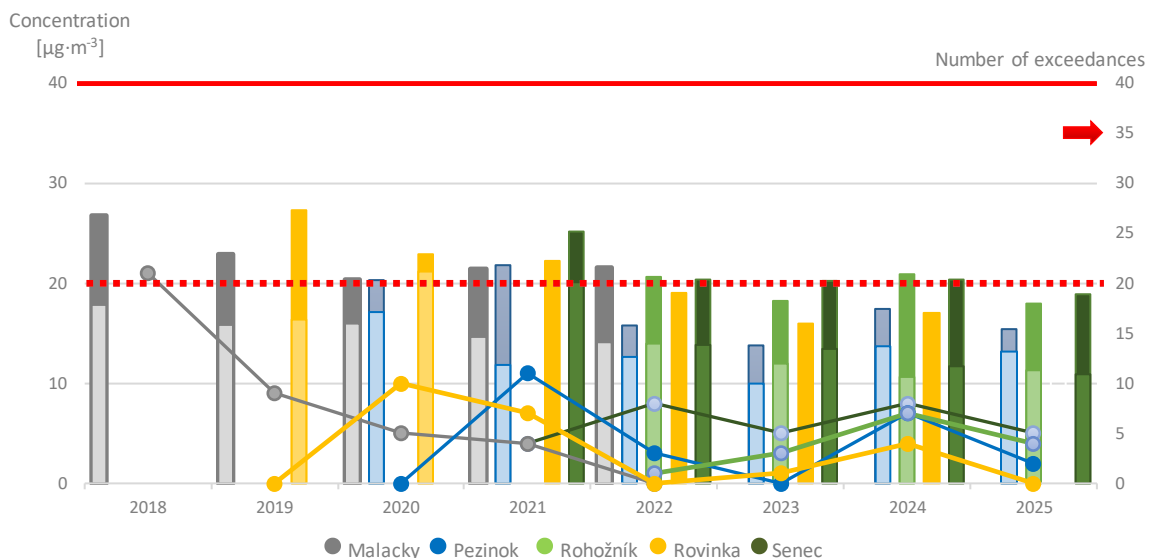
² Neutral water has a pH of 7. Rainwater absorbs carbon dioxide from the atmosphere and forms carbonic acid, which is slightly acidic; therefore, the typical pH of rainwater is 5.6. Acid rain typically has a pH ranging from 4.2 to 4.4.

3.2 Bratislava Region Zone

3.2.1 PM₁₀ and PM_{2,5}

Fig. 3.8 shows the annual mean concentrations of PM₁₀ and PM_{2,5} and the number of exceedances of the daily limit value (50 µg·m⁻³), based on measurement results from monitoring stations in the Bratislava Region Zone during the period 2018–2025.

Fig. 3.8 Annual mean concentrations of PM₁₀, PM_{2,5} and the number of exceedances of the daily limit value PM₁₀.



PM₁₀ – dark-coloured bars, PM_{2,5} – light-coloured bars; number of exceedances – lines.

Red lines – limit values (LVs): solid line – PM₁₀ (annual mean concentration: 40 µg·m⁻³); dashed line – PM_{2,5} (annual mean concentration: 20 µg·m⁻³).

Red arrow – LV for the number of exceedances (daily mean PM₁₀ concentration of 50 µg·m⁻³; maximum number of exceedances: 35 per year).

Since 2024, the air quality monitoring programme has been established at four monitoring stations: two urban background stations in Pezinok and Rovinka, and two traffic stations in Senec and Rohožník. At the monitoring station in Rovinka, monitoring was temporarily interrupted in 2025 due to technical reasons related to the installation of a permanent electricity connection. Monitoring was resumed at the end of the year, with an extended monitoring programme including particulate matter PM_{2,5}.

In 2025, the limit value for the annual mean concentration of PM₁₀ (40 µg·m⁻³) and PM_{2,5}, as well as the daily limit value for PM₁₀, was not exceeded (Fig. 3.8).

In 2025, the number of exceedances of the PM₁₀ daily limit value (50 µg·m⁻³) decreased at all AMS in the region compared with the previous year. At the AMS Pezinok, the number of exceedances decreased to a level meeting the WHO recommendation.

■ Assessment of Compliance with the Requirements of the New Directive

The annual limit value according to the stricter requirements of the new Directive for PM₁₀ (20 µg·m⁻³) **would not be exceeded** at any monitoring station. The annual limit value for PM_{2,5} (10 µg·m⁻³) **would be exceeded at all AMS**. At the Rohožník and Senec stations, the concentrations were only one microgram higher (11 µg·m⁻³), representing a favourable prospect for meeting the Directive requirements in the future, even with the implementation of less extensive measures.

For $PM_{2,5}$, the new Directive introduces a daily limit value of $25 \mu\text{g}\cdot\text{m}^{-3}$, with a maximum of 18 exceedances per year, and tightens the daily limit value for PM_{10} to $45 \mu\text{g}\cdot\text{m}^{-3}$, also with a maximum of 18 permitted exceedances. The daily limit value for PM_{10} would be met at all monitoring stations in the zone (Fig. 3.9).

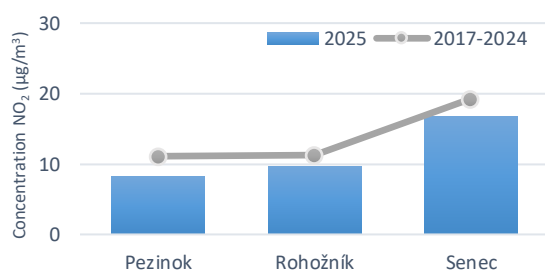
The new daily limit value for $PM_{2,5}$ would not be exceeded at the AMS Rohožník. At the AMS Pezinok, this limit value would be exceeded significantly (34 exceedances), while in Senec 19 exceedances would be recorded. The entire zone would also comply with the stricter requirements of the new EU Directive for the annual PM_{10} limit value ($20 \mu\text{g}\cdot\text{m}^{-3}$). However, in 2025 none of the AMS would meet the annual $PM_{2,5}$ limit value ($10 \mu\text{g}\cdot\text{m}^{-3}$).

3.2.2 Nitrogen dioxide

The annual mean nitrogen dioxide concentrations at individual stations compared with the long-term average are shown in Fig. 3.10.

In the Bratislava Region Zone, the limit value for the annual mean NO_2 concentration ($40 \mu\text{g}\cdot\text{m}^{-3}$) was not exceeded at any monitoring station.

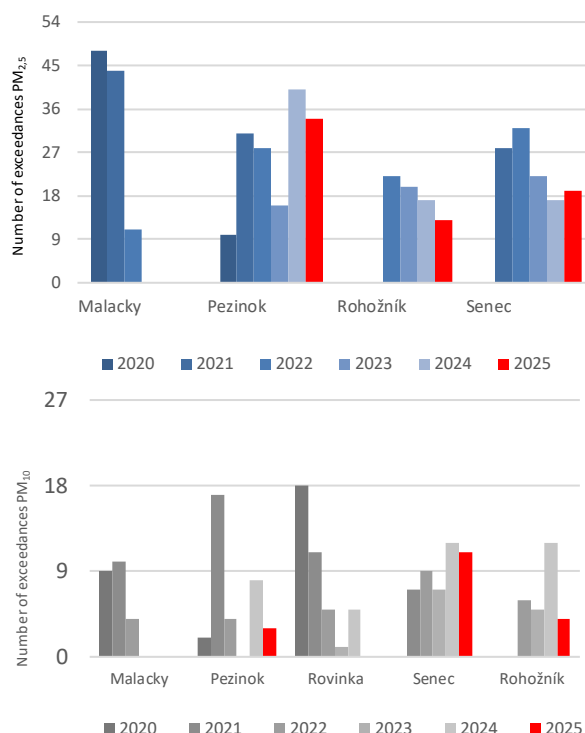
Fig. 3.10 Comparison of annual NO_2 concentrations with the long-term trend.



Overall, NO_2 concentrations in the zone show a decreasing trend and remain at a relatively low level. In 2025, no significant concentration peaks were recorded (Fig. 3.1).

The WHO guideline value for the annual mean NO_2 concentration ($10 \mu\text{g}\cdot\text{m}^{-3}$) is met at the AMS in Pezinok ($8 \mu\text{g}\cdot\text{m}^{-3}$) and Rohožník ($10 \mu\text{g}\cdot\text{m}^{-3}$).

Fig. 3.9 Number of exceedances of the daily limit values for $PM_{2,5}$ and PM_{10} applicable from 2030*.

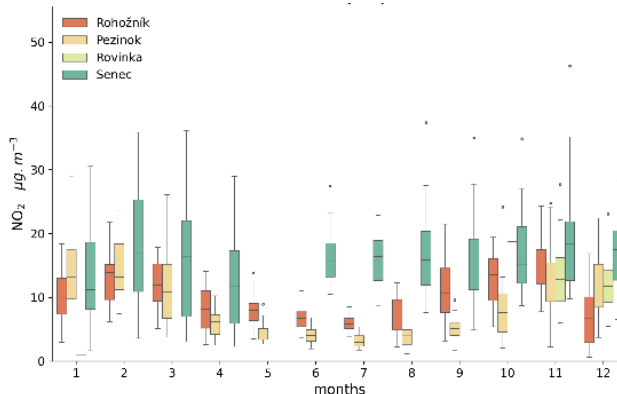


* The daily mean concentration of $PM_{2,5} > 25 \mu\text{g}\cdot\text{m}^{-3}$ and $PM_{10} > 45 \mu\text{g}\cdot\text{m}^{-3}$ may be exceeded a maximum of 18 times per year; the limit value applies from 1 January 2030.

Measurements at the AMS Senec and Pezinok in 2020 are not representative, as the stations started operating during the year. Measurements at Rohožník in 2022 are also not representative, as monitoring started during the year.

The main source of NO_2 emissions in the zone is road transport. For this reason, the highest concentrations are recorded at the traffic monitoring station in Senec ($16 \mu\text{g}\cdot\text{m}^{-3}$). This traffic station is located at a site with higher traffic intensity than the traffic station in Rohožník, where concentrations are only slightly higher than those measured in Pezinok.

Fig. 3.11 Boxplots of NO_2 concentrations by months



■ Assessment of Compliance with the Requirements of the New Directive

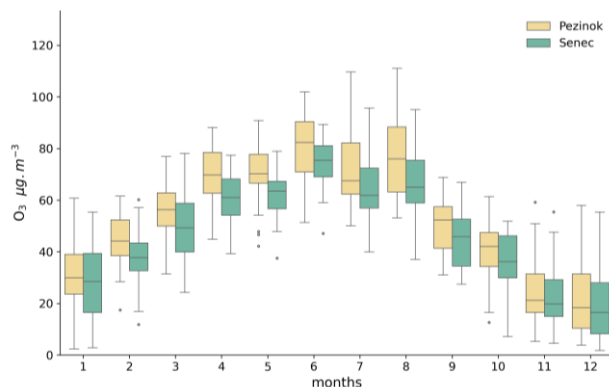
The EU's ambition is to move closer to the WHO recommendations through the Zero Pollution Action Plan, which includes new EU limit values for several pollutants, including NO₂ (20 µg·m⁻³), entering into force in 2030. All monitoring stations in the zone would meet these stricter requirements for NO₂.

3.2.3 Ozone

Ozone monitoring (Fig. 3.12) is carried out at the monitoring stations in Senec and Pezinok. Concentrations began to increase with the onset of warmer weather and a more pronounced occurrence of sunshine in April. The highest concentrations were recorded during the period from June to August.

September was colder and characterised by higher precipitation, which resulted in a significant decrease in ozone concentrations compared with the summer months.

Fig. 3.12 Box plots of O₃ concentrations by months..



Tab. 3.4 Number of days with a maximum daily 8-hour mean O₃ concentration above 120 µg·m⁻³

Station	2023	2024	2025	Average 2023 – 2025
Pezinok, Obrancov mieru	16	26	14	19
Senec, Boldocká	3	3	10	5

■ ≥ 90 % Required valid data

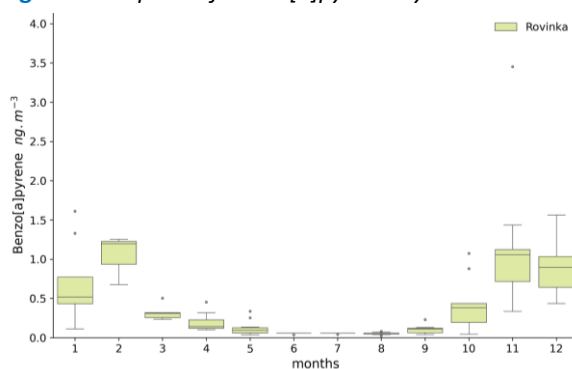
■ Assessment of Compliance with the Requirements of the New Directive

The target value for the protection of human health for ozone **would be exceeded** at the Pezinok monitoring station (19).

3.2.4 Benzo(a)pyrene

The annual mean concentration at the Rovinka monitoring station was 0.4 ng·m⁻³ in 2025 and therefore did not exceed the target value of 1 ng·m⁻³. The highest monthly concentrations of this pollutant were recorded during the winter months, with a maximum in November. The highest measured concentration, 3.5 ng·m⁻³, was substantially lower than the maximum recorded in 2024 (Fig. 3.13).

Fig. 3.13 Boxplots of benzo(a)pyrene by months.



Tab. 3.5 Annual mean concentrations of benzo(a)pyrene in 2020–2025

	2020	2021	2022	2023	2024	2025
Target value [ng·m ⁻³]	1,0	1,0	1,0	1,0	1,0	1,0
Rovinka	0,4	0,6	0,5	*0,4	0,5	0,4

■ ≥ 90 % valid data

* 81 % valid data

4 AIR QUALITY MODELLING

Fig. 4.1 and Fig. 4.2 shows the PM_{10} modelling results for the Bratislava Region Zone, including the Bratislava agglomeration, calculated using the RIO model in combination with the IDW-R interpolation method (for a more detailed description of the methodology, see Chapter 4 of the Air Quality Report of the Slovak Republic for 2025).

4.1 PM_{10} and $PM_{2,5}$

Fig. 4.1 Annual mean concentrations of PM_{10} according to the results of RIO, IDW-R.

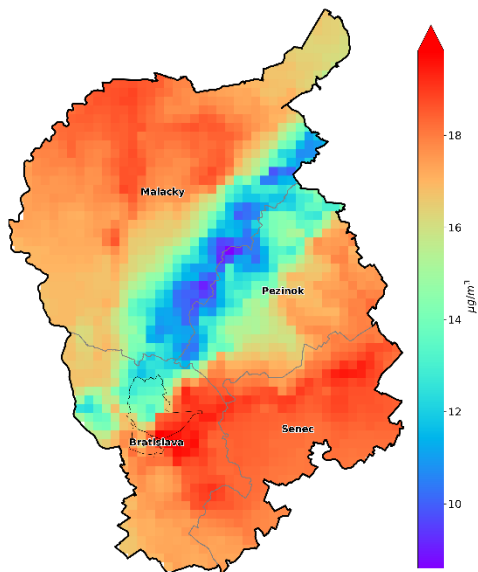


Fig. 4.2 Number of exceedances of the PM_{10} daily limit value. Only areas with a non-zero number of exceedances are shown.

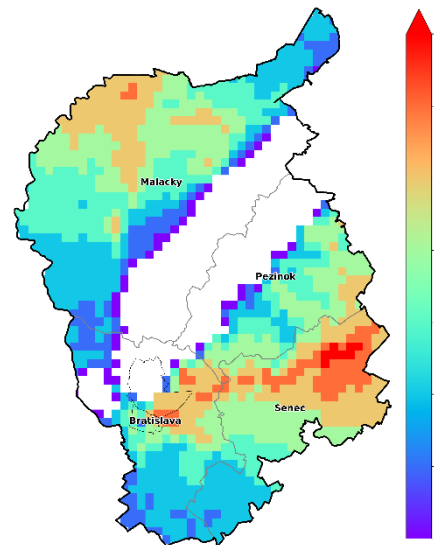


Fig. 4.3 Annual mean concentrations of $PM_{2,5}$ according to the results of RIO, IDW-R.

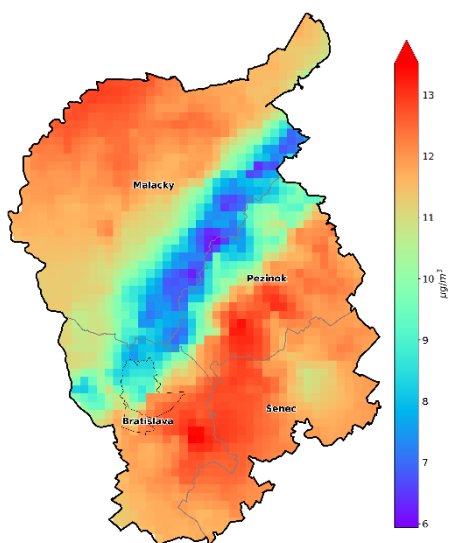
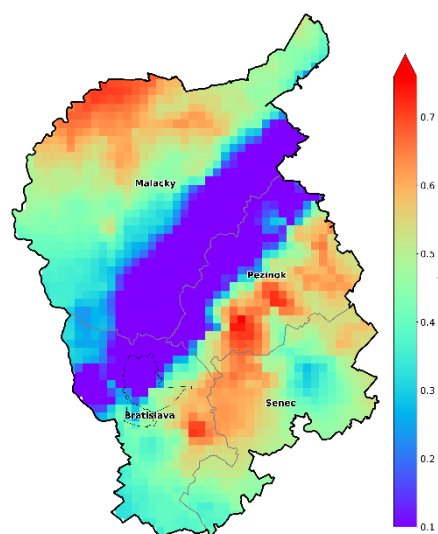


Fig. 4.4 Annual mean concentrations of benzo(a)pyrene according to the results of RIO, IDW-R.



Map in Fig. 4.3 shows the spatial distribution of annual mean PM_{2,5} concentrations based on the output of the RIO model combined with the IDW-R model. The highest concentrations are located in the Podunajská Lowland and in the Záhorie region. In Bratislava, the highest concentrations occur in the vicinity of busy roads within street canyons.

The showing the spatial distribution of annual mean benzo[a]pyrene concentrations based on the output of the RIO and IDW-R models (Fig. 4.4) indicates a possible occurrence of higher concentrations in some municipalities located east and north-east of Bratislava. However, more detailed high-resolution modelling would be required in the future to obtain more accurate information.

4.2 Benzene

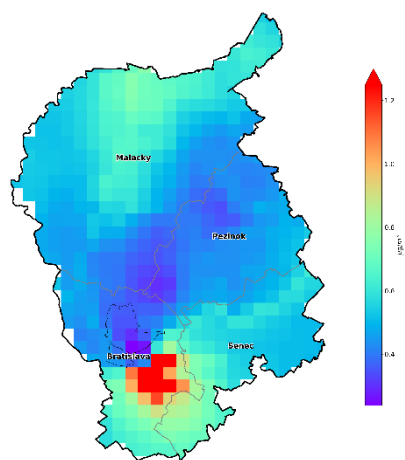
The CMAQ model outputs shown in Fig. 4.5 indicate that the highest benzene concentrations in Bratislava and the Bratislava Region Zone occur in the south-western part of the area, particularly in the Bratislava area, where the influence of the refinery industry is significant. However, these concentrations remain below the lower assessment threshold ($3.4 \mu\text{g}\cdot\text{m}^{-3}$).

Outside this area, concentrations are considerably lower and reach low levels across most of the region.

Despite locally elevated values, the modelled annual benzene concentrations remain low throughout the region and do not exceed the limit value of $5 \mu\text{g}\cdot\text{m}^{-3}$.

The modelled concentration at the location of the AMS Bratislava, Trnavské mýto was $0.4 \mu\text{g}\cdot\text{m}^{-3}$.

Fig. 4.5 Annual mean concentrations of benzene according to the results of CMAQ



4.3 Risk areas

Fig. 4.6 shows municipalities at risk of deteriorated air quality, identified using the Integrated Assessment Method for municipalities.

In the Bratislava Region Zone, based on outputs from the CMAQ chemical transport model, the RIO interpolation model and high-resolution modelling results obtained using the CALPUFF model, two areas with risk level 3 were identified – Bratislava I and Bratislava III. These areas were identified due to the risk of high NO₂ concentrations near busy roads in these Bratislava districts.

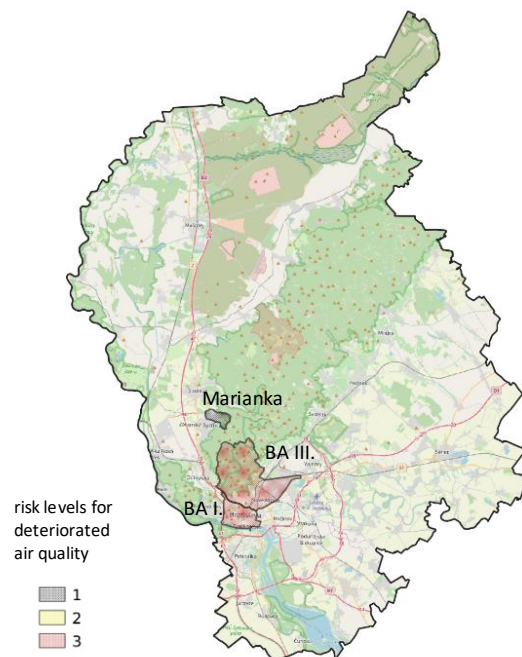
Due to the risk of high PM_{2,5} concentrations caused by a high number of local heating sources, one area with risk level 1 was identified – Marianka.

Municipalities where high-resolution modelling indicated exceedances of the limit value for PM or NO₂, or the target value for benzo[a]pyrene (B[a]P), were automatically assigned risk level 3. The same approach was applied to municipalities where exceedances of limit or target values were identified based on measurements. The list of municipalities and their assigned risk levels is published on the *SHMÚ website*.

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 with risk level 3 correspond to air quality management areas. However, emission reduction measures must be implemented within the designated zone in all municipalities with risk level 2 or 3 and, ideally, also in municipalities with risk level 1.

The assessment using the Integrated Assessment Method aims to identify areas where measures to improve air quality need to be targeted. Considering the distribution of pollution sources and the microclimatic characteristics of the area, it is likely that the level of air pollution varies between individual locations within the risk area. An overview of the spatial distribution of air pollution is provided by high-resolution modelling results, which are progressively being added to the *website*.

Fig. 4.6 Map of risk areas (municipalities and districts) in the Bratislava Region and the Bratislava agglomeration



5 SUMMARY

According to the monitoring results, **no limit value for any pollutant was exceeded in the Bratislava agglomeration or in the Bratislava Region Zone in 2025.** The target value for O₃ **was exceeded at the suburban background monitoring station Bratislava, Jeséniova.** Long-term trends in particulate matter (PM) pollution (Fig. 3.1) and NO₂ pollution show a decreasing pattern in both the agglomeration and the zone.

Based on the high spatial resolution model outputs³, it can be concluded that in the Bratislava Region Zone, including the Bratislava agglomeration, there is a risk of higher PM and NO₂ concentrations than those measured at the traffic monitoring station Bratislava – Trnavské mýto, particularly in the vicinity of heavily trafficked road sections with street canyon characteristics in the Bratislava I and Bratislava III districts. A level I risk of higher PM_{2,5} concentrations was identified in Marianka based on the integrated assessment methodology.

When assessing compliance with the requirements of the new Ambient Air Quality Directive, the main challenge for the Bratislava agglomeration and the Bratislava Region Zone would be meeting the limit value for nitrogen dioxide (NO₂) at the Bratislava – Trnavské mýto monitoring station. However, the greatest challenge will be compliance with the new directive requirements for PM_{2,5} at most monitoring stations, which will require the adoption of additional measures.

If air quality were assessed according to the WHO guidelines, none of the monitoring stations in the Bratislava agglomeration and the Bratislava Region Zone would meet the recommended concentration levels for all pollutants. The ambition of the Zero Pollution Action Plan is to achieve air quality in line with these recommendations by 2050.

Despite the conclusions above, the Bratislava Region Zone and the Bratislava agglomeration are among the least problematic areas in Slovakia in terms of air quality.

The year 2025 was relatively favourable in terms of dispersion conditions, which was reflected in lower pollutant concentrations at most automatic monitoring stations. Although Bratislava and the Bratislava Region are among the areas with the best air quality in Slovakia, meeting the stricter limit values of the forthcoming European legislation by 2030 will represent a significant challenge. The main difficulty will be compliance with the new daily limit value for PM_{2.5} and, in the case of the Trnavské mýto station, also with the annual limit value for nitrogen dioxide (NO₂), where the annual mean concentration in 2025 was approximately 40% higher than the future limit value.

The results of mathematical modelling also indicate that there are locations within Bratislava with higher NO₂ concentrations than those measured at the Trnavské mýto monitoring station. For these reasons, effective measures to improve air quality will be necessary, with priority given to reducing PM_{2.5} and nitrogen oxide emissions from road transport, particularly in areas with high traffic loads.

³ <https://www.shmu.sk/sk/?page=2849>