AIR POLLUTION IN THE SLOVAK REPUBLIC 2021

ANNEX

AIR QUALITY ASSESSMENT IN KOŠICE AGGLOMERATION AND ZONE KOŠICE REGION

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Air quality monitoring department
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

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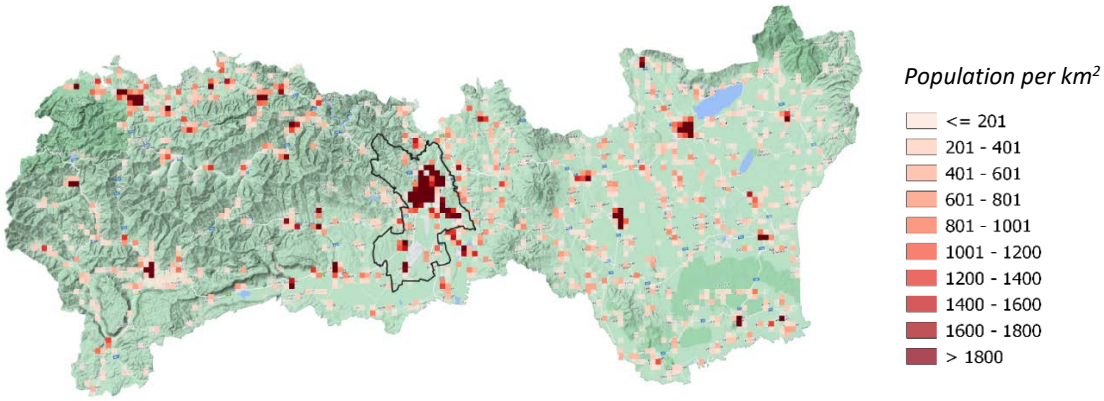
Version 2

1 DESCRIPTION OF AGGLOMERATION KOŠICE AND ZONE KOŠICE REGION TERRITORY

For the purposes of air quality assessment, the territory of Slovakia is divided into zones and agglomerations (*https://www.shmu.sk/sk/?page=1&id=oko_info_az*). The territory of the Košice Region includes the Košice agglomeration (the territory of the city of Košice and the municipalities of Bočiar, Haniska, Sokoľany and Veľká Ida) and the zone Košice region (Košice NUTS-3 region without the Košice agglomeration). **Fig. 1.1** shows the spatial distribution of population density in the Košice NUTS-3 region. The borders of the Košice agglomeration are marked with a dark line in the picture.

Fig. 1.1 *Population density in Košice region (Source: EUROSTAT, 2018).*



1.1 AGGLOMERATION KOŠICE (territory of Košice city and municipalities Bočiar, Haniska, Sokoľany and Veľká Ida)

The city of Košice is located in the Hornád valley in the Košice basin and, according to the orographic classification, belongs to the inner Carpathian range. From the southwest, it extends into the Slovak Karst region, to the north lies the Slovak Ore Mountains, and to the east of the city are the Slanské vrchy. Wind conditions in Košice are characterized by a prevailing flow from the north, the area is relatively well ventilated.

Air pollution sources in agglomeration Košice

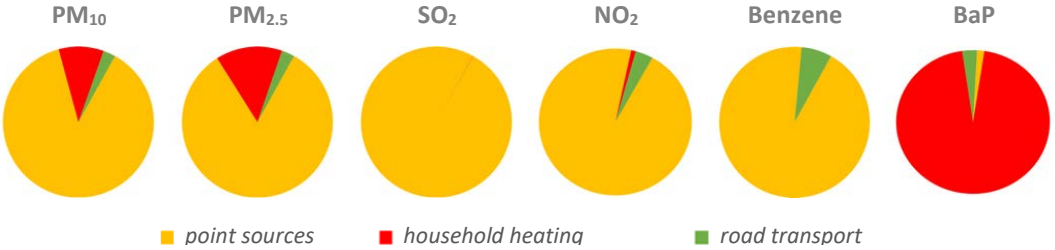
In the Košice agglomeration, the Košice-Šaca district, there is an industrial complex focused on metallurgy of iron, steel and coke production, which is the dominant industrial source of air pollution. Other industrial sources include cement plants.

Air quality in the villages of Veľká Ida, Haniska, Sokoľany and Bočiar, and to a lesser extent in Košice, is affected by sources of pollution from the nearby industrial complex. A relatively favourable circumstance here is the prevailing flow from the northern directions.

The source of air pollution in Košice is also road traffic, with the highest intensity on the bypass of the city center - section PR3 (southeast bypass) with a daily average maximum of 50 895 vehicles (6 905 cars and 43 827 trucks), expressway R2 (southern bypass) with 32 061 vehicles (4 166 trucks and 27 751 passenger cars), route No. 547 (northern bypass) with 28,756 vehicles (2 004 trucks and 26 631 passenger cars) and the PR3 road section (eastern bypass) with 36,261 vehicles (6 056 trucks and 30 103 passenger cars[1]).

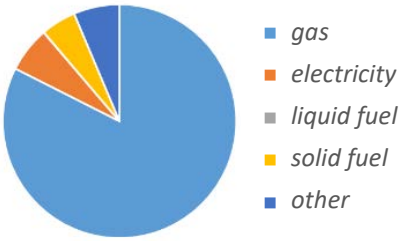
[1] *https://www.ssc.sk/files/documents/dopravne-inzinierstvo/csd_2015/ke/scitanie_tabulka_ke_2015.pdf*

Fig. 1.2 *Share of different types of air pollution sources in total emissions in the Košice agglomeration.*



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

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 mainly used for heating in family houses in the agglomeration. Heating of households is partially provided by municipal heating plants, in the case of independent heating, natural gas is the predominant fuel. Solid fuels are probably used more in rural type of settlements.

1.2 ZONE KOŠICE REGION (without Košice agglomeration)

The relief of the eastern part of the zone Košice region has a predominantly flat character thanks to the East Slovak Plain, which is separated from the Košice Basin by the Slanské vrchy. On the border with the Prešov region stretch the Vihorlatské vrchy, from west to east the Hornád basin stretches. In the western, more mountainous part of the region, stretch the Volovské vrchy, separated from the Slovak Karst by the Rožňavská basin. The Hornád basin in the northern part of the territory extends into the southern part of the Prešov region. The highest point of the Košice region is Stolica, the highest point of the Stolické vrchy is 1 476 m above sea level, the lowest point is 94 m above sea level.

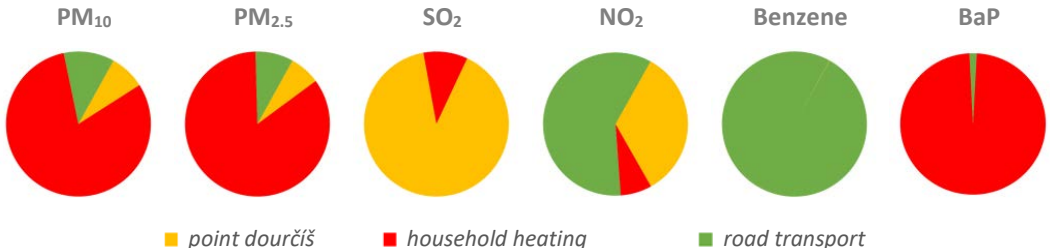
Air pollution sources in zone Košice region.

The roads with the highest traffic intensity in this region (outside of Košice) – road No. 50 in the Michalovce district with 14 783 vehicles (1 721 trucks and 13 021 cars), road No. 3244 in the district of Spišská Nová Ves with 12 384 vehicles (1 391 trucks and 10 872 passenger cars), road No. 526 in the Rožňava district with 10 433 vehicles (626 trucks and 9 747 passenger cars) and road No. 3710 in the Trebišov district with 9 328 vehicles (614 trucks and 8 686 passenger cars) [3].

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

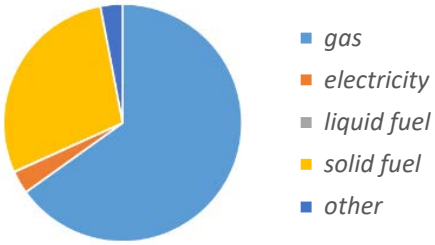
[3] *https://www.ssc.sk/sk/cinnosti/rozvoj-cestnej-siete/dopravne-inzinierstvo/celostatne-scitanie-dopravy-v-roku-2015/kosicky-kraj.ssc*

Fig. 1.4 *Share of different types of air pollution sources in total emissions in the Košice region.*



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

Fig. 1.5 *Share of different types of fuel used for heating in family houses [4].*



According to the Population and Housing Census (PHC) 2021 data, natural gas is mainly used for heating in family houses in the zone. In the mountainous area of the western part of the Košice region, a significant source of air pollution is the heating of households using solid fuels, especially firewood. The situation is aggravated by adverse dispersion conditions in areas with low wind speed.

2 AIR QUALITY MONITORING STATIONS IN KOŠICE AGGLOMERATION AND ZONE KOŠICE REGION

Tab. 2.1 and **Tab. 2.2** contain information on air quality monitoring stations in the Košice agglomeration and in the zone Košice region:

- international EoI code, station characteristics according to dominant sources of air pollution (traffic, background, industrial), type of area monitored (urban, suburban, rural/regional) and geographical coordinates;
- monitoring programme. Continuous monitoring automated instruments provide hourly average concentrations of PM_{10}, $PM_{2.5}$, nitrogen oxides, sulphur dioxide, ozone, carbon monoxide and benzene. The SHMÚ test laboratory analyses heavy metals and polycyclic aromatic hydrocarbons as part of manual monitoring and the results are mean 24-hours values.

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

2.1 AGLOMERATION KOŠICE

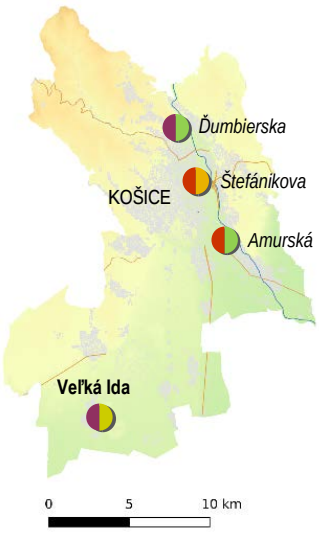
(territory of Košice city and municipalities of Bočiar, Haniska, Sokoľany and Veľká Ida)

Air quality monitoring in Košice began in 1971. Currently, air quality is measured at four stations. Košice, Štefánikova reflects the impact of road traffic, the monitoring stations Košice, Amurská and Košice, Ďumbierska characterise urban (or suburban) background pollution. The monitoring station in Veľká Ida* measures near the railway station in a grassy open area on the south-eastern edge of the village. To the northeast of the station is a metallurgical complex with iron, steel, and coke production (the U. S. Steel site), and to the southeast of the station is a mostly grassy heap.

**Note: In terms of air quality assessment and its division into zones and agglomerations, the Košice agglomeration also includes the municipalities of Veľká Ida, Bočiar, Haniska and Sokoľany.*

Tab. 2.1 *Monitoring programme of air quality in the Košice agglomeration.*

Agglomeration Košice								Measurement programme									
								Continuously								Manually	
District	EoI code	Station name	Type of area	Type of station	Co-ordinates longitude	Co-ordinates latitude	Altitude [m]	PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
Košice I	SK0264A	Košice, Amurská	U	B	21°17'08"	48°41'25"	201										
Košice I	SK0267A	Košice, Štefánikova	U	T	21°15'32"	48°43'35"	209										
Košice I	SK0016A	Košice, Ďumbierska	S	B	21°14'42"	48°45'12"	240										
Košice okolie	SK0018A	Veľká Ida, Letná	S	I	21°10'31"	48°35'32"	209										
							Total	3	3	1	1	1	2	1	0	1	1



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

Station type:
B – background
T – traffic
I – industrial

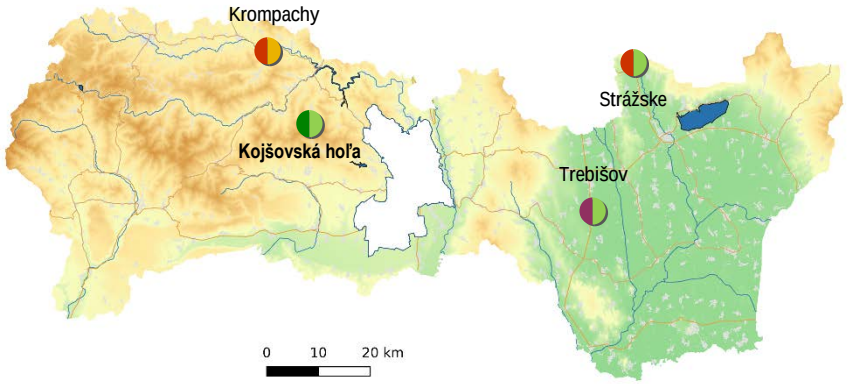
2.2 ZONE KOŠICE REGION (without Košice agglomeration)

Air quality monitoring in the Košice Region is complicated by the diversity of the terrain and the size of the area. There are four monitoring stations, and two of the sites have a relatively long history of measurements. The beginnings of air quality monitoring in Krompachy and Strážske date back to the 1980s. The aim was to capture the impact of industrial activity. Over the years, the impact of industrial sources has declined, the station in Krompachy is categorised as an urban traffic station and in Strážske as an urban background station. In 2020, a suburban monitoring station was added in Trebišov.

The station at Kojšovská hora is located at a radar site at an altitude of 1 232 m above sea level, in the eastern part of the Snina district. It characterizes the air quality in a less polluted area. Air quality monitoring started here in 2009.

Tab. 2.2 *Monitoring programme of air quality in the zone Košice region.*

Zone Košice region (without Košice agglomeration)								Measurement programme									
								Continuously								Manually	
District	EoI code	Station name	Type of area	Type of station	Co-ordinates longitude	Co-ordinates latitude	Altitude [m]	PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
Gelnica	SK0042A	Kojšovská hoľa	R	B	20°59'14"	48°46'58"	1232										
Michalovce	SK0030A	Strážske, Mierová	U	B	21°50'15"	48°52'27"	133										
Spišská Nová Ves	SK0265A	Krompachy, SNP	U	T	20°52'26"	48°54'56"	372										
Trebišov	SK0073A	Trebišov, T. G. Masaryka	S	B	21°42'45"	48°37'42"	107										
							Total	3	3	3	1	2	1	1	0	0	1



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

Station type:
B – background
T – traffic
I – industrial

3 ASSESSMENT OF AIR QUALITY IN AGGLOMERATION KOŠICE AND ZONE KOŠICE REGION

This chapter deals with a more detailed analysis of the air quality assessment based on the results of the monitoring in the Košice agglomeration and in the zone Košice Region for the year 2021. Recall that the Košice agglomeration includes the city of Košice and the municipalities of Veľká Ida, Haniska, Sokoľany and Bočiar. The reason for the introduction of such an extended area for air quality assessment is the fact that the metallurgical complex with the production of iron, steel and coke affects to some extent the whole agglomeration. The zone Košice region covers the territory of the region excluding the Košice agglomeration.

Tab. 3.1 *Assessment of air pollution according to limit values for protection of human health and numbers of alert threshold exceedances in agglomeration Košice and zone Košice region – 2021.*

Agglomeration/ Zone		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 exceedance	number of exceedance	number of exceedance	average	number of exceedance	average	average	average	average	number of exceedance	number of exceedance
	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						
KOŠICE	Košice, Štefánikova	0	0	0	22	28	28	18	1 500	0.66	0	0
	Košice, Amurská					21	25	18				
	Veľká Ida, Letná					56	35	21	2 186			
Košice region	Kojšovská hoľa			0	5							0
	Trebišov, T. G. Masaryka			0	12	20	23	17				0
	Strážske, Mierová					12	22	18				
	Krompachy, SNP	0	0	0	14	26	25	20	1 574	0.90	0	0

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

[1] *maximum eight-hour concentration*

[2] *limit values for alert thresholds*

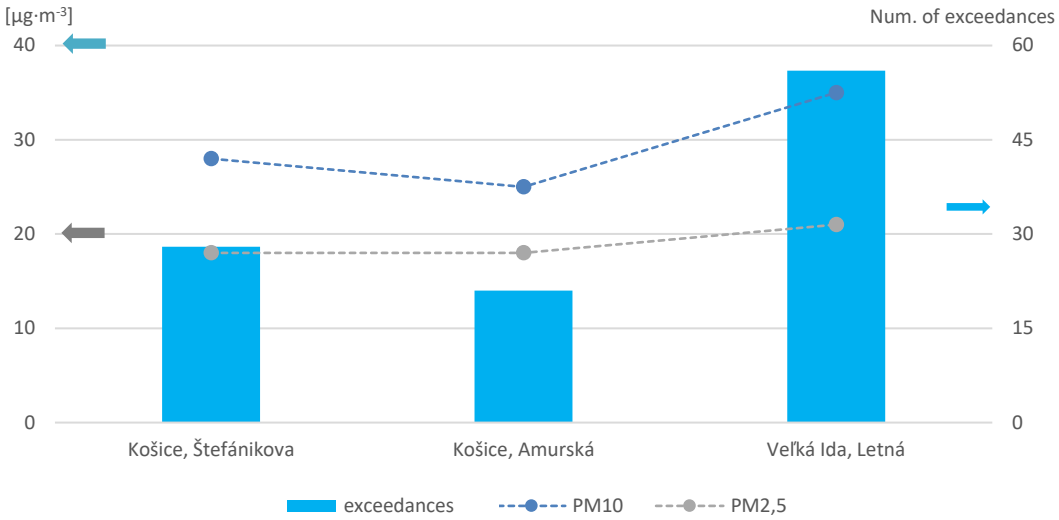
With the exception of NO_2 at the monitoring station in Trebišov (NO_2 started to be measured in Trebišov on 30. 1. 2021) was in accordance with the Regulation of the Ministry of Environment of the Slovak Republic No. 244/2016 Coll. on air quality, as amended, the required proportion of valid values at the other monitoring stations was observed in the Košice agglomeration and in the zone Košice region.

3.1 AGGLOMERATION KOŠICE

3.1.1 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 $\mu g \cdot m^{-3}$ according to the results of measurements at monitoring stations in the Košice agglomeration 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 – captures daily average concentrations greater than 50 $\mu g \cdot m^{-3}$

*Arrows show limit values, **grey arrow** $PM_{2.5}$ (annual average concentration: 20 $\mu g \cdot m^{-3}$); **blue left** PM_{10} (annual average concentration: 40 $\mu g \cdot m^{-3}$); **blue right** 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).*

In 2021, the limit value for the average daily concentration of PM_{10} and the limit value for the average annual concentration of $PM_{2.5}$ were exceeded in the analysis area. (**Tab. 3.1**, **Fig. 3.1**). The station in Veľká Ida recorded the highest annual mean concentration of PM_{10} (35 $\mu g \cdot m^{-3}$). The number of daily exceedances was two and a half times higher than the previous year (56 compared to 22 in 2020). Almost all exceedances of the daily mean value above 50 $\mu g \cdot m^{-3}$ (**Fig. 3.2**) were recorded in the cold half of the year (January to March and October to December). The exceptions are summer episodes of long-range transport of dust from dry areas in the third decade of June and in July. The limit value for the annual average PM_{10} concentration (40 $\mu g \cdot m^{-3}$) was not exceeded.

Monthly PM_{10} concentrations (**Fig. 3.3**) show a distinct annual pattern with a peak in winter. In June and July, we recorded unusually high PM concentrations for the summer period, which were due to the aforementioned long-range transport of dust from dry areas. The limit value for the annual average $PM_{2.5}$ concentration was exceeded at the monitoring station in Veľká Ida.

Fig. 3.2 *Number of exceedances of the daily limit value for PM_{10} for individual months in 2021.*

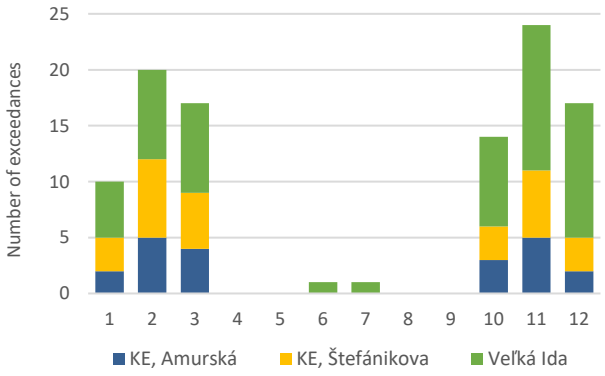
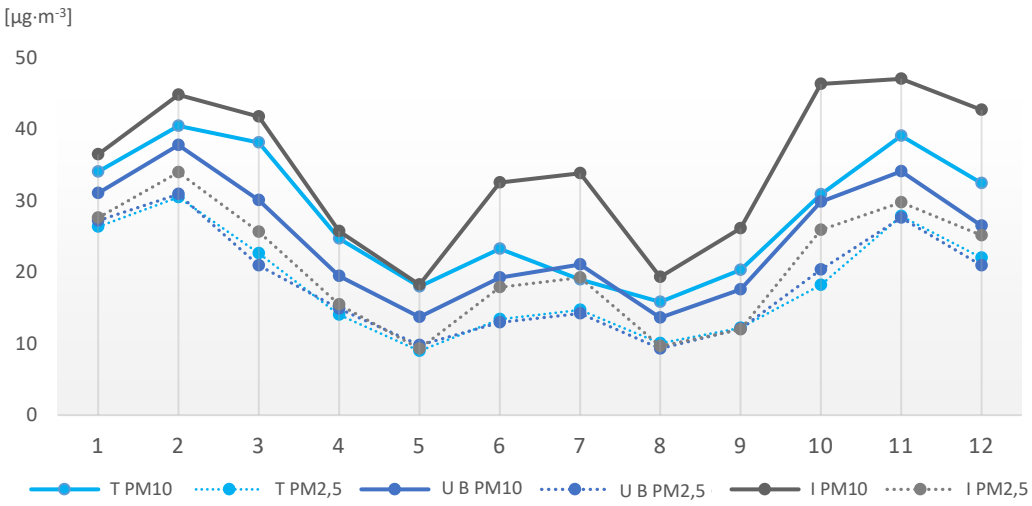


Fig. 3.3 *Average monthly concentrations of PM_{10} and $PM_{2.5}$ in the Košice agglomeration by station type.*



T PM10 *and* ***T PM2,5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the traffic station Košice, Štefánikova;* ***U B PM10*** *and* ***U B PM2,5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the urban background station: Košice, Amurská;* ***I PM10*** *and* ***I PM2,5*** *– average monthly concentrations of PM_{10} and $PM_{2.5}$ at the industrial station: Veľká Ida, Letná;*

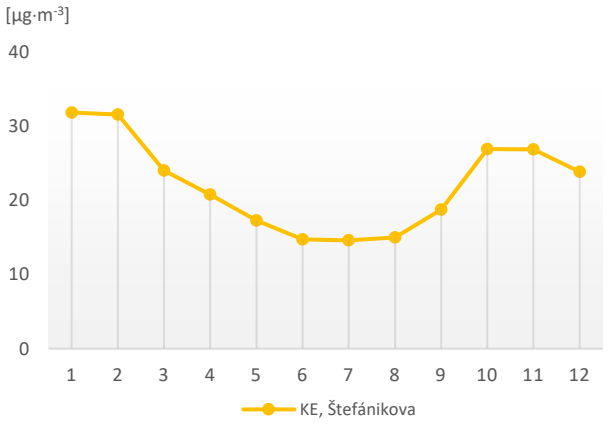
In Fig. 3.3, the average monthly $PM_{2.5}$ concentrations are shown by the dashed line. As with PM_{10}, $PM_{2.5}$ concentrations show a marked seasonal pattern. This is probably due to unfavourable dispersion conditions in the winter months and, to a lesser extent in this area, the seasonal nature of the sources (heating). The local maximum in June and July is probably attributable to a combination of industrial source influence and long-range transport of dust from dry areas in the third decade of June and July. In the Košice agglomeration, the average annual concentration at all monitoring stations is higher than the WHO recommendation (5 $\mu g \cdot m^{-3}$). This was not met in any month of the year, i.e. not even in summer when $PM_{2.5}$ concentrations are usually lowest. High average concentrations of $PM_{2.5}$ are risky mainly because of their adverse effects on human health.

3.1.2 Nitrogen dioxide

Nitrogen dioxide monitoring is carried out at the traffic air quality monitoring station in Košice, Štefánikova. The average monthly values are shown in Fig. 3.4.

The main source of NO_2 emissions is road transport. For this reason, the highest concentrations are recorded at NMSKO traffic stations. The annual average level (22 $\mu g \cdot m^{-3}$) does not exceed the limit value for the annual average concentration (40 $\mu g \cdot m^{-3}$). Concentrations maintain a relatively constant level throughout the year, with a non-significant minimum in the summer period (Fig. 3.4). Although the measured concentrations do not reach high values, they do not meet the WHO recommendations (average annual concentration up to 10 $\mu g \cdot m^{-3}$), which are significantly stricter than the EU limits.

Fig. 3.4 *Average monthly concentrations NO_2.*



3.1.3 Ozone

Ozone monitoring takes place at the suburban background station in Košice, Ďumbierska.

The highest concentrations of ground-level ozone generally occur in warm months with high levels of sunshine (Fig. 3.5). Fig. 3.6 and Fig. 3.7 show the so-called daily course of O_3 concentrations: concentrations increase with sunrise, peaking around midday and gradually decreasing in the evening to a minimum, which occurs early in the morning. Large differences in ground-level ozone concentrations are also observed in the warm and cold seasons.

Fig. 3.5 *Average monthly O_3 concentrations.*

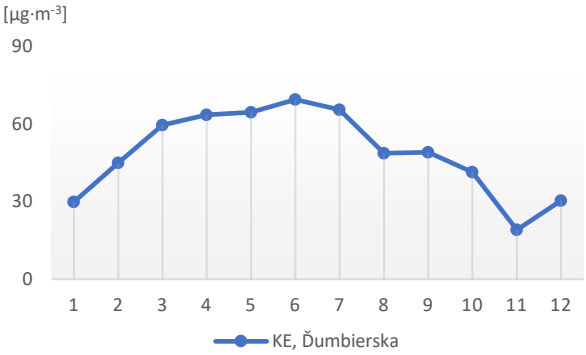


Fig. 3.6 *Daily O_3 concentration in January 2021.*

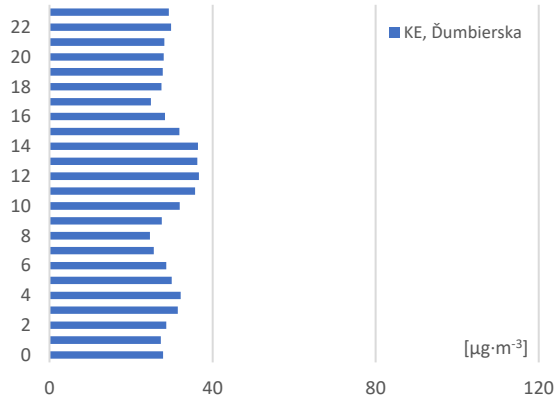
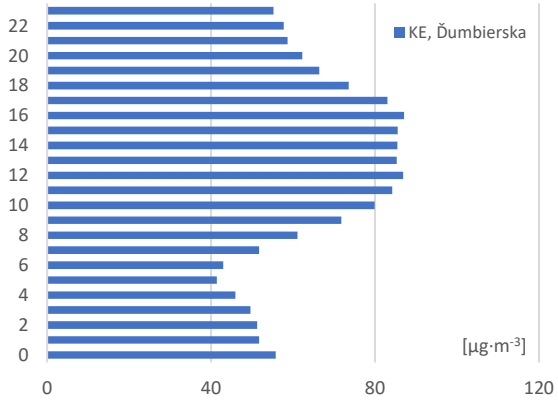


Fig. 3.7 *Daily O_3 concentration in July 2021.*

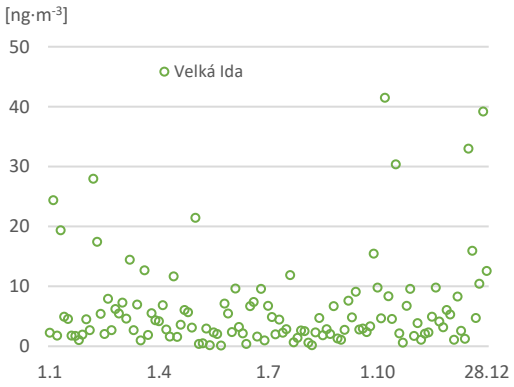


3.1.4 Benzo(a)pyrene

The pollutant benzo(a)pyrene is monitored in this zone at the suburban industrial station in Veľká Ida, Letná. The site is affected by emissions from a nearby metallurgical complex, mainly from coke production. To a lesser extent, however, it is also affected by emissions from domestic heating with solid fuel.

The average annual concentration of benzo(a)pyrene in Veľká Ida exceeds the target value (1 ng·m^{-3}) every year. High concentrations of benzo(a)pyrene have been recorded throughout the year (Fig. 3.8). This is probably due to the dominant influence of the industrial source. The measured values are the highest in the whole NMSKO network, with a year-on-year increase in 2021.

Fig. 3.8 *Results of benzo(a)pyrene measurements in agglomeration Košice in 2021.*



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

	2017	2018	2019	2020	2021
Target value [ng·m^{-3}]	1,0	1,0	1,0	1,0	1,0
Veľká Ida, Letná	4.3	5.8	4.5	4.6	6.1

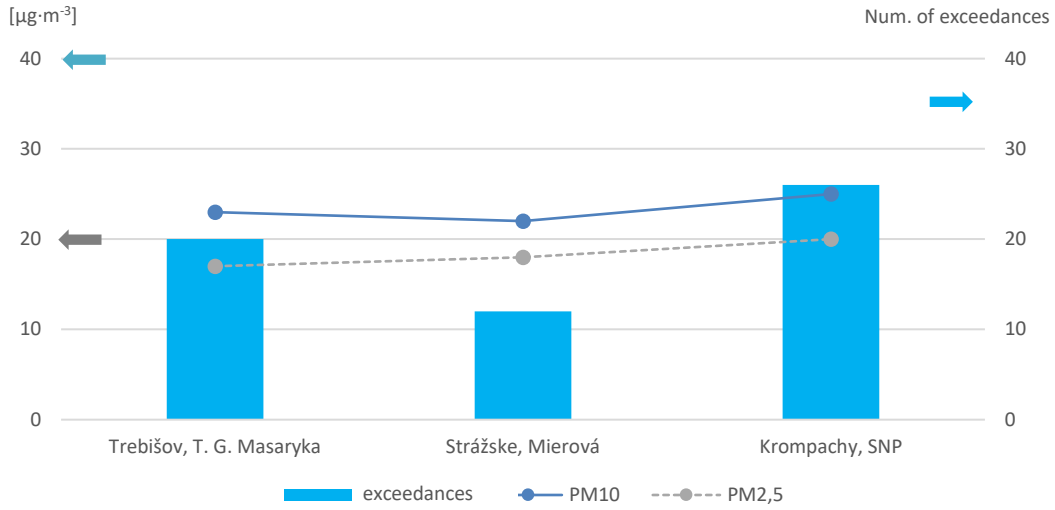
≥ 90% of valid measurements *Exceeding the target value is marked in red.*

3.2 ZONE KOŠICE REGION

3.2.1 Particulate matter PM_{10} and $PM_{2.5}$

Fig. 3.9 shows the average annual concentrations of PM_{10}, $PM_{2.5}$ and the number of days with an average daily concentration of PM_{10} above 50 µg·m^{-3} according to the results of measurements at monitoring stations in the zone Košice region in 2021.

Fig. 3.9 *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 – captures daily average concentrations greater than 50 µg·m^{-3}

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

The limit value for the annual average concentration of PM_{10} (40 µg·m^{-3}) in the zone Košice region was not exceeded. Similarly, the limit value for the number of exceedances per year (35 times) of the average daily concentration of PM_{10} (50 µg·m^{-3}) was not exceeded by any station (**Fig. 3.10**). The traffic station Krompachy recorded the highest annual average PM_{10} concentration of 25 µg·m^{-3} and a higher number of daily exceedances (26). Among the background stations – the urban one in Strážske, Mierová and the suburban one in Trebišov, T. G. Masaryk - we observed very small differences in the annual concentrations (22 µg·m^{-3}and 23 µg·m^{-3}, respectively).

Fig. 3.10 *Number of exceedances of the PM_{10} daily limit value for each month in 2021.*

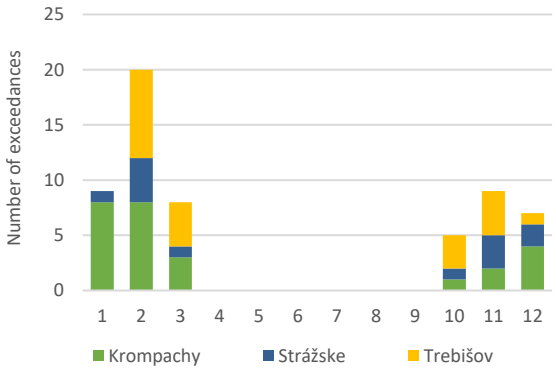
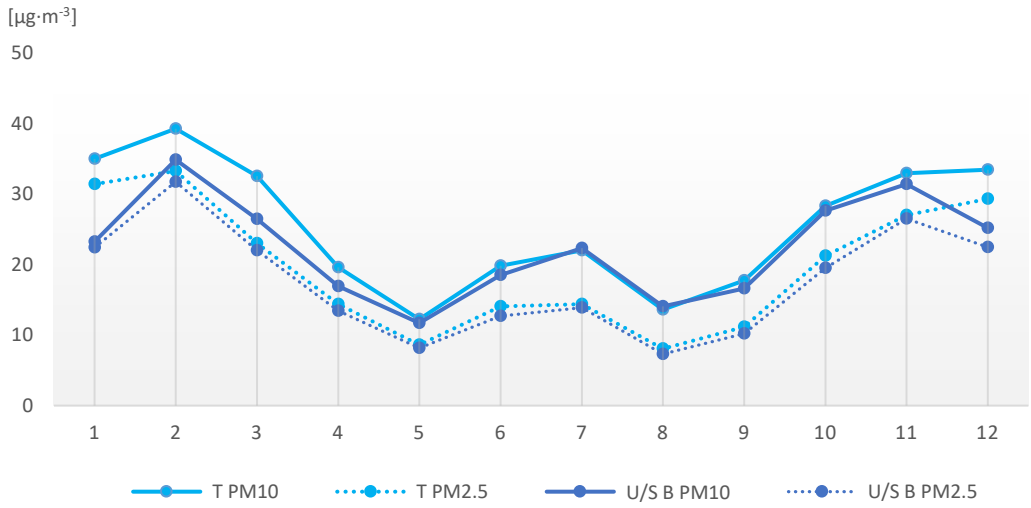


Fig. 3.11 *Average monthly concentrations of PM_{10} and $PM_{2.5}$ in the region by station type.*



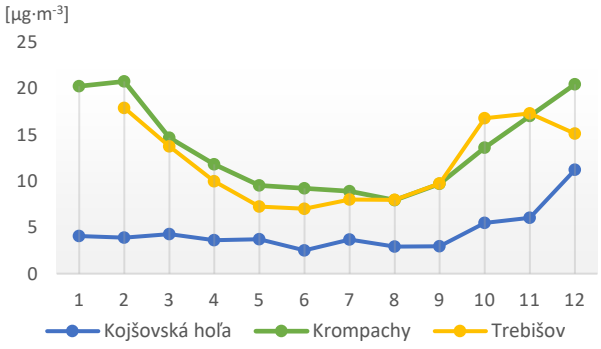
T PM10 *and* ***T PM2.5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the traffic station in Krompachy;* ***U/S B PM10*** *and* ***U/S B PM2.5*** *– average monthly concentrations of PM_{10} and $PM_{2.5}$ at the urban/suburban background stations Strážske and Trebišov;*

The pattern of monthly mean concentrations of PM_{10} and $PM_{2.5}$ (**Fig. 3.11**) is characterized by the highest values in the cold months of the year. This is due to the heating of households with solid fuel and worsened dispersion conditions. Noteworthy is the fact that very similar values were measured at the traffic monitoring station in Krompachy as at the urban and suburban background stations in Strážske and Trebišov, respectively. This is probably due to the similar nature of the sources (less influence of road traffic, more influence of domestic heating).

As noted above, increased concentrations of $PM_{2.5}$ are risky mainly because of their adverse impact on health. In **Fig. 3.9**, the annual average fine particle concentrations are shown by the dashed line. The highest annual average concentration was measured in Krompachy (20 µg·m^{-3}). High $PM_{2.5}$ concentrations were observed in the cold months of the year. This is, as with PM_{10}, a consequence of heating households with solid fuel or various wastes. At all stations, the annual average $PM_{2.5}$ concentration was higher than the level recommended by WHO (5 µg·m^{-3}). This was also true for the monthly average values. This was not only in winter, but even in the summer months when $PM_{2.5}$ concentrations tend to be lowest.

3.2.2 Nitrogen dioxide

Fig. 3.12 *Average monthly concentrations NO_2.*



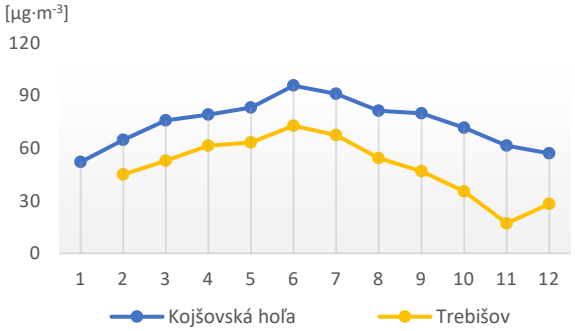
Nitrogen dioxide monitoring is carried out at three stations. The average monthly values for each station are shown in **Fig. 3.12**.

The main source of NO_2 emissions is road transport. For this reason, the highest concentrations are recorded at the Krompachy traffic station. However, the annual average level (14 µg·m^{-3}) does not exceed the limit value for this pollutant (40 µg·m^{-3}) even here. The measured values remain relatively constant level throughout the year, with a slight minimum in the summer months (**Fig. 3.12**), which is almost not observed at the regional station on Kojšovská hora. The average annual concentrations at the background stations reached 12 µg·m^{-3} (Trebišov) and 5 µg·m^{-3} (Kojšovská hoľa). Concentrations of NO_2 in the zone Košice region are at a relatively low level. The only station that met the WHO recommendations (10 µg·m^{-3}), with significantly stricter limits than the EU limits, is Kojšovská hoľa.

3.2.3 Ozone

Ground-level ozone monitoring is carried out in the zone at two monitoring stations – Trebišov and Kojšovská hoľa, which is located at a higher altitude. Therefore, higher concentrations of ground-level ozone are measured at this station (this is probably also a transfer from higher layers of the atmosphere).

Fig. 3.13 *Average monthly concentrations O_3.*



The highest concentrations of O_3 occur in warm months with high sunshine intensity (**Fig. 3.13**). **Fig. 3.14** and **Fig. 3.15** show the so-called daily course of O_3 concentrations: an increase with sunrise, a peak reached around noon and a gradual decrease in the evening to a minimum, occurring in the morning. Large differences in ground-level ozone concentrations are also observed in the warm and cold seasons. The higher values measured at Kojšovská hora are probably due to transport from the upper atmosphere.

Fig. 3.14 *Daily O_3 concentration in January 2021.*

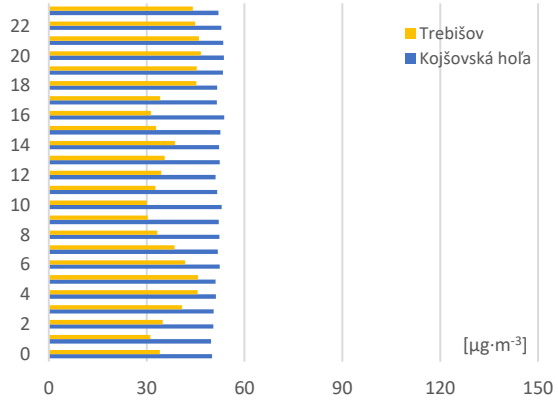
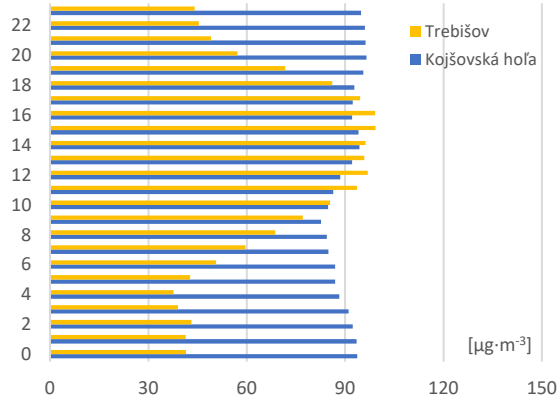


Fig. 3.15 *Daily O_3 concentration in July 2021.*

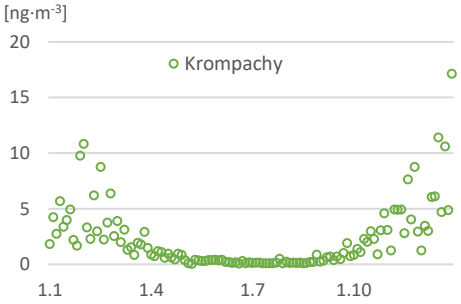


3.2.4 Benzo(a)pyrene

Benzo(a)pyrene is monitored at one monitoring station in the zone Košice region – Krompachy, SNP. The target value for benzo(a)pyrene (1 ng·m^{-3}) is significantly exceeded here every year. However, the concentrations do not reach the values measured in Veľká Ida.

The concentrations of benzo(a)pyrene recorded during the year in Krompachy (**Fig. 3.16**), in contrast to Veľká Ida (**Fig. 3.8**), are characterized by a characteristic pronounced maximum during winter. This indicates a significant influence of household heating, in conjunction with worse dispersion conditions. When compared with the PM concentration trend (**Fig. 3.11**), it can be assumed that seasonal sources influence high concentrations even more than for PM in the case of benzo(a)pyrene. For particulate matter, road traffic, including resuspension, and long-distance transport are more influential.

Fig. 3.16 *Results of benzo(a)pyrene measurements in 2021.*



Tab. 3.4 *Evaluation of benzo(a)pyrene air pollution.*

	2017	2018	2019	2020	2021
Target value [ng·m^{-3}]	1.0	1.0	1.0	1.0	1.0
Krompachy, SNP			2.7	2.1	2.2

≥ 90% of valid measurements *Exceeding the target value is marked in red.*

4 AIR QUALITY MODELLING

In **Fig. 4.1** and **Fig. 4.2**, the PM_{10} modelling results are calculated using the RIO model in combination with IDW-R (see Chapter 4 of *Air pollution in the Slovak Republic 2021 Report* for a more detailed description of the method). For better illustration, only areas for which the annual mean concentrations came out higher than the more stringent annual limits recommended by WHO are shown.

Fig. 4.1 *Average annual concentration of PM_{10} in 2021. Only values above 15 µg·m^{-3} are shown.*

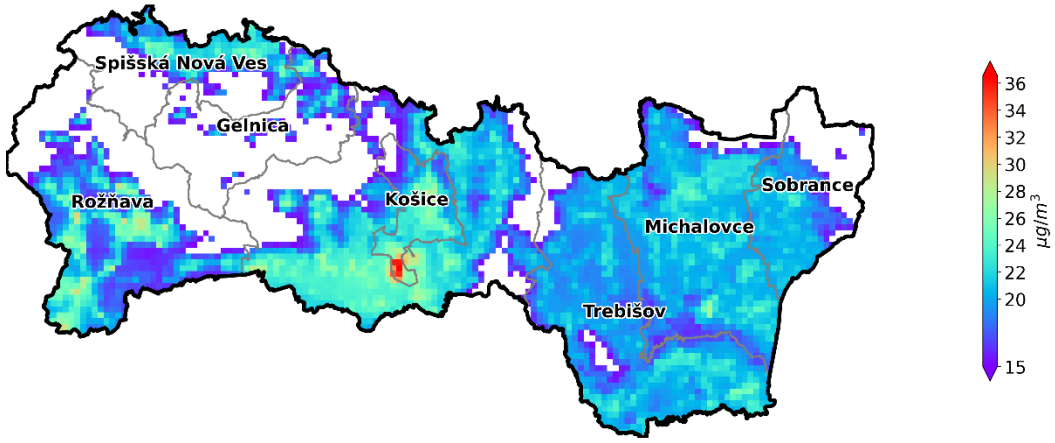
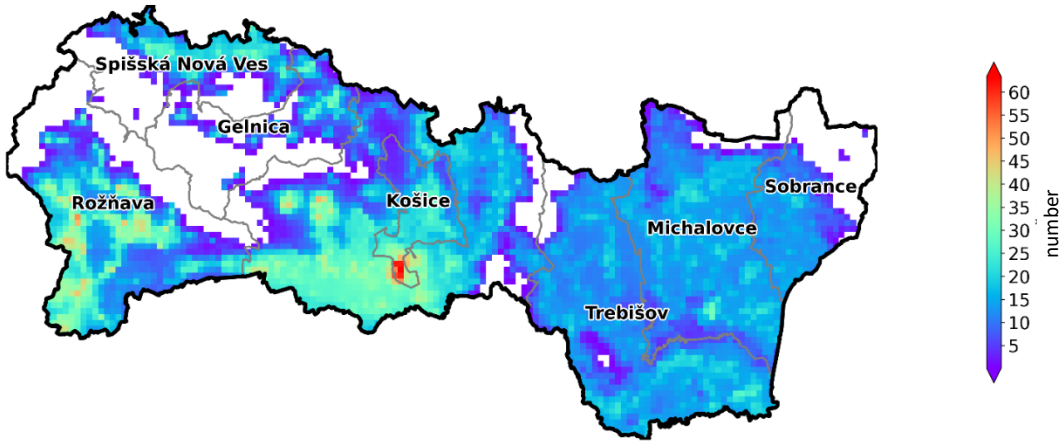


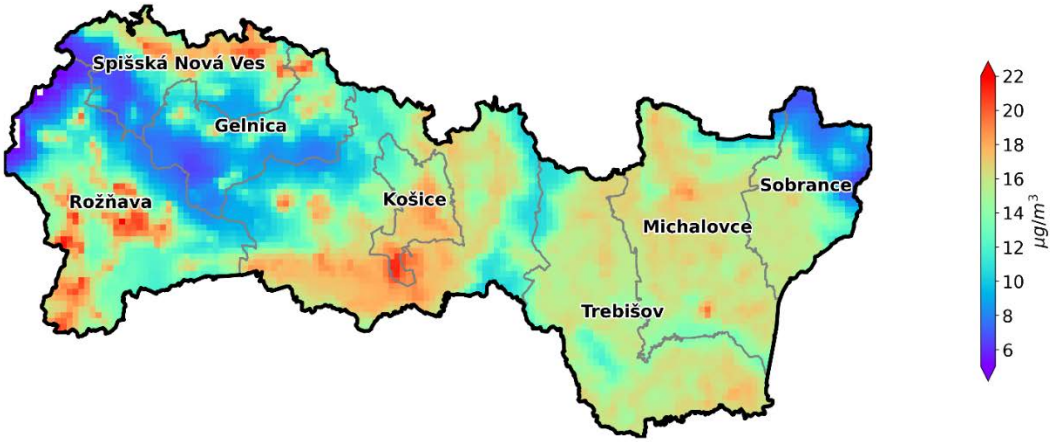
Fig. 4.2 *Number of exceedances of the PM_{10} daily limit value in 2021. Only areas for which the number of exceedances was non-zero are shown.*



Based on the results of mathematical modelling with the interpolation model RIO, IDW-R, we can assume that the highest concentrations of PM occur in the southern part of the Košice agglomeration (in the villages of Veľká Ida, Sokoľany, Haniska, Bočiar) and are influenced by emissions from the metallurgical complex.

In the zone Košice region, PM values are likely to be highest, especially in Above region and in the districts of Rožňava, Spišská Nová Ves and Geľnica (**Fig. 4.1**, **Fig. 4.2**).

Fig. 4.3 *Average annual $PM_{2.5}$ concentration in 2021 according to the output of the RIO model, IDW-R.*



The map in **Fig. 4.3** shows the spatial distribution of annual mean $PM_{2.5}$ concentrations according to the output of the RIO model combined with the IDW-R model. According to the model output, the annual mean $PM_{2.5}$ concentration across the zone was higher than the WHO recommended limit value (the WHO limit values are more stringent than the EU limits).

The spatial distribution of annual mean $PM_{2.5}$ concentrations according to the RIO, IDW-R model has a similar pattern as for PM_{10}. Maximum values are likely to occur in Above, Rožňava and Spišská Nová Ves districts, except for the Košice agglomeration.

Fig. 4.4 *Average annual concentration of benzo(a)pyrene in 2021 according to the output of the RIO model, IDW-R.*

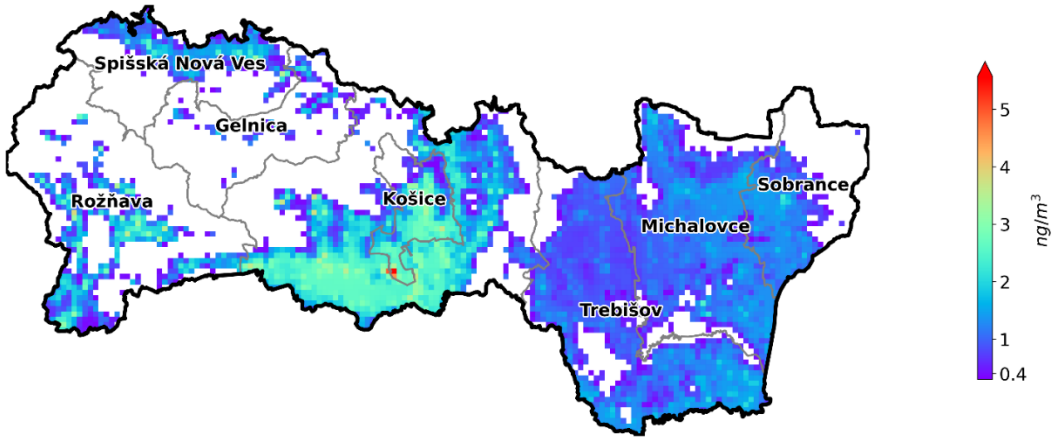


Fig. 4.4 shows the spatial distribution of the annual mean benzo(a)pyrene concentration as output by the RIO model, IDW-R. Since the model is based on measured data (and auxiliary fields), the outputs are burdened with considerable uncertainty over the large area of the zone Košice region.

The model may overestimate benzo(a)pyrene concentrations especially in the vicinity of Košice and the East Slovak Lowland. It is strongly influenced by the high annual average concentration measured in Veľká Ida. It is one of the two stations in the zone Košice region where benzo(a)pyrene is monitored, together with Krompachy.

High-resolution modelling using detailed emission data (i.e. data on the amount and type of fuels, type of equipment used for domestic heating, etc.) is needed to obtain a more detailed picture of the spatial distribution. The most significant source of benzo(a)pyrene in the Košice agglomeration is coke production, and to a lesser extent domestic heating. The situation is reversed in the zone Košice region, where the most significant source is household heating with solid fuel, mainly insufficiently dried wood or unsuitable fuel (various types of waste).

4.1 Risk areas

Fig. 4.5 *Municipalities and districts at risk in the zone Košice region and in the Košice agglomeration.*

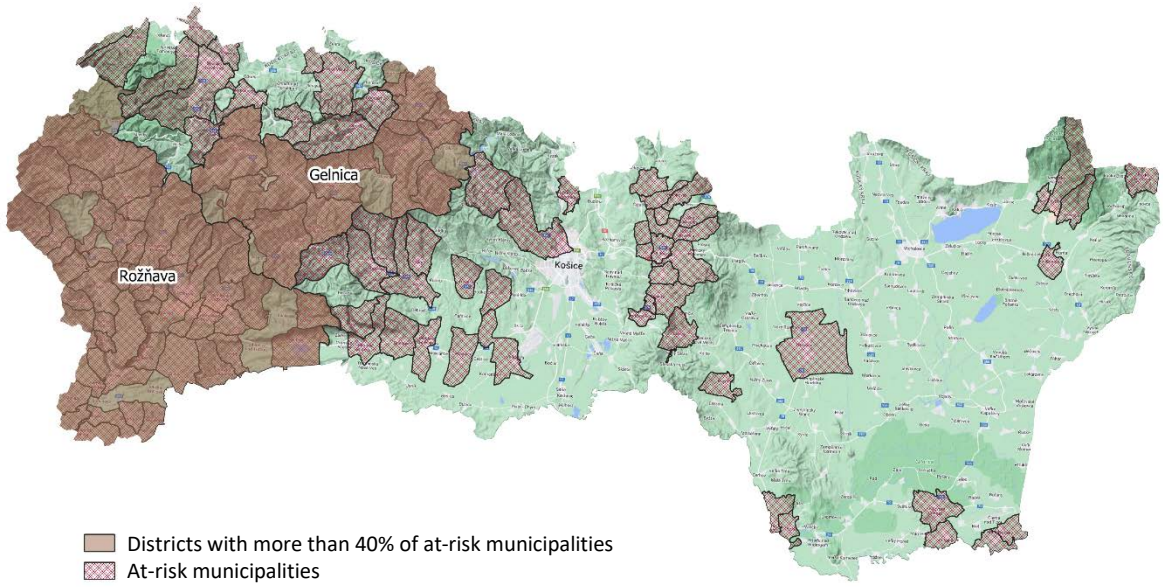
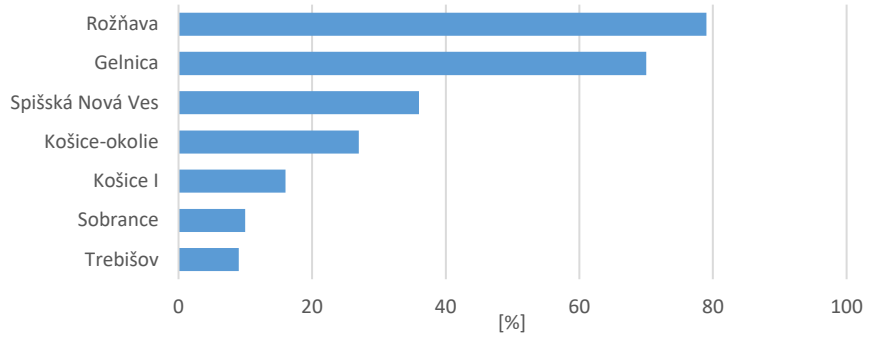


Fig. 4.5 shows the areas that are at risk of poor air quality due to PM and benzo(a)pyrene from domestic heating according to the modelling results, processed according to the methodology of *D. Štefánik: Identification of communities at risk of air quality compromised by local heating and impaired dispersion conditions (updated in 2022)*[5]. The methodology is based on data on the use of solid fuels for domestic heating according to the Population and Housing Census (PHC) 2021 data, takes into account high PM concentrations according to mathematical modelling outputs and takes into account adverse dispersion conditions. For mathematical modelling, input data covering the whole country with a high spatial resolution are not available. Therefore, we assume that an area is at risk if it has a high proportion of solid fuel heating, even if the mathematical modelling has not captured this fact.

The significantly higher representation of at-risk areas in the western part of the zone is influenced by the higher share of solid fuels in household heating in mountainous areas with good availability of firewood, mountainous terrain, with worse dispersion conditions in the Slovak Ore Mountains area as opposed to the well-ventilated area of the East Slovak Lowland. It should be noted that the assessment is based on data from the PHC 2021, which did not yet reflect the impact of the energy crisis.

The percentage of at-risk villages in each district is shown in Fig. 4.6. If more than 40% of the villages in a district are at risk, the entire district is defined as at-risk.

Fig. 4.6 *Percentage of at-risk municipalities in the districts of the Košice region.*



[5] *https://www.shmu.sk/File/oko/studie_analyzy/Popis_metody_na_urcenie_rizikovych_oblasti_aktualizacia.pdf*

The highest number of at-risk municipalities in the Košice region is in the Rožňava district, a high proportion of at-risk municipalities is also in the Gelnica district, especially problematic are areas in mountain valleys and basins with poorer ventilation and good availability of firewood. More than 80% of the at-risk municipalities in the Košice region have less than 2 500 inhabitants, which confirms the assumption that the problem is significantly greater in areas with a rural type of settlement.

In the Košice I district, the Košice-North urban district is at risk in terms of this methodology. Veľká Ida is one of the at-risk municipalities of the Košice-okolie district. According to the division of the Slovak Republic into zones and agglomerations for the purpose of air quality assessment, Veľká Ida is included under the Košice agglomeration. The other at-risk municipalities and the two at-risk districts (Rožňava and Gelnica) belong to the zone Košice region. More detailed data are available on the interactive map[5].

5 SUMMARY

In 2021, in the agglomeration of Košice, the limit value for the average daily concentration of PM_{10}, for the average annual concentration of $PM_{2.5}$ and the target value for benzo(a)pyrene were exceeded (all at the monitoring station Veľká Ida, Letná). Exceeding the limit value for SO_2, NO_2, CO and benzene was not measured here.

The agglomeration of Košice (the territory of the city of Košice and the municipalities of Veľká Ida, Haniska, Bočiar and Sokoľany) has long been among the problem areas in terms of air quality. Emissions of bezo(a)pyrene from coke production are a particular problem and, to a lesser extent, the heating of households with solid fuel also contributes to this.

In 2021, the limit value for SO_2, NO_2, CO and benzene was not exceeded in the zone Košice region, nor was the limit value exceeded for the average annual concentration of PM_{10} and $PM_{2.5}$. The number of days with an average daily PM_{10} concentration above 50 $\mu g \cdot m^{-3}$ was below the permitted limit.

The target value for the average annual concentration of benzo(a)pyrene was exceeded in Krompachy.

On the basis of air quality monitoring, air quality management areas were defined in the Košice region in those places where the limit or target value was exceeded in the last three evaluated years (**Tab. 5.1**).

Tab. 5.1 *Air quality management areas for year 2022 defined in the Košice agglomeration and the zone Košice region according to the measurement of basic pollutants in the years 2019 – 2021.*

AGGLOMERATION Zone	Air quality management area	Pollutant	AMS and year of exceedance of limit/target value
KOŠICE	Territory of Košice city and municipalities Bočiar, Haniska, Sokoľany and Veľká Ida	PM_{10}, $PM_{2.5}$, BaP	PM_{10}: Košice, Štefánikova (2019); Veľká Ida (2019, 2021) $PM_{2.5}$: Veľká Ida 2019 (20.7 $\mu g \cdot m^{-3}$), 2021 (20.8 $\mu g \cdot m^{-3}$) BaP: Veľká Ida (2019 – 2021)
Košice region	Territory of Krompachy city	BaP	Krompachy, SNP (2019 – 2021)

Based on the results of mathematical modelling, we can assume that in some areas (**Fig. 4.1** – **Fig. 4.5**) higher values of PM and benzo(a)pyrene may occur especially in the winter months in locations with a higher proportion of solid fuels used for household heating, especially under poor dispersion conditions.