AIR POLLUTION IN THE SLOVAK REPUBLIC
2024

ANNEX

AIR QUALITY ASSESSMENT IN ZONE TRNAVA REGION

Emissions and Air Quality Division
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

Bratislava, September 2025
Version 1

1 DESCRIPTION OF TRNAVA REGION TERRITORY IN TERMS OF AIR QUALITY

The Trnava region is predominantly lowland and hilly. Its two important lowlands – the Danube and Záhorie – are separated by the Little Carpathians, which have a significant influence on the air flow. In the northwestern part of the region, an outcrop of the Považský Inovec Mountains extends into the territory of the region. The highest point of the region is Záruby in the Liitle Carpathians with an altitude of 768 m above sea level, but the majority of this zone lies below 200 m above sea level. Larger closed basins do not occur in the Trnava region. According to data from the Statistical Office of the Slovak Republic[1], the average population density in the Trnava Region is 137 inhabitants per km².

The **highest population density** in the Trnava Region is in the **Trnava District** (179 inhabitants per km²), the **Senica District has the lowest density** (86 inhabitants per km²).

The whole Trnava region is one zone in terms of air quality assessment for SO_2, NO_2, NO_X, PM_{10}, $PM_{2.5}$, benzene, polycyclic aromatic hydrocarbons and CO in the air.

Air pollution sources in zone Trnava region

According to data from the latest Census of Population, Houses and Dwellings 2021, natural gas is mainly used for heating households in this zone.

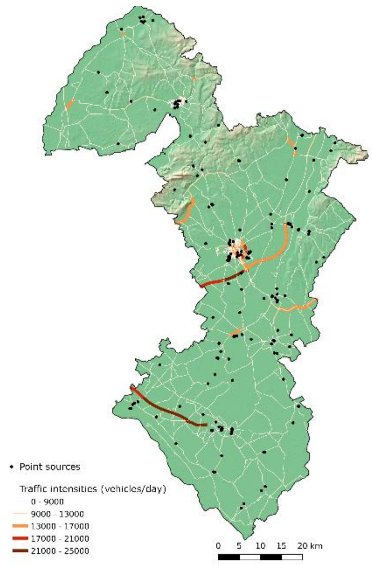
Industrial sources of air pollution are less significant in this zone in terms of their contribution to local air pollution by basic pollutants. Road transport in the Trnava Region contributes to air pollution depending on its intensity. **Tab. 1.1** contains the traffic intensity on major roads in the region according to the national transport census in 2022 and 2023). The map in **Fig. 1.1** shows road sections with higher traffic intensity, which were processed by the Transport Research Center (Centrum dopravního výzkumu, CDV) for the year 2024. The map also shows the locations of point sources.

Map on shows the more frequent road sections, as processed by the Transport Research Centre

Tab. 1.1 Number of vehicles on the most frequented roads of the Trnava region.

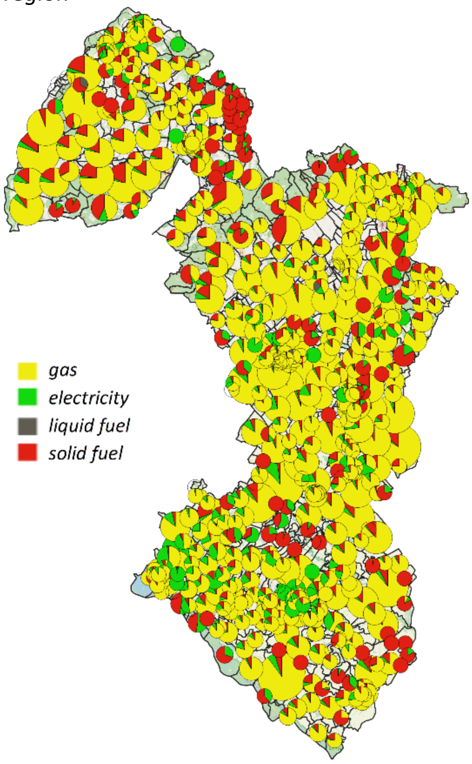
Highway/road	Number of vehicles	Trucks	Passenger cars
D2	19 332	10 036	9 245
426 Holíč – Skalica	13 220	1 473	11 626
D2 Kúty – Holíč	13 153	1 246	11 843
D1 (stred)	49 185	10 734	38 336
R1 Trnava – Sereď – Pata	51 031	11 864	39 084
62 Senec – Sládkovičovo – Sereď	14 405	1 000	13 374
561 Galanta – Veľký Meder	12 141	2 009	10 013
507 Galanta – Dunajská Streda	15 909	1 388	14 396
507 Hlohovec – Sereď	15 810	1 573	14 180
51 – vých. obchvat Trnavy	27 040	5 692	21 268
61 Trnava – Senec	26 567	2 641	23 819
61 Trnava – Piešťany	14 847	2 002	12 740
51 Trnava – Senica a Holíč (okr. Trnava)	27 040	5 692	21 268
51 Trnava – Senica a Holíč	16 868	2 797	13 994
63 Dunajská Streda – Šamorín	17 678	3 310	14 294
R7 Dunajská Streda – Šamorín	12 622	2 048	10 535
Southern Ring Road of Dunajská Streda (road N. 63)	17 678	3 310	14 294
572 Dunajská Streda – Most pri Bratislave	18 849	975	17 776

Fig. 1.1 Road traffic intensity in the Trnava region. Source: CDV



[1]https://slovak.statistics.sk/wps/portal/ext/themes/regional/trnavsky%20kraj

Fig. 1.2 *Share of different types of fuel usedfor heating in the municipalities of the region*[2]



The share of solid fuels in the zone is among the lowest compared to other regions, with fuelwood consumption being slightly higher in the more mountainous area of the Little Carpathians (***Fig. 1.2***).

[2] *https://www.scitanie.sk*

2 AIR QUALITY MONITORING STATIONS IN ZONE TRNAVA REGION

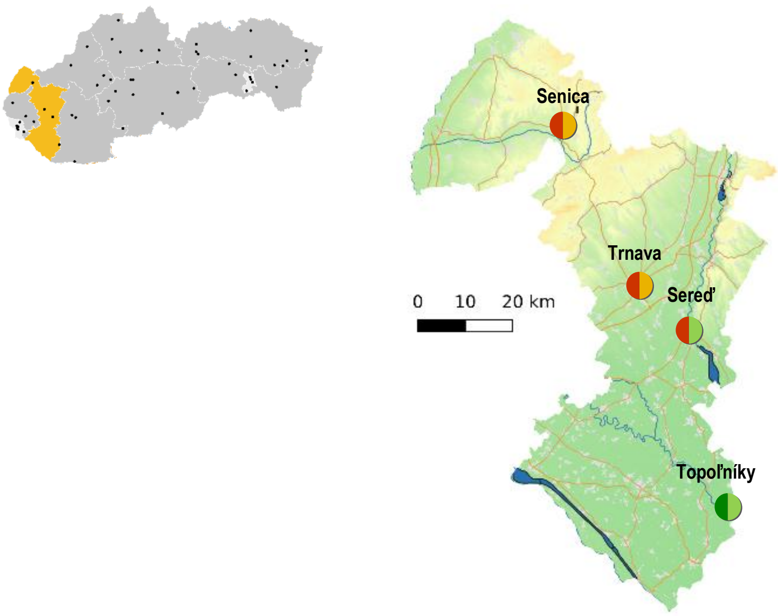
In the Trnava region, air quality is monitored at 4 stations. In **Trnava**, on a busy road (Kollárova street), near the train station, we observe the impact of traffic. Another traffic station is located in the northwestern part of the region in the district town of **Senica**. The monitoring station in **Sereď** is a representative of the urban background and is located in a housing estate of concrete high-rise block of flats. There is a rural background station with the lowest altitude in the municipality of **Topoľníky**, near the Klátov river arm, belonging to the EMEP network in Slovakia. It monitors the impact of longrange air pollution transport on the territory of Slovakia, as well as other monitoring stations included in the EMEP monitoring network (Chapter 2 of Air pollution in the Slovak Republic 2023 Report).

Tab. 2.1 contains information on air quality monitoring stations in the zone Trnava region:

- international EoI code, station characteristics according to the dominant sources of air pollution (traffic, background, industrial), type of monitored area (urban, suburban, rural/regional) and geographical coordinates;
- monitoring programme. Continuous monitoring automatic instruments provide hourly average concentrations of PM_{10}, $PM_{2.5}$, nitrogen oxides, sulphur dioxide, ozone, carbon monoxide, benzene and mercury. The SHMÚ test laboratory analyses heavy metals and polycyclic aromatic hydrocarbons as part of manual monitoring, resulting in 24-hour average concentrations. The exception is the EMEP station Topoľníky, whose monitoring programme is described in **Tab. 2.2**.

Tab. 2.1 Air quality monitoring programme in the zone Trnava region

Zone Trnava Region								Monitoring programme									
								Continuously								Manually	
District	EoI code	Station	Type of area	Type of station	Geographical longitude	Geographical latitude	altitude [m]	PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
Dunajská Streda	SK0007R	Topoľníky, Aszód, EMEP	R	B	17°51'37"	47°57'34"	113									*	
Senica	SK0021A	Senica, Hviezdoslavova	U	T	17°21'47"	48°40'51"	212										
Trnava	SK0045A	Trnava, Kollárova	U	T	17°35'06"	48°22'17"	152										
Sereď	SK0063A	Sereď, Vinárska	U	B	17°44'07"	48°17'01"	130										
							Total	4	4	3	2	1	1	1	1	2	1



* *Monitoring of heavy metals at the station Topoľníky is carried out according to the EMEP monitoring programme (**Tab. 2.2**)*

Type of area:
U – urban
S – suburban
R – rural (regional)

Type of station:
T – traffic
B – background
I – industrial

The Topoľníky monitoring station is included in the EMEP[3] monitoring program. The AMS carries out extended monitoring of heavy metals (**Tab. 2.2**) and sampling of atmospheric precipitation (**Tab. 2.3**). Heavy metals in the air are analyzed from weekly samples of atmospheric aerosol (sampling interval is 3 days).

Tab. 2.2 *Monitoring program at the EMEP station Topoľníky.*

	PM_{10}	Pb	As	Cd	Ni	Cr	Cu	Zn
Topoľníky	x	x	x	x	X	x	x	x

Precipitation is analyzed in a sampling interval of one week – basic parameters of precipitation and calendar month – heavy metals (**Tab. 2.3**). A "wet-only" rain gauge is used to collect precipitation, which only captures precipitation (it is closed during periods when precipitation does not occur). Based on the analyses of the samples collected in this way, the wet deposition of the monitored substances is evaluated.

Tab. 2.3 *Precipitation monitoring programme at EMEP station Topoľníky.*

	pH	Conductivity	SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Alkaline ions K^+, Na^+, Ca^{2+}, Mg^{2+}	Pb	As	Cd	Ni	Cr	Cu	Zn
Topoľníky	x	x	x	x	X	x	x	x	x	x	x	x	x	x

[3] *https://www.emep.int*

3 ASSESSMENT OF AIR QUALITY IN ZONE TRNAVA REGION

This chapter contains an assessment of air quality in the zone Trnava region based on monitoring, supplemented by mathematical modelling results for PM_{10}, $PM_{2.5}$ and benzo(a)pyrene for the year 2024.

Tab. 3.1 *Assessment of air pollution according to limit values for protection of human health and smog warning system for PM_{10} in the zone Trnava region – 2024.*

Pollutant	Type	Protection of human health									IT 2)	AT 2)
		SO_2		NO_2		PM_{10}		$PM_{2,5}$	CO	Benzene	PM_{10}	PM_{10}
Averaging period		1 h	24 h	1 h	1 year	24 h	1 year	1 year	8 h 1)	1 year	12 h	12 h
Parameter	Area / station	number of exceedances	number of exceedances	number of exceedances	average	number of exceedances	average	average	average	average	Duration of exceedance [h]	Duration of exceedance [h]
Limit value [µg·m⁻³]		350	125	00	40	50	40	20	10 000	5	100	150
Maximum number of exceedances		24	3	18		35						
Senica, Hviezdoslavova	UT	0	0			6	19	12			12	2
Trnava, Kollárova	UT			0	24	6	21	13	2 331	0,3	16	5
Topoľníky, Aszód, EMEP	RB	0	0	0	4	7	17	12			14	0
Sereď, Vinárska	UB			0	11	7	18	13			24	5

≥90 % valid measurements 1) *eight-hour maximum concentration*

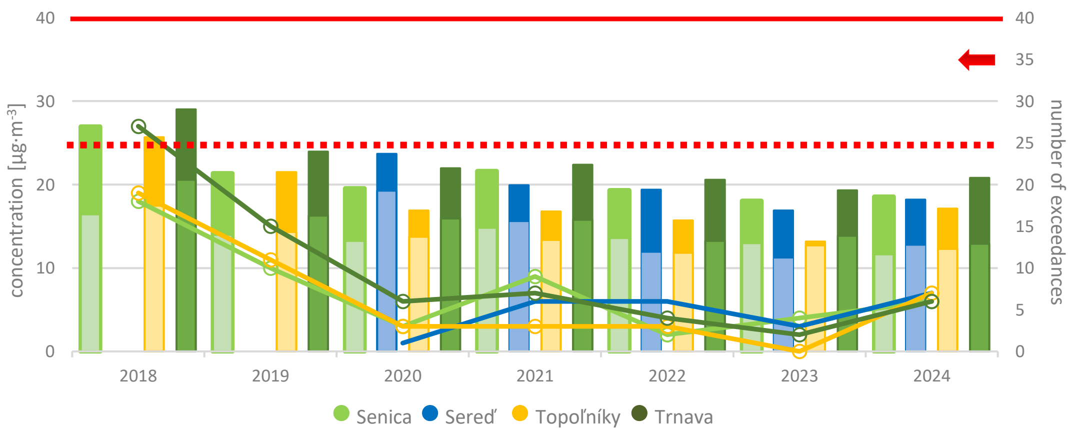
2) *IT, AT – duration of exceedance (in hours) of the information threshold (IT) and alert threshold (AT) for PM_{10}*

In accordance with the Decree of the Ministry of Environment of the Slovak Republic No. 250/2023 Coll. on air quality, the required proportion of valid values was observed at the monitoring stations.

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

Fig. 3.1 shows the average annual concentrations of PM_{10}, $PM_{2.5}$ and the number of days with average daily PM_{10} concentrations above 50 µg·m^{-3} according to the results of measurements at monitoring stations in the Trnava region in 2018 – 2024.

Fig. 3.1 *Average annual concentrations of PM_{10}, $PM_{2.5}$ and the number of exceedances of the daily limit value for PM_{10}*



PM_{10} *dark column color,* ***$PM_{2,5}$*** *– light column color;* ***number of exceedances*** *– solid broken lines Horizontal lines show limit values (LV), red solid PM_{10} (average annual concentration: 40 µg·m^{-3}); red striped $PM_{2.5}$ (average annual concentration: 20 µg·m^{-3}); red solid arrow – LV number of exceedances (average daily PM_{10} concentration 50 µg·m^{-3} max. number of exceedances 35/calendar year).*

The highest PM concentrations are measured at the transport station in Trnava on Kollárová Street, but thanks to the good ventilation of the area, the values are not high compared to the currently valid limits. Monitoring stations in the Trnava Region do not reach a high number of days with an average daily PM_{10} concentration above 50 µg.m^{-3} (**Fig. 3.1**). In 2024, it was 6–7 days, of which 2 days (Topoľníky, Sereď) to 3 days (Trnava, Senica) must be attributed to the episode of Saharan dust transport at the turn of March and April.

The new limit value (which EU Member States are to achieve by 1. 1. 2030) for the average annual PM_{10} concentration was met by all stations in the region except the traffic AMS in Trnava. The stricter WHO recommendation (annual average PM_{10} up to 15 µg.m^{-3}) was not met by any station in the Trnava region in 2024.
Fig. 3.2 shows the modeling results for PM_{10}, calculated for 2024 using the RIO model subsequently adjusted using the regression IDW-R method. The model outputs also indicate that the level of PM_{10} concentrations does not exceed the limit values.

In 2024, there were several periods with worsened dispersion conditions, especially in the months of January, November and December. Despite this, none of the currently valid air quality limit values were exceeded in the Trnava Region. The area is characterized by good ventilation, which contributes to more favorable conditions for the dispersion of pollutants.

A significant episode of desert dust transport from the Sahara region at the turn of March and April caused an increase in daily PM_{10} concentrations above 50 µg·m^{-3} for 2 to 3 days at all monitoring stations in the region.

Fig. 3.2 *Average annual PM_{10} concentration (left) and number of PM_{10} daily limit value exceedances (right) in 2024.*

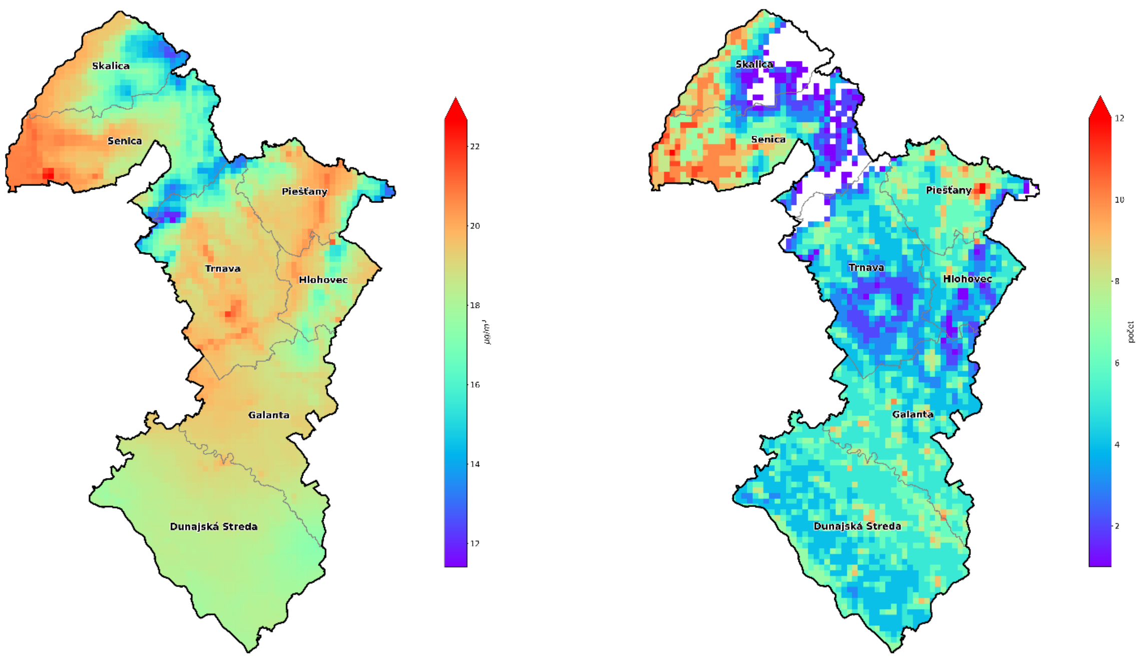
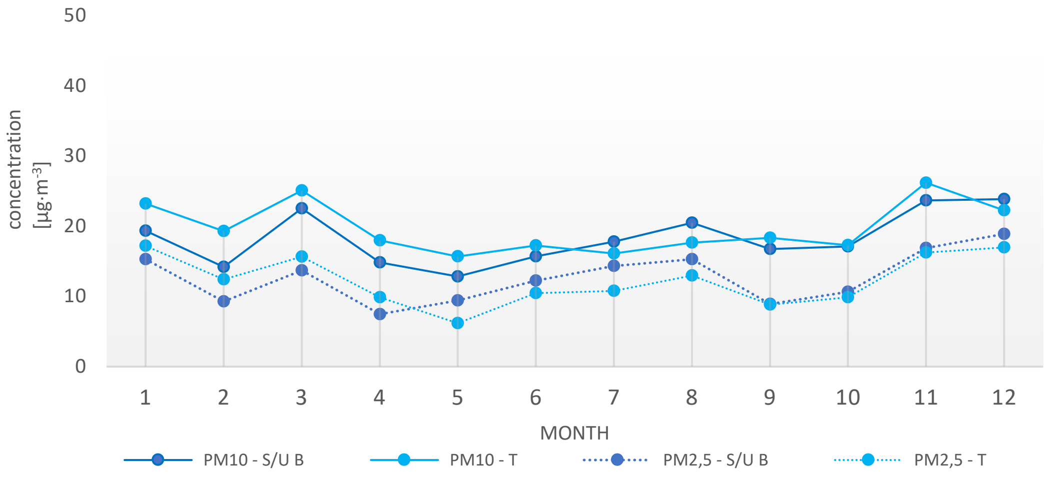


Fig. 3.3 Average monthly concentrations of PM_{10} and $PM_{2.5}$ in the Trnava region by station type.



***T PM10** and **T PM2.5** – average of monthly mean concentration of PM_{10} and $PM_{2,5}$ at traffic stations in Trnava. and Senica; **U/S PM10** and **U/S B PM2.5** – average of monthly mean concentrations of PM_{10} and $PM_{2,5}$ at urban background station Sereď, Vinárska.*

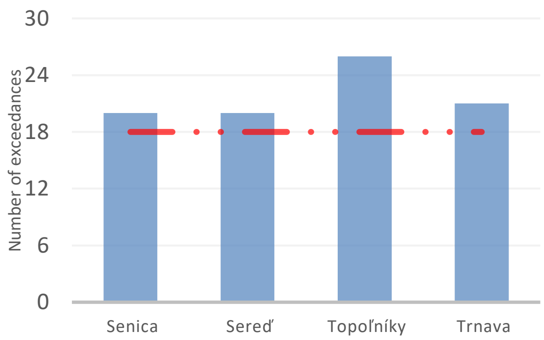
The graph in (**Fig. 3.3**) shows the average monthly concentrations of PM_{10} and $PM_{2.5}$ during the year by type of monitoring station. In March, there is a noticeable increase in PM_{10} values, probably due to an episode of Saharan dust transport.

The difference in PM_{10} values measured in the summer and winter months is less significant in the Trnava region than, for example, in the Banská Bystrica region. The reason may be the lower share of solid fuels in household heating and the prevailing more favorable dispersion conditions. On the contrary, it was in November and December 2024 - the graph shows an increase in concentrations at the end of the year under unfavorable dispersion conditions.

$PM_{2.5}$ are considered particularly risky for human health due to their ability to penetrate deep into the respiratory system.

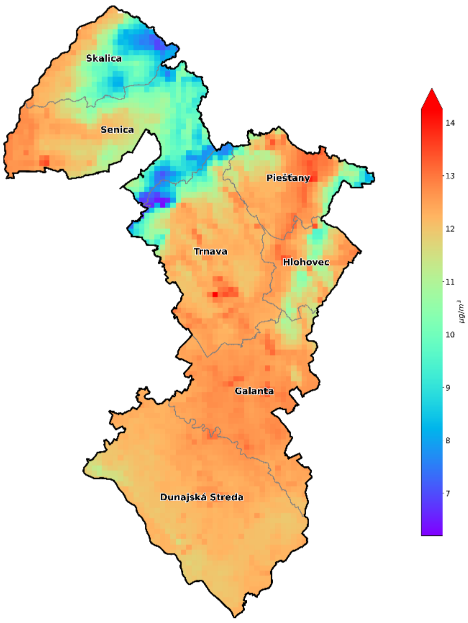
As with PM_{10}, **the limit value for $PM_{2.5}$ was not exceeded** in the Trnava Region.
Fig. 3.4 illustrates the number of exceedances of the new EU daily limit for $PM_{2.5}$ at individual AMS in 2024. The daily average concentration of $PM_{2.5}$ (25 µg.m^{-3}) should not be exceeded more than 18 times per calendar year. In 2024, this limit would be exceeded by all AMS in the Trnava Region, and paradoxically, the most exceedances were recorded at the regional AMS Topoľníky. In 2023, this limit was met by the AMS in Sereď. Compared to other zones, the new limit value for daily $PM_{2.5}$ concentration was only slightly exceeded at stations in the Trnava Region zone, and it is realistic to expect that this value could be reached by 2030.

Fig. 3.4 Number of days with average daily $PM_{2.5}$ concentration > 25 µg.m^{-3} in 2024 – evaluation with respect to the newly introduced EU limit.*



** Under the new EU limit, which will come into force on 1 January 2030, the average daily concentration of $PM_{2.5}$ must not exceed 25 µg.m^{-3} more than 18 times a year*

Fig. 3.5 Annual average $PM_{2,5}$ concentration in 2024. Output of model RIO/IDW-R.



The new EU limit value for the average annual $PM_{2.5}$ concentration (10 µg m^{-3}) – which is to be achieved by 1 January 2030 – was not met by any station in the zone in 2024. The map in **Fig. 3.5** shows the spatial distribution of the average annual $PM_{2.5}$ concentrations according to the output of the RIO model in combination with the IDW-R model. The map shows that the average annual $PM_{2.5}$ concentrations exceed 10 µg.m^{-3} outside mountainous areas, and in 2024 the new EU limit value would be exceeded almost throughout the zone.

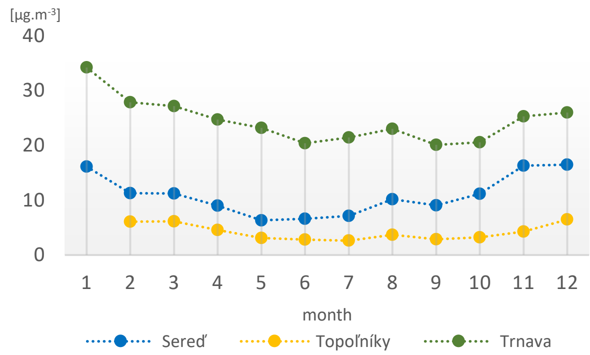
3.2 Nitrogen dioxide

Nitrogen dioxide monitoring is carried out at three stations. The **limit value for NO_2 was not exceeded** at any monitoring station in the region.

The average monthly values for individual stations is shown in **Fig. 3.6**.

The main source of NO_2 emissions is road transport. For this reason, the highest NO_2 values are recorded at the Trnava, Kollárova traffic station, where the annual mean concentration in 2024 reached 24 µg.m^{-3} (an annual decrease of 3 µg·m^{-3}), while the limit value is 40 µg·m^{-3}. Overall, NO_2 concentrations in the Trnava region were at a relatively low level. Nevertheless, the only station in the zone meeting the WHO recommendation (10 µg.m^{-3}) in 2024 is the regional background station Topoľníky with a level of 4 µg·m^{-3}. WHO recommendations are generally significantly stricter than national and EU limits (the new EU limit for annual NO_2 concentration, which must be met by 1 January 2030, is 20 µg·m^{-3}). The new EU limit value would be exceeded by the Trnava station.

Fig. 3.6 Average monthly NO_2 concentrations in 2024.

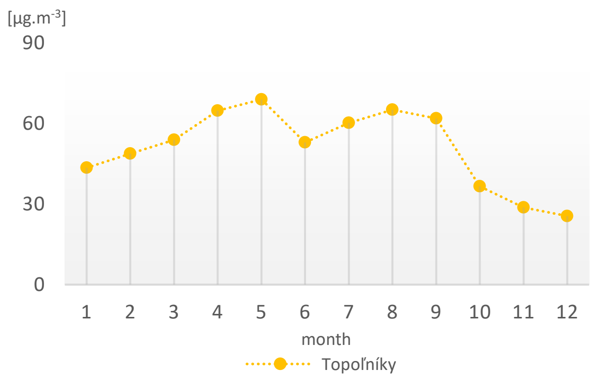


3.3 Ozone

Ozone monitoring is carried out in the Trnava region at the rural background station Topoľníky.The highest concentrations of ground-level ozone generally occur in warm months with high sunlight intensity. In the figure (**Fig. 3.7**) we can see a decrease in concentrations compared to other warm months in rainy June.

Ozone concentrations also have a significant diurnal variation – they rise with sunrise, peak around noon and gradually decrease in the evening to a minimum that occurs in the early morning..

Fig. 3.7 Average monthly O_3 concentrations in 2024.



3.4 Benzo(a)pyrene

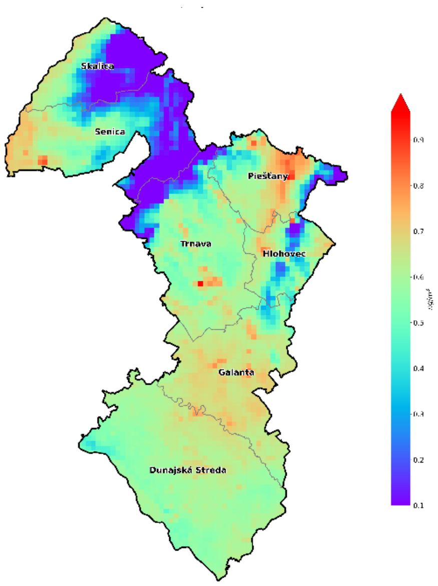
Benzo(a)pyrene is monitored in this zone at the **Trnava**, Kollárova monitoring station. Similar to previous years, the target value (1 ng·m^{-3}) **was not exceeded**.

Tab. 3.2 Average annual concentrations of benzo(a)pyrene in 2018 – 2024.

	2018	2019	2020	2021	2022	2023	2024
Target value [ng·m^{-3}]	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Trnava, Kollárova	0,9	0,7	0,5	0,6	*0,5	0,5	0,6

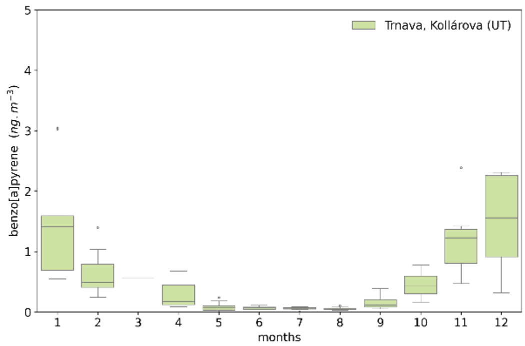
≥ 90 % valid measurements

Fig. 3.8 Average annual concentration of BaP according to RIO/IDW- R model output, (2024).



Higher levels of benzo(a)pyrene were measured in the colder months of the year (**Fig. 3.9**). Based on the mathematical modelling outputs (**Fig. 3.8**), we can assume that the annual target value for benzo(a)pyrene is probably largely not exceeded in the zone Trnava region

Fig. 3.9 Concentrations of benzo(a)pyrene in 2024.



3.5 Chemical composition of precipitation

At the rural background station Topoľníky, precipitation quality is monitored on a weekly basis. The qualitative composition of basic ions, pH parameters and conductivity are monitored. The annual weighted average pH value in precipitation (580 mm) was 5.4, the lowest in January with a weighted average of 4.7. Wet deposition of NO_3^- was 0.15 g/m^2/year, SO_4^{2-} 0.19 g/m^2/year. Wet deposition of lead was at the level of 4.6 g/ha/year. Detailed monitoring results are presented in *Chapter 3.4 Regional Monitoring* in the main part of the *Air Pollution Report in the Slovak Republic.* 2024.

3.6 Risk municipalities

Fig. 3.10 displays municipalities at risk due to deteriorated air quality as determined by the integrated municipal assessment method[4]. Level 3 corresponds to the highest probability of air pollution risk.

The methodology includes the level of household heating with solid fuels, the impact of worsened dispersion conditions from both short-term and long-term perspectives, results from the chemical transport model CMAQ, the interpolation model RIO, and high-resolution modelling results using the CALPUFF model in selected domains with an assumed deteriorated air quality.

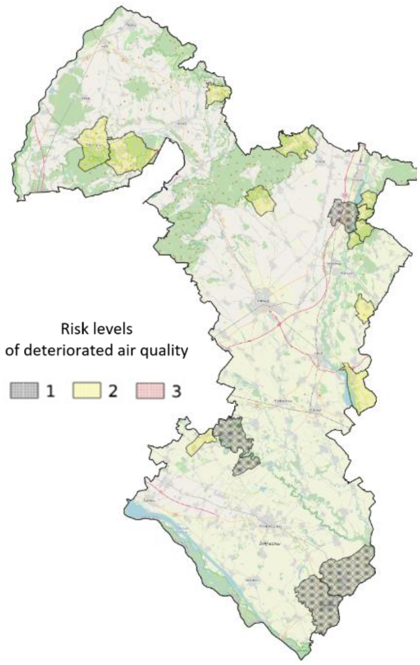
[4] *Štefánik, D., Krajčovičová, J.: Metóda integrovaného posúdenia obcí vzhľadom na riziko nepriaznivej kvality ovzdušia, Slovenský hydrometeorologický ústav, 2023, dostupné na https://www.shmu.sk/sk/?page=996*

Municipalities in which the limit value for PM, NO_2, or the target value for BaP was exceeded based on high spatial resolution modelling were automatically assigned a risk level 3, similar to municipalities where the limit or target value exceedance was detected through measurement. The list of municipalities and their risk levels can be found on the SHMÚ website[5].

Zones and agglomerations that include at least one municipality with a risk level 3 will develop an Air Quality Plan. In this regard, municipalities with a risk level 3 correspond to air quality management areas. However, measures to reduce emissions must be implemented in all municipalities within this designated zone with a risk level 2 or 3, ideally also in municipalities with a risk level 1.

The assessment using the integrated assessment method aims to identify areas where action to improve air quality needs to be targeted. Given the distribution of air pollution sources and considering the microclimatic characteristics of the region, it is likely that pollution levels vary at different locations within the risk area. Spatial distribution of air pollution is provided by high-resolution modelling results, which are updated on the SHMÚ website[6].

***Fig. 3.10** Risk municipalities in zone Trnava region 2024.*



3.7 Summary

In 2024, no exceedance of the limit value for SO_2, NO_2, CO and benzene was measured in the Trnava Region zone, nor was the limit value for the average annual concentration of PM_{10} and $PM_{2.5}$ exceeded, while overall there was a slight year-on-year deterioration of air quality in the monitored locations.

The number of days with average daily PM_{10} concentrations above 50 $\mu g \cdot m^{-3}$ was below the permissible limit in 2024. The target value for the annual average concentration of benzo(a)pyrene was not exceeded. In the Trnava region, no exceedance of the limit or target value for any pollutant has been measured in the last three assessment years, therefore no *air quality management area* has been designated in this zone on the basis of the monitoring. However, the energy crisis may cause an increase in firewood consumption, which may result in a deterioration of air quality in areas with poorer ventilation..

If we were to assess compliance with the requirements of the new Air Quality Directive adopted by the European Parliament in April 2024 (setting new EU limit values applicable from 1 January 2030), in the Trnava region we would meet the 2030 targets for annual averages of PM_{10} as early as 2024, except for the traffic station in Trnava The new EÚ limit value for daily and annual concentrations of $PM_{2.5}$ would be exceeded at all stations in the zone. The new limit for the annual average of NO_2 would be exceeded at the traffic station in Trnava.

If we were to evaluate the air quality in the zone according to WHO recommendations[7], none of its stations would meet the recommended concentration values for annual PM_{10} and $PM_{2.5}$ concentrations. Only AMS Topoľníky, EMEP would meet the limit for the annual average of NO_2.The ambition of the Zero Pollution Action Plan is to achieve the following air quality recommendations by 2050.

The zone Trnava region is one of the least problematic areas in Slovakia in terms of air quality.

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5 *https://www.shmu.sk/sk/?page=2919*
6 *https://www.shmu.sk/sk/?page=2699*
7 *WHO GLOBAL AIR QUALITY GUIDELINES, 2021. Recommendations on classical air pollutants, str. 4. https://apps.who.int/iris/bitstream/handle/10665/345334/9789240034433-eng.pdf*