AIR POLLUTION IN THE SLOVAK REPUBLIC 2024

ANNEX

AIR QUALITY ASSESSMENT IN ZONE BANSKÁ BYSTRICA REGION

Emissions and Air Quality Division
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

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Version 1

1 DESCRIPTION OF TRNAVA REGION TERRITORY IN TERMS OF AIR QUALITY

The terrain of the Banská Bystrica region is predominantly mountainous. The mountain basins in the area are characterised by low wind speeds and frequent temperature inversions, especially in winter. In the north there are the higher mountains of the Low Tatras and outcrops of Veľká Fatra. Quite a large part is occupied by the medium-high mountains – the Slovak Ore Mountains, Štiavnické vrchy and Krupinská plain in the central part of the region. The southern part of the region is characterised by lower altitudes – Juhoslovenská kotlina and Cerová vrchovina are located here. The highest point is Ďumbier (2 046 m a. s. l.), the lowest is 124 m a. s. l.

The Banská Bystrica and Prešov regions have the lowest population density compared to other regions in Slovakia. According to the Statistical Office of the Slovak Republic, the average population density in the Banská Bystrica region is 65 inhabitants per km² (as assessed as of 31 March 2025). **The highest population density** is reported by the **Banská Bystrica district** with 132 inhabitants per km², while the **Krupina district** has **the lowest density** in the region with 36 inhabitants per km². For comparison, the Slovak Republic had an average population density of 111 inhabitants per km² on that date.

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

Air pollution sources in zone Banská Bystrica region

The dominant source of air pollution in the Banská Bystrica region is household heating. The problem is mainly in areas where the share of firewood is the highest, and where heating devices with high emissions are used for heating. The share of solid fuel for heating households in different regions of the region is shown in **Fig. 1.2**. Locally, especially in larger cities, the influence of road transport is also evident.

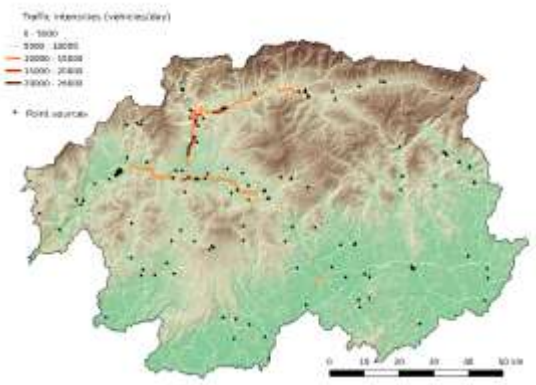
Map on **Fig. 1.1** shows the more frequent road sections, as processed by the Transport Research Centre (Centrum dopravního výzkumu, CDV) for the year 2024.

Tab. 1.1 contains the traffic intensity on major roads in the region according to the national transport census in 2022 and 2023). The selection of sections is based on their traffic load, regional location and importance in the road network of the Slovak Republic.

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

District	Highway/road	Number of vehicles	Trucks	Passenger cars
Banská Bystrica	č. 59	14 203	2 652	11 467
	R1	53 018	7 964	44 898
	č. 66	5 833	631	5 154
Brezno	č. 66	32 321	3 358	28 849
	č. 66	10 842	1 461	9 306
Detva	č. 526	7 523	1 137	6 277
	R2	15 129	5 248	9 810
	č. 16	9 975	1 398	8 511
Lučenec	č. 16	12 826	3 093	9 685
	č. 71	5 976	1 116	4 834
	č. 16	9 354	2 134	7 182
Veľký Krtíš	č. 527	5 971	429	5 501
	č. 75	8 736	847	7 810
Zvolen	č. 16	34 579	6 647	27 786
	č. 66	18 354	3 312	14 978
	R1	34 535	7 858	26 532
Žarnovica	R1	26 419	5 325	20 985
Žiar nad Hronom	č. 65	9 653	2 631	6 972
	R1	28 059	6 407	21 581
	č. 9	17 856	1 782	15 987

***Fig. 1.1** Road traffic intensity in the Banská Bystrica region. Source: CDV*



Industrial sources of air pollution in the Banská Bystrica region are less dominant in terms of their contribution to local air pollution by basic pollutants. Depending on meteorological conditions, the influence of heating plants may also be felt in this zone.

A significant source of air pollution in the zone is household heating in the case of particulate matter and BaP, but also road transport in the case of NO_2.

Fig. 1.2 *Share of different types of fuel used for heating in the municipalities of the region[1].*

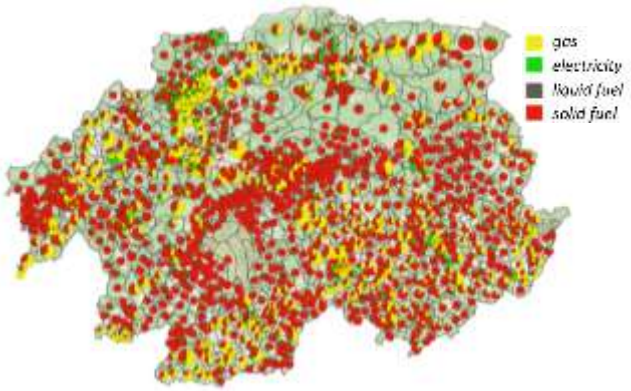


Fig. 1.1 shows the shares of fuel types in heating family houses in individual municipalities or basic settlement units of the Banská Bystrica Region, while it is clear that the spatial distribution of fuel types is not geographically homogeneous. Compared to other regions, a high share of heating with solid fuel is evident, especially in areas with good availability of firewood.

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

2 AIR QUALITY MONITORING STATIONS IN ZONE BANSKÁ BYSTRICA REGION

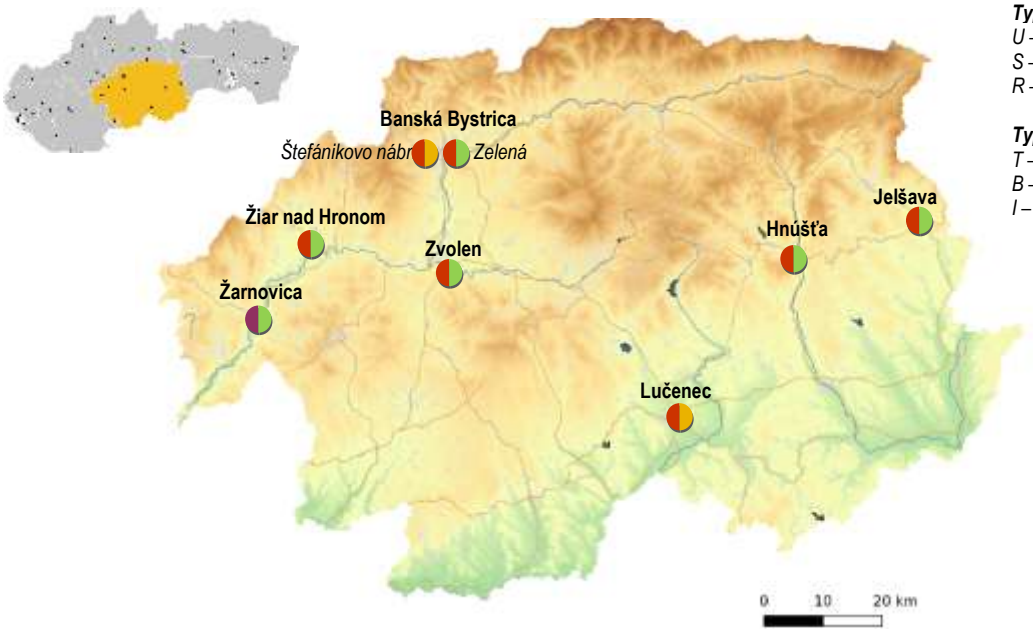
In the Banská Bystrica region, air quality monitoring is being monitored at eight locations. **The traffic station** is in **Banská Bystrica on Štefánikovo nábrežie** and in **Lučenec**. The station **Banská Bystrica, Zelená** monitors the **urban background**, similarly to the stations in **Zvolen and Žiar nad Hronom**. The urban/suburban background stations in **Jelšava, Hnúšťa and Žarnovica** are focused mainly **the impact of household heating** in rural settlements.

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.

Tab. 2.1 *Air quality monitoring programme in the zone Banská Bystrica region.*

Zone Banská Bystrica region								Monitoring programme									
								Continuously								Continuously	
District	EoI code	Station	Type		Geographical		Altitude[m]	PM_{10}	$PM_{2,5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
			area	station	longitude	latitude											
Banská Bystrica	SK0214A	Banská Bystrica, Štefánikovo nábrežie	U	T	19°09'18"	48°44'06"	346										
Banská Bystrica	SK0263A	Banská Bystrica, Zelená	U	B	19°06'55"	48°44'01"	425										
Revúca	SK0025A	Jelšava, Jesenského	U	B	20°14'26"	48°37'52"	289										
Rimavská Sobota	SK0022A	Hnúšťa, Hlavná	U	B	19°57'06"	48°35'02"	320										
Lučenec	SK0072A	Lučenec, Gemerská cesta	U	T	19°40'33"	48°20'12"	183										
Zvolen	SK0262A	Zvolen, J. Alexyho	U	B	19°09'25"	48°33'30"	321										
Žarnovica	SK0078A	Žarnovica	S	B	18°43'04"	48°28'59"	222										
Žiar n/Hronom	SK0268A	Žiar n/Hronom, Jilemnického	U	B	18°50'34"	48°35'59"	296										
							Total	8	8	5	1	3	2	2	0	2	4



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

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

3 ASSESSMENT OF AIR QUALITY IN ZONE BANSKÁ BYSTRICA REGION

This chapter contains an assessment of air quality in the zone Banská Bystrica 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 Banská Bystica 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	Area / station	1 h	24 h	1 h	1 year	24 h	1 year	1 year	8 h[1]	1 year	12 h	12 h
Parameter		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	200	40	50	40	20	10 000	5	100	150
Maximum number of exceedances		24	3	18		35						
Banská Bystrica, Štefánikovo nábr.	UT	0	0	0	23	22	26	15	1 360	0.2	22	8
Banská Bystrica, Zelená	UB			0	7	4	17	11			17	9
Jelšava, Jesenského	UB			0	6	53	30	20			94	0
Hnúšťa, Hlavná	UB					8	21	14			17	6
Lučenec, Gemerská cesta	UT			0	13	22	25	17	1 423	0.2	18	8
Zvolen, J. Alexyho	UB					5	19	14			19	7
Žarnovica	SB			0	11	24	24	20			34	9
Žiar n/H, Jilemnického	UB					3	16	10			20	7

≥ 90 % valid measurements *Exceedance of the limit value is marked in red.*

[1] *eight-hour maximum concentration*

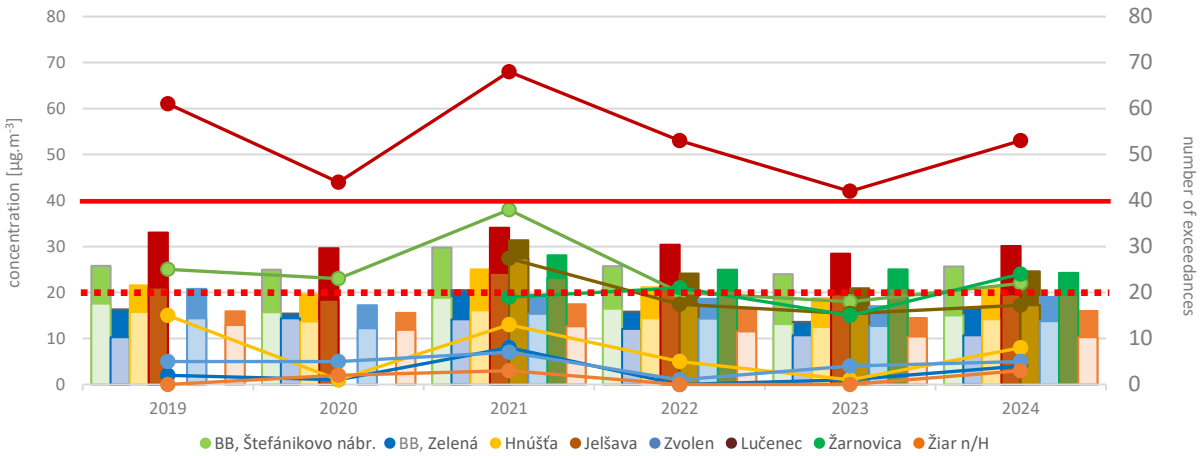
[2] *I IT, AT – duration of exceedance (in hours) of the information threshold (IT) and alert threshold (AT) for PM_{10}*

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. 1.1 shows the average annual concentrations of PM_{10}, $PM_{2.5}$ and the number of days with average daily PM_{10} concentrations above 50 $\mu g \cdot m^{-3}$ according to the results of measurements at monitoring stations in the Banská Bystrica region in 2019 – 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 (LH), red solid PM10 (average annual concentration: 40 $\mu g \cdot m^{-3}$); red striped $PM_{2.5}$ (average annual concentration: 20 $\mu g \cdot m^{-3}$); red solid arrow – LV number of exceedances (average daily PM_{10} concentration 50 $\mu g \cdot m^{-3}$ max. number of exceedances 35/calendar year).*

The average annual concentration of **PM_{10} or $PM_{2.5}$ did not exceed the limit value** in the Banská Bystrica region at any monitoring station.

The limit value for the average **daily** concentration of **PM_{10}** (50 $\mu g \cdot m^{-3}$) **was exceeded in Jelšava in 2024** – 53 exceedances**,** with **the most exceedances** (18) recorded in Jelšava during **January.** At most other stations, adverse dispersion conditions were more pronounced at the end of the year. The situation was more unfavorable in 2024 than in 2023, when Jelšava had 42 exceedances, of which the most (19) were measured in December, unlike other stations, for which February was the most problematic month in 2023. **The traffic station in Banská Bystrica has not exceeded the daily limit for PM_{10}** for a long time. This last exceedance happened in 2021, when the AMS was affected by construction activities near the station**.**

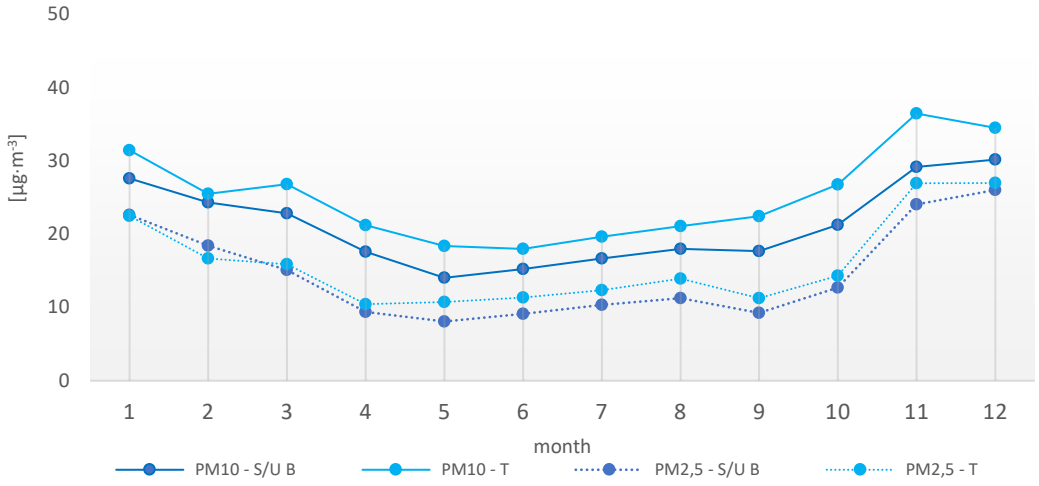
In 2024, adverse dispersion conditions in the zone were particularly evident in November, when elevated PM_{10} concentrations were recorded. A significant episode of Saharan dust transport at the turn of March and April led to daily limit values being exceeded for three days at all AMS in the zone. These two factors significantly contributed to the year-on-year increase in PM_{10} concentrations compared to 2023, which was exceptionally rich in precipitation. Given the expected decrease in precipitation in the future and the frequent occurrence of adverse dispersion conditions during the heating season, meeting the tightened EU air quality limits will continue to be a significant challenge.

In 2024, the maximum PM_{10} values were measured on 1. 4. 2024 during the desert dust transport episode, when the average daily PM_{10} concentrations exceeded 130 $\mu g \cdot m^{-3}$at 6 stations in the Banská Bystrica region. At all stations in the zone, we recorded three days during this episode at the turn of March and April with an average daily PM_{10} concentration > 50 $\mu g \cdot m^{-3}$. The $PM_{2.5}/PM_{10}$ ratio was significantly lower during this

episode than on other days, which is typical for natural sources of this type - they bring a relatively coarse particle size fraction.

Fig. 3.2 compares the monthly average of PM_{10} and $PM_{2.5}$ by station type. In September, there was a decrease in concentrations due to heavy precipitation.

Fig. 3.2 *Average monthly concentrations of PM_{10} and $PM_{2.5}$ in the Banská Bystrica 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 Banská Bystrica, Štefánikovo nábr. and Lučenec;* ***U/S PM10*** *and* ***U/S B PM2.5*** *– average of monthly mean concentrations of PM_{10} and$PM_{2,5}$ at urban/suburban background stations: Banská Bystrica, Zelená; Jelšava, Hnúšťa, Žarnovica, Zvolen, Žiar nad Hronom.*

Monthly concentrations for individual AMS are shown in **Fig. 3.3** where we can see a difference in PM_{10} concentrations at Jelšava in the winter months due to heating with solid fuels and also the more frequent occurrence of unfavorable dispersion conditions. High concentrations of $PM_{2.5}$ are risky mainly because of their adverse impact on human health. In Jelšava and Žarnovica, the average annual concentration of $PM_{2.5}$ was also at the limit value (20 $\mu g \cdot m^{-3}$) in 2024. As with PM_{10}, we also recorded high concentrations for $PM_{2.5}$, especially in January, November and December at most stations in the Banská Bystrica region.

Fig. 3.3 *Monthly average PM_{10} concentrations at individual AMS in the zone in 2024.*

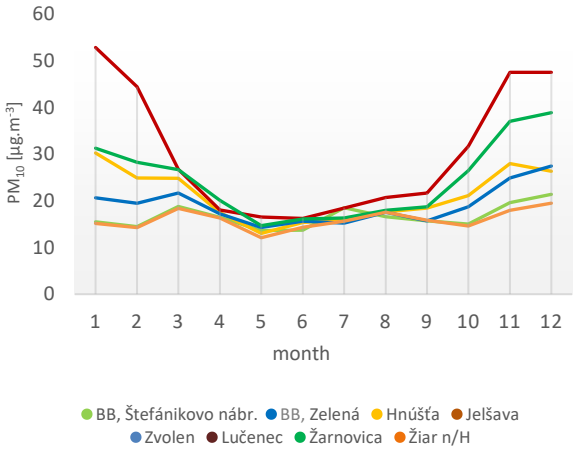


Fig. 3.4 *Average annual PM_{10} concentration (left) and number of PM_{10} daily limit value exceedances (right) in 2024.*

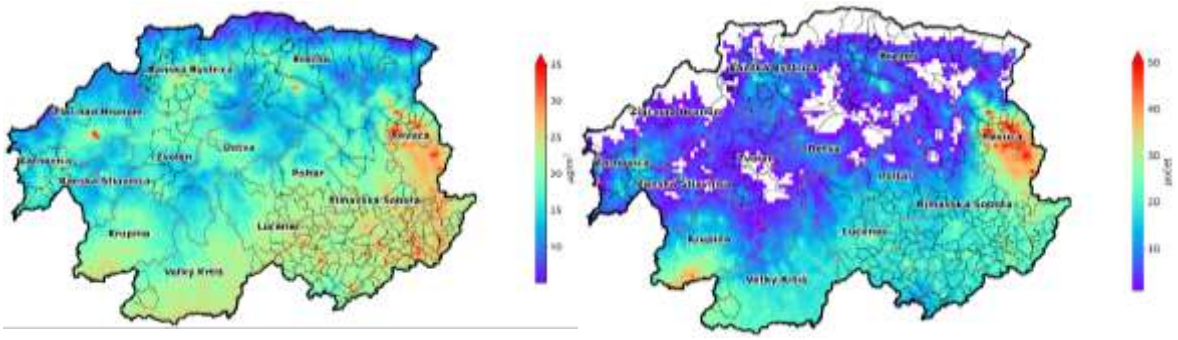
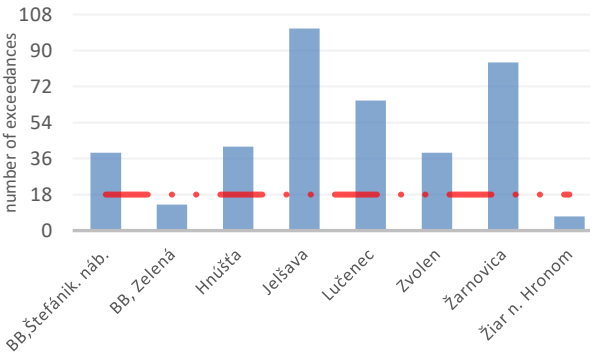


Fig. 3.4 and **Fig. 3.6** show the modelling results for PM_{10} and $PM_{2.5}$, calculated for the year 2024 using the RIO model subsequently adjusted using the regression IDW-R method. More detailed information is provided in Chapter 4 of the Air Pollution Report in the Slovak Republic for the year 2024.

Fig. 3.5 *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. 3.6 *Average annual $PM_{2.5}$ concentrations in 2024. Output of the RIO/IDW model.*

Fig. 3.5 shows $PM_{2.5}$ concentrations in relation to the new EU limit, which will apply from 1 January 2030. In this case, the newly introduced EU limit determines that the daily average $PM_{2.5}$ concentration (25 µg·m^{-3}) should not be exceeded more than 18 times per calendar year. In the Banská Bystrica region, this limit value would be met only by the station in Žiar nad Hronom and the city background station in Banská Bystrica on Zelená Street.

The new EU limit value of 10 µg·m^{-3} – which is to be achieved by 1 January 2030 – for the average annual $PM_{2.5}$ concentration would again be narrowly met in 2024 only by the station in Žiar nad Hronom.

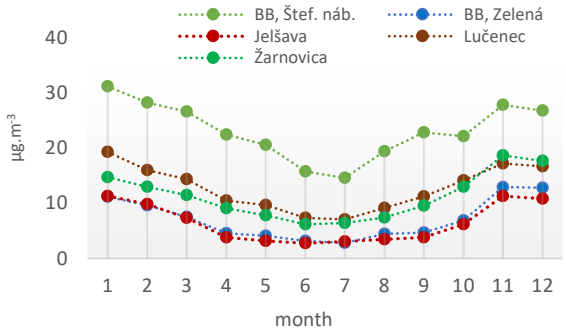
The new EP Directive 2024/2881 contains a forward-looking objective and new EU limits for air pollutants. These limits are binding on EU Member States and are to be achieved by 1 January 2030.

A comparison of the PM_{10} values for 2024 with this objective shows that the new EU limit – 20 µg/m³ for the annual average PM_{10} concentration – would be exceeded at the transport station in Banská Bystrica and Lučenec, as well as at the urban background station in Jelšava, Žarnovica and Hnúšťe.

3.2 Nitrogen dioxide

Nitrogen dioxide monitoring is carried out in the zone at five stations. The limit value for the average annual or hourly concentration was not exceeded at any monitoring station. The average monthly NO_2 concentrations for individual stations are shown in **Fig. 3.7**. Higher NO_2 concentrations are at traffic stations (BB Štefánikovo náberežie and Lučenec), and as expected, the highest values are in Banská Bystrica, where is higher traffic intensity. **The limit value** for NO_2 **was not exceeded** in the zone.

Fig. 3.7 Average monthly NO_2 concentrations I n2024.



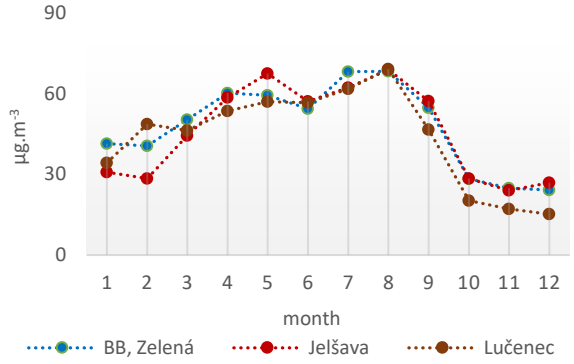
The average annual NO_2 concentrations in the zone exceeded 10 $\mu g \cdot m^{-3}$ at all monitoring stations except AMS Jelšava and Banská Bystrica, Zelená. This NO_2 level represents the WHO recommendation (from 2021). In general, the WHO recommendations are significantly stricter than the EU limits.

Only the traffic station in Banská Bystrica would exceed the new EU limit value for the average annual concentration of NO_2 (20 $\mu g/m^3$), which must be achieved by 1 January 2030 according to the new European Parliament Directive 2024/2881.

3.3 Ozone

Ozone monitoring is carried out at three monitoring stations, namely in the regional city of Banská Bystrica, Zelená, in Jelšava and Lučenec. The highest concentrations of ground-level ozone generally occur in warm months with high sunlight intensity, which is caused by the photochemical reaction that produces ground-level ozone (**Fig. 3.8**). For transport stations, lower concentrations of O_3 are characteristic, which can be seen in (**Fig. 3.8**). (Lučenec compared to Banská Bystrica Zelená and Jelšava). The opposite case was February, but the values are low considering the time of year. The decrease that occurred in June was probably caused by wet deposition with unusually high precipitation totals

Fig. 3.8 Average monthly O_3 concentrations in 2024.



In the Banská Bystrica Region, in 2024, no exceedance of the information or warning threshold for ground-level ozone was measured.

3.4 Benzo(a)pyrene

Benzo(a)pyrene is monitored in the Banská Bystrica Region at one urban and two suburban background stations (in Banská Bystrica on Zelená Street, in Jelšava and from 2021 also in Žarnovica) and at the transport station in Banská Bystrica on Štefánikový nábrežie.

In 2024, **the target value was exceeded in Jelšava and Žarnovica**. (**Tab. 3.1**). In the winter months, BaP values in Žarnovica, like in Jelšava, are alarmingly high, as can be seen in **Fig. 3.9**.

The average annual concentration of BaP in Jelšava is more than three times the target value. The highest concentrations were measured in December.

Tab. 3.1 *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
Banská Bystrica, Štefánikovo nábrežie	2,1	1,7	1,6	1,7	1,4	1,2	1,0
Banská Bystrica, Zelená		1,1	1,2	1,3	0,9	0,9	0,8
Jelšava, Jesenského	3,9	4,0	3,0	2,8	2,7	3,4	3,4
Žarnovica				2,2	2,7	*1,9	2,2

≥ 90 % valid measurements

**station relocation in 2023, outage in November and fewer measurements in December, 82% valid measurements.*

Red color indicates exceeding the target value if there were enough (≥ 90%) valid measurements at the station in a given year.

The most significant source of benzo(a)pyrene is household heating with solid fuel, especially insufficiently dried wood or unsuitable fuel (various types of waste). Modern heating equipment achieves relatively low emissions when properly maintained and operated. However, modern boilers are probably used only to a small extent in problem areas, which is related to the significant presence of low-income households in these locations.

In Jelšava, which has long been characterized by a reduced level of air quality, samples for analysis of polycyclic aromatic hydrocarbons were taken every second day and at other stations every third day. In **Fig. 3.9** we see that significant concentration maxima were recorded at the AMS in Jelšava and Žarnovica, highest in November and December.

Fig. 3.10 shows the average annual concentration according to the outputs of mathematical modeling. In areas with extremely unfavorable dispersion conditions, such as Jelšava, air pollution with this carcinogenic substance represents a significant problem.

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

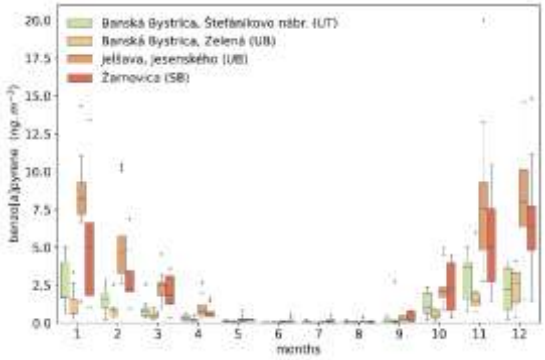
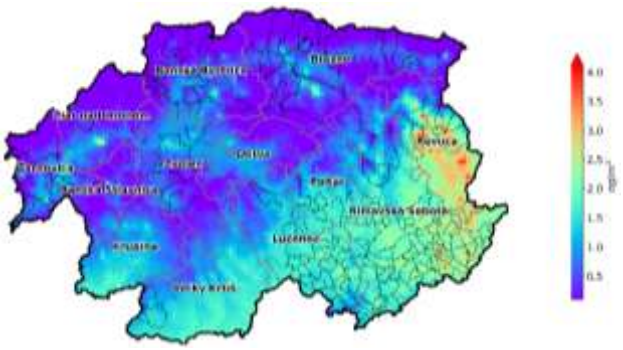


Fig. 3.10 *Average annual concentration of BaP according to RIO/IDW- R model output, (2024).*

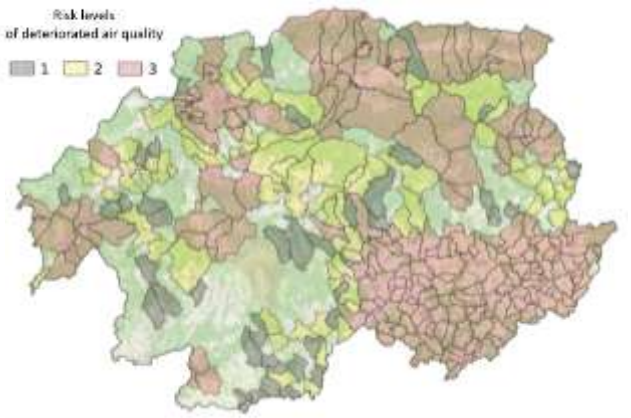


3.1 Risk municipalities

Fig. 3.11 shows municipalities at risk of poor air quality, identified by the integrated municipal assessment method with regard to the risk of adverse air quality Risk level 3 corresponds to the highest probability of being at risk from air pollution. The methodology includes the rate of household heating with solid fuels, the impact of impaired dispersion conditions in the short and long term, the results of the CMAQ chemical-transport model, the RIO inter-field model and the results of high-resolution CALPUFF modelling on selected domains with a presumption of impaired air quality.

Municipalities where the limit value for PM, NO_2 or the target value for BaP was exceeded according to modelling with high spatial resolution were automatically assigned a risk level 3, similarly to mu-nicipalities where the limit or target value was exceeded according to measurement. A list of municipalities and their risk levels is available on the SHMÚ website[2].

Fig. 3.11 *Risk municipalities in zone Banská Bystrica region* 2024**.**



Zones and agglomerations containing at least one municipality with a risk level 3 are required to prepare Air Quality Plan. Based on this, municipalities at risk level 3 correspond to *air quality management areas.* However, measures to reduce emissions must be implemented in all municipalities with a risk level 2 or 3 included in the zone, ideally also in municipalities with a risk level of 1.

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 the microclimatic characteristics of the area, it is likely that the level of pollution in the risk area will vary from one location to another. An idea of the spatial distribution of air pollution is provided by the results of high-resolution modelling, which are progressively added to the website [3].

3.2 Summary

The target value for the average annual concentration of benzo(a)pyrene was exceeded in Jelšava and Žarnovica. The average annual concentration of benzo(a)pyrene at the monitoring station in Banská Bystrica on Štefánikový nábreží was at the target value (1 ng·m^{-3}). A decrease in B(a)P concentrations can be observed at both monitoring stations in Banská Bystrica.

The limit value for **the average daily concentration of PM_{10} was exceeded at the Jelšava, Jesenského** monitoring station.

The new limit values, which will come into effect from 2030**, would be exceeded at most stations** in the Banská Bystrica region in 2024. The most significant problem is the high concentrations of $PM_{2.5}$ concentrations. Only the AMS in Žiar nad Hronom would be in line with the stricter limits for 2030 in 2024.

On the contrary, only the traffic station in Banská Bystrica on Štefánikovo nábreží would exceed the new limit value for the average annual concentration of NO_2.

Air pollution is particularly significant in poorly ventilated areas with frequent temperature inversions. The dominant source of pollution is heating households with solid fuel, probably often insufficiently dried wood, or various types of waste, when using heating equipment with high emissions.

[2] *https://www.shmu.sk/sk/?page=2768*
[3] *https://www.shmu.sk/sk/?page=2699*

Localities with higher values of pollutants, especially B(a)P, occur in closed mountain valleys. The situation is also influenced by the social composition of the population, whose economic situation does not allow the purchase and operation of low-emission heating equipment.

When analyzing the long-term development of pollution in the Banská Bystrica region, we see an improvement compared to the situation several decades ago, but in recent years the values have fluctuated depending on meteorological conditions.

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An illustration is the high values measured in cold January 2017, or to a lesser extent during anticyclonic situations with unfavorable dispersion conditions in combination with long-distance dust transport from dry areas in March 2022, then the more favorable year 2023 (but with unfavorable February and December) and the more unfavorable year 2024, when the highest values were measured during January, November and December.

Exceedance of the limit value for SO_2, NO_2, CO and benzene, nor exceedance of the limit value for the average annual concentration of PM_{10} and $PM_{2.5}$ in 2024 was not measured in the Banská Bystrica Region zone.