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AIR POLLUTION IN THE SLOVAK REPUBLIC

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SLOVAK HYDROMETEOROLOGICAL INSTITUTE

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Analyses of air and atmospheric precipitation samples were carried out in the Testing laboratory of SHMÚ.

CONTENT

FOREWORD

The problem of air quality is a part of complicated system of relations in environment of the earth. Substances released from air pollution sources undergo to atmospheric dispersion, horizontal and vertical transport and chemical changes. Part of them settles at the earth surface and penetrate into the surface and underground waters, soil and sediments, from where they can release back into ambient air. In any part of circulation, the substances can enter into the chemical reactions. Air reacts the quickest to different changes – if air pollution source becomes extinct, the air becomes usually quickly clean, in contrary, and the pollutants persist longest in soil and sediments. It is obvious, that the problem of environment is not possible to delimit by political borders. The international association accepted transboundary character of air pollution already before the decades, resulting in signing of several international conventions.

To answer the often-accentuated question about air quality in our country, if the quality is improving or worsening, may be said, that comparing to the status of half century ago, the situation is mostly improved. Until in the 1970s of the twenty century, i.e., the average annual concentrations of sulphur dioxide in Slovakia reached the level 80 – 150 $\mu g \cdot m^{-3}$, for the time being it is approximately 10-times less. Acidity of atmospheric precipitation decreased, as well as the concentrations of oxides of nitrogen. Concentrations of heavy metals are several times lower. Emissions of solid pollutants decreased significantly. Air quality improvement may be credited to the strict legislative measures, adopted at the end of last century, aimed at the large air pollution sources. Implementation of leadless fuel in road transport reflected in reaching such a level of lead in air, which is several times lower than the target value.

Advancement occurred also in measurement – until at the beginnings, the total weight mass of dust concentrations in air were monitored, later, approximately two decades, the attention is aiming on finer (suspended) particles, which have more serious consequences on health. Monitoring programme was later enhanced about benzo(a)pyrene, carcinogenic substance, which origins from imperfect combustion.

Contrary to the decrease of basic air pollutants, as compared to the historical measurements, the situation is not satisfactory at present. Air reacts quickly on changes of emitted amount of pollutants and therefore the influence of large air pollution sources manifests episodically on elevated concentrations of pollutants in vicinity of these sources at present. As a reason may be considered meteorological conditions, source problem, or combination of both these factors. Emissions from large sources are mostly relatively effectively dispersed, thanks to the fact, they are discharged from higher stacks and thermal ascend increases the effective height of the place of discharge. By this, the large and medium sources of air pollution still contribute to the higher level of background concentrations and their influence manifests via long-range transport on the distant localities. In case, the stack is under the inversion, fume track may get to the vicinity of surface. In such situations, the episodically worsening of air quality manifests also in vicinity of source. Metallurgical complex on east of Slovakia is the only large source, which contributes within annually to the higher concentrations of pollutants also in its vicinity.

Crux of the air pollution problem in Slovakia in last period shifts to the heating of households and road transport. Using solid fuels, the heating of households is source of dust particles and benzo(a)pyrene. Outstanding problem represents mainly in places with good accessibility of fuel wood and unfavourable dispersion conditions, which manifest also by often occurrence of temperature inversions.

Road transport is significant source of nitrogen dioxide and dust particles, in smaller range also benzo(a)pyrene. High concentrations of these pollutants may be expected in vicinity of road communications, with high traffic intensity, in vicinity of frequent crossroads and parking places. In winter season, the cold starts cause outstanding higher emissions of petrol and diesel vehicles. To the higher dustiness in vicinity of roads participates dust resuspension from insufficient cleaning of roads.

In places, where the accessible results of measurements are not available, the information are supplemented by the mathematical modelling, which may help to look for the answer on the question of pollution origin in problematic locations and share of different sources on the measured concentrations. The results of mathematical modelling may help also to identify the problematic localities, on which is necessary to aim the attention.

Ministry of environment of the Slovak Republic upon the Act No. 137/2010 Coll. of Acts on air in wording of later prescriptions, with aim to secure information on air quality to the public, authorized the Slovak Hydrometeorological Institute by elaboration of:

- Report on air quality assessment in the Slovak Republic;
- Information on air quality.

Slovak Hydrometeorological Institute as authorized organization fulfils by this Report commitments resulting from §13 section (1) letters c) and d) cited Act and submits to the laic and expert public the Report, containing all belongings in such a way as requested in the Act No. 137/2010 Coll. of Acts on air in wording of later prescriptions.

1 DESCRIPTION OF THE TERRITORY OF SLOVAKIA IN TERM OF AIR QUALITY

Pollutants of various physical and chemical properties are released into the atmosphere from natural sources or as a consequence of human activity. Air quality does not depend only on amount of emissions and spatial distribution of air pollution sources, but also on meteorological characteristics and properties of surrounding terrain.

Among the processes which influence air pollutants are included change of consistency (e.g. condensation of hot combustion products leaking from stacks at cooling), chemical reactions (e.g. oxidation of NO to NO_2 from road transport), transport in horizontal and vertical direction (advection, convection), dry, wet and hidden deposition. Dry deposition performs interception of pollutants on the earth surface, or on vegetation. Wet deposition means washing out by atmospheric precipitation, which by this way very effectively diminish air pollutant concentrations and enable their transport into the other components of environment – water, soil and sediments. Hidden deposition means interception of fog drops (eventually clouds) on various surfaces, mainly on plant surfaces. This kind of deposition plays more significant role in forest vegetation of mountainous locations.

Segmentation of terrain influences the air circulation velocity and direction and is one of the characteristics, determining the conditions for dispersion of pollutants, which are unfavourable at the territory of Slovakia, mainly in closed mountain basins. Frequent occurrence of inversions in these regions is the factor complicating pollutant dispersion and is one of the reasons of high pollutant concentration occurrence in winter season. Potential long-range transport of pollutants depends upon the weather conditions. Some of these pollutants can persist in air also several days. In the following text is introduced the short characteristics of the territory of SR from the aspects of terrain segmentation and meteorological elements, which mostly influence the air quality.

Wind conditions

Direction of air circulation is mostly influenced by the general air circulation in central Europe and country relief. In Slovakia prevails west and northwest air circulation (being modified in some locations, mainly in passes, valleys and basins as a consequence of relief). In Záhorie southeast wind prevails over the northwest, in Danube lowlands opposite. West convection dominates in middle Považie, Ponitrie and east Slovakia.

In the lowlands of west Slovakia, the annual average wind speed in height of 10 meters above the surface varies between 3 – 4 $m \cdot s^{-1}$, on the east of Slovakia 2 – 3 $m \cdot s^{-1}$.

In basins, the dustiness depends upon their location and openness towards the prevailing convection. Annual average wind velocity is in more open basins (e.g. Považie valley, Podtatranská basin, Košice basin) 2 – 3 $m \cdot s^{-1}$. In more closed basins, where is the major occurrence of inversions (e.g. Zvolen basin, Žiar basin, Žilina basin) 1 – 2 $m \cdot s^{-1}$ and in closed basins (e.g. Brezno basin, Rožňava basin, west part of Liptov basin in Ružomberok region) is more often occurrence of calm and average wind speeds are even often lower.

In mountains, the annual average wind velocity reaches 4 – 8 $m \cdot s^{-1}$. In lower positions are also localities (Košice, Bratislava) with annual average wind velocity higher than 4 $m \cdot s^{-1}$, while Bratislava belongs to the windiest cities in central Europe.

Well-ventilated regions can be distinguished by lower pollutant concentrations, despite of close presence of air pollution sources

- **Atmospheric precipitation**

The amount of precipitation in Slovakia generally increases with elevation above sea level, approximately 50 – 60 mm on 100 m of height. Their annual sum varied from 500 mm (east part of Žitný ostrov, region Galanta and Senec) to 2 000 mm (the High Tatras).

Relatively low precipitation totals are in the so-called rain shadow of mountains. It does concern e.g. Spiš basins, which are relatively dry and protected from southwest up to northwest by the Low Tatras and from south by Slovak Rudohorie.

The major amount of precipitation occurs in June, July and August (40% – most rainy is June or July), in spring 25%, in autumn 20% and in winter 15% (the least amount of precipitation is in January, February and March).

Large precipitation variability within the year causes mainly in lowlands often and sometimes long-lasting periods of drought, forming conditions for elevated erosion of soil, not covered by vegetation. The Danube lowland belongs to the driest one and is the warmest and relatively windiest area of Slovakia.

1.1 ALLOCATION OF THE TERRITORY INTO AGGLOMERATIONS AND ZONES IN 2020

Pollution sources are evenly distributed in the country. Due to the effective air quality assessment in coincidence with European parliament direction and Council 2008/50/EC about ambient air quality and cleaner air in Europe, as well as legal prescriptions of the Slovak Republic (e.g. Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording of later prescriptions), the territory of the Slovak Republic is allocated into zones and agglomerations.

The list of agglomerations and zones is published in Appendix No. 11 to Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording of later prescriptions and is published on the SHMÚ webpage.

Regulation of MoE SR No. 32/2020 Coll. of Acts, by which changes and amends Regulation No. 244/2016 Coll. of Acts on air quality in wording of Regulation No. 296/2017 Coll. of Acts, came into force 1st March 2020.

1.1.1 Allocation of the territory into zones and agglomerations in 2020, for SO_2, NO_2, NO_X, PM_{10}, $PM_{2.5}$, benzene, polycyclic aromatic hydrocarbons and CO

Agglomerations: Bratislava (territory of the capital of the Slovak Republic, Bratislava), Košice (territory of the Košice city and municipalities Bočiar, Haniska, Sokoľany and Veľká Ida.)
Note: Last amendment of Regulation on air quality (No. 32/2020) modified the list of agglomerations and zones as compared to year 2019. The content of change was assign of municipalities Bočiar, Haniska, Sokoľany and Veľká Ida to the agglomeration Košice. At the same time the polycyclic aromatic hydrocarbons were added to the list of pollutant substances for both agglomerations.

Zones: Banská Bystrica region, Bratislava region (without Bratislava agglomeration), Košice region (without Košice agglomeration), Nitra region, Prešov region, Trenčín region, Trnava region and Žilina region.
Note: Last amendment of Regulation on air quality (No. 32/2020), the polycyclic aromatic hydrocarbons were added to the list of pollutant substances for both zones.

Chapter 1.1.1 involves the short characteristics of zones and agglomerations in light of orography and air pollution sources.

- **AGGLOMERATION BRATISLAVA** (territory of the capital of the Slovak Republic, Bratislava)

Bratislava is located in segmented terrain of altitude from 126 m (Čuňovo) to 514 m (Devínska Kobyla). From southwest to northeast is extented the mountain of the Small Carpathians, west part of Bratislava is in Záhorie lowland and east and southeast part is occupied by the Danube lowland.

In domain of Devin gate, which separates the Hainburg hills and the Devin Carpathians and in domain of Lamač gate between the Devin Carpathians and Pezinok Carpathians commute to the orographic wind speed increasing, favourably affecting the city ventilation. The Danube river flows through Bratislava and is used for ship transport.

Air pollution sources in Bratislava agglomeration

Dominant source of air pollution in capital city is road transport. The most vehicles in Bratislava overpass through by-pass city highway D1 from port bridge in direction on Žilina (in the most frequent section daily number of vehicles represents 93 344, from it 12 762 long distance lorries and 80 058 passenger vehicles), through by-pass city highway D2 behind the Lafranconi bridge in direction to Austria and Hungary (82 646 vehicles, 11 913 long distance lorries and 70 519 passenger vehicles), by road No. 2 (59 121 vehicles, 3 273 long distance lorries and 55 545 passenger vehicles) running parallel alongside highway R1 in Petržalka, by road No. 61 (Trnavská road – 48 720 vehicles, 3 420 long distance lorries and 45 141 passenger vehicles) and by road of 2nd class No. 572 in direction to Most at Bratislava (35 051 vehicles, 2 915 long distance lorries and 31 984 passenger vehicles [1]).

For household heating in Bratislava is used (upon the data of inhabitant counting) predominantly natural gas, share of solid fuels is the lowest as compared to the other zones (probably it deals about additional heating in intermediate annual seasons using hearths).

Industrial air pollution sources are less significant from point of contribution to the local air pollution by basic pollutants.

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

Košice city is located in the valley of Hornád river, in Košice basin and according to the orographic classification, it belongs to the belt of inner Carpathians. Slovenský kras interferes into this region from the south-west, Slovenské Rudohorie is situated in the north from city and Slánske vrchy in the east of city. Wind conditions in Košice are characteristic by the prevailing wind from the north directions; the region is relatively well ventilated.

Air pollution sources in Košice agglomeration

In Košice agglomeration, city part Košice-Šaca, is situated industrial complex, aimed at iron metallurgy, steel and coke production, which is dominant industrial source of air pollution. Among other industrial sources belong also cement factories.

Air quality in municipalities Veľká Ida, Haniska, Sokoľany and Bočiar and in smaller range in Košice is influenced by the sources of pollution from close industrial complex. Relatively favourable circumstance is prevailing convection from north directions.

Apart from the above mentioned, the source of air pollution in Košice is road transport with the major intensity on by-pass of city centre – section of road PR3 (southeast by-pass) with daily average maximum of 50 895 vehicles (6 905 passenger vehicles and 43 827 long distance lorries), high speed road R2 (south by-pass) with 32 061 vehicles (4 166 long distance lorries and 27 751 passenger vehicles), road No. 547 (north by-pass) with 28 756 vehicles (2 004 long distance lorries and 26 631

[1] *https://www.ssc.sk/files/documents/dopravne-inzinierstvo/csd_2015/ba/scitanie_tabulka_ba_2015.pdf ; State wide census of traffic, which was realized in SR each 5 years, was postponed in year 2020 due to ongoing, resp. new measures, which are accepted in connection with prevention of spreading affection COVID -19 and therefore the data from year 2015 are used.*

passenger vehicles) and section of road PR3 (east by-pass) with 36 261l vehicles (6 056 long distance lorries and 30 103 passenger vehicles[2].

Household heating is partly provided by the city heating plants; in case of individual heating, the predominant fuel is natural gas.

- **ZONE BRATISLAVA REGION** (apart from Bratislava agglomeration)

Bratislava region is by the territory of Slovakia the smallest one among regions of Slovakia. It includes the south part of the Small Carpathians, Záhorie lowland and bigger part of Danube lowland. Surface of zone is predominantly plain. The height above sea level of the territory varies in range from 126 m to 754 m (hill Vysoká). The most densely populated cities are regional cities Pezinok, Senec and Malacky. Average density of settlement in district Malacky is significantly lower as compared to the other districts of Bratislava region.

Air pollution sources in zone Bratislava region

For household heating in this zone is used (upon the data of inhabitant counting) predominantly natural gas, share of solid fuels is the lowest as compared to the other zones.

More significant source of emissions into ambient air is road transport, concentrating in major scale on highway drafts. The results of national counting of road transport in 2015 demonstrate, that highway D1 leading to Senec reaches the daily intensity in average 62 652 vehicles (10 385 long distance lorries and 52 260 passenger vehicles), however highway D2 leading from Bratislava to Malacky and Brno in section at Stupava 32 968 vehicles (9 787 long distance lorries and 23 132 passenger vehicles) [3].

Industrial sources of air pollution apart from cement factories (their contribution can be manifested mainly in coarse size fraction of particulate matter) are less significant from point of contribution to local air pollution by basic air pollutants.

- **ZONE TRNAVA REGION**

Trnava region is predominantly of lowlands and uplands character. Two significant lowlands, the Danube lowlands and the Záhorie lowlands separate the Small Carpathians, which have outstanding influence on air convection. In northwest part, the territory of region is interfered by spur of Považský Inovec. The highest point of region are Záruby reaching 768 m a.s.l., however its predominant part lies in heights below 200 m a.s.l. Larger closed basins do not exist in Trnava region

Air pollution sources in zone Trnava region

For household heating in this zone is used (upon the data of inhabitant census) predominantly natural gas, share of solid fuels is the lowest as compared to the other zones, consumption of fuel wood in more mountainous area of the Small Carpathians is slightly higher.

Road transport in Trnava region participates mostly in air pollution on the following communications: on the section of highway D1 in front of Trnava from Bratislava (daily average overpass 54 519 vehicles, 7 615 long distance lorries and 46 881 passenger vehicles) and on high speed road R1 Trnava-Sereď (39 058 vehicles as daily average, 7 449 long distance lorries and 31 599 passenger vehicles). Apart from highways and high-speed roads, the major intensity of road transport in this region is on the by-pass of Trnava (road No. 61) with 25 111 vehicles as daily average (2 806 long distance lorries and 22 242 passenger vehicles), on the section of road No. 51 connecting Trnava and Senica with 16 915 vehicles (2 586 long distance lorries and 14 270 passenger vehicles), on the road No. 426 Holíč - Skalica with 14 422 vehicles (1 712 long distance lorries and 12 686 passenger vehicles), on the road No. 499 from Piešťany to Vrbové with 14 590 vehicles (1 665 long distance lorries and 12 855 passenger vehicles), on the section of road No. 63 behind Šamorín (direction Dunajská Streda - Veľký

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

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

Meder) with 12 914 vehicles (1 991 long distance lorries and 10 849 passenger vehicles) and on road No. 513 leading from Hlohovec to west with 12 507 vehicles daily (2 450 long distance lorries and 10 004 passenger vehicles).[4]

Industrial sources of air pollution are from point of contribution to local air pollution by basic pollutants less significant.

ZONE NITRA REGION

Nitra region is extended from larger part on the Danube lowlands, partly interfered by mountains Považský Inovec, Tríbeč, Pohronský Inovec and Štiavnické vrchy. The highest point is Panská Javorina (943 m a.s.l.). The lowest altitude in Nitra region reaches about 100 m a.s.l. Area of region is from bigger part well ventilated.

Air pollution sources in zone Nitra region

Dominant air pollution source in Nitra region is road transport. For household heating is used mainly natural gas. Share of solid fuels is smaller as compared to the other zones, apart from more mountainous area in the north of region (upon the data of inhabitant census)

Characteristics of road transport: the most frequent is high speed road R1 on sector in front of Nitra from Trnava with daily average number 28 785 vehicles (5 582 long distance lorries and 23 154 passenger vehicles), section of road No. 64 in Nitra, (23 436 vehicles, 3 503 long distance lorries and 19 798 passenger vehicles), sector of road No. 63 connected Veľký Meder and Komárno (21 847 vehicles, including 2 171 long distance lorries and 19 573 passenger vehicles), sector of road No. 75 from Šaľa to Nové Zámky (20 019 vehicles, 2 848 long distance lorries and 17 045 passenger vehicles), road No. 51 passing Levice (17 367 vehicles, 2 162 long distance lorries and 15 146 passenger vehicles) and high speed road R1 at Zlaté Moravce 17 998 vehicles (from which 4 119 long distance lorries and 13 802 passenger vehicles)[5].

Industrial air pollution sources are less significant from aspect of contribution to the local air pollution by basic pollutants. Depending on meteorological conditions, the influence of chemical industry can manifest in Nitra region.

ZONE TRENČÍN REGION

Relief of Trenčín region is mostly mountainous apart from the basin Horná Nitra. It includes Myjava uplands and White Carpathians, partly Považský Inovec, Javorníky, Vtáčnik and Strážovské vrchy. The highest point is Vtáčnik of altitude 1346 m a.s.l., the lowest point is 165 m a.s.l. Zone is from prevailing part well ventilated, minor wind speeds occur in valley of the Váh river.

Air pollution sources in zone Trenčín region

Household heating in more mountainous part of region is more significant source of pollution than in Trnava region or Bratislava region. In bigger cities, mainly natural gas is used, in mountainous north part of region fuel wood.

Characteristics of road transport: from aspect of road transport density in this region dominates road No. 61 in district Trenčín, 32 705 vehicles (3 349 long distance lorries and 29 128 passenger vehicles), highway D1 with density from 21 000 to 28 000 vehicles (in district Trenčín, on the most frequent section 5 666 long distance lorries and 22 392 passenger vehicles), road No. 64 in district Prievidza 18 014 vehicles (2 457 long distance lorries and 15 452 passenger vehicles), road No. 54 in district Nové Mesto nad Váhom 17 261 vehicles (2 293 long distance lorries and 14 861 passenger vehicles), road No. 507 in district Trenčín 18 979 vehicles (2 193 long distance lorries and 16 743 passenger

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

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

vehicles), road No. 517 in district Považská Bystrica 18 026 vehicles (2 440 long distance lorries and 15 453 passenger vehicles) and road No. 1774 in district Prievidza 18 329 vehicles (1 245 long distance lorries and 16 998 passenger vehicles)[6].

Industrial air pollution sources apart from cement factories are less significant from aspect of contribution to local pollution by basic pollutants. Influence of heat power plant is demonstrating more significantly, however depending on meteorological conditions it contributes more to regional background.

ZONE ŽILINA REGION

The territory of Žilina region is mostly mountainous, belonging to West Carpathians. The river Váh separates the area of region on north and south part. In north part are located mountains the High Tatras, West Tatras and Belianske Tatras, Skorušinské vrchy-mountains, Oravské Beskydy, Oravská Magura, Oravská vrchovina-uplands, Chočské vrchy-mountains, Kriváňska Fatra, Kysucké Beskydy, Kysucká vrchovina-uplands and Javorníky, in south part the Low Tatras, Veľká Fatra, Lúčanská Fatra and Strážovské vrchy-mountains. The highest point is Kriváň, in altitude 2 494 m a.s.l., the lowest point is 285 m a.s.l. The area is also characterised by the deep and closed basins, which unfavourably influence on ventilation and therefore on the pollutant dispersion in ambient air, as well.

Air pollution sources in zone Žilina region

In mountainous part of region, the significant source of air pollution is household heating by solid fuel. In the districts Žilina, Martin and Bytča the air pollution is influenced most intensively by road transport. In Žilina, the road No. 11 reaches daily average number 37 927 vehicles (6 867 long distance lorries and 30 972 passenger vehicles), road No. 18 in average daily 32 334 vehicles (3 736 long distance lorries and 28 523 passenger vehicles), 30 659 vehicles is daily on road No. 18A (6 080 long distance lorries and 24 513 passenger vehicles) and 23 579 vehicles on highway D3 (5 661 long distance lorries and 17 819 passenger vehicles). In district Martin traffic on road No. 65 in daily average is 22 973 vehicles (2 767 long distance lorries and 20 153 passenger vehicles) and on road No. 65 daily 23 002 vehicles (2932 long distance lorries and 19 982 passenger vehicles). In district Bytča via highway D1 drive daily in average 23 956 vehicles (5 141 long distance lorries and 18 725 passenger vehicles)[7].

Industrial air pollution sources, such as paper mills, cement factories, lime or ferroalloy production are less significant in this region from aspect of contribution to local air pollution by basic pollutants.

ZONE BANSKÁ BYSTRICA REGION

The territory of Banská Bystrica region is prevailingly mountainous, while mountain basins on this area are characterized in dependence on orography by low wind velocity and frequent temperature inversions, mainly in winter season. At the north of this region are situated higher mountains the Low Tatras and spurs of Veľká Fatra. Relatively large part is occupied by the medium high mountains – Slovenské Rudohorie, Štiavnické vrchy and Krupinská planina (plain) in central part of region. South of the region is characterized by lower altitudes – there is found Juhoslovenská kotlina (basin) and Cerová vrchovina (uplands). The highest point of the region is Ďumbier, in elevation of 2 046 m a.s.l., the lowest point lies in 124 m a.s.l.

Air pollution sources in zone Banská Bystrica region

Dominant source of air pollution in Banská Bystrica region is household heating, mainly in north part of region, where the share of fuel wood is the highest in comparison to the other regions. Locally also road transport is important. The highest intensity reaches in Banská Bystrica region – on highway R1 (daily pass in average is 40 011 vehicles, 4 644 long distance lories and 35 174 passenger vehicles) and on road No. 66 (34 559 vehicles, 2 740 long distance lorries a 31 719 passenger vehicles). Significant

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

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

from the aspect of carrying capacity of communications is road No. 50 in district Zvolen, Detva and Žiar nad Hronom – with level 29 988 vehicles (19% long distance lorries), 16 707 vehicles (23% long distance lorries) and 14 357 vehicles, (11% long distance lorries) – and road No. 66 in districts Zvolen (14 715 vehicles, 2 534 long distance lorries and 12 135 passenger vehicles) and Brezno (12 289 vehicles, 1 659 long distance lorries and 10 559 passenger vehicles). In district Lučenec are important roads No. 585, No. 50 and No. 75, most loaded traffic is on road No. 585 (13 815 vehicles, 1 387 long distance lorries and 12 370 passenger vehicles)[8].

Industrial sources of air pollution, such as metallurgy of non-ferrous metals are less significant from aspect of contribution to local air pollution by basic pollutants. In dependence on meteorological conditions, the influence of heating plants can manifest in this region.

■ ZONE PREŠOV REGION

Prešov region is characterized prevailingly by mountainous relief, the highest point is Gerlachovský štít – height 2 655 m a.s.l., the lowest point is in altitude of 109 m a.s.l. Its territory is occupied predominantly by outer Carpathians (Spišská Magura, Podtatranská brázda, Spišsko-šarišské medzihorie, Levočské vrchy, Bachureň, Šarišská vrchovina, Pieniny, Ľubovnianska vrchovina, Čergov, Busov, Ondavská and Laborecká vrchovina, Beskydské predhorie and Bukovské vrchy). The High Tatras, our most significant mountains, do belong to the inner Carpathians.

Air pollution sources in zone Prešov region

Dominant source of air pollution in Prešov region is household heating, mainly in smaller districts of mountainous part of area, where the highest share of fuel wood is using, as compared to the other districts of region. Further emission source is road transport. Upon the all-country traffic counting in 2015 is known the daily average 30 731 vehicles (4 025 long distance lorries and 26 528 passenger vehicles) – the most in region – passing via road No. 18 in Prešov district. Very frequented in this district is also road No. 3450 (23 597 vehicles, 3 009 long distance lorries and 20 518 passenger vehicles). For comparing – loaded highway D1 in region is lower, with maximum 16 560 vehicles (4 002 long distance lorries and 12 527 passenger vehicles) in Prešov district. The other among roads with heavy traffic – in Poprad district is road No. 3080 with 21 639 vehicles in daily average (1 573 long distance lorries and 19 997 passenger vehicles) and road No. 67 with 21 488 vehicles (1 378 long distance lorries and 20 058 passenger vehicles), in district Humenné road No. 74 with 18 790 vehicles (1 481 long distance lorries and 17 213 passenger vehicles), in district Bardejov road No. 77 with 19 833 vehicles (2 315 long distance lorries and 17 441 passenger vehicles), in district Humenné road No. 74 with 18 790 vehicles (1 481 long distance lorries and 17 213 passenger vehicles), in district Vranov nad Topľou road No. 18 with 7 371 vehicles (2 958 long distance lorries and 14 340 passenger vehicles) and in district Kežmarok road No. 67 with 17 095 vehicles (2 306 long distance lorries and 14 733 passenger vehicles)[9].

Industrial air pollution sources in region are less significant from point of contribution to local air pollution by basic pollutants. In dependence on meteorological conditions, the influence of wood processing industry and heating plants can manifest here.

■ ZONE KOŠICE REGION (apart from Košice agglomeration)

Relief of the east part of Košice region is predominantly of plain character due to East Slovakian plain, which is separated from Košice basin by Slanské vrchy-mountains. At the boundary with Prešov region are extended Vihorlatské vrchy (hills), from west to east spreads Hornádska kotlina (basin). In west, more mountainous part of region are extended the Volovské vrchy (hills), separated from Slovenský kras by Rožňavská kotlina (basin). Hornádska kotlina (basin) on the west part of territory interferes

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

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

into the south part of Prešov region. Major point of Košice region is Stolica, the highest point of Stolica hills reaches altitude 1 476 m a.s.l., the lowest one 94 m a.s.l.

Air pollution sources in zone Košice region

In mountainous area of west part of Košice region is significant source of air pollution household heating, using the solid fuels, mainly fuel wood. Situation is complicated by unfavourable dispersion conditions in areas with low wind speed.

The most overloaded roads in this region (apart from Košice) are road No. 50 in district Michalovce with 14 783 vehicles (1 721 long distance lorries and 13 021 passenger vehicles), road No. 3244 in district Spišská Nová Ves with 12 384 vehicles (1 391 long distance lorries and 10 872 passenger vehicles), road No. 526 in district Rožňava with 10 433 vehicles (626 long distance lories and 9 747 passenger vehicles) and road No. 3710 in district Trebišov with 9 328 vehicles (614 long distance lorries and 8 686 passenger vehicles)[10].

Tab. 1.1 contains information about the area and settlements of respective regions according to data accessible on web pages of ŠÚ SR (Statistical Office of SR).

Tab. 1.1 Area, settlement density and number of inhabitants in respective regions of SR.

	Area [km^2]	**Number * of inhabitants**
Bratislava region	2 053	677 024
Trnava region	4 146	565 324
Trenčín region	4 502	582 567
Nitra region	6 344	671 507
Žilina region	6 809	691 139
Banská Bystrica region	9 454	643 102
Prešov region	8 973	827 026
Košice region	6 754	802 092

** Status to 31. 12. 2020* *Source: Statistical Office of SR*

1.1.2 Allocation of the territory into zones and agglomerations in 2020 for arsenic, cadmium, nickel, lead and ozone

Agglomeration: Bratislava (territory of the capital city of the Slovak Republic, Bratislava)

Zone: Slovakia (apart from Bratislava agglomeration)

For the time being heavy metals As, Cd, Ni and Pb do not conceive the problem from point of exceeding limit or target values at the territory of SR, in difference e.g. from Poland, where high share of heating by coal brings the problem with high concentrations of As during cool half of year, which is reflected also in the high annual average values (Air quality in Europe – 2019, p. 48). However, the return to the solid fuel burning is possible to observe also in our territory, in difference from Poland it is dealing mainly about wood; therefore, high concentrations of arsenic are not observable.

Problem of tropospheric ozone is of regional character; significant is share of transport from stratosphere and transboundary transport is also not negligible (EMEP, 2019). Road transport in bigger cities is the source of ozone precursors, on the contrary oxides of nitrogen cause ozone titration (chemical reaction of ozone with oxides of nitrogen causes ozone decay) in vicinity of the most loaded communications. Target value for human health protection used to be exceeded at the territory of SR, especially in photochemical more active years and possibilities to improve the situation by local measures are limited.

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

As is quoted in Regulation of Ministry of Environment of SR No. 32/2020 Coll. of Acts, by which is changes and amends Regulation of Ministry of Environment of SR No. 244/2016 Coll. of Acts on air quality in wording of Regulation of Ministry of Environment of SR No. 296/2017 Coll. of Acts, zone for arsenic, cadmium, nickel, lead and ozone is the whole territory of SR apart from Agglomeration Bratislava.

1.2 THE LIST OF AIR QUALITY MANAGEMENT AREAS FOR YEAR 2020

Zones and agglomerations create large territories and cover overall the whole territory of SR. In each zone is relatively variable spatial distribution of pollutant concentrations and usually implies areas with significant emission sources and deteriorated air quality, but also relatively clean areas without sources. Due to reason to make the air quality management easier, the so called areas of air quality management were defined. These areas are the subset of individual zones and each zone can contain several of them.

In case, the measured concentrations of some air pollutant on respective monitoring station exceed limit or target value in monitored year, the respective area representing by measurement of its station, is (in coincidence with Act No. 137/2010 Coll. of Acts on air in statutory text of later pre-scriptions) announced as Area of air quality management (ORKO). District office in establishment of region elaborates for this area Programme for air quality improvement. In case, the limit or target values are exceeded for more pollutants, district office in establishment of region elaborates inte-grated programme for ORKO.

Air quality monitoring and assessment is carried out by the Slovak Hydrometeorological Institute (SHMÚ), as accredited organization in all agglomerations and zones for air pollutants, for which are stated limit values or target values and for ozone precursors, by manner of the determined executive prescription, according to § 33 letter d).

SHMÚ proposes annually the list of ORKO, upon the base of air pollution monitoring (for the period longer than one year), while the list of zones and agglomerations becomes unchanged. Pollutant is removed from ORKO list, if pollutant concentration on the station did not exceed the limit value within the three consecutive years.

Areas of air quality management in SR, proposed by SHMÚ, upon the base of air quality assessment in zones and agglomerations in years 2017 – 2019 for year 2020, are presented in **Tab. 1.2.**

Tab. 1.2 Areas of air quality management for year 2020, defined upon the base of measurements in years 2017 – 2019 (with respect to measurement results in previous years, in case of not sufficient number of valid measurements).

AGGLOMERATION Zone	Delimited air quality management area	Pollutant	Area [km²]	Number of inhabitants*
BRATISLAVA	Territory of capital of SR, Bratislava	NO_2	368	440 948
KOŠICE Košice region	Territories of Košice city and municipalities Veľká Ida, Sokoľany, Bočiar and Haniska	PM_{10}, BaP	296	246 344
Banská Bystrica region	Territory of Banská Bystrica city	PM_{10}, BaP	103	77 719
	Territory of Jelšava city and municipalities Lubeník, Chyžné, Magnezitovce, Mokrá Lúka, Revúcka Lehota	PM_{10}, $PM_{2.5}$, BaP	109	6 316
	Territory of Hnúšťa city and the valley of the river Rimava from the local part Hnúšťa - Likier to the town of Tisovec	PM_{10}	191	11 426
Košice region	Territory of Krompachy city	PM_{10}, BaP	23	8 658
Prešov region	Territory of Prešov city and Ľubotice municipality	PM_{10}, NO_2	79	91 570
Trenčín region	Territory of Prievidza city	PM_{10}	82	55 416
	Territory of Trenčín city	BaP	43	45 141
Žilina region	Territory of Ružomberok city and Likavka municipality	PM_{10}	145	29 386
	Territory of Žilina city	PM_{10}, $PM_{2.5}$, BaP	80	80 386

** Status to 31. 12. 2020*

2 AIR QUALITY MONITORING NETWORK

Despite of the fact, the first air pollutant measurements in Slovakia were carried out in the second half of the fifties in 20th century, systematic monitoring in our territory begun in 1967, when the first Act on air protection (Act No. 35/1967 Coll. of Acts about measures against air pollution) entered into force. Measurements, which included at the beginning only SO2 and dust fallout in Bratislava, Košice and surrounding, were gradually amended for other air pollutants and locations. Legislation was changed several times. Present version is implementation of EU legislation (directions of European parliament and Council 2008/50/EC on ambient air quality and cleaner air in Europe).

As the aim of monitoring is to characterize air quality as best as possible, taking into account human health protection, the structure of monitoring network was proposed in such a way, as the individual stations characterize the extent of pollution in most loaded areas – in past those were mainly locations in vicinity of large industrial air pollution sources. These stations are also now a part of monitoring network, similarly as locations loaded by emissions from road transport. Plan of monitoring is gradually enlarging also on the measurements in locations, where the dominant air pollution source is household heating.

Locations, sufficiently distant from sources of anthropogenic air pollution are also covered by monitoring. Monitoring stations located in these areas are called the regional background stations. Pollutants depending on their properties (e.g. sedimentation velocity, chemical reactivity) can persist in air even several days and according to air masses convection, can be transported on large distances. High concentrations of air pollutants can be therefore find also in relatively clean mountainous areas. Monitoring of air quality in regional background stations plays essential role also at the assessment of long-term air quality trends, because these trends are influenced predominantly by local sources at the other stations.

Network of measurement stations under the name National monitoring air quality network (NMSKO) started to be build up already in ČSFR in 1991 (Závodský, 2010) and at present it comprises continual measurements by automatic instruments and manual measurements, based on the sampling and chemical analyses in the Testing laboratory of SHMÚ. Manual monitoring covers the air measurements of heavy metal concentrations, volatile organic compounds VOC and polycyclic aromatic hydrocarbons PAH in air and also air quality monitoring and analyses of precipitation quality on regional background stations, with monitoring programme EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe). Location of NMSKO network monitoring stations and their measurements programme in year 2020 is presented in **Fig. 2.1**.

Detailed list of monitoring instruments of individual stations and methods which instruments used is described in “Annex A – Measurement stations of monitoring air quality networks – 2020”.

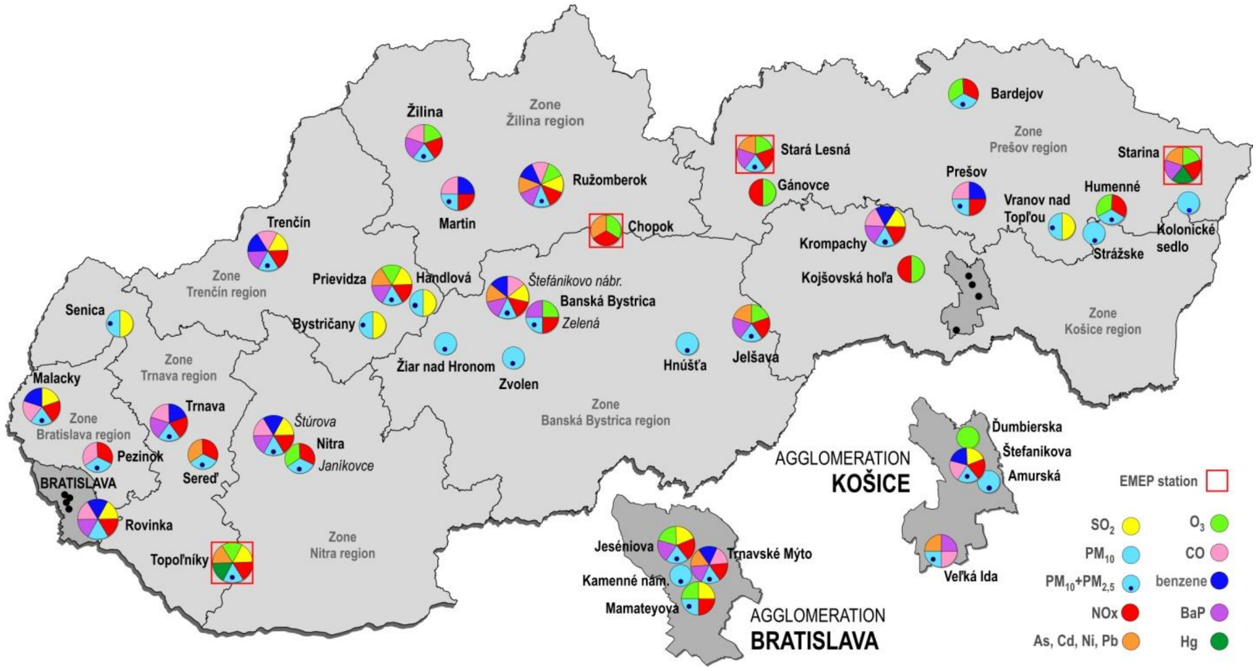
The UN ECE Convention on Long Range Transboundary Air Pollution (CLRTAP) was signed in Geneva in 1979. Up to now, in frame of the Convention were signed eight protocols. The first one among them was Protocol on Long-term Financing of the Co-operative Programme for Monitoring and Evaluation of the Long-range Transport of Air Pollutants in Europe (EMEP) (Geneva, 1984).

In accordance to the Convention, the EMEP is mandatory for all European countries. Its goal is to monitor, model and evaluate the long-range transport of air pollutants in Europe, and elaborate foundations for the strategy to reduce European emissions. The EMEP monitoring network comprises 181 regional stations and four EMEP stations in the territory of Slovakia belonging to the national monitoring air quality network (NMSKO) are at the same time also a part of EMEP network. The first EMEP station at the territory of present SR was established at Chopok meteorological observatory of SHMÚ, in elevation 2008 m a.s.l. Measurements of air quality were put into operation in year 1977.

Station Chopok is part of EMEP and GAW/WMO (Global Atmosphere Watch/World Meteorological Organization) networks since 1978. EMEP station Stará Lesná (elevation 808 m a.s.l.) is in operation from year 1988, since 1992 became part of EMEP network. EMEP station Starina is situated in area of water reservoir Starina, in vicinity of state boundary with Ukraine and Poland, in elevation 345 m a.s.l. Measurements initiated to carry out on this station in 1994, at the same time it became a part of EMEP network. EMEP station Topoľníky is located close to small Danube river, 7 km southeast from village Topoľníky in plain terrain of the Danube lowlands. Measurements are realized here from year 1983, since year 2000 the station became a part of EMEP network.

Monitoring programme in EMEP network was gradually extended. Measurements of sulphur compounds and analyses of precipitation were enhanced for oxides of nitrogen, nitrates, ammonium ions in ambient air, particulate matter and ozone. In 1994, the measurements of volatile organic compounds (VOCs) began to be carried out under the auspices of Chemical Coordinating Centre - NILU (Norwegian Institute for Air Research). Later on, also heavy metals (HMs) have been included into the measurement programme.

Fig. 2.1 *National air quality monitoring network in year 2020.*

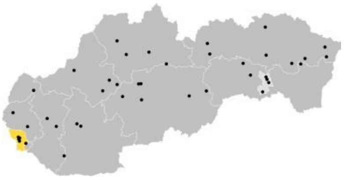


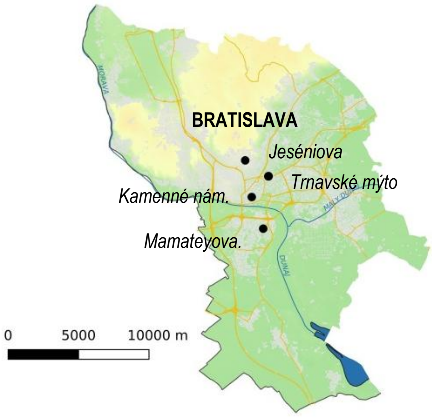
The following tables contain information about air quality monitoring stations belonging to NMSKO according to agglomerations and zones:

- the international EoI code, characteristics of stations in coincidence with the dominant air pollution sources (traffic, background, industrial), the type of region, which individual station monitors (urban, suburban, rural/regional) and geographical coordinates,
- monitoring programme. Automatic instruments of continual monitoring provide annual hourly concentrations of PM_{10}, $PM_{2.5}$, oxides of nitrogen, sulphur dioxide, ozone, carbon monoxide, benzene and mercury. The SHMÚ Testing laboratory in frame of manual monitoring analysis heavy metals and polycyclic aromatic hydrocarbons and the results are mean 24-hours values. Exceptions are EMEP stations, the monitoring programme of which is described in **Tab. 2.1** and **Tab. 2.2**.

Agglomeration Bratislava

District	Code EoI	Station name	Type of area	Type of station	Geographical longitude	Geographical latitude	Altitude [m]	Continuously: PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	Manually: As, Cd, Ni, Pb	BaP
Bratislava I	SK0004A	Bratislava, Kamenné nám.	U	B	17°06'49"	48°08'41"	139										
Bratislava III	SK0002A	Bratislava, Trnavské mýto	U	T	17°07'44"	48°09'30"	136										
Bratislava III	SK0048A	Bratislava, Jeséniova	S	B	17°06'22"	48°10'05"	287										
Bratislava V	SK0001A	Bratislava, Mamateyova	U	B	17°07'31"	48°07'29"	138										
							Together	4	4	3	2	2	1	1		1	2



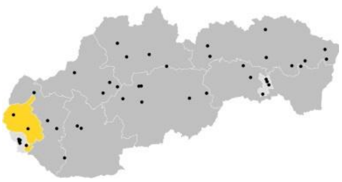


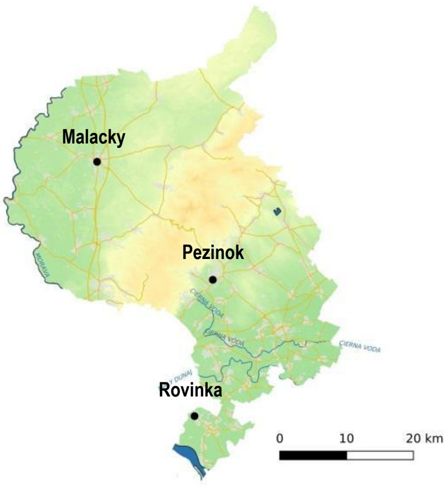
Type of area: *U – urban*
S – suburban
R – rural (regional)

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

Zone Bratislava region

District	Code EoI	Station name	Type of area	Type of station	Geographical longitude	Geographical latitude	Altitude [m]	Continuously: PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	Manually: As, Cd, Ni, Pb	BaP
Malacky	SK0407A	Malacky, Mierové nám.	U	T	17°01'09"	48°26'13"	197										
Pezinok	SK0075A	Pezinok	U	B	17°15'35"	48°17'00"	150										
Rovinka	SK0076A	Rovinka, mobile station	S	B	17°13'50"	48°05'59"	129										
							Together	3	2	3	2		3	2			1



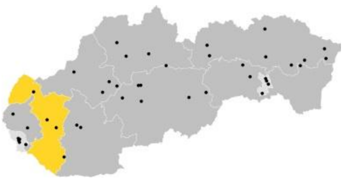


Type of area: *U – urban*
S – suburban
R – rural (regional)

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

Zone Trnava region

District	Code EoI	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
								Continuously								Manually	
Dunajská Streda	SK0007R	Topoľníky, Aszód, EMEP	R	B	17°51'37"	47°57'34"	113									*	
Senica	SK0021A	Senica, Hviezdoslavova	U	T	17°21'47"	48°40'51"	212										
Trnava	SK0045A	Trnava, Kollárova	U	T	17°35'06"	48°22'17"	152										
Sereď	SK0063A	Sereď, Vinárska	U	B	17°44'07"	48°17'01"	130										
							Together	4	4	3	2	1	1	1	1	2	1



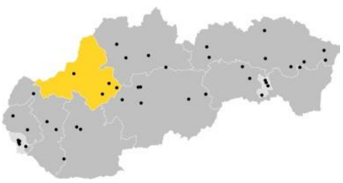
* *Monitoring of heavy metals at the Topoľníky station is under way in coincidence with EMEP monitoring programme (Tab. 2.1)*

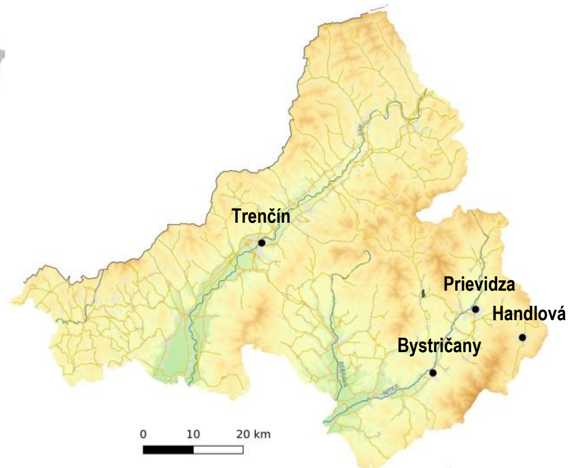
Type of area: *U – urban*, *S – suburban*, *R – rural (regional)*

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

Zone Trenčín region

District	Code EoI	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
								Continuously								Manually	
Prievidza	SK0013A	Bystričany, Rozvodňa SSE	S	B	18°30'51"	48°40'01"	261										
Prievidza	SK0027A	Handlová, Morovianska cesta	U	B	18°45'23"	48°43'59"	448										
Prievidza	SK0050A	Prievidza, Malonecpalská	U	B	18°37'41"	48°46'58"	276										
Trenčín	SK0047A	Trenčín, Hasičská	U	T	18°02'29"	48°53'47"	214										
							Together	4	4	2	4	1	1	1		1	2



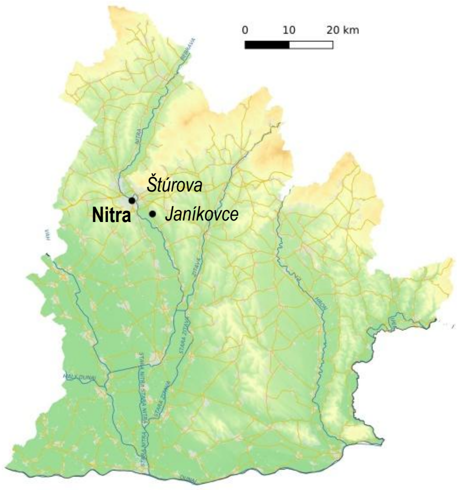


Type of area: *U – urban*, *S – suburban*, *R – rural (regional)*

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

Zone Nitra region

District	Code EoI	Station name	Type of area	Type of station	Geographical longitude	Geographical latitude	Altitude [m]	Monitoring programme: Continuously								Manually	
								PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
Nitra	SK0269A	Nitra, Štúrova	U	T	18°04'37"	48°18'34"	143										
Nitra	SK0134A	Nitra, Janíkovce	U	B	18°08'27"	48°16'59"	149										
							Together	2	2	2	1	1	1	1			1

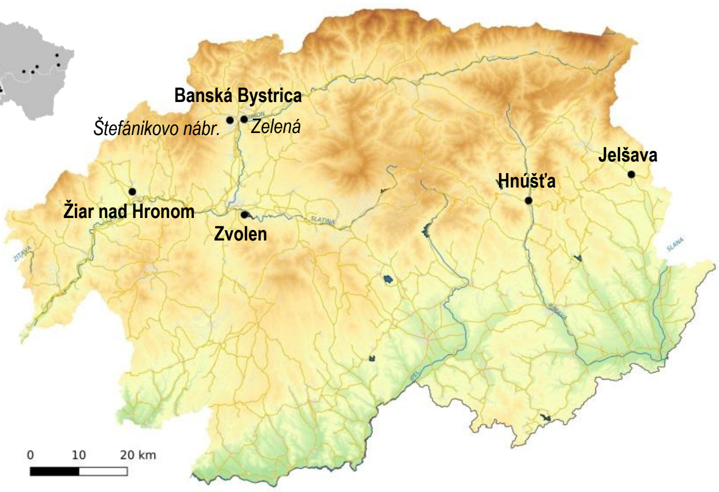


Type of area: *U – urban*
S – suburban
R – rural (regional)

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

Zone Banská Bystrica region

District	Code EoI	Station name	Type of area	Type of station	Geographical longitude	Geographical latitude	Altitude [m]	Monitoring programme: Continuously								Manually	
								PM_{10}	$PM_{2.5}$	NO, NO_2	SO_2	O_3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
Banská Bystrica	SK0214A	Banská Bystrica, Štefánikovo nábr.	U	T	19°09'18"	48°44'06"	346										
Banská Bystrica	SK0263A	Banská Bystrica, Zelená	U	B	19°06'55"	48°44'01"	425										
Revúca	SK0025A	Jelšava, Jesenského	U	B	20°14'26"	48°37'52"	289										
Rimavská Sobota	SK0022A	Hnúšťa, Hlavná	U	B	19°57'06"	48°35'02"	320										
Zvolen	SK0262A	Zvolen, J. Alexyho	U	B	19°09'25"	48°33'30"	321										
Žiar n/Hronom	SK0268A	Žiar n/Hronom, Jilemnického	U	B	18°50'34"	48°35'59"	296										
							Together	6	6	3	1	2	1	1		2	3

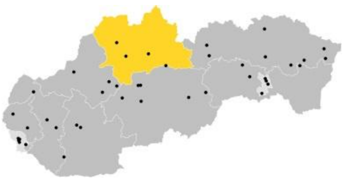


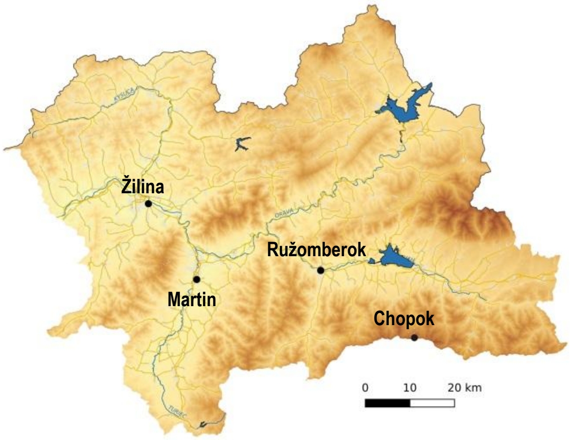
Type of area: *U – urban*
S – suburban
R – rural (regional)

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

Zone Žilina region

District	Code EoI	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
								Monitoring programme – Continuously								Manually	
Liptovský Mikuláš	SK0002R	Chopok, EMEP	R	B	19°35'21"	48°56'37"	2008									*	
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										
							Together	3	3	4	1	3	3	2		2	2





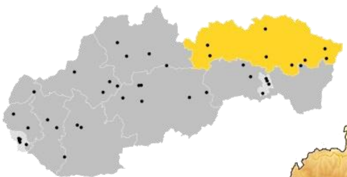
* *Monitoring of heavy metals at the Chopok station is under way in coincidence with EMEP monitoring programme (Tab. 2.1)*

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

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

Zone Prešov region

District	Code EoI	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
								Monitoring programme – Continuously								Manually	
Humenné	SK0037A	Humenné, Nám. Slobody	U	B	21°54'50“	48°55'51"	160										
Kežmarok	SK0004R	Stará Lesná, AÚ SAV, EMEP	R	B	20°17'22"	49°09'05"	808									*	
Poprad	SK0041A	Gánovce, Meteo. st.	R	B	20°19'22"	49°02'05"	706										
Prešov	SK0266A	Prešov, Arm. gen. L. Svobodu	U	T	21°16'00"	48°59'33"	252										
Snina	SK0006R	Starina, Vodná nádrž, EMEP	R	B	22°15'36"	49°02'34"	345									*	
Snina	SK0406A	Kolonické sedlo, Hvezdáreň	R	B	22°16'26“	48°56'06“	431										
Vranov n/Topľou	SK0031A	Vranov n/Topľou, M. R. Štefánika	U	B	21°41'15"	48°53'11"	133										
Bardejov	SK0074A	Bardejov, pod Vinbargom	S	B	21°16'38"	48°18'00"	263										
							Together	6	6	6	1	5	1	1	1	2	2



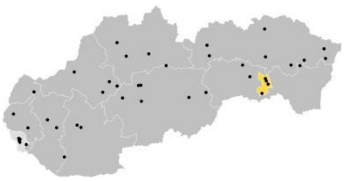
* *Monitoring of heavy metals at the Stará Lesná and Starina station is under way in coincidence with EMEP monitoring programme (Tab. 2.1)*

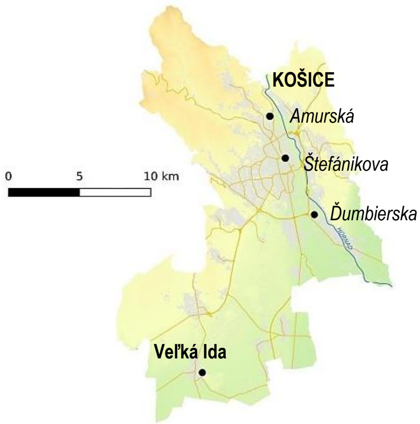
Type of area: *U – urban*, *S – suburban*, *R – rural (regional)*

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

Agglomeration Košice

District	Code EoI	Station name	Type of area	Type of station	Geographical longitude	Geographical latitude	Altitude [m]	PM10	PM2.5	NO, NO2	SO2	O3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
								Monitoring programme: Continuously								Manually	
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 surrounding	SK0018A	Veľká Ida, Letná	S	I	21°10'31"	48°35'32"	209										
							Together	3	3	1	1	1	2	1		1	1





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

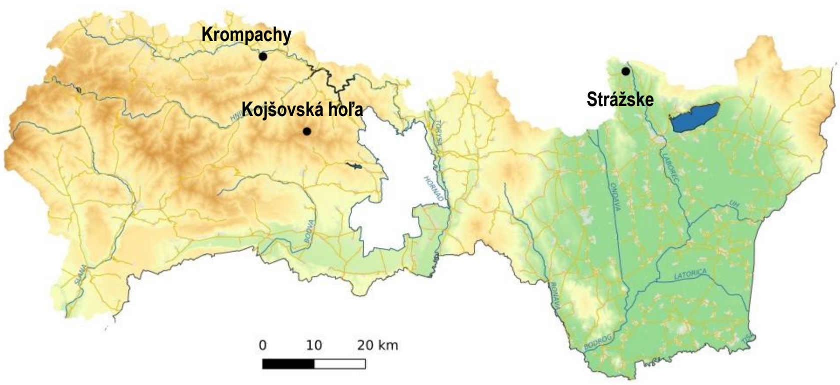
Type of station: *B – background*
T – traffic
I – industrial

Zone Košice region

District	Code EoI	Station name	Type of area	Type of station	Geographical longitude	Geographical latitude	Altitude [m]	PM10	PM2.5	NO, NO2	SO2	O3	CO	Benzene	Hg	As, Cd, Ni, Pb	BaP
								Monitoring programme: Continuously								Manually	
Gelnica	SK0042A	Kojšovská hoľa	R	B	20°59'14"	48°46'58"	1253										
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										
							Together	2	2	2	1	1	1	1			1

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

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



Air quality monitoring programme on EMEP stations in year 2020 is listed in **Tab. 2.1**. Ozone is measured continuously. Sampling interval for heavy metals is one week, for VOC once weekly 10 minutes and the other substances are analysed from 24-hour sampling

Tab. 2.1 *Measurement programme of EMEP stations – air.*

	Ozone (O_3)	Sulphur dioxide (SO_2)	Nitrogen dioxide (NO_2)	Sulphates (SO_4^{2-})	Nitrates (NO_3^-)	Nitric acid (HNO_3)	Chlorides (Cl)	Ammonia, Ammonium ions (NH_3, NH_4^+)	Alkali ions (K^+, Na^+, Ca^{2+}, Mg^{2+})	VOC	PM_{10} / TSP*	EC/OC	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)	Cooper (Cu)	Zinc (Zn)	Mercury (Hg)**
Chopok	x	x	x	x	x	x	x				x*		x	x	x	x	x	x	x	
Topoľníky	x										x		x	x	x	x	x	x	x	x
Starina	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Stará Lesná	x										x	x	x	x	x	x	x	x	x	

** TSP – total suspended particles*
*** mercury is monitored out of EMEP monitoring programme*

Precipitation quality (pH, conductivity, sulphates, nitrates, chlorides, ammonium and alkali ions) is analysed from samples, collected on EMEP stations, according to the monitoring programme, listed in **Tab. 2.2**, either upon daily base (Chopok, Starina), or weekly (Topoľníky, Stará Lesná), in monthly interval the precipitation quality is observed in station Bratislava, Jeséniova. Results of analyses are daily or weekly average values, in dependence on sampling interval.

Heavy metals occur in these locations in lower concentrations, sampling precipitation intervals for heavy metal analyses are one month, apart from the EMEP station Starina, where sampling interval is upon weekly sampling. For precipitation sampling are used precipitation collectors of two types: "wet-only" or "bulk". "Wet-only" is precipitation collector, which collects only precipitation and upon the base of such collected samples the wet deposition is evaluated. Type "Bulk" samples dry and wet deposition. This kind of sampling is carried out on the Chopok station, where the precipitation sampling is performed into the open bucket due to unfavourable weather.

Tab. 2.2 *Measurement programme of precipitation on EMEP stations and on station Bratislava, Jeséniova.*

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

2.1 ASSESSMENT OF MONITORING EXTENT FOR INDIVIDUAL POLLUTANTS

- **Sulphur dioxide SO_2**

This pollutant was monitored on 16 stations. Minimum required extent of monitoring[11] was fulfilled. Sulphur dioxide monitoring was secured on all 16 stations continuously, by reference method. Required number of valid measured data (90%) was reached on all 16 monitoring stations.

- **Oxides of nitrogen NO_2 and NO_X**

These pollutants were monitored on 29 stations. Minimum required extent of monitoring[11] was fulfilled. Oxides of nitrogen monitoring was secured at all 29 stations, continuously by reference method. Required number of valid measured data (90%) was reached at all 26 monitoring stations (smaller share of valid measurements was recorded only on new monitoring stations Pezinok; Bardejov, Pod Vinbargom; Sereď, Vinárska, which were put into operation only in the second half of year 2020).

- **Particulate matter PM_{10}**

This pollutant was monitored on 37 stations. Minimum required extent of monitoring[11] was fulfilled. PM_{10} monitoring was secured by equivalent, continuous method of oscillation microbalance, by the instruments TEOM and by method of beta radiation absorption – BAM. Required number of valid measured data (90%) was reached on 34 monitoring stations (smaller share of valid measurements was recorded only on new monitoring stations Pezinok; Bardejov, Pod Vinbargom; Sereď, Vinárska, which were put into operation only in the second half of year 2020).

- **Particulate matter $PM_{2.5}$**

This pollutant was monitored on 36 stations. Minimum required extent of monitoring[11] was fulfilled. $PM_{2.5}$ monitoring was secured by the same method as PM_{10} monitoring, by instruments TEOM and BAM. Required number of valid measured data (90%) was reached on 33 monitoring stations. (smaller share of valid measurements was recorded only on new monitoring stations Pezinok; Bardejov, Pod Vinbargom; Sereď, Vinárska, which were put into operation only in the second half of year 2020).

- **Carbon monoxide CO**

This pollutant was monitored on 15 monitoring stations. Minimum required extent of monitoring[11] was fulfilled. The CO monitoring was secured on 15 stations, continuously by reference method. Required number of valid measured data (90%) was reached on 14 monitoring stations. (smaller share of valid measurements was recorded only on new monitoring station in Pezinok, which was put into operation in the second half of year 2020). Concentrations of CO are below the low limit for assessment, number of measurements is therefore sufficient.

- **Ozone O_3**

Ozone was monitored on 17 monitoring stations. Minimum required extent of monitoring[11] was fulfilled. Ozone monitoring was secured on all 17 stations, continuously by reference method. Required number of valid measured data (90%) was reached on 16 monitoring stations. (smaller share of valid measurements was recorded only on new monitoring stations Bardejov, Pod Vinbargom, which was put into operation only in the second half of year 2020).

[11] *Number and location according to Appendix No. 6 to regulation of MoE SR No. 244/2016 Coll. A on air quality in reading of later directives*

- **Benzene**

  Benzene was monitored on 12 monitoring stations. Minimum required extent of monitoring[11] was fulfilled. Benzene monitoring was secured on all 12 stations, continuously by reference method. Required number of valid measured data (90%) was reached at all 12 stations, as well.

- **Mercury**

  Overall gas mercury was monitored at two EMEP stations (Topoľniky and Starina). Mercury monitoring was secured continuously, by the method of Zeeman atomic absorbtion spectrometry. Share of valid measured data extended 90% at both monitoring stations.

- **Heavy metals (Pb, As, Cd, Ni)**

  Samples for heavy metal analyses are collected on nitrocellulose filter, each second day during 24 hours and consequently analysed in the Testing laboratory of SHMÚ, by the ICP OES (inducted coupled plasma optical emission spectrometer). In half of 2020 the manner of detection changed as well as method of laboratory analysis, which is in process of adjustment. In 2020 the samples for heavy metal analysis (Pb, As, Cd, Ni) were collected on one suburban, six urban and four EMEP stations (Pb, As, Cd, Ni, Cr, Zn, Cu) – weekly sampling.

- **Polyaromatic hydrocarbons – benzo(a)pyrene**

  In 2020, the benzo(a)pyrene monitoring was provided on 16 monitoring stations. Collection of samples was realized on quartz filter each third day, 24 hours. Samples are analysed after extraction in the Testing laboratory of SHMÚ, by the method of GC MS (gas chromatography mass spectrometer). Minimum required extent of monitoring[11] was fulfilled.

- **VOC**

  Volatile organic compounds $C_2 - C_8$, or the so called light hydrocarbons, begun to be sampled on station Starina in autumn, in 1994. Starina is one of a few European stations, included into EMEP network, with regular volatile organic compound monitoring. They are carried out in Central immision laboratory of Czech Hydrometeorological Institute by method of gas chromatography with inducted coupled plasma.

- **EC/OC**

  In autumn of year 2020, in coincidence with EMEP monitoring strategy, started in Stará Lesná with monitoring of share of organic and elementary carbon in $PM_{2.5}$. Chemical analyses are carried out in Central imissions laboratory of Czech Hydrometeorological Institute.

- **Air quality monitoring on EMEP**

  Air quality measurements were realized on all four EMEP monitoring stations, in coincidence with EMEP monitoring strategy (**Tab. 2.1**), according to the approved monitoring programme.

- **Atmospheric precipitation monitoring on EMEP stations**

  Precipitation quality measurements were realized on all four EMEP monitoring stations, in coincidence with EMEP monitoring strategy (**Tab. 2.2**), according to the approved monitoring programme.

Apart from air quality monitoring stations in NMSKO network are at the territory of SR also monitoring stations, established by operators of large air pollution sources (VZZO), for purposes of air pollution level monitoring. Decision for establishment of VZZO stations is delivered by the District office, in settlement of region. The VZZO data from monitoring stations, which passed through function tests (**Tab. 2.3**), serve as the supplementing data, to the measurements from NMSKO network for the air quality assessment, in cases, the data were gained by the reference or equivalent method. Concentrations of those pollutants, monitored at VZZO by different method (Annex A), represent on contrary to it, the important information for air quality assessment.

Tab. 2.3 *Monitoring stations of other operators of large air pollution sources (VZZO).*

	District	Station name*	Type of		Geographical		Altitude [m]
			area	station	longitude	latitude	
BRATISLAVA	Bratislava II	Bratislava, Vlčie Hrdlo (Slovnaft, a.s.)	S	I	17°10'10"	48°08'00"	134
	Bratislava II	Bratislava, Pod. Biskupice (Slovnaft, a.s.)	U	B	17°12'20"	48°08'05"	132
KOŠICE	Košice II	Košice, Haniska (U.S. Steel, s.r.o.)	S	I	21°15'07"	48°36'54"	212
	Košice II	Košice, Poľov (U.S. Steel, s.r.o.)	R	B	21°11'54"	48°39'40"	271
Bratislava region	Senec	Rovinka (Slovnaft, a.s.)	S	B	17°13'40"	48°06'15"	133
Košice region	Košice - surrounding	Veľká Ida (U.S. Steel, s.r.o.)	S	I	21°10'12"	48°33'35"	208
	Trebišov	Leles (Slovenské elektrárne, a.s.)	R	B	22°01'23"	48°27'46"	100
Nitra region	Šaľa	Trnovec nad Váhom (Duslo, a.s.)	S	B	17°55'43"	48°08'60"	114
Trenčín region	Prievidza	Oslany (Slovenské elektrárne, a.s.)	S	B	18°28'12"	48°37'60"	228
Žilina region	Ružomberok	Ružomberok (Mondi a.s. - Supra)	U	I	19°19'12"	49°04'43"	478

** Next of station name is quoted owner of station in bracket*

Type of area: U – urban, S – suburban, R – rural/regional
Type of station: B – background, T – traffic, I – industrial

3 AIR QUALITY ASSESSMENT IN AGGLOMERATIONS AND ZONES OF SLOVAKIA

3.1 INTRODUCTION

Problems, concerning environment, accompanied technological progress of mankind since the ancient times. Environmental disasters connected with endangering of human life and health stimulated common procedure to search the solution of this issue. Due to the fact, the pollutants can be transported via air on long distances, the coordinated procedure of the major number of countries at air quality monitoring and assessment, showed to be the essential basis to accept the measures. These activities resulted in international conventions, also in European legislation, implemented consequently into the legislation of SR.

Air quality assessment, according to the requirements of § 6 of Act No. 137/2010 Coll. of Acts on air in wording of later prescriptions, is realized by SHMÚ upon the base of air quality monitoring, using the mathematical modelling.

Chapter 3 introduces the processed results of air quality monitoring. Air quality assessment, processed by mathematical modelling is in Chapter **4**.

In Chapter **3.3** are assessed the results of air quality measurements in cities and countryside, according to limit and target values for human health protection. Chapter **3.4** processes the results of measurements from monitoring stations, with monitoring programme EMEP, according to the limit values for vegetation protection. Programme EMEP comprises also atmospheric precipitation quality analyses

3.2 AIR QUALITY ASSESSMENT CRITERIA

Air quality (according to §5 section 4 of Act No. 137/2010 Coll. of Act on air in wording of later prescriptions) is considered for good, if the air pollution level is lower than the limit value or target value.

Limit value is (in coincidence with §5 section 5 of Act No. 137/2010 Coll. of Acts on air in wording of later prescriptions further only Air act) air pollution level, determined upon the base of scientific knowledge, with the aim to protect, prevent or decrease harmful effects on human health or environment as a whole. This air pollution level shall be reached in given time and from this time, it must not be exceeded. Limit values and conditions of their validity are determined by the executive prescription, according to § 33 letter b) for sulphur dioxide, nitrogen dioxide, carbon monoxide, lead, benzene, particulate matter PM_{10} and particulate matter $PM_{2.5}$.

Target value is, in coincidence with §5 section 11 of Air act, air pollution level determined upon the aim to protect, prevent or decrease harmful effects on human health or environment as a whole. This air pollution level shall be reached in given time, if possible. Target value is determined by executive prescription, according to § 33 letter b) for ozone, arsenic, cadmium, nickel and benzo(a)pyrene.

Warning threshold (according §12 section 6 of Air act) is air pollution level and when exceeded it, the risk of human health deterioration exists already under the short-term exposition. At exceedance of warning threshold is necessary to issue the warning in front of the serious smog situation. Warning thresholds are determined by the executive prescription, according to § 33 letter b) for sulphur dioxide, nitrogen dioxide, ozone and particulate matter PM_{10}.

Critical level for purposes of air quality assessment is (according §5 section 10 of Air act), is air pollution level, determined upon the base of scientific know how, at exceedance of which can occur apart from people, direct or indirect effects on trees, plants or natural ecosystems. Critical level is determined by the executive prescription according to § 33 letter b, for sulphur dioxide and nitrogen dioxide.

Method, which is necessary to use for air quality assessment in respective location, depends on extent of air pollution in given location. For this purpose, were established low and upper limits to each monitored pollutant for pollution level assessment.

Upper limit for air pollution level assessment, is according §6 section 8 of Air Act, determined as air pollution level, under which is possible to use the combination of continuous measurements and mathematical modelling, or also indicative measurements for air quality assessment.

Low limit for air pollution level assessment is, according §6 section 8 of Air Act, determined as air pollution level, under which is possible to use mathematical modelling or techniques of objective estimation for air quality assessment.

In **Tab. 3.1** are presented the limit values for human health protection and critical levels for vegetation protection, upper and low limits for ambient air pollution level assessment for SO_2, NO_2, NO_X, PM_{10}, $PM_{2.5}$, Pb, CO and benzene. **Tab. 3.2** presents the target values for human health protection and vegetation protection for As, Cd, Ni and benzo(a)pyrene (BaP).

Tab. 3.1 *Limit values for human health protection and critical levels for vegetation protection, upper and low limits of pollutants for ambient air pollution level assessment.*

	Receptor	Interval of averaging	Limit value* [μg·m⁻³]	Limit for assessment [μg·m⁻³] Upper*	Low*
SO_2	Human health	1h	350 (24)		
SO_2	Human health	24h	125 (3)	75 (3)	50 (3)
SO_2	Vegetation	1y, winter season	20 (-)	12 (-)	8 (-)
NO_2	Human health	1h	200 (18)	140 (18)	100 (18)
NO_2	Human health	1y	40 (-)	32 (-)	26 (-)
NO_X	Vegetation	1y	30 (-)	24 (-)	19.5 (-)
PM_{10}	Human health	24h	50 (35)	35 (35)	25 (35)
PM_{10}	Human health	1y	40 (-)	28 (-)	20 (-)
Pb	Human health	1y	0.5 (-)	0.35 (-)	0.25 (-)
CO	Human health	8h (maximum)	10 000 (-)	7 000 (-)	5 000 (-)
Benzene	Human health	1y	5 (-)	3.5 (-)	2 (-)
$PM_{2.5}$	Human health	1y	25**	17	12

* *Permitted number of exceedances is listed in brackets*
** *Limit value for $PM_{2.5}$ until 1.1.2020: 25 $\mu g \cdot m^{-3}$*
Limit value for $PM_{2.5}$ since 1.1.2020: 20 $\mu g \cdot m^{-3}$

Tab. 3.2 *Target values for human health and vegetation protection for As, Cd, Ni and BaP.*

	Averaging season	Target value [ng·m⁻³]
As	1y	6
Cd	1y	5
Ni	1y	20
BaP	1y	1

3.3 AIR QUALITY MONITORING RESULTS - LOCAL AIR POLLUTION

In **Tab. 3.3** is introduced share of valid data from air quality measurements in monitoring network NMSKO for SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, benzene, O_3.

Tab. 3.3 *Share of valid data* in % in year 2020.*

AGGLOMERATION Zone	Pollutant	SO_2	NO_2	PM_{10}	$PM_{2.5}$	CO	Benzene	O_3
BRATISLAVA	Bratislava, Kamenné nám.			99	96			
	Bratislava, Trnavské mýto		95	98	98	95	98	
	Bratislava, Jeséniova	96	95	99	99			94
	Bratislava, Mamateyova	97	98	98	97			98
KOŠICE	Košice, Štefánikova	94	96	99	100	95	94	
	Košice, Amurská			99	99			
	Košice, Ďumbierska							95
	Veľká Ida, Letná			100	100	96		
Banská Bystrica region	Banská Bystrica, Štefánik. nábr.	95	96	99	99	95	99	
	Banská Bystrica, Zelená		96	99	98			95
	Jelšava, Jesenského		95	99	99			93
	Hnúšťa, Hlavná			97	97			
	Zvolen, J. Alexyho			97	97			
	Žiar n/H, Jilemnického			98	98			
Bratislava region	Malacky, Mierové nám.	96	96	99	97	96	98	
	Pezinok**		24	23	20	24		
	Rovinka	99	99	98		99	95	
Košice region	Kojšovská hola		95					95
	Strážske, Mierová			99	99			
	Krompachy, SNP	95	96	99	99	90	99	
Nitra region	Nitra, Janíkovce		96	92	98			96
	Nitra, Štúrova	95	96	99	98	96	99	
Prešov region	Gánovce, Meteo. st.		95					96
	Humenné, Nám. Slobody		96	100	100			94
	Prešov, Arm. gen. L. Svobodu		96	100	97	95	99	
	Vranov n/T, M. R. Štefánika	95		99	100			
	Stará Lesná, AÚ SAV, EMEP		96	96	100			95
	Starina, Vodná nádrž, EMEP		96					96
	Kolonické sedlo, Hvezdáreň			99	98			
	Bardejov, Pod Vinbargom**		13	13	13			13
Trenčín region	Prievidza, Malonecpalská	96	96	99	99			94
	Bystričany, Rozvodňa SSE	94		98	98			
	Handlová, Morovianska cesta	95		99	99			
	Trenčín, Hasičská	96	96	99	98	96	98	
Trnava region	Senica, Hviezdoslavova	90		96	96			
	Trnava, Kollárova		96	99	99	96	99	
	Topoľníky, Aszód, EMEP	96	96	99	91			95
	Sereď, Vinárska**		17	17	17			
Žilina region	Chopok, EMEP		94					94
	Martin, Jesenského		95	99	98	95	99	
	Ružomberok, Riadok	96	96	98	98	95	98	93
	Žilina, Obežná		96	98	98	96		95

* *≥ 90% of valid measurements (requested by our legislation after implementation of EU legislation in Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording of Regulation 296/2017 Coll. of Acts)*

** *In Pezinok air quality monitoring begun 2.10.2020, in Sereď 27.10.2020 and in Bardejov 13.11.2020.*

Air quality assessment according to limit values (LV) for human health protection for SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO and benzene for individual monitoring stations and pollutants in year 2020 is presented in **Tab. 3.4**. In this table are at the same time introduced the numbers of warning threshold exceedances.

Tab. 3.4 *Air quality assessment according to limit values for human health protection and numbers of warning threshold exceedances – 2020.*

AGGLOMERATION Zone		Health protection									WT 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 conse-cutively	3 h conse-cutively
	Parameter	number of exceedances	number of exceedances	number of exceedances	average	number of exceedances	average	average	average	average	number of exceedances	number of exceedances
	Limit value [μg·m⁻³]	350	125	200	40	50	40	20	10 000	5	500	400
	Maximum number of exceedances	24	3	18		35						
BRATISLAVA	Bratislava, Kamenné nám.					5	20	14				
	Bratislava, Trnavské mýto			0	33	14	25	15	1 059	0.6		0
	Bratislava, Jeséniova	0	0	0	9	4	18	12			0	0
	Bratislava, Mamateyova	0	0	0	16	4	20	13			0	0
KOŠICE	Košice, Štefánikova	0	0	0	23	19	26	16	1 247	0.6	0	0
	Košice, Amurská					9	23	15				
	Veľká Ida, Letná					22	28	19	2 998			
Banská Bystrica region	Banská Bystrica, Štefánik.nábr.	0	0	0	24	23	25	16	2 068	0.8	0	0
	Banská Bystrica, Zelená			0	8	1	16	14				0
	Jelšava, Jesenského			0	8	44	30	18				0
	Hnúšťa, Hlavná					1	20	14				
	Zvolen, J. Alexyho					5	17	12				
	Žiar n/H, Jilemnického					2	16	12				
Bratislava region	Malacky, Mierové nám.	0	0	0	18	5	20	16	1 242	0.5	0	0
	Pezinok			0	19	0	20	12	1 395			0
	Rovinka	0	0	0	12	10	23		813	0.8	0	0
Košice region	Kojšovská hola			0	3							0
	Strážske, Mierová					5	20	16				
	Krompachy, SNP	0	0	0	14	13	23	17	1 892	1.4	0	0
Nitra region	Nitra, Janíkovce			0	8	3	20	15				0
	Nitra, Štúrova	0	0	0	26	7	22	13	976	0.5	0	0
Prešov region	Gánovce, Meteo. st.			0	8							0
	Humenné, Nám. slobody			0	8	10	22	14				0
	Prešov, Arm. gen. L. Svobodu			0	31	15	26	16	1 520	0.8		0
	Vranov n/T, M. R. Štefánika	0	0			6	18	14			0	
	Stará Lesná, AÚ SAV, EMEP			0	5	0	12	9				0
	Starina, Vodná nádrž, EMEP			0	3							0
	Kolonické sedlo, Hvezdáreň					1	16	9				
	Bardejov, Pod Vinbargom*			0	13	0	20	18				0
Trenčín region	Prievidza, Malonecpalská	0	0	0	14	3	16	15			0	0
	Bystričany, Rozvodňa SSE	0	0			7	20	16			0	
	Handlová, Morovianska cesta	0	0			6	20	16			0	
	Trenčín, Hasičská	0	0	0	23	17	24	15	1 325	0.8	0	0
Trnava region	Senica, Hviezdoslavova	0	0			3	19	13			0	
	Trnava, Kollárova			0	27	6	22	16	1 365	0.6		0
	Topoľníky, Aszód, EMEP	0	0	0	8	3	17	13			0	0
	Sereď, Vinárska			0	11	1	23	19				0
Žilina region	Chopok, EMEP			0	2							0
	Martin, Jesenského			0	19	12	22	15	1 788	0.8		0
	Ružomberok, Riadok	0	0	0	17	21	24	19	2 550	1.0	0	0
	Žilina, Obežná			0	16	14	23	17	1 664			0

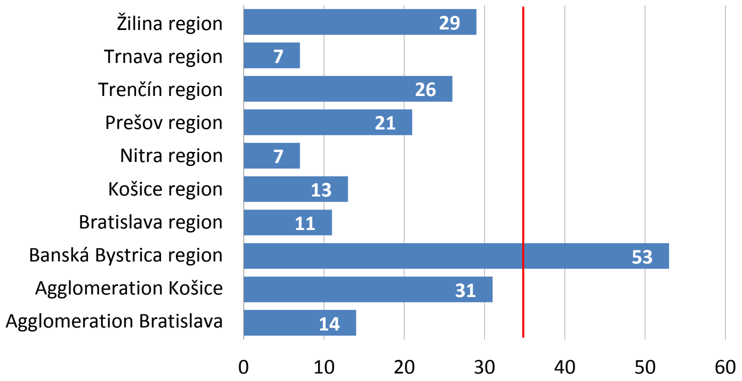
≥90% of valid measurements *Exceedances of limit value are marked by red colour.*

1) *maximum 8-hour concentration* 2) *Limit values for warning thresholds (WT).*

* *AMS started to measure in year 2020, exact date is listed under the **Tab. 3.3**.*

Limit value from daily mean concentration PM_{10} (daily mean concentration PM_{10} 50 µg·m^{-3} must not be exceeded more than 35-times in calendar year) was exceeded in year 2020 only on monitoring station Jelšava, Jesenského.

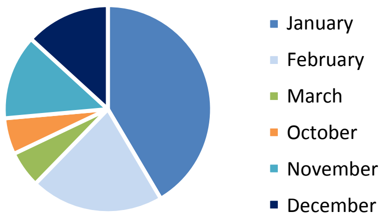
Fig. 3.1 *Number of days with daily mean concentration $PM_{10} > 50$ µg·m^{-3} at least on one station in agglomeration/zone.*

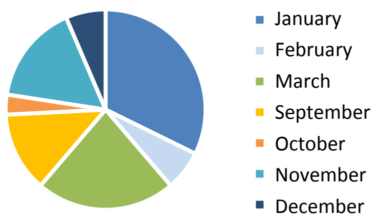


Note: Red line identifies limit value (35 days/year of daily mean concentration > 50 µg·m^{-3}).

At calculation of all days, in which came at least on one station in given zone (agglomeration) to exceedance of daily mean concentration 50 µg·m^{-3}, for Banská Bystrica region comes to 53 exceedances. It is the highest value of this parameter among all zones and agglomerations in year 2020 (**Fig. 3.1**). To the number of 53 exceedances contributed the most station Jelšava, Jeséniova (44 exceedances). Apart from 44 days, in which came to exceedances in Jelšava, in Banská Bystrica region were exceedances else on two stations – Banská Bystrica, Štefánikovo nábrežie (8 exceedances) and Zvolen, Janka Alexyho (1 exceedance) (in these 9 days in Jelšava the exceedance was not recorded).

Fig. 3.2 *The number of days with daily annual concentration $PM_{10} > 50$ µg·m^{-3} at least at one station in zone Banská Bystrica region (left) and agglomeration Košice (right) – allocation according to months.*

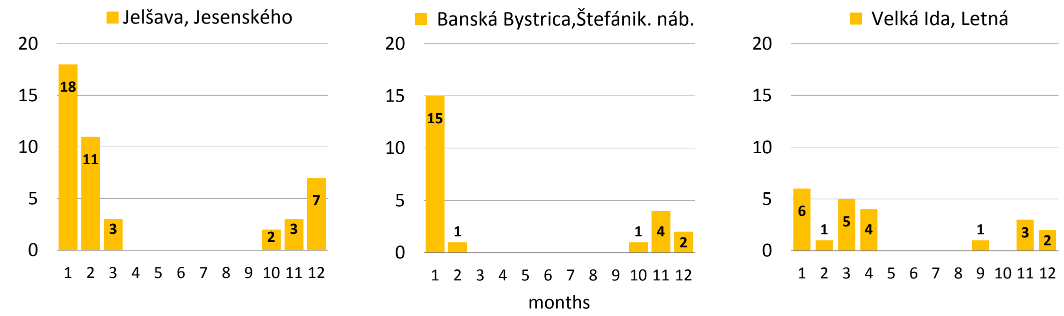




Note: In graphs are depicted only those months, in which were measured daily mean concentrations $PM_{10} > 50$ µg·m^{-3} in year 2020.

On **Fig. 3.2** is allocation of occurrence of days with daily mean concentration $PM_{10} > 50$ µg·m^{-3} at least on one station in zone Banská Bystrica region and in agglomeration Košice, which had the highest number of those days in year 2020, as is seen also on **Fig. 3.1**.

Fig. 3.3 *Comparison of number of days with the exceedance of limit value for daily mean concentration PM_{10} on stations with the highest number of exceedances in year 2020 – AMS Jelšava, Jesenského (left), Banská Bystrica, Štefánikovo nábrežie (in middle) and Veľká Ida, Letná (right) – allocation according months.*



Tab. 3.5 *Air pollution assessment by heavy metals (As, Cd, Ni a Pb) – 2020.*

			As	Cd	Ni	Pb
AGGLOMERATION Zone	Pollutant	[ng·m⁻³]	**As**	**Cd**	**Ni**	**Pb**
	Target value	[ng·m⁻³]	6.0	5	20	-
	Limit value	[ng·m⁻³]	-	-	-	500
	Upper limit for assessment	[ng·m⁻³]	3.6	3	14	350
	Low limit for assessment	[ng·m⁻³]	2.4	2	10	250
BRATISLAVA	Bratislava, Trnavské mýto		*0.6	*0.1	0.7	11.9
Slovakia	Banská Bystrica, Štefánik. náb.		*0.6	0.2	1.1	15.1
	Jelšava, Jesenského		1.6	*0.1	2.3	11.3
	Ružomberok, Riadok		0.9	*0.1	0.8	7.4
	Velká Ida, Letná		0.6	*0.2	*0.9	7.2
	Prievidza, Malonecpalská		*0.9	*0.3	1.5	21.0
	Sereď, Vinárska**		1.0	*0.6	*0.8	98.0

** > 50% data under the detection limit*
*** Measurements on station Sereď, Vinárska started by the end of October 2020.*

In **Tab. 3.6** are presented annual mean concentrations of benzo(a)pyrene (BaP) in air according to measurements in years 2017 – 2020.

Tab. 3.6 *Air pollution assessment by benzo(a)pyrene.*

			2017	2018	2019	2020
AGGOMERATION Zone	Target value	[ng·m⁻³]	1.0	1.0	1.0	1.0
	Upper limit for assessment	[ng·m⁻³]	0.6	0.6	0.6	0.6
	Low limit for assessment	[ng·m⁻³]	0.4	0.4	0.4	0.4
BRATISLAVA	Bratislava, Jeséniova				0.2	0.2
	Bratislava, Trnavské Mýto		0.4	0.9	0.4	0.5
KOŠICE	Veľká Ida, Letná		**4.3**	**5.8**	**4.5**	**4.6**
Banská Bystrica region	Banská Bystrica, Štefánikovo nábrežie		**2.9**	**2.1**	**1.7**	**1.6**
	Banská Bystrica, Zelená				**1.1**	**1.2**
	Jelšava, Jesenského			3.9	**4.0**	**3.0**
Bratislava region	Rovinka					*0.4
Košice region	Krompachy, SNP				**2.7**	**2.1**
Nitra region	Nitra, Štúrova		1.3	0.9	0.8	0.6
Prešov region	Starina, Vodná nádrž, EMEP			1.2	0.4	0.3
	Stará Lesná, EMEP				0.4	0.3
Trenčín region	Prievidza, Malonecpalská				1.4	**1.2**
	Trenčín, Hasičská					*0.8
Trnava region	Trnava, Kollárova			0.9	0.7	0.5
Žilina region	Žilina, Obežná			6.0	**2.0**	**1.9**
	Ružomberok, Riadok					*4.5

≥ 90% of valid measurements *By red colour is distinguished the exceedance of target.*

Note:
At the Bratislava, Trnavské mýto station, the measurements of benzo(a)pyrene were not carried out in February and May, and at the station Bratislava, Jeséniova the measurements were disrupted in January and October 2020. Upon the base of available data (i.e. measurement $PM_{2.5}$ and modelling results by the method of neuron networks) on these monitoring stations is possible to suppose, that mean value would not exceed 1ng·m^{-3} even in case of the whole year measurements in of year 2020.

** The measurements on AMS Ružomberok, Riadok started in December and in Rovinka and at the station Trenčín, Hasičská in June 2020.*

The high concentrations of benzo(a)pyrene occur predominantly in winter months, because the dominant source is heating of households by solid fuel. Due to the start of measurements on AMS Ružomberok, Riadok in December, the mean annual concentration reached probably lower value, however is not possible to judge certainly, what does not exceed the target value.

Occurrence and period of pollution duration at the level of warning thresholds for SO_2 during the last 8 years is presented in **Tab. 3.7**. Warning threshold for SO_2 in NMSKO was exceeded last time in year 2013 on AMS Bystričany, Rozvodňa SSE. Warning threshold for NO_2 was not exceeded in years 2013 – 2020.

Tab. 3.7 *Assessment of air pollution by SO_2 according the occurrence and duration of exceedance warning threshold in years 2013 – 2020 on station Bystričany, Rozvodňa SSE.*

Year	2013	2014	2015	2016	2017	2018	2019	2020
Number of warning threshold exceedances	2	0	0	0	0	0	0	0
Duration in hours	7	0	0	0	0	0	0	0

Legislation constitutes the conditions to settle the announcement about the occurrence of smog situation also for PM_{10} with the aim to protect human health, also at the shorter-term deterioration of air quality. According to Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording of later prescription, the announcement about occurrence of smog situation also for particulate matter PM_{10} is settled in case when the 12-hour moving average of PM_{10} concentration exceeds the information threshold 100 µg·m^{-3}, and at the same time according to the air pollution development and upon the base of meteorological forecast is not reasonable to assume the decreasing of concentration of this pollutant below the value of information threshold due to next 24 hours.

Warning before serious smog situation for particles PM_{10} is settled, when the 12-hour moving average of PM_{10} concentrations exceeds warning threshold 150 µg·m^{-3}, and at the same time, according to the air pollution development and upon the base of meteorological forecast, is not reasonable to assume the decreasing of concentration of this pollutant below the value of warning threshold in course of next 24 hour.

Conditions to issue the announcement about the end of smog situation or announcement about the abolishment of warning before serious smog situation occur, when PM_{10} concentration does not exceed the respective threshold value and this state persists:

- continuously 24 hours, and according to the air pollution development and upon the base of meteorological forecast is not possible to reasonably assume the repeated exceedance of respective threshold value due to next 24 hours, or
- at least 3 hours and according to the air pollution development and upon the base of meteorological forecast is almost excluded the repeated exceedance of the respective warning threshold value over next 24 hours.

Duration of exceedance of information and warning threshold[12] for PM_{10} in year 2020 as compared to year 2019 is presented in **Tab. 3.8**. In year 2020 was recorded less exceedances of information and warning threshold than in year 2019 (decrease over 60*%)*

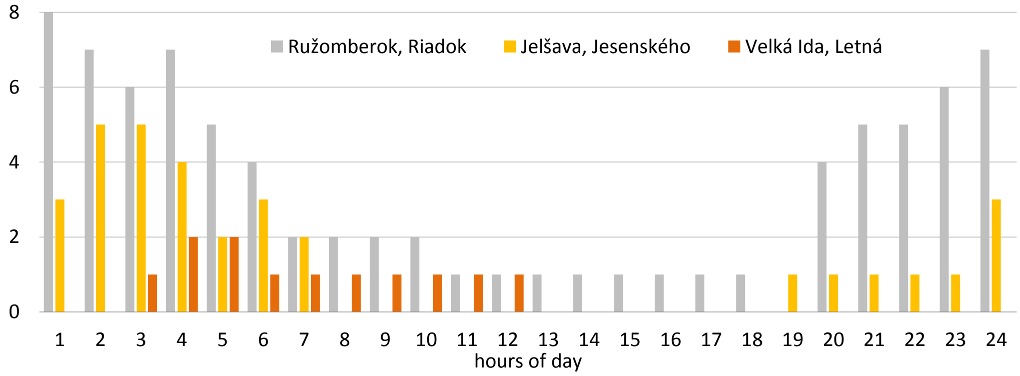
[12] *Announcement about the initiation of smog situation, or warning before serious smog situation were delivered in case of achievement the above mentioned conditions.*

Tab. 3.8 Duration of information and warning thresholds for PM_{10} in 2020 as compared to the year 2019.

Station	Type		2019 Duration of exceedance [h]		2020 Duration of exceedance [h]	
	area	station	information threshold	warning threshold	information threshold	warning threshold
Bratislava, Trnavské Mýto	U	T			11	
Košice, Amurská	U	B			1	
Košice, Štefánikova	U	T	4			
Veľká Ida, Letná	S	I	47		12	
Banská Bystrica, Štefánik. náb.	U	T			4	
Jelšava, Jesenského	U	B	119	17	33	
Malacky, Mierové nám.	U	T	12			
Rovinka, mobil AMS	S	B			10	
Krompachy, SNP	U	T			21	
Nitra, Štúrova	U	T	7			
Prešov, Arm. gen. L. Svobodu	U	T	6			
Vranov nad Top., M. R. Štefánika	U	B	12	10		
Prievidza, Malonecpalská	U	B	8			
Trenčín, Hasičská	U	T	40			
Senica, Hviezdoslavova	U	T	8			
Trnava, Kollárova	U	T	8			
Ružomberok, Riadok	U	B	87		80	3
Martin, Jesenského	U	T	78	22	8	
Žilina, Obežná	U	B	57	5		

The most exceedances of information threshold and the only exceedance of warning threshold was recorded in year 2020 on monitoring stations Ružomberok, Riadok, whereby all exceedances on this station were measured in January, in difference from Jelšava, where the exceedances occurred also in February and December. In Jelšava apart from low temperatures manifest also the influence of temperature inversions. Fig. 3.4 illustrates exceedances of information threshold according to hours of a day. The most exceedances were recorded in evening and night hours, what can indicate under the prevailing influence of household heating the different intensity of heating during the days, however its role play also evening and night temperature inversions. To the more detailed explanation would be necessary to investigate situation by aid of mathematical modelling with emission inputs of good time and spatial resolution and take into account also possible other influences.

Fig. 3.4 Number of hours with exceedance of information threshold for PM_{10} – comparison of AMS Jelšava, Jesenského, Ružomberok Riadok and Veľká Ida, Letná – according to hours of day.



Air quality assessment is carried out by continuous measurements in agglomerations and zones in such places, where the air pollution level is higher than the upper limit for air pollution level assessment. In case, the sufficient data are at disposal, the upper and low limit exceedances for air pollution level assessment have to be determined upon the base of concentrations measured within last five years. Limit for air pollution level assessment is considered for exceeded, if the exceedance appears at least over three years from last five years.

In case, the less than five years data are at disposal, the exceedances of upper and low limits for air pollution level assessment are possible to determine by combination of the results from measurement campaigns of shorter duration, executed within one year in locations, with probably the highest air pollution levels and results gained from emission inventories and modelling (Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording of later prescription). Classification of monitoring stations according to the upper and low limits for assessment is listed in **Tab. 3.9** and **Tab. 3.10**.

Tab. 3.9 *Classification of AMS according to upper limits (ULA) and low limits (LLA) for assessment to determine manner of air quality assessment within years 2016 and 2020.*

AGGLOMERATION Zone	Station	ULA and LLA with regard to human health protection																							
		SO_2			NO_2						PM_{10}						$PM_{2.5}$			CO			Benzene		
		24h average			1h average			annual average			24h average			annual average			annual average			8h maximum			annual average		
		> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA
BRATISLAVA	Bratislava, Kamenné nám.										x					x		x							
	Bratislava, Trnavské mýto					x		x			x				x			x				x			x
	Bratislava, Jeséniova			x			x			x	x					x		x							
	Bratislava, Mamateyova			x			x			x	x				x			x							
KOŠICE	Košice, Štefánikova			x		x			x		x			x			x					x			x
	Košice, Amurská										x				x			x							
	Veľká Ida, Letná										x			x			x					x			
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.			x			x	x			x			x			x					x			x
	Banská Bystrica, Zelená						x			x		x				x		x							
	Zvolen, J. Alexyho										x					x		x							
	Jelšava, Jesenského						x			x	x			x			x								
	Hnúšťa, Hlavná										x				x			x							
	Žiar nad Hronom, Jilemnického											x				x		x							
Bratislava region	Malacky, Mierové nám.			x			x			x	x				x			x				x			x
	Pezinok**						x			x			x			x						x			
	Rovinka			x			x			x	x				x				x			x			x
Košice region	Kojšovská hoľa*						x			x															
	Strážske, Mierová										x				x		x								
	Krompachy, SNP			x			x			x	x				x		x					x		x	
Nitra region	Nitra, Janíkovce						x			x	x				x			x							
	Nitra, J. Štúrova			x			x		x		x				x			x				x			x
Prešov region	Humenné, Nám. slobody						x			x	x				x		x								
	Prešov, Arm. gen. L. Svobodu						x	x			x				x		x					x			x
	Gánovce, MS SHMÚ*						x			x															
	Starina, Vodná nádrž, EMEP*						x			x															
	Vranov n/Topľou, M. R. Štefánika			x							x				x			x							
	Stará Lesná, AÚ SAV, EMEP*						x			x			x			x			x						
	Kolonické sedlo, Hvezdáreň											x				x			x						
	Bardejov, Pod Vinbargom																								
Trenčín region	Prievidza, Malonecpalská			x			x			x	x				x		x								
	Bystričany, Rozvodňa SSE			x							x				x			x							
	Handlová, Morovianska cesta			x							x				x			x							
	Trenčín, Hasičská			x			x		x		x			x			x					x			x
Trnava region	Senica, Hviezdoslavova,			x							x				x			x							
	Trnava, Kollárova					x		x			x				x			x				x			x
	Topoľníky, Aszód, EMEP*			x			x			x	x				x			x							
	Sereď, Vinárska**																								
Žilina region	Martin, Jesenského						x			x	x				x			x				x			x
	Chopok, EMEP*						x			x															
	Ružomberok, Riadok			x			x			x	x				x		x					x			x
	Žilina, Obežná						x			x	x				x		x					x			

* *Stations indicate regional background level.*

** *AMS started to measure in the course of year 2020, see note under **Tab. 3.3**.*

Tab. 3.10 Classification of monitoring stations, on which heavy metals and benzo(a)pyrene were monitored in coincidence with upper (ULA) and low limit (LLA) assessment to determine manner of air quality assessment within years 2016 – 2020.

Station	As			Cd			Ni			Pb			BaP		
	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA	> ULA	≤ ULA; >LLA	≤ LLA
Bratislava, Jeséniova															x
Bratislava, Trnavské mýto			x			x			x			x		x	
Banská Bystrica, Štefánikovo nábr.			x			x			x			x	x		
Banská Bystrica, Zelená													x		
Veľká Ida, Letná			x			x			x			x	x		
Krompachy, SNP						x			x			x	x		
Prievidza, Malonecpalská						x			x			x	x		
Trnava, Kollárova														x	
Ružomberok, Riadok			x			x			x			x			
Nitra, Štúrova													x		
Žilina, Obežná													x		
Jelšava, Jesenského			x			x			x			x	x		
Starina, Vodná nádrž, EMEP															x
Stará Lesná, EMEP															x
Sereď, Vinárska *			x			x			x			x			
Rovinka *														x	

** AMS started to measure in the course of year 2020, see note under **Tab. 3.3**.*

In **Tab. 3.11** are listed annual average concentrations of tropospheric ozone in years 2008 – 2020 as compared to photochemical extraordinary active year 2003.

Tab. 3.11 *Annual average concentrations of surface ozone [μg·m^{-3}] in years 2003, 2008 – 2020.*

Station	2003	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bratislava, Jeséniova	71	59	60	61	63	65	62	60	71	56	64	68	66	61
Bratislava, Mamateyova	53	48	48	46	51	53	48	46	54	36	51	54	54	49
Košice, Ďumbierska	68	56	81	63	73	62	61	55	57	55	55	63	56	46
Banská Bystrica, Zelená			53	56	60	66	66	58	48	45	57	56	47	48
Jelšava, Jesenského	55	51	49	44	-	-	41	36	45	48	49	49	45	39
Kojšovská hoľa	91	76	85	90	87	83	78	75	61	81	80	82	78	72
Nitra, Janíkovce			74	53	-	62	58	52	63	43	60	60	54	56
Humenné, Nám. slobody	66	55	59	53	53	55	60	40	41	50	52	51	54	49
Stará Lesná, AÚ SAV, EMEP	67	74	61	67	65	63	71	56	66	58	63	67	59	57
Gánovce, Meteo. st.	68	65	62	63	64	66	67	58	66	38	53	56	57	51
Starina, Vodná nádrž, EMEP	73	59	58	51	59	60	64	55	64	58	60	64	62	54
Prievidza, Malonecpalská		53	50	49	51	52	50	53	54	39	51	52	49	46
Topoľníky, Aszód, EMEP	67	60	59	55	-	59	64	51	51	49	47	54	55	24
Chopok, EMEP	109	92	90	87	96	93	96	52	88	91	98	95	90	91
Žilina, Obežná	48	46	48	47	48	49	53	42	36	43	38	44	44	36
Ružomberok, Riadok										37	37	36	36	35
Average	**65**	**61**	**62**	**59**	**61**	**63**	**63**	**53**	**58**	**52**	**57**	**59**	**57**	**51**

≥ 90% requested valid data

Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording of later prescriptions, determines ozone target value for human health protection as follows: "120 μg·m^{-3} will not be exceeded more than 25 days in calendar year on average of three years*". Number of days exceeding target value of surface ozone is quoted in **Tab. 3.12**.

**<u>Methodical note</u>:*
Average period is the major daily 8-hour medium value (chosen by investigation of 8-hour moving averages calculated from hourly data and actualized each hour. Each 8-hour average calculated in such a way, will be allocated to the day, in which it finishes, i.e., the first calculated period for any day is period from 17.00 hour of former day until 1.00 hour of the given day; the last calculation period for any one day is period from 16.00 hour until the end of a given day).

Tab. 3.12 *Number of days with exceedance of surface ozone target value for human health protection.*

Station	2018	2019	2020	Average 2018 – 2020
Bratislava, Jeséniova	54	40	17	**37**
Bratislava, Mamateyova	33	32	12	**26**
Košice, Ďumbierska	16	6	0	7
Banská Bystrica, Zelená	20	2	0	7
Jelšava, Jesenského	11	4	2	6
Kojšovská hoľa	41	11	2	18
Nitra, Janíkovce	44	10	9	21
Humenné, Nám. Slobody	2	3	3	3
Stará Lesná, AÚ SAV, EMEP	33	3	5	14
Gánovce, Meteo. st.	4	0	0	1
Starina, Vodná nádrž, EMEP	7	3	4	5
Prievidza, Malonecpalská	9	1	2	4
Topoľníky, Aszód, EMEP	6	19	0	8
Chopok, EMEP	82	36	33	**50**
Žilina, Obežná	12	6	0	6
Ružomberok, Riadok	1	1	0	1

≥ 90% requested valid data
Exceedance of target value is marked by red colour.

Tab. 3.13 *Number of exceedances (in hours) of information threshold (IT) and warning threshold (WT) for surface ozone to draw attention and warning of inhabitants.*

Station	IT1h = 180 μg·m^{-3}			WT1h = 240 μg·m^{-3}		
	2018	2019	2020	2018	2019	2020
Bratislava, Jeséniova	1	0	0	0	0	0
Bratislava, Mamateyova	2	0	0	0	0	0
Košice, Ďumbierska	0	0	0	0	0	0
Banská Bystrica, Zelená	0	0	0	0	0	0
Jelšava, Jesenského	0	0	0	0	0	0
Kojšovská hoľa	0	0	0	0	0	0
Nitra, Janíkovce	0	0	0	0	0	0
Humenné, Nám. slobody	0	0	0	0	0	0
Stará Lesná, AÚ SAV, EMEP	0	0	0	0	0	0
Gánovce, Meteo. st.	0	0	0	0	0	0
Starina, Vodná nádrž, EMEP	0	0	0	0	0	0
Prievidza, Malonecpalská	0	0	0	0	0	0
Topoľníky, Aszód, EMEP	0	0	0	0	0	0
Chopok, EMEP	0	0	0	0	0	0
Žilina, Obežná	0	0	0	0	0	0
Ružomberok, Riadok	0	0	0	0	0	0

≥ 90% requested valid data

Values of surface ozone AOT40 for vegetation protection are presented in **Tab. 3.14**. AOT40 is the sum of exceedances of level 80 μg·m^{-3} calculated from 1-hour concentrations during the day (from 8 00 to 20 00 hour MET) since 1st May to 31st July. Target value is 18 000 μg·m^{-3} (relating to average five calendar years, following one after another). This value was exceeded at three stations (i.e. on these stations the average of values AOT40 during years 2016 – 2020 exceeded value 18 000 μg·m^{-3}).

Tab. 3.14 *Values of surface ozone AOT40 for vegetation protection (May – July). Target value AOT40 is 18 000 μg·m^{-3}.*

Station	2016	2017	2018	2019	2020	Average 2016 – 2020
Bratislava, Jeséniova	13 612	25 042	25 103	20 609	12 501	**19 373**
Bratislava, Mamateyova	4 450	21 525	22 658	19 340	10 655	15 726
Košice, Ďumbierska	15 560	11 557	14 384	11 752	3 269	11 305
Banská Bystrica, Zelená	*9 771	17 198	16 982	8 298	7 723	12 550
Jelšava, Jesenského	*14 597	12 756	6 660	12 361	5 191	9 242
Kojšovská hoľa	18 259	13 056	18 706	12 202	4 995	13 444
Nitra, Janíkovce	18 684	25 925	25 036	13 313	12 741	**19 140**
Humenné, Nám. slobody	13 008	14 209	10 833	13 326	5 981	11 471
Stará Lesná, AÚ SAV, EMEP	13 151	13 197	22 437	8 666	7 890	13 068
Gánovce, Meteo. st.	2 678	7 020	6 646	8 954	3 251	5 476
Starina, Vodná nádrž, EMEP	10 235	12 154	13 116	11 601	5 072	10 436
Prievidza, Malonecpalská	*5 835	16 167	15 889	8 301	6 198	11 639
Topoľníky, Aszód, EMEP	11 812	9 334	15 886	17 690	-	10 944
Chopok, EMEP	23 014	29 820	32 667	23 711	15 957	**23 837**
Žilina, Obežná	14 359	10 956	13 364	11 800	559	10 208
Ružomberok, Riadok	3 875	2 801	3 789	5 307	1 999	3 496

** A given year was not calculated into the average, due to lack of data in summer season.*
Exceedance of target value is marked by red colour.

According to assessment of measurements from monitoring stations of other operators (industrial stations apart from NMSKO), the limit value for PM_{10} was exceeded on one location (**Tab. 3.15**).

Tab. 3.15 *Air pollution assessment according to limit values for human health protection in year 2020 from industrial stations of other operators – VZZO.*

AGGLOMERATION Zone	Pollutant / Averaging period / Limit value [μg·m^{-3}] / (number of exceedances)	Health protection SO₂ 1 h 350 (24)	SO₂ 24 h 125 (3)	NO₂ 1 h 200 (18)	NO₂ 1 rok 40	PM₁₀ 24 h 50 (35)	PM₁₀ 1 rok 40	CO 8 h [1)] 10 000
BRATISLAVA	Bratislava, Pod. Biskupice (Slovnaft, a.s.)	0	0	0	15	6	19	1 060
	Bratislava, Vlčie Hrdlo (Slovnaft, a.s.)	0	0	0	17	1	19	974
KOŠICE	Košice, Poľov (U.S. Steel, s.r.o.)	0	0	0	3	0	16	5 736
	Košice, Haniska (U.S. Steel, s.r.o.)	0	0	0	6	2	20	4 229
Bratislava region	Rovinka (Slovnaft, a.s.)	0	0	0	12	6	21	1 462
Košice region	Veľká Ida (U.S. Steel, s.r.o.)	0	0	0	5	30	27	1 807
	Leles (Slovenské elektrárne, a.s.)	0	0	0	6			
Nitra region	Trnovec nad Váhom (Duslo, a.s.)	0	0	0	9	2	15	
Trenčín region	Oslany (Slovenské elektrárne, a.s.)	0	0	0	8			
Žilina region	Ružomberok (Mondi a.s. - Supra)					**41**	25	

[1)] maximum 8-hour concentration
Limit value exceedance is marked by red colour.

3.3.1 Air quality assessment according to limit and target values for human health protection concerning SO_2, NO_2, PM_{10}, $PM_{2.5}$, benzene, CO and benzo(a)pyrene in classification on agglomerations and zones in 2020

In the following text, the results of measurements are assessed, concerning limit and target values of individual pollutants for human health protection. Air pollution assessment is complex problem and to solve it, the mathematical modelling methods are used, apart from the monitoring. Those data serve as added information about spatial distribution of air pollutant concentrations and in case, the input data are at disposal about relation to emission pollutant sources. Air quality assessment with the aid of mathematical modelling is presented in Chapter 4.

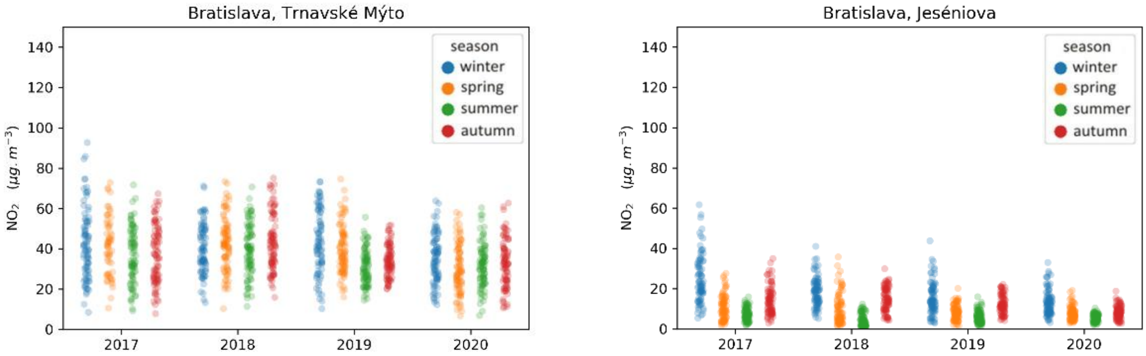
- **Agglomeration Bratislava**

In year 2020 the limit values for human health protection for SO_2, PM_{10}, $PM_{2.5}$, NO_2, benzene and CO were not exceeded in Bratislava agglomeration, also exceedance of target value for benzo(a)pyrene was not measured. **Fig. 3.5** compares selected AMS with the highest and lowest NO_2 measured concentrations in Bratislava. On course of mean daily NO_2 concentrations are clear the higher values on traffic AMS Trnavské mýto, while seasonality characteristic for heating is more manifested on AMS Bratislava, Jeséniova, where in summer season are usually measured the lower NO_2 concentrations.

The impact of measures against pandemy implemented at the beginning of year 2020, manifested into the decreases of road traffic intensity and concentrations of oxides of nitrogen[13].

The exceedance of limit value for PM_{10} was not recorded in Bratislava agglomeration since year 2015, where the limit value for mean daily concentration was exceeded in Trnavské mýto. Limit value for NO_2 was exceeded at this station in year 2018. The results of air quality modelling with high spatial resolution indicate the possibility of the limit value exceedance nearby of road communications with high traffic intensity.[14].

Fig. 3.5 *Mean daily concentrations of NO_2 in years 2017 – 2020 on AMS Bratislava, Trnavské mýto and $PM_{2.5}$ on AMS Bratislava, Jeséniova.*



[13] *http://www.shmu.sk/sk/?page=2049&id=1054*

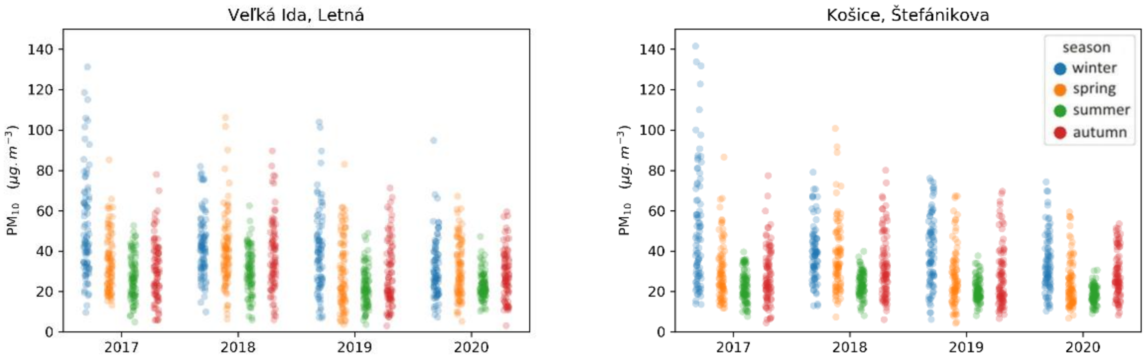
[14] *Štúdia kvality ovzdušia v aglomerácii Bratislava, SHMÚ, 2020. http://www.shmu.sk/File/oko/studie_analyzy/Studia_BA_2020.pdf*

Agglomeration Košice

In year 2020 the limit values for human health protection were not exceeded for SO_2 PM_{10}, $PM_{2.5}$, benzene and CO in agglomeration Košice, contrary to the year 2019, when exceedance of limit value for daily mean concentration of PM_{10} was recorded on monitoring station Veľká Ida, Letná. (AMS Veľká Ida, Letná belongs since the year 2020 to a part of Košice agglomeration).

On **Fig. 3.6** is seen higher concentrations of PM_{10} on industrial station Veľká Ida, Letná against traffic AMS Košice, Štefánikova, whereby more expressive difference on traffic station in summer season would indicate possible influence of heating sources also in Košice. Concentrations measured on AMS Košice, Amurská are against mentioned locations considerably lower (**Tab. 3.4**), what is given by the kind of location, which characterized urban background.

Fig. 3.6 *Daily mean concentrations of PM_{10} in years 2017 – 2020 on AMS Veľká Ida, Letná and Košice, Štefánikova.*



On station Veľká Ida, Letná the target value for benzo(a)pyren was also exceeded, probably the influence of metallurgical complex with coke production and in smaller range also household heating manifested.

Zone Banská Bystrica region

Daily mean of PM_{10} concentrations exceeded limit value on the only AMS station: Jelšava, Jesenského. Limit value for annual mean concentration of PM_{10} was not exceeded on any of stations in this zone.

Concentrations of benzo(a)pyrene exceeded significantly the target value in AMS Jelšava, Jesenského, exceedance was registered on both monitoring stations in Banská Bystrica.

High number of exceedances of daily limit value for PM_{10} in Jelšava in year 2020 (44 exceedances of limit value for daily mean concentration) as well as also high concentration of benzo(a)pyrene (annual mean concentration had value 3.0 $ng{\cdot}m^{-3}$) is possible to assign mainly to heating by solid fuel in this area, where situation is even worse by extremely unfavourable scatter conditions in closed mountain walley. Influence of industrial sources is demonstrated less expressively in Jelšava.

Influence of meteorology, mainly temperature manifests also in different intensity of heating in different months of year (**Fig. 3.8**) and so indirectly influences also emissions. Higher wind velocity impacts favourable on improvement of dispersion conditions and higher precipitation totals indicate higher extent of wet deposition (washing out of pollution substances by atmospheric precipitation) and therefore lower concentrations. These processes is possible to simulate in more details by the method of mathematic modelling.

On the contrary, AMS Banská Bystrica, Štefánikovo nábrežie registered relatively high number of daily limit value exceedances, caused mainly by road transport, but at the same time also household heating influence manifests here.

Limit values in this zone for $PM_{2.5}$, SO_2, NO_2, benzene and CO concentrations were not exceeded.

Fig. 3.7 *Daily mean concentrations of PM_{10} in years 2017 – 2020 on AMS Banská Bystrica, Štefánikovo nábrežie and Banská Bystrica, Zelená.*

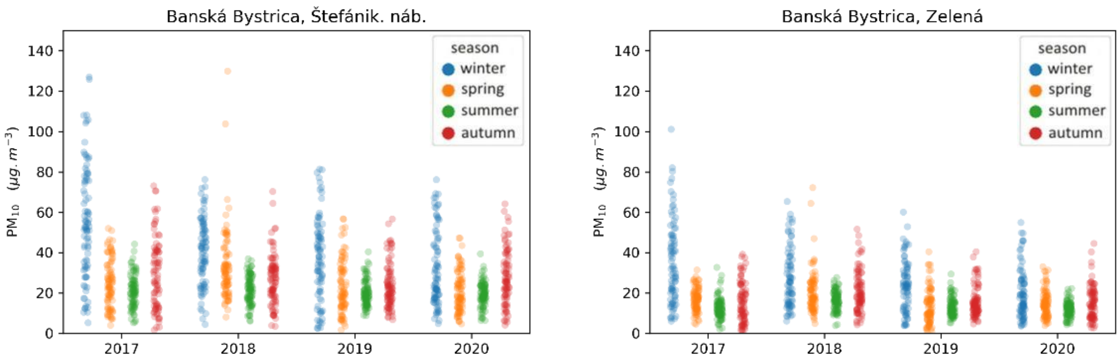
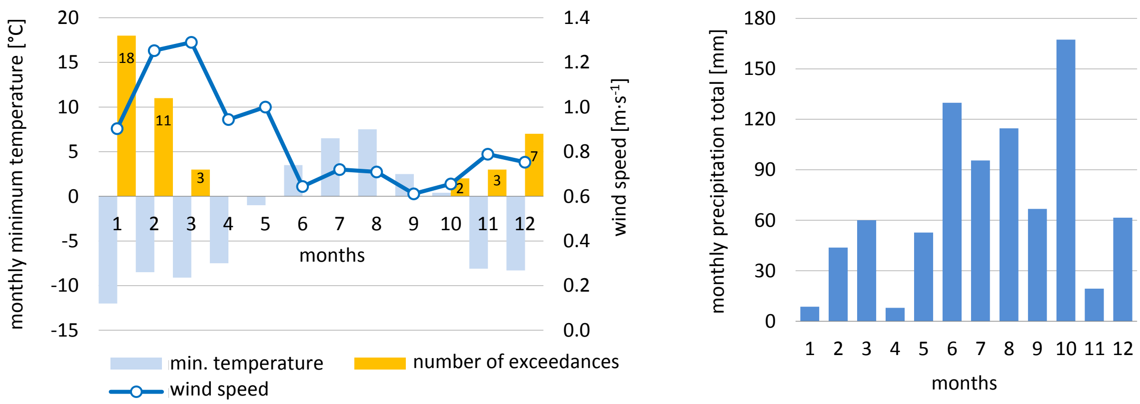


Fig. 3.8 *Number of days with daily mean concentrations $PM_{10} > 50\ \mu g\cdot m^{-3}$ on AMS Jelšava, Jeséniova in year 2020 – comparison with minimum month temperature, wind speed and precipitation total.*



Zone Bratislava region

Concentrations of SO_2, NO_2, PM_{10}, $PM_{2.5}$, benzene, CO and benzo(a)pyrene on monitoring stations in this zone did not exceed limit, respectively target value

Remark: Benzo(a)pyrene started to be measured in Rovinka in June 2020. Upon the base of present benzo(a)pyrene and PM results in years 2020 – 2021 in this location can be concluded, that target value for benzo(a)pyrene on this station was not exceeded.

Zone Košice region

Limit values for SO_2, NO_2, PM_{10}, $PM_{2.5}$, benzene and CO measured concentrations were not exceeded in zone Košice region. Target value for annual average concentration of benzo(a)pyrene was exceeded on monitoring station Krompachy, SNP in year 2020 as well as in previous year. The influence of combination of more sources, road transport, household heating and industrial source manifest

Zone Nitra region

Limit values for SO_2, NO_2, PM_{10}, $PM_{2.5}$, benzene and CO concentrations were not exceeded in this zone, as well as target values for benzo(a)pyrene concentrations were not exceeded in year 2020.

- **Zone Prešov region**

  Limit value for mean annual average concentration of PM_{10} was not exceeded in this zone, similarly as limit values for SO_2, NO_2, benzene, CO and $PM_{2.5.}$ Exceedance of target value for benzo(a)pyrene was not measured in zone, however it could occur in locations, where prevail household heating by solid fuel.

- **Zone Trenčín region**

  Limit value for annual mean concentration and daily mean concentration of PM_{10} was not exceeded in Trenčín region, similarly as limit values for SO_2, NO_2, benzene, CO and $PM_{2.5}$.

  On monitoring station Prievidza, Malonecpalská the exceedance of target value for benzo(a)pyrene. The household heating by solid fuel and in lesser extent system energetics (heat power plants) manifest here.

- **Zone Trnava region**

  Limit values for SO_2, NO_2, $PM_{10,}$ $PM_{2.5,}$ benzene and CO concentrations were not exceeded in this zone. Also target value for benzo(a)pyrene in Trnava region was not exceeded.

- **Zone Žilina region**

  Žilina region did not record exceedance of limit values for daily mean concentrations of PM_{10} and also for annual mean concentration of PM_{10} were not exceeded, similarly as limit mean annual values for $PM_{10,}$ SO_2, NO_2, benzene and CO.

  On monitoring station Žilina, Obežná was measured exceedance of target value for benzo(a)pyrene – probably the influence of household heating, road transport and transboundary transport from Malopoľské vojvodstvo (duchy) manifest here.

3.3.2 Air quality assessment according to limit and target values for human health protection concerning Pb, As, Cd, Ni and $O_{3,}$ in classification on agglomeration and zones in 2020

- **Agglomeration Bratislava**

  Limit value for Pb as well as target values for As, Cd and Ni, were not exceeded in Bratislava agglomeration. Target value for ozone (120 $\mu g \cdot m^{-3}$ should not to be exceeded more than 25 days in calendar year on average of three years) was exceeded at monitoring stations Bratislava, Jeséniova and Bratislava, Mamateyova. This reality could be caused by more factors – good access of ozone precursors, higher relation NO_2/NO in advance of NO_2 in these locations, so ozone is not degraded in such extent by NO from road traffic as at frequented roads. Also episodes of long range transport could have been manifested here. In year 2020 the information threshold and warning threshold were not exceeded in Bratislava.

- **Zone Slovakia**

  Zone allocates the territory of the Slovak Republic apart from the territory of capital of SR, Bratislava.

  Limit value for Pb and target values for As, Cd and Ni were not exceeded in zone Slovakia.

  Target value for ozone was exceeded on monitoring station Chopok, EMEP. Station is situated in 2008 m a.s.l., where on higher concentrations of tropospheric ozone contribute apart from horizontal long range transport also transport from lower layers of stratosphere.

3.4 REGIONAL MONITORING

Regional air pollution is a pollution of a boundary layer of a rural country at a sufficient distance from local industrial and urban sources. The boundary layer of the atmosphere is a mixing layer extending itself from the Earth surface up to the height of about 1 000 m. In regional positions, the industrial emissions are more or less evenly vertically dispersed in the entire boundary layer and ground level concentrations are smaller than those ones, in cities. In the following text are presented results from EMEP regional monitoring stations, chapter **3.4.1** contains the air quality monitoring results and chapter **3.4.2** is devoted to atmospheric precipitation quality.

3.4.1 Air

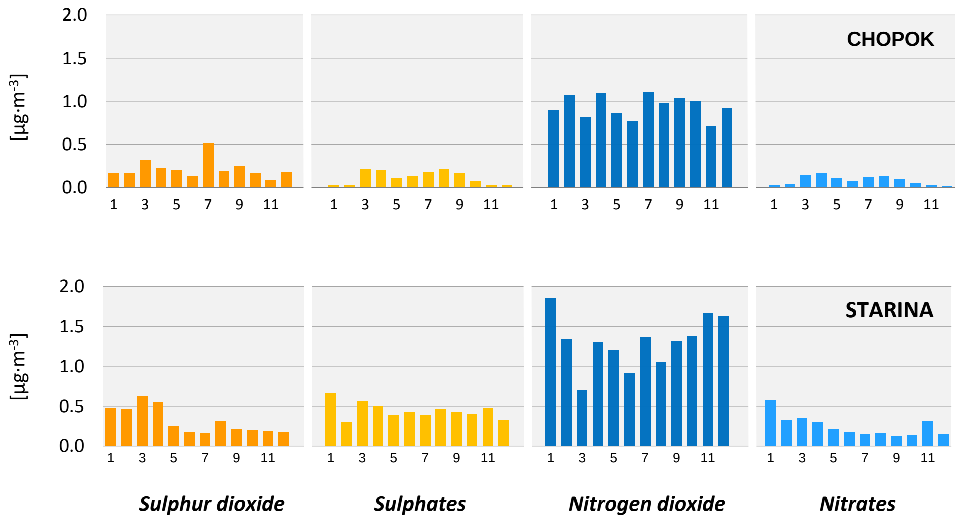
- **Sulphur dioxide, sulphates**

In year 2020 the regional level of sulphur dioxide concentrations recalculated on sulphur was 0.22 $\mu g \cdot m^{-3}$ on the Chopok station and 0.31 $\mu g \cdot m^{-3}$ on the Starina station (**Tab. 3.16**, **Fig. 3.9**). In coincidence with Annex No. 2 to the Regulation of the Ministry of Environment of the Slovak Republic No. 244/2016 Coll. of Acts on air quality, in wording of later prescriptions, the critical value for protection of vegetation is 20 $\mu g\ SO_2 \cdot m^{-3}$ in calendar year and winter season. This value was exceeded neither at the calendar year (Chopok 0.44 $\mu g\ SO_2 \cdot m^{-3}$ and Starina 0.62 $\mu g\ SO_2 \cdot m^{-3}$), nor in winter season (Chopok 0.50 $\mu g\ SO_2 \cdot m^{-3}$ and Starina 1.1 $\mu g\ SO_2 \cdot m^{-3}$). Annual average concentration of sulphates, recalculated in sulphur, was 0.12 $\mu g \cdot m^{-3}$ on the Chopok station and 0.44 $\mu g \cdot m^{-3}$ on the Starina station (**Tab. 3.16**, **Fig. 3.9**).

- **Nitrogen dioxide, nitrates**

Nitrogen dioxide concentrations recalculated on nitrogen, presented on the regional stations in year 2020 were 0.94 $\mu g \cdot m^{-3}$ on the Chopok station and 0.31 $\mu g \cdot m^{-3}$ on the Starina station (**Tab. 3.16**, **Fig. 3.9**). In coincidence with Annex No. 2 to the Regulation of the Ministry of Environment of the Slovak Republic No. 244/2016 Coll. of Acts on air quality in wording of later prescriptions, the critical value for protection of vegetation is 30 $\mu g\ NO_X \cdot m^{-3}$ in calendar year. This level was not exceeded during the calendar year (Chopok 3.09 $\mu g\ NO_2 \cdot m^{-3}$ and Starina 4.33 $\mu g\ NO_2 \cdot m^{-3}$). Nitrates on Chopok and on Starina (**Tab. 3.16**, **Fig. 3.9)** were predominantly in particulate form. Gas and particulate nitrates are collected on filters and measured separately. Their phase division is depended on ambient air temperature and humidity. The higher the temperature is, the higher the tendency in favour of gas phase dominates, i.e. HNO_3 formation and vice versa, the higher the humidity is, the higher the tendency in favour of particulate phase dominates, i.e. NO_3^-.

Fig. 3.9 *Monthly average concentrations of air pollutants – 2020 (recalculated on sulphur, resp. nitrogen).*



■ Ammonia, ammonium ions and ions of alkali metals

In coincidence with the requests of the EMEP monitoring strategy for the EMEP stations "level one", the measurements of ammonia, ammonium ions, ions of sodium, potassium, calcium and magnesium in ambient air started to be measured in May 2005 on the Stará Lesná station. These measurements were finished in September 2007. Since July 2007, these ions started to be measured at the Starina station. Annual concentrations of the above mentioned components (NH_3 and NH_4 recalculated in nitrogen) from the Starina station in 2020 are listed in **Tab. 3.16**. Annual concentrations of ammonia represent 0.68 µg N·m^{-3} and ammonium ions 1.52 µg N·m^{-3}.

Tab. 3.16 *Annual average concentrations of pollutants [µg·m^{-3}] in air on EMEP stations – 2020.*

	SO_2	SO_4^{2-}	NO_2	NO_3^-	HNO_3	Cl^-	NH_3	NH_4^+	Na^+	K^+	Mg^{2+}	Ca^{2+}
Chopok	0.22	0.12	0.94	0.08	0.03	0.09	-	-	-	-	-	-
Starina	0.31	0.44	1.31	0.24	0.05	0.19	1.52	0.68	0.18	0.13	0.03	0.15

SO_2, SO_4^{2-} – recalculated on sulphur, NO_2, NO_3^-, HNO_3, NH_3, NH_4^+ – recalculated on nitrogen

■ Atmospheric aerosol, heavy metals

Values of heavy metals lead, copper, cadmium, nickel, chromium, zinc and arsenic concentrations in year 2020 are listed in **Tab. 3.17**. The highest concentration values of copper, lead and zinc were recorded in the Starina station and on the contrary, the lowest values were measured in the Chopok station. In fourth quarter of year 2020 started at the EMEP station Stará Lesná the observation of quantitative composition of fraction PM_{10} on the content of elementary and organic carbon.

Tab. 3.17 *Annual average concentrations of ozone [µg·m^{-3}] and heavy metals [ng·m^{-3}] in air on EMEP stations – 2020.*

	O_3	Pb	Cu	Cd	Ni	Cr	Zn	As	Hg*	EC/OC
Chopok	91	0.82	0.30	0.03	0.22	0.09	1.93	0.07	-	
Topoľníky	24	5.23	1.07	0.04	0.11	0.27	9.81	0.15	1.60	
Starina	54	2,50	0,66	0.04	0.13	0.17	9.73	0.14	1.65	
Stará Lesná	57	2.72	0.65	0.03	0.23	0.20	5.84	0.09	-	2/0.5**

* *Hg is measured out of EMEP monitoring programme.*
** *Calculated only from values for the fourth quarter of year 2020.*

■ Ozone

The longest time series of ozone measurements is in Stará Lesná station, from 1992. The measurements of ozone in Topoľníky, Starina and Chopok begun to be carried out later, in 1994. In 2020, the annual ozone average concentration at the Chopok station reached 91 µg·m^{-3}, in Topoľníky 24 µg·m^{-3}, in Stará Lesná 57 µg·m^{-3} and in Starina 54 µg·m^{-3} (**Tab. 3.17**).

■ Volatile Organic Compounds

VOCs (Volatile Organic Compounds) $C_2 – C_8$, (the so-called light hydrocarbons) started to be sampled in autumn 1994 at the Starina station. Starina is one of few European stations, included into the EMEP network, with regular sampling of volatile organic compounds. The 2020 annual VOC data are listed in **Tab. 3.18**. The laboratory analyses of VOC were carried out in the Central Laboratory of Air Quality (CLI) of Czech Hydrometeorological Institute (ČHMÚ) in Prague in 2020.

Tab. 3.18 *Annual average of volatile organic compound concentrations [ppb] on EMEP station Starina – 2020.*

ethane	ethene	propane	propene	i-butane	butene	2-metylbutane	pentane	hexane	isoprene
2.21	1.11	1.36	0.22	0.41	0.54	0.38	1.57	0.09	0.43
Σ of butenes	**Σ of pentenes**	**benzene**	**i-octane**	**heptane**	**toluene**	**ethylbenzene**	**octane**	**m+p-xylene**	**o-xylene**
0.13	0.05	0.58	0.12	0.13	0.54	0.75	0.12	1.06	0.51

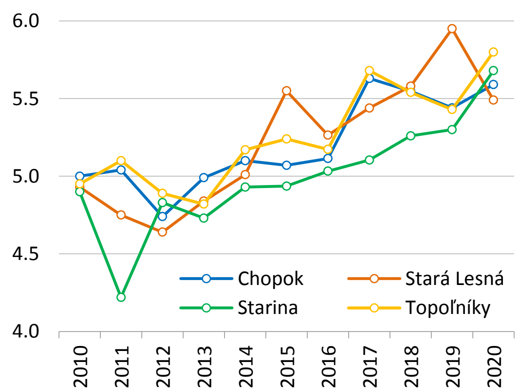
3.4.2 Atmospheric precipitation

Quality of atmospheric precipitation is monitored apart from four EMEP stations also at the Bratislava, Jeséniova, urban background station, which serves as comparison to the measured values on regional stations.

Major ions, pH, conductivity

In 2020, the amount of precipitation recorded at background stations ranged between from 441 to 1285 mm, with upper level of range on Chopok and lowest amount of precipitation on Starina. The lowest annual of pH were recorded in Stará Lesná. On this station was in January recorded precipitation total 14.1 with pH value 4.12 due to very high concentration of sulphates. Precipitation of such low pH is considered as very acid. January and winter seasons on regional stations are regularly months with the lowest pH values, mean values of pH is below 5. In Bratislava such seasonal pH decrease was not observed. It is caused mainly by the different manner of household heating – by gas in Bratislava. Regional stations are influenced by emissions from household heating by solid fuel, in this case probably by coal. The highest mean annual pH values were measured in Topoľníky (**Tab. 3.19**, **Fig. 3.10**). Conductivity of atmospheric precipitation is reflection of cations and anions presence, which are conductive. Concentrations of dominant sulphates in precipitation recalculated in sulphur, present on EMEP stations the range (**Tab. 3.19**, **Fig. 3.11**) 0.22 – 0.33 $mg \cdot l^{-1}$. Concentrations of sulphates are at the low level of range on Chopok and slightly higher on the other stations. Due to significant decrease of sulphate concentrations in air within the last decades, the nitrates, which contributed to acidity of precipitation in smaller role as compared to sulphates, started to play bigger role for the time being also due to less significant decreases of their concentrations. Nitrates showed out the concentration range on EMEP stations recalculated on nitrogen 0.17 – 0.29 $mg \cdot l^{-1}$ (**Tab. 3.19**, **Fig. 3.11**). Low level of concentration range is represented by Chopok and upper by Topoľníky. Ammonium ions also belong to the major ions and their concentration range on EMEP stations presented 0.31 – 0.58 $mg \cdot l^{-1}$ (**Tab. 3.19**). Development of mean annual pH values of atmospheric precipitation on EMEP stations within last eleven years is introduce on graph of **Fig. 3.10.**

Fig. 3.10 pH in atmospheric precipitation.

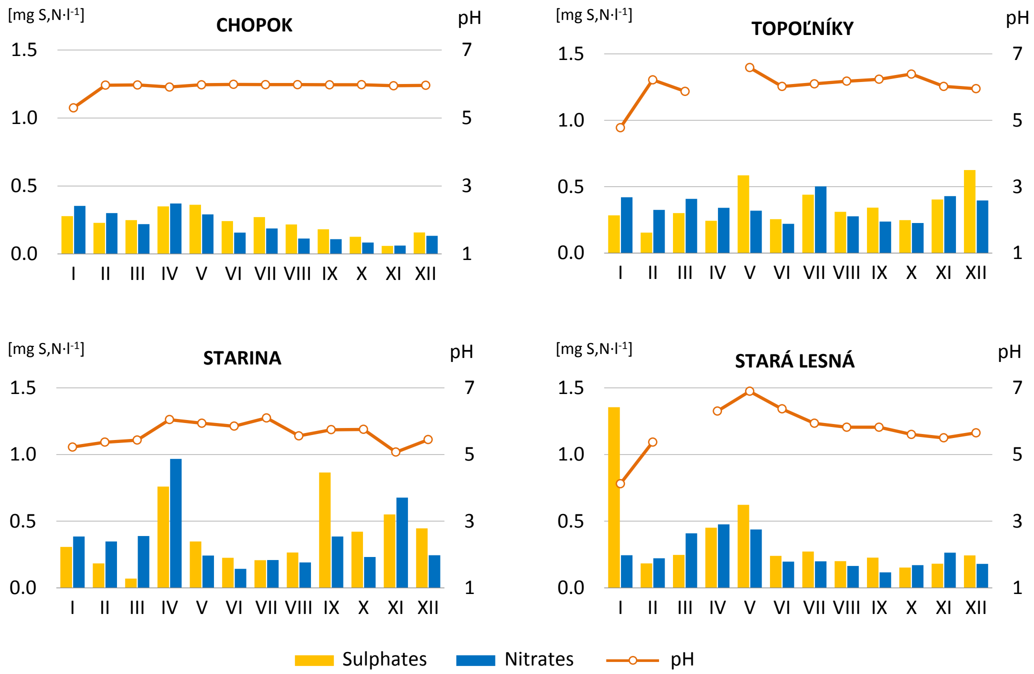


Tab. 3.19 Annual weighted averages of pollutants in atmospheric precipitation – 2020.

	Precip. [mm]	pH	Cond. [μS·cm−1]	SO_4^{2-} [mg·l−1]	NO_3^- [mg·l−1]	NH_4^+ [mg·l−1]	Cl^- [mg·l−1]	Na^+ [mg·l−1]	K^+ [mg·l−1]	Mg^{2+} [mg·l−1]	Ca^{2+} [mg·l−1]
Chopok	1 285	5.59	11.75	0.22	0.17	0.31	0.27	0.15	0.05	0.02	0.12
Topoľníky	494	5.80	13.64	0.33	0.29	0.58	0.20	0.14	0.06	0.04	0.38
Starina	441	5.68	9.87	0.31	0.24	0.30	0.28	0.18	0.20	0.04	0.30
Stará Lesná	716	5.49	9.88	0.27	0.21	0.39	0.35	0.17	0.07	0.02	0.17
Bratislava, Jeséniova	676	6.22	18.39	0.62	0.51	1.00	0.41	0.54	0.24	0.12	1.17

SO_4^{2-} – recalculated on sulphur *NO_3^-, NH_4^+ – recalculated on nitrogen*

Fig. 3.11 Atmospheric precipitation – 2020.



Heavy metals in atmospheric precipitation

Since 2000, the measurement programme of heavy metals in precipitation has been gradually modified and more adopted to meet the requirements of the CCC EMEP (Chemical Co-ordinating Centre of EMEP) monitoring strategy. In frame of EMEP programme, for the stations of "level one", were included the following heavy metals – lead, copper, cadmium, nickel, chromium, zinc and arsenic. In Bratislava-Jeséniova station, the measurements of the same set of heavy metals in precipitation were implemented as in background stations of Slovakia. This station serves for comparison and is not considered as the background station. The results of annual weighted means of heavy metals in atmospheric precipitation in year 2020 are presented in **Tab. 3.20**. Zinc, lead and copper have higher representation among the monitored metals, than the other metals, similarly as at metals in ambient air (**Tab. 3.17**). Long lasting trend of heavy metals has decreasing tendency.

Tab. 3.20 Annual weighted averages of heavy metal concentrations in atmospheric precipitation on EMEP stations – 2020.

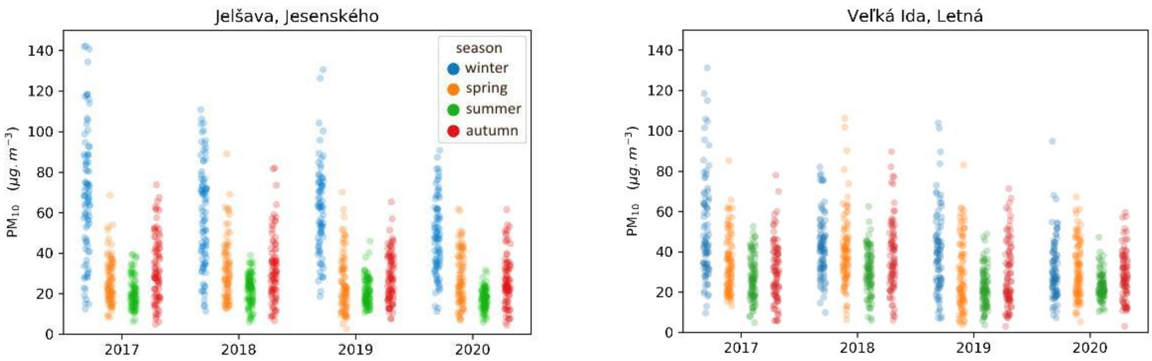
	Precipitation [mm]	Pb [μg·l-1]	Cd [μg·l-1]	Cr [μg·l-1]	As [μg·l-1]	Cu [μg·l-1]	Zn [μg·l-1]	Ni [μg·l-1]
Chopok	1 082	1.21	0.07	0.12	0.19	0.90	17.53	0.21
Topoľníky	457	0.87	0.07	0.15	0.13	0.61	31.94	0.36
Starina	749	0.77	0.09	0.14	0.27	0.74	17.98	0.27
Stará Lesná	754	0.73	0.10	0.12	0.08	0.85	10.41	0.40
Bratislava, Jeséniova	956	1.23	0.08	0.16	0.25	1.14	14.94	0.32

3.5 SUMMARY

■ PM_{10}

The aim of monitoring not only of PM_{10}, $PM_{2.5}$, but also benzo(a)pyrene is sufficiently to cover the territory of Slovakia, considering possible influence of different air pollution sources. Therefore the monitoring stations, reflecting also the impact of heating, will gradually increased. Exceedance of limit value for annual average concentration of PM_{10} was not recorded on any monitoring station in year 2020. Exceedances of limit value for human health protection for 24 hour concentrations were recorded on one AMS Jelšava, Jesenského, as dominant source of PM_{10} on results of monitoring manifests heating of household by solid fuel. Problems are obviously very unfavourable dispersion conditions in winter season. This location is in smaller extent influence also by industrial source. **Fig. 3.12** illustrates more expressive decrease of concentrations of PM_{10} on AMS Jelšava, Jesenského in summer season as compared to AMS Veľká Ida, Letná, reflecting different seasonality of sources. Concentrations measured on location influenced mainly by household heating (Jelšava) are comparable high, as on industrial station Veľká Ida, Letná, sometime even higher. Both stations show longtime higher PM concentrations (as it was mentioned, Veľká Ida is in lesser extent influenced by household heating, it deals mainly about the influence of metallurgical complex).

Fig. 3.12 *Daily mean PM_{10} concentrations on AMS Jelšava, Jesenského and Veľká Ida, Letná.*



Upon the base of exceeding of information, respectively warning threshold, were emitted to the public seven announcements about the smog situation (four for Ružomberok and and per one for Jelšava, Krompachy and Martin and one (Ružomberok) warning before the serious smog situation for PM_{10}. In case, that upon the meteorological forecast was possible to assume the improvement of scatter situation, the announcement, respectively warning were not emitted (conditions are described in chapter **3.3**). **Tab. 3.8** quotes the list of monitoring stations and duration of exceedance of information or warning threshold for PM_{10}.

■ $PM_{2.5}$

For $PM_{2.5}$ is determined the limit value 20 $\mu g \cdot m^{-3}$ (for annual average concentration), valid from 1. 1. 2020. (Executive decision of Commission 2011/850/EU, Annex 1, point 5). This value was not exceeded on any of monitoring station in year 2020.

Health consequences, resulting from air pollution by PM_{10} particles, depend on size and composition of solid pollutants (particles). The smaller the particles are, the more the serious health consequences appear. European and Slovakian legislation therefore dislocate the centre of attention on $PM_{2.5}$. Index, which expresses the trend of loading of inhabitants by $PM_{2.5}$ concentrations, is Indicator of Average Exposition (IAE). It is defined as three years moving average of annual averages of $PM_{2.5}$ from selected urban and suburban background stations (for SR was in year 2020 the whole time line of IAE recalculated - after the agreement with EEA and EC were selected those stations, which had in year 2010 data completeness at least 75%. E.g. IAE 2020 is calculated as average of three average annual concentrations in years 2018, 2019 and 2020. According to the Annex No. 1 to Regulation No. 244/2016 Coll. of Acts, in wording of later prescriptions since 1st January 2020 the limit value was stated on 20 μg·m^3. In **Tab. 3.21** are presented values of this index since the year 2010, which is for IAE reference year. National target of decreasing exposition for $PM_{2.5}$ particles in year 2020 was fulfilled by the Slovak Republic.

National target of exposition decrease for particles $PM_{2.5}$

Target of exposition decrease concerning average exposition indicator in year 2010		Year, in which the target of exposition decrease shall be reached
Beginning concentration in μg·m^{-3}	Aim of decrease	
≤ 8.5	0%	2020
> 8.5 – < 13	10%	
= 13 – < 18	15%	
= 18 – < 22	20%	
≥ 22	All convenient measures to reach 18 μg·m^{-3}	

Commitment of decreasing concentration exposition for particles $PM_{2.5}$

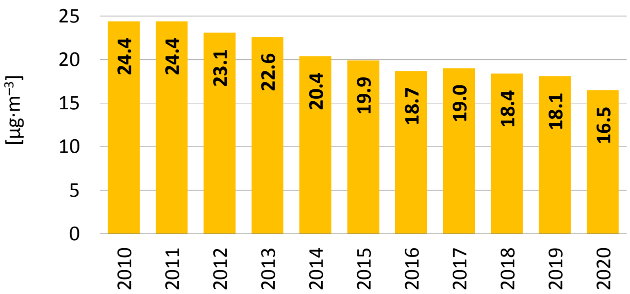
Commitment of decreasing concentration exposition valid from year 2015	**20 μg·m^{-3}**

Tab. 3.21 *Indicator of averaging exposition for $PM_{2.5}$.*

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IAE [μg·m^{-3}]	24.4	24.4	23.1	22.6	20.4	19.9	18.7	19.0	18.4	18.1	16.5

Fig. 3.13 shows the development of Indicator of average exposition (IAE) of $PM_{2.5}$ within last ten years. Its decrease in year 2020 is probably possible to explain by the emission decrease in Slovakia and neighbouring countries. More detailed information will be at disposal after the processing of emission inventories in year 2020 and following analysis by mathematical modelling.

Fig. 3.13 *Indicator of averaging exposition for $PM_{2.5}$ in years 2010 – 2020.*



- **SO_2**

In contrast to PM, NO_2, CO and benzo(a)pyrene, on SO_2 emissions participate mainly industrial sources and system energetics (heat power plants).

In year 2020, the limit values for the average hourly and average daily SO_2 were not exceeded in any agglomeration or zone. At the same time no case of warning threshold exceedance was recorded on monitoring stations of SR this year. Measured concentrations are long term under the limit value.

Critical value for vegetation protection is 20 μg·m^{-3} in calendar year and winter season. This limit value was not exceeded in the year 2020 on any EMEP stations in calendar year, or winter season. All values were below the low limit for vegetation protection.

NO_2

NO_2 originates in atmosphere by oxidation of NO, which is emitted from road transport and different industrial sources. With the distance of source – e.g. from road communication – the share of NO/NO2 is therefore significantly changing in favour of NO_2.

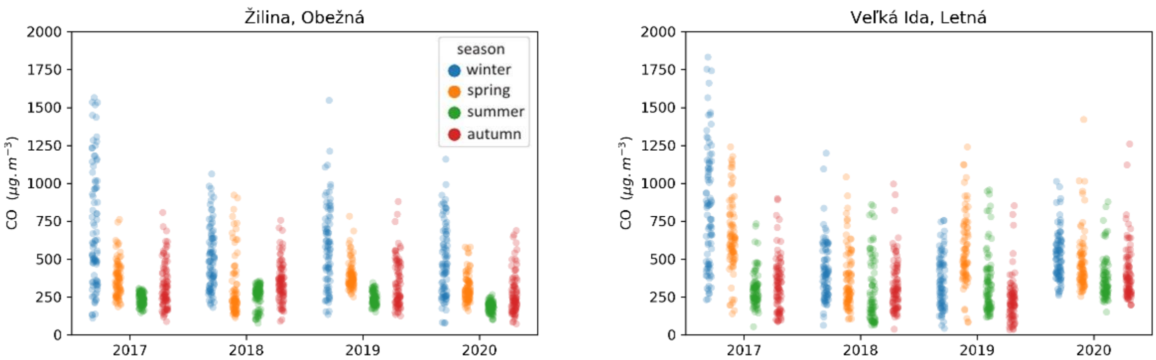
Annual limit value for NO_2 was not exceeded in year 2020, on any monitoring stations. Exceeding of limit value for human health protection for hourly concentrations was also not recorded on any monitoring station. In year 2020 was not recorded even the case of NO_2 warning threshold exceedance.

Critical value for vegetation protection (30 $\mu g \cdot m^{-3}$ in calendar year, expressed as NO_X) was not exceeded on any of EMEP stations in year 2020. Values were deeply below the low limit for vegetation protection and nature ecosystems.

CO

Source of CO emission are burning processes in industry, energetic, household heating and road transport. CO limit value was not exceeded on any of monitoring stations in Slovakia in the year 2020 and level of air pollution during previous period of years 2012 – 2020 is below the low limit for assessment of air pollution level of aerial air. On **Fig. 3.14** is possible to compare course of daily mean concentrations at two different locations – on AMS Veľká Ida, Letná the concentrations are divided approximately uniformly during year, – on AMS Žilina, Obežná the maximum occur in winter months, what can be caused by the influence household heating.

Fig. 3.14 *Daily mean CO concentrations on AMS Veľká Ida, Letná and Žilina, Obežná.*



Benzene

Benzene emissions originate from road transport, in lesser extent from industrial sources.

The major level of benzene was measured on station Krompachy, SNP, in year 2020. However, the values of annual average concentrations were significantly below limit value 5 $\mu g \cdot m^{-3}$.

Ozone

Problem of tropospheric ozone is of regional character, because ozone and its precursors subject to long distance transmission in horizontal and vertical direction. Situation is complicated also by chemism and its origin and degradation in atmosphere – ozone occurs under the presence of sun radiation, e.g. from nitrogen monoxide (from road transport) and volatile organic hydrocarbons (from different burning processes, coatings and dissolvents, but also biogenic sources), under the presence of nitrogen monoxide however the ozone decays. Therefore in vicinity of frequent roads are mostly low ozone concentrations. Higher concentration is possible to measure on suburbs, because nitrogen monoxide oxidizes quickly on nitrogen dioxide and therefore in bigger distance from roads it occurs less.

Fig. 3.15 restrains seasonality of tropospheric ozone concentrations. Ozone distinguishes from other pollutants, (Annex B of this Report) by expressive maximum in summer season. Surface ozone originates at photochemical reactions, from nitrogen monoxide or carbon monoxide and volatile organic substances. Reaction depends upon the intensity of sun radiance (UV-B part of spectrum. In high mountain locations (e.g. on Chopok) the concentrations of ozone are the highest ones.

Target value of surface ozone was exceeded at measurements on three stations: Bratislava, Jeséniova; Bratislava, Mamateyova and Chopok, EMEP. Warning and information thresholds were not exceeded in year 2020 on any station.

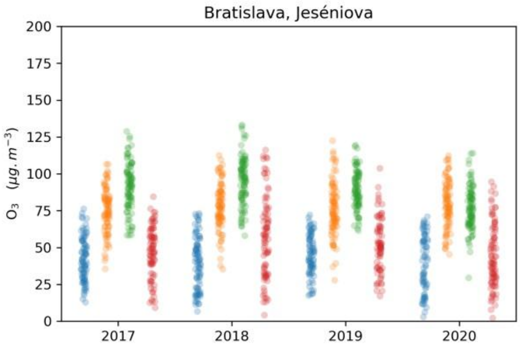
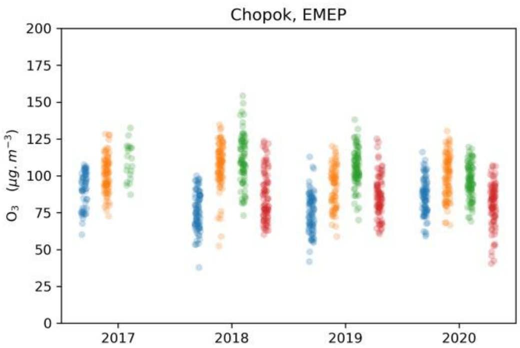
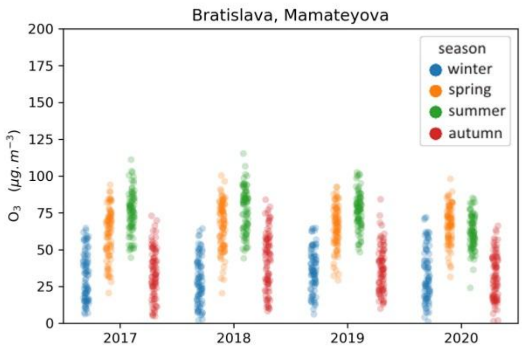


Fig. 3.15 *Daily average concentrations of surface ozone on monitoring stations Bratislava, Jeséniova; Bratislava, Mamateyova and Chopok, EMEP.*





Pb, As, Ni, Cd

Neither limit, nor target values were exceeded in year 2020. Annual average concentrations of heavy metals, measured on NMSKO stations, are mostly only fragment of target, respectively limit value.

BaP

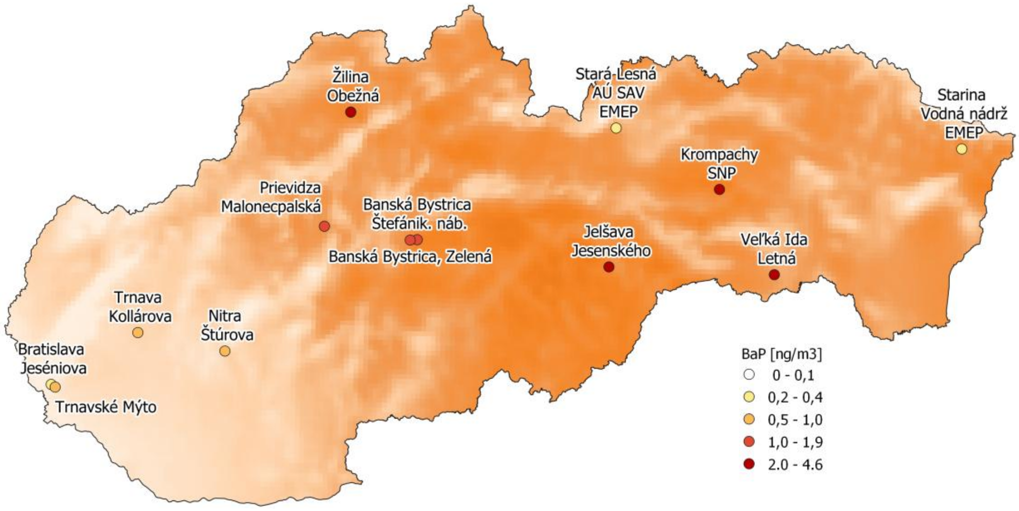
Target BaP value was exceeded on majority of monitoring stations. Therefore is necessary to ***pay increased attention to this pollutant.***

Exceedance of target value (1ng·m^{-3}) was recorded on stations Veľká Ida, Letná; Banská Bystrica, Štefánikovo nábrežie; Banská Bystrica, Zelená; Žilina, Obežná; Jelšava, Jesenského; Krompachy, SNP and Prievidza, Malonecpalská. On monitoring station Ružomberok, Riadok were also measured high concentrations of benzo(a)pyrene, however the measurement started in December, therefore the results cannot be compared with target value, which relates to annual average concentrations. In Veľká Ida the exceedance can be assigned to the industrial activity (mainly to coke production) and partly to the household heating. In Jelšava manifested mainly the influence of the household heating by solid fuel. On the other stations it is dealing about the combination of influence of road transport and the household heating by solid fuels at coal heating. Expressively higher values of benzo(a)pyrene use to be therefore measured mainly in cool half of year at all stations apart from Veľká Ida. Cooler months are in addition characteristic by more often appearing temperature inversions.

Regard to the significance of influence of emissions from household heating and scatter conditions on air quality, the regions endangered by possible high concentrations of PM and benzo(a)pyrene were closer examined. More detailed method and first results are described in Chapter 5.

Map on Fig. 3.16 illustrates ventilation index and annual concentrations of benzo(a)pyrene.

Fig. 3.16 Areal distribution of ventilation index in year 2020 (according to ALADIN model) and annual average concentrations of benzo(a)pyrene [ng·m^{-3}].

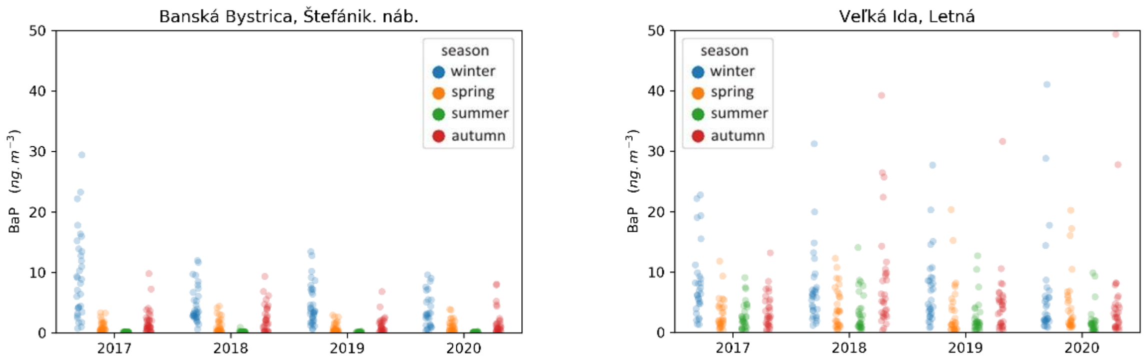


By colour scale is depicted ventilation index in winter months (December, January, February.) Darker colour responds to unfavourable scatter conditions (lower value of ventilation index.) [15]

Note: AMS Trenčín, Hasičská, Ružomerok, Riadok a Rovinka are not depicted on the map, because they started to measure in second half of year 2020.

Annual course of benzo(a)pyrene contains significant maximums winter months at all stations apart from AMS Veľká Ida, Letná, which is influenced apart from household heating also by industrial source – mainly production of coke (Fig. 3.17).

Fig. 3.17 Daily average concentrations of benzo(a)pyrene in yea 2020 on AMS Veľká Ida, Letná and Banská Bystrica, Štefánikovo nábrežie



[15] *The height of mixing multiplied by average wind velocity in layer under this height.*

4 RESULTS OF AIR QUALITY MATHEMATICAL MODELLING

The procedure and the criteria for air quality assessment are set in Act No. 137/2010 Coll. of Acts in wording of later prescriptions, in full compliance with EU directions. According to its rules, mathematical modelling is enable to use for air quality assessment as a supplementary method to the measurements from monitoring stations. The basis for the air quality assessment in Slovakia are results of air pollutant concentration measurements, realized by the Slovak Hydrometeorological Institute on the stations of the National air quality monitoring network (NMSKO). In continuation on measurements, the methods of mathematical modelling are used for spatial assessment of air quality.

Calculations for air quality assessment using mathematical modelling were realized by application of adapted models RIO and CMAQ. These models are different by its method from the models, which were used to air quality assessment in past years. This fact is necessary to take into account at comparison of actual results and results from Report on air quality in year 2019 and years before.

4.1 BRIEF CHARACTERISTICS OF MODELS USED

- **Chemical-transport model CMAQ v5.3**

Community Multiscale Air Quality Modeling System – CMAQ[16], is developing and supporting in Development Centre EPA National Exposure Research Laboratory in Research Triangle Park, NC. CMAQ performs air quality model of the third generation, which means, that it is able to model more air pollutants at the same time in large scales, which can cover the whole continents. It is three-dimensional Euler chemical-transport model, using on simulation of ozone, atmospheric aerosols (PM), oxides of sulphur, nitrogen and other pollutants in troposphere. Expressing mathematically, CMAQ calculates the changes of matter concentrations in time for each cell of grid by the formula of continuity. These changes of concentrations include processes of emissions, advection, diffusion, chemical transformations of air pollutants and removing processes from atmosphere, such are dry and wet deposition on the earth surface. For air quality assessment was initiated the simulation with horizontal resolution 2 x 2 km, with meteorological data from model ALADIN. Calculating domain of model covers the area of central Europe.

- **Regression-interpolation model RIO**

Model RIO[17] is advanced regression interpolation model. Inputs are the measured concentrations and different collater of Regress-interpolation model and spaced fields, which have relation to the space allocation of given pollutant as for example the maps of elevation, traffic intensity, ventilation index, gridded emissions from local heating – while at Regress-interpolation model the complex of these drivers is specific for concrete pollutant. As spatial driver can serve also the results of models, e.g. also of model CMAQ, satellite observations, etc., while with the help of RIO model is possible to gain higher spatial resolution of concentrations. In the first step of calculation, the model detects spatial correlation of given pollutant with individual possible drivers in places of monitoring stations. In further step is optimalized the parameter beta, which comes from combination of spatial drivers with best correlation of spatial allocation of pollutants. The differences among the values in places of monitoring stations, calculated with help of beta parameter and real measurements are then interpolated by the method of ordinary kriging and thereafter are added to the data with the help of

[16] *United States Environmental Protection Agency. (2020). CMAQ (Version 5.3.2) [Software]. Available from https://doi.org/10.5281/zenodo.4081737*

[17] *Janssen, S., Dumont, G., Fierens, F., Mensink, C., 2008: Spatial interpolation of air pollution measurements using CORINE land cover data. Atmos. Environ. 42, 4884–4903. doi: 10.1016/ j.atmosenv.2008.02.043*

beta parameter for each point of grid. For the air quality assessment by RIO model, the spatial resolution 1 x 1 km was used.

- **IDW-R**

Interpolation model RIO belongs to the so called approximate interpolation methods, which means, that field of concentrations smoothest and in places of monitoring stations do not calculate necessarily the same concentration as it had been measured. Therefore the outputs of model RIO or CMAQ for the time being have to be adapted by the technique of IDW-R (inverse distance weighting - regression). In the first step of IDW-R is calculated linear regression curve among the measured data and outputs of model. In the second step is carried out standard IDW interpolation of differences between the measured data and data, calculated by linear regression and by this is gained the 2D map with interpolation differences. This is multiplied by the prescaled input data with values from 0 to 1 and consequently added to the values calculated by regression. Technique is possible to repeat several times consequently under the improving statistical parameters. To the final comparison of model with measurements was used root mean square error (RMSE) and systematic error (BIAS).

4.2 RESULTS AND OUTPUTS

- **PM_{10}**

Dominant source of PM_{10} emissions is household heating, mainly by solid fuel, which performs more than 60% of the total PM_{10} emissions. Emissions of PM_{10} from road transport produces less than 10%, in spite of it; their influence on air quality in vicinity of loaded road communications is not negligible. Large and middle industrial sources and system energetics produce approximately 10% of PM_{10} emissions, by smaller extent contribute waste disposal and agriculture[18]. Problems of PM modelling by chemical-transport, or dispersion model is complicated also relatively outstanding, even if time limited influence of activities, the emissions of which is complicated to quantify and at least localize in space and time – e.g. building and demolition works, agricultural works such as for example ploughing, or harvesting and illegal combustion of agricultural leftovers and waste.

Spatial allocation of PM_{10} concentrations in Slovakia was calculated by RIO model, whereby as additional spatial data were used the emissions from local furnaces (13.7%), ventilation index[19] (5.8%), elevation (45.5%), utilization of country[20] (26%), concentrations from CMAQ model (9%)[21]. After the following adaptation of results by IDW-R method and comparison with measurements is obtained RMSE = 0.2 $\mu g \cdot m^{-3}$ and BIAS = 0.1 $\mu g \cdot m^{-3}$.

Final mean annual concentrations of PM_{10} are on **Fig. 4.1**. As you can see, limit value for mean annual concentration (40 $\mu g \cdot m^{-3}$) was not in this spatial resolution of model ever exceeded. The highest PM_{10} concentrations occur in valley of Gemer, Šariš, Spiš and at the northwest of Slovakia. Relatively high concentrations in East Slovakian lowlands are into certain extent conditioned by the relatively low ventilation index in this domain, however in year 2020 no representative station existed here. If the concentrations forecasted by model are correct, or partly caused also by the error of used method, will be possible to verify in next year, because in between the new station of NMSKO was installed in Trebišov.

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[18] https://www.ceip.at/status-of-reporting-and-review-results - on the individual years and countries
[19] The height of mixing multiplied by average wind velocity in layer under this height.
[20] CORINE Land Cover 2018 https://www.eea.europa.eu/data-and-maps/data/external/corine-land-cover-2018
[21] Percents in brackets express the contribution of individual spatial fields

On **Fig. 4.2** is depicted the number of days, during which was exceeded limit daily mean value of PM_{10} concentrations equal 50 $\mu g \cdot m^{-3}$. Such days must not occur more than 35 times in year. From figure is seen, that this condition is not meet in valleys on Gemer. Higher number of exceedances are generally in less ventilated basin areas of Slovakia with higher share of solid fuel from local heating.

Fig. 4.1 *Mean annual concentrations of PM_{10} [$\mu g \cdot m^{-3}$] in year 2020.*

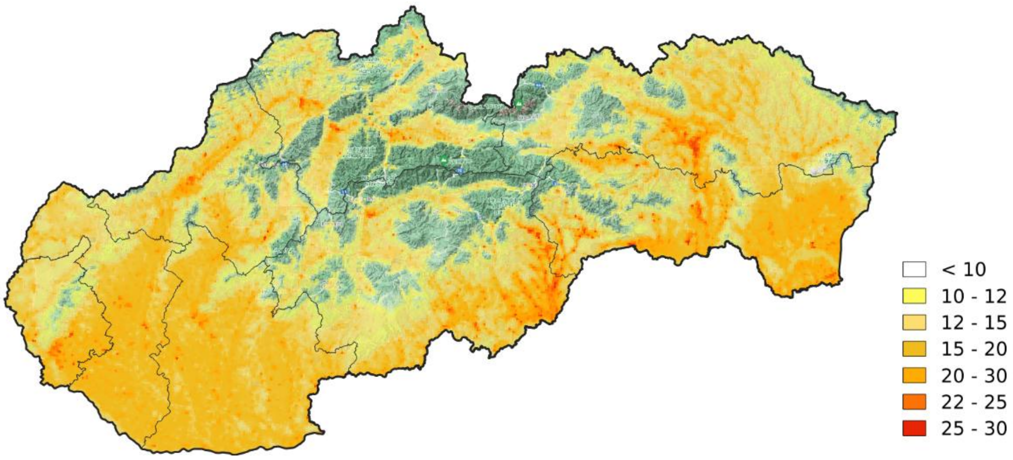
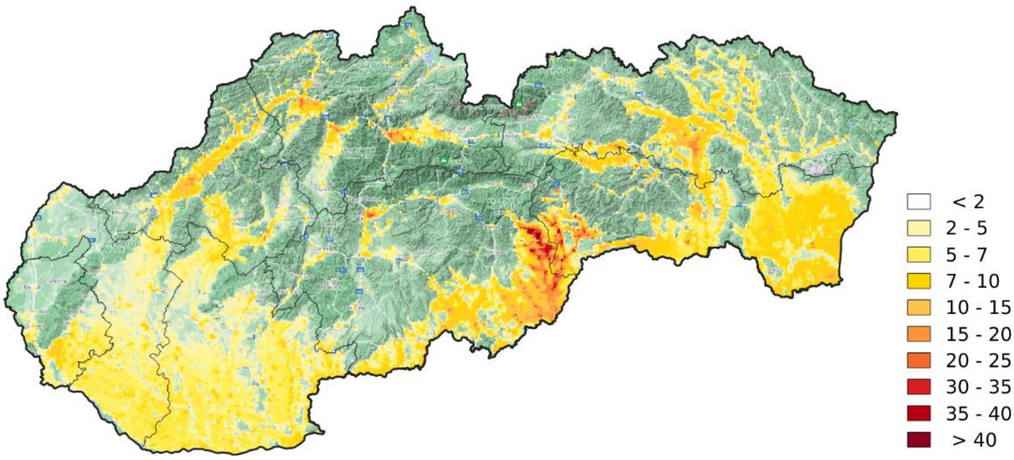


Fig. 4.2 *Number of days with exceedances of limit value for 24-hour concentration of (50 $\mu g \cdot m^{-3}$) in year2020.*



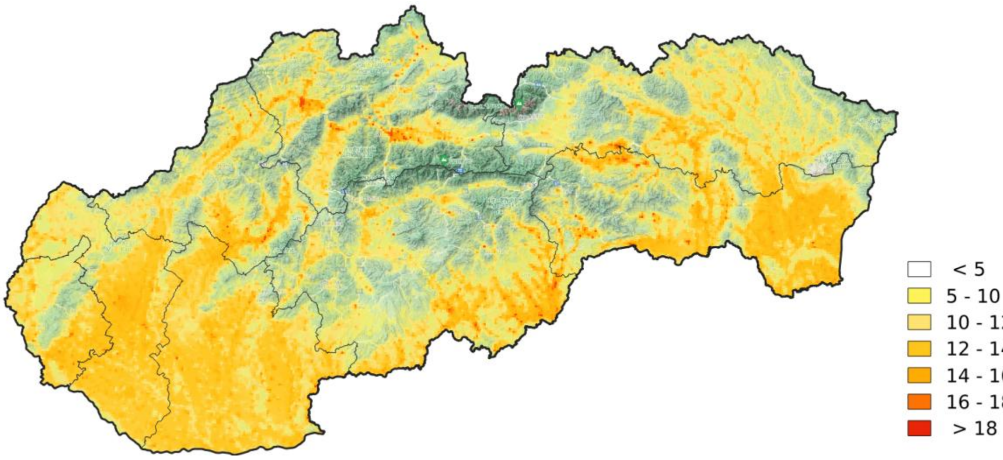
- **$PM_{2.5}$**

Dominant source of $PM_{2.5}$ emissions is household heating, predominantly by solid fuel, which reaches each year for $PM_{2.5}$ even 80% of the total emissions.[22]

Spatial distribution of $PM_{2.5}$ concentrations in Slovakia was calculated by RIO model, whereby as additional spatial data were used emissions from local heating (12.1%), ventilation index (6.4%), altitude (49.3%), country utilization[23] (19.9%), results of CMAQ model (6%) and temperature in 2m (10.7%). After the consequent adaptation of RIO model output by method IDW-R is gained at comparison with measurements RMSE is equal 0.2 $\mu g \cdot m^{-3}$ and BIAS is equal 0.2 $\mu g \cdot m^{-3}$. Final annual mean $PM_{2.5}$ concentrations are depicted on **Fig. 4.3**. Annual mean limit value 20 $\mu g \cdot m^{-3}$ in year 2020 in this spatial resolution was not exceeded in any area of Slovakia, caused probably by mainly mild up to warm winter in given year. The highest concentrations were similarly as in case of PM_{10} in locations with large number of local heating on solid fuel, in closed mountainous valleys.

[22] *https://www.ceip.at/status-of-reporting-and-review-results* - - IIR po jednotlivých rokoch a krajinách
[23] *CORINE Land Cover 2018 https://www.eea.europa.eu/data-and-maps/data/external/corine-land-cover-2018*

Fig. 4.3 *Annual mean concentrations of $PM_{2.5}$ [μg·m^{-3}] in year 2020.*



Benzo(a)pyrene

The most significant source of benzo(a)pyrene emissions is similarly as in case of $PM_{10,}$ the household heating by solid fuel. Share of household heating on the total of benzo(a)pyrene emissions is close to 70%, whereas e.g. in year 2017 (when occurred thermal strongly subnormal January[24]), reached this share more than 80%[25]. From industrial sources the most significant is the coke production, the influence of which is recorded on high concentrations from measurements on industrial monitoring station Veľká Ida, Letná. This station is also in municipality with local furnaces and in vicinity of marginalized community. Household heating almost exclusively manifests in aggravated concentrations of benzo(a)pyrene in mountainous valleys with good accessibility of fuel wood and frequent occurrence of unfavourable dispersion conditions as well as thermal inversions, mainly during winter months. An example of monitoring station, located in such domain is Jelšava, Jesenského. Annual mean concentration of benzo(a)pyrene in year 2020 reach on this station value 3 ng·m^{-3}, while target value is 1 ng·m^{-3}. Annual mean concentration of benzo(a)pyrene on station Veľká Ida, Letná was 4.6 ng·m^{-3}, the highest monthly mean concentrations were measured in December.

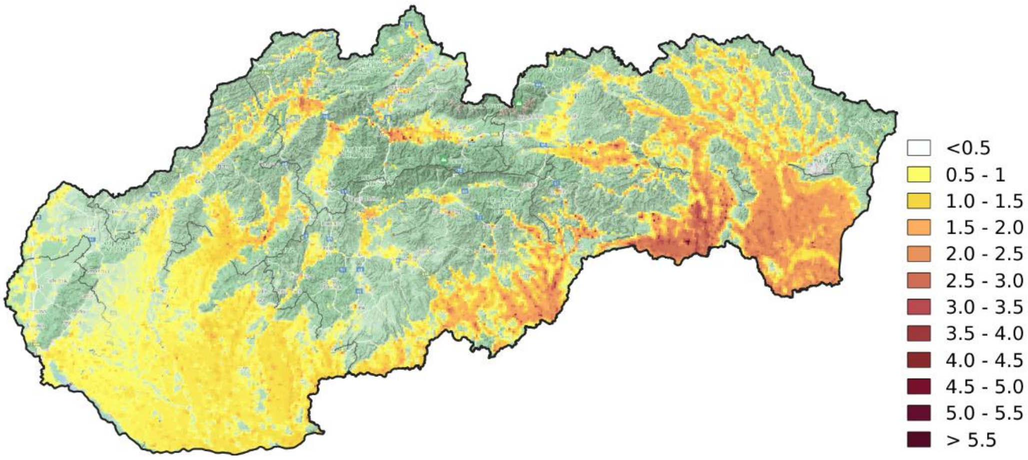
For spatial distribution assessment the interpolation models RIO and IDW-R were used, because the usage of chemical-transport model is in case of benzo(a)pyrene connected with a high uncertainty in spatial and time emission distribution. Situation is complicated also by difficult chemical reactions, which are still the point of research[26]. Due to the relatively small number of stations with monitoring programme of benzo(a)pyrene is quite problematic to carry out the regression and interpolation with RIO model. As far as the correlation of measurement concentrations of benzo(a)pyrene and values of annual mean concentrations of $PM_{2.5}$, calculated in places of monitoring stations by combination RIO and IDW-R is relatively high (correlation coefficient = 0.76), as the input into IDW-R model were used already calculated values of annual mean $PM_{2.5}$ concentrations. Spatial distribution of annual mean values of benzo(a)pyrene at the territory of Slovakia calculated in such way is depicted on **Fig. 4.4**. As compared to measurements, RMSE = 0.1 ng·m^{-3} and BIAS = 0.2 ng·m^{-3}. Limit value of annual mean concentration of benzo(a)pyrene 1 ng·m^{-3}was exceeded in many measurement sites, with exception of background stations and places in the Danube lowlands. This fact reflects also on the results of modelling, whereby on the east of country, the concentrations are the highest ones. Model can the concentrations of benzo(a)pyrene overestimate, mainly in vicinity of Košice and East Slovakian lowlands, because is strongly influenced by high annual mean concentration, measured in Veľká Ida reaching value 4.6 ng·m^{-3}.

[24] *http://www.shmu.sk/sk/?page=1613&id=*

[25] *https://www.ceip.at/status-of-reporting-and-review-results/2019-submissions, - the data submitted in year 2019 are related to the year 2017 http://www.shmu.sk/File/oko/rocenky/SHMU_Sprava_o_kvalite_ovzdusia_SR_2018_v3.pdf*

[26] *Fernández, Israel. (2020). Understanding the reactivity of polycyclic aromatic hydrocarbons and related compounds. Chemical Science. 11. 10.1039/D0SC00222D.*

Fig. 4.4 *Annual mean concentrations of benzo(a)pyrene [ng·m^{-3}] in year 2020.*

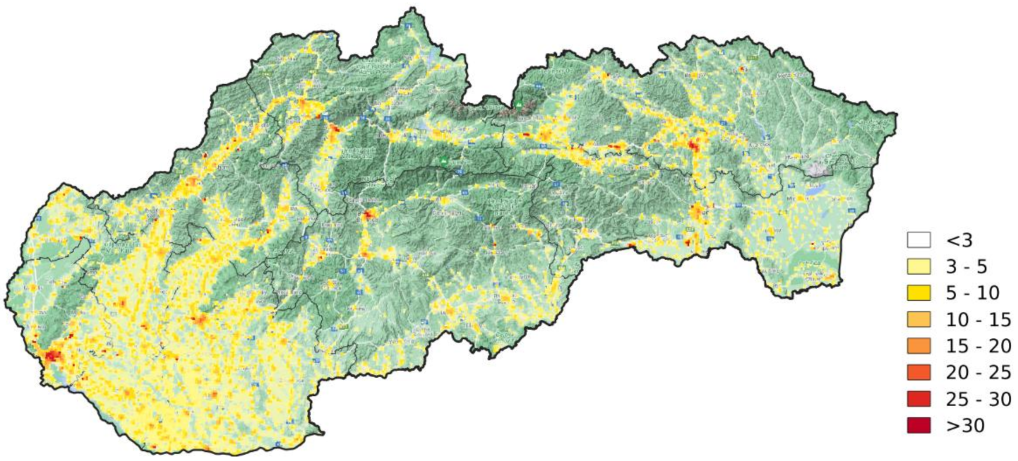


NO_2

In spite of the share of emissions from road transport performs about 35% of total NO_X emissions, the influence of road transports in vicinity of loaded road communications is substantially more significant than the influence of the other kinds of sources, flue gases of which exhausted from higher chimneys are effectively dispersed under the common meteorological conditions.

Spatial resolution of NO_2 concentrations in Slovakia was calculated by RIO model, whereas these auxiliary spatial data were used population density (10.2%), road transport intensity (8%), values of tropospheric column of NO_2 from measurements of satellite Sentinel-5P (5,9%), land use[27] (75%). After following adjustment of model by method IDW-R and comparison with measurements is RMSE = 1.6 µg·m^{-3} and BIAS = – 0.9 µg·m^{-3}. Resulting annual mean concentrations of NO_2 are on **Fig. 4.5**. The highest concentrations occur in vicinity of big cities, so in places with higher road transport intensity. As seen, the model does not capture increasing of concentrations in vicinity of roads out of municipalities. It can be caused either by the really low concentrations here (emissions are in form of NO and did not have time to transform on NO_2 in vicinity of narrow road) or also RIO method with given inputs and resolution is not sufficient. Answer to this question can be provided in near future by modelling with high resolution. From figure is possible to see, that the limit value for annual mean concentration (40 µg·m^{-3}) in year 2020 was not exceeded in given resolution. The similarly also limit value for hourly mean concentration (200 µg·m^{-3}) was exceeded neither according to measured, nor model values of concentrations.

Fig. 4.5 *Annual mean concentrations of NO_2 [µg·m^{-3}] in year 2020.*



[27] *https://land.copernicus.eu/pan-european/corine-land-cover*

Ozone

Spatial distribution of ozone concentrations in Slovakia was calculated by RIO model, whereas as auxiliary spatial field was used only the height above sea level. After the following adaptation of calculated concentrations by IDW-R method and comparing with measurements is received RMSE = 1.2 μg·m^{-3} and BIAS = 0 μg·m^{-3}. Into analyses were taken the data from monitoring stations with relevant data in year 2020. Resulting annual mean ozone concentrations are in **Fig. 4.6**. **Fig. 4.7** illustrates the number of days, in which eight-hour mean concentration of surface ozone exceeded value 120 μg·m^{-3} (i.e. target value for human health protection), whereas the mean number of days is displayed during the period 2018 – 2020. (This mean number of days cannot exceed value of 25). From figure is seen, that more than 25 exceedances in average within period 2018-2020 have high situated mountainous areas and areas on west Slovakia. On **Fig. 4.8** are depicted mean values of AOT40 for vegetation protection during period 2016 – 2020 (according to Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording later prescriptions). Target value 18 000 μg·m^{-3} is also exceeded in high situated mountainous areas and in west Slovakia.

Fig. 4.6 *Annual mean concentration of ozone [μg·m^{-3}] in year 2020.*

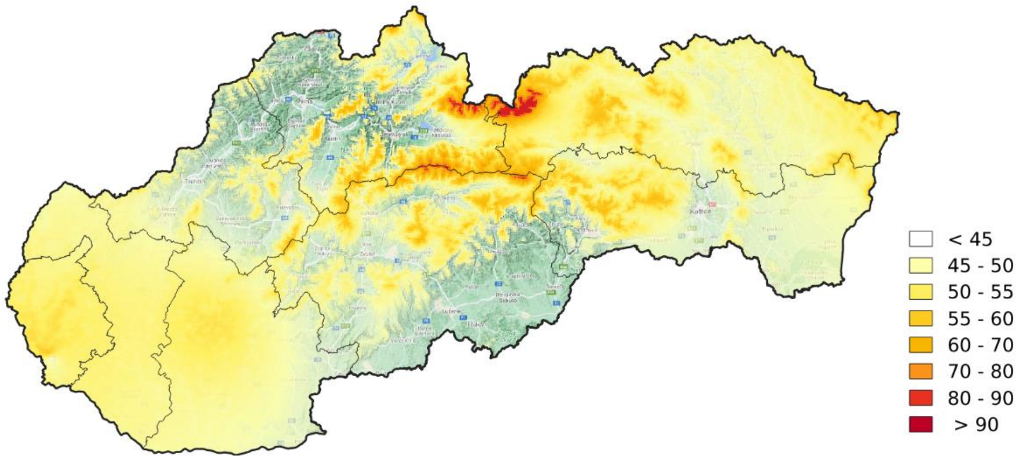
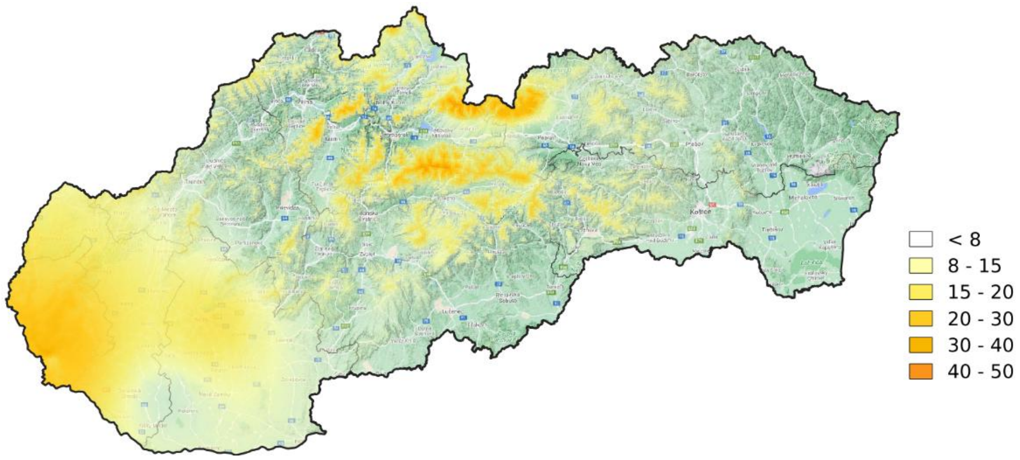
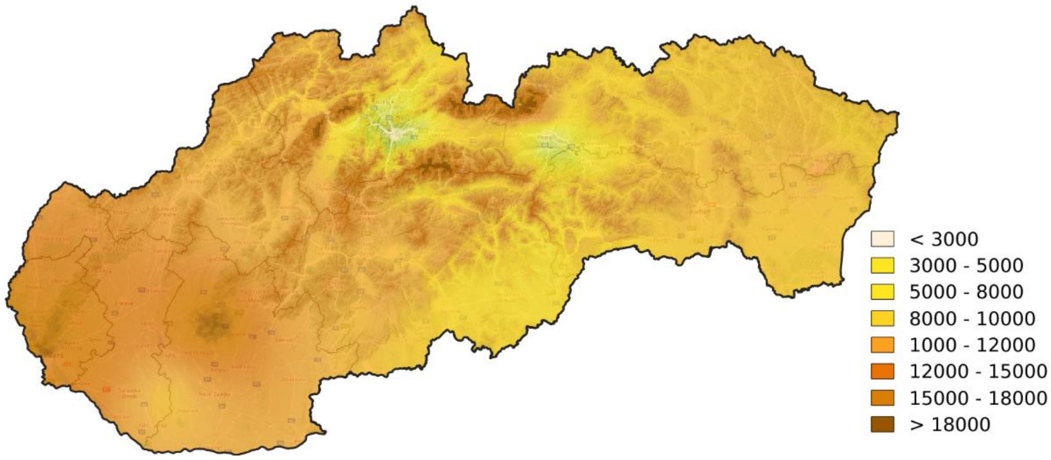


Fig. 4.7 *Number of days, in which eight-hour mean concentration of surface ozone exceeded value 120 μg·m^{-3} (mean during years 2018 – 2020).*



Annual mean concentrations of surface ozone generally increase with altitude, what is caused by penetration of stratospheric ozone into upper layers of troposphere. In year 2020, similarly as in previous years, the maximum values were measured on the highest situated areas and minimum values on the stations in centres of cities, where ozone level is reduced by high NO concentrations. Increased values of ozone are also in marginal domains of bigger urban agglomerations, respectively in industrial zones, where ozone arises mainly by photochemical reactions of oxides of nitrogen with VOCs and CO. For more detailed examination of spatial distribution of tropospheric ozone would be necessary to use chemical-transport model with high resolution and quality emission inputs of ozone precursors. Due to better calibration of model, it would be needed to cover the territory by denser network of stations, or carry out the series of indicative measurements, which would characterized more kinds of environment (locations immediately influenced by road transport, locations in different distances from centre of agglomeration, or from sources of zone precursors. Maps on **Fig. 4.6** to **Fig. 4.8** do not catch therefore the reality sufficiently precise.

Fig. 4.8 *Mean values of AOT40 during period of five years (2016 – 2020).*



SO_2

On SO_2 emissions participate mainly large industrial sources and energetics, in difference from PM and benzo(a)pyrene. Share of household heating on total emissions performs less than 10%. Locally the influence of small sources can manifest in domains, where for households heating is used coal in bigger extent.

Spatial distribution of SO_2 concentrations in Slovakia was calculated by CMAQ model, while the meteorological data from ALADIN model were used.

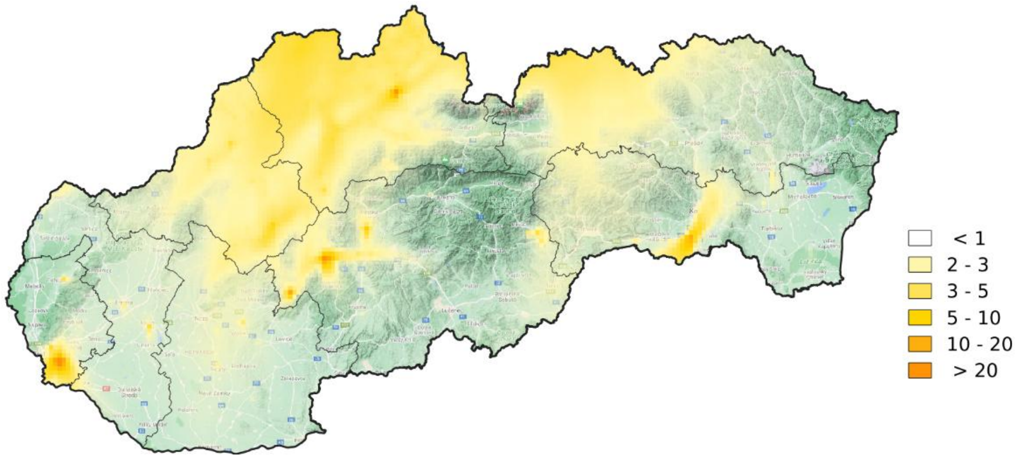
The most important emissions of SO_2 are altitudinal sources (chimneys of industrial or energetic operations). These sources were for the territory of SR gained from NEIS (National emission information system) database. Into calculation were included 711 stacks (vents), the emissions of which represent together 99% of all SO_2 emissions from large and middle sources registered in NEIS database. The most significant sources of SO_2 are U. S. Steel Košice, s.r.o., SLOVNAFT, a.s. (Bratislava), Slovalco, a.s. (Žiar nad Hronom) and Slovenské elektrárne, a.s. (elektráreň Nováky). According to preliminary data the SO_2 emissions registered in NEIS database decreased in year 2020 as compared to year 2019 about 16%. Further into simulation were included SO_2 emissions from local heating (approximately 8% from total emissions) and emissions from road transport (which in case of SO_2 represent less than 1% from total emissions). Outside the territory of SR were used emissions from database TNO-MAC III[28]. Further needed characteristics are changes of emissions during year, which were determined upon the base of character and kind of source (annual operation, seasonal operation, energetics, local heating etc.). However, these changes are in case of large sources sudden and big and is not possible to reconstruct them back with the needed accuracy. It contributes to source of uncertainty in model concentrations.

The measured annual mean concentrations of SO_2 are within the last year's low. It seems, that at such low values the level of sensitivity of measured instruments (analysers) SO_2 was reached, therefore in case of annual mean concentrations of SO_2 the model is calibrated on values of measured concentrations. On resulting map of annual mean concentrations of SO_2 from modelling (**Fig. 4.9**) is possible to see several basic features:

[28] *Kuenen, J.J.P., Visschedijk, A.J.H., Jozwicka, M., Denier van der Gon, H.A.C., 2014. TNOMACC_ II emission inventory; a multi-year (2003-2009) consistent high-resolution European emission inventory for air quality modelling. Atmos. Chem. Phys. 14, 10963–10976. https://doi.org/10.5194/acp-14-10963-2014*

1. The highest concentrations are in locations with direct reach of significant point sources.
2. Increase concentrations are on northeast of Slovakia, where the biggest share of household heating by coal is suppose.
3. The weaker transboundary transport is recognized on north and mainly on northwest of Slovakia, which comes predominantly from Poland Malopoľsko and Sliezko and Czech Ostravsko.

Fig. 4.9 *Annual mean concentrations of SO_2 [μg·m^{-3}] in year 2020.*



Hourly mean concentrations of SO_2 should not exceed 350 μg·m^{-3} more than 24 times in calendar year. Therefore, is calculated 99.7 percentile from hourly values (this percentile corresponds approximately to 25th highest hourly concentration). Interesting is, that in case of 99.7 hourly percentile the results from measurements correlate with CMAQ model relatively good (r = 0.63). It is possible to suppose, that measurements relatively good catch maxim concentrations. Concentrations calculated by CMAQ model were consequently processed by IDW-R method for reaching match with measurements as best as possible (RMSE = 6.7 μg·m^{-3} a BIAS = –2.2 μg·m^{-3}). Resulting 99.7 hourly percentile of SO_2 concentrations is on **Fig. 4.10**, from which is possible to see, that 25th the highest hourly concentration was deeply under the limit value 350 μg·m^{-3}.

Daily mean concentration of SO_2 should not exceed 125 μg·m^{-3} more than 3 times in calendar year. This is represented by 99.2 percentile from daily annual values, value of which correspond approximately the fourth highest daily concentration. Similarly as in previous case were results of CMAQ model processed additionally by IDW-R method (RMSE = 4.1 μg·m^{-3} and BIAS = 1.7 μg·m^{-3}). Resulting 99.2 percentile from daily mean values of concentrations is on **Fig. 4.11**, from which is possible to see, that the 4th highest daily mean concentration was deeply under the limit value 125 μg·m^{-3}.

Fig. 4.10 *99.7 hourly percentile [μg·m^{-3}] of SO_2 concentrations in year 2020.*

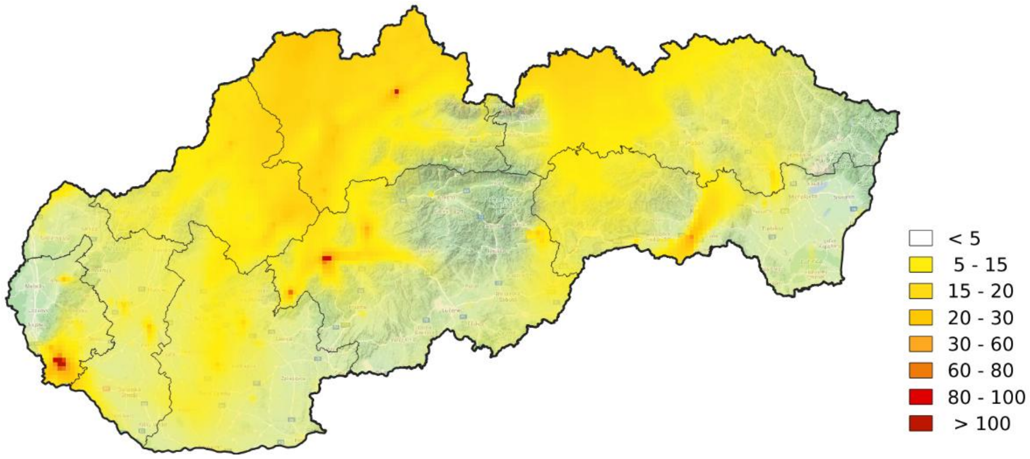
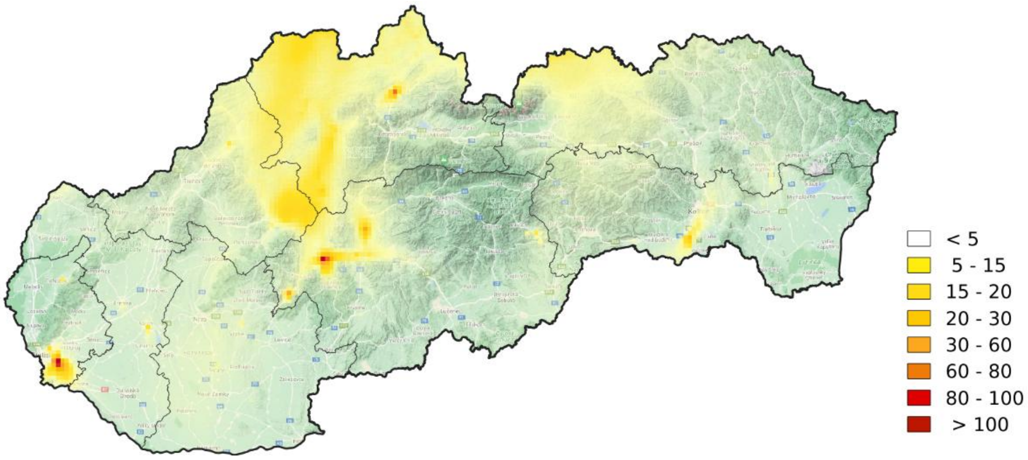


Fig. 4.11 99.2 percentile [μg·m^{-3}] from daily mean values of SO_2 concentrations in year 2020.



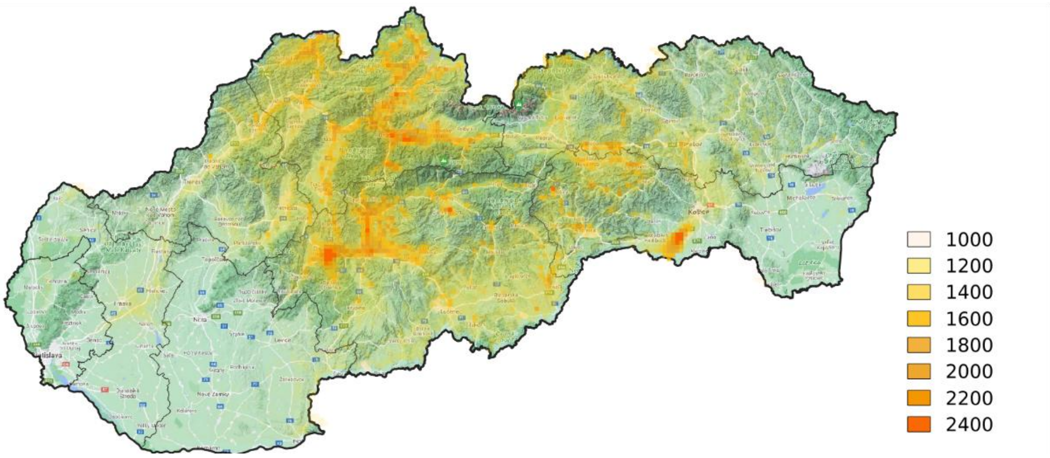
CO

Spatial resolution of CO concentrations in Slovakia was calculated by CMAQ model, whereby the meteorological data from ALADIN model were used.

The most important source of CO emissions are local furnaces (almost 55% of total emissions), following by industrial altitudinal sources, while more than 80% from urban sources create emissions from U. S. Steel Košice, s.r.o.; Slovalco, a.s. (Žiar nad Hronom) and CEMMAC a.s. (Horné Srnie). Into calculation were engaged 912 stacks (vents), from which total annual emissions make up 81% of all CO emissions from large and middle sources registered in NEIS database. Into the simulation were included also emissions from road transport (approximately 20% from total emission inputs) and agriculture (approximately 5% from total emission inputs). Out of the territory of SR were used emissions from TNO-MAC III database. Maximum daily 8-hour moving CO concentrations in year 2020 on Fig. 4.12 were gained from CMAQ model and consequently processed by the use of IDW-R method. Limit value 10 000 μg·m^{-3} was not exceeded. At comparison of model with measurements is gained RMSE = 139 μg·m^{-3} and BIAS = –129 μg·m^{-3}. It is seen from figure, that the highest CO concentrations are in vicinity of significant point sources, in domain of significant roads and in vicinity of local furnaces. Due to the CO is measured practically only on traffic and industrial stations, the real background concentration is difficult to determine also because the CO is chemically stabile and remains in atmosphere relatively long. The lowest measured 8-hour moving CO concentration reached the value approximately 1000 μg·m^{-3}, therefore depicted is upper interval from 0 up to 1000 μg·m^{-3}.

This pollutant does not introduce the problem from point of exceedance the limit value for human health protection.

Fig. 4.12 Maximum daily 8-hour moving concentrations of CO [μg·m^{-3}] in year 2020.

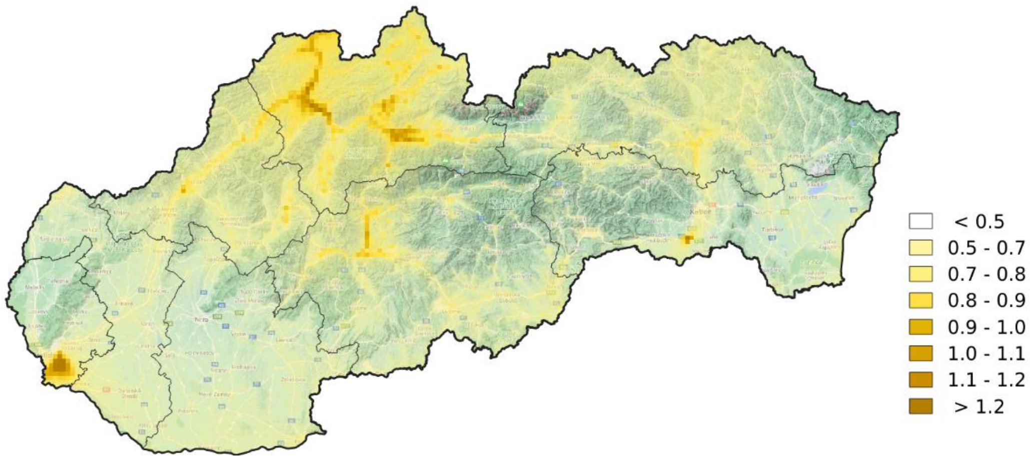


- **Benzene**

Spatial resolution of benzene concentrations in Slovakia was calculated by CMAQ model, whereby the meteorological data from ALADIN model were used.

The highest share on emission inputs for benzene modelling comes from road transport (approximately 66%), local furnaces (more than 19%) and industrial sources (more than 16%) while the most significant sources are SLOVNAFT, a.s. Bratislava a U. S. Steel Košice, s.r.o. Outside the territory of SR the emissions from TNO-MAC III database were used. Annual mean concentrations of benzene in year 2020 on **Fig. 4.13** were gained from CMAQ model and consequently process by use of IDW-R method. Into analyses were included monitoring stations with relevant data. At comparison of model with measurements is gained RMSE = 0.03 μg·m^{-3} and BIAS = – 0.02 μg·m^{-3}. It is seen from **Fig. 4.13**, that the highest concentrations of benzene are in vicinity of significant roads, mainly in v areas with worsen dispersion conditions and in domains in impact of two mentioned industrial sources. However totally, the benzene concentrations are below the limit value 5 μg·m^{-3} also in vicinity the most significant sources.

Fig. 4.13 *Annual mean concentrations of benzene [μg·m^{-3}] in year 2020.*



4.3 CONCLUSION

Mathematical models, anyhow sophisticated, are only approaching to reality, and their results are influenced by relatively high extent of uncertainty, which is considerably depended on quality of input data. The most important input data are meteorological fields and spatial distribution of emissions. At present time the meteorological data can be considered from the point of annual assessment for much more reliable than the emission data, consequently it is possible to state, that emission data are primary source of uncertainties in outputs from air quality mathematical models. Further factor, which is necessary to keep in mind at spatial distribution of concentrations with help of models on regional level, is their spatial resolution. Models used in analyses have horizontal spatial resolution 1 km. Concentration, which is calculated, should represent mean concentration at the territory 1 x 1 km. However on such a territory the spatial changeability of concentrations is usually relatively big, mainly in build-up areas, respectively areas influenced by man. Model with resolution 1 x 1 km therefore necessarily underestimates local maximums (and of course overestimates local minimums). This is related particularly domains, where occur big concentrations of local heating or frequent roads within build up domains, because these sources are in small height above earth surface and cause generally the most outstanding strongly localized PM and benzo(a)pyrene concentrations. For more precise distribution of concentrations in individual cities and determination of local maximums is therefore necessary to use local models with high resolution. Preciseness of these models is however also strongly dependent from preciseness of quality improvements in individual areas of air quality management.

Concentrations of basic pollutants decreased in majority of locations at the territory of Slovakia in year 2020, what is also consequence of meteorologically more favourable situation (smaller emissions from heating during warmer winters, more favourable distribution conditions). The most outstanding problem remains air pollution by PM_{10}, $PM_{2.5}$ and benzo(a)pyrene, whereby the substantial task comes from household heating by solid fuel. Situation is the most complicated in mountainous valleys, in areas with good accessibility of fuel wood and often occurrence of unfavourable dispersion conditions, mainly during heating season. Financial conditions do not permit the local inhabitants to use natural gas for heating or purchase of modern low emission heating equipment.

5 AIR QUALITY ASSESSMENT – FINAL

5.1 PROPOSAL OF ALLOCATION AREAS FOR AIR QUALITY MANAGEMENT IN 2021

SHMÚ upon the base of air quality in zones and agglomerations in years 2018 – 2020, according to § 8 article 3 of Act No. 137/2010 Coll. of Acts on air in wording of later prescriptions proposes updating of allocation areas for air quality management in SR for year 2021.

Air quality management areas (ORKO) are allocated with the aim to identify locations, in which is necessary preferentially target the measures for air quality improvement. By measures for air quality improvement is necessary to cover the largest part of territory, where the high concentrations of pollutants can occur.

As monitoring stations with their limited spatial representation cannot cover the whole country with such complex terrain, as Slovakia has, ***the air quality management areas*** (**Tab. 5.1**), which are identified according to measurements were supplemented about ***risk areas*** (**Fig. 5.5**), identified on the basis of mathematical modelling. In risk areas can occur mainly higher PM and benzo(a)pyrene concentrations.

Allocation of risk areas is complicated problem, therefore for their identification were used several methods – output of chemical-transport CMAQ model with spatial resolution 1.6 x 1.6 km and output of interpolation RIO model with resolution 1 x 1 km (see Chapter **4.1**). Allocation of risk areas use simulations, relating to the year 2017, which was from point of air quality unfavourable. From both models were chosen areas with values of annual mean $PM_{2.5}$ concentrations higher than 90th percentile from values calculated (modelled) for the whole territory of SR.

Air quality can be worsen also on places, on which any from mentioned models may identify. Reasons can be different – e.g. meteorological conditions of reference year are not fully representative for all areas in longer lasting criterion e.g. 10 years. For the time being the accessible information about spatial distribution and the amount of emissions, mainly from local heating are distinguished by big uncertainty, spatial distribution of models is not sufficient to catch the local extremes etc. Therefore also ***areas with possible occurrence of worsen air quality*** were allocated (**Fig. 5.2**). These areas cover places, which can have unfavourable dispersion conditions (mean wind speed in year 2020 less than 2 $m \cdot s^{-1}$ according to the output of ALADIN model with resolution 2 x 2 km). If in such an area occur emission sources, these can cause the higher concentrations of pollutants in air as the equal emissions released into air on places with better dispersion conditions. This additional method is also not fully representative, because for determination of mean wind speed only one year was used. (Outputs from ALADIN model with such a high resolution are not accessible for previous years)

Inaccessibility of sufficient detailed data about household heating, which are important input for the mathematical models, considerably influenced uncertainty of calculated concentrations. Part of measures for air quality improvement should be therefore specification of data about the usage of different fuels at household heating mainly in risk areas and in dependence from local conditions also in domains with possible occurrence of worsen air quality.

Tab. 5.1 *Areas of air quality management for year 2020, allocated upon the base of measurement in years 2018 – 2020 amended for risk areas endangered by possible high PM and BaP concentrations upon the base of mathematical modelling.*

AGGLOMERATION Zone	Allocated area for air quality management	Pollutant	AMS and year of exceedance of limit /target value
BRATISLAVA	Territory of SR capital, Bratislava	NO_2	Bratislava, Trnavské mýto (2018)
	In agglomeration were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
KOŠICE [29]	Territory of Košice city and municipalities Bočiar, Haniska, Sokoľany and Veľká Ida	PM_{10}, $PM_{2.5}$, BaP	PM_{10}: Košice, Štefánikova (2018 – 2019); Veľká Ida (2018 – 2019) $PM_{2.5}$: Veľká,Ida 2018 (24.4 μg·m^{-3}), 2019 (20.7 μg·m^{-3}) BaP: Veľká Ida (2009 – 2020)
	In agglomeration were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Banská Bystrica region	Territory of Banská Bystrica city	PM_{10}, BaP	PM_{10}: Banská Bystrica, Štefánikovo nábr, (2018) BaP: BB Štefánikovo nábr. (2018 – 2020), Zelená (2019 – 2020)
	Territory of Jelšava city and municipalities Lubeník, Chyžné, Magnezitovce, Mokrá Lúka, Revúcka Lehota	PM_{10}, $PM_{2.5}$, BaP	PM_{10}: Jelšava (2018 – 2020) $PM_{2.5}$: Jelšava 2018 (23.7 μg·m^{-3}), 2019 (20.9 μg·m^{-3})
	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Bratislava region	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Košice region [30]	Territory of Krompachy city	BaP	Krompachy, SNP (2019 – 2020)
	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Nitra region	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Prešov region	Territory of Prešov city and municipality Ľubotice	NO_2	Prešov, Arm. Gen. L. Svobodu (2018)
	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Trenčín region	Territory of Trenčín city	PM_{10}	Trenčín, Hasičská (2018)
	District Prievidza	BaP	Prievidza, Malonecpalská (2020)
	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Trnava region	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	
Žilina region	Territory of Ružomberok city and municipality Likavka	$PM_{2.5}$	Ružomberok, Riadok 2018 (20.7 μg·m^{-3})
	Territory of Žilina city	$PM_{2.5}$, BaP	$PM_{2.5}$: Žiliina, Obežná 2018 (21.7 μg·m^{-3}) BaP: Žiliina, Obežná (2019 – 2020)
	In zone were determined risk areas upon the base of modelling.*	PM_{10}, $PM_{2.5}$	

** These areas are marked on the map of risk municipalities and districts* **Fig. 5.5.**

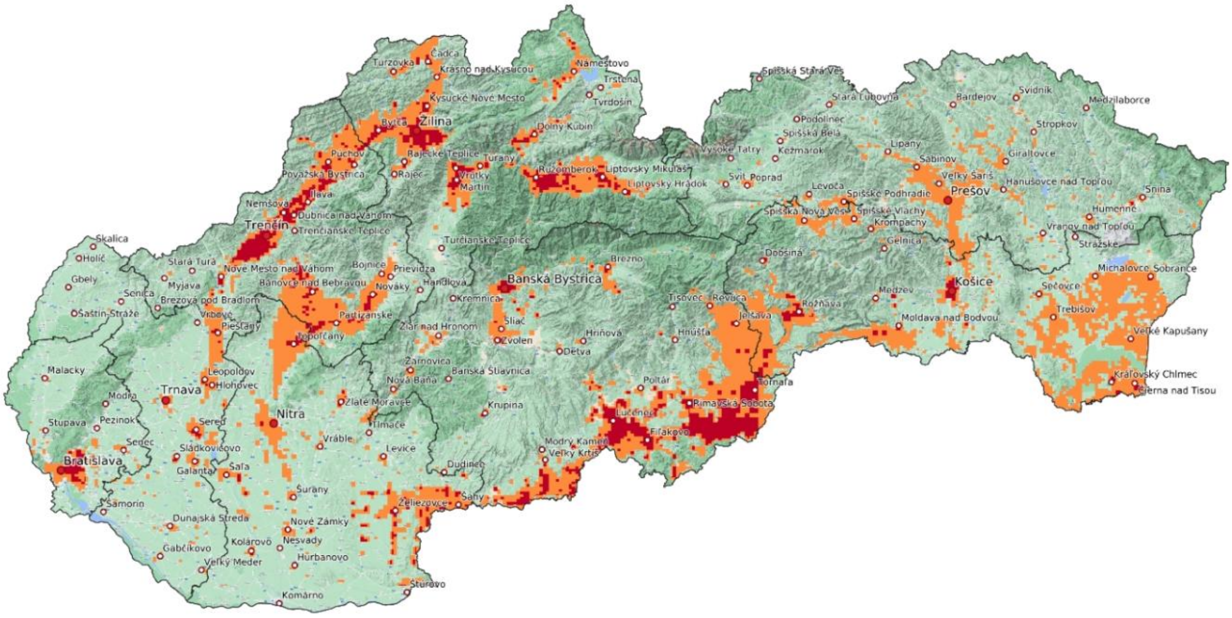
Note: Concentrations of $PM_{2.5}$ were assessed taking into account limit value for annual mean concentration, which is valid since 1.1.2020 (20 μg·m^{-3}).

Target value for human health protection for ozone was exceeded in assessed years 2018 – 2020 in Bratislava agglomeration and also in zone Slovakia (**Tab. 3.12**).

[29] *Agglomeration Košice - territory of the Košice city and municipalities Bočiar, Haniska, Sokoľany and Veľká Ida http://www.shmu.sk/sk/?page=1&id=oko_info_az*

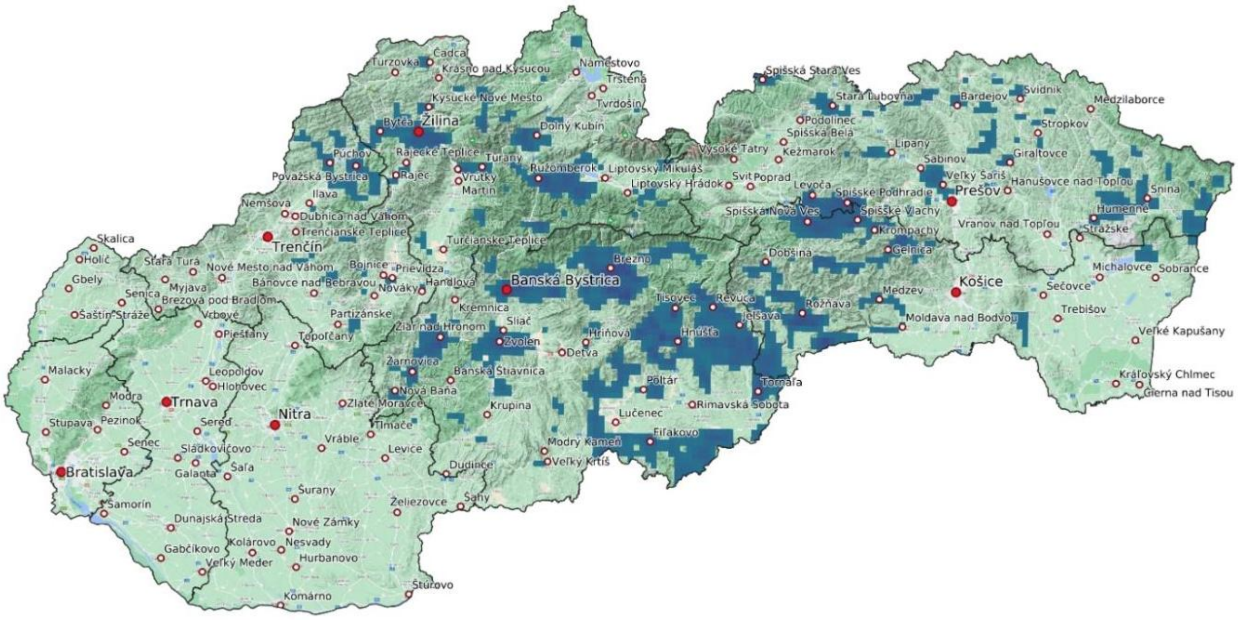
[30] *Zone Košice region - territory of Košice region without Košice agglomeration http://www.shmu.sk/sk/?page=1&id=oko_info_az*

Fig. 5.1 *Risk areas allocated upon the base of air quality modelling results.*



Note: Risk areas were allocated upon the output of RIO interpolation model and chemical-transport model CMAQ. By darker colour (red) are highlighted areas, where maximum concentrations on outputs of both models overlap and the probability of higher PM concentration occurrence is here therefore higher. By orange colour are marked areas indicated only by one of the models (CMAQ or RIO).

Fig. 5.2 *Areas with possible occurrence of worsen air quality.*



Note: As areas with possible worsen air quality the selected locations were chosen, where the mean wind velocity is less than 2 m·s^{-1} (according the output of ALADIN model, spatial resolution 2 x 2 km). On the map are these areas marked by blue colour.

Fig. 5.3 *Risk areas and areas with possible occurrence of worse air quality.*

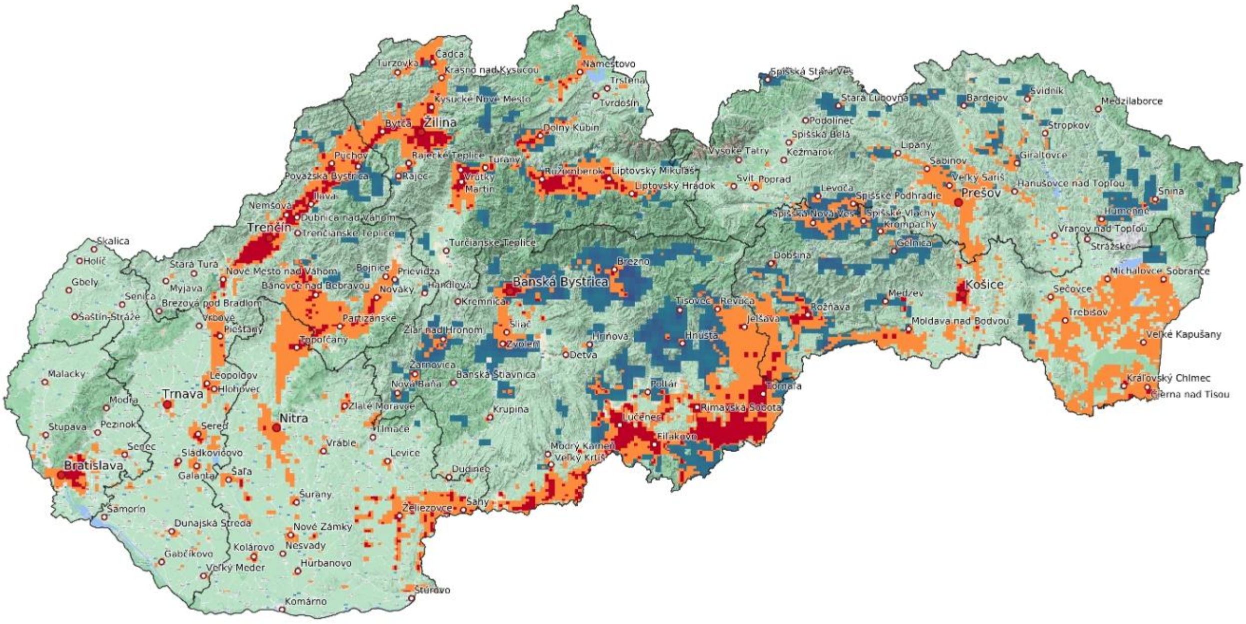
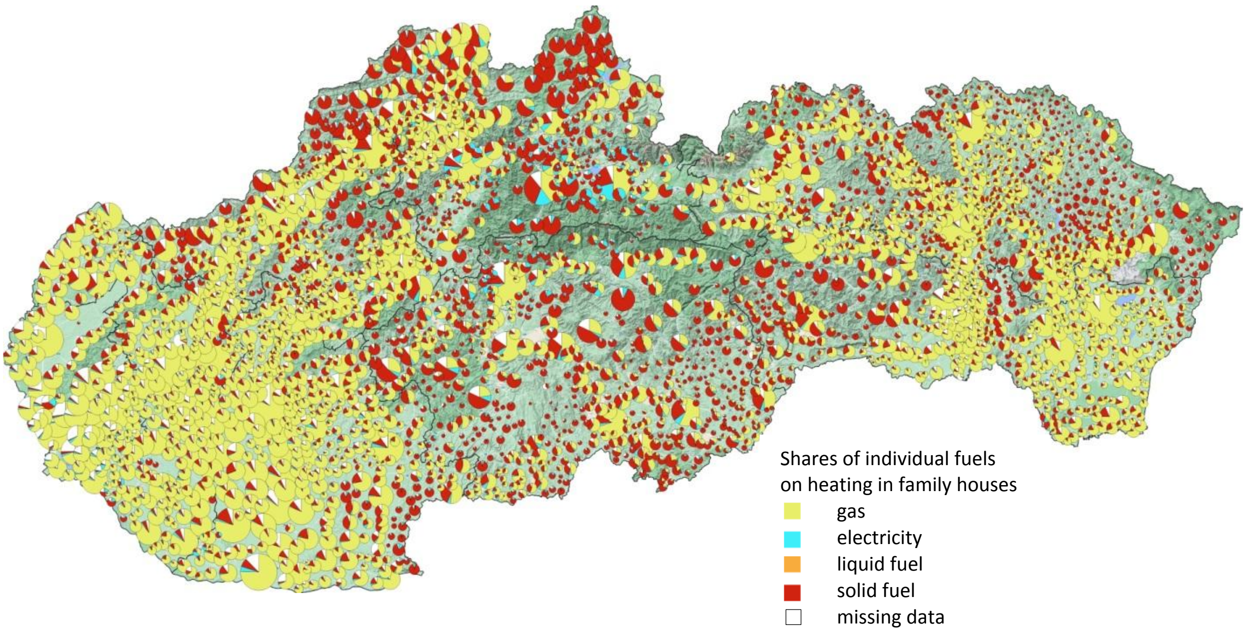


Fig. 5.3 connects maps on **Fig. 5.1** and **Fig. 5.2.** Risk areas are marked by red and orange colours, while by red colour are highlighted areas, where risk is higher (were indicated by chemical-transport CMAQ model and also by interpolation model RIO, adapted by method IDW-R), meanwhile orange areas were indicated by the one of models (CMAQ or RIO). Areas marked by blue colour have probably worsen dispersion conditions (mean wind speed < $2 m \cdot s^{-1}$ according to ALADIN model).[31]

Fig. 5.4 *Share of fuels used for heating in family houses.*



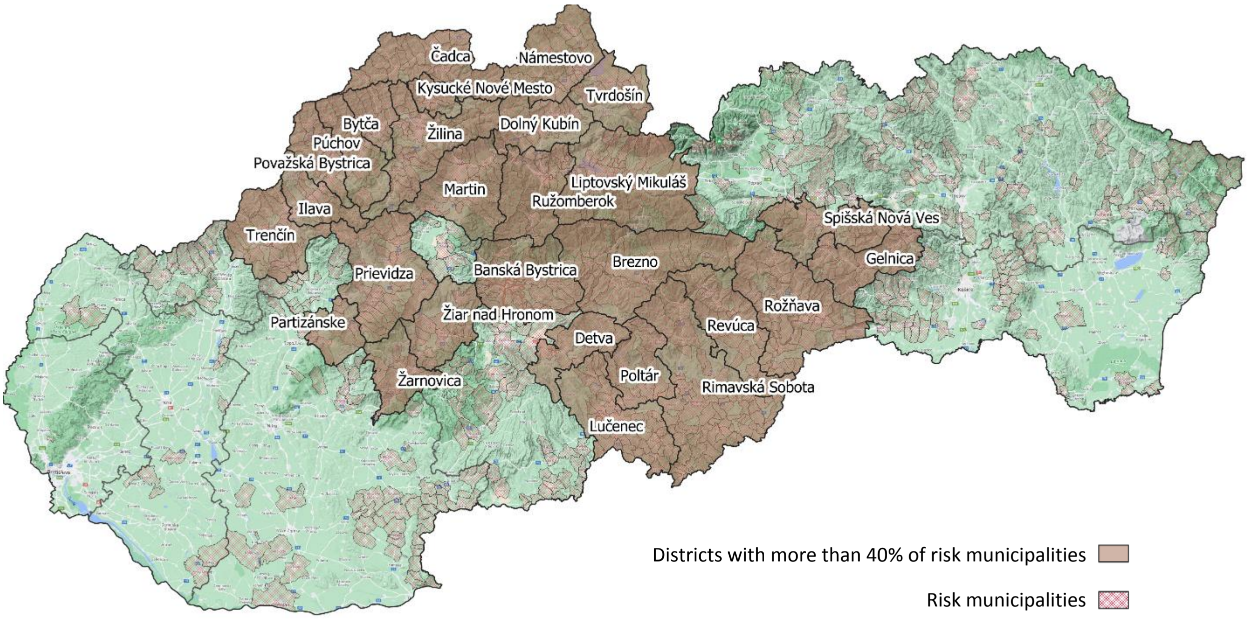
Note: In map are processed information from inhabitant census, houses and flats in year2011.

[31] map is accessible here: https://ruraj-git.github.io/folium_html/orko_2021.html

For illustration on **Fig. 5.4** is depicted the share of fuels used for heating of family houses, processed according data from census of inhabitants, houses and flats in year 2011[32]. These are the last complex and relatively detailed information about the kind of heating, kind of fuel used, in SR. Estimates of emissions in following season are calculated by the help of different collateral data and extrapolations, which are however necessary regularly to validate by the direct investigation and until now were realized only in very limited extent.

Using of mentioned data was proposed the method for determination of risk municipalities[33] endangered by possible worsen air quality a consequence of household heating by solid fuel and unfavourable dispersion conditions. Note: Districts containing at least 40% of risk municipalities were allocated the whole as risky. Risk municipalities and districts are demarcated on the map **Fig. 5.5**.

Fig. 5.5 Map of risk municipalities and districts



Results of mathematical modelling are burdened by bigger error than the results from monitoring. They are influenced mainly by uncertainties of emission inputs in chemical-transport model and by locations of monitoring stations in interpolation models.

It is expected, that results will be more precise in the future, taking into account increasing quality of input data.

[32] *https://slovak.statistics.sk/wps/portal/ext/Databases/datacube/!ut/p/z0/04_Sj9CPykssy0xPLMnMz0vMAfIjo8ziw3wCLJycDB0NLEw9TA0cnZ0CTUJ9DIxMfAz1C7IdFQHnSkqO/*

[33] *D. Štefánik: Určenie rizikových obcí s kvalitou ovzdušia ohrozenou lokálnym vykurovaním a zhoršenými rozptylovými podmienkami. SHMÚ, Bratislava, august 2021 dostupné na https://www.shmu.sk/File/oko/studie_analyzy/Popis%20met%C3%B3dy%20na%20ur%C4%8Denie%20rizikov%C3%BDch%20oblast%C3%AD.pdf*

LIST OF ANNEXES