AIR POLLUTION IN THE SLOVAK REPUBLIC 2023

ANNEX

AIR QUALITY ASSESSMENT IN ZONE ŽILINA REGION

Emissions and Air Quality Division
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

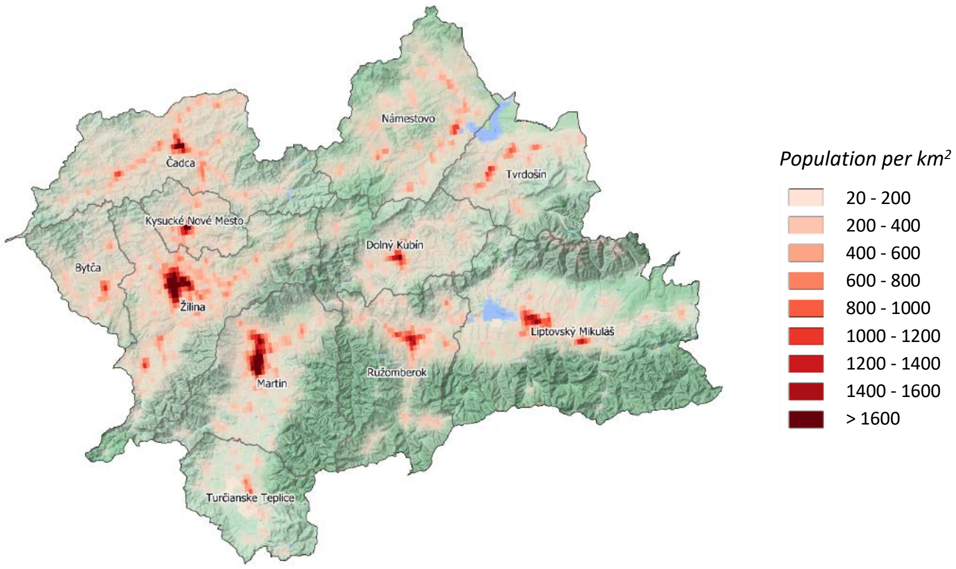
Bratislava, September 2024
Version 1

1 DESCRIPTION OF ŽILINA REGION TERRITORY IN TERMS OF AIR QUALITY

The Žilina region is located in the Central Western Carpathians the major part of its territory is mountainous, encompassing several basins. The River Váh divides the territory into the northern and southern parts. In the northern part are Vysoké and Západné Tatry (the High and the West Tatras), Skorušinské vrchy, Oravské Beskydy, Oravská Magura., Oravská vrchovina, Chočské vrchy, Malá Fatra, Kysucké Beskydy, Kysucká vrchovina and Javorníky, in the southern part are Nízke Tatry, Veľká Fatra, Lúčanská Fatra and Strážovské vrchy. The highest peak is Kriváň (2 494 m a. s. l.), and the lowest point is at 285 m a. s. l. The area is characterised by deep and closed basins between high mountains, with frequent occurrence of air temperature inversions, especially in the winter. The geomorphological character of the area contributes to poor ventilation and thus, may adversely affect the dispersion of pollutants. **Fig. 1.1** shows the spatial distribution of population density in the 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), the whole Žilina region is considered one zone.

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



Air pollution sources in zone Žilina region

In the mountainous part of the region, household heating using solid fuel is a significant source of air pollution. Car traffic contributes most to air pollution in the districts of Žilina, Bytča, and Ružomberok[1].

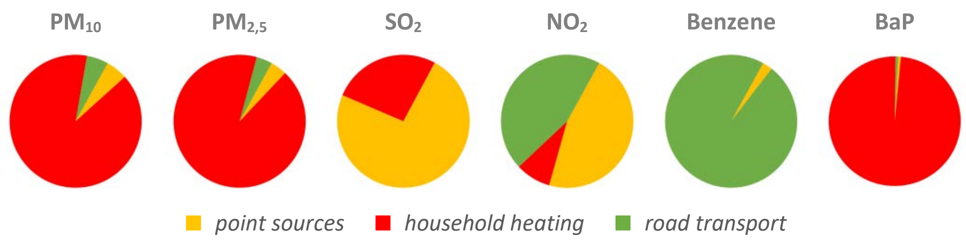
The road traffic characteristics – the busiest roads of the zone Žilina region along with the average number of vehicles per 24 hours:

- the highest traffic intensity is in the northern part of Žilina **road No. 11** with 43 995 vehicles (7 739 trucks/ busses (hereafter referred to as T/B) a 36 069 cars (hereafter referred to as C)) and **road No. 60** with 41 493 vehicles (6 427 T/B, 34 772 C);
- the northern Žilina **D3 motorway bypass**: 25 837 vehicles (7 439 T/B, 18 311 C);
- **D1 motorway** near Bytča: 29 649 vehicles (9 111 T/B, 20 470 C);
- **road No. 18** in W-E direction through Žilina - Martin - Ružomberok - Liptovský Mikuláš: the section eastwards from Žilina 28 333 vehicles (6 765 T/B, 21 477 C), in the district of Martin 25 325 vehicles (6 321 T/B, 18 915 C), in the district of Ružomberok 29 580 vehicles (5 828 T/B, 23 665 C), in the district of Liptovský Mikuláš 24 361 vehicles (2 037 T/B, 22 184 C);

[1] *https://www.ssc.sk/sk/cinnosti/rozvoj-cestnej-siete/dopravne-inzinierstvo/celostatne-scitanie-dopravy-v-roku-2022-a-2023.ssc*

- **road No. 65** in the part just after Martin southwards to Turčianske Teplice: 23 226 vehicles (4 420 T/B, 18 661 C);
- northern bypass of Martin – **road No. 18:** 18 436 vehicles (4 553 T/B, 13 810 C) and **D1 motorway:** 14 737 vehicles (3 627 T/B, 11 060 C);
- **D1 motorway**: in the district of Ružomberok 19 637 vehicles (4 519 T/B, 15 046 C) and in the district of Liptovský Mikuláš 20 448 vehicles (4 633 T/B, 15 746 C);
- **road No. 59** in Ružomberok (to the north to Dolný Kubín and to the south to Donovaly): 19 636 vehicles (3 380 T/B, 16 156 C);
- **road No. 18** through Liptovský Mikuláš (direction of Liptovský Hrádok): 24 361 vehicles (2 037 T/B, 22 184 C);
- connection to the highway D1 in Liptovský Mikuláš (**road No. 584**): 21 083 vehicles (1 969 T/B, 19 045 C);
- **road No. 59** Dolný Kubín - Tvrdošín (in the Tvrdošín district): 16 950 vehicles (2 607 T/B, 14 289 C);
- **road No. 78** in Námestovo: 16 134 vehicles (2 607 T/B, 14 289 C);
- southern bypass of Trstená, **R3 highspeed road**: 6 971 vehicles (2 002 T/B, 4 942 C);
- **road No. 484** in the district of Čadca: 4 608 vehicles (401 T/B, 4 175 C).

Fig. 1.2 *Share of different types of air pollution sources in total emissions in the Žilina 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, such as paper mills, cement plants, lime, and ferroalloy production, are less significant in terms of their contribution to local air pollution by basic pollutants in the region of Žilina.

Fig. 1.3 *Share of different types of fuel used for heating in the municipalities of the region*[2].

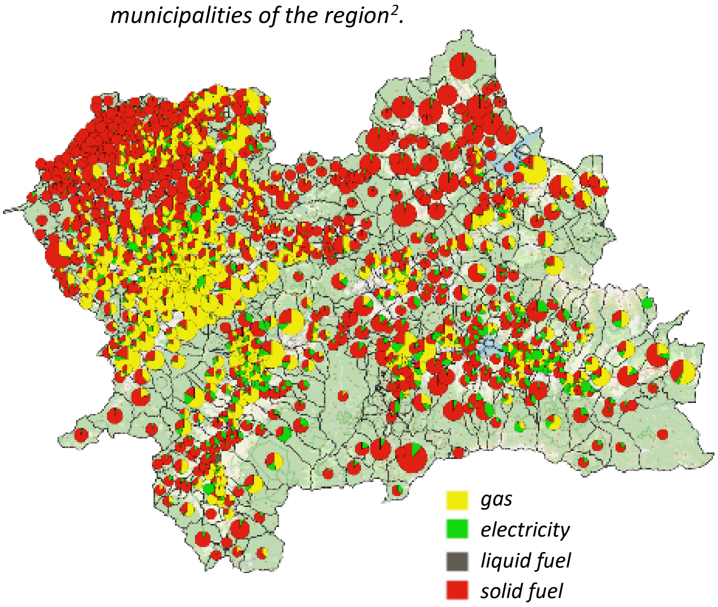


Fig. 1.3 shows the spatial differences and the share of the type of fuel used for household heating in municipalities (Population and Housing Census (PHC) 2021) of the zone Žilina region. The gas is used as heating fuel mostly in the west of the central part; especially in larger cities and municipalities. In the mountainous parts of the region, such as Orava, foothills of Low Tatras mountains range, heating using solid fuel prevails. However, across the whole zone in 2021, gas was predominantly used for heating.

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

2 AIR QUALITY MONITORING STATIONS IN ZONE ŽILINA REGION

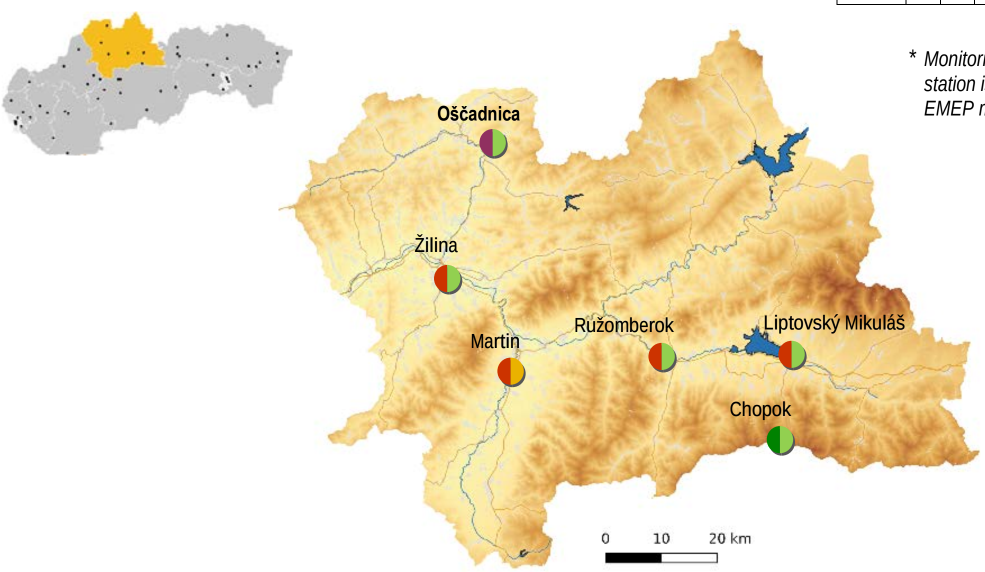
The air quality is being monitored at six monitoring stations in the Žilina region, three of them represent an urban background, one station captures the impact of traffic, and two are rural stations. The monitoring station in Ružomberok-Riadok, active since the 1980s, characterizes the air quality of an urban background with a possible contribution of traffic from a nearby infrequently used road. The stations in the city of Žilina and Liptovský Mikuláš, both represent the urban background pollution. The traffic monitoring station is in the city of Martin. The station in Oščadnica represents a rural station, aimed to capture the impact of household heating using solid fuel. The rural background station at Chopok (2024 m a. s. l.) is a part of the EMEP and GAW monitoring networks (*https://www.emep.int/*; *https://community.wmo.int/activity-areas/gaw*).

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

- the international EoI code, station type (traffic, background, industrial), type of monitored area (urban, suburban, rural/regional), and GPS location;
- the monitoring programme. Continuous monitoring automatic devices provide hourly average concentrations of PM_{10}, $PM_{2.5}$, nitrogen oxides, sulphur dioxide, ozone, carbon monoxide, and benzene. The SHMÚ laboratory analyses heavy metals and polycyclic aromatic hydrocarbons, that return 24-hour average concentrations.

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

Zone Žilina region								Monitoring programme									
								Continuously								Manually	
District	EoI code	Station	Type: area	Type: station	Geographical: longitude	Geographical: latitude	Attitude [m]	PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
Liptovský Mikuláš	SK0002R	Chopok, EMEP	R	B	19°35'21"	48°56'37"	1990									*	
Liptovský Mikuláš	SK0067A	Liptovský Mikuláš, Školská	U	B	19°37'10"	49°05'02"	578										
Čadca	SK0071A	Oščadnica	S	B	18°53'01"	49°26'07"	465										
Martin	SK0039A	Martin, Jesenského	U	T	18°55'17"	49°03'35"	383										
Ružomberok	SK0008A	Ružomberok, Riadok	U	B	19°18'09"	49°04'45"	475										
Žilina	SK0020A	Žilina, Obežná	U	B	18°46'17"	49°12'41"	356										
							Total	5	5	6	3	4	3	2	0	2	3



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

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

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

The Chopok monitoring station (the EMEP monitoring programme[3]) monitors a wider area and includes an analysis of atmospheric precipitation. The air quality monitoring program at this station is shown in **Tab. 2.2**. Heavy metals are analysed from weekly samples (sampling period is 7 days), other pollutants are analysed from 24-hour samples.

Tab. 2.2 Monitoring programme at the EMEP station Chopok.

	Ozone (O_3)	Sulphur dioxide (SO_2)	Nitrogen oxides (NO_X)	Sulphates (SO_4^{2-})	Nitrates (NO_3^-)	Nitric acid (HNO_3)	Chlorides (Cl)	TSP*	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
Chopok	x	x	X	x	x	x	x	x	x	x	x	x	x	x	x

* *TSP – total suspended particles*

Precipitation quality (pH, conductivity, sulphate, nitrates, chlorides) is analysed from samples collected at EMEP stations according to the monitoring programme shown in **Tab. 2.3** on a daily basis. The analyses result in average daily values.

The sampling interval for heavy metal analysis is the calendar month. A "bulk" type precipitation collectors is used to collect precipitation, which records both wet and dry deposition (in the period when no precipitation occurs, it does not close). Analysis of the samples thus collected is used to assess the total (dry and wet) deposition.

Tab. 2.3 Precipitation measurement programme at the EMEP station Chopok.

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

This chapter summarises the main results relevant to the air quality assessment in the zone Žilina region. It includes data from annual monitoring and the results of mathematical modelling for PM_{10}, $PM_{2,5}$ and benzo(a)pyrene for 2023.

Tab. 3.1 *Assessment of air pollution according to limit values for the protection of human health and smog warning system for PM_{10} in the zone Žilina region – 2023.*

	Protection of human health									IT[2)]	AT[2)]
Pollutant	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	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						
Chopok, EMEP			0	2							
Liptovský Mikuláš, Školská	0	0	0	12	8	17	12			24	11
Martin, Jesenského			0	16	11	20	15	1 752	0.47	47	0
Oščadnica	0	0	0	6	8	18	15			9	0
Ružomberok, Riadok	0	0	0	17	15	19	15	2 690	0.79	86	15
Žilina, Obežná			0	18	13	20	15	1 346		0	0

≥ 90% of valid measurements

[1)] *eight-hour maximum concentration*

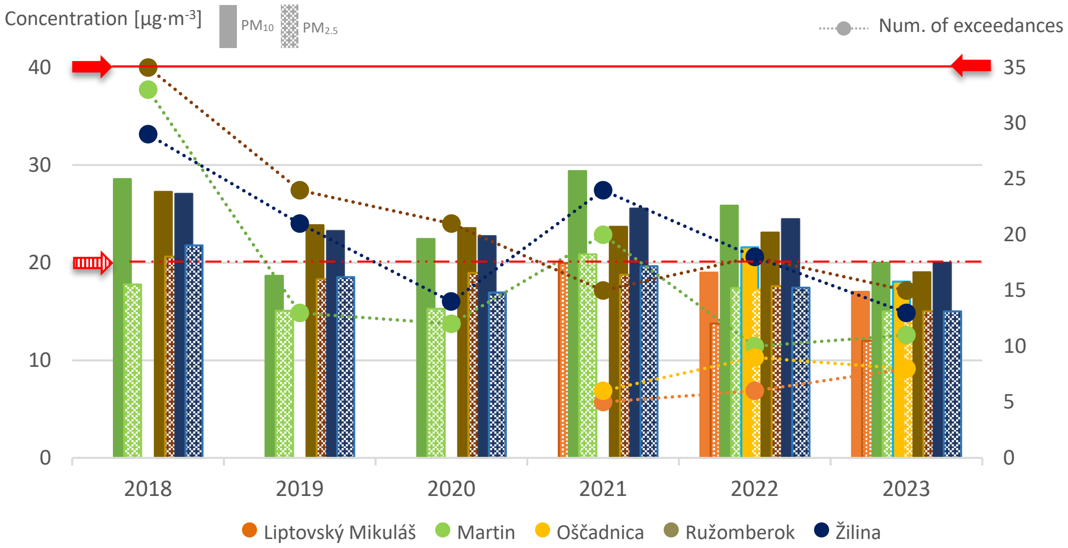
[2)] *IT, AT – duration of exceedance (in hours) of the information threshold (IT) and alert threshold (AT) for PM_{10}*

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} a $PM_{2.5}$

Fig. 3.1 shows the average annual concentration of PM_{10}, $PM_{2.5}$ and the number of days when the PM_{10} concentration exceeded the limit of 50 µg·m^{-3} over the period 2018 – 2023.

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}.*



*The arrows show the limit values, **red striped** $PM_{2.5}$ (average annual concentration: 20 µg·m^{-3}); **red on the left** PM_{10} (average annual concentration: 40 µg·m^{-3}) and **red on the right** the 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).*

The mean annual concentration limits for PM_{10} (40 µg·m^{-3}) and $PM_{2.5}$ (20 µg·m^{-3}) as well as the number of allowed exceedances (35) of daily limit (50 µg·m^{-3}) for PM_{10} were not exceeded at any station in 2023 (**Fig. 3.1**). The highest annual average concentrations of PM_{10} (20 µg·m^{-3}) were recorded at stations in Martin and Žilina. In Martin, the annual average decreased of about 6 µg·m^{-3} compared to 2022. The number of daily exceedances was the highest in Ružomberok with most occurrences in the cold months of February and December (**Fig. 3.2**). It is in the coldest months that we can expect to see higher PM_{10} and $PM_{2.5}$ emissions from local heating. The annual average of $PM_{2.5}$ concentrations were at all stations very similar, reaching values of 15 µg·m^{-3}, except for the station in Liptovský Mikuláš with an annual average of 12 µg·m^{-3}.

Fig. 3.2 *Monthly precipitation totals, the mean and the minimum temperature (data provided by climatological station in Čadca).*

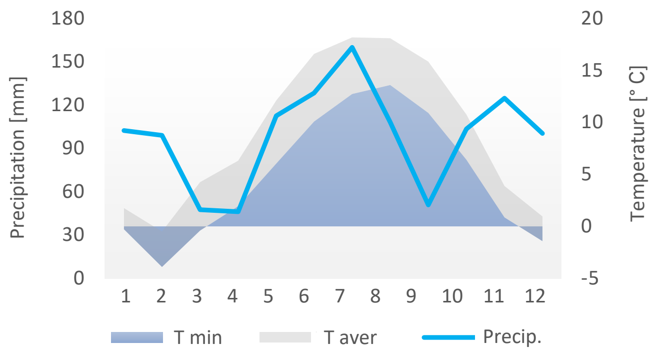


Fig. 3.3 shows the results of PM_{10} modelling calculated for the year 2023 using the RIO model subsequently adjusted by the IDW regression method (for more details see Chapter 4 of *Air pollution in the Slovak Republic 2023 Report*). According to this simulation, the highest annual average concentration of PM_{10} and the highest number of daily limit exceedances can be anticipated in the vicinity of Ružomberok and Námestovo. The region of Orava (the northern part of the studied area) can be at risk of poor air quality, as suggested by this model as well as by the indicative monitoring in the village of Breza that underwent in 2022. This area is currently not permanently monitored.

Fig. 3.3 *Annual average PM_{10} concentration (left) and number of PM_{10} daily limit value exceedances (right) in 2023.*

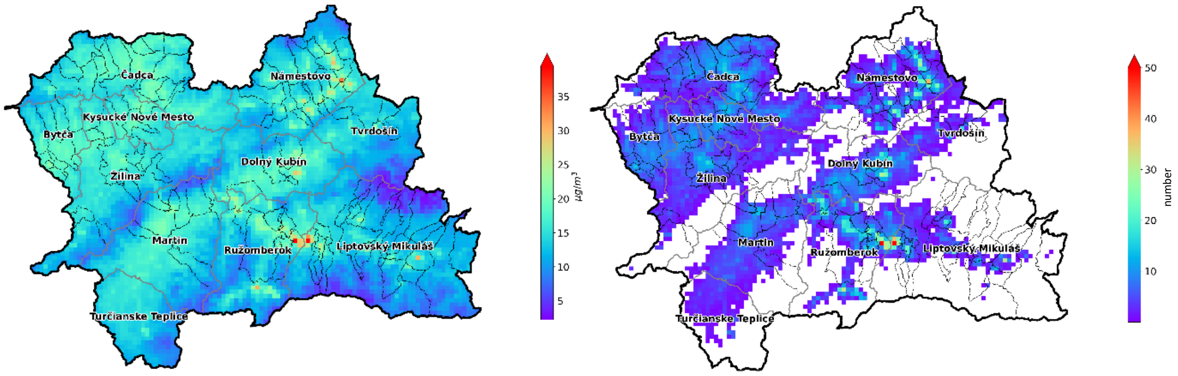
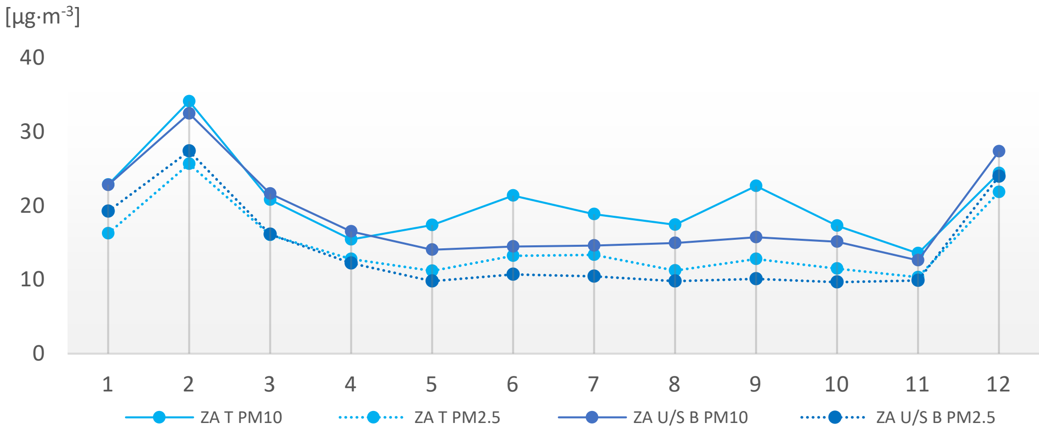


Fig. 3.4 *Average monthly concentrations of PM_{10} and $PM_{2.5}$ in Žilina region according to the station type.*

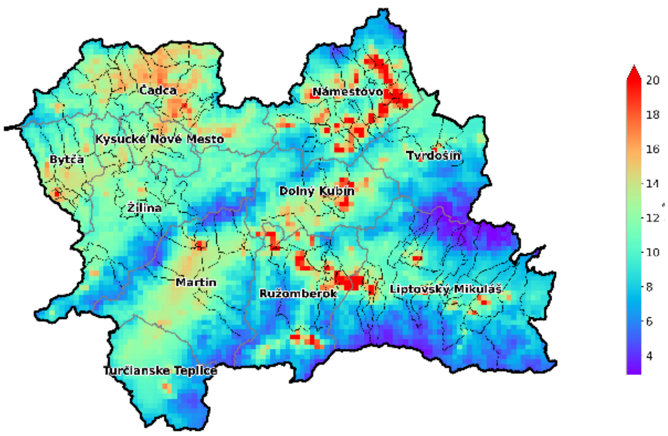


T PM10 *and* ***T PM2.5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the traffic station Martin;*
U/S B PM10 *and* ***U/S B PM2.5*** *– average monthly concentrations of PM_{10} and $PM_{2.5}$ at the urban/suburban background stations: Liptovský Mikuláš, Oščadnica, Ružomberok, Žilina.*

The monthly average $PM_{2.5}$ concentrations (**Fig. 3.4**) were the highest in cold December and February. If we compare the monthly average concentrations (**Fig. 3.4**) with the monthly average temperatures in **Fig. 3.2**, which captures the meteorological conditions in Čadca, we see a significant negative correlation. In the winter period, monthly average $PM_{2.5}$ concentrations were higher at suburban/urban stations, than at traffic stations. This means, that the contribution from local sources, likely household heating, does have a significant influence on the air quality in the whole region.

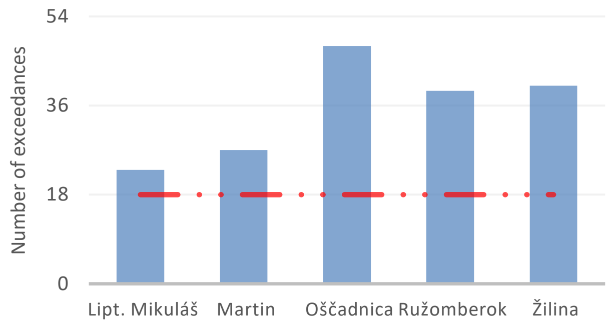
The air quality $PM_{2.5}$ modelling (**Fig. 3.5**) shows several regions with high concentrations of $PM_{2.5}$ reaching the limit values mostly in the regions of Orava, Kysuce, and near the cities of Ružomberok and Liptovský Mikuláš. The map in **Fig. 3.5** is the output of the RIO model in combination with IDW-R. Mathematical modelling shows a number of problematic locations in Orava, Kysuce, in the vicinity of Ružomberok and Liptovský Mikuláš.

Fig. 3.5 *Average annual $PM_{2.5}$ concentrations in 2023.*



The European Zero Pollution Action Plan[4], sets a vision to decrease air pollution below the levels considered harmful for living systems by 2050. The Action Plan includes new EU limit and target values for many pollutants (valid from 1st January 2030). As current monitoring has shown, the biggest challenge would be to meet the new criteria for $PM_{2.5}$. (with new limit 25 µg·m^{-3}, not to be exceeded more than 18 times per year). **Fig. 3.6** shows how many exceedances of the new EU daily limit for $PM_{2.5}$ would be reached in 2023. In the zone Žilina region, no monitoring station would meet of the new EU limit value, and the most stations the number of exceedances would have more than 2 times the number of exceedances. The WHO[5] recommends the mean annual concentration to be below 5 µg·m^{-3}, which would not be met in any month at any station in this region in 2023.

Fig. 3.6 *Number of days with average daily $PM_{2.5}$ concentration > 25 µg·m^{-3} in 2023 – evaluation in view of the newly introduced EU limit*.*

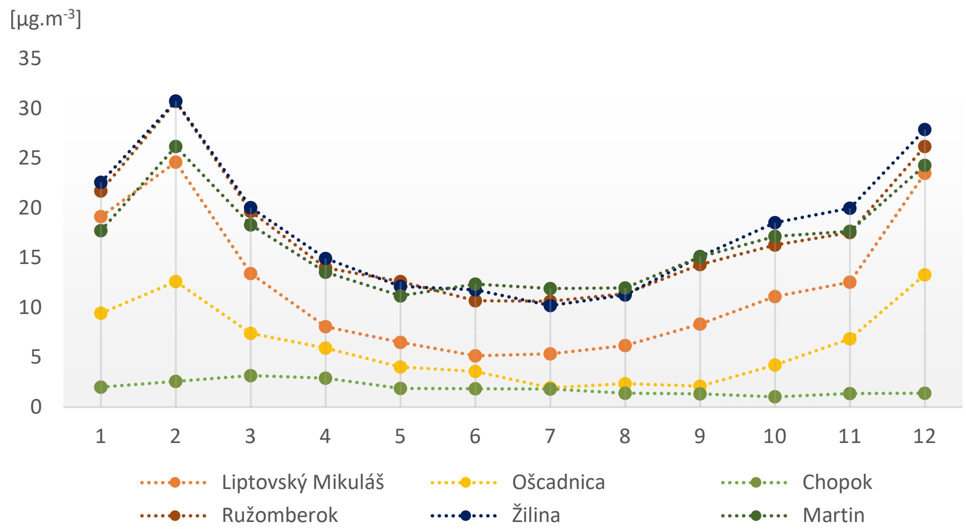


** Under to the new EU limit, which will enter into force on 1 January 2030, the average daily concentration of $PM_{2.5}$ must not exceed 25 µg·m^{-3} more than 18 times per year.*

3.2 Nitrogen dioxide

Nitrogen dioxide is being monitored in the zone at all six stations (**Fig. 3.7**). Despite the fact that the main source of NO_2 emissions is road traffic, the highest concentrations, as in the previous year, were recorded at the urban background station Žilina, Obežná (18 µg·m^{-3}) and Ružomberok, Riadok (17 µg·m^{-3}). The traffic station in Martin recorded mean annual concentration of 16 µg·m^{-3}. The highest monthly concentrations were measured in the coldest months of February and December (**Fig. 3.2**) with the occurrence of poor dispersion conditions. The limit value for the annual mean NO_2 concentration (40 µg·m^{-3}) was not exceeded at any of the stations in this zone in 2023.

Fig. 3.7 *Average monthly NO_2 concentrations in 2023.*



[4] *https://www.consilium.europa.eu/en/press/press-releases/2024/02/20/air-quality-council-and-parliament-strike-deal-to-strengthen-standards-in-the-eu/*

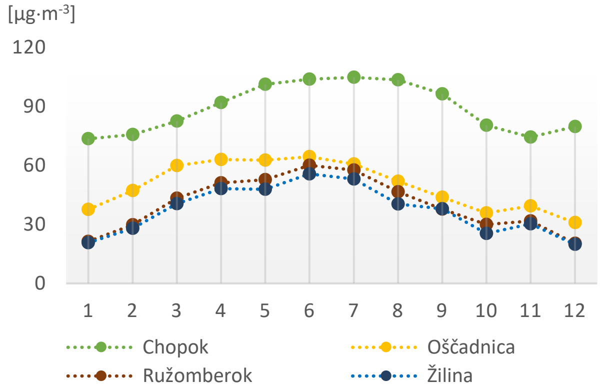
[5] *WHO GLOBAL AIR QUALITY GUIDELINES, 2021. Recommendations on classical air pollutants. (str. 4) https://apps.who.int/iris/bitstream/handle/10665/345334/9789240034433-eng.pdf*

The monthly concentrations at the traffic station in Martin are almost identical to the values measured at the urban background station in Ružomberok and Žilina. In 2023, two stations in the zone Žilina region met the WHO recommendations (10 μg·m^{-3}) for the annual average NO_2 concentration - Chopok (2 μg·m^{-3}) and Oščadnica (6 μg·m^{-3}).

3.3 Ozone

Ozone is being monitored at four stations: Chopok, Žilina, Ružomberok and Oščadnica. The highest concentrations of ozone are being recorded at Chopok as a consequence of the high altitude of the station (ozone input from the upper troposphere is more significant here). Ružomberok and Žilina returns one of the lowest O_3 concentrations among all monitoring stations in Slovakia, as a consequence of the intense traffic near these cities and the phenomena known as "ozone titration" by NO.

Fig. 3.8 *Average monthly O_3 concentration in 2023.*



The highest concentrations of the ground level ozone are being recorded in warm months with intense and long sunlight. Its diurnal regime is typical by increasing values from the morning reaching the peak at noon, and slow decrease throughout the evening reaching minima at night before sunrise. Large differences in O_3 concentrations are also between warm and cold periods.

No station recorded exceedance of the information nor the alert threshold for the ground-level O_3 concentration in 2023.

3.4 Benzo(a)pyrene

Benzo(a)pyrene (BaP) is being monitored at three stations in the zone – Žilina (since 2018), Ružomberok (since 2020) a Oščadnica (since 2021). The target value of 1 ng·m^{-3} was exceeded at all three AMS (**Tab. 3.2**), in some instances, two-fold. The monitoring station in Oščadnica showed, that BaP poses a potential risk also in the surrounding region of Kysuce, in agreement with the results of mathematical modelling (**Fig. 3.10**). This area is typical of increased heating requirements as well as frequent temperature inversions or unfavourable dispersion conditions.

Tab. 3.2 *Average annual concentration of benzo(a)pyrene in 2018 – 2023.*

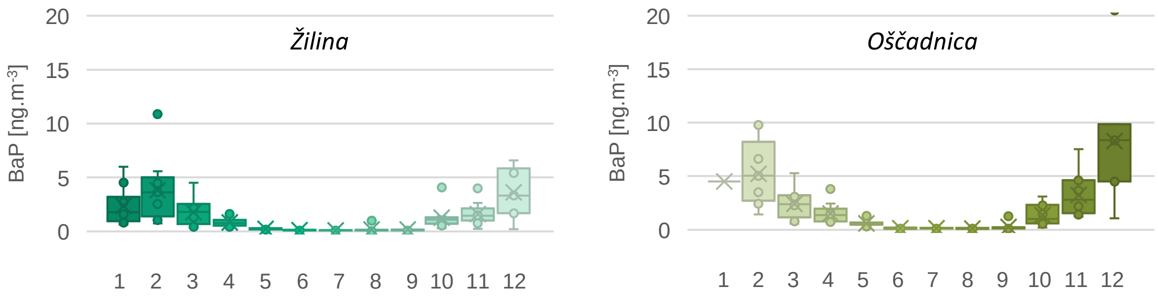
	2018	2019	2020	2021	2022	2023
Target value [ng·m-3]	1.0	1.0	1.0	1.0	1.0	1.0
Žilina, Obežná	6.0	2.0	1.9	1.9	1.9	1.2
Ružomberok, Riadok			4.5	2.3	2.2	2.0
Oščadnica				*12.0	*2.5	1.9

≥ 90% of valid measurements

The red colour indicates that the target value has been exceeded in case of sufficient data coverage (≥ 90%) in a given year.

** In 2021, BaP measurements were started during the year (there were not enough valid measurements for a full-year assessment in 2021), and in 2022 the recovery was 88% (device malfunction during the whole month of December).*

Fig. 3.9 *Average monthly concentration of benzo(a)pyrene in 2023.*



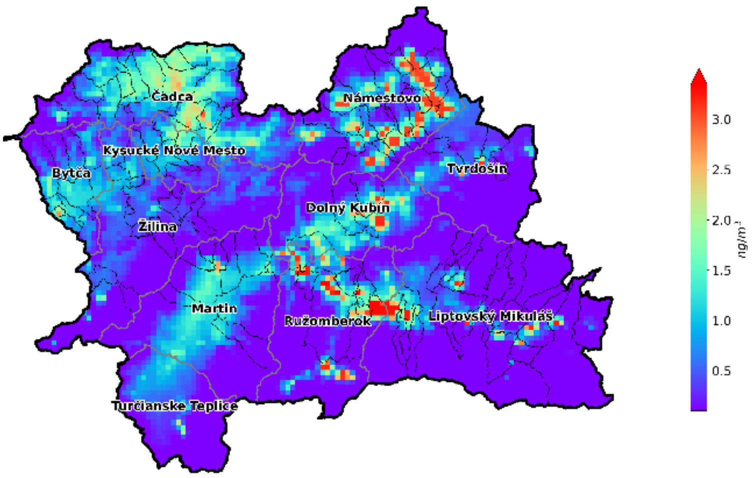


Fig. 3.10
Average annual concentration of benzo(a)pyrene according to the RIO and IDW-R models (2023).

The most significant source of benzo(a)pyrene is the use of solid fuels for household heating; particularly the use of ill-dried wood, or unsuitable fuel (as different kinds of waste). The contribution of BaP from traffic may be significant in Žilina and Ružomberok. The monthly mean concentration of BaP in Žilina and Oščadnica is shown in **Fig. 3.9**. The highest benzo(a)pyrene concentrations were, as for other pollutants, recorded in the cold month of February with a maximum of more than 10 ng·m^{-3} and in December, when a maximum of 20 ng·m^{-3} was recorded in Oščadnica.

3.5 The chemical composition of precipitation

At the Chopok rural background station, the quality of precipitation is monitored on a daily basis. The annual average pH value was 5.43. Wet deposition of SO_4^{2-} was 0.4 g S/m^2/year and NO^{3-} was 0.3 g N/m^2/year. The wet deposition of lead was 0.8 mg/m^2/year. Detailed monitoring results are presented in Chapter 3.4 of *Air pollution in the Slovak Republic 2023 Report*.

3.6 Risk municipalities

Fig. 3.11 presents the municipalities at risk of deteriorated air quality as determined by the Integrated Assessment Method[6]. 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.

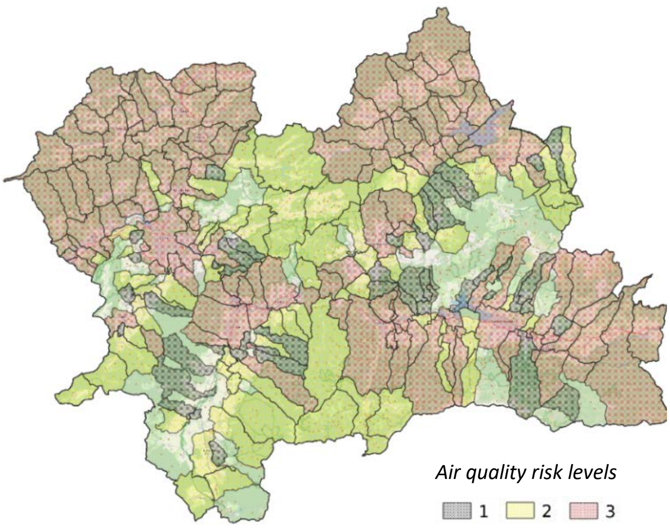
[6] *Štefánik, D., Krajčovičová, J.: Metóda integrovaného posúdenia obcí vzhľadom na riziko nepriaznivej kvality ovzdušia, SHMÚ, 2023, available at https://www.shmu.sk/sk/?page=996*

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[7]

Zones and agglomerations that include at least one municipality with a risk level 3 are obligated to 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. The high-resolution modelling provides information on the spatial distribution of air pollution, publicly available at the SHMÚ website[8].

Fig. 3.11 *Risk municipalities in zone Žilina region (2023).*



3.7 Summary

In 2023, no exceedances of the limit values for SO_2, NO_2, CO benzene, PM_{10} and a $PM_{2.5}$ were recorded in the Žilina region. The target value for the annual average concentration of benzo(a)pyrene according to measurements was exceeded at the stations in Ružomberok, Žilina and Oščadnica. The target value for O_3 was exceeded at the rural background station Chopok. We observe a decrease in the long-term trends of the PM (**Fig. 3.1**) and NO_2 concentrations in this region. Since 2018 the number of exceedances in PM_{10} sharply decreased at all stations. The major problem of zone Žilina region in terms of air quality is high level of pollution by benzo(a)pyrene.

Based on the modelling results using RIO, IDW-R tools, we conclude the risk of increased concentrations of $PM_{2.5}$ and BaP is present in several municipalities in Orava, Kysuce, in the surroundings of Ružomberok, Martin and also in some municipalities located in the Liptovský Mikuláš district.

In terms of the future requirements of the novel Directive of the European parliament, accepted in April 2024, that sets stricter limit values for pollutants in the atmosphere (to come into force from 1 January 2030), the major challenge for the zone Žilina region would be to meet the limits for $PM_{2.5}$. As of 2023, the new lower limits are not being met at any station in the zone. Despite the observable improvement in the air quality over the past several years, meeting the requirements on the new European directive by 2030 will require additional measures, that will effectively contribute to lowering the air pollution to the required levels.

The WHO's recommendations[9] for the content of different pollutants are typically even lower than those of the new EU Directive. As of 2023, none of the stations meets the recommended limits.

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[7] *https://www.shmu.sk/sk/?page=2768*

[8] *https://www.shmu.sk/sk/?page=2699*

[9] *WHO GLOBAL AIR QUALITY GUIDELINES, 2021. Recommendations on classical air pollutants, p. 4. https://apps.who.int/iris/bitstream/handle/10665/345334/9789240034433-eng.pdf*