AIR POLLUTION IN THE SLOVAK REPUBLIC 2021

ANNEX

AIR QUALITY ASSESSMENT IN ZONE BANSKÁ BYSTRICA REGION

Air quality monitoring department
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

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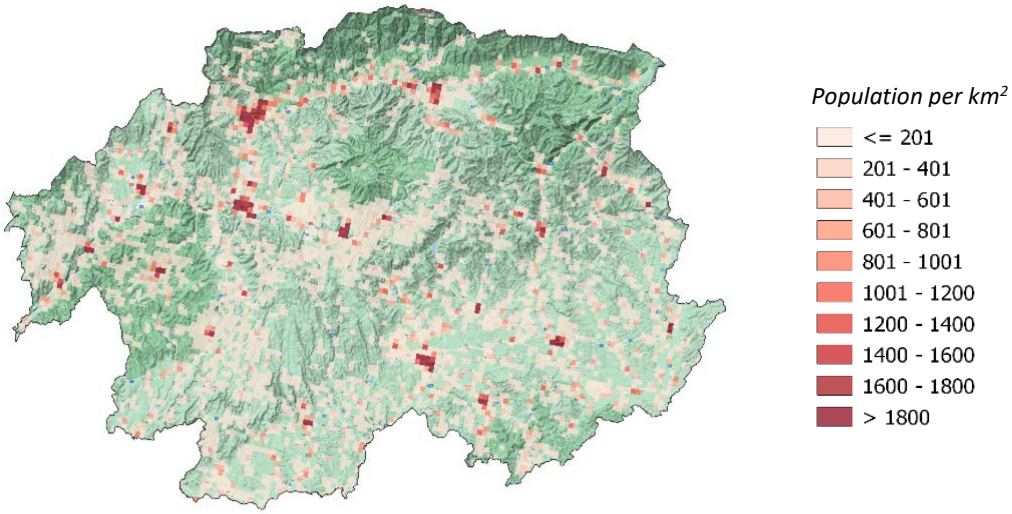
Version 2

1 DESCRIPTION OF BANSKÁ BYSTRICA REGION TERRITORY IN TERMS OF AIR QUALITY

The terrain of the Banská Bystrica region is predominantly mountainous. The mountain basins in the area are characterized by low wind speeds and frequent temperature inversions, especially in winter. In the north of the district there are the higher mountains of the Low Tatras and outcrops of the Veľká Fatra. A relatively large part is occupied by the medium-high mountains - the Slovenské Rudohorie, Štiavnické vrchy a Krupinská planina in the central part of the district. The south of the district is characterized by lower altitudes - Juhoslovenská kotlina and Cerová vrchovina are located here. The highest point is Ďumbier with an altitude of 2 046 m above sea level, the lowest point is 124 m above sea level. **Fig. 1.1** shows the spatial distribution of population density in the zone.

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.

Fig. 1.1 *Population density in the zone Banská Bystrica region (Source: EUROSTAT, 2018).*

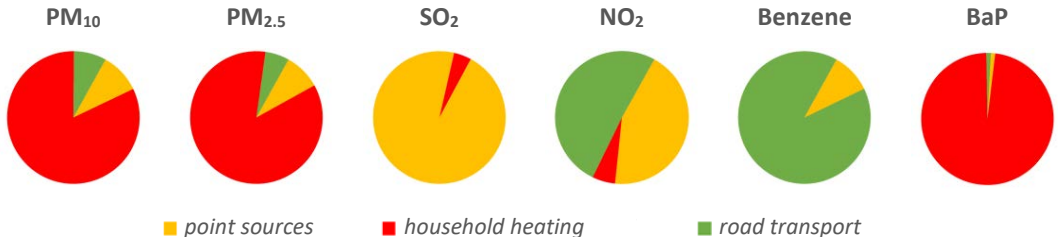


Air pollution sources in zone Banská Bystrica region

The dominant source of air pollution in the Banská Bystrica region is household heating, especially in the northern part, where the share of firewood use is the highest compared to other areas. Road transport is also important locally. It reaches the highest intensity in the district of Banská Bystrica - on the R1 highway (an average of 40 011 vehicles pass through it daily, of which 4 644 trucks and 35 174 passenger cars) and on road No. 66 (34 559 vehicles, of which 2 740 trucks and 31 719 passenger cars). Road No. 50 is significant in terms of traffic congestion in the district of Zvolen, Žiar nad Hronom and Detva - in Zvolen with a level of 29 988 vehicles (19% trucks), in Žiar nad Hronom 16 707 vehicles (23% trucks) and in Detva with 14 357 vehicles (11% trucks) - and route No. 66 in the districts of Zvolen (14 715 vehicles, of which 2 534 trucks and 12 135 cars) and Brezno (12 289 vehicles, of which 1 659 trucks and 10 559 cars). In the district of Lučenec, roads are No. 585, No. 50 and No. 75 are important, while the heaviest traffic is on the first of them (13 815 vehicles, of which 1 387 trucks and 12 370 passenger cars) [1].

[1] *https://www.ssc.sk/sk/cinnosti/rozvoj-cestnej-siete/dopravne-inzinierstvo/celostatne-scitanie-dopravy-v-roku-2015/banskobystricky-kraj.ssc*

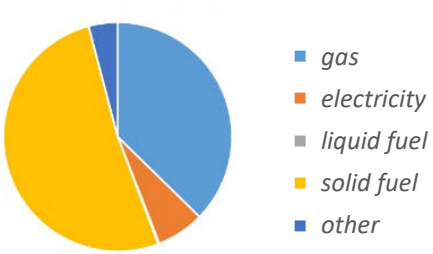
Fig. 1.2 *Share of different types of air pollution sources in total emissions in the Banská Bystrica region.*



Note: Medium and large air pollution sources registered in the NEIS database are identified for this purpose as "point sources".

Non-ferrous metallurgy and other industrial sources have a less significant contribution to local air pollution with the basic pollutants in Banská Bystrica region. Under suitable meteorological conditions, the impact of heating plants will also appear in this zone. A significant source of PM and BaP in this region is household heating, road transport is a source of NO_2 and benzene.

Fig. 1.3 *Share of different types of fuel used for heating in family houses [2].*



According to the Population and Housing Census (PHC) 2021 data, both solid fuels and natural gas are used for heating in family houses in the zone. According to the SODB, the Banská Bystrica region has the second highest share of solid fuels for household heating. Solid fuels are probably used more in rural type of settlements with good availability of firewood. The districts of Detva, Krupina and Zvolen have the highest share of solid fuels in the zone.

2 AIR QUALITY MONITORING STATIONS IN ZONE BANSKÁ BYSTRICA REGION

In the Banská Bystrica Region, air quality has been monitored at eight locations. In the city of Banská Bystrica, there are two stations, a transport station on Štefániková street and a city background station on Zelená street in a sloping terrain with residential-type buildings. Urban background stations, which mainly monitor the effect of household heating in a rural environment, are represented in the south-eastern part of the region in the cities of Jelšava and Hnúšťa. In 2021, a station was added in Lučenec to monitor the impact of traffic. The north-western part of the region is covered by stations in Zvolen and Žiar nad Hronom and Žarnovica, which monitor the urban or suburban (Žarnovica) background. Measurements at the station Žarnovica, Dolná began in 2021 as part of the expansion of the monitoring network.

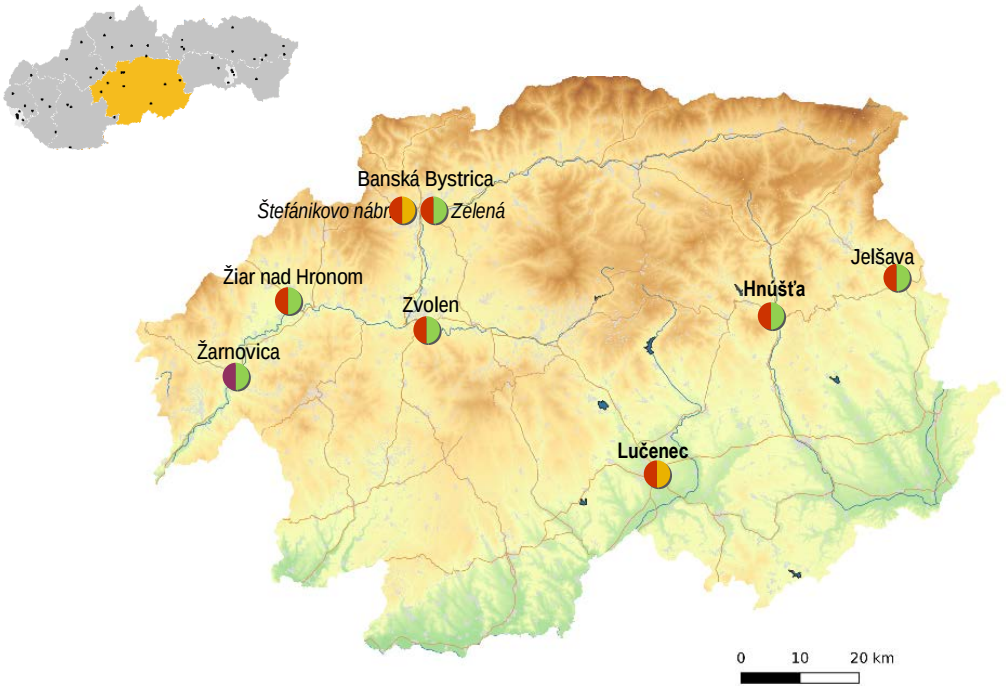
[2] *https://www.scitanie.sk*

Tab. 2.1 contains information about air quality monitoring stations in the Banská Bystrica region zone:

- international EoI code, characteristics of the station according to dominant sources of air pollution (traffic, background, industrial), type of area that the station monitors (urban, suburban, rural/ regional) and geographical coordinates;
- monitoring programme. Automatic continuous monitoring devices 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. The results of measurement are average 24-hour values.

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

Zone Banská Bystrica region								Measurement programme									
								Continuously								Manually	
District	EoI code	Station name	Type of		Co-ordinates		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	SK0065A	Žarnovica, Dolná	S	B	18°43'10"	48°28'58"	222										
Žiar n/Hronom	SK0268A	Žiar n/Hronom, Jilemnického	U	B	18°50'34"	48°35'59"	296										
							Total	8	8	5	1	2	2	2	0	2	4



Type of area:
U – urban
S – suburban
R – regional

Type of station:
B – background
T – traffic
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 2021.

Tab. 3.1 *Air quality assessment according to limit values for human health protection and numbers of warning threshold exceedances – 2021.*

	Protection of human health									AT [2]	
Pollutant	SO_2		NO_2		PM_{10}		$PM_{2.5}$	CO	Benzene	SO_2	NO_2
Averaging period	1 h	24 h	1 h	1 year	24 h	1 year	1 year	8 h [1]	1 year	3 h in a row	3 h in a row
Parameter	number of exceedances	number of exceedances	number of exceedances	average	number of exceedances	average	average	average	average	number of exceedances	number of exceedances
Limit value [µg·m^{-3}]	350	125	200	40	50	40	20	10 000	5	500	400
Maximum number of exceedances	24	3	18		35						
Banská Bystrica, Štefánik. nábr.	0	0	2	25	38	30	19	1 828	0.85	0	0
Banská Bystrica, Zelená			0	10	8	20	14				0
Jelšava, Jesenského			0	9	68	34	24				0
Hnúšťa, Hlavná					13	25	16				
Lučenec, Gemerská cesta*			0	20	3	31	**27	1 059	3.12		0
Zvolen, J. Alexyho					7	20	15				
Žarnovica, Dolná*			0	12	19	28	**23				0
Žiar n/H, Jilemnického					3	17	13				

≥90% of valid measurements

Exceedance of the limit value is marked in red.

[1] eight-hour maximum concentration

[2] limit values for alert thresholds

** AMS began measuring during 2021*

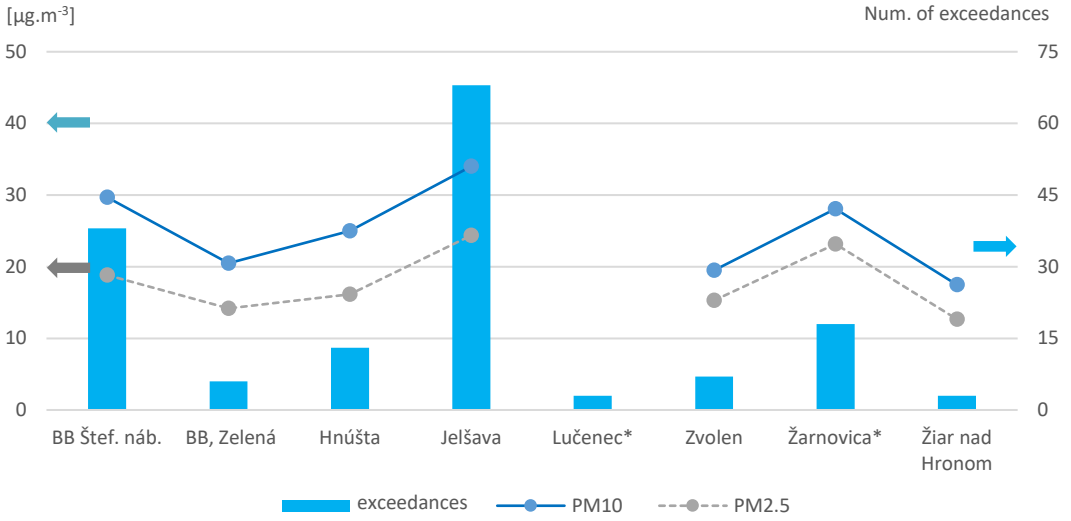
*** measurements started during 2021, there are not enough valid measurements to assess the exceedance of limit values on a yearly basis*

With the exception of the new monitoring station in Lučenec and Žarnovica (installed during the calendar year), in accordance with the Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality, as amended, the required proportion of valid values at the other stations has been fulfilled.

3.1 PM_{10} a $PM_{2.5}$

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 $\mu g \cdot m^{-3}$ according to the results of measurements at monitoring stations in the Banská Bystrica region in 2021.

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



Number of exceedances – show daily average concentrations of PM_{10} higher than 50 $\mu g \cdot m^{-3}$;
** the stations Lučenec and Žarnovica do not reflect air pollution for the whole year.*

*The arrows show the limit values, **grey arrow** $PM_{2.5}$ (average annual concentration: 20 $\mu g \cdot m^{-3}$); **blue left arrow** PM_{10} (average annual concentration: 40 $\mu g \cdot m^{-3}$); **blue right arrow** number of exceedances (average daily PM_{10} concentration of 50 $\mu g \cdot m^{-3}$ must not be exceeded more than 35 times in a calendar year).*

PM_{10}

The limit value for the average annual concentration of PM_{10} (40 $\mu g \cdot m^{-3}$) in the zone Banská Bystrica region was not exceeded. The limit value for the number of exceedances (35) of the average daily concentration of PM_{10} was exceeded by the transport station Banská Bystrica, Štefánikovo nábrežie (38 exceedances) and Jelšava (68 exceedances) (**Fig. 3.1**). Values at the traffic monitoring station Banská Bystrica, Štefánikovo nábrežie were affected by the construction activity near the station.

In the western part of the region, the new NMSKO station in Žarnovica appears to be problematic. Although it monitored the air pollution only in the second half of 2021, from the measured values of PM_{10} and $PM_{2.5}$ we can assume that these concentrations are in Žarnovica at the level of the traffic station in Banská Bystrica, Štefánikovo nábrežie. The number of exceedances of the average daily concentration of PM_{10} is also high - in the second half of the year there were 19 in Žarnovica. The Banská Bystrica traffic station, Štefánikovo nábrežie recorded an average annual PM_{10} concentration of 30 $\mu g \cdot m^{-3}$ (for comparison, Žarnovica 28 $\mu g \cdot m^{-3}$ and Jelšava 34 $\mu g \cdot m^{-3}$). However, it should be taken into account that the station in Banská Bystrica, Štefánikovo nábrežie reflects the impact of traffic and the measured pollution on Štefánikovo nábrežie does not directly affect the city's residents in residential areas. This is confirmed by the average annual level of PM_{10} at the city background station on Zelená Street (20 $\mu g \cdot m^{-3}$). For a long time, the most problematic monitored location in Slovakia is Jelšava (we assume that there are more such locations in the Banská Bystrica region as well, due to the same geographical and meteorological conditions, the same accessibility to fuels, etc.). In 2021, it recorded 68 days with an average daily PM_{10} concentration above 50 $\mu g \cdot m^{-3}$, which is almost twice the daily limit value (35 exceedances).

High concentrations of PM_{10} in Jelšava are related to the cold months of the year (**Fig. 3.2**). Alarmingly high concentrations of PM_{10} were measured in Jelšava, especially in January and February, when they reached almost three times the average PM_{10} values of other stations in that period. zone. From **Fig. 3.2** it is also clear that in the warm period of the year, PM_{10} concentrations in Jelšava are only slightly above the average of other stations, which confirms the assumption that the source of PM_{10} and $PM_{2.5}$ is local heating - i.e. inappropriate way of heating households with low-quality solid fuel in old boilers and stoves. The situation here is further aggravated by frequent adverse dispersion conditions.

Fig. 3.2 *Number of PM_{10} daily limit value exceedances per month in 2021.*

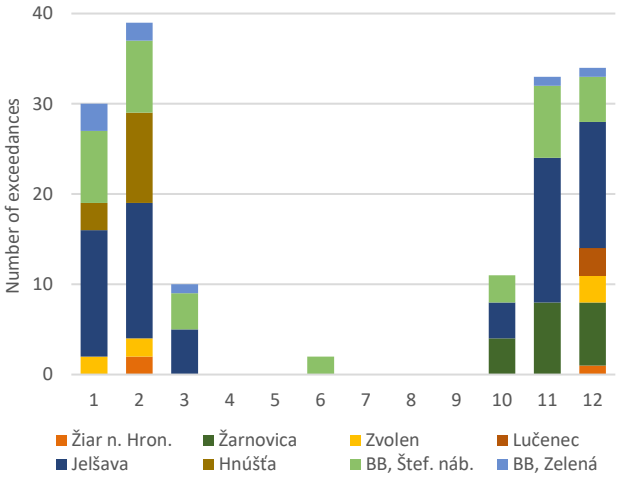
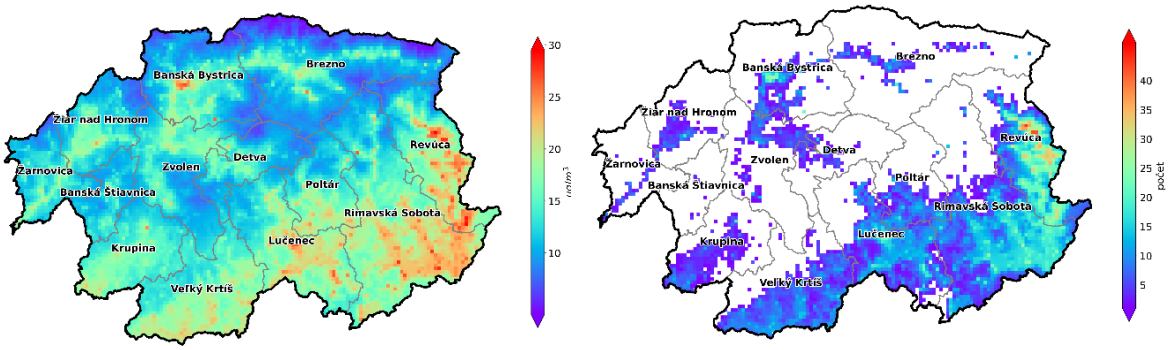


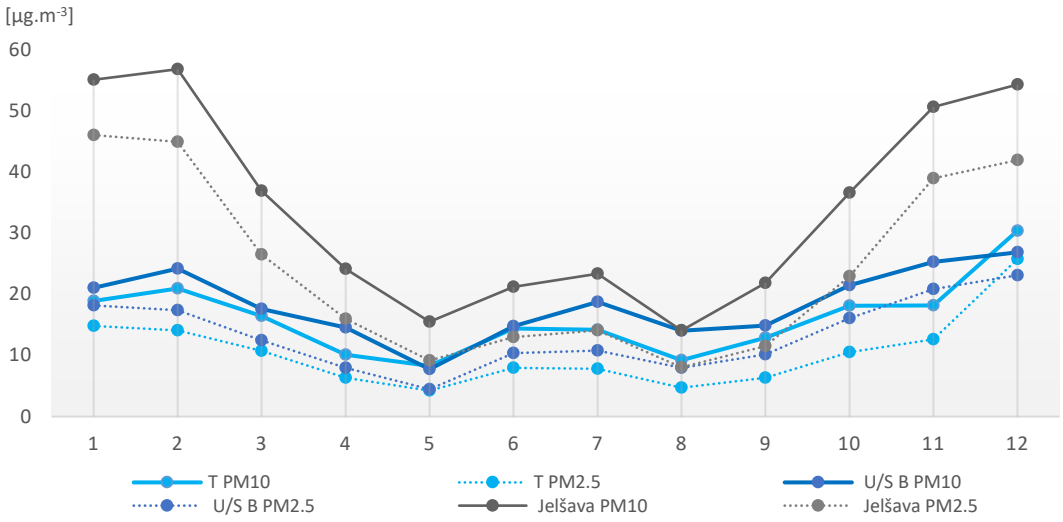
Fig. 3.3 and **Fig. 3.5** show the modelling results for PM_{10} and $PM_{2.5}$, calculated for the year 2021 using the RIO model subsequently adjusted using the regression IDW-R method (see Chapter 4 *Air pollution in the Slovak Republic 2021 Report* for more details). For ease of illustration, only areas for which the annual mean concentrations were higher than the more stringent annual limits recommended by WHO are shown.

Fig. 3.3 *Average annual PM_{10} concentration (left) and number of exceedances of the PM_{10} daily limit (right) in 2021. Only values above 15 $\mu g \cdot m^{-3}$ and non-zero number of exceedances are shown.*



Both traffic stations in the region have similar average monthly concentrations of PM_{10} and $PM_{2.5}$. With the exception of Jelšava, this also applies to urban and suburban background stations. Therefore **Fig. 3.4** compares the monthly average PM_{10} and $PM_{2.5}$ of traffic stations in the region, the level in Jelšava and the monthly average of urban and suburban background stations in the region outside Jelšava.

Fig. 3.4 *Average monthly concentrations of PM_{10} and $PM_{2.5}$ in the region by station type.*



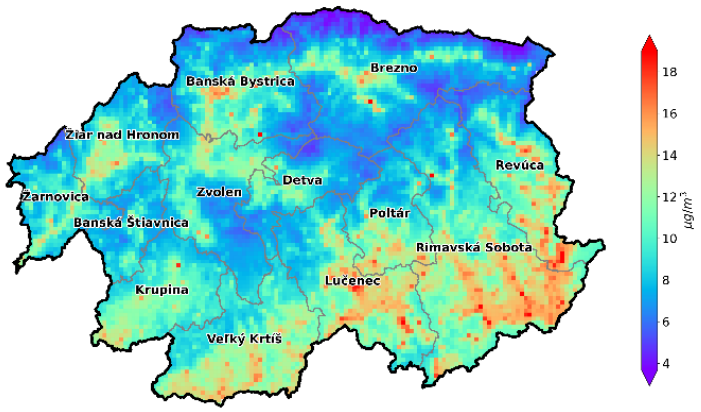
T PM10 *and* ***T PM2.5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the traffic stations Banská Bystrica, Štefánikovo. nábr. and Lučenec;* ***U/S B PM10*** *and* ***U/S B PM2.5*** *– average monthly concentrations of PM_{10} and $PM_{2.5}$ at urban/suburban background stations Banská Bystrica, Zelená; Hnúšťa; Zvolen; Žarnovica and Žiar n/Hronom;* ***Jelšava PM10*** *and* ***Jelšava PM2.5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the suburban background station Jelšava.*

$PM_{2.5}$

Compared to PM_{10}, fine $PM_{2.5}$ particles have a significantly higher negative impact on human health. In Fig. 1.1 and Fig. 3.4, annual mean concentrations of $PM_{2.5}$ are shown by a dashed line. In Jelšava, the average annual concentration of $PM_{2.5}$ (24 µg·m^{-3}) exceeded the limit value (20 µg·m^{-3}) and, as with PM_{10}, very high concentrations of $PM_{2.5}$ were measured in the cold period of the year. In Žarnovica, there is not enough measurements available for the annual air quality assessment in 2021, but measurements so far show that this location will also be problematic from the point of view of $PM_{2.5}$; in November and December, the average monthly concentrations in Žarnovica (33 µg·m^{-3} and 38 µg·m^{-3}) were twice as high as the other stations in the region, and the values measured in November and December were close to values measured in Jelšava. We also observed higher average concentrations in the winter months in Hnúšťa. The average concentration measured in Lučenec in December reached 27 µg·m^{-3}. Since the measurements started here this month, there is not enough measurements available for the annual air quality assessment.

The map at Fig. 3.5 shows the spatial distribution of the annual mean $PM_{2.5}$ concentration according to the output of the RIO model, adjusted by IDW-R.

Fig. 3.5 *Average annual $PM_{2.5}$ concentration.*

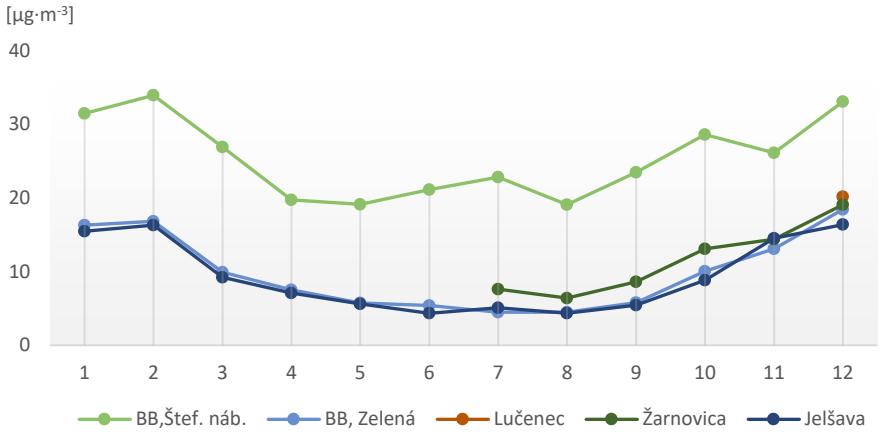


Average annual concentrations of $PM_{2.5}$ in 2021. Only values above 5 µg·m^{-3} are shown, which is the limit value recommended by the WHO.

3.2 Nitrogen dioxide

Nitrogen dioxide is monitored at five stations in the zone. The average monthly concentrations for each station are shown in **Fig. 3.6**

Fig. 3.6 *Average monthly NO_2 concentrations.*



The main source of NO_2 emissions is road transport. The highest concentrations occur at the traffic station Banská Bystrica, Štefánikovo nábrežie, although even here the annual average level (25 µg·m^{-3}) is significantly below the limit value for the annual average concentration (40 µg·m^{-3}). The monitoring station in Lučenec started measuring NO_2 in the second half of December 2021. Concentrations at this station in December were at the level of urban background stations in the Banská Bystrica region.

NO_2 at urban background stations in the Banská Bystrica region had an annual average concentration of 10 µg·m^{-3} and below. This level of NO_2 (10 µg·m^{-3}) represents the WHO recommended limit value (2021 Recommendation). In general, the WHO recommendations are significantly more stringent than the EU limits. Overall, therefore, the average NO_2 concentrations in the Banská Bystrica region do not reach high values.

3.3 Ozone

Ozone monitoring is carried out at two monitoring stations - in the regional town of Banská Bystrica, Zelená and in Jelšava.

The highest concentrations of ground-level ozone generally occur in warm months with high sunshine intensity (**Fig. 3.7**). **Fig. 3.8** and **Fig. 3.9** show the so-called daily course of O_3 concentration at stations (urban background stations Jelšava and Banská Bystrica, Zelená). It shows the increase of their levels with sunrise, the peak they reach around noon and the gradual decrease in the evening to the minimum occurring in the morning. Large differences in ground-level ozone concentrations are also observed in the warm and cold seasons.

Fig. 3.7 *Monthly average O_3 concentrations.*

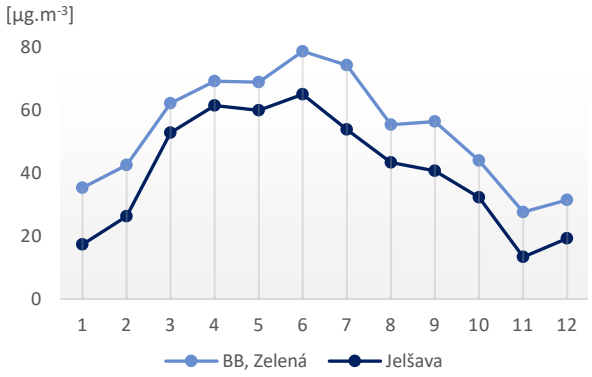


Fig. 3.8 *Daily O_3 concentration in January 2021.*

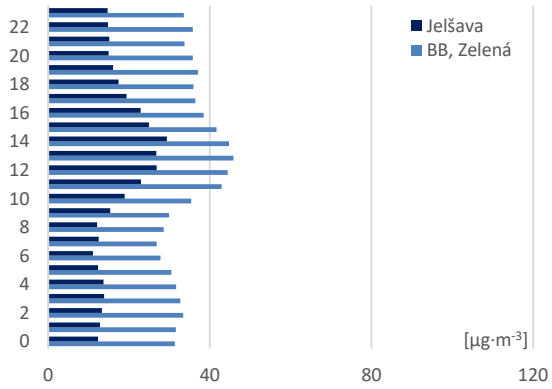
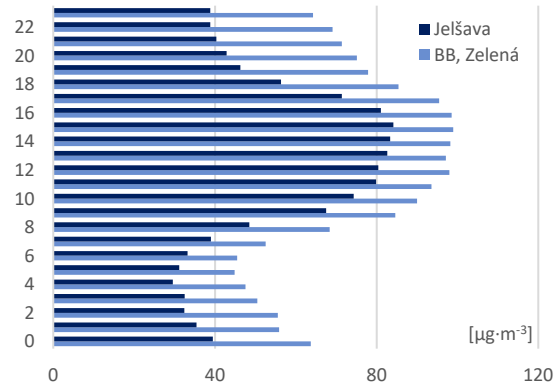


Fig. 3.9 *Daily O_3 concentration in July 2021.*



3.4 Benzo(a)pyrene

Benzo(a)pyrene is monitored in the Banská Bystrica region at monitoring stations in Banská Bystrica (on Zelená Street and Štefánikovo nábrežie), Jelšava and in 2021 monitoring started at the station Žarnovica, Dolná. Compared to PM, BaP has an even more significant maximum in the cold season (**Fig. 3.10**).

The values measured in Žarnovica in the winter months are, like in Jelšava, alarmingly high. The target value for benzo(a)pyrene (1 ng·m^{-3}) was also exceeded in the past in the Banská Bystrica region at all stations, more significantly in Jelšava than in Banská Bystrica (**Tab. 3.2**).

Tab. 3.2 *Assessment of air pollution by benzo(a)pyrene*.

	2017	2018	2019	2020	2021
Target value [ng·m^{-3}]	1.0	1.0	1.0	1.0	1.0
Banská Bystrica, Štefánikovo nábrežie	2.9	2.1	1.7	1.6	1.7
Banská Bystrica, Zelená			1.1	1.2	1.3
Jelšava, Jesenského		3.9	4.0	3.0	2.8
Žarnovica, Dolná					2.2

≥90% of valid measurements

Exceeding the target value is marked in red if there were enough (≥90%) valid measurements at the station in the given year.

The most significant source of benzo(a)pyrene is the heating of households with solid fuel, especially insufficiently dried wood, or unsuitable fuel (various types of waste). Modern heating devices achieve relatively low emissions with proper maintenance and operation. However, in areas such as Jelšava, modern boilers are probably only used to a small extent, which is a reflection of the significant representation of low-income households. **Fig. 3.11** shows the average annual concentration according to the outputs of mathematical modelling. In areas with extremely adverse dispersion conditions, such as Jelšava, this substance with carcinogenic properties represents a significant problem.

Fig. 3.10 *Concentrations of benzo(a)pyrene measured in 2021.*

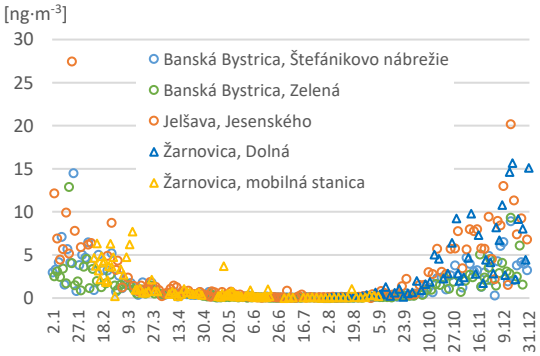
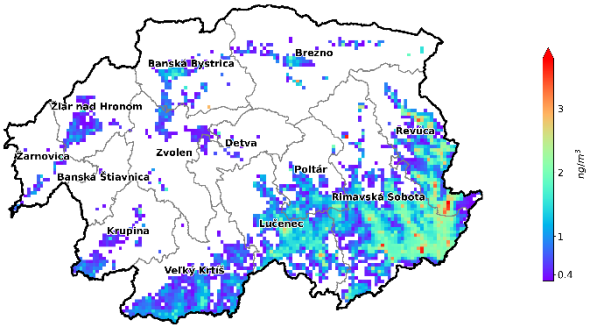


Fig. 3.11 *Average annual concentration of benzo(a)pyrene from RIO model output, IDW-R (2021).*

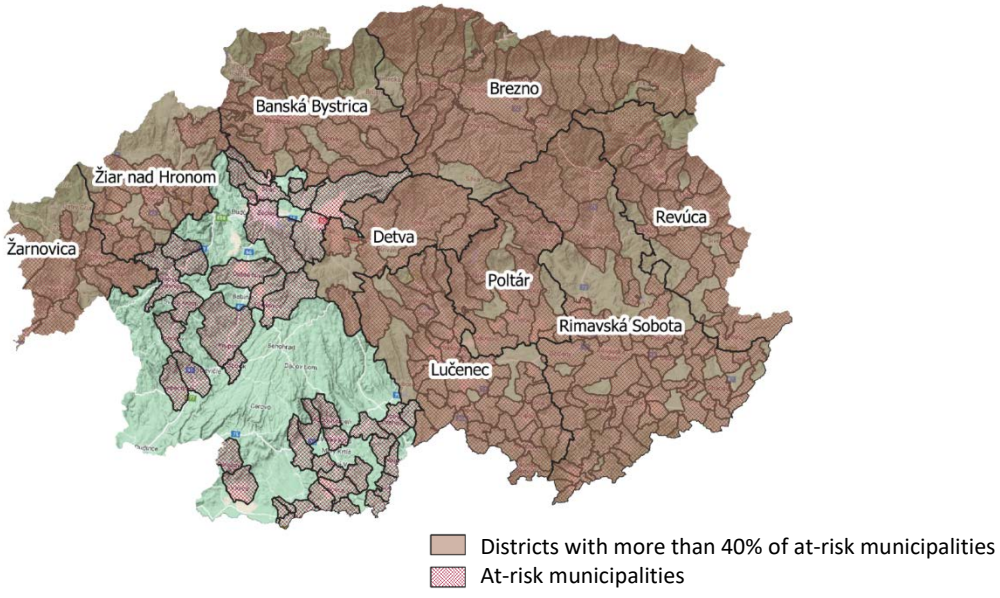


3.5 Risk areas

Fig. 3.12 shows the areas at risk of air quality deterioration due to pollutants (PM and benzo(a)pyrene) from domestic heating based on the modelling results. The modelling results were obtained by using the methodology of *D. Štefánik: Identification of at-risk municipalities with air quality threatened by local heating and adverse dispersion conditions* (updated in 2022)[3].

This methodology is based on data from Population and Housing Census (PHC) 2021 (usage of solid fuels for household heating), and it also takes into account high PM concentrations obtained from mathematical modelling and adverse dispersion conditions. There are no available input data with high spatial resolution covering the whole country for mathematical modelling. Therefore, we assume that the area is at risk is if it has a high proportion of solid fuel heating even though this was not indicated by mathematical modelling.

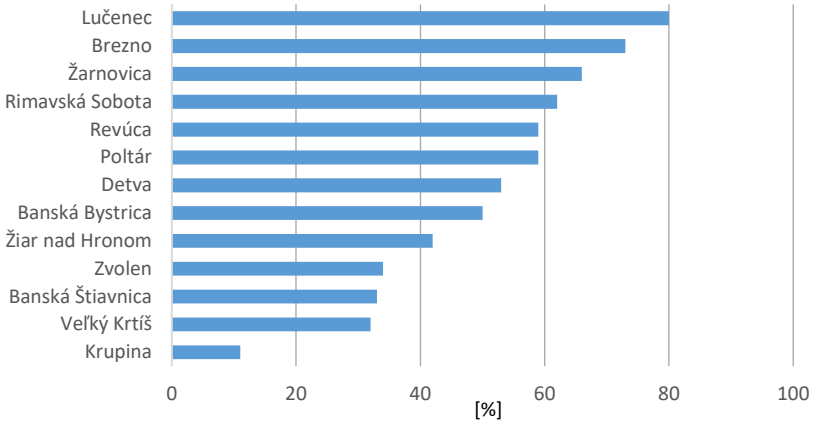
Fig. 3.12 *Risk areas in the zone Banská Bystrica region.*



The percentage of at-risk municipalities in individual districts is shown in **Fig. 3.13**. If a district has more than 40% of the municipalities at risk, the whole district is defined as at risk. In the Banská Bystrica Region these districts are: Lučenec, Brezno, Žarnovica, Rimavská Sobota, Revúca, Poltár, Detva, Banská Bystrica, Žiar nad Hronom.

[3] *https://www.shmu.sk/File/oko/mesacne_spravy/Popis_metody_na_urcenie_rizikovych_oblasti_aktualizacia.pdf*

Fig. 3.13 *The percentage of risky municipalities in the districts of the Banská Bystrica region.*



The highest proportion of at-risk municipalities in the Banská Bystrica region is in the Lučenec district (80%), the highest number of at-risk municipalities is in the Rimavská Sobota district. Mountain basins with good availability of firewood are especially problematic. More than 75% of the at-risk municipalities of the Banská Bystrica region have less than 1 500 inhabitants, which confirms the assumption that the problem is significantly greater in areas with a rural type of settlement. ***More detailed data is available on the interactive map[4].***

3.6 Summary

In 2021 in the Banská Bystrica Region zone, no exceedances of the limit values for SO_2, NO_2, CO and benzene were measured, nor exceedances of the limit value for the annual average concentration of PM_{10}. The limit value for the average daily concentration of PM_{10} was exceeded at the monitoring station Jelšava, Jesenského and Banská Bystrica, Štefánikovo nábrežie, and the limit value for the average annual concentration of $PM_{2.5}$ was exceeded at the monitoring station in Jelšava.

The target value for the annual mean concentration of benzo(a)pyrene was exceeded at the NMSKO stations in Jelšava and Žarnovica and at both monitoring stations in Banská Bystrica.

Based on air quality monitoring, air quality management areas have been defined in the Banská Bystrica region in those locations where the limit or target value has been exceeded in the last three years (**Tab. 3.3**).

Tab. 3.3 *Air quality management areas for 2022, defined in the Banská Bystrica Region based on measurements in 2019 – 2021.*

Air quality management area	Pollutant	AMS and year of exceedance of limit/target value
Territory of Banská Bystrica city	PM_{10} BaP	PM_{10}: Banská Bystrica, Štefánikovo nábr. (2021) BaP: BB Štefánikovo nábr. (2019 – 2021), Zelená (2019 – 2021)
Area of Jelšava and municipalities Lubeník, Chyžné, Magnezitovce, Mokrá Lúka, Revúcka Lehota	PM_{10}, $PM_{2.5}$, BaP	PM_{10}: Jelšava, Jesenského (2019 – 2021) $PM_{2.5}$: 2019 (20.9 $\mu g \cdot m^{-3}$), 2021 (24.3 $\mu g \cdot m^{-3}$) BaP: (2019 – 2021)
Territory of Žarnovica city	BaP	Žarnovica, Dolná (2021)

Based on the results of mathematical modelling, we can assume that in the Banská Bystrica region, high concentrations of PM and benzo(a)pyrene can occur especially in the winter months and in other areas that have been defined as risky, especially in mountain valleys with adverse dispersion conditions and a high proportion of solid fuels for household heating.

[4] *https://ruraj-git.github.io/folium_html/*