AIR POLLUTION IN SLOVAK REPUBLIC 2022

ANNEX

AIR QUALITY ASSESMENT IN AGGLOMERATION KOŠICE AND ZONE KOŠICE REGION

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Air quality monitoring department
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

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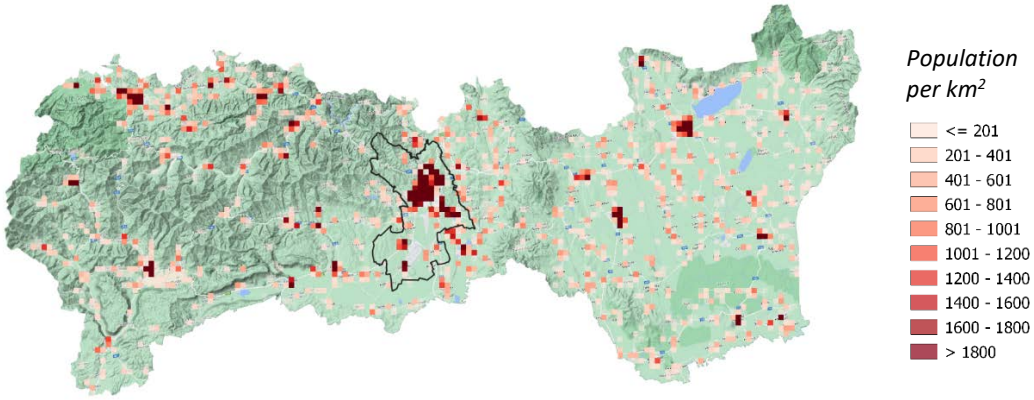
Version 1

1 DESCRIPTION OF AGGLOMERATION KOŠICE AND ZONE KOŠICE REGION TERRITORY IN TERMS OF AIR QUALITY

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 region without the Košice agglomeration. **Fig. 1.1** shows the spatial distribution of population density in the Košice region. The borders of the agglomeration Košice 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.

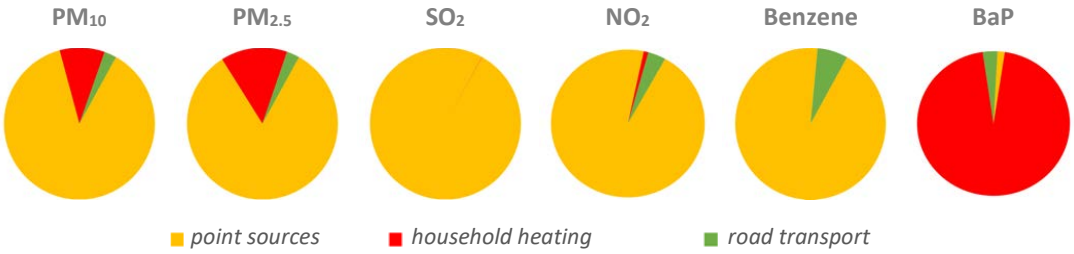
Air pollution sources in agglomeration Košice

In the Košice agglomeration, within the Košice-Šaca district, there is an industrial complex focused on the metallurgy of iron, steel, and coke production, which serves as 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, as well as to a lesser extent in Košice, is affected by pollution sources emanating from the nearby industrial complex. A relatively favourable circumstance here is the prevailing flow from the northern directions.

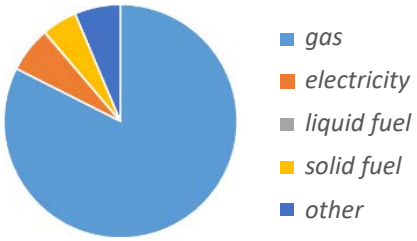
Road traffic is also a significant source of air pollution in Košice. Based on the last national traffic census in 2015, we know that the highest intensity is observed on the city centre bypass - section PR3 (south-eastern bypass) with a daily average maximum of 50,895 vehicles (6 905 cars and 43 827 trucks), expressway R2 (southern bypass) with 32 061 vehicles (4 166 trucks and 27 751 passenger cars), road 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).

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 [1]



For heating in family houses in the agglomeration, according to the Population and Housing Census (PHC) 2021 data, natural gas is mainly used. Household heating is partially provided by urban heating plants, with natural gas being the predominant fuel for independent heating. Solid fuels are likely more commonly used in rural type of settlements.

1.2 ZONE KOŠICE REGION (without Košice agglomeration)

The relief in the eastern part of the Košice region is predominantly flat due to the Eastern Slovak Plain, which separates it from the Košice Basin. On the border with the Prešov region, you'll find the Vihorlatské vrchy, while the Hornád Basin extends from west to east. In the western, more mountainous part of the region, the Volovské vrchy stretch, separated from the Slovak Karst by the Rožňava Basin. The Hornád Basin extends into the southern part of the Prešov region in the northern part of the territory. The highest point in the Košice region is Stolica, the highest point in the Stolické vrchy has an elevation of 1 476 meters above the sea level, and the lowest point is at an elevation of 94 meters above the sea level.

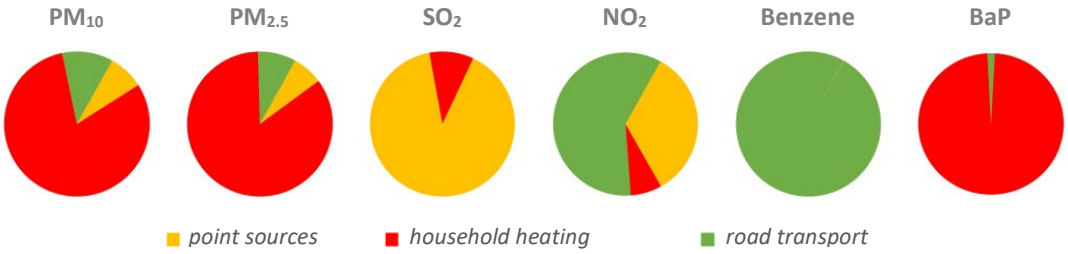
Sources of air pollution in the Košice region

The busiest roads in this region (outside Košice) according to the last national traffic census in 2015 are as follows: road No. 50 in the Michalovce district with 14 783 vehicles (1 721 trucks and 13 021 passenger cars), road No. 3244 in the Spišská Nová Ves district 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)[2].

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

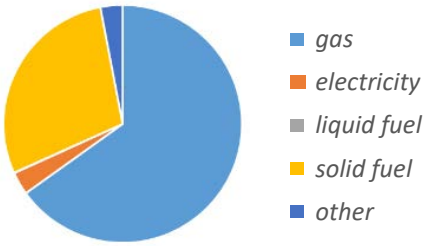
[2] *https://www.ssc.sk/sk/cinnosti/rozvoj-cestnej-siete/dopravne-inzinierstvo/celostatne-scitanie-dopravy-v-roku-2015/kosicky-kraj.ssc*

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 [3].*



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

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

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

- international EoI code, station characteristics based on dominant sources of air pollution (traffic, background, industrial), the type of area monitored by each station (urban, suburban, rural/regional), and geographical coordinates;
- monitoring program: Automatic continuous monitoring devices provide average hourly concentrations of PM_{10}, $PM_{2.5}$, nitrogen oxides, sulphur dioxide, ozone, carbon monoxide, and benzene. The SHMÚ testing laboratory conducts manual monitoring, analysing heavy metals and polycyclic aromatic hydrocarbons, resulting in average 24-hour values.

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

2.1 AGGLOMERATION KOŠICE

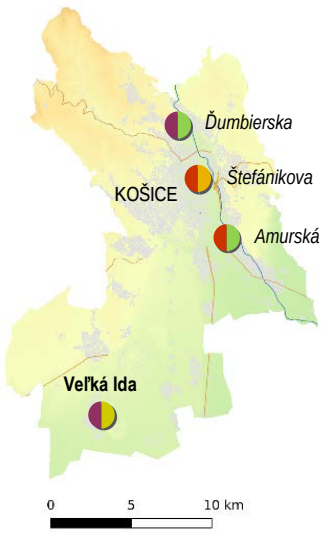
(territory of Košice city and municipalities Bočiar, Haniska, Sokoľany and Veľká Ida)

Air quality monitoring in Košice began in 1971. Currently, air quality is monitored at four stations in the area. The Košice, Štefánikova station reflects the influence of road traffic, while the monitoring stations Košice, Amurská, and Košice, Ďumbierska characterize urban (or suburban) background pollution. The monitoring station in Veľká Ida* is located near the railway station in an open grassy area on the southeastern edge of the municipality. To the northeast of the station, there is a metallurgical complex producing iron, steel, and coke (U. S. Steel facility), and to the southeast, there is predominantly grass-covered slag heap.

* *Note: For the purpose of air quality assessment and its division into zones and agglomerations, the municipalities of Veľká Ida, Bočiar, Haniska, and Sokoľany are considered part of the Košice agglomeration.*

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

Agglomeration Košice								Measurement programme									
								Continuously								Manually	
District	EoI code	Station name	Type of area	Type of station	Geographical longitude	Geographical 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 – regional

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

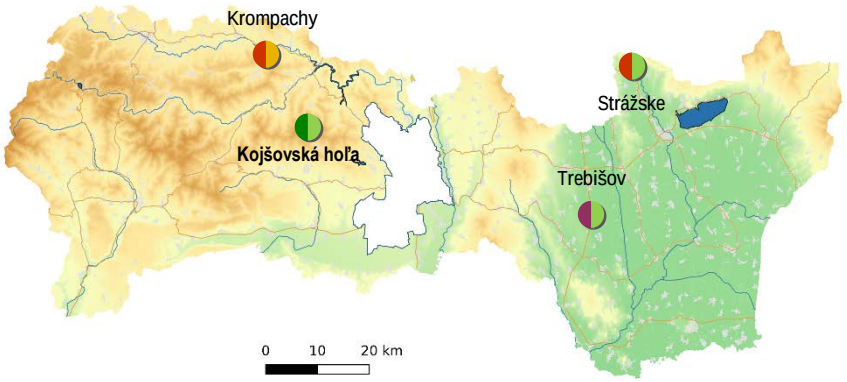
2.2 ZONE KOŠICE REGION (without agglomeration Košice)

Air quality monitoring in the Košice region is complicated due to the diversity of terrain and the vast size of the area. There are four monitoring stations in the region, with two of the locations having a relatively long history of measurements. The beginnings of air quality monitoring in Krompachy and Strážske date back to the 1980s. The goal was to capture the impact of industrial activities. Over the years, the influence of industrial sources has decreased, and the station in Krompachy is categorized as urban traffic, while the one in Strážske is categorized as urban background. In 2020, a suburban monitoring station was added in Trebišov.

The station on Kojšovská Hola is located near a radar station at an altitude of 1 232 meters above the sea level in the eastern part of the Snina district. It characterizes the air quality in a less polluted area. Air quality monitoring began here in 2009.

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

Zone Košice region (without agglomeration Košice)								Measurement programme									
								Continuously								Manually	
District	EoI code	Station name	Type of area	Type of station	Geographical longitude	Geographical 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 – regional

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

3 EVALUATION OF AIR QUALITY MONITORING RESULTS IN AGGLOMERATION KOŠICE AND IN ZONE KOŠICE REGION

This chapter focuses on a detailed analysis of air quality assessment based on the monitoring results in the Košice agglomeration and the zone Košice region for the year 2022. Recall that the Košice agglomeration encompasses the urban center of Košice as well as the municipalities of Veľká Ida, Haniska, Sokoľany and Bočiar. The reason for expanding the assessment of air quality to cover this extended area is the fact that the metallurgical complex producing iron, steel, and coke, located to the south of Košice near these four municipalities, to some extent influences the entire agglomeration Košice. The zone Košice region covers the territory of the region, excluding the agglomeration Košice.

Tab. 3.1 *Evaluation of air pollution according to limit values for the protection of human health and the number of exceedances of alert thresholds in the Košice agglomeration and in the zone Košice region – 2022*

Agglomeration Zone		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	number 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						
KOŠICE	Košice, Štefánikova	0	0	0	22	21	26	17	2 292	0.91	24	0
	Košice, Amurská					12	22	16			0	0
	Veľká Ida, Letná					68	37	22	2 736		72	0
Košice region	Kojšovská hoľa			0	3							
	Trebišov, T. G. Masaryka			0	11	10	22	16			0	0
	Strážske, Mierová					5	20	16			0	0
	Krompachy, SNP	0	0	0	13	13	23	17	1 607	0.94	0	0

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

[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}*

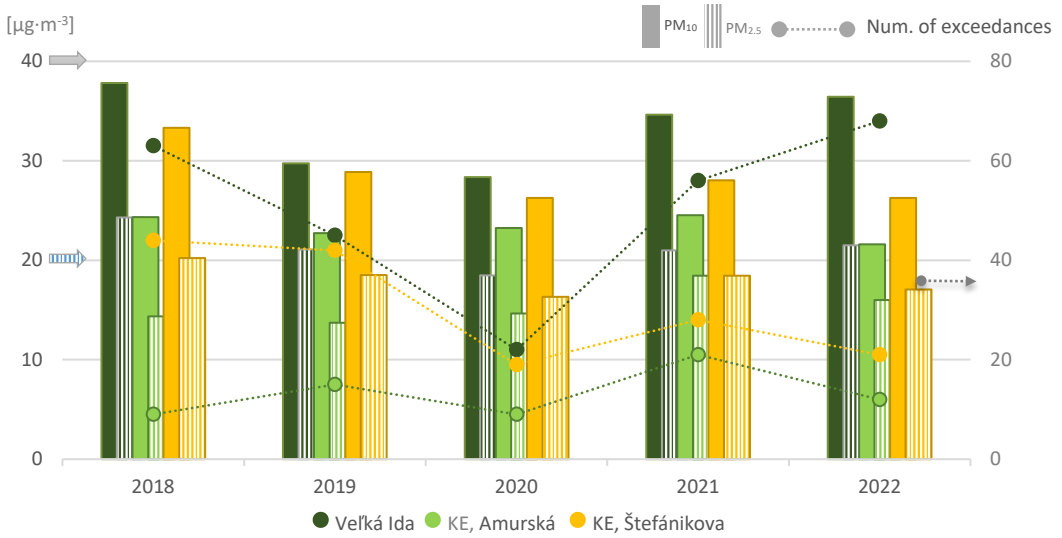
In accordance with the Decree of the Ministry of Environment of the Slovak Republic No. 244/2016 Coll. on air quality as amended, the required proportion of valid values was observed at the monitoring stations.

3.1 AGGLOMERATION KOŠICE

3.1.1 PM_{10} and $PM_{2.5}$

Fig. 3.1 illustrates the annual average concentrations of PM_{10}, $PM_{2.5}$, and the number of days with an average daily PM_{10} concentration exceeding 50 $\mu g \cdot m^{-3}$ based on the measurement results at monitoring stations within the Košice agglomeration in the year 2022.

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}.*

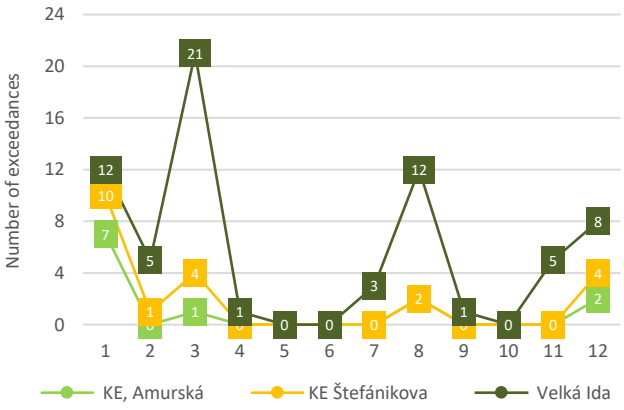


Number of exceedances – captures daily average concentrations greater than 50 $\mu g \cdot m^{-3}$

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

In the year 2022, within the analysed area, the limit value for the daily average concentration of PM_{10} and the limit value for the annual average concentration of $PM_{2.5}$ were exceeded at the station in Veľká Ida (**Tab. 3.1**, **Fig. 3.1**). The number of daily exceedances, amounting to 68, was the highest in the past five years. On the other monitoring stations, the annual average concentrations were lower than in previous years. The number of exceedances of the daily limit value at both monitoring stations in Košice was significantly lower compared to the previous year. A very high number of 21 exceedances of the daily average value above 50 $\mu g \cdot m^{-3}$ (**Fig. 3.2**) was observed in Veľká Ida in March and unusually in August (12). The limit value for the annual average concentration of PM_{10} (40 $\mu g \cdot m^{-3}$) was not exceeded in the agglomeration.

Fig. 3.2 *Number of exceedances of the daily limit value for PM_{10} for individual months in 2022.*



The histogram in **Fig. 3.3** displays the frequency of hourly PM_{10} concentrations at the Košice, Štefánikova, and Veľká Ida stations. At the AMS Štefánikova station, lower concentrations below 20 $\mu g \cdot m^{-3}$ are significantly more prevalent compared to the Veľká Ida station. When comparing the maximum hourly concentrations at these stations, the highest hourly concentration recorded was 296 $\mu g \cdot m^{-3}$ in Veľká Ida, while on Štefánikova street, it reached 133 $\mu g \cdot m^{-3}$.

Fig. 3.3 *Histogram of hourly concentrations of PM_{10} in 2022.*

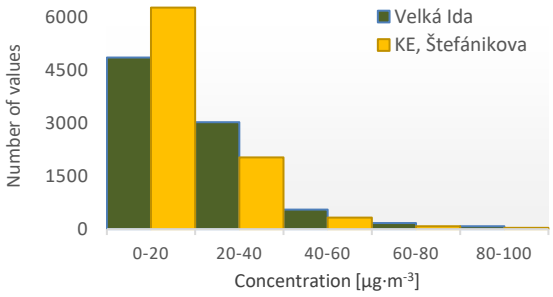
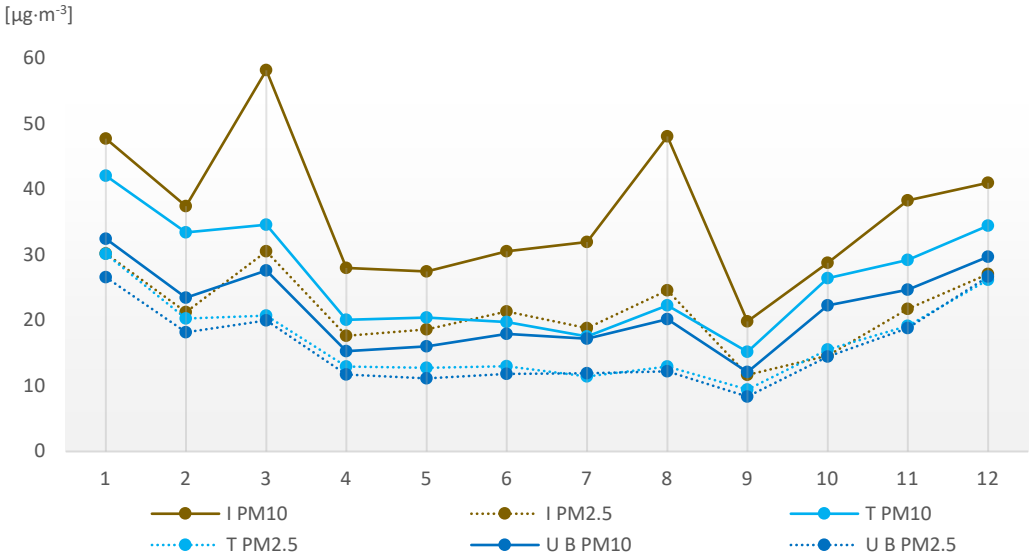


Fig. 3.4 *Average monthly concentrations of PM_{10} and $PM_{2.5}$ in Košice agglomeration according to the type of the station.*

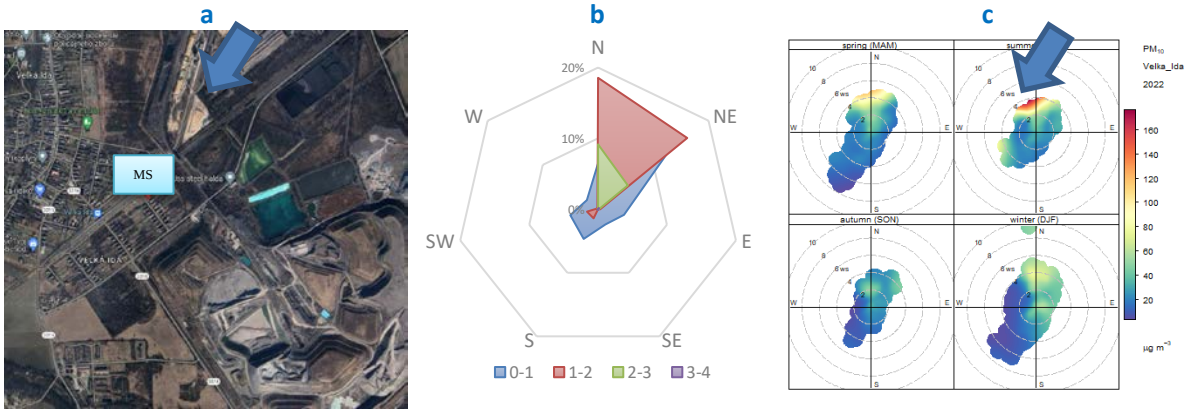


T PM10 *and* ***T PM2.5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the traffic station Košice, Štefánikova;* ***U B PM10*** *and U* ***B PM2.5*** *– average monthly concentration of PM_{10} and $PM_{2.5}$ at the urban background station: Košice, Amurská;* ***I PM10*** *and* ***I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

In **Fig. 3.4**, the average monthly concentrations of $PM_{2.5}$ are depicted by the dashed line. Compared to the monitoring stations in Košice, higher-than-average monthly concentrations of PM_{10} and $PM_{2.5}$ were recorded in Veľká Ida, especially in the months of March and August, and to a lesser extent in other summer months. From the analysis of wind roses from previous years, we observed a correlation between high PM_{10} concentrations and the occurrence of north winds of higher intensity (**Fig. 3.5**). In March, such winds accounted for 61.4% of the total, and similarly, in August, dry weather with low humidity prevailed, and the average wind direction from the north and northeast was over 68.1%. To the north of the monitoring station lies an uncovered landfill, which is not secured against the suspension of deposited materials (**Fig. 3.5a**). We assume that the suspended particles from this landfill are a likely cause of very poor air quality in these months. In March, there were still cold days, contributing to increased emissions of PM_{10} and $PM_{2.5}$, partly due to increased heating emissions in nearby communities. Unfavourable dispersion conditions during anticyclonic situations prevailed for more than half of the month[4].

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

Fig. 3.5 *a. View of the surroundings of the Veľká Ida Air Quality Monitoring Station. b. Wind rose for the month of March. c. Wind rose for the year 2022.*



3.1.2 Nitrogen dioxide

The monitoring of nitrogen dioxide (NO_2) is carried out at the traffic monitoring station for air quality in Košice on Štefánikova street. **Fig. 3.6** displays a histogram of hourly NO_2 concentrations at this station. The most frequently observed hourly concentrations fall in the range of 10 – 20 µg·m^{-3}, and there are also numerous concentrations in the range of 20 – 30 µg·m^{-3}. Concentrations exceeding 50 µg·m^{-3} occurred in 2022 in more than 4% of the cases, which corresponds to the station's traffic-related character. The highest recorded hourly concentration reached 126 µg·m^{-3}. Average monthly values are depicted in **Fig. 3.7**. The annual average level (22 µg·m^{-3}) does not exceed the limit value for the annual average concentration (40 µg·m^{-3}). The highest monthly concentration (31 µg·m^{-3}) was recorded in February, significantly lower concentrations occurred during the summer months.

Fig. 3.6 *Histogram of the hourly concentrations of NO_2 in 2022.*

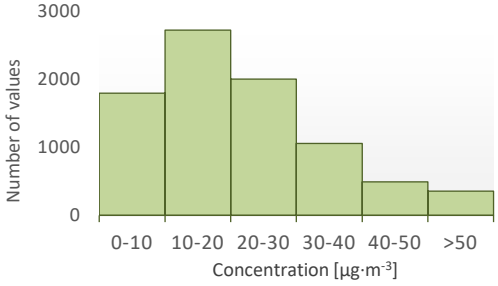
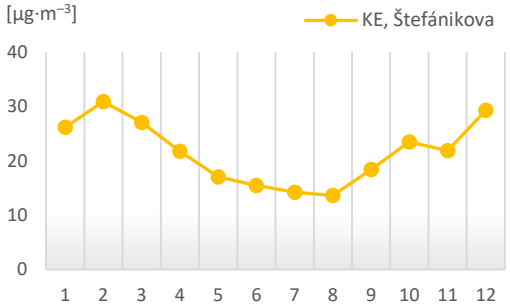


Fig. 3.7 *Average monthly concentrations of NO_2 in 2022*



3.1.3 Ozone

Ozone monitoring takes place at the suburban background station in Košice on Ďumbierska street. The highest concentrations of ground-level ozone are typically observed in warm months. In 2022, high monthly ozone concentrations were recorded in March, comparable to the summer months, despite the cold weather (**Fig. 3.8**). **Fig. 3.9** and **Fig. 3.10** illustrate the so-called daily ozone concentration pattern: concentrations rise with the rising sun, peak around noon, and gradually decrease in the evening to reach a minimum that occurs overnight. Significant differences in ground-level ozone concentrations are also observed between the warm and cold seasons.

Fig. 3.8 *Average monthly concentrations of O_3 in 2022.*

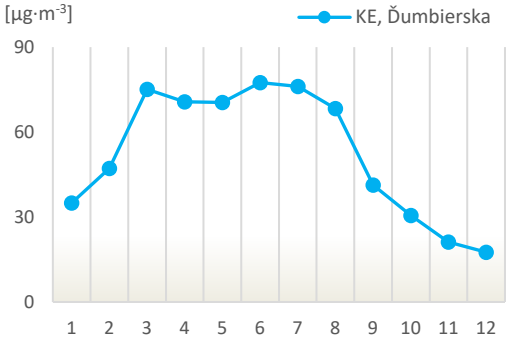


Fig. 3.9 *Daily concentrations of O_3 in January 2022 at AMS Košice, Ďumbierska.*

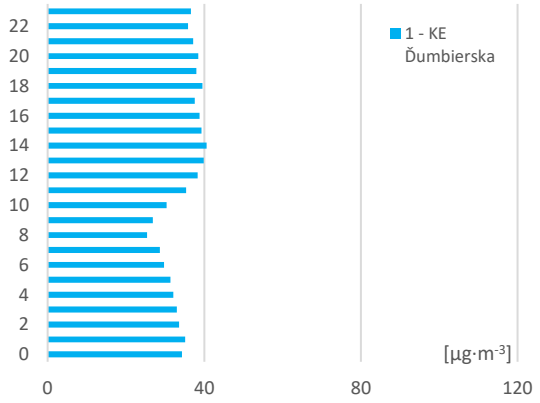
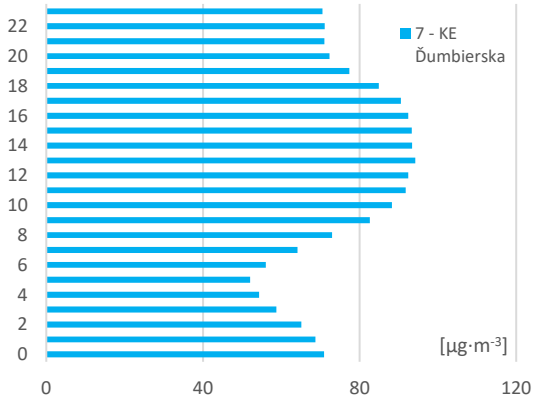


Fig. 3.10 *Daily concentrations of O_3 in July 2022 at AMS Košice, Ďumbierska.*



3.1.4 Benzo(a)pyrene

The pollutant benzo(a)pyrene [B(a)P] is monitored in this zone at the suburban industrial station in Veľká Ida on Letná street (B(a)P measurements in Krompachy, in the zone Košice region, are described in the following Chapter 3.2). The location is influenced by emissions from the nearby metallurgical complex, especially coke production. This is indicated by the relatively constant distribution of monthly concentrations throughout the year, even in the warm months when B(a)P levels significantly decrease at other monitoring stations (**Fig. 3.11**). The average annual concentration of B(a)P in Veľká Ida consistently exceeds the target value (1 ng·m^{-3}) each year, and values exceeded this level in every month in 2022. Concentrations below 1 ng·m^{-3} were only present in 8.4% of measurements, while concentrations exceeding 5 ng·m^{-3} were found in 31% of samples. An extremely high concentration of B(a)P in the air occurred on December 1, 2022, reaching 62 ng·m^{-3}. The histogram of measured B(a)P concentrations shows that values most frequently fall in the range of 1 – 3 ng·m^{-3}, which is a very high level. For comparison, in Bratislava, for example, the largest proportion of concentrations is below 0.5 ng·m^{-3}.

Fig. 3.11 *Average monthly concentration of benzo(a)pyrene in Košice agglomeration and zone Košice region in 2022*

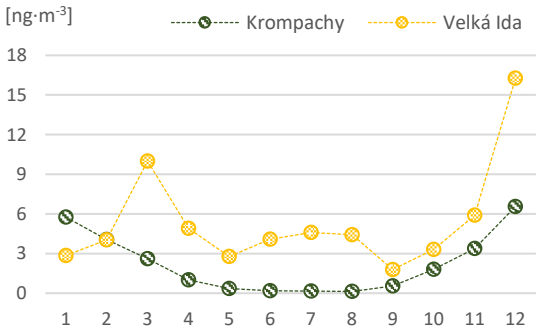
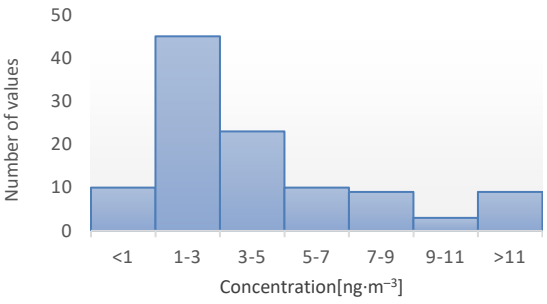


Fig. 3.12 *Histogram of daily concentrations of benzo(a)pyrene in 2022*



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

	2018	2019	2020	2021	2022
Target value [ng·m^{-3}]	1.0	1.0	1.0	1.0	1.0
Veľká Ida, Letná	5.8	4.5	4.6	6.1	5.4

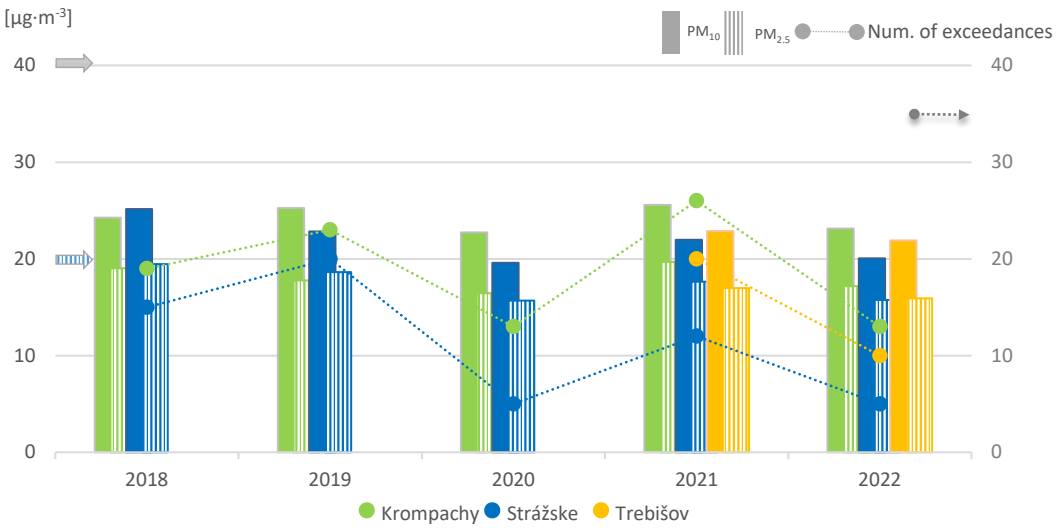
≥ 90% of valid measurements *Exceeding the target value is marked in red.*

3.2 ZONE KOŠICE REGION

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

Fig. 3.13 displays the average annual concentrations of PM_{10}, $PM_{2.5}$, and the number of days with an average daily PM_{10} concentration exceeding 50 $\mu g \cdot m^{-3}$ based on measurement results at monitoring stations in the zone Košice region in the year 2022.

Fig. 3.13 *Average annual concentration of PM_{10}, $PM_{2.5}$ and number of exceedances of 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, **blue striped** $PM_{2.5}$ (annual average concentration: 20 $\mu g \cdot m^{-3}$); **grey solid** PM_{10} (annual average concentration: 40 $\mu g \cdot m^{-3}$); **grey dotted right** number of exceedances (average daily concentration of PM_{10} 50 $\mu g \cdot m^{-3}$ must not be exceeded more than 35 times in a calendar year).*

The limit value for the annual average concentration of PM_{10} (40 $\mu g \cdot m^{-3}$) in the zone Košice region was not exceeded. Similarly, none of the stations exceeded the limit value for the number of exceedances per year (35 times) of the average daily PM_{10} concentration (50 $\mu g \cdot m^{-3}$) (**Fig. 3.13**). The average annual concentration was slightly lower at all stations compared to 2021, with the Krompachy traffic station recording the highest PM_{10} level at 23 $\mu g \cdot m^{-3}$. The number of daily exceedances in Krompachy (13) was half of that in 2021, and likewise, a significant decrease in daily exceedance counts was observed at other stations, returning to the favourable levels seen in 2020. The highest number of daily limit exceedances in 2022 was recorded in January at the Krompachy station (**Fig. 3.14**), and most exceedances occurred in this month at the other stations as well.

Fig. 3.14 *Number of daily exceedances of the daily limit value of PM_{10} for each month in 2022.*

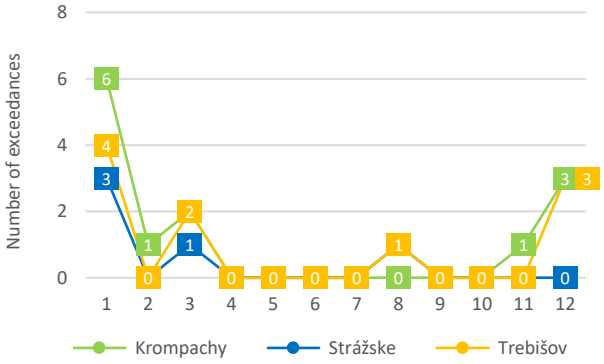
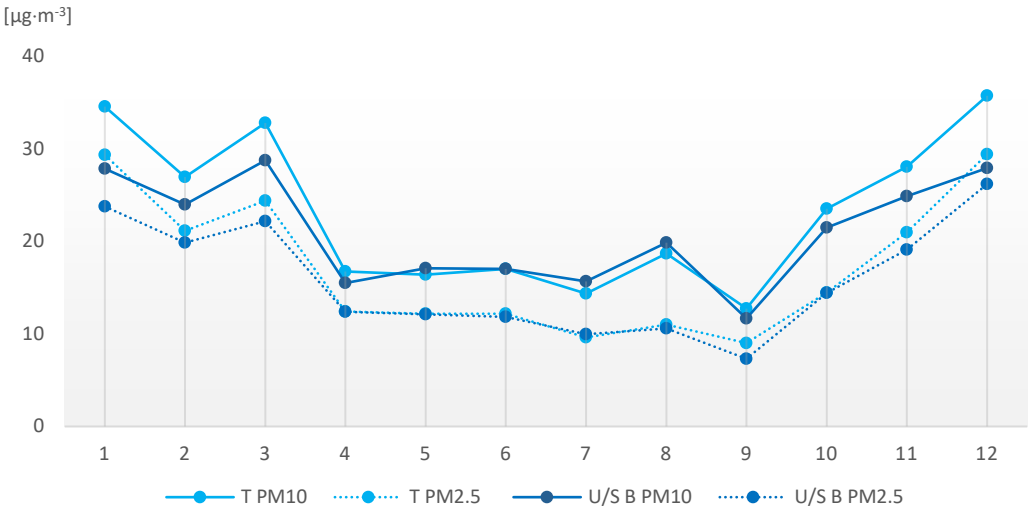


Fig. 3.15 *Average monthly concentrations of PM_{10} and $PM_{2.5}$ in Košice region by station type.*



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

The trend of average monthly concentrations of PM_{10} and $PM_{2.5}$ (**Fig. 3.15**) is characterized by the highest values during the colder months of the year due to household heating with solid fuels and more frequent occurrences of unfavourable dispersion conditions. In 2022, the differences were less pronounced, mainly because of the relatively warm start to the year. It's noteworthy that the traffic monitoring station in Krompachy recorded very similar values to those at the urban or suburban background station in Strážsko and Trebišov. This is likely due to similar source characteristics (less influence from road traffic, more significant household heating).

As previously mentioned, increased $PM_{2.5}$ concentrations pose a health risk. In **Fig. 3.15**, the average annual concentrations of fine particles are represented by the dashed line. The highest average annual concentration was measured in Krompachy (17 µg·m^{-3}), showing an improvement of 3 µg·m^{-3} compared to 2021. High concentrations of $PM_{2.5}$ were observed during the cold months, primarily due to household heating with solid fuels or various types of waste. The average annual $PM_{2.5}$ concentration exceeded the WHO recommended level (5 µg·m^{-3}) at all stations, and this was also the case for average monthly values, not only during the winter but even in the summer months when $PM_{2.5}$ concentrations are typically lower.

3.2.2 Nitrogen dioxide

The monitoring of nitrogen dioxide (NO_2) is carried out at three stations, and the average monthly values for each station are depicted in **Fig. 3.16**.

The primary source of NO_2 emissions is road traffic, which is why the highest concentrations are observed at the traffic station in Krompachy. However, even here, the average annual level (13 µg·m^{-3}) does not exceed the limit value for this pollutant (40 µg·m^{-3}). The measured values maintain a relatively constant level throughout the year, with a slight minimum during the summer months (**Fig. 3.16**). The average annual concentrations at background stations were 11 µg·m^{-3} (Trebišov) and 3 µg·m^{-3} (Kojšovská hoľa) in 2022. On all stations, the average annual concentrations were slightly lower compared to 2021. NO_2 concentrations in the zone Košice region are relatively low, as indicated by the hourly value histogram in Trebišov in **Fig. 3.17**, with the majority of concentrations below 10 µg·m^{-3}. Despite this, the only station that met WHO recommendations (10 µg·m^{-3}) with significantly stricter limits than EU limits is Kojšovská hoľa.

Fig. 3.16 *Daily concentrations of NO_2.*

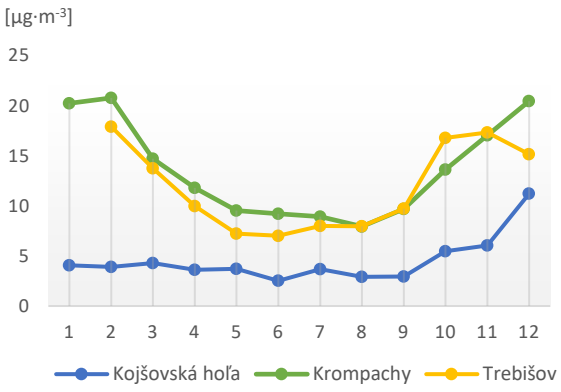
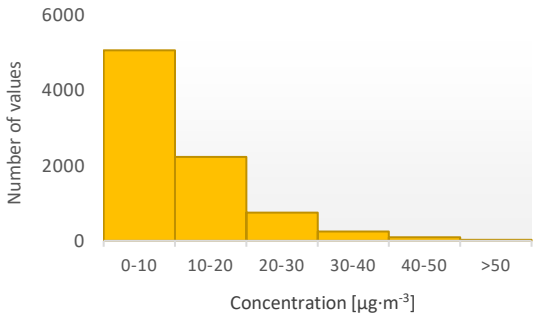


Fig. 3.17 *Histogram of the hourly concentrations of NO_2 at Trebišov.*



3.2.3 Ozone

Ground-level ozone monitoring is conducted at two monitoring stations in the zone - Trebišov and Kojšovská hoľa, which is located at a higher altitude. Therefore, higher concentrations of ground-level ozone are measured at this station (likely due to transport from higher atmospheric layers).

The highest concentrations of O_3 typically occur in warm months with high sunlight intensity (**Fig. 3.18**). **Fig. 3.19** and **Fig. 3.20** depict the so-called diurnal variation of O_3 concentrations - an increase with the rising sun, reaching a peak around noon, and a gradual decrease in the evening until reaching a minimum in the early morning. Significant differences in ground-level ozone concentrations are also observed between warm and cold periods. Higher values measured at Kojšovská hoľa are likely caused by the transport from higher atmospheric layers.

Fig. 3.18 *Average monthly concentrations O_3.*

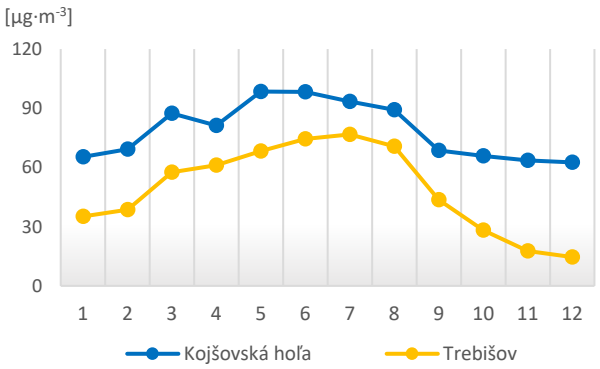


Fig. 3.19 *Daily O_3 concentrations in January 2022.*

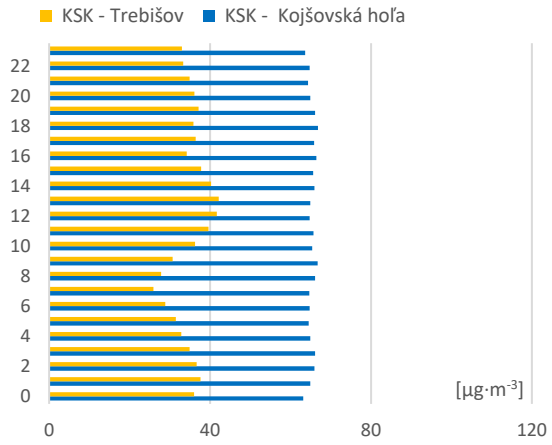
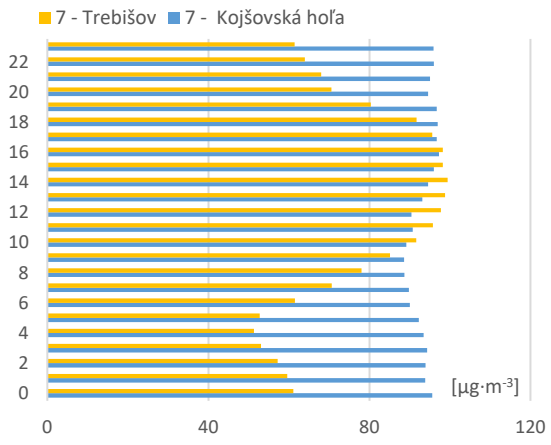


Fig. 3.20 *Daily O_3 concentrations in July 2022.*



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 consistently exceeded every year. However, the concentrations do not reach the levels measured in Veľká Ida.

Unlike Veľká Ida (**Fig. 3.11**), benzo(a)pyrene concentrations recorded throughout the year in Krompachy exhibit a distinctive peak during the winter months. This indicates the dominant influence of household heating in Krompachy, coupled with poorer dispersion conditions. When comparing it to the pattern of PM concentrations (**Fig. 3.15**), it can be assumed that seasonal sources have an even greater impact on high benzo(a)pyrene concentrations than on PM.

Tab. 3.3 *Evaluation of benzo(a)pyrene air pollution.*

	2018	2019	2020	2021	2022
Target value [ng·m^{-3}]	1.0	1.0	1.0	1.0	1.0
Krompachy, SNP		2.7	2.1	2.2	2.2

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

4 AIR QUALITY MODELLING

Fig. 4.1 displays the results of PM_{10} modelling calculated using the RIO model in combination with IDW-R (a more detailed description of the method is provided in Chapter 4 of *Air pollution in the Slovak Republic 2022 Report*).

Based on the results of mathematical modelling with the interpolation model RIO and IDW-R, we can assume that the highest concentrations of PM_{10} are found in the southern part of the Košice agglomeration (in the municipalities of Veľká Ida, Sokoľany, Haniska, Bočiar) and are influenced by emissions from the metallurgical complex.

In the zone Košice region, the highest PM_{10} values are likely to occur mainly in Above and in the districts of Rožňava, Spišská Nová Ves, and Geľnica (Fig. 4.1, Fig. 4.2).

Fig. 4.1 *Average annual concentration of PM_{10} in 2022.*

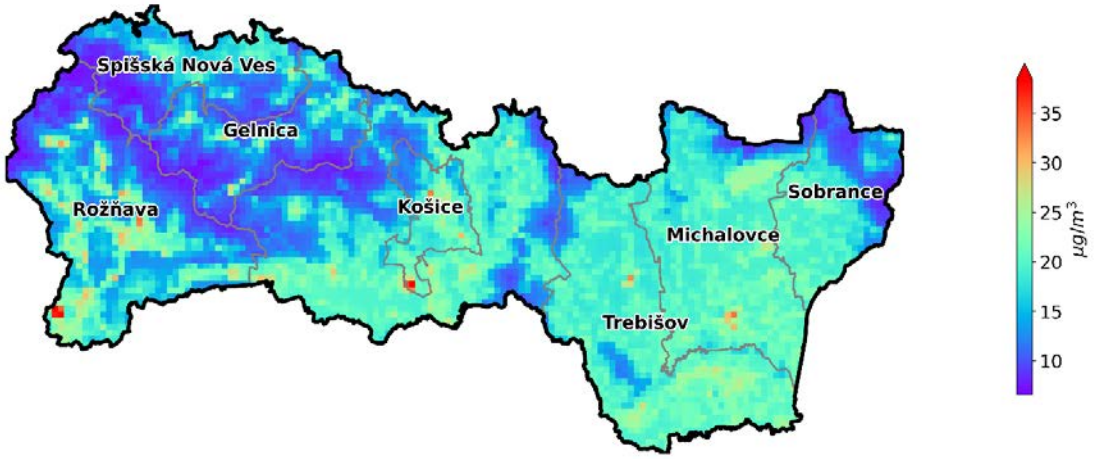
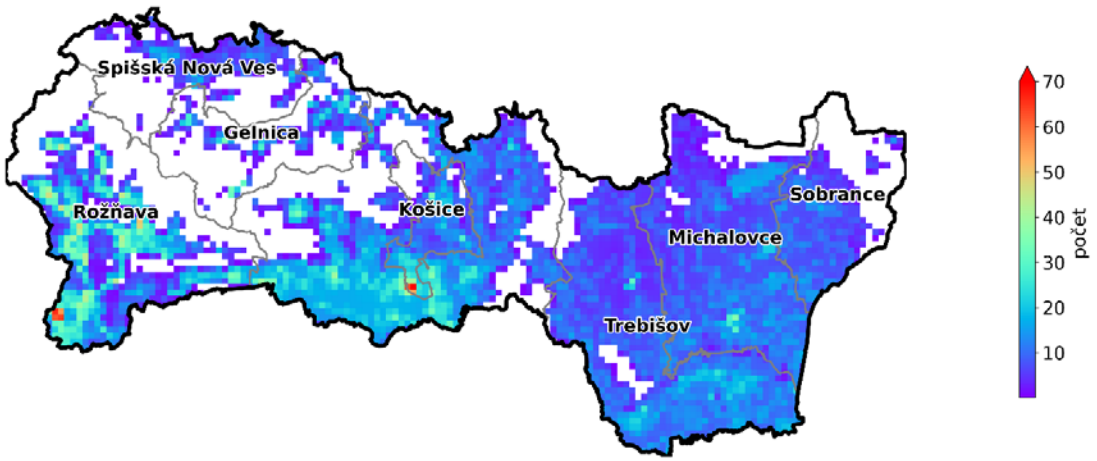


Fig. 4.2 *Number of exceedances of the PM_{10} daily limit value in 2022. Only areas for which the number of exceedances was non-zero are shown.*



The map in Fig. 4.3 displays the spatial distribution of average annual $PM_{2.5}$ concentrations based on the output from the RIO model in combination with the IDW-R model. According to the model outputs, the average annual $PM_{2.5}$ concentration across the entire zone was higher than the limit value recommended by the WHO. (WHO limit values are stricter than EU limits).

The spatial distribution of average annual $PM_{2.5}$ concentrations according to the RIO model, IDW-R, exhibits a similar pattern to that of PM_{10}. Maximum values are likely to be found not only in the Košice agglomeration but also in Abovo, in the Rožňava district, and in Spišská Nová Ves.

Fig. 4.3 *Average annual $PM_{2.5}$ concentration in 2022 according to the output of the RIO model, IDW-R.*

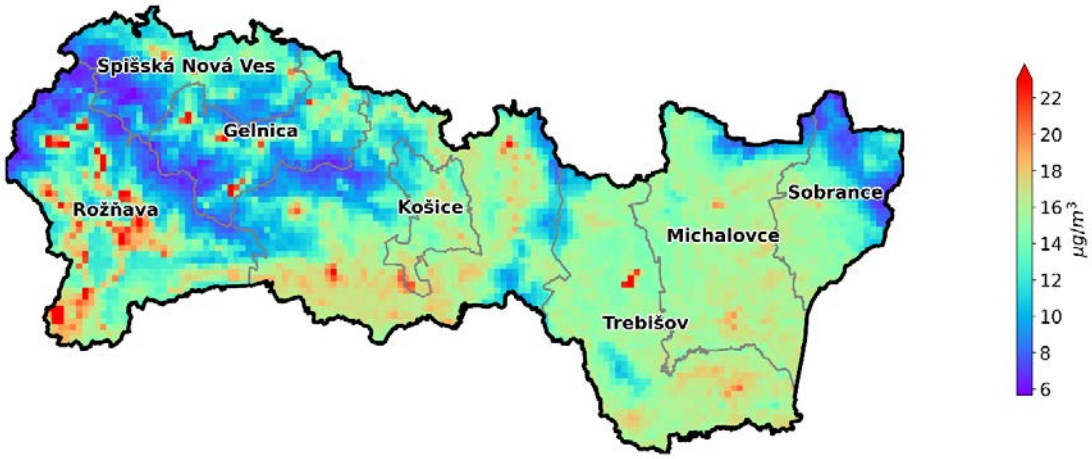
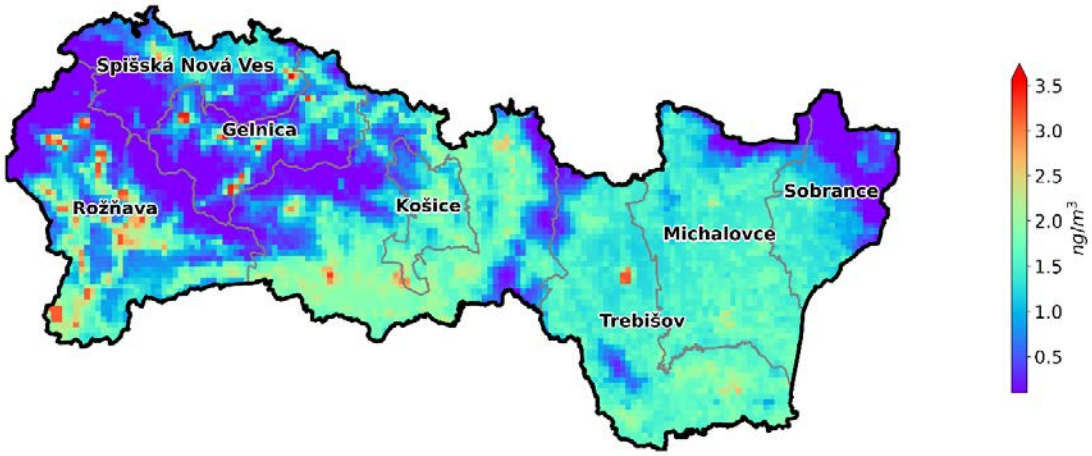


Fig. 4.4 displays the spatial distribution of average annual benzo(a)pyrene concentrations based on the output from the RIO model, IDW-R. Since the model relies on measured data (and auxiliary fields), the outputs over the extensive territory of the Košice region are subject to considerable uncertainty.

The model may tend to overestimate benzo(a)pyrene concentrations, particularly in the vicinity of Košice and the Eastern Slovak Lowland. This is primarily influenced by the high average annual concentration measured in Veľká Ida, which is one of the two stations in the zone Košice region where benzo(a)pyrene is monitored.

To gain a more detailed understanding of the spatial distribution, modelling with high resolution using detailed emission data (such as information on the quantity and type of fuels, the type of household heating equipment used, etc.) is necessary. The most significant source of benzo(a)pyrene in the Košice agglomeration is coke production, while household heating is a smaller contributor. The situation is reversed in the zone Košice region, where household heating with solid fuels, especially inadequately dried wood or inappropriate fuels (various types of waste), is the most significant source.

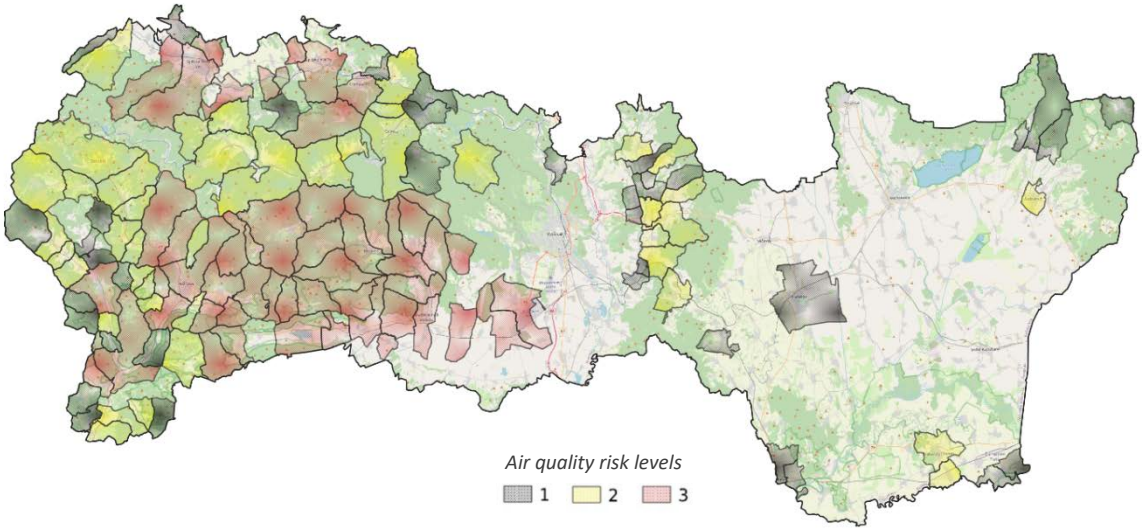
Fig. 4.4 *Average annual concentration of benzo(a)pyrene in 2022 according to the output of the RIO model, IDW-R.*



4.1 Risk municipalities

Fig. 4.5 displays the municipalities at risk of deteriorated air quality as determined by the integrated municipal assessment method for municipalities. Level 3 corresponds to the highest likelihood of air pollution risk. This methodology considers the extent of household heating with solid fuels, the impact of poor dispersion conditions in both the short and long term, results from the chemical transport model CMAQ, the interpolation model RIO, and the outcomes of high-resolution modelling using the CALPUFF model in selected domains with an assumption of worsened air quality.

Fig. 4.5 *Risk municipalities in zone Košice region and agglomeration Košice.*



The municipalities in which the limit value for PM, NO_2, or the target value for BaP was exceeded according to high-resolution modelling were automatically assigned risk level 3, similar to municipalities where the limit or target value exceedance was detected by measurements. The list of municipalities and their risk levels can be found on the SHMÚ website[5].

Zones and agglomerations that contain at least one municipality with risk level 3 will develop an Air Quality Improvement Program. In this regard, municipalities with risk level 3 correspond to air quality management areas. However, emission reduction measures must be implemented in such designated zones in all municipalities with risk levels 2 or 3, ideally also in municipalities with risk level 1.

The assessment using the integrated assessment method aims to identify areas where measures to improve air quality are necessary. Given the distribution of air pollution sources and considering the microclimatic characteristics of the region, the level of pollution is likely to vary at different locations within the risk area. The results of high-resolution modelling, which provide insights into the spatial distribution of air pollution, are gradually being supplemented on the website[6].

[5] *https://www.shmu.sk/sk/?page=2768*
[6] *https://www.shmu.sk/sk/?page=2699*

5 SUMMARY

In 2022, the Košice agglomeration (comprising the city of Košice and the municipalities of Veľká Ida, Haniska, Bočiar, and Sokoľany) experienced exceedances of the limit value for the daily average concentration of PM_{10}, the annual average concentration of $PM_{2.5}$, and the target value for benzo(a)pyrene (all at the Veľká Ida, Letná monitoring station). However, there were no exceedances of the limit values for SO_2, NO_2, CO, and benzene.

The Košice agglomeration has been a long-term problematic area concerning air quality. Emissions of benzo(a)pyrene from coke production are a significant issue, with household heating using solid fuels contributing to a lesser extent.

In the zone Košice region, there were no exceedances of the limit values for SO_2, NO_2, CO, and benzene in 2022, nor were there exceedances of the limit values for the annual average concentrations of PM_{10} and $PM_{2.5}$. The number of days with daily average concentrations of PM_{10} above 50 $\mu g \cdot m^{-3}$ was below the permitted limit.

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

Based on the results of mathematical modelling, it can be assumed that in some areas (as shown in **Fig. 4.1** to **Fig. 4.4**) higher PM and benzo(a)pyrene levels may occur, especially during winter months in locations with a higher proportion of solid fuels used for household heating, particularly under adverse dispersion conditions.