AIR POLLUTION IN THE SLOVAK REPUBLIC
2021

ANNEX

AIR QUALITY ASSESSMENT
IN ZONE PREŠOV REGION

Air quality monitoring department
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

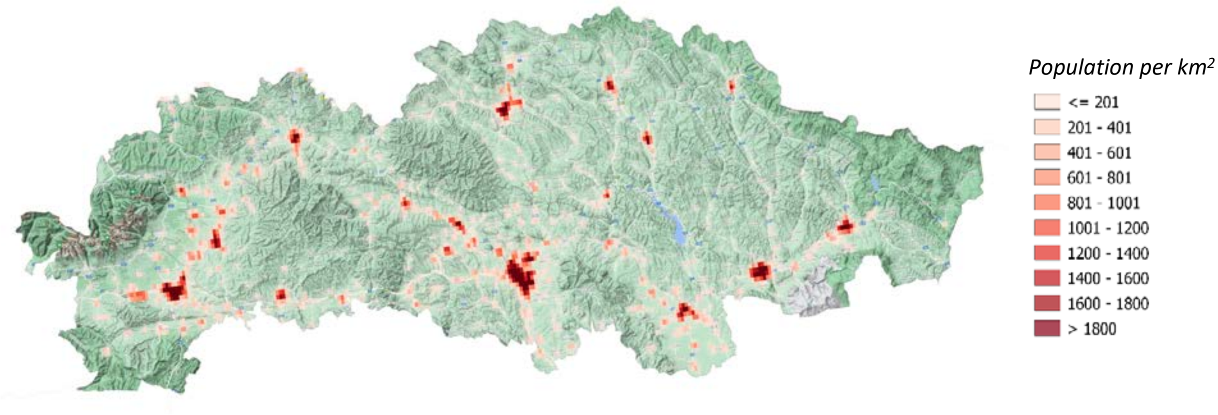
Bratislava, November 2023
Version 2

1 DESCRIPTION OF PREŠOV REGION TERRITORY IN TERMS OF AIR QUALITY

The Prešov region is characterized by a predominantly mountainous relief, the highest point is Gerlachovský štít - height 2 655 m above sea level, the lowest point has an altitude of 109 m. Its territory is occupied mainly by the outer Carpathian Mountains (Spišská Magura, Podtatranská brázda, Spišsko-šarišské mezihorie, Levočské vrchy, Bachureň, Šarišská vrchovina, Pieniny, Ľubovnianska vrchovina, Čergov, Busov, Ondavská and Laborecká vrchovina, Beskydské predhorie and Bukovské vrchy). The High Tatras, our most important mountain range, belong to the Inner Carpathians. **Fig. 1.1** shows the spatial distribution of population density in the zone.

The whole zone Prešov 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.

Fig. 1.1 *Distribution of population density in the zone Prešov region (Source: EUROSTAT, 2018).*



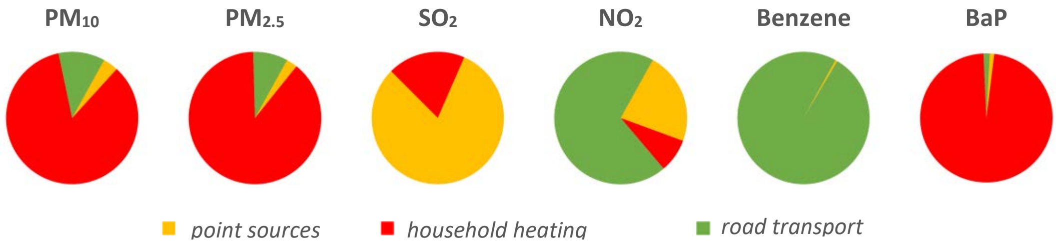
Air pollution sources in zone Prešov region

The dominant source of air pollution in the zone Prešov region is household heating, especially in smaller villages in the mountainous part of the territory, where the share of firewood use is the highest compared to other areas of the region.

Another source of emissions is road transport. Based on the 2015 national traffic census, we know that an average of 30 731 vehicles (4 025 trucks and 26 528 passenger cars) pass along road No. 18 in the Prešov district every day - the highest in the region. Road No. 3450 is also very busy in this district (23 597 vehicles, of which 3 009 trucks and 20 518 passenger cars). By comparison, the D1 motorway in the region is less busy, with a maximum of 16 560 vehicles (4 002 trucks and 12 527 passenger cars) in the Prešov district. Other roads with heavy traffic - in the Poprad district, road No. 3080 with 21 639 vehicles on average per day (1 573 trucks and 19 997 passenger cars) and road No. 67 with 21 488 vehicles (1 378 trucks and 20 058 passenger cars), in the Humenné district, road No. 74 with 18 790 vehicles (1 481 trucks and 17 213 passenger cars), in the Bardejov district, road No. 77 with 19 833 vehicles (2 315 trucks and 17 441 passenger cars), in Humenné district road No. 74 with 18 790 vehicles (1 481 trucks and 17 213 passenger cars), in Vranov nad Topľou district road No. 18 with 17 371 vehicles (2 958 trucks and 14 340 passenger cars) and in Kežmarok district road No. 67 with 17 095 vehicles (2 306 trucks and 14 733 passenger cars)[1].

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

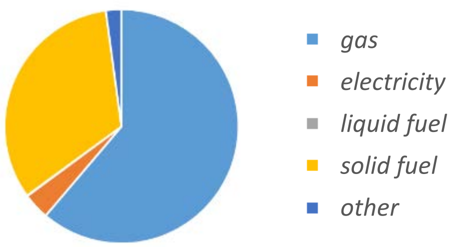
Fig. 1.2 *Share of different types of air pollution sources in total emissions in the Prešov region.*



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

Industrial sources of air pollution in the zone Prešov region are less significant in terms of their contribution to local air pollution by basic pollutants. Depending on meteorological conditions, the influence of the wood processing industry and heating plants can have influence here.

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, natural gas is mostly used for heating in family houses in the zone, especially in the larger cities. The share of solid fuels is higher than in the Trnava and Nitra regions. Solid fuels are more likely to be used in rural settlement types with good availability of firewood. According to the PHC 2021, the districts of Humenné, Medzilaborce and Snina have the highest share of solid fuels in the zone.

2 AIR QUALITY MONITORING STATIONS IN ZONE PREŠOV REGION

There are nine air quality monitoring stations in the Prešov region, of which four stations (Stará Lesná, Gánovce, Starina and Kolonické sedlo) are rural background stations. These ones monitor areas distant from the main sources of air pollution and reflect the change in the vertical pollution profile due to the different altitudes. The monitoring stations in Stará Lesná and Starina follow the EMEP monitoring programme (*https://www.emep.int/*). The station at Kolonické sedlo is located near the Astronomical Observatory at an altitude of 454 m above sea level, in the eastern part of the Snina district. It characterises the air quality in a less polluted area. Air quality monitoring started here in 2009. The monitoring station in Prešov on Arm. gen. L. Svobodu captures the impact of road traffic in a location with relatively high traffic intensity. Stations in Humenné, Poprad, Vranov nad Topľou and Bardejov represent urban and suburban background pollution respectively.

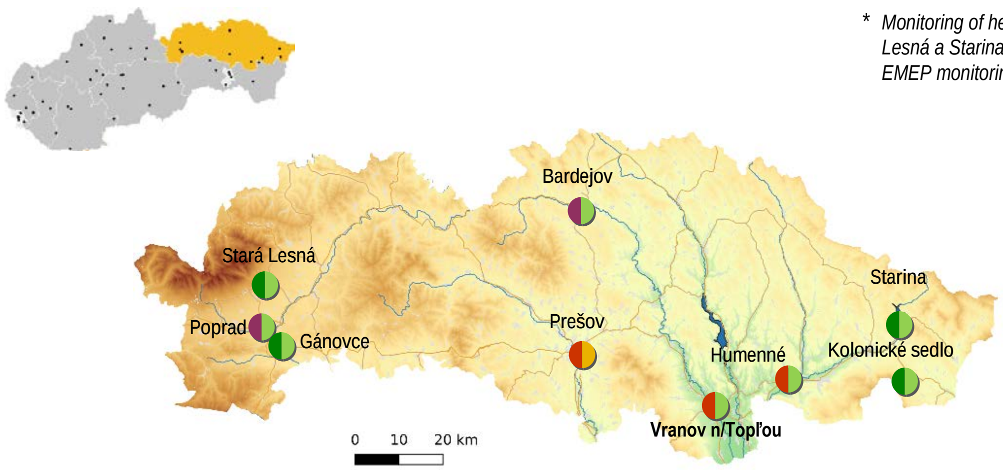
[2] *https://www.scitanie.sk*

Table **Tab. 2.1** contains information on air quality monitoring stations in the zone Prešov region:

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

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

Zone Prešov region								Measurement programme									
								Continuously								Manually	
District	Code EoI	Name of station	Type of area	station	Geographical longitude	latitude	Altitude [m]	PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
Humenné	SK0037A	Humenné, Nám. Slobody	U	B	21°54'50"	48°55'51"	149										
Kežmarok	SK0004R	Stará Lesná, AÚ SAV, EMEP	R	B	20°17'22"	49°09'05"	808									*	
Poprad	SK0041A	Gánovce, Meteo. st.	R	B	20°19'22"	49°02'05"	706										
Poprad	SK0069A	Poprad, Železničná	S	B	20°17'09"	49°03'42"	678										
Prešov	SK0266A	Prešov, Arm. gen. L. Svobodu	U	T	21°16'00"	48°59'33"	252										
Snina	SK0006R	Starina, Vodná nádrž, EMEP	R	B	22°15'36"	49°02'34"	345									*	
Snina	SK0406A	Kolonické sedlo, Hvezdáreň	R	B	22°16'26"	48°56'06"	454										
Vranov n/Topľou	SK0031A	Vranov n/Topľou, M. R. Štefánika	U	B	21°41'15"	48°53'11"	133										
Bardejov	SK0074A	Bardejov, pod Vinbargom	S	B	21°16'38"	48°18'00"	263										
							Total	7	7	7	1	5	1	1	1	2	2



* *Monitoring of heavy metals at the stations Stará Lesná a Starina is carried out according to the EMEP monitoring programme (Tab. 2.2).*

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

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

The monitoring stations Stará Lesná and Starina characterise the regional background level of pollution. They are included in the EMEP[3] monitoring programme which, in addition to extended air pollution monitoring, also covers the analysis of atmospheric precipitation.

The air quality monitoring programme at EMEP stations in 2021 is shown in **Tab. 2.2**. Heavy metals are analysed from weekly samples (sampling duration 7 days), other pollutants are analysed from 24-hour samples.

Tab. 2.2 *Measuring programme at EMEP stations Starina and Stará Lesná.*

	Sulphur dioxide (SO_2)	Nitrogen oxides (NO_X)	Sulphates (SO_4^{2-})	Nitrates (NO_3^-)	Nitric acid (HNO_3)	Chlorides (Cl)	Ammonia, Ammonium ions (NH_3, NH_4^+)	Alkaline ions (K^+, Na^+, Ca^{2+}, Mg^{2+})	VOC	PM_{10}	EC/OC	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
Starina	x	x	x	x	x	x	x	x	x	x		x	x	x	X	x	x	x
Stará Lesná										x	x	x	x	x	x	x	x	x

Precipitation quality (pH, conductivity, sulphate, nitrate, chloride, ammonium and alkaline ions) is analysed from samples collected at EMEP stations according to the monitoring programme listed in **Tab. 2.3** on either a daily (Starina) or weekly (Stará Lesná) basis. The analyses result in average weekly or monthly values depending on the sampling interval.

The sampling interval for heavy metal analysis is a calendar week at the Starina monitoring station and a calendar month at Stará Lesná. A "wet-only" type rain gauge is used to collect precipitation at Stará Lesná and Starina, which captures only precipitation (it is closed during periods when precipitation does not occur). Wet deposition is assessed on the basis of analyses of the samples thus collected.

Tab. 2.3 *Precipitation measurement programme at EMEP stations Starina a Stará Lesná.*

	pH	Conductivity	Sulphates (SO_4^{2-})	Nitrates (NO_3^-)	Chlorides (Cl^-)	Ammonium ions (NH_4^+)	Alkali ions (K^+, Na^+, Ca^{2+}, Mg^{2+})	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
Starina	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Stará Lesná	x	x	x	x	x	x	x	x	x	x	x	x	x	x

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

3 ASSESSMENT OF AIR QUALITY IN ZONE PREŠOV REGION

This chapter contains an assessment of air quality in the zone Prešov 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 *Assessment of air pollution according to limit values for protection of human health and numbers of alert threshold exceedances in the zone Prešov region – 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 [$\mu g \cdot m^{-3}$]	350	125	200	40	50	40	20	10 000	5	500	400
Maximum number of exceedances	24	3	18		35						
Gánovce, Meteo. st.			0	8							0
Humenné, Nám. slobody			0	10	23	25	18				0
Prešov, Arm. gen. L. Svobodu			0	33	22	27	18	1 472	1.01		0
Vranov n/T, M. R. Štefánika	0	0			16	22	16			0	
Stará Lesná, AÚ SAV, EMEP			0	5	1	12	8				0
Starina, Vodná nádrž, EMEP			0	3							0
Kolonické sedlo, Hvezdáreň					1	16	11				
Poprad, Železnicná*			0	17	1	16	10				0
Bardejov, Pod Vinbargom*			0	10	7	20	15				0

≥ 90% of valid measurements

Exceedance of the limit value is marked in red.

[1] *eight-hour maximum concentration*

[2] *limit values for alert thresholds*

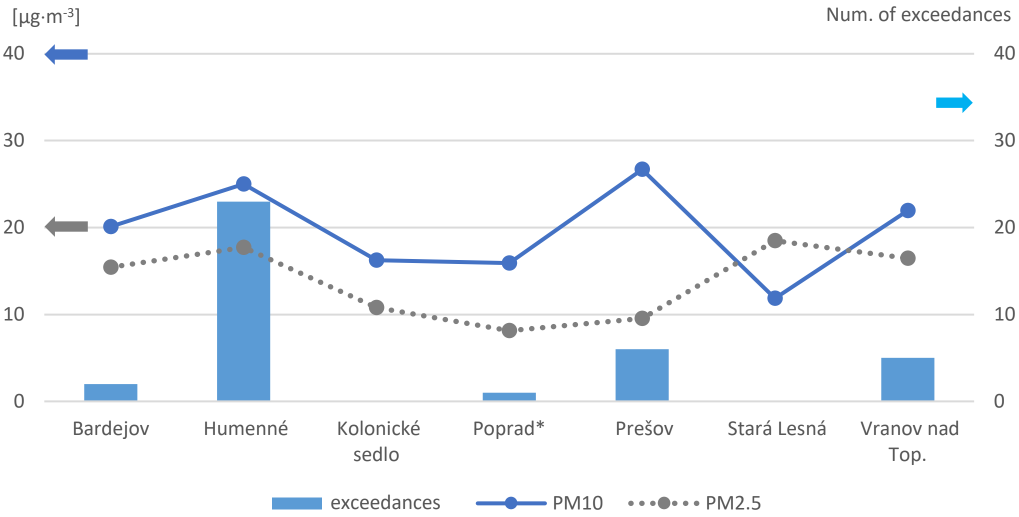
** AMS began measuring during 2021*

With the exception of the new monitoring station in Poprad (installed during the calendar year; started measuring on 22.7.2021), 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} 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 Prešov region in 2021.

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}.*



Number of exceedances – show daily average concentrations of PM_{10} higher than 50 µg·m^{-3};
**the Poprad station does not reflect air pollution for the whole year.*

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

PM_{10}

The limit value for the annual average concentration of PM_{10} (40 µg·m^{-3}) in the zone Prešov region was not exceeded. The limit value for the number of exceedances (35) of the average daily limit concentration of PM_{10} (50 µg·m^{-3}) was not exceeded by any station. (**Fig. 3.1**).

The traffic station Prešov recorded the highest annual average of PM_{10} 27 µg·m^{-3} and 22 daily exceedances of the daily limit value. Among urban and suburban background stations, the highest concentrations were measured in Humenné: 25 µg·m^{-3}. This is almost at the level of the annual average of the traffic station in Prešov, while in Humenné, up to 23 exceedances of the limit for the average daily concentration of PM_{10} were recorded. **Fig. 3.2** shows the number of exceedances of the average daily limit concentration of PM_{10} for each month of the year. All exceedances are concentrated in the cold months with the need for heating.

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

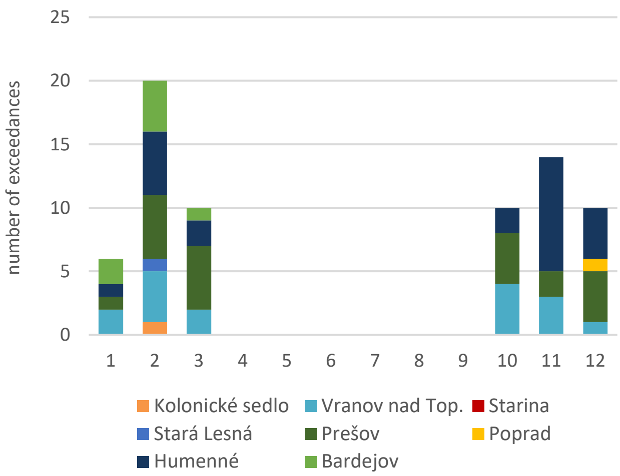


Fig. 3.3 and **Fig. 3.5** show the modelling results for PM_{10} and $PM_{2.5}$, calculated for the year 2021 using the RIO model subsequently adjusted using the regression IDW-R method (see Chapter 4 of *Air pollution in the Slovak Republic 2021 Report* for more details). For ease of illustration, only 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 (up) and number of exceedances of the PM_{10} daily threshold (down) in 2021. Only values above 15 $\mu g \cdot m^{-3}$ and non-zero number of exceedances are shown.

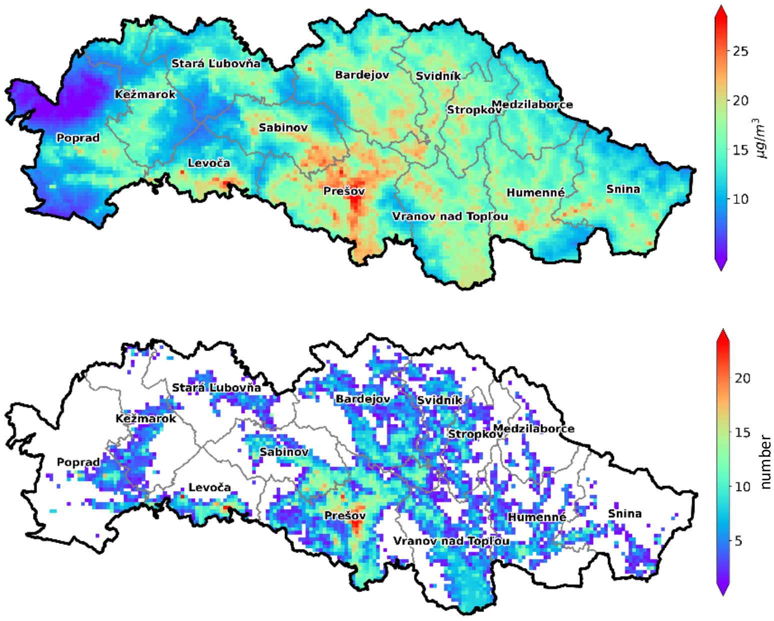
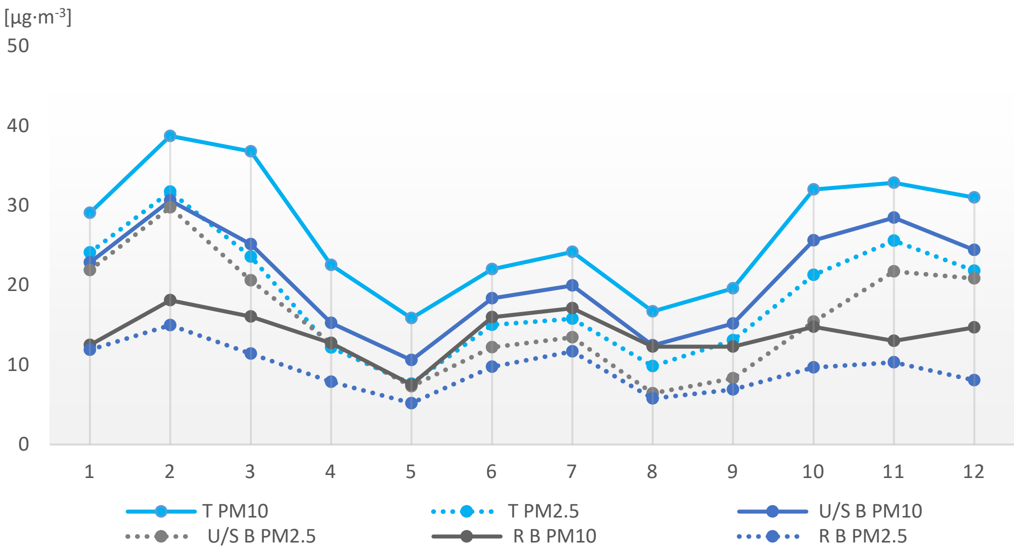


Fig. 3.4 Average monthly concentrations of PM_{10} and $PM_{2.5}$ in the region by station type.



***T PM10** and **T PM2.5** – average monthly concentration of PM_{10} and $PM_{2.5}$ at the traffic station Prešov;*
***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 Humenné, Vranov n/T, Bardejov and Poprad (the station did not measure the whole year);*
***R B PM10** and **R B PM2.5** – average monthly concentrations of PM_{10} and $PM_{2.5}$ at regional background station Stará Lesná a Kolonické sedlo;*

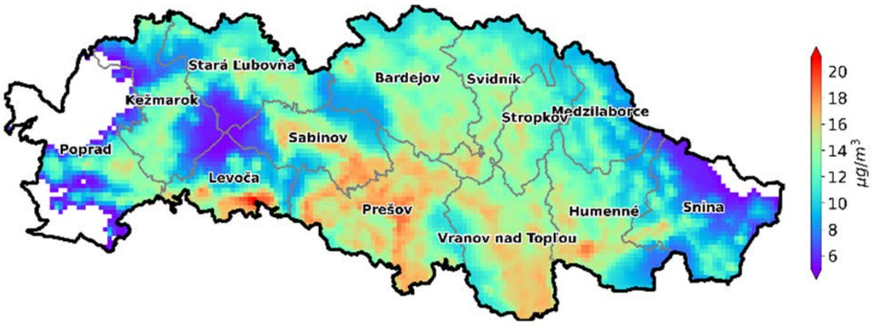
From **Fig. 3.4** it is clear that in the warmer months of the year PM_{10} concentrations at the regional stations (Starina, Stará Lesná and Kolonické sedlo) and the urban background are at very similar levels, and the differences start to increase only in the colder months. This is because PM_{10} air pollution is likely to be caused by household heating with solid fuels (insufficiently dried wood, possibly in combination with various types of waste materials) in older heating installations. This is also illustrated in **Fig. 3.2**.

- **$PM_{2.5}$**

Compared to PM_{10}, fine $PM_{2.5}$ particles have a significantly more negative impact on human health. In **Fig. 3.1** the annual average concentrations of fine particles are shown by the dashed line. High $PM_{2.5}$ values were observed in the cold months of the year, which, as with PM_{10}, is probably due to emissions from domestic solid fuel heating. The highest annual average $PM_{2.5}$ concentrations were measured in Humenné and Prešov (18 µg·m^{-3}). At all stations, including regional background stations, the annual mean $PM_{2.5}$ concentration was higher than the level recommended by WHO (5 µg·m^{-3}). Monthly average values are also relatively high, not only in winter but even in summer months when $PM_{2.5}$ concentrations tend to be lowest.

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, IDW-R.

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

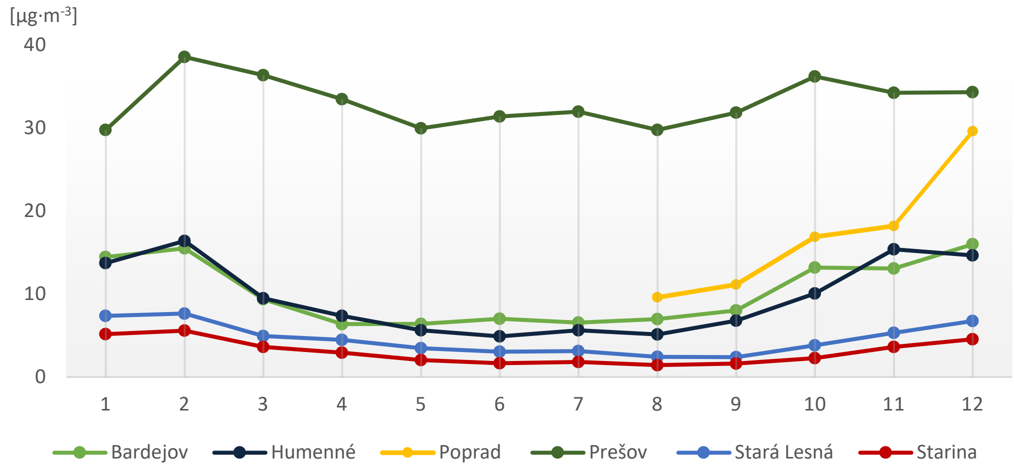


Average annual concentrations of $PM_{2.5}$ in 2021. Only values above 5 µg·m^{-3} are shown, which is the threshold recommended by the WHO..

3.2 Nitrogen dioxide

Nitrogen dioxide monitoring is carried out at seven stations in the zone, the average monthly concentrations for each station are shown at **Fig. 3.6**.

Fig. 3.6 *Average monthly NO_2 concentrations.*



The main source of NO_2 emissions is road transport. The highest concentrations for this reason are recorded at the traffic station Prešov, Arm. gen. L. Svobodu. The annual average level (33 μg·m^{-3}) does not exceed the limit for the annual average concentration (40 μg·m^{-3}). The measured NO_2 levels maintain a relatively constant level throughout the year with no seasonal variations (**Fig. 3.6**). The annual average concentrations at the background stations reached values up to 20 μg·m^{-3}. Overall, air pollution by this pollutant is at a relatively low level in the Prešov region. At five stations the average NO_2 concentrations in 2021 were lower or equal to the WHO recommendation (10 μg·m^{-3}), which is significantly stricter than the EU limits.

3.3 Ozone

Ozone monitoring is carried out in the region at five monitoring stations – in Stará Lesná and Gánovce in the foothills of the High Tatras, in Starina, situated on the north-eastern border of Slovakia, and in the two district towns of Bardejov and Humenné.

The highest concentrations of ground-level ozone generally occur in warm months with high sunshine (**Fig. 3.7**). **Fig. 3.8** and **Fig. 3.9** show the so-called daily course of O_3 concentration at stations (urban background station Bardejov and regional background station Stará Lesná). 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.*

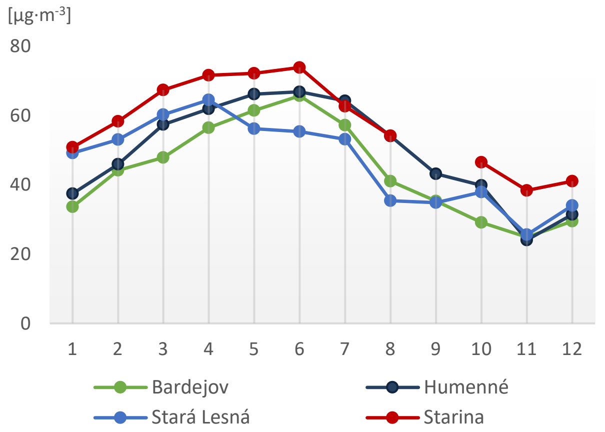


Fig. 3.8 *Daily O_3 concentration in January 2021.*

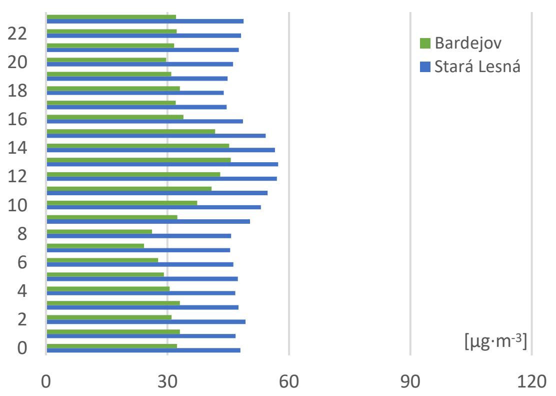
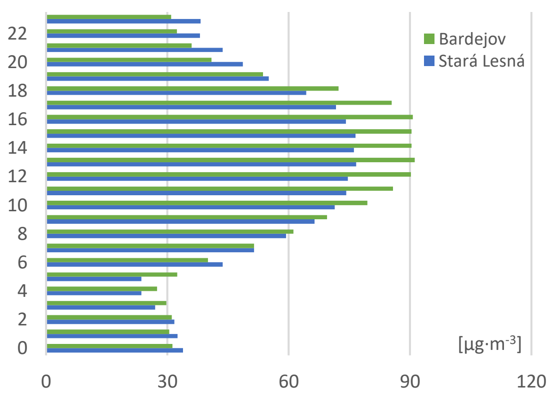


Fig. 3.9 *Daily O_3 concentration in July 2021.*



We did not observe exceedances of the ground-level ozone information or alert threshold at any station in 2021. This is because 2021 was a relatively cool year, even in summer and especially in spring.

3.4 Benzo(a)pyrene

Benzo(a)pyrene is monitored at two monitoring stations in the Prešov region - at Starina and Stará Lesná. The target value for benzo(a)pyrene (1 ng·m^{-3}) has not been exceeded. The stations at which monitoring is carried out, are characterised as rural background stations, and these are not directly affected by emissions from household heating with solid fuel (**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
Starina, Vodná nádrž, EMEP		1.2	0.4	0.3	0.4
Stará Lesná, EMEP			0.4	0.3	0.4

≥90% of valid measurements

Fig. 3.10 shows the average daily concentrations of benzo(a)pyrene at rural background stations. Although the target value has not been exceeded, the values are relatively high in winter, which may be due to regional transport or local influence. **Fig. 3.11** shows the annual average concentration calculated from the mathematical modelling outputs. As the model is based on measured data (and auxiliary fields), the outputs are burdened with considerable uncertainty over the large area of the Prešov region. It is therefore necessary to note relative differences between areas rather than relying on absolute values. According to the RIO model outputs, the highest concentrations are found in the municipalities of the districts of Levoča, Vranov nad Topľou, Prešov, Svidník, Sabinov and Stropkov. To obtain a more detailed picture of the spatial distribution, high-resolution modelling using detailed emissions data (i.e. the amount and type of fuels, and the type of equipment used for heating households, etc.) is needed. The most significant source of benzo(a)pyrene is domestic heating with solid fuels, in particular insufficiently dried wood or unsuitable fuels (various types of waste).

Fig. 3.10 *Results of benzo(a)pyrene measurements in 2021.*

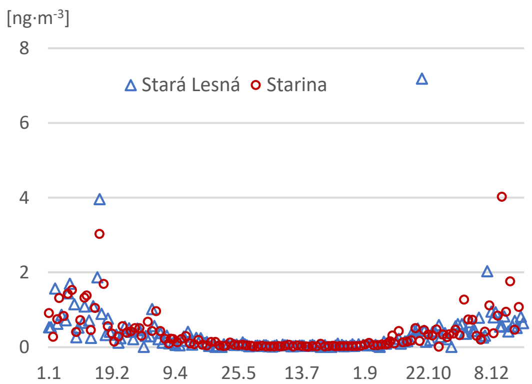
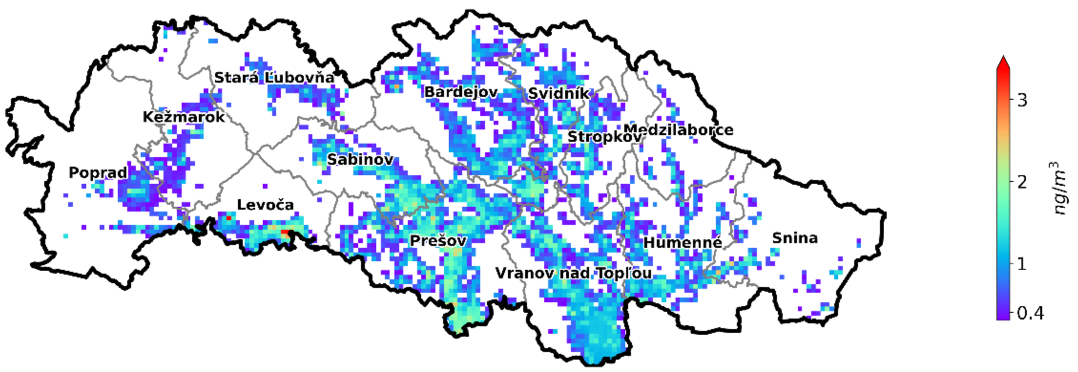


Fig. 3.11 *Average annual concentration of benzo(a)pyrene from RIO model output, IDW-R (2021).*



3.5 Chemical composition of precipitation

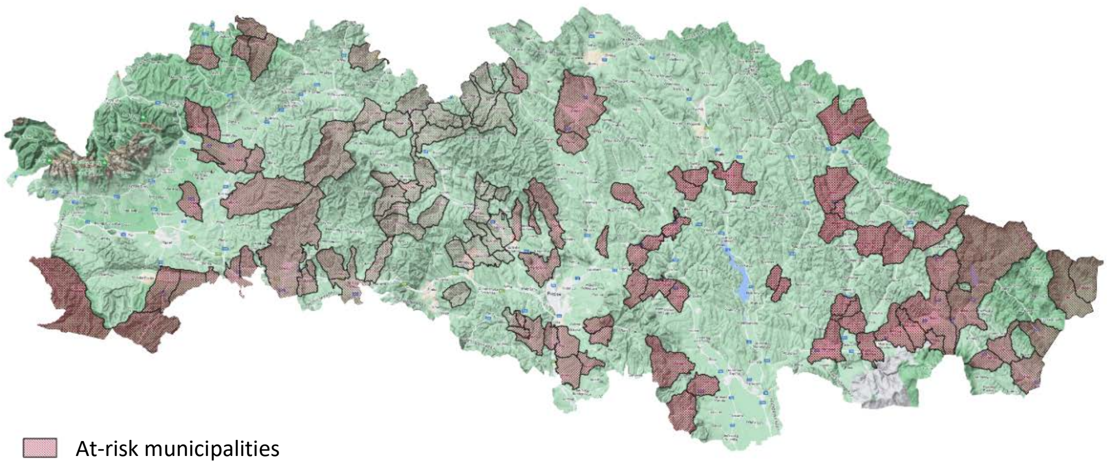
The Starina rural background station monitors precipitation quality on a daily basis. The qualitative composition of basic ions, pH parameters and conductivity are monitored. The annual average pH value was 5.45 and the monthly averages did not fall below pH 5. It can therefore be concluded that there is no excessive acidification of the environment in the zone Prešov region. Detailed monitoring results are presented in Chapter 3.4 Regional monitoring section of *Air pollution in the Slovak Republic 2021 Report*.

3.6 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)[4].

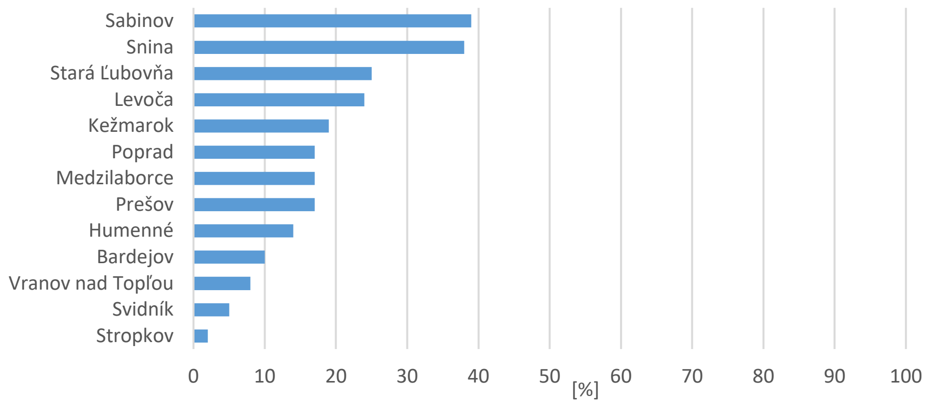
This methodology is based on data from Population and Housing Census (PHC) 2021 (usage of solid fuels for household heating), and it also takes into account high PM concentrations obtained from mathematical modelling and adverse dispersion conditions. There are no available input data with high spatial 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 Prešov region.*



It should be noted that this assessment is based on data from PHC 2021, which does not yet reflect the impact of the energy crisis. The percentage of at-risk municipalities in individual districts is shown in **Fig. 3.13**.

Fig.3.13 *Percentage proportion of at-risk municipalities in the districts of Prešov region.*



The highest number of at-risk municipalities in the Prešov region is in the Sabinov District, but other areas with poor ventilation and good availability of firewood are also problematic. More than 75% of at-risk municipalities in Prešov region have less than 2 500 inhabitants, which confirms the assumption that the problem is considerably greater in areas with a rural type of settlement. ***More detailed data is available on the interactive map***[5].

[4] *https://www.shmu.sk/File/oko/mesacne_spravy/Popis_metody_na_urcenie_rizikovych_oblasti_aktualizacia.pdf*
[5] *https://ruraj-git.github.io/folium_html/*

3.7 Summary

In the Prešov 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 defined in this zone on the basis of monitoring.

Based on the results of the mathematical modelling, we can assume that in some areas (**Fig. 3.3**, **Fig. 3.5**, **Fig. 3.11**, **Fig. 3.12**) higher PM and benzo(a)pyrene values may occur, especially in the winter months, in locations with a higher share of solid fuels in domestic heating, especially when dispersion conditions are impaired.