2019

AIR POLLUTION IN THE SLOVAK REPUBLIC

Air quality department
SLOVAK HYDROMETEOROLOGICAL INSTITUTE

Bratislava, September 2020
Version 1

Material was elaborated by:

Slovak Hydrometeorological Institute
Air quality department
Jeséniova 17, 833 15 Bratislava

Responsible: M. Kremler

Coordination: M. Mladý, J. Jagnešáková

Editor: M. Mladý

Graphical design and processing: K. Pukančíková

Authors:

Chapter 1 - J. Matejovičová, D. Štefánik, J. Krajčovičová, M. Mladý
Chapter 2 - B. Paveleková, M. Mitošinková, M. Mladý
Chapter 3 - B. Paveleková, M. Mitošinková, J. Matejovičová, V. Mináriková
Chapter 4 - G. Szabó, J. Matejovičová
Chapter 5 - B. Paveleková, J. Matejovičová, J. Krajčovičová, D. Štefánik
Chapter 6 - J. Szemesová, I. Bellušová, M. Jalšovská, Z. Jonáček, K. Tonhauzer, J. Horváth, L. Zetochová, M. Câmpian
Annexes - L. Čaracký, M. Mladý, A. Camara, J. Matejovičová

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

CONTENT

FOREWORD

By the Report on air quality in the Slovak Republic in 2019, is submitted to the wide laic and professional public, the information on air status, monitoring network, emission inventories, the results of modelling and air quality assessment. It is dealing about the integrated document, aiming to improve informedness of citizens about pollutants in ambient air and impact of actual international and national politics in the field of air quality management. Behind the presented results are years of labour, studies, consultations with domestic partners and experts from abroad. Only real knowing of present status may help to the air protection authorities to look for the possibilities how to improve its quality and how to abate the amount of emissions.

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 reached the level 80 – 150 $ug.m^{-3}$, for the time being it is approximately 10-times less. Acidity of atmospheric precipitation decreased, as well as concentrations of oxides of nitrogen. Concentrations of heavy metals decreased several times. 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 lead-free fuel in road transport was reflected in reaching such level of lead in air, which is several times lower than the limit 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 arises at 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, also at present. As causes 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 results via long range transport, also 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 episodical worsening of air quality manifests also in vicinity of source. Metallurgical complex on east of Slovakia is the only large source, which contributes within the whole year to the higher concentrations of pollutants also in its vicinity.

Crux of the air pollution problem in Slovakia in last period is shifted 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 dispersal 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 frequented 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 insufficiently cleaning 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 sharing of different sources on the measured concentrations. The results of mathematical modelling may help also to identify the problematic areas, 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 and share of individual air pollution sources on air pollution at the territory of the Slovak Republic.

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 pollutant on the Earth surface, or vegetation. Wet deposition means washing out by atmospheric precipitation, which by this way very effectively diminishes air pollutant concentrations and enables 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 appearance 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 the Slovak Republic 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 $m.s^{-1}$, on the east of Slovakia 2 – 3 $m.s^{-1}$.

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 $m.s^{-1}$, in more closed basins, where is the major occurrence of inversions (e.g. Zvolen basin, Žiar basin, Žilina basin) 1 – 2 $m.s^{-1}$ 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 $m.s^{-1}$. In lower positions exist also localities (Košice, Bratislava) with annual average wind velocity higher than 4 $m.s^{-1}$, 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 ones and is the warmest and relatively windiest area of Slovakia.

1.1 ALLOCATION OF THE TERRITORY INTO AGGLOMERATIONS AND ZONES IN 2019

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. This Report on air quality assessment in the Slovak Republic is submitted for 2019. From the above mentioned reason, the described allocation and assessment reflects the status in 2019, i.e. without valid amendment 32/2020, which is already valid for the time being.

1.1.1 Allocation of the territory into zones and agglomerations in 2019, for SO_2, NO_2, NO_X, PM_{10}, $PM_{2.5}$, benzene and CO

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

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.

Chapter 1.1.1 involves the short characteristics of zones and agglomerations in light of orography and air pollution sources (Chapter 6 is devoted more detailed to air pollution sources).

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

Bratislava is located in segmented terrain of altitude from 126 m (Čuňovo) to 514 m (Devínska Kobyla). From southwest to northeast is extended the mountain of the Small Carpathians, west part of Bratislava is situated 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)

Košice city is situated in the valley of Hornád River, in Košice basin, according to the orographic classification it belongs to the belt of inner Carpathians. Slovenský kras interfers into this region from the southwest, 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

Air quality in Košice is influenced by the sources of pollution from close industrial complex (production of coke, iron, steel, cement), which is situated in distance about 10 km in southwest direction apart from cadastral territory. 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 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 at the territory of Slovakia the smallest one by extending among regions. 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.

[1] *https://www.ssc.sk/files/documents/dopravne-inzinierstvo/csd_2015/ba/scitanie_tabulka_ba_2015.pdf*
[2] *https://www.ssc.sk/files/documents/dopravne-inzinierstvo/csd_2015/ke/scitanie_tabulka_ke_2015.pdf*

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 counting) 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 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 less significant as compared to basic air pollutants.

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 ventilated well from larger part.

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

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

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 counting).

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 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, Krivánska Fatra, Kysucké Beskydy,

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

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

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 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.

---

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

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

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 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 Košice region at Veľká Ida is located industrial complex, dedicated to metallurgy of iron, steel and coke production. This complex is the dominant industrial source of air pollution. Among the further industrial sources belong production of secondary copper and cement factories.

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

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

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 [km²]	Number * of inhabitants
Bratislava region	2 053	669 592
Trnava region	4 146	564 917
Trenčín region	4 502	584 569
Nitra region	6 344	674 306
Žilina region	6 809	691 509
Banská Bystrica region	9 454	645 276
Prešov region	8 973	826 244
Košice region	6 754	801 460

** Status to 31. 12. 2019* *Source: Statistical office of SR*

1.1.2 Allocation of the territory into zones and agglomerations in 2019 for arsenic, cadmium, nickel, lead, polycyclic aromatic hydrocarbons, mercury 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.

Opposite situation occurs in relation to polycyclic aromatic hydrocarbons, which are released into the air from imperfect combustion, mainly of solid fuels and waste. Dominant source in SR for the time being is household heating by solid fuels, road transport (predominantly exhausted emissions from diesel combustion motors), further metallurgy and heating plants. From the completely big group of polycyclic aromatic hydrocarbons, which contains more potential carcinogens (*Air quality in Europe – 2019*, p. 43), benzo(a)pyrene (BaP) was chosen by the EU legislation. Determined target value for BaP is in Chapter 3. Zone for BaP is the whole territory of SR, due to the fact, that air pollution sources, such are household heating and road transport, occur in all regions. Bratislava was allocated as agglomeration.

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.

As zone for arsenic, cadmium, nickel, lead, polycyclic aromatic hydrocarbons and ozone, the whole territory of SR without agglomeration Bratislava was chosen for simplification.

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

1.2 THE LIST OF AIR QUALITY MANAGEMENT AREAS FOR YEAR 2019

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 prescriptions) 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 integrated 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 2016 – 2018, are presented in **Tab. 2.1.**

Tab. 1.2 *Areas of air quality management for year 2018, defined upon the base of measurements in years 2016 – 2018 (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 [km^2]	Number of inhabitants*
BRATISLAVA	Territory of capital of SR, Bratislava	NO_2, BaP	368	437 726
KOŠICE **Košice region**	Territories of Košice city and municipalities Veľká Ida, Sokoľany, Bočiar and Haniska	PM_{10}, BaP	296	245 642
Banská Bystrica region	Territory of Banská Bystrica city	PM_{10}, BaP	103	78 084
	Territory of Jelšava city and municipalities Lubeník, Chyžné, Magnezitovce, Mokrá Lúka, Revúcka Lehota	PM_{10}, $PM_{2.5}$, BaP	109	6 283
	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	11 498
Košice region	Territory of Krompachy city	PM_{10}, BaP	23	8 684
Prešov region	Territory of Prešov city and Ľubotice municipality	PM_{10}, NO_2	79	92 066
Trenčín region	Territory of Prievidza city	BaP	43	45 634
	Territory of Trenčín city	PM_{10}	82	55 383
Nitra region	Territory of Nitra city	BaP	100	76 533
Žilina region	Territory of Ružomberok city and Likavka municipality	PM_{10}	145	29 590
	Territory of Žilina city	PM_{10}, $PM_{2.5}$, BaP	80	80 727

** Status to 31. 12. 2019*

2 AIR QUALITY MONITORING NETWORK

Despite of the fact, the first air pollutant measurements in Slovakia were performed 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 SO_2 and dust fall 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 about 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 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 Transport of Air Pollutants in Europe). Location of monitoring stations of network NMSKO and their measurements programme in year 2019 is presented in **Fig. 2.1**.

Detailed list of monitoring instruments and methods used for the individual stations is in Annex A – Measurement stations of monitoring air quality networks – 2019.

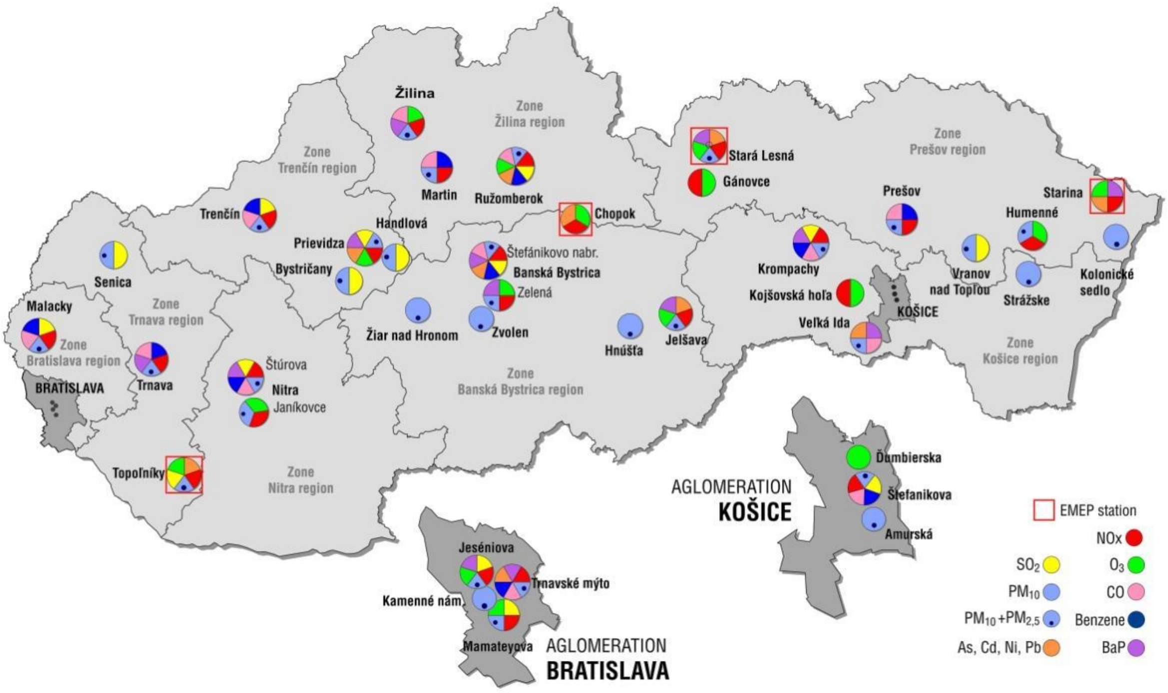
The UN ECE Convention on Long Range Transboundary Air Pollution (CLRTAP) was signed in Geneva in 1979. In frame of the Convention were signed eight protocols, until now. The first one among them was Protocol on Long-term Financing of the Co-operative Programme for Monitoring and Evaluation of the Long-range 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, 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) network 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 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 it is part of EMEP network.

Monitoring programme in EMEP network was gradually extended. Measurements of sulphur compounds and 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 2019.*



Tab. 2.1 contains the list of air quality monitoring stations, which do belong into the monitoring network of NMSKO, introduces the international EOI code, characteristics of stations in coincidence with the dominant air pollution sources (traffic, background, industrial) and at the same time, the type of region (urban, suburban, rural/regional), which the respective station monitors.

Tab. 2.1 National air quality monitoring network (NMSKO).

AGGLOMERATION Zone	District	Code EoI	Station name	Type of area	Type of station	Geographical longitude	Geographical latitude	Altitude [m]
BRATISLAVA	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
KOŠICE	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
Banská Bystrica region	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
Bratislava region	Malacky	SK0407A	Malacky, Mierové nám.	U	T	17°01'09"	48°26'13"	197
Košice region	Gelnica	SK0042A	Kojšovská hoľa	R	B	20°59'14"	48°46'58"	1253
	Košice okolie	SK0018A	Veľká Ida, Letná	S	I	21°10'31"	48°35'32"	209
	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
Nitra region	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
Prešov region	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
Trenčín region	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
Trnava region	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
Žilina region	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

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

Monitoring programme of air quality stations in NMSKO network is listed in **Tab. 2.2.** Automatic instruments of continuous monitoring provide average 1-hour concentrations of sulphur dioxide, ozone, oxides of nitrogen, carbon monoxide, benzene, PM_{10} and $PM_{2.5}$. In frame of manual monitoring, the Testing laboratory of SHMÚ analysis heavy metals and polycyclic aromatic hydrocarbons. The results are average 24-hour values. EMEP stations are exception; their monitoring programme is described in **Tab. 2.3** and **Tab. 2.4**.

***Tab. 2.2** Measurement program in monitoring air quality networks of SR – 2019.*

AGGLOMERATION Zone	Station name	Continuously							Manually	
		PM_{10}	$PM_{2.5}$	Oxides of nitrogen NO, NO_2, NO_X	Sulphur dioxide SO_2	Ozone O_3	Carbon monoxide CO	Benzene	Heavy metals, As, Cd, Ni, Pb	Polyaromatic hydrocarbons BaP
BRATISLAVA	Bratislava, Kamenné nám	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				
	Together 4 stations	**4**	**4**	**3**	**2**	**2**	**1**	**1**	**1**	**2**
KOŠICE	Košice, Amurská	x	x							
	Košice, Štefánikova	x	x	x	x		x	x		
	Košice, Ďumbierska					x				
	Together 3 stations	**2**	**2**	**1**	**1**	**1**	**1**	**1**		
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	x	x	x	x		x	x	x	x
	Banská Bystrica, Zelená	x	x	x		x				x
	Jelšava, Jesenského	x	x	x		x			x	x
	Hnúšťa, Hlavná	x	x							
	Žiar nad Hronom, Jilemnického	x	x							
	Zvolen, J. Alexyho	x	x							
	Together 6 stations	**6**	**6**	**3**	**1**	**2**	**1**	**1**	**2**	**3**
Bratislava region	Malacky, Mierové nám.	x	x	x	x		x	x		
	Together 1 stations	**1**	**1**	**1**	**1**		**1**	**1**		
Košice region	Kojšovská hoľa			x		x				
	Veľká Ida, Letná	x	x				x		x	x
	Strážske, Mierová	x	x							
	Krompachy, SNP	x	x	x	x		x	x		x
	Together 4 stations	**3**	**3**	**2**	**1**	**1**	**2**	**1**	**1**	**2**
Nitra region	Nitra, Štúrova	x	x	x	x		x	x		x
	Nitra, Janíkovce	x	x	x		x				
	Together 2 stations	**2**	**2**	**2**	**1**	**1**	**1**	**1**		**1**
Prešov region	Humenné, Nám. slobody	x	x	x		x				
	Stará Lesná, AÚ SAV, EMEP	x	x	x		x			x	x
	Gánovce, Meteo. st.			x		x				
	Prešov, Arm. gen. L. Svobodu	x	x	x			x	x		
	Starina, Vodná nádrž, EMEP			x		x			x	x
	Vranov nad Topľou, M. R. Štefánika	x	x		x					
	Kolonické sedlo	x	x							
	Together 7 stations	**5**	**5**	**5**	**1**	**4**	**1**	**1**	**2**	**2**
Trenčín region	Prievidza, Malonecpalská	x	x	x	x	x			x	x
	Bystričany, Rozvodňa SSE	x	x		x					
	Handlová, Morovianska cesta	x	x		x					
	Trenčín, Hasičská	x	x	x	x		x	x		
	Together 4 stations	**4**	**4**	**2**	**4**	**1**	**1**	**1**	**1**	**1**
Trnava region	Topoľníky, Aszód, EMEP	x	x	x	x	x			x	
	Senica, Hviezdoslavova	x	x		x					
	Trnava, Kollárova	x	x	x			x	x		x
	Together 3 stations	**3**	**3**	**2**	**2**	**1**	**1**	**1**	**1**	**1**
Žilina region	Chopok, EMEP			x		x			x	
	Martin, Jesenského	x	x	x			x	x		
	Ružomberok, Riadok	x	x	x	x	x	x	x	x	
	Žilina, Obežná	x	x	x		x	x			x
	Together 4 stations	**3**	**3**	**4**	**1**	**3**	**3**	**2**	**2**	**1**
NMSKO altogether 38 monitoring stations		**33**	**33**	**25**	**15**	**16**	**13**	**11**	**10**	**13**

Air quality monitoring programme on EMEP stations in year 2019 is listed in **Tab. 2.3**. Ozone is measured continuously. Sampling interval for PM_{10}/TSP and heavy metals is one week, for VOC twice weekly and the other substances are analysed upon the base of 24-hour sampling.

Tab. 2.3 *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*	Lead (Pb)	Arsenic (As)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)	Cooper (Cu)	Zinc (Zn)
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
Starina	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

* *TSP – total suspended particles*

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. 2.4**, either upon daily base (Chopok, Starina), or weekly (Topoľníky, Stará Lesná). Results of analyses are daily or weekly average values, in dependence on sampling interval.

Heavy metals occur in these locations in very low 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 cover is open only during rain and such samples serve for wet deposition assessment. Type "Bulk" samples dry and wet deposit at the same time. This kind of sampling is carried out on the Chopok station, where the precipitation sampling is performed into the open bucket.

Tab. 2.4 *Measurement programme of EMEP stations – precipitation.*

	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

2.1 ASSESSMENT OF MONITORING EXTENT FOR INDIVIDUAL POLLUTANTS

- **Sulphur dioxide SO_2**

This pollutant was monitored on 15 stations. Minimum required extent of monitoring[11] was fulfilled. Sulphur dioxide monitoring was secured on all 15 stations continuously, by reference method. Required number of valid measured data (90%) was reached on 14 monitoring stations. (Note: Percentage of valid measurements was 22% on AMS Bratislava, Jeséniova, because the monitoring started in second half of 2019).

- **Oxides of nitrogen NO_2 and NO_X**

These pollutants were monitored on 25 stations. Minimum required extent of monitoring[11] was fulfilled. Oxides of nitrogen monitoring was secured at all 25 stations, continuously by reference method. Required number of valid measured data (90%) was reached at all 25 monitoring stations.

- **Particulate matter PM_{10}**

This pollutant was monitored on 33 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 all monitoring stations.

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

This pollutant was monitored on 33 stations. Minimum required extent of monitoring[11] was also 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 30 monitoring stations. (Note: failure of measurements on AMS Bratislava, Kamenné námestie a Topoľníky, Aszód, was caused by technical breakdown of analysers, Trnavské mýto started to measure to the end of 2019).

- **Carbon monoxide CO**

This pollutant was monitored on 13 monitoring stations. Minimum required extent of monitoring[11] was fulfilled. The CO monitoring was secured on 13 stations, continuously by reference method. Required number of valid measured data (90%) was reached on all 13 monitoring stations. Concentrations of CO are below low limit for assessment, therefore number of measurements is satisfactory.

- **Ozone O_3**

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

- **Benzene**

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

[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*

- **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 MS (inducted coupled plasma mass spectrometer). In 2019 the samples for heavy metal analysis (Pb, As, Cd, Ni) were collected on one suburban, five urban and four EMEP stations (Pb, As, Cd, Ni, Cr, Zn, Cu).

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

  In 2019 the benzo(a)pyrene monitoring was provided on 13 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).

- **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 analysed and assessed in coincidence with NILU method GC MS in EMEP manual of NILU

- **Air quality monitoring on EMEP stations**

  Air quality measurements were realized on all four EMEP monitoring stations, in coincidence with EMEP monitoring strategy (**Tab. 2.3**), 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. 2.4**), 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. 2.5**), 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. 2.5 *Monitoring stations of other operators of large air pollution sources (VZZO).*

AGGLOMERATION Zone	District	Station name*	Type		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 - okolie	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 large 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 is, according §12 section 6 of Air act, 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, ozone and particulate matter PM_{10}.

Critical level for purposes of air quality assessment is, according §5 section 10 of Air act, air pollution level, determined upon the base of scientific know how, at exceedance of which can occur direct or indirect effects on trees, other plants or natural ecosystems, apart from people. 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	1r	40 (-)	32 (-)	26 (-)
NO_X	Vegetation	1r	30 (-)	24 (-)	19.5 (-)
PM_{10}	Human health	24h	50 (35)	35 (35)	25 (35)
PM_{10}	Human health	1r	40 (-)	28 (-)	20 (-)
Pb	Human health	1r	0.5 (-)	0.35 (-)	0.25 (-)
CO	Human health	8h (maximum)	10 000 (-)	7 000 (-)	5 000 (-)
Benzene	Human health	1r	5 (-)	3.5 (-)	2 (-)
$PM_{2.5}$	Human health	1r	25**	17	12

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

Tab. 3.2 *Target values for human health protection 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 2019.*

AGGLOMERATION Zone	Pollutant	SO_2	NO_2	PM_{10}	$PM_{2.5}$	CO	Benzene	O_3
BRATISLAVA	Bratislava, Kamenné nám.			96	83			
	Bratislava, Trnavské mýto		96	98	9	98	97	
	Bratislava, Jeséniova	22	95	99	99			91
	Bratislava, Mamateyova	95	95	98	99			95
KOŠICE	Košice, Štefánikova	96	96	99	99	96	99	
	Košice, Amurská			98	97			
	Košice, Dumbierska							100
Banská Bystrica region	Banská Bystrica, Štefánik. nábr.	95	96	99	98	96	99	
	Banská Bystrica, Zelená		96	99	96			94
	Jelšava, Jesenského		94	97	97			94
	Hnúšťa, Hlavná			97	97			
	Zvolen, J. Alexyho			97	96			
	Žiar n/H, Jilemnického			99	99			
Bratislava region	Malacky, Mierove nám.	95	96	98	99	95	97	
Košice region	Kojšovská hola		96					95
	Veľká Ida, Letná			98	99	94		
	Strážske, Mierová			99	99			
	Krompachy, SNP	95	96	99	99	96	99	
Nitra region	Nitra, Janíkovce		95	99	98			95
	Nitra, Štúrova	95	96	99	98	96	99	
Prešov region	Gánovce, Meteo. st.		95					95
	Humenné, Nám. Slobody		96	98	98			96
	Prešov, Arm. gen. L. Svobodu		96	99	99	96	99	
	Vranov n/T, M. R. Štefánika	96		99	99			
	Stará Lesná, AÚ SAV, EMEP		96	99	99			94
	Starina, Vodná nádrž, EMEP		95					90
	Kolonické sedlo, Hvezdáreň			97	96			
Trenčín region	Prievidza, Malonecpalská	95	95	98	97			91
	Bystričany, Rozvodňa SSE	96		99	98			
	Handlová, Morovianska cesta	95		98	98			
	Trenčín, Hasičská	95	95	99	99	95	96	
Trnava region	Senica, Hviezdoslavova	95		99	99			
	Trnava, Kollárova		96	98	98	96	99	
	Topoľníky, Aszód, EMEP	95	96	98	89			95
Žilina region	Chopok, EMEP		93					92
	Martin, Jesenského		96	98	99	96	99	
	Ružomberok, Riadok	94	94	97	97	94	96	93
	Žilina, Obežná		98	97	98	98		95

** $\geq$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)*

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 2019 is introduced 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 – 2019.*

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 consecutively	3 h consecutively
	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	25	10 000	5	500	400
	Maximum number of exceedances	24	3	18		35						
BRATISLAVA	Bratislava, Kamenné nám.					8	22	15				0
	Bratislava, Trnavské mýto			0	37	11	24	18	917	1.0		0
	Bratislava, Jeséniova	0	0	0	10	9	19	12			0	0
	Bratislava, Mamateyova	5	0	0	21	9	21	13			0	0
KOŠICE	Košice, Štefánikova	0	0	0	28	42	29	18	1 505	0.7	0	
	Košice, Amurská					15	23	14				0
Banská Bystrica region	Banská Bystrica, Štefánik. nábr.	0	0	0	29	25	26	18	1 768	1.0	0	0
	Banská Bystrica, Zelená			0	9	2	16	10				0
	Jelšava, Jesenského			0	9	61	33	21				
	Hnúšťa, Hlavná					15	22	16				
	Zvolen, J. Alexyho					5	21	14				
	Žiar n/H, Jilemnického					0	16	13				0
Bratislava region	Malacky, Mierové nám.	0	0	0	22	9	23	16	1 266	0.5	0	0
Košice region	Kojšovská hola			0	3							
	Veľká Ida, Letná					45	30	21	1 966			
	Strážske, Mierová					20	23	19				0
	Krompachy, SNP	0	0	0	17	23	25	18	1 908	2.1	0	0
Nitra region	Nitra, Janíkovce			0	10	10	20	15				0
	Nitra, Štúrova	0	0	0	31	14	24	15	1 221	0.5	0	0
Prešov region	Gánovce, Meteo. st.			0	8							0
	Humenné, Nám. slobody			0	9	20	23	18				0
	Prešov, Arm. gen. L. Svobodu			0	39	28	28	18	1 413	1.1		
	Vranov n/T, M. R. Štefánika	0	0			20	23	16			0	0
	Stará Lesná, AÚ SAV, EMEP			0	5	0	14	11				0
	Starina, Vodná nádrž, EMEP			0	3							
	Kolonické sedlo, Hvezdáreň					2	18	10				0
Trenčín region	Prievidza, Malonecpalská	0	0	0	16	7	20	14			0	
	Bystričany, Rozvodňa SSE	0	0			6	20	11			0	
	Handlová, Morovianska cesta	0	0			3	17	13			0	0
	Trenčín, Hasičská	0	0	0	27	21	25	18	1 239	0.9	0	
Trnava region	Senica, Hviezdoslavova	0	0			10	21	14			0	0
	Trnava, Kollárova			0	34	15	24	16	1 619	0.8		0
	Topoľníky, Aszód, EMEP	0	0	0	8	11	21	14			0	0
Žilina region	Chopok, EMEP			0	2							0
	Martin, Jesenského			0	24	13	19	15	2 319	0.8		0
	Ružomberok, Riadok	0	0	0	18	24	24	18	2 353	1.1	0	0
	Žilina, Obežná			0	21	21	23	18	2 093			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)*

Tab. 3.5 *Assessment of air pollution by heavy metals (As, Cd, Ni a Pb) – 2019.*

			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		1.1	0.9	0.7	15.6
Slovakia	Banská Bystrica, Štefánik. náb.		0.9	0.8	2.2	26.1
	Jelšava, Jesenského		0.8	0.3	0.8	12.5
	Ružomberok, Riadok		0.6	0.3	0.7	20.4
	Velká Ida, Letná		1.0	1.1	2.0	77.2
	Prievidza, Malonecpalská*		0.6	0.2	0.5	13.0

** measurements on station Prievidza, Malonecpalská were restored in June 2019*

In **Tab. 3.6** are quoted annual average concentrations of benzo(a)pyrene (BaP) in air, according to the measurements in years 2014 – 2019.

Tab. 3.6 *Assessment of air pollution by benzo(a)pyrene.*

AGGLOMERATION Zone			**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
	Target value	[ng.m^{-3}]	1.0	1.0	1.0	1.0	1.0	1.0
	Upper limit for assessment	[ng.m^{-3}]	0.6	0.6	0.6	0.6	0.6	0.6
	Low limit for assessment	[ng.m^{-3}]	0.4	0.4	0.4	0.4	0.4	0.4
BRATISLAVA	Bratislava, Jeséniova		0.7	0.6				0.2
	Bratislava, Trnavské mýto		0.6	0.8	**1.2**	0.4	0.9	0.4
Slovakia	Banská Bystrica, Štefánikovo nábrežie				**4.4**	**2.9**	**2.1**	**1.7**
	Banská Bystrica, Zelená							**1.1**
	Veľká Ida, Letná		**4.1**	**6.2**	**3.8**	**4.3**	**5.8**	**4.5**
	Krompachy, SNP		**2.1**	**1.9**				**2.7**
	Prievidza, Malonecpalská		**1.5**	**1.4**				**1.4**
	Trnava, Kollárova		0.7	0.8			0.9	0.7
	Nitra, Štúrova				**1.3**	**1.3**	0.9	0.8
	Žilina, Obežná						**6.0**	**2.0**
	Jelšava, Jesenského						**4.0**	**4.0**
	Starina, Vodná nádrž, EMEP						**1.2**	0.4
	Stará Lesná, EMEP							0.4

Limit value exceedance is marked by red colour

Remark:

At the Starina station, water reservoir, EMEP, the measurement began in November 2018, while the measured data of target values from these two months are not representative for the annual assessment of year 2018. In year 2019, the data for the whole calendar year are available, i.e., it is dealing about the representative measurements. In year 2019, the target value was not exceeded.

At the Prievidza, Malonecpalská station, the BaP measurements were restored in August 2019 and therefore they did not include either the whole calendar year, or the traditional problem months January and February with high BaP concentrations. In spite of this, we may suppose, that target value at this station in year 2019 was exceeded, what is indicated by the advancement in November and December, when mean concentration reached value 2.2 ng.m^{-3} and concentrations in some days exceeded even 6 ng.m^{-3}.

The highest concentrations were measured at AMS Veľká Ida, Letná and Jelšava, Jesenského. At the Bratislava, Trnavské mýto station, the BaP measurements were not carried out in January, October and November and at the Bratislava, Jeséniova station, the measurements were re-established in June 2019. From accessible data, (PM_{10} measurements, in case of Bratislava, Jeséniova station also $PM_{2.5}$, modelling by the method of neuron networks, including also meteorological parameters, e.g. temperature), at these two Bratislava monitoring stations is possible to suppose, that mean value would not exceed 1 ng.m^{-3}, even in case of the annual measurements in year 2019.

Occurrence and period of pollution duration at the level of warning thresholds for SO_2 during the last 7 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 – 2019.

Tab. 3.7 *Assessment of air pollution by SO_2 according to the occurrence and duration of warning threshold exceedance within the years 2013 – 2019 on station Bystričany, Rozvodňa SSE.*

Year	2013	2014	2015	2016	2017	2018	2019
Number of warning threshold exceedances	2	0	0	0	0	0	0
Duration in hours	7	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 $\mu g.m^{-3}$, 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 $\mu g.m^{-3}$, 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 information and warning threshold exceedances for PM_{10} is presented in **Tab. 3.8**.

Tab. 3.8 *Duration of information and warning thresholds for PM_{10} in 2019.*

Station	Duration of exceedance [h]		Station	Duration of exceedance [h]	
	information threshold	warning threshold		information threshold	warning threshold
Jelšava, Jesenského	119	17	Vranov nad Top., M.R.Štefánika	12	10
Ružomberok, Riadok	87	0	Prievidza, Malonecpalská	8	0
Martin, Jesenského	78	22	Senica, Hviezdoslavova	8	0
Žilina, Obežná	57	5	Trnava, Kollárova	8	0
Veľká Ida, Letná	47	0	Nitra, Štúrova	7	0
Trenčín, Hasičská	40	0	Prešov, Arm. gen. L. Svobodu	6	0
Malacky, Mierové nám.	12	0	Košice, Štefánikova	4	0

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 2015 and 2019.*

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								
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
Košice region	Veľká Ida, Letná										x			x			x					x			
	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						
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							
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*

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 2015 – 2019.*

AGGLOMERATION zone	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	Bratislava, Jeséniova													x		
	Bratislava, Trnavské mýto			x			x			x			x	x		
Slovensko	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

In **Tab. 3.11** are listed annual average concentrations of tropospheric ozone in years 2008 – 2019 as compared to photochemical extraordinary active year 2003.

Tab. 3.11 *Annual average concentrations of surface ozone [μg.m^{-3}] in years 2003, 2008 – 2019.*

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

≥ 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**.

**Methodical remark:*
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	2017	2018	2019	Average 2017 – 2019
Bratislava, Jeséniova	38	54	40	44
Bratislava, Mamateyova	22	33	32	29
Košice, Ďumbierska	10	16	6	11
Banská Bystrica, Zelená	17	20	2	13
Jelšava, Jesenského	11	11	4	9
Kojšovská hoľa	23	41	11	25
Nitra, Janíkovce	42	44	10	32
Humenné, Nám. Slobody	7	2	3	4
Stará Lesná, AÚ SAV, EMEP	3	33	3	13
Gánovce, Meteo. st.	0	4	0	1
Starina, Vodná nádrž, EMEP	3	7	3	4
Prievidza, Malonecpalská	19	9	1	10
Topoľníky, Aszód, EMEP	8	6	19	11
Chopok, EMEP	*31	82	36	59
Žilina, Obežná	3	12	6	7
Ružomberok, Riadok	0	1	1	1

** Year was not calculated in the average due to lack of data in summer season*
≥ 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}		
	2017	2018	2019	2017	2018	2019
Bratislava, Jeséniova	6	1	0	0	0	0
Bratislava, Mamateyova	6	2	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 2015 – 2019 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	Average 2015 – 2019
Bratislava, Jeséniova	13 612	25 042	25 103	20 609	22 506
Bratislava, Mamateyova	4 450	21 525	22 658	19 340	17 678
Košice, Ďumbierska	15 560	11 557	14 384	11 752	13 673
Banská Bystrica, Zelená	*9 771	17 198	16 982	8 298	14 159
Jelšava, Jesenského	*14 597	12 756	6 660	12 361	9 472
Kojšovská hoľa	18 259	13 056	18 706	12 202	15 556
Nitra, Janíkovce	18 684	25 925	25 036	13 313	20 952
Humenné, Nám. slobody	13 008	14 209	10 833	13 326	10 338
Stará Lesná, AÚ SAV, EMEP	13 151	13 197	22 437	8 666	13 379
Gánovce, Meteo. st.	2 678	7 020	6 646	8 954	6 217
Starina, Vodná nádrž, EMEP	10 235	12 154	13 116	11 601	11 776
Prievidza, Malonecpalská	*5 835	16 167	15 889	8 301	13 452
Topoľníky, Aszód, EMEP	11 812	9 334	15 886	17 690	12 853
Chopok, EMEP	23 014	29 820	32 667	23 711	23 737
Žilina, Obežná	14 359	10 956	13 364	11 800	11 150
Ružomberok, Riadok	3 875	2 801	3 789	5 307	3 994

** 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 the Veľká Ida location (**Tab. 3.15**).

Tab. 3.15 *Air pollution assessment according to limit values for human health protection in year 2019 from industrial stations of other operators – VZZO.*

AGGLOMERATION Zone	Pollutant / Averaging period / Limit value [μg.m^{-3}] (number of exceedances)	Health protection						
		SO_2		NO_2		PM_{10}		CO
	Averaging period	1 h	24 h	1 h	1 year	24 h	1 year	8 h [1)]
	Limit value [μg.m^{-3}] (number of exceedances)	350 (24)	125 (3)	200 (18)	40	50 (35)	40	10000
BRATISLAVA	Bratislava, Pod. Biskupice (Slovnaft, a.s.)	0	0	0	19	5	21	973
	Bratislava, Vlčie Hrdlo (Slovnaft, a.s.)	9	1	0	21	6	21	908
KOŠICE	Košice, Poľov (U.S. Steel, s.r.o.)	0	0	0	8	1	18	3 188
	Košice, Haniska (U.S. Steel, s.r.o.)	0	0	0	14	3	18	2 720
Bratislava region	Rovinka (Slovnaft, a.s.)	1	0	0	14	6	22	687
Košice region	Veľká Ida (U.S. Steel, s.r.o.)	0	0	0	11	38	29	2 091
	Leles (Slovenské elektrárne, a.s.)	0	0	0	7			
Nitra region	Trnovec nad Váhom (Duslo, a.s.)	0	0	0	11	5	17	
Trenčín region	Oslany (Slovenské elektrárne, a.s.)	0	0	0	9			
Žilina region	Ružomberok (Mondi a.s. - Supra)					30	27	

[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 and CO, in classification on agglomerations and zones in 2019

In the following text, the results of measurements are assessed, in regard to 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, also about relation to emission pollutant sources. Air quality assessment with the aid of mathematical modelling is presented in Chapter **4**.

- **Agglomeration Bratislava**

In year 2019 the limit values for human health protection for SO_2, PM_{10}, $PM_{2.5}$, benzene and CO were not exceeded in Bratislava agglomeration. Limit value for annual average concentration of NO_2 was not exceeded on AMS Bratislava, Trnavské mýto.

- **Agglomeration Košice**

Daily limit value for PM_{10} was exceeded in agglomeration Košice on AMS Košice, Štefánikova in year 2019. Limit values for annual average concentration of PM_{10} as well as SO_2 and NO_2 for human health protection were not exceeded. Target value for $PM_{2.5}$ was not exceeded in agglomeration Košice in year 2019.

- **Zone Banská Bystrica region**

Daily average concentrations of PM_{10} exceeded limit value on one AMS: Jelšava, Jesenského. Limit value for annual average concentration of PM_{10} was not exceeded on any station in this zone. High number of daily limit value exceedances for PM_{10} in Jelšava (61 exceedances of daily limit value) is possible to assign mainly to the heating by solid fuel in this area, where situation is even worse by extremely unfavourable scatter conditions. Influence of industrial sources is demonstrated less expressively in Jelšava. On the contrary, AMS Banská Bystrica, Štefánikovo nábrežie registered relatively high number of daily limit value exceedances, caused mainly by road transport. Limit values in this zone for $PM_{2.5}$, SO_2, NO_2, benzene and CO were not exceeded.

- **Zone Bratislava region**

Limit values in this zone for concentrations of SO_2, NO_2, PM_{10}, benzene and CO were not exceeded, similarly also target value for annual average concentrations of $PM_{2.5}$ was not exceeded.

- **Zone Košice region**

In zone Košice region, the daily limit value for human health protection for PM_{10} was exceeded only on station Veľká Ida, Letná, where the number of 24-hour limit value exceedances of PM_{10} for human health protection reached value 45, in year 2019. This location is influenced mainly by near metallurgy complex, in lesser extent by household heating.

Limit for values for SO_2, NO_2, PM_{10}, benzene and CO concentrations were not exceeded in this zone, equally also target value for annual average concentration of $PM_{2.5}$ in zone Košice region was not exceeded.

- **Zone Nitra region**

Limit values for SO_2, NO_2, PM_{10}, benzene and CO concentrations were not exceeded in this zone, as well as target values for $PM_{2.5}$ concentrations were not exceeded in year 2019.

- **Zone Prešov region**

  Limit value for annual average concentration of PM_{10} was not exceeded in this zone, similarly as limit values for SO_2, NO_2, benzene and CO and target value for $PM_{2.5}$.

- **Zone Trenčín region**

  Limit value for annual average concentration of PM_{10} was not exceeded in this zone, similarly as limit values for SO_2, NO_2, benzene and CO and target value for $PM_{2.5}$.

- **Zone Trnava region**

  Limit values for SO_2, NO_2, $PM_{10,}$ benzene and CO concentrations were not exceeded in this zone. Also target value for $PM_{2.5}$ in zone Trnava region was not exceeded in year 2019.

- **Zone Žilina region**

  Limit values for daily average concentrations and also for annual average concentration of PM_{10} were not exceeded in zone Žilina region, similarly as limit values for SO_2, NO_2, benzene and CO. Target value for $PM_{2.5}$ was also not exceeded, as well.

3.3.2 Air quality assessment according to limit and target values for human health protection concerning Pb, As, Cd, Ni, BaP, and $O_{3,}$ in classification on agglomeration and zones in 2019

- **Agglomeration Bratislava**

  Limit value for Pb as well as target values for As, Cd and Ni, were not exceeded in Bratislava agglomeration. Concentrations of BaP measured on AMS Bratislava, Trnavské mýto did not exceed target value in last years

  Target value for ozone (120 $\mu g.m^{-3}$ 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. In year 2019 the information threshold and warning threshold were not exceeded.

- **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.

  In 2019 the target value for BaP was exceeded on stations Veľká Ida, Letná; Banská Bystrica, Štefánikovo nábrežie; Banská Bystrica, Zelená; Žilina, Obežná; Jelšava, Jesenského; Krompachy, SNP and Previdza, Malonecpalská. In vicinity of Veľká Ida manifests dominant industrial source, which is for BaP coke production and partly also household heating. In Jelšava, manifested mainly influence of the household heating by solid fuel and less industrial source. On the other stations, the most distinctive problem in connection with BaP is road transport, in combination with household heating.

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

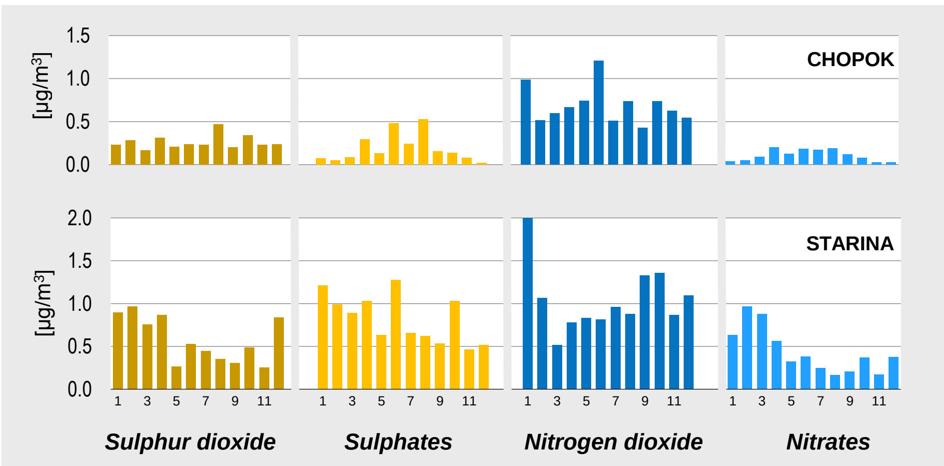
- **Sulphur dioxide, sulphates**

In year 2019 the regional level of sulphur dioxide concentrations recalculated on sulphur was 0.26 $\mu g.m^{-3}$ on the Chopok station and 0.58 $\mu g.m^{-3}$ on the Starina station (**Tab. 3.16**, **Fig. 3.1**). 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 $\mu g\ SO_2.m^{-3}$ in calendar year and winter season. This value was exceeded neither at the calendar year (Chopok 0.52 $\mu g\ SO_2.m^{-3}$ and Starina 1.16 $\mu g\ SO_2.m^{-3}$), nor in winter season (Chopok 0.60 $\mu g\ SO_2.m^{-3}$ and Starina 1.3 $\mu g\ SO_2.m^{-3}$). Annual average concentration of sulphates, recalculated in sulphur, was 0.21 $\mu g.m^{-3}$ on the Chopok station and 0.90 $\mu g.m^{-3}$ on the Starina station (**Tab. 3.16**, **Fig. 3.1**).

- **Nitrogen dioxide, nitrates**

Nitrogen dioxide concentrations recalculated on nitrogen, presented on the regional stations in year 2019 0.70 $\mu g.m^{-3}$ on the Chopok station and 1.04 $\mu g.m^{-3}$ on the Starina station (**Tab. 3.16**, **Fig. 3.1**). 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 $\mu g\ NO_X.m^{-3}$ in calendar year. This level was not exceeded during the calendar year (Chopok 2.29 $\mu g\ NO_2.m^{-3}$ and Starina 3.42 $\mu g\ NO_2.m^{-3}$). Nitrates on Chopok and on Starina (**Tab. 3.16**, **Fig. 3.1**) 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. 3.1 *Monthly average concentrations of air pollutants – 2019 (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 2019 are listed in **Tab. 3.16**. Annual concentrations of ammonia represent 0.59 µg N.m^{-3} and ammonium ions 0.28 µg N.m^{-3}.

Tab. 3.16 *Annual average concentrations of pollutants [µg.m^{-3}] in air on EMEP stations – 2019.*

	SO_2	SO_4^{2-}	NO_2	NO_3^-	HNO_3	Cl^-	NH_3	NH_4^+	Na^+	K^+	Mg^{2+}	Ca^{2+}
Chopok	0.26	0.21	0.70	0.12	0.04	0.07	-	-	-	-	-	-
Starina	0.58	0.90	1.04	0.48	0.06	0.29	0.59	0.28	0.14	0.05	0.01	0.05

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

Heavy metals

Values of heavy metals lead, copper, cadmium, nickel, chromium, zinc and arsenic concentrations in year 2019 are listed in **Tab. 3.17**. The highest concentration values of copper, lead and zinc were recorded in the Topoľníky station and on the contrary, the lowest values were measured in the Chopok station.

Tab. 3.17 *Annual average concentrations of ozone [µg.m^{-3}] and heavy metals [ng.m^{-3}] in air on EMEP stations – 2019.*

	O_3	Pb	Cu	Cd	Ni	Cr	Zn	As	Hg*
Chopok	90	1.45	0.69	0.07	0.35	0.07	3.40	0.12	-
Topoľníky	55	8.08	2.36	0.15	0.45	0.05	12.13	0.29	1.60
Starina	62	4.16	1.17	0.11	0.32	0.16	7.78	0.26	1.65
Stará Lesná	59	4.26	1.67	0.12	0.31	0.13	8.92	0.25	-

**Hg is measured out of EMEP monitoring programme*

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 2019, the annual ozone average concentration at the Chopok station reached 90 µg.m^{-3}, in Topoľníky 55 µg.m^{-3}, in Stará Lesná 59 µg.m^{-3} and in Starina 64 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 the few European stations, included into the EMEP network, with regular sampling of volatile organic compounds. The 2019 annual VOC data are listed in **Tab. 3.18**.

Tab. 3.18 *Annual average of volatile organic compound concentrations [ppb] on EMEP station Starina – 2019.*

ethane	ethene	propane	propene	i-butane	n-butane	butene	2-metylbutane	n-pentane	pentene
2.90	1.47	1.00	0.20	0.23	0.37	0.34	0.15	0.18	0.02
n-hexane	**isoprene**	**n-heptane**	**benzene**	**i-octane**	**n-octane**	**toluene**	**ethylbenzene**	**m+p-xylene**	**o-xylene**
0.04	0.01	0.05	0.29	0.03	0.05	0.12	0.03	0.02	0.04

** Due to the technical reasons, the annual mean concentrations of VOCs are calculated only from values in first-half of year 2019.*

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 2019, the amount of precipitation recorded at background stations ranged between from 425 to 1391 mm. The upper level of precipitation amount belongs to the highest situated station Chopok and lowest to Starina. Acidity of atmospheric precipitation dominated at the Starina station, with the low level of pH range 5.30 – 5.95 (**Tab. 3.19**). Time series and pH trend within a longer time period on station Chopok (**Fig. 3.2**) indicate clearly the decrease of acidity. Conductivity of atmospheric precipitation is reflection of cations and anions presence, which are conductive. Concentrations of dominant sulphates in precipitation recalculated in sulphur, presented on EMEP stations the range 0.38 – 0.46 mg.l^{-1} (**Tab. 3.19**, **Fig. 3.3**). Concentrations of sulphates at the Chopok station are at the low level of the concentration range and slightly higher at the other stations. Total decrease of sulphates in long-term time series corresponds to the SO_2 emission reduction, since 1980. Nitrates, which share on precipitation acidity in smaller extent than sulphates, record concentration range on EMEP stations recalculated on nitrogen 0.22 – 0.37 mg.l^{-1} (**Tab. 3.19**, **Fig. 3.3**). Low level of concentration range is represented by Chopok and upper by Topoľníky. Ammonium ions also do belong to the major ions and their concentration range on EMEP stations presented 0.37 – 0.73 mg.l^{-1} (**Tab. 3.19**).

Fig. 3.2 pH in atmospheric precipitation – Chopok.

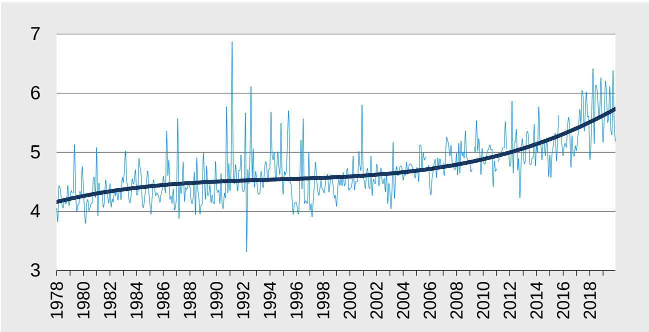
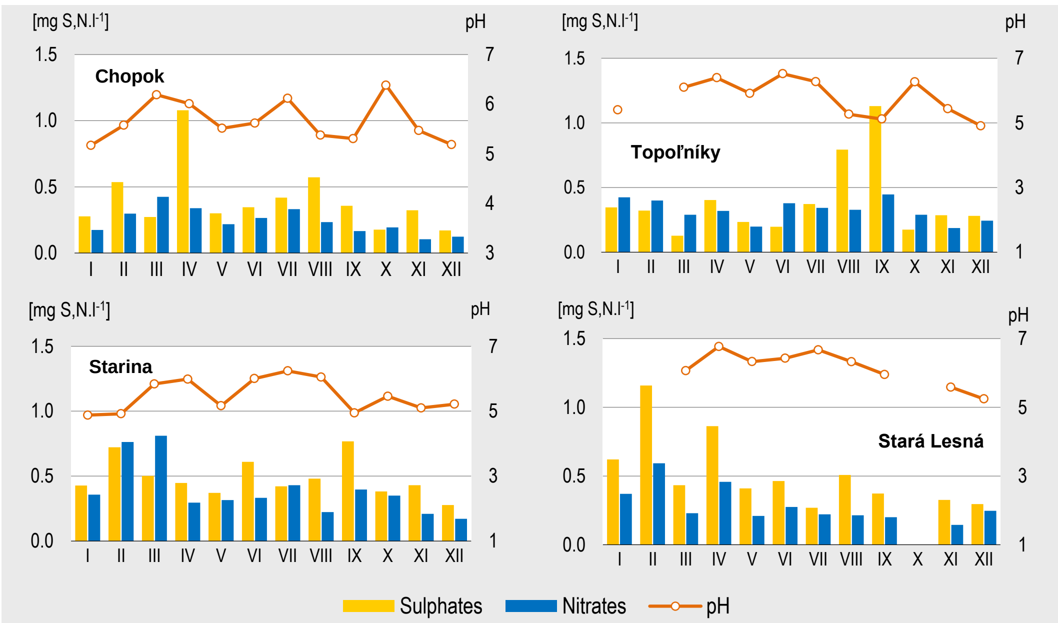


Fig. 3.3 Atmospheric precipitation – 2019.



Tab. 3.19 Annual weighted averages of pollutants in atmospheric precipitation – 2019.

	Precipitation [mm]	pH	Conductivity [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	1 391	5.44	11.8	0.383	0.219	0.366	0.175	0.280	0.067	0.024	0.198
Topoľníky	520	5.43	10.4	0.411	0.289	0.511	0.175	0.241	0.049	0.032	0.280
Starina	425	5.44	13.4	0.457	0.317	0.430	0.198	0.349	0.118	0.028	0.223
Stará Lesná	795	5.95	16.3	0.437	0.242	0.726	0.182	0.289	0.121	0.037	0.271
Bratislava, Jeséniova	642	5.87	17.3	0.480	0.367	1.092	0.355	0.334	0.387	0.153	0.998

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

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 was 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 2019 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 – 2019.

	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	1 468	0.89	0.05	0.20	0.09	1.16	21.00	0.30
Topoľníky	404	1.03	0.02	0.16	0.07	1.40	58.37	0.50
Starina	619	1.29	0.06	0.36	0.07	1.53	19.48	0.72
Stará Lesná	527	0.56	0.06	0.14	0.03	0.76	8.57	0.42
Bratislava, Jeséniova	732	1.06	0.04	0.27	0.05	3.57	13.85	0.50

3.5 SUMMARY

SO_2

Limit values for the average hourly and average daily SO_2 were not exceeded in any agglomeration or zone, in year 2019. At the same time no case of warning threshold exceeding was recorded on monitoring stations of SR this year.

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 2019 on any EMEP stations in calendar year, or winter season. All values were below low limit for vegetation protection assessment.

NO_2

Annual limit value for NO_2 was not exceeded in year 2019, 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 2019 was not recorded even the case of NO_2 warning threshold exceeding.

Critical value for vegetation protection (30 μg.m^{-3} in calendar year, expressed as NO_X) was not exceed-ed on any of EMEP stations in year 2019. Values were deeply below the low limit for vegetation protection assessment.

- **PM_{10}**

Monitoring of PM_{10} sufficiently covers the territory of Slovakia. The exceedance of limit value for annual average concentration of PM_{10} was not recorded on any monitoring station in year 2019. Exceedances of limit value for human health protection for 24 hour concentrations were recorded on three AMS: Košice, Štefánikova; Jelšava, Jesenského and Veľká Ida, Letná.

Upon the base of exceeding of information resp. warning threshold, the announcements were emitted to the public, about the smog situation resp. warnings before 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 was not necessary to emit. **Tab. 3.8** presents the list of stations and duration of information or warning threshold exceedance for PM_{10}.

- **$PM_{2.5}$**

For $PM_{2.5}$ is determined the limit value 25 μg.m^{-3} (for annual average concentration), valid from 1. 1. 2015. (Executive decision of Commission 2011/850/EU, Annex 1, point 5). This value was not exceeded on any of monitoring station in year 2019.

Health consequences, resulting from air pollution, depend on size and composition of solid pollutants (particles). The smaller the particles are, the more the serious health consequences appear. European and after implementation also Slovakian legislation therefore dislocate the centre of attention on $PM_{2.5}$. One of indicators, which shall characterize the loading of inhabitants by higher concentrations of $PM_{2.5}$, is indicator of average exposition (IAE), which is defined for respective year as a continuous middle concentration, averaging for all sampling places on urban background stations, in last three years. According to Annex No. 41 to Regulation No. 244/2016 Coll. of Acts, in wording of later prescriptions in year 2020, the limit value 20 μg.m^{-3} has to be reached. In **Tab. 3.21** are quoted values of this indicator from year 2010, which is for IAE reference year. National target to decrease exposition for particles $PM_{2.5}$ in 2019, Slovakia fulfilled.

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 $PM_{2.5}$ averaging exposition.*

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
IPE [μg.m^{-3}]	23.8	24.4	23.2	22.6	20.3	19.7	18.2	18.3	17.6	17.5

- **CO**

CO limit value was not exceeded on any of monitoring stations in Slovakia in the year 2019 and level of air pollution during previous period of years 2012 – 2019 is below the low assessment limit of this level.

Benzene

The major level of benzene was measured on station Krompachy, SNP, in year 2019. However, the values of annual average concentrations were significantly below limit value 5 μg.m^{-3}.

Ozone

Target value of surface ozone was exceeded at measurements on four stations: Bratislava, Jeséniova; Nitra, Janíkovce; Kojšovská hoľa and Chopok. Information threshold was not exceeded in year 2019 on any station.

Pb, As, Ni, Cd

Neither limit, nor target values were exceeded in year 2019.

Annual average concentrations of heavy metals, measured on NMSKO stations, are mostly only fragment of target, respectively limit value.

BaP

Annual average value of BaP concentration on the stations Veľká Ida, Letná; Banská Bystrica, Štefánikovo nábrežie; Žilina, Obežná and Jelšava, Jesenského, exceeded in last year target value 1 ng.m^{-3}. Exceeding of target value on AMS in Veľká Ida can be assigned to industrial activity (mainly coke production) and partly also household heating. In Jelšava manifested mainly the influence of household heating by solid fuel. On the other two stations the most outstanding problem in connection with BaP is road transport. Apart from Veľká Ida, BaP is characteristic at all stations by expressively higher values in cool half of year, when the influence of unfavourably scatter conditions manifests.

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 later prescriptions, in full compliance with EU directions. According to its rules, mathematical modelling can be used for air quality assessment as a supplementary method to the measurements on 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). 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 models CEMOD and IDW-A. For pollutants SO_2, NO_2, NO_X, CO and benzene was used model CEMOD. Ozone, PM_{10} and $PM_{2.5}$ were processed by interpolation scheme IDWA.

Authorised input data on emissions from large and medium air pollution sources in 2019 will be available in the last quarter of 2020. Waiting for these data would mean the annual delay in modelling calculations. Analyses carried out in recent years – after refining on emissions from large and medium sources – have shown only minor differences as compared to the results of the calculations using preliminary emissions from this category of sources. Therefore, in order to ensure that the overall assessment of air quality in Slovakia is kept up to date, tentative actualized NEIS emission data for assessed year 2019 will be used.

In case of surface ozone, PM_{10} and $PM_{2.5,}$ the interpolation by method IDW-A was used for model calculation. Results of model calculations for PM_{10} and $PM_{2.5}$ by using CEMOD model would be in regard of high uncertainty inputs and unnecessity to count further processes (such as chemical reactions, processes of particulate formation) presumably considerably underestimated.

4.1 BRIEF CHARACTERISTICS OF MODELS USED

Model for spatial assessment of gas pollutant concentrations (CEMOD)

CEMOD model is based on the US EPA-ISC methodology for the calculation of air pollution from stationary sources and the US EPA-CALINE methodology for line (mobile) sources, up to 30 km from the sources. For larger distances it uses a sectoral approach, with the sector angle increasing with the distance from the source and taking into account the complexity of the terrain in accordance with the ISC methodology. The methodology includes a correction factor for the decrease in the concentration of pollution with altitude, which is determined on base of measurements from regional background stations

The chemical transformation of NO to $NO_{2,}$ for all stationary sources outside the urban environment and in the urban environment, for sources with an effective height of sources more than twice the mean of build-up area height, is calculated in accordance with the TA-Luft 2002 methodology.

The cited methodology is amended by a correction coefficient to take into account the density and structure of the build-up area (surface roughness) in urban environment for mobile sources and for the stationary sources with an effective source height less than twice the mean height of build-up area. CEMOD requires hourly sequential meteorological and emission input data. Calculated set of hourly concentrations (8 760 values annually from each nodal point) enables to determine eight-hour, daily and annual average concentrations and the respective percentiles, corresponding to the limit values for hourly and daily data.

Input data for the model

- **Geographical data**, e.g., altitudes, coordinates of node and reference points, structure of build-up urban areas, geometrical characteristics of selected streets.
- **Emissions –** outputs from data base of large and medium air pollution sources of National air pollution system NEIS, data about traffic intensity from company AUREX or Slovak road administration, composition of car fleet, mean speed of vehicles in road segments and types of roads.
- **Meteorological data** – sequential meteorological input data, acquired from meteorological stations (database KMIS) and meteorological model.
- **Background concentrations** from the stations of NMSKO, with monitoring programme EMEP.

Model output:

- Concentrations for all reference, resp. nodal points are calculated by the model.
- From calculated values are derived all characteristics of air pollution, required by Act about air, for each reference point (in regard to limit values for respective averaging periods).

Anisotropic weighted inverse distance interpolation for area air quality assessment (IDW-A)

The IDW-A interpolation scheme was used for those pollutants, for which is difficult to use CEMOD dispersion model. In the interpolation scheme, a factor of anisotropy was applied, which takes into account the impact of orography on the dispersion of pollutants in respective location. The measured data were used as input values for the calculation. Upon the base of significant attributes of environment, for each input value were defined smoothing parameters and exponent of the horizontal representativeness. Regionalization (spatial representativeness) of measurements (of input values for IDW-A) was introduced. The input values were transformed on reference level by empirically derived dependence of concentrations on the altitude of NMSKO stations, with EMEP programme. The interpolation scheme on the base of measured data thus did enable to determine the 3D spatial distribution of the individual derived air pollution characteristics.

Input data for calculation:

- Measured or derived data from air quality monitoring stations.
- Factors of anisotropy of environment, taking into account the impact of orography on spreading of pollutants in a given location.
- Attributes in dependence of character of environment for each measuring point (presence and significance of sources – weights, geographical integrity – choice of subset, extent of urban area – smoothing parameter).

Output from model calculations:

- By model are calculated concentrations for all node points, which are the foundation for processing in GIS.
- From calculated values for each node is derived all characteristics of air pollution, requested in Air Act (in regard to limit values for respective averaging periods).

4.2 RESULTS AND OUTPUTS

- **Sulphur dioxide – SO_2**

Calculation of spatial distribution of all characteristics of the SO_2 concentration level, at the whole territory of the country, was processed by CEMOD. This model requires meteorological and emission input data, in sequential form (i.e. in consecutiveness per hours). Preparation of meteorological inputs for modelling contains processing of data from meteorological stations and outputs from meteorological model, while apart from information on surface layer, also vertical profiles of meteorological characteristics are needed. Emission input data were gained from database NEIS (National emission information system), from which were processed annual emission rates, locations and parameters of stacks, temperature and speed of pollutants. Further needed characteristic are annual emission time profiles, determined upon the base of character and source type (the whole year operation, seasonal operation, energetics, etc.). As additional data for spatial assessment of territory, the measured SO_2 concentrations from background stations NMSKO with EMEP programme, were used. The measurements were used for validation of model calculations.

Emissions – From the total number of 9 408 stacks (vents) of medium and large sources with SO_2 emissions, into the calculation were included 331 stacks (which represent together 99.4% of all SO_2 emissions from large and medium sources, registered in NEIS database). Only 258 stacks made up the whole year SO_2 emissions over 1 tone (for comparison is possible to quote, that in 2006 the SO_2 emissions higher than 1 tone had 898 chimneys). From the mentioned above is clear that also in 2019, similarly as in former years, significant share of stacks (vents), which have small annual emissions is further growing. In 2016 was recorded distinctive decrease of SO_2 emissions and this trend persists further. In 2018 was recorded moderate decrease, but in 2019 this decrease was relatively distinctive (around 25%). Outstanding share on this decrease had U.S. Steel Košice, s.r.o. (inter-annually more than about 1/3). This source belongs among 4 dominant air pollution sources in Slovakia, the emissions of which present more than 60% of all SO_2 emissions from large and medium sources in our country. More significant source of SO_2 is apart from U.S. Steel Košice, s.r.o., Slovnaft Bratislava, a.s., Slovalco, a.s., (Žiar nad Hronom) and Slovenské elektrárne, a.s. (ENO-elektráreň Nováky). Stacks and exhausts are represented in model by point sources. Small sources (mainly household heating) as well as medium and large sources with small emission flows represent at calculations the area sources.

Model results – Model calculation confirmed the decrease of air pollution by sulphur dioxide in 2019, as compared to 2018. It is in coincidence with measured values on NMSKO measurement stations, as well as with inter-annual outstanding decrease of SO_2 emissions in Slovakia. Significant decrease of annual average concentration on stations Bratislava, Mamateyova; Malacky, Mierové námestie and Košice, Štefánikova corresponds with the inter-annual decrease of SO_2 emissions from dominant sources at the territory of individual agglomerations (Slovnaft Bratislava, a.s, U.S. Steel Košice, s.r.o.).

At nonsignificant changes in emission rates from sources registered in NEIS system, the measured inter-annual increases of annual average SO_2 concentrations on some monitoring stations is not possible to assign only to the aggravated conditions for air pollutant dispersion.

At comparison of annual average SO_2 concentrations on model outputs to the measured data is clear, that model mostly under-estimated these concentrations. It can indicate on the presence of bigger number of smaller air pollution sources (parking places, domestic heating systems). It is indicated also by increased concentrations in summer days as well as outside night hours in daily cycle of air pollution. Successfulness of model at the detection of discrepancies is illustrated also by results quoted in Tab.4.1. At the station Bratislava, Mamateyova is from measured values at relatively small annual SO_2 average concentration very high value of hour-percentile, also by comparison with the other stations. Model calculation at good agreement with measurements for annual average concentration was very underestimated for hourly percentile. On this station was at the begging of June recorded also five exceedances of permitted limit value of hourly concentration (permitted is 24 exceedances within year). Further example is also evidence of influence of heating systems with relatively small building height of vents – stacks in the assessment location. Average annual SO_2 concentration measured at the

Krompachy, SNP station belongs among the highest ones at the territory of Slovakia, while in the mentioned location no dominant source of air pollution was recorded. Calculated percentiles from the measured values are relatively small and do not confirm the existence of more significant source in location. Model estimation for annual average concentration gives expressively underestimated result and besides calculated percentiles are in the allowed tolerance with the measured ones. In further locations with the direct impact of more significant air pollution sources by SO_2, the highest values of hourly concentrations appeared, however they did not exceed even low limit of air pollution level for human health protection.

Exceedance of hourly limit value was measured only on the station Bystričany, Rozvodňa SSE (2 exceedances, while Bystričany did not reach 24 permitted exceedances of average hour concentration within calendar year). In 2019 no exceedance of limit value for average 24-hour concentration of SO_2 was measured within the frame of NMSKO.

Underestimation of hourly concentrations in CEMOD model outputs in vicinity of air pollution source ENO and sources in location Vranov nad Topľou is a consequence of various character of altitude and ground wind. Dispersion of plum from stacks of these sources is in regard to the effective height of stacks influenced rather by wind in upper layer than ground wind, which enters as parameter into the model calculations.

Fig. 4.1 *Annual mean concentration of SO_2 [µg.m^{-3}] – 2019.*

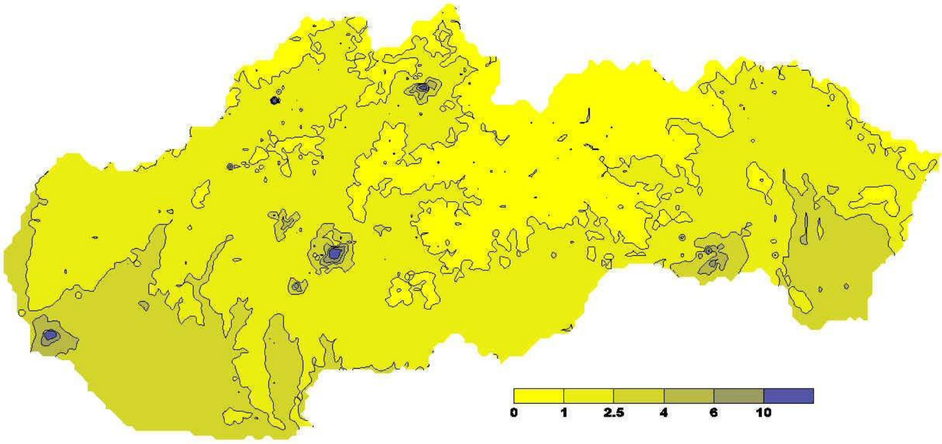


Fig. 4.2 *99,2nd percentile of daily mean SO_2 concentration [µg.m^{-3}] – 2019.*

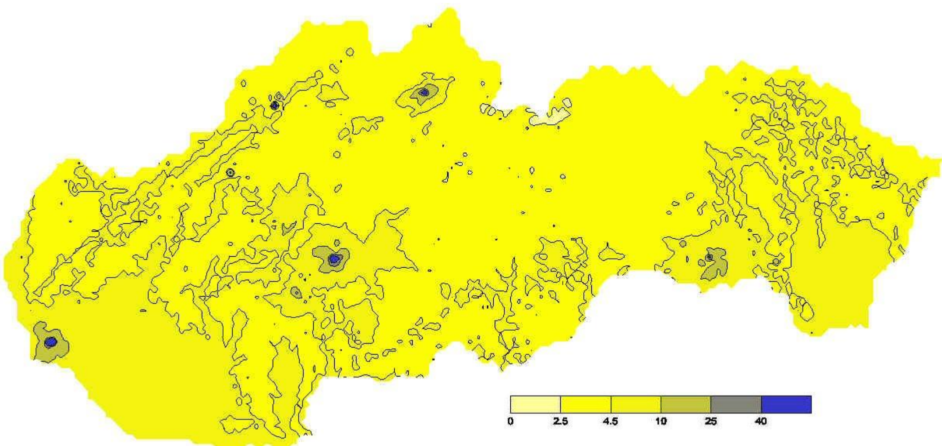
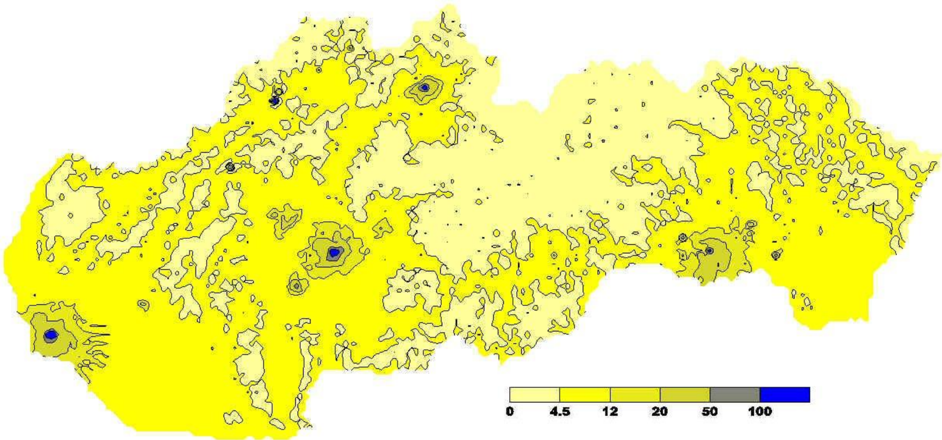


Fig. 4.3 *99,7th percentile of hourly mean SO_2 concentration [μg.m^{-3}] – 2019.*



From **Fig. 4.1**, **Fig. 4.2** and **Fig. 4.3** is evident, that the territory affected by higher SO_2 concentrations is related to the locations of the most important (most abundant) sources of air pollution by SO_2. The location of dominant sources (Slovenské elektrárne, a.s. - ENO - Elektráreň Nováky; U.S. Steel, s.r.o.; Slovalco, a.s. and Slovnaft, a.s.) of air pollution by this pollutant and some air pollution sources with limited influence is evident from these three maps. All retain the results of mathematical modelling, using only air pollution sources, registered in NEIS. Modelling confirmed, that at the territory of SR the limit value for SO_2 was not exceeded in 2019. It was last exceeded in 2004 at Bystričany monitoring station.

Tab. 4.1 *Measured (AMS) and calculated (CEMOD) air quality indicators for the sulphur dioxide (SO_2) in NMSKO SR network 2019 and their difference in percentage [%].*

AGGLOMERATION Zone	Monitoring station	(SO_X) – annual mean concentration [μg.m^{-3}]			99.2-percentile from 24-hours concentration of sulphur dioxide			99.7-percentile from hourly concentrations of sulphur dioxide		
		AMS	CEMOD	Diff	AMS	CEMOD	Diff	AMS	CEMOD	Diff
BRATISLAVA	Bratislava, Jeséniova*	3.2	5.1	59.4%	11	15	36%	34	33	-3%
	Bratislava, Mamateyova	4.3	4.7	9.3%	23	12	-48%	116	30	-74%
KOŠICE	Košice, Štefánikova	11.2	9.3	-17.0%	24	21	-13%	34	48	41%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	9.4	7.9	-16.0%	17	17	0%	22	35	59%
Bratislava region	Malacky, Mierové nám.	4.4	4.8	9.1%	14	10	-29%	24	18	-25%
Košice region	Krompachy, SNP	11.1	6.4	-42.3%	18	15	-17%	23	32	39%
Nitra region	Nitra, Štúrova	7.2	6.4	-11.1%	13	10	-23%	16	16	0%
Prešov region	Vranov n/Topľou, M. R. Štefánika	10.4	9.6	-7.7%	19	25	32%	33	46	39%
Trenčín region	Prievidza, Malonecpalská	7.8	6.3	-19.2%	17	12	-29%	23	20	-13%
	Bystričany, Rozvodňa SSE	6.2	5.9	-4.8%	11	13	18%	19	24	26%
	Handlová, Morovianska cesta	9.3	7.1	-23.7%	26	18	-31%	32	42	31%
	Trenčín, Hasičská	4.5	5	11.1%	8	9	13%	13	17	31%
Trnava region	Senica, Hviezdoslavova	3.7	3.7	0.0%	11	7	-36%	13	11	-15%
Žilina region	Ružomberok, Riadok	3.6	3.4	-5.6%	8	6	-25%	12	7	-42%

** Lack of valid data – beginning of measurement programme for SO_2 at the station in October 2019*

Tab. 4.1 contains the calculated and measured indicators for air quality assessment (99.2nd percentile corresponds to the limit value for 24-hour data and 99.7th percentile corresponds to the limit value for hourly data). It is obvious from comparison, that to reach the required success of modelling calculations in comparison to the measured values, is the more complicated, the lower the measured value is. This is particularly valid in the case of annual average concentrations, when the absolute difference of 1 μg.m^{-3} represents a percentage share up to 15% (which is a common measurement uncertainty of air quality monitoring instruments), while a required model uncertainty is 30%. For the mean daily and hourly values, the absolute value of the differences between the measured and modelled concentrations is relatively small. Absolute value of hourly percentiles from data measured in 2019 did not exceed 10% of limit value, resp. 20% in case of daily mean concentrations. From this is resulting, that as in case of annual average concentration, the big percentage difference is also at small absolute differences (prescribed successfulness for estimation of these values by model is 50, resp.60%). Decreasing trend of absolute values of percentiles of short-term concentrations in last years as well as status in 2019 unambiguously point on decreasing influence of dominant sources on air quality by sulphur dioxide in Slovakia.

Comparison of calculation results with measured values in **Tab. 4.1** points partially to the problem of small air pollution sources (residential heating systems) in the given location. Until 2016, ENO power plant, as the only point source, had a dominant influence on SO_2 concentrations, measured at the monitoring stations in its vicinity (i.e., Prievidza, Bystričany and Handlová). At present, however, the household heating by solid fuel is influencing the air quality in Nováky (in case of this locality it is dealing about heating by coal). Under the outstanding decrease of emissions from dominant sources input into the spotlight the problematics of localities with significant share of solid fuel burning in heating systems, domestic, as well as local.

Missing input information for calculation at the other localities have mostly as consequence, the smaller values of model estimations of annual mean concentrations as compared to the measured data.

Annual mean background concentration measured at the rural background monitoring stations of NMSKO with monitoring programme EMEP, was less than 1.15 $\mu g.m^{-3}$. This value is lower than 6% of the critical air pollution level for protection of vegetation. In 2019 was recorded nonsignificant decrease of this value on background EMEP stations Chopok and Starina.

We can therefore establish, that the decreasing trend of emissions of large and medium air pollution sources. favourably manifest also on air quality.

- **Nitrogen dioxide, oxides of nitrogen – NO_2, NO_X**

Model CEMOD is used to obtain the areal assessment of NO_2 concentrations. Procedure at modelling is similar as in case of SO_2. However, the model takes into account the transformation of NO to NO_2 and is more ambitious on inputs, mainly those ones, which do relate mobile sources, including density and structure of build-up area in vicinity of roads. CEMOD works also with information about the landuse (it characterizes residential or industrial build-up area and type of vegetation). Emission input data from stationary sources of data base NEIS, were amended about the determination of time profile of emission fluxes, during the year (the whole year or seasonal operation, energy production has specific time profile, etc.). Emissions from mobile sources (road transport), as does concern this pollutant, have not negligible significance, what is indicated also by monitoring - exceeding of limit value is recorded on monitoring stations of traffic type with high intensity of traffic. For modelling in control points were calculated area sources, which take into account the emissions from road transport, outside of main road network, as well as influence of close parking places and pump stations of fuels. The model was calibrated upon the base of the measured values - **Tab. 4.2**). In model calculations, the fugitive emissions and other known local influences are substituted by area sources. As supplementary data at assessment of area distribution of nitrogen dioxide concentrations, serve the results of measurements from background stations of NMSKO, with monitoring programme EMEP.

Emissions – Emissions from mobile sources classified on passenger cars and trucks, were divided on 3258 road sections of traffic network at the territory of SR, with total length 10634 km. For model calculation of control points (**Tab. 4.2**), the road network was used, broaden about the local communications. In addition to information from the traffic census in 2015, the growth coefficients, according to the projected traffic intensity provided by the Slovak Road Administration, were applied.

From the total number of 9 998 stacks and vents of stationary sources of nitrogen dioxide, belonging to the group of large and medium sources, into the model calculations, were included 666 stacks (vents), which represent more than 94% from total amount of emissions from large and medium sources. From this total amount only five more significant sources U.S. Steel, s.r.o.; CRH (Slovakia); Slovnaft, a.s. Bratislava; Slovenské elektrárne, a.s. (ENO- Nováky) and Mondi SCP, a.s. – emit annually over 1000 t of NO_x emissions, which represent together approximately 35% share of total emissions from medium and large sources. Emissions of oxides of nitrogen are not a matter of several dominant sources in such a range, as it is in case of sulphur dioxide. It is indicated also by higher number of stacks (vents), affiliated into the model calculations as compared to the modelling of CO or benzene. Bigger part of remaining share of NO_X emissions of medium and large air pollution sources, perform the local heating systems – heating plants. From the total amount of 9998 chimneys with NO_x emissions, only 890 had annual emissions over 1 tone and only 54 stacks over 100 tones (in 2018 it was 61 stacks). In 2019 was recorded decrease of NO_x emissions, approximately about 15%, as compared to 2018. Small air pollution sources (predominantly domestic heating systems) emitted around 10% of $NO_{X,}$ as compared to the emissions of from medium and large sources. From the mentioned amount is approximately 30% from burning of fuel wood.

Small sources (household heating), medium and large sources from NEIS data base with small emission rates for the purposes of model calibration in reference points (**Tab. 4.2 –** NMSKO stations), are supplied by the area air pollution sources, similarly as influence of near parking places and motor vehicle traffic for locations with non-complete information on traffic intensity (for calculations were used 47 such area sources). Results of calculations in these points serve predominantly to search the share of indirect influences (parking places, fugitive emissions, short-term economic provision, etc.). Analysis of these results is precious information to propose measures in process of air quality management.

Model results – In 2019, the limit values for protection of human health for hourly mean concentrations (over 18 allowed exceedances of limit value in calendar year) and for annual mean concentration were not exceeded at the NMSKO monitoring stations. Annual mean concentrations of NO_2, which exceeded upper limit for assessment of air pollution level (annual mean concentration 32 $\mu g.m^{-3}$), were measured only at three stations (Bratislava, Trnavské Mýto, Trnava, Kollárova and Prešov, Arm. gen. Ľ. Svobodu). Hourly percentiles did not exceed the upper limit for air pollution level assessment on any of monitoring stations (limit value 140 $\mu g.m^{-3}$). Low limit (limit value 100 $\mu g.m^{-3}$) was exceeded on three stations Bratislava, Trnavské Mýto; Košice, Štefánikova and Trnava, Kollárova. It is dealing about the monitoring stations of traffic type, located close to the road communications, with dense intensity of motor vehicle traffic. The highest value of one hour percentile was recorded on the Trnava, Kollárova. Model estimations of percentiles on five urban background stations were expressively underestimated, as compared with the measured values (-28 up to -56%), however the estimations of annual mean concentrations showed very good agreement. Air quality monitoring in these locations is obviously influenced by occasional episodes from small local, resp. more significant farther air pollution sources. These episodes do not influence more significantly annual mean concentration in location. On four stations, the model estimation strongly underestimated annual mean concentrations (–19 up to –37%), under the relative good agreement of percentiles. It is dealing about the stations of traffic type in big cities of Slovakia. It is evident result of complexity absence of emission inputs into the calculations, resp. of influence of elevated inversion, over the of city heat islands to air pollution cummulation.

In 2019, the values of nitrogen dioxide concentrations across the territory of Slovakia showed a more favourable state of air quality, than in 2018. This is apart from good conditions for dispersion of air pollutants, apparently also as a consequence of expressive emission decrease of one from the significant air pollution sources: U.S. Steel Košice, s.r.o. Calculated results contain also annual mean concentration of oxides of nitrogen (NO_X), which are as pollution matter, the main indicator for vegetation protection.

The mean annual critical level for NO_X for protection of vegetation is set, however no limit value of NO_X is set for the protection of human health. Model calculations, as well as their mapping display for $NO_{X,}$ are only informative and serve only to verify the functionality of the CEMOD model. The measured data for NO_X are not presented, because the continuous measuring instruments in the NMSKO network are not intended for vegetation protection purposes.

Tab. 4.2 *Measured (AMS) and calculated (CEMOD) air quality indicators for nitrogen dioxide (NO_2) in NMSKO SR – 2019 and their difference in percentage [%].*

AGGLOMERATION Zone	Monitoring station	(NO_2) – annual mean concentration [μg.m^{-3}]			99.8th-percentile from hourly concentrations of nitrogen dioxide		
		AMS	CEMOD	Difference	AMS	CEMOD	Difference
BRATISLAVA	Bratislava, Trnavské mýto	37.2	32.6	-12%	104.5	142	36%
	Bratislava, Jeséniova	10.5	10.3	-2%	55.5	40	-28%
	Bratislava, Mamateyova	20.8	17.4	-16%	89.4	70	-22%
KOŠICE	Košice, Štefánikova	27.7	21.5	-22%	104.3	86	-18%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	29.3	23.8	-19%	96.5	107	11%
	Banská Bystrica, Zelená	8.9	9.3	4%	53.6	32	-40%
	Jelšava, Jesenského	9.3	8.2	-12%	43.1	26	-40%
Bratislava region	Malacky, Mierové nám.	21.5	18.4	-14%	74.8	71	-5%
Košice region	Krompachy, SNP	16.6	17.0	2%	65.2	66	1%
Nitra region	Nitra, Janíkovce	10.2	10.8	6%	56.5	33	-42%
	Nitra, Štúrova	30.6	24.1	-21%	93.7	96	2%
Prešov region	Humenné, nám. slobody	9.0	9.2	2%	54.3	24	-56%
	Prešov, Arm. gen. L. Svobodu	39.0	24.6	-37%	93.8	93	-1%
Trenčín region	Prievidza, Malonecpalská	15.8	15.7	-1%	69.0	44	-36%
	Trenčín, Hasičská	26.6	32.6	23%	93.4	142	52%
Trnava region	Trnava, Kollárova	33.8	10.3	-70%	111.9	40	-64%
Žilina region	Martin, Jesenského	24.0	17.4	-28%	83.3	70	-16%
	Ružomberok, Riadok	18.4	21.5	17%	65.8	86	31%
	Žilina, Obežná	21.4	23.8	11%	89.4	107	20%

Fig. 4.4 *Annual mean NO_X concentration [μg.m^{-3}] – 2019.*

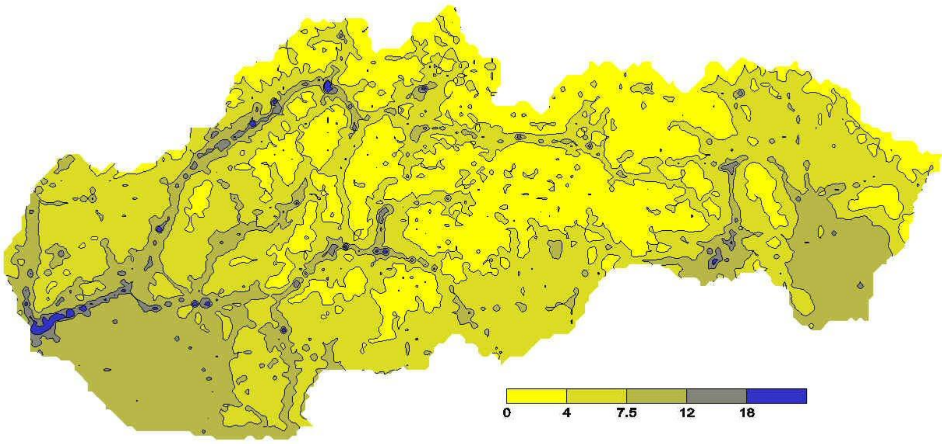


Fig. 4.5 *Annual mean NO_2 concentration [μg.m^{-3}] – 2019.*

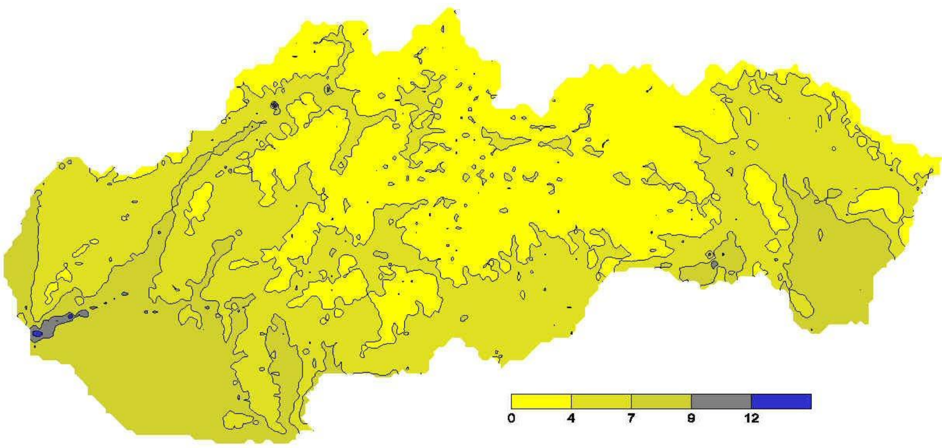


Fig. 4.6 *99.8th percentile of the hourly NO_2 concentration [µg.m^{-3}] – 2019.*

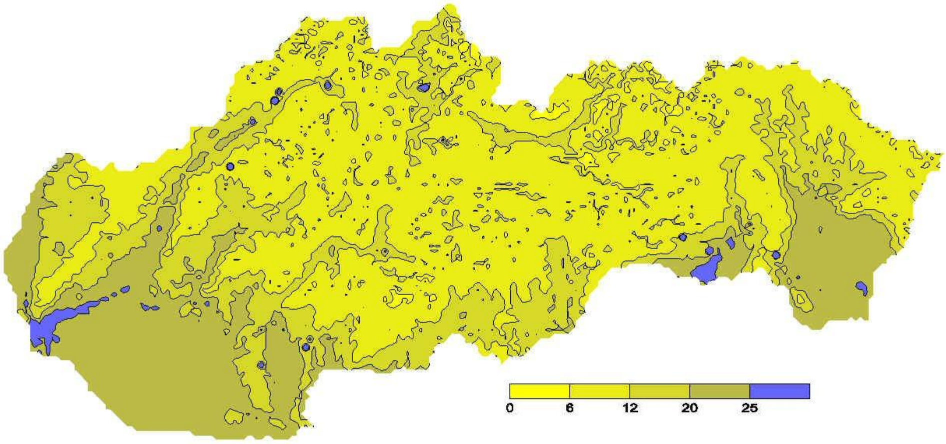


Fig. 4.4 – **Fig. 4.6** illustrate the spatial distribution of mean annual concentrations of nitrogen dioxide, as well as oxides of nitrogen. In case of nitrogen dioxide (**Fig. 4.5**, **Fig. 4.6**), the impact of mobile sources (i.e. the road network) is in the whole areas only inexpressive as a consequence of the gradual transformation of the emitted nitrogen oxide into nitrogen dioxide (this transformation is a function of time, respectively, due to dispersion and air advection as a function of distance). The result is a combination of the effects of the road transport, stationary air pollution sources and background air pollution concentrations. In case of CO, the share of road transport is more expressive – this is due to the fact, that only a few dominant stationary air pollution CO sources are registered, the others are of little importance (but it is not valid in case of stationary air pollution sources of $NO_{2,}$ in consequence of gradual chemical transformation of NO to NO_2). The same applies to the mean hourly concentrations of nitrogen dioxide. In case of NO_X in **Fig. 4.4** (immediate chemical transformation of NO to NO_2), we can already see the outlines of the more significant road sections, similarly as in the case of CO).

The annual mean background concentration, measured in 2019, at rural background stations of NMSKO with EMEP programme, is 3.42 µg.m^{-3} or less, which represents a slight decrease, as compared to 2018. These stations did not record even 20% of the limit value for vegetation protection.

- **Carbon monoxide – CO**

Mathematical modelling by dispersion model CEMOD was used also for spatial assessment of carbon monoxide concentrations. The same procedure was used as for NO_2, however the model calculated maximum 8-hour moving means for each day. The input information about mobile parameters, as well as stationery sources, is identical as in case of nitrogen dioxide modelling.

The concentrations measured in the NMSKO monitoring network were used to calibrate the model. In 2015, in the frame of reorganization and innovation of measurement network NMSKO, the measurement programme of stations Košice, Štefánikova; Ružomberok, Riadok a Žilina, Obežná, was enhanced about the measurements of carbon monoxide concentrations, which was monitored at 13 stations of the NMSKO network in 2019.

Emissions –The emissions from road transport (mobile sources), as well as from industrial and heat production and energy sources (stationary sources), were used at calculation.

Emissions from mobile sources (in classification on personal vehicles and trucks) included into the calculations, were spatially divided on 3 258 road sections at the territory of SR, about the total distance 10 634 km, similarly as for nitrogen dioxide. Apart from counting of transport in 2015, the growth coefficients were used according to perspective prognoses from the Slovak road administration. In case of trucks, the slightly more pessimistic combination of emission factors was elected, which does take into account the technical status of vehicles in SR. Carbon monoxide emissions are more expressive depended on the working regime of motor (i.e. mean speed of vehicles), as nitrogen dioxide emissions, not speaking about the cold start, resp. driving with cold motor on short distances, which enhances the exhaust emissions from road transport, mainly in cities.

Emissions of carbon monoxide from large and medium stationary sources have in last years the decreasing tendency. From total number 9 943 stacks and vents of carbon monoxide emissions, 205 were included into calculation. This reduced number represents almost 97.3% of carbon monoxide emissions, from which more than 80% create emissions from U.S. Steel Košice, s.r.o.; Slovalco, a.s. Žiar nad Hronom and CEMMAC, a.s. Further more significant originator of carbon monoxide emissions is metallurgy and production of cement and lime.

Small, medium and large sources with low emissions were represented by the area sources, similarly as parking places and road sections, about which is not accessible summary information about the traffic intensity. In model calculations, the fugitive emissions and other local influences were represented by 28 area sources.

Model results – In 2019, the limit value for the protection of human health (10 000 μg.m^{-3}) and the low limit for air pollution assessment (5 000 μg.m^{-3}) were not exceeded. As far as the air quality in Slovakia is concerning, this pollutant has been unproblematic for several years. In 2019 came to the expressive inter-annual decrease of carbon monoxide from stationary sources (around 28%) and therefore their share on total air pollution changed by this pollutant. By this is explained, that the present trend of spatial inter-annual modest decrease of carbon monoxide measured values at the territory of Slovakia on traffic type stations changed on the manifestation of local particularities of automobile traffic. In regard to the reached relatively low level of air pollution by carbon monoxide from the view of limit value (10 – 20% of limit value), these local inter-annual changes do not influence more significantly the air quality of given location.

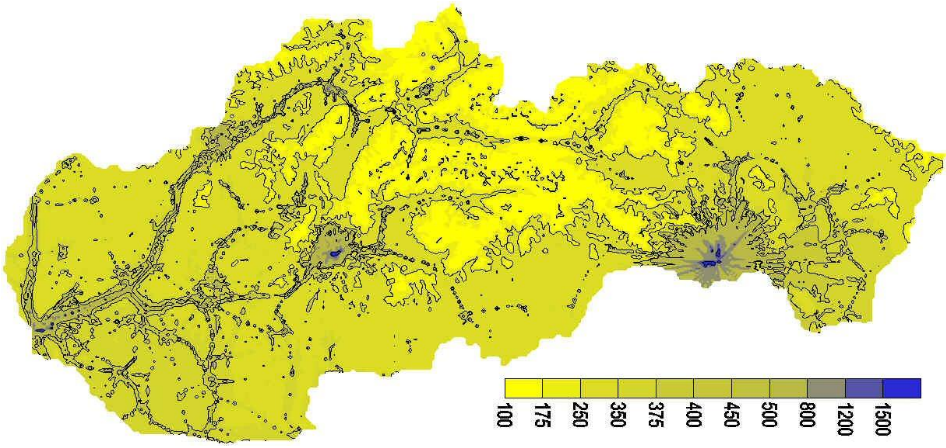
Tab. 4.3 Measured (AMS) and modelled (CEMOD) air quality indicators for carbon monoxide in NMSKO SR network in 2019 and their percentage difference [%].

AGGLOMERATION Zone	Monitoring station	CO – 8-hour mean [μg.m^{-3}]		
		AMS	CEMOD	Difference
BRATISLAVA	Bratislava, Trnavské mýto	917	1 178	28%
KOŠICE	Košice, Štefánikova	1 505	1 505	0%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	1 768	1 706	-4%
Bratislava region	Malacky, Mierové nám.	1 266	1 029	-19%
Košice region	Veľká Ida, Letná	1 966	2 218	13%
	Krompachy, SNP	1 908	2 076	9%
Nitra region	Nitra, Štúrova	1 221	1 366	12%
Prešov region	Prešov, Arm. gen. L. Svobodu	1 413	1 374	-3%
Trenčín region	Trenčín, Hasičská	1 239	1 506	22%
Trnava region	Trnava, Kollárova	1 619	1 639	1%
Žilina region	Martin, Jesenského	2 319	1 895	-18%
	Ružomberok, Riadok	2 353	1 963	-17%
	Žilina, Obežná	2 093	1 886	-10%

Fig. 4.7 shows the spatial distribution of maximum daily 8-hour moving means, with the dominant influence of mobile sources. The increased impact of road traffic on the level of carbon monoxide air pollution occurred at the most of traffic measuring stations, while the local character of road traffic being more pronounced, including local problems with traffic flow and parking. Impact of U.S. Steel, Košice, s.r.o. dominates over the mobile sources near this air pollution source. Concentrations of carbon monoxide, measured at the monitoring stations Veľká Ida, Letná correspond to the size of source, located in its vicinity. This air pollution source influences by its massiveness the air quality also on longer distances. With the expressive emission decrease in Veľká Ida (U.S. Steel, Košice, s.r.o.) correlates also the decrease of carbon monoxide concentrations in station Košice, Štefánikova, in 2019. As compared Figure 4.7 to the analogical visualizations from former seasons, the evident favourable impact of emission decrease on air quality in the whole area is visible. In the surroundings

of Žiar nad Hronom, it is possible to recognize the effect of emissions from the Slovalco a.s. The annual mean background concentration, estimated for 2019 was about 150 to 350 μg.m^{-3}. When interpreting the results, it is necessary to keep in mind, that a spatial resolution of 1 km was used (the model calculates the resulting concentrations in a regular grid with a node point distance of 1 km).

Fig. 4.7 *Maximum daily 8-hour moving mean [μg.m^{-3}] of CO – 2019.*



Under the expression maximum 8-hour moving mean concentrations is understand the maximum daily 8- hour mean value

Benzene

Due to the high potential risk of benzene to human health, the increased attention should be given to this pollutant.

Low limit for air pollution assessment (2 μg.m^{-3}) for benzene was in 2019 exceeded on the monitoring station Krompachy, the upper limit for air pollution assessment (3.5 μg.m^{-3}) was not exceeded.

Emissions – The main source of benzene emissions is road transport and combustion processes in industry. The most significant industrial sources of benzene emissions are Slovnaft, a.s. Bratislava and U.S. Steel Košice, s.r.o. However, the amount of benzene emissions from road transport reaches values about the order of magnitude higher, as compared to the emissions from registered industrial sources. Products from petrol combustion in road transport are more serious, because they are emitted directly in breathing zone of human. We cannot forget about the fugitive sources (although petrol contains only about 1% by volume of benzene).

Emissions from road transport in classification according to the vehicle types (personal vehicles and trucks) were budgeted on 3 258 road sections at the territory of SR in total distance 10 634 km, similarly as for carbon monoxide. For visualization of model calculations was used traffic network, from traffic counting in 2015. Apart from traffic counting in 2015, the growing coefficients were used, according to the perspective prognoses of traffic intensity from Slovak road administration. At model calculations of control points (stations of NMSKO network) was included also automobile transport, apart from the main road network. Influence of close parking places and pump stations of fuels were taking into account at model calibration. For modelling of total imission situation were apart from 79 stacks and exhausts of benzene emissions, which were registered in NEIS system, included into calculations also fugitive emissions and known local influences, represented by 6 area sources.

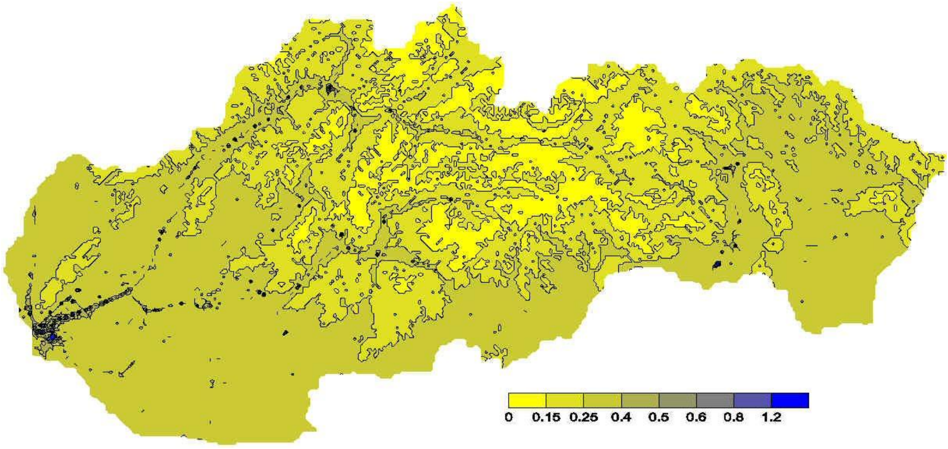
Model results – Fig. 4.8 are presented calculation results of the annual mean benzene concentration. Although the spatial resolution of the mathematical model is 1 km, at figure is possible to recognize the road network fragments. The contribution of road transport outside the city, close to roads, represents only 0.1 μg.m^{-3} in an annual mean. In the agglomeration Bratislava manifests the influence of dominant stationary sources (Slovnaft, a.s. Bratislava) apart from the intensive automobile transport.

The background concentration, based on previous measurements at EMEP stations, represents less than 10% of the limit value for the protection of human health. Annual mean benzene concentrations on the background stations decreased about 20 – 30% in recent years. It seems to be a pan-European trend.

Tab. 4.4 *Measured (AMS) and modelled (CEMOD) air quality indicators for benzene in NMSKO SR network in 2019 and their percentual difference in [%].*

AGGLOMERATION Zone	Monitoring station	Benzene – annual mean concentration [µg.m⁻³]		
		AMS	CEMOD	Difference
BRATISLAVA	Bratislava, Trnavské mýto	1.0	1.1	10%
KOŠICE	Košice, Štefánikova	0.7	0.7	0%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	1.0	0.9	-10%
Bratislava region	Malacky, Mierové nám.	0.5	0.5	0%
Košice region	Krompachy, SNP	2.1	2.2	5%
Nitra region	Nitra, Štúrova	0.5	0.5	0%
Prešov region	Prešov, Arm. gen. L. Svobodu	1.1	1.2	9%
Trenčín region	Trenčín, Hasičská	0.9	0.8	-11%
Trnava region	Trnava, Kollárova	0.8	0.6	-25%
Žilina region	Martin, Jesenského	0.8	1.0	25%
	Ružomberok, Riadok	1.1	1.3	18%

Fig. 4.8 *Annual mean concentration of benzene [µg.m^{-3}] – 2019.*



According to the results of mathematical modelling, the limit value for benzene was not exceeded in 2019, at the territory of Slovakia. Monitoring stations in Krompachy, SNP, recorded annual mean benzene concentration 2.1 µg.m^{-3}, which is the highest value in NMSKO network. This elevated level is probably influenced by parking of older vehicles, between residential houses, in vicinity of measurement station. Also, quite close pump station of fuels, in distance about 200 m has its influence. This situation gradually improved in last years. Measured annual mean concentration in 2019 only negligible exceeds the upper limit for air quality assessment (in 2014 annual average concentration value was 3.2 µg.m^{-3}). In monitored year (2019) was recorded the decrease of annual mean benzene concentrations at all measuring stations, apart from Ružomberk, Riadok, where was recorded inexpressive increase. The most expressive decrease of benzene concentrations was measured at the station Malacky, Mierové námestie, (decrease about 1.4 µg.m^{-3}, as compare to 2018). At the station Trnavské mýto was measured expressive decrease of annual mean concentration, reflecting the expressive decrease of benzene emissions from air pollution source Slovnaft, a.s., Bratislava in 2019.

Air pollution by benzene has at the all-area territory of Slovakia the inter-annually slight decreasing trend, which persists also in 2019. All-area decrease of air pollution level in Slovakia in 2019 is also a consequence of expressive benzene decrease emissions, from the registered large air pollution sources, as compared to 2018. At the benzene emission decrease on monitored locations, has expressive share apparently also decrease of vehicle age level. It is obvious also on the benzene level on monitoring stations in vicinity of parking places, resp. residential zones with free waiting (Trnava, Kollárova; Malacky, Mierové námestie; Krompachy, SNP).

- **Ground level ozone – O_3**

It is known, that concentrations of ground level ozone in Europe were growing in connection with anthropogenic emissions of ozone precursors (NO_X, VOC, CO) up to 1990 (Závodský, 2001; Lin, 2017). This growing, it seems, does not continue and after the extreme hot summer in 2003, the indicators of ground level ozone returned into the frame of common previous values. Even though in Slovakia were recorded exceedances of warning limit threshold, Slovakia does not have local potential to influence these increased values of ground level ozone concentrations.

For visualization of spatial distribution of ozone ground level indicators at the territory of Slovakia, the interpolation model IDWA-A was used. Basic input data for calculation are measurements from NMSKO and parameters, stated in terms of methodology for IDWA-A. **Fig. 4.9** shows the annual mean ozone concentrations in 2019. **Fig. 4.10** illustrates the number of days, in which the average eight-hour concentration of O_3 exceeded 120 $\mu g.m^{-3}$ i.e. the target value for the protection of human health. **Fig. 4.11** shows AOT40 values for the protection of vegetation, corrected for the missing period (according to the Regulation of the Ministry of Environment SR No. 244/2016 Coll. of Acts on air quality, in wording of later prescriptions).

Annual mean concentrations of ground level ozone are growing generally with the elevation. In 2019, similarly as in previous years, the maximum values were measured on the highest situated locations and minimum values on the stations in city centres. In 2019 was recorded spatial decrease of annual mean concentrations, in average about 4.4%, as compared to 2018. The largest decrease (over 10%) in annual mean O_3 concentrations in 2019, was recorded on four stations (Banská Bystrica, Zelená; Nitra, Janíkovce; Košice, Ďumbierska and Stará Lesná, EMEP), which represent all types of areas (urban, suburban and rural). Also decrease of annual mean concentrations on most of the monitoring stations (on eleven from sixteen), may be considered as one from evidences about the regional ozone transport, over the territory of SR. In last years was recorded the increase of annual mean concentrations in regions of bigger urban agglomerations, resp. in industrial zones. Because these years are similar from the point of photochemical activity, the mentioned increase of ozone concentrations could be assigned to the changes in structure of emitted ozone precursors.

Fig. 4.9 *Annual mean of ground level ozone concentrations [$\mu g.m^{-3}$] – 2019.*

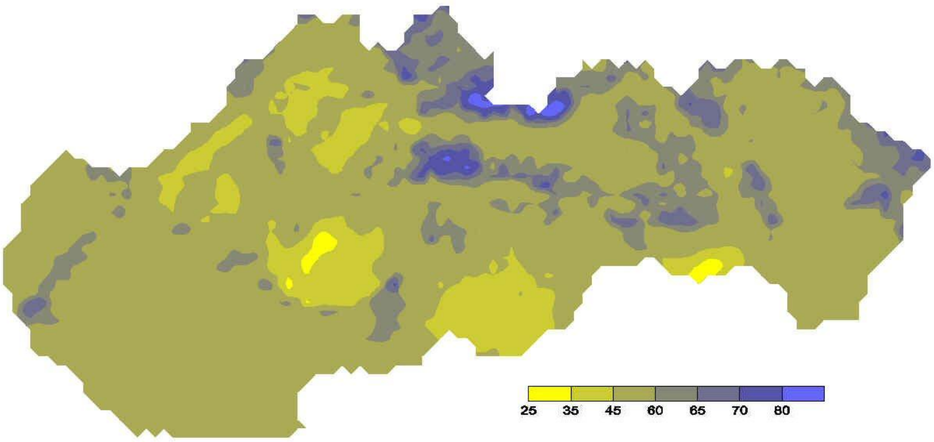


Fig. 4.10 *Number of days, in which the target value of ozone for the human health protection (120 µg.m^{-3}) was exceeded within the years 2016 – 2019 (limit value is 25 µg.m^{-3}).*

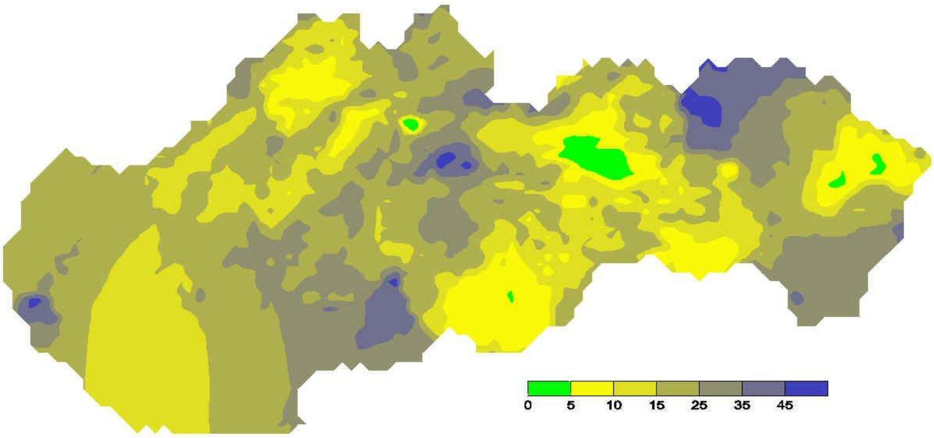
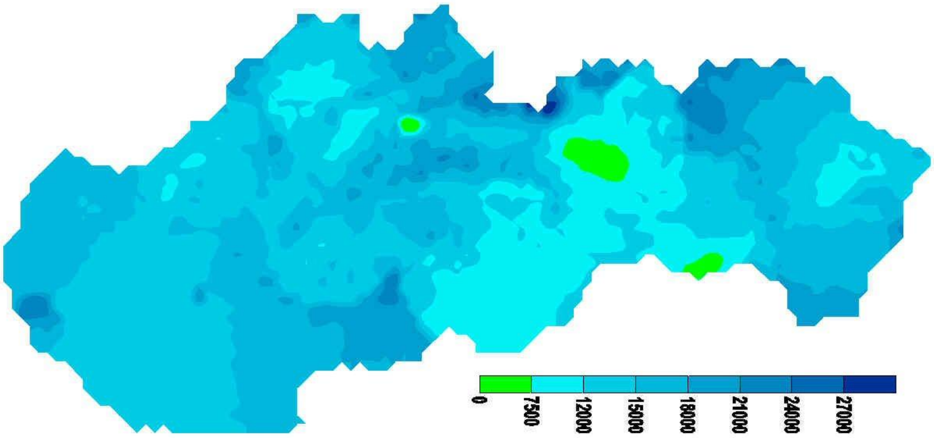


Fig. 4.11 *Mean values of AOT40 [µg.m^{-3}.h] for a period of five years (2015 – 2019) for the protection of the vegetation, corrected on missing season.*



At the territory of Slovakia are exceeded the target values for the protection of human health for tropospheric ozone. In the judged period 2017 – 2019, the target value for the protection of human health (more than 25 days within the calendar year, on average of three years) was exceeded at four, out of sixteen monitoring stations. The most significant exceedances were recorded in localities, where the highest annual mean concentrations were measured (apart from high mountainous stations - Kojšovská hoľa, Chopok). Significant number of limit value exceedances (44) was recorded on measurement station Bratislava, Jeséniova. This fact indicates possibility of significant concentration of ozone precursors, in domain of Bratislava.

The exceedances of AOT40 target values for vegetation protection (18 000 µg.m^{-3} in average of five years) in May – July (average for 2015 – 2019) occurred at three monitoring stations out of 16, Bratislava, Jeséniova; Nitra, Janíkovce; and Chopok, EMEP). In the last period of assessment for vegetation protection (season May-June, on average of years 2015 – 2019), the mean AOT40 measured value was lower about 3.4%, than in previous period.

In 2019, expressive decrease was recorded, as in case of number of target values for the protection of human health exceedances (120 µg.m^{-3} will not be exceeded more than 25 days in calendar year on average of three years), at the territory of Slovakia, as well as the increase of absolute values AOT40 for protection of vegetation. Cause of measured decrease in both cases is evidently similar, as in the mentioned case of annual mean concentrations – ozone concentrations at our territory are influenced dominantly by regional, to global long range transport.

The year 2019 could be considered as photochemically modest active years, according to the mean values in vegetation season. The average monthly deviations of sums of solar erythema ultraviolet radiation from the average for the period 2000 – 2019 at the stations Bratislava, Jeséniova and Poprad, Gánovce, had slightly increased values (9%, resp. 6%), as compared to the previous season (4% at both stations). The average daily deviations of sums of solar erythema ultraviolet radiation in 2019 on the stations Bratislava, Jeséniova and Poprad, Gánovce were less significant, as compared to values in 2018. Average daily deviation of total atmospheric ozone (D.U.) from the long-term average in 1962 – 1990, measured in Hradec Králové, in 2019, was –3.3%. In 2018, this value was only minus 0.1%. Increase of the negative value of mean daily deviation in 2019, was reflected also in measured values of tropospheric ozone in Slovakia.

Suspended particulate matter – PM_{10} a $PM_{2.5}$

For spatial assessment of locations with exceedance of limit values was used model (interpolation scheme) IDWA-A. It was elected for the assessment of territory carrying capacity by particles PM_{10} and $PM_{2.5}$, just for the high degree of uncertainty of input emission data for CEMOD model, in case of PM. For assessment at the CEMOD model would be necessary to count the creation of PM_{10} and $PM_{2.5}$ by chemical reactions in atmosphere and by condensation of hot flues, releasing from stacks, to calculate resuspension of solid air pollutants, sedimented on traffic roads, to count fugitive emissions, respectively take into account the occurrence of particles of biogenic origin. As it is complicated to gain the relevant emission inputs with high spatial resolution, for such complex problem, the quoted interpolation scheme IDWA-A was used.

Basic input data for calculation perform the results from measurements of PM_{10} and $PM_{2.5}$ from NMSKO, gained by the continual monitoring. Measurements of $PM_{2.5}$ begun in 2005 on three stations. In 2019, the continual monitoring of $PM_{2.5}$ was realized on 32 monitoring stations, including two stations with EMEP programme. Results of measurements of PM_{10} **(**direct or derived from TSP) from stations with EMEP programme, are achieved by gravimetric method under the weekly sampling interval and serve as additional information at the spatial territory assessment.

Emissions – Emissions of PM from large and medium sources of air pollution in 2019 decreased again. Sources of air pollution included into the category of small sources (it is dealing mainly about the household heating) emit however totally several times more of PM as large and medium stationery sources. It is necessary to realize, that share of wood burning performs the biggest part of solid particle emissions from small sources. Emissions from mobile sources (abrasive also) created in 2019 only about 10% from the total registered amount of solid pollutants.

Model results **(**PM_{10}**) –** for the time being, the biggest problem in Slovakia and in most European countries in the field of air quality, is PM_{10} pollution. Limit value for protection of human health for averaging season of one year (40 $\mu g.m^{-3}$) was not exceeded on any of NMSKO stations in 2019 and from 2016 also no exceedance appeared on station Veľká Ida, Letná, in vicinity of the most significant source of solid pollutants – US Steel, Košice. Number of daily limit value exceedances was over permitted limit value for protection of human health (50 $\mu g.m^{-3}$ must not be exceeded more than 35 times in calendar year) on three stations, of which is one traffic (in 2018 it was 5 stations, of which 3 traffic). From the quoted three stations, the biggest number of exceedances (over 60) was measured on monitoring station Jelšava, Jesenského (61). Number of exceedances on station Veľká Ida, Letná (45) in 2019 is historically the lowest one (in 2018 was registered 63 exceedances). The most expressive decrease of exceedance number in 2019, as compared to 2018, was recorded on station Martin, Jesenského (about 20). To the increased number of exceedances came in localities, situated in valley locations, which are distinguished by significant share of solid fuels, as well as by vicinity of significant air pollution sources, resp. locations with high economy activity. To the inter-annual increase of exceedance number came only on the stations, situated on East Slovakia. Obviously, the regional differences demonstrate in precipitation occurrence. In spatial average came to the decrease of exceedance number almost about 28%, as compared to 2018. In cases of annual average concentrations came in 2019 to the decrease in almost at all stations of Slovakia (even about 15.2%). The most outstanding decrease was recorded on stations Martin, Jesenského and Veľká Ida, Letná. Results of calculations of air pollution spatial distribution are shown in **Fig. 4.12** and **Fig. 4.13**. Based on the measured data, it can be concluded, that the annual mean concentration in the territory of Slovakia in 2019, as compared to 2018, statistically significantly decreased. Similarly, also the decrease of daily limit exceedances is significant. One of the reasons may be that the cold season of 2019, was less heating intensive than in 2018. In year 2019, the emissions from large and medium sources of air pollution was decreasing hereinafter and in regarding to relative warm winter season in last years, also the emissions from domestic heating systems, mainly from burning of wood fuels, decrease. The elaborated statistical analysis reveals also high statistical significance of the dependence between the measured values from EMEP stations and values from the other local stations, in individual regions. According to the model estimations (LOTOS, Holland), in Slovakia the background PM_{10} concentrations create approximately 19%. Under the present decreasing trend of PM emissions in Slovakia, this share will be probably growing. From the quoted investigations follows, that to solute the problems of air pollution by PM_{10} particles, is demanding apart from local measures, also making provisions for undertaken of regional to continental mechanisms for genesis and long range transport of fine suspended particles with the small aerodynamic average ($PM_{2.5}$). At continuation of decreasing tendency of PM emissions from sources in Slovakia, the significance of transboundary transport will grow in coming years.

Fig. 4.12 *Annual mean concentration of PM_{10} [μg.m^{-3}] – 2019.*

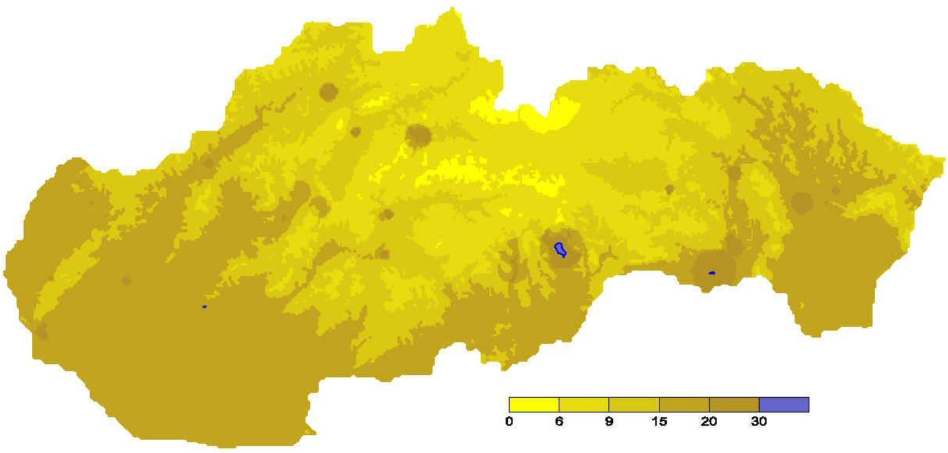


Fig. 4.13 *Number of days with exceedance of limit value for 24-hour concentration of PM_{10} (50 μg.m^{-3}) in 2019 (Blue line delimits an area with exceeded limit value).*

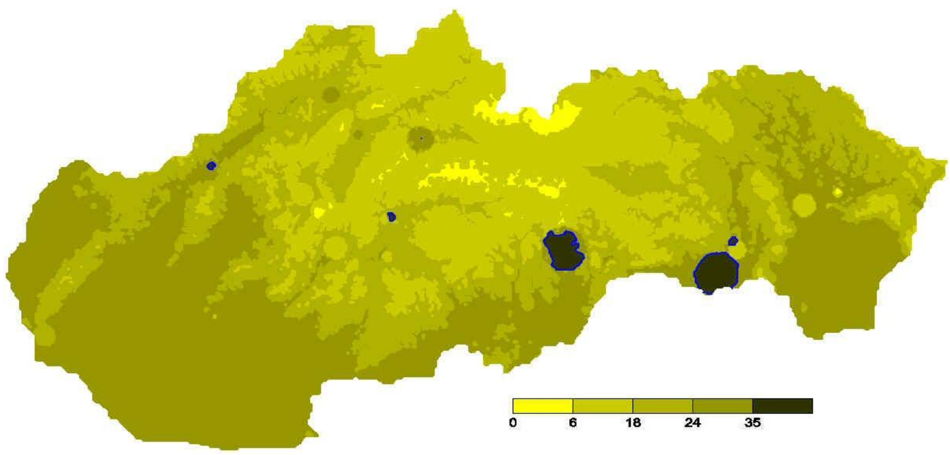
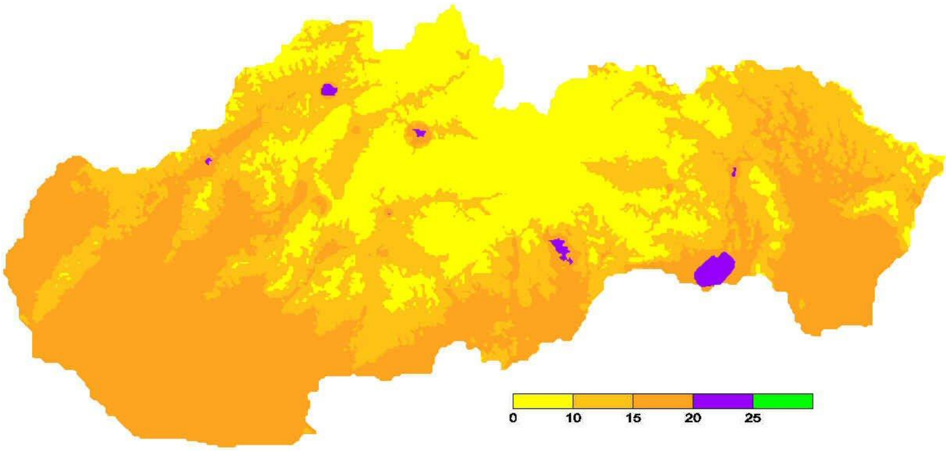


Fig. 4.14 Annual mean concentration of $PM_{2.5}$ [µg.m^{-3}] – 2019.



Model results **($PM_{2.5}$)** – In 2015, the limit value for $PM_{2.5}$ came into force: 25 µg.m^{-3} for calendar year. In this and following year (2015 and 2016), no exceedance of the annual limit value was recorded at any of NMSKO monitoring stations at the territory of Slovakia. In 2017, the limit value of annual mean concentration in case of $PM_{2.5}$ was exceeded at two stations (Jelšava, Jesenského and Žilina, Obežná). The value measured at the station Veľká Ida, Letná, is exactly equal to the target value. In 2018 and 2019, the target value of annual mean concentration was not exceeded at any monitoring station. Annual mean concentration in 2019 decreased, as compared to 2018, at all measurement stations. The whole-area decrease of annual mean concentration of $PM_{2.5}$ in Slovakia in 2019, performed even 12.4%,s as compared to the previous year. The most expressive decrease was recorded on measurement station Bystričany, Rozvodňa SSE, about 35.3%. There is evident decrease of fossil fuel burning in the thermal power plant. In case of $PM_{2.5}$, only the limit value for protection of human health for annual mean concentration is defined.

Regarding the smaller aerodynamic diameter of $PM_{2.5}$, this pollutant needs more energy for resuspension, comparing to PM_{10}. From the mentioned reason, the resuspension of particles (winter sanding) and various episodes, relevant to resuspension, have expressively smaller significance in case of $PM_{2.5,}$ than in case of PM_{10}. Decreasing of air pollution by $PM_{2.5}$ particles is not possible to separate from decreasing level of PM_{10} in air. The conclusions, cited in previous section for PM_{10} are therefore generally related also to $PM_{2.5}$.

Source apportionment – Contribution of individual types of air pollution sources to total PM_{10} was determined by model calculations. Conclusion, is, that the proportion of large and medium sources on measured annual mean concentrations in NMSKO network, is less than 2%, apart from the surroundings of US Steel, Košice, s.r.o. (In Veľká Ida the monitored proportion represented 25 – 30%). In case of mobile sources in agglomerations Bratislava and Košice, this proportion represents 12 – 25%, in the other cities 5 – 15%. Into the calculation were included also the contributions from brake deterioration, tyres and road way, as well as resuspension. Contribution of regional background create the measurements on background stations, with EMEP programme. Model calculations pointed out on the so called share from unknown sources, which perform unregistered sources (e.g. fugitive) and small sources, determined only by balance.

Predominant local air pollution sources by fine suspended particles in Slovakian cities are at present following:
- Local heating systems on solid fuels;
- Small and medium local industrial sources without proper air pollution abatement technique;
- Road transport (abrasion of road surfaces, tyres, and brake wear);
- Wind erosion from unconsolidated surfaces (source mainly of coarse size fraction);
- Construction and demolition works (spatially delimited source mainly of coarse size fraction);

- Agricultural works (time delimited source mainly of coarse fraction);
- Secondary dustiness – fine particles, which originate in air by chemical reaction (e.g. oxides of nitrogen from road transport and ammonia from agriculture).

On these sources should be oriented the local measures on decreasing of PM_{10} level (i.e. on decreasing of solid fuel consumption in local heating, changes in organization of traffic, pedestrian zones, enhancing of greenery, consolidate surfaces, checking of technical state and pollution of vehicle tyres, cleaning of streets and pavements of cities, conservation measures on build-up ground and on dumps of crispy materials, dumps of wastes, and strict checking of local industrial sources). Concentration of 50 $\mu g.m^{-3}$ is often already exceeded on windward of cities, at circulation from south and east (episodically), or at some agricultural works, e.g. dry tillage, harvest or beet campaign. Within last year the share of air pollution increased from burning of wood matter at household heating.

To propose the local measures for PM_{10} level is very difficult, regarding to the high level of PM_{10} background concentration. Until for the other assessed air pollutants, the level of background concentration performs less than 30% from limit value, for PM_{10} it is up to 75% and in case of $PM_{2.5}$ even more – i.e. exceedance of upper limit for air quality assessment is caused already by alone PM background concentration. The PM_{10} city background of bigger cities in Slovakia (over 50 000 inhabitants) is estimated at level of 20 – 30 $\mu g.m^{-3}$. In last years the probability of limit value exceedances for annual mean concentration (40 $\mu g.m^{-3}$) decreased. In regard to the short measurement programme duration, in case of $PM_{2.5}$ air pollution as compared to PM_{10}, there is not enough information to assess long term trend.

4.3 CONCLUSION

Decreasing trend of emissions from dominant air pollution sources puts the bigger accent on the significance of air quality mathematical modelling at the acceptance of measures to improve air quality. Contribution of large sources does not exceed so expressively the contributions from less efficient air pollution sources. Expressively higher value of the measured hourly (daily) percentiles, as compared to calculated ones, reveals the incompatibility of source with approved operation conditions. When model significantly underestimates annual mean concentrations, as compared to the measured ones, it points to the more extensive group of small air pollution sources (parking places, domestic heating systems).

Concentrations of basic air pollutants decreased in 2019, at majority of localities at the territory of Slovakia. It is also consequence of more favourable meteorological situation. The most expressive problem remains PM_{10} and $PM_{2.5}$ air pollution, while elementary task plays the household heating by solid fuel. Situation is the most complicated in mountain valleys, in area with good accessibility of fuel wood and often occurrence of adverse dispersion conditions, mainly during heating period. Financial conditions often do not allow to local inhabitants to use natural gas for heating, or to purchase the modern low-emission heating equipment.

5 AIR QUALITY ASSESSMENT – CONCLUSION

5.1 PROPOSAL OF ALLOCATION OF AIR QUALITY MANAGEMENT AREAS IN YEAR 2020

The Slovak Hydrometeorological Institute proposes, upon the basis of the air quality assessment in zones and agglomerations in 2017 – 2019, according to § 8, section 3 of Act No. 137/2010 Coll. of Acts on air, in wording of later prescriptions, actualization of the allocation of air quality management areas in SR for year 2020. The pollutant will be removed from the air quality management areas only when it reaches the level below limit value for 3 consecutive years. In case of necessity, also older results may be considered.

In 2020 came to the change in allocation of zones and agglomerations, which contains the Regulation of MoE SR No. 32/2020 Coll. of Acts, by which is changed and amended Regulation of MoE SR No. 244/2016 Coll. of Acts, on air quality, in wording of Regulation n.296/2017 Coll. of Acts. This novel takes into force 1. March 2020. Proposal of allocation of air quality management areas for year 2020 therefore is in coincidence to this change.

Tab. 5.1 *The Air Quality Management Areas for 2020 allocated upon the basis of measurements in 2017 – 2019.*

AGGLOMERATION Zone	Air quality management area	Pollutant*
BRATISLAVA	Territory of capital of SR, Bratislava	NO_2
KOŠICE[12]	Territories of Košice city and municipalities Bočiar, Haniska, Sokoľany and Veľká Ida	PM_{10}, BaP
Banská Bystrica region	Territory of Banská Bystrica city	PM_{10}, BaP
	Territory of Jelšava city and municipalities Lubeník, Chyžné, Magnezitovce, Mokrá Lúka, Revúcka Lehota	PM_{10}, $PM_{2.5}$, BaP
	Territory of Hnúšťa city and the valley of the river Rimava from the local part Hnúšťa - Likier to the town of Tisovec	PM_{10}
Košice region[13]	Territory of Krompachy city	PM_{10}, BaP
Prešov region	Territory of Prešov city and Ľubotice municipality	PM_{10}, NO_2
Trenčín region	Territory of Trenčín city	PM_{10}
	Territory of Prievidza district	BaP
Žilina region	Territory of Ružomberok city and Likavka municipality	PM_{10}
	Territory of Žilina city	PM_{10}, $PM_{2.5}$, BaP

** Taking into account the measurements in previous years in case of insufficient number of valid measurements.*

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

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

5.2 AIR QUALITY ASSESSMENT IN CLASSIFICATION BY ZONES AND AGGLOMERATIONS IN 2020 ACCORDING TO THE REQUIREMENTS OF DIRECTIVE OF EUROPEAN PARLIAMENT AND COUNCIL 2008/50/EC

EU legislation[14] implies an obligation to assess the air quality in classification on zones and agglomerations. Tab. 5.2 shows agglomerations and zones, where the limit value for PM_{10}, $PM_{2.5}$ or NO_2 exceeded in the years under review.

Tab. 5.2 Assessment of zones and agglomeration, according to the limit values for PM_{10}, $PM_{2.5}$, NO_2 and BaP, based on measurements in 2017 – 2019 (taking into account data in previous years in case of insufficient number of valid measurements).

AGGLOMERATION Zone	Pollutant	AMS/year of limit exceedance
BRATISLAVA	NO_2	Bratislava, Trnavské mýto / 2018
KOŠICE	PM_{10},	Košice, Štefánikova / 2017 – 2019; Košice, Amurská / 2017, Veľká Ida / 2016 – 2019;
Banská Bystrica region	PM_{10}	Banská Bystrica, Štefánikovo nábr. / 2017, 2018; Jelšava / 2017 – 2019; Hnúšťa / 2017
	$PM_{2.5}$	Jelšava / 2017
Košice region	PM_{10}	Krompachy / 2017
Prešov region **Trenčín region**	PM_{10}	Prešov / 2017
	NO_2	Prešov / 2018
Žilina region	PM_{10}	Trenčín, Hasičská / 2017, 2018
Košice region	PM_{10}	Ružomberok, Riadok / 2017
	$PM_{2.5}$	Žilina, Obežná / 2017

In the evaluated years 2017 – 2019, the target value for the protection of human health for O_3 was exceeded in the agglomeration Bratislava, as well as in the Slovakia zone (Tab. 3.12).

[14] *Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe and http://ec.europa.eu/environment/air/pdf/guidanceunderairquality.pdf*

6 EMISSIONS

INTRODUCTION TO EMISSIONS

What are the emissions?

Air polluting substance (the emission) is a material present in the air that may have adverse effects on human health and the environment. These substances can be of natural origin, e.g. volcanic activities or can be caused by human activities. The emissions associated with human activities, so-called *anthropogenic emissions*, are important in terms of air protection. The concept of emissions is defined in the legislation of the Slovak Republic.

> *Emission is every direct or indirect discharge of polluting substance into the atmosphere.*[1]
> *Emission means the release of a substance from a point source into the atmosphere.*[2]
> *Emission means the direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into air, water or land.*[3]

What relationship is between released emissions and air quality?

Air pollutants can be divided into primary and secondary emissions. Emissions of air pollutants released into the atmosphere from human activities represent primary pollution. Primary air pollutants arise principally from the combustion processes, for instance transport, industry and energy. However, substances occurring in the air have also a natural origin, do not arise by human activities. The atmosphere allows their transport, dispersion and deposition from the source to the receptor. The receptors can be other components of the environment (for instance water, soil, living organisms). Secondary air pollutants are not emitted directly. They are created by the chemical or photochemical processes and mutual interactions of primary emissions after their release and occurring in the atmosphere. A suitable example of secondary air pollution represents the ground ozone. Certain air pollutants can be of primary as well as the secondary origin, which means that they are emitted directly but also can be created from other primary air pollutants. The pollution of atmosphere respectively the air quality is detected by measuring of air polluting substances concentration in the atmosphere or through the usage of mathematical models.

What are the consequences of excessive emission discharge?

The emissions emitted into the air as a result of human activities have a negative impact on human health and the environment. They cause a decrease of air quality, for instance the acidification of atmospheric precipitation, which influences the fauna and flora, the destruction of buildings and constructions and the damage of the ozone layer in the atmosphere. As indirect precursors, they contribute to global warming and climate change. Various health risks and life quality decline are being associated with the deteriorating of air quality, for instance the occurrence and worsening of asthma and other respiratory problems.

According to data published by the European Environment Agency (EEA), air pollution in Slovakia caused 5 421[4] premature deaths in 2015, in the year 2016 their number decreased to 4 980.[5] The

---

[1] *Act on air protection No. 137/2010 Coll.*
[2] *Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC*
[3] *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)*
[4] *https://www.eea.europa.eu//publications/air-quality-in-europe-2018*
[5] *https://www.eea.europa.eu//publications/air-quality-in-europe-2019*

contribution of individual evaluated pollutants ($PM_{2.5}$ - fine particulate matter with an aerodynamic diameter of less than 2.5 µm; NO_2 - nitrogen dioxide and O_3 - ozone) to the overall number of premature deaths is provided in the **Tab. 6.1**. The EEA defines premature deaths as deaths that occur before a person reaches an expected age. This expected age is typically the life expectancy for a country stratified by sex. The most common causes of premature death are cardiovascular disease, stroke, lung and respiratory diseases.

Tab. 6.1 *The number of estimated premature deaths in SR. The share of individual contributions of air pollutants: fine particulate matters $PM_{2.5}$, nitrogen dioxide NO_2 and ozone O_3.*

Year	Number of deaths	$PM_{2.5}$	NO_2	O_3
2014	5 416	5 160	100	160
2015	5 421	5 200	240	210
2016	4 980	4 800	20	160

For what purposes is information on released emissions of air pollutants used?

The calculation, control and assessment of emissions are important activities due to the consequential possibility to regulate their discharge into the air. Quantitative information on the emission and their sources is inevitable condition of:

- decision making of responsible bodies,
- providing the information to the professional audience and public,
- definition of environmental priorities and identification of problem causes,
- various plans and strategies estimation of environmental effects,
- environmental costs and benefits assessment of different approaches,
- monitoring of impact respectively the effectiveness of implemented measurements,
- achievement of compliance with national and international commitments.

■ BALANCING OF AIR POLLUTANT EMISSIONS RELEASED INTO THE AIR

The Slovak Hydrometeorological Institute, Department of Emissions and Biofuels is responsible for the preparation of national emission inventory of discharged air pollutant. This balancing of emission amounts is required on the national, European and international levels. At the national level, emissions from medium and large sources of air pollution are collected and recorded in the **National Emission Information System (NEIS)** (Chapter **6.4** National Emission Information System). At the European and international level is required regular **annual reporting of emission inventories** of certain air pollutants for the time period since the year 1990 (Chapter **6.2** Emission Inventories of air pollutants). The scope of required data in the submission reports for implementation of European directives and international conventions is broader than the coverage of resources and activities in the NEIS database. The summary of emissions from air pollution sources in the NEIS is therefore smaller than the national summary reported under European and international conventions.

6.1 THE OVERVIEW OF REPORTING OBLIGATIONS OF THE SLOVAK REPUBLIC UNDER THE INTERNATIONAL COMMITMENTS AND INTERNATIONAL AND EUROPEAN LEGISLATION

Air protection is one of the important pillars of the European and international environmental legislation, which is currently being a subject of regular tracking, controlling and monitoring. In recent two decades, there has been a visible progress in the regulation of anthropogenic emissions. This advance is a result of various legislation changes at the European level. The main goals of these changes have been the assurance of clean air without harming effects on human health and the ecosystems.

European legislation focused on the achievement of targets and the monitoring of development uses different legislative tools, for instance: the national emission ceilings[6] to limit the released amounts of air pollutants into the air from stationary sources of air pollution,[7] from diffuse (fugitive) sources[8] as well as from mobile sources,[9] the commitments of Member States on reduction of annually released national emissions, tightening of emission limits and technical requirements on sources of air pollution, obligation of introduction the best available techniques (BAT)[10] and others. All legislative measures set the duties of regular and detail reporting on emissions.

Recent changes in the field of air protection in Europe represent following legislation:

- Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC,
- Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control),
- Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants,
- Regulation (EC) No. 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC,
- Regulation (EU) No. 538/2014 of the European Parliament and of the Council of 16 April 2014 amending Regulation (EU) No. 691/2011 on European environmental economic accounts,
- the others.

6.1.1 The UNECE Convention on Long-Range Transboundary Air Pollution (Convention LRTAP)

The Slovak Republic, the Member States of European Union (EU) and other states outside of EU are the signatories of the United Nations Economic Commission for Europe (UNECE) Convention On Long-Range Transboundary Air Pollution in 1979 (Convention LRTAP) and its several protocols including the Protocol on acidification, eutrophication and ground ozone from the year 1999, which was revised in year 2012 (revised Gothenburg protocol).

The overview of Convention LRTAP Protocols:

- Geneva Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP),
- Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent (1985),
- Sofia Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes (1988),
- Geneva Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes (1991),
- Oslo Protocol on Further Reduction of Sulphur Emissions (1994),
- Aarhus Protocol on Heavy Metals (1998),
- Aarhus Protocol on Persistent Organic Pollutants (POPs) (1998),
- Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (1999), revised (2012).

---

[6] *Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants*

[7] *Point sources*

[8] *Diffuse (fugitive) sources or emissions are non-managed, surface leakages of emissions into the external atmosphere, for instance: sorting or crushing of stones without abatement technique, animal farming, steaming and burning landfills, surface dustiness, conveyor belts outside of closed buildings, areas of open storages and tanks with a fixed roof if not abated, open composting areas, sewage sludge tanks of wastewater treatment plants, etc.*

[9] *Transport*

[10] *BAT „Best Available Technique“- (definition of Directive IED) means the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and where that is not practicable, to reduce emissions and the impact on the environment as a whole.*

6.1.2 Directive (EU) 2016/2284 of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC

New Directive 2016/2284 (further "new NECD") repealed the Directive on national emission ceilings 2001/81/EC, and brought about the harmonisation with revised Gothenburg Protocol. Previous Directive on national emission ceilings (2001/81/EC, NECD) had determined the ceilings for the year 2010 – the amounts of four air pollutant in absolute values for each member state, which were not allowed to be exceeded. Monitored emissions of air pollutants were nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOC), sulphur oxides (SO_X) and ammonia (NH_3). Determined ceilings are currently still valid for maintaining the continuity with historical emissions until to the year 2020 when emissions and the achievement of commitments will be assessed for the first time in accordance to rules of new NECD. The Slovak Republic meets all current requirements and ceilings. The overview of obligations related to Directive 2001/81/EC is shown in **Tab. 6.2**.

Tab. 6.2 *Emission ceilings determined by Directive 2001/81/EC for year 2010 valid until 2020.*

	Emission ceilings 2010 [kt]			
	NO_X	SO_X	VOC	NH_3
SR	130	110	140	39
EÚ 28	8 297	9 003	8 848	4 294

New NECD has set for the Slovak Republic and the Member States new reduction commitments for certain air pollutants. Compliance is divided into two phases. The first phase relates to the time period from the year 2020 to the year 2029. The second phase will enter into force from the year 2030. The reduction commitment of overall emissions released into the air is expressed as percentage decline compares to the emission of the base year of 2005. In addition, the list of monitored pollutants has been extended of one other substance – fine particulate matters $PM_{2.5}$. **Tab. 6.3** provides the overview of reduction commitments values for particular air pollutants in both phases.

Tab. 6.3 *The overview of new NECD commitments for air pollutants SO_2, NO_X, NMVOC, NH_3, $PM_{2.5}$.*

Member state		**Reduction compared with 2005** for any year from 2020 to 2029	for any year from 2030		**Reduction compared with 2005** for any year from 2020 to 2029	for any year from 2030
SR	**SO_2**	57%	***82%***	**NO_X**	36%	***50%***
EU 28		59%	***79%***		42%	***63%***
SR	**NMVOC**	18%	***32%***	**NH_3**	36%	***50%***
EU 28		28%	***40%***		42%	***63%***
SR	**$PM_{2.5}$**	36%	***49%***			
EU 28		22%	***49%***			

6.1.3 Regulation (EU) No. 538/2014 of the European Parliament and of the Council amending, Regulation (EU) No. 691/2011 on European environmental economic accounts

Since 2013 the European environmental economic accounts (EEEA) and their reporting have become mandatory for the Member States. The EEEA constitute the tool for the impact assessment of industry, households and environment mutual interactions (emission intensity). On the principle of common statistical classification of economic activities of economy units ("KAU" kind-of-activity unit) is determined the final emission intensity of individual categories for air pollutants. This integrated statistical system links economic and environmental information into certain outputs in order to provide the base for policy and strategic decision making. The EEEA are delineated into several modules.

Fulfilment of reporting obligations requires the cooperation with the Statistical Office of the Slovak Republic which is in charge of the EEEA and their reporting to the European Commission (EUROSTAT). The Slovak Hydrometeorological Institute ensures the preparation of the Module I: **Air Emission**

Accounts (AEA). Reporting of the AEA is concerned to 15 pollutants and greenhouse gases (CO_2, biomass CO_2, N_2O, CH_4, PFC, HFC, SF_6 and NF_3, NO_X, SO_2, NMVOC, CO, PM_{10}, $PM_{2.5}$ and NH_3). The AEA are closely intertwined to the emission inventories under the Convention LRTAP and the UN Framework Convention on Climate Change (UNFCCC).

The emissions in AEA are stratified in the same degree as NACE Rev. 2. (A*64), statistical classification of economic activities in the European Community. This classification system of European industry is standardized into 6-digit code classification providing the framework for specific economic activity. Reported division NACE Rev. 2 is aggregated into 64 categories (that means by first 2-digit code).

The Slovak Republic uses for the preparation of AEA two methods. In the case of air pollutants, the **inventory-first approach** is used. Reported data is based on the official Air Pollutants Emission Inventory Submission under the Convention LRTAP. However, division of emissions is not coherent and thus adjusted methods with use of input data of the National Emission Information System (NEIS) is needed, but other statistical and auxiliary data. The energy-first approach is applied for greenhouse gases (GHG). This approach is based on energy statistics used in the GHG emission inventory under the UNFCCC.

The EEEA apply the residence principle and have the same system boundaries as the European System of Accounts (ESA). The residence principle defines the scope of the national economy and what is included in the accounts. The resident unit is defined as an institutional unit having its centre of economic interest in the economic territory of a given country. The national economy is defined as a unit, including all activities of resident institutional units. Therefore, the AEA records air emissions that arise from the activities of resident units that create the national economy, regardless of where these emissions in fact occur.

For instance, the enterprise Ryanair is a big airline company which is a resident unit of Ireland. The emissions rising from an operated flight between Frankfurt and Barcelona of Ryanair company should be accounted to the Irish AEA, because Ryanair's profits from this flight contribute to the Irish GDP. It is necessary to note that the national emission inventories under the Convention LRTAP and UNFCCC and their activity data (e. g. energy statistics) are not similar with residential principle, which is applied in national accounts. The national emission inventories follow a territorial principle, which means they record the emission originated from the area of the country regardless of who discharges the emissions.

6.2 EMISSION INVENTORIES OF AIR POLLUTANTS

The compliance with the objectives of the Convention LRTAP and the new NECD has to be proved by required reporting of emission inventory for the following pollutants:

- nitrogen oxides (NO_X),
- non-methane volatile organic compounds (NMVOC),
- sulphur oxides (SO_X),
- ammonia (NH_3),
- carbon oxide (CO),
- total suspended particles (TSP):
    - particulate matter PM_{10} (with aerodynamic diameter equal or less than 10 µm),
    - fine particulate matter $PM_{2.5}$ (with aerodynamic diameter equal or less than 2.5 µm),
- black carbon (BC)
- heavy metals (Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn),
- certain persistent organic pollutants (POPs).

Principles of emission inventories to be followed:

- transparency,
- consistency,
- comparability,
- completeness,
- accuracy of reported data.

Emission inventory is an annual report of air pollutants emission amounts that were released to the atmosphere from all stationary, fugitive and mobile sources at the territory of the Slovak Republic. Emission data is provided in weight units for the period since 1990, the last reported data is two years older than current year – that means submission of inventory reported in 2020 includes the period of years 1990 – 2018. The structure of provided data is in accordance with the internationally standardized format – Nomenclature for Reporting (NFR). Currently, it constitutes from 127 different categories in which emissions are reported. Data covers anthropogenic activities divided into particulate groups.

The **Tab. 6.6** is provided complete tree structure of nomenclature NFR14. It contains also the activities that do not occur in the Slovak Republic. The nomenclature has a multilevel structure and allows the aggregation of individual categories to the bigger groups, for instance: aggregation to the sectors for the purposes of evaluation, comparability and overview statistics.

One of the most important data sources in the preparation process of final inventory is the database of the **National Emission Information System (NEIS)**[11] (more detail in Chapter **6.4** National Emission Information System). This system provides detailed data from the operator of air pollutants sources. Direct emission data (national methodology) are processed in line with the reporting requirements. The second main data source is the statistical data from the Statistical Office of the Slovak Republic. Input statistical data are annually updated and revised in the timeline since 1990, if necessary in compliance with the principles of emission inventories. The calculations are performed by methodologies of international guidelines EMEP/EEA Air pollutant emission inventory guidebook[12] or national methodologies.

6.2.1 Evaluation of emission trends

- **90's of 20th century and the period before Slovakia joined the EU**

Social and political changes in the 1990s, the establishment of an independent state of the Slovak Republic and efforts to join the European Union (accession during the enlargement in 2004) enabled significant legislative changes to be made in the area of the environment. But strict air protection was introduced already in 1991 (Act No. 309/1991 Coll. on the environment, as amended).[13] The base for the legislation was inspired by German legislation and tried to prevent uncontrolled growth of the industry. The development of all monitored emissions in the 1990s reflected the socio-political changes that occurred in Slovakia and resulted in remarkable decrease of emissions. The Register of Emissions and Air Pollution Sources (REZZO) was the first database used to record emissions in the Slovak Republic during the period 1990 – 1999. Later, database NEIS has been developed. It records emissions from 2000 to the present. **Tab. 6.4** shows the overview of important changes that have influenced the emission trends in the Slovak Republic.

- **Development since 2005**

The year 2005 is fundamental because it is considered as a baseline for comparison with the achievement of current commitments. The emissions of air pollutants have a downward trend in the most of the sectors due to the legislative measures, application of new environmental technologies as well as the economic reasons. However, the decline in recent years is weak. Selected factors that contribute to emission reduction are presented in the **Tab. 6.5**. In this period the sector of fuel combustion in households has recorded more fluctuation or increasing trend for the particular emissions. It is connected to the use of solid fuels and production of fine particulate matter $PM_{2.5}$ originated in combustion.

11 NEIS (National Emission Information System), 2016 http://www.air.sk/neis.php
12 EMEP/EEA Air pollutant emission inventory guidebook – 2016 and 2019 (on-line: http://www.eea.europa.eu/publications/emep-eea-guidebook-2016, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019)
13 https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/1991/309/vyhlasene_znenie.html

The European Environment Agency (EEA) annually process and publish data provided by member states. The comparison of amounts of the Slovak air pollutant emissions with other member states of EU is available at the websites of EEA,[14] the websites of the EMEP Centre on Emission Inventories and Projections (CEIP)[15] and others.[16]

Tab. 6.4 *The overview of the significant activities and factors, which has contributed to emission reduction during the years 1990 – 2004.*

	TSP	SO_X	NO_X	CO	HM	POPs
Change of composition in fuel base in favour of NG	X				X	
Reduction in consumption of HC, BC, HFO (replacement with low-sulphur fuel oils)		X	X		X	
Introduction of separation techniques e. g. denitrification of Vojany	X		X		X	
Increasing of abatement efficiency			X			
Installation of desulphurization equipment (Power plants Zemianske Kostoľany, Vojany)		X				
Reduction of production volume (Power plants Zemianske Kostoľany, Vojany)		X	X			
Effectiveness of policies and measures to limit CO emissions from major sources 1996				X		
Decline of pig iron and sinter production				X		
Change in technology of aluminium production						X
Reconstruction of certain waste incineration facilities						X
Road transport - unleaded petrol since 1996					X	

Notes: HM – heavy metals; NG – natural gas; HC – hard coal; BC –brown coal; HFO – heavy fuel oil; POPs – persistent organic pollutants

Tab. 6.5 *The overview of the significant activities and factors, which has contributed to emission reduction during the years 2005 – 2018.*

	TSP	SO_X	NO_X	CO	NH_3	HM
Reduction in consumption of HC, BC, HFO (replacement with low-sulphur fuel oils)	X	X		X		
Change in sulphur content in fuel (Decree of the MoE No. 53/2004 Coll.; Decree of the MoE No. 228/2014 Coll.)		X				
Reconstruction of separators (SE – Nováky; U. S. Steel Košice) 2006	X					
Reduction in glass production 2007						X
Decommissioning of non-ecologized boilers (Vojany Power Plant 2007)	X	X				
Decline in pig iron and sinter production due to the 2009 crisis			X	X		X
Decrease in magnesite clinker production due to the 2009 crisis			X			
Reduction of production volume by 2007 (Zemianske Kostoľany Power Stations)			X			
Road transport 2008/09 - generation fleet renewal with new vehicles			X	X		
Reduction of gas transported by pipelines 2012 (Compressor stations Eustream, a.s)			X			
Installation of a new desulphur. unit in heating plant CM European Power Slovakia 2012		X				
Extremely high average annual temperature 2014 decreased demand in the household sector		X	X			
Shutdown of Units 3 and 4 in 2016 (Power Plant Nováky that used BC)	X	X	X			
Manure spreading in 12 and 24 hours into the soil					X	
Biogas stations					X	
Isolation of manure and slurry tanks from the surroundings					X	
Implementation of more strict legislation in the field of air protection	X	X	X	X	X	X

Notes: HM – heavy metals; NG – natural gas; HC – hard coal; BC –brown coal; HFO – heavy fuel oil; MoE – the Ministry of the Environment of the Slovak Republic

[14] *https://www.eea.europa.eu/data-and-maps*
[15] *http://www.ceip.at/ms/ceip_home1/ceip_home/ceip_intro/*
[16] *https://www.eea.europa.eu//publications/air-quality-in-europe-2018*

The overall development of individual pollutants since 2005 is shown in the figures (**Fig. 6.1** – **Fig. 6.6**). For better transparency, a wide range of values and different scale of units, the figures are divided into six groups on air pollutants, particulate matter, heavy metals, selected heavy metals, polycyclic aromatic hydrocarbons and persistent organic pollutants.

Fig. 6.1 *Emission trends of air pollutants in years 2005 – 2018.*

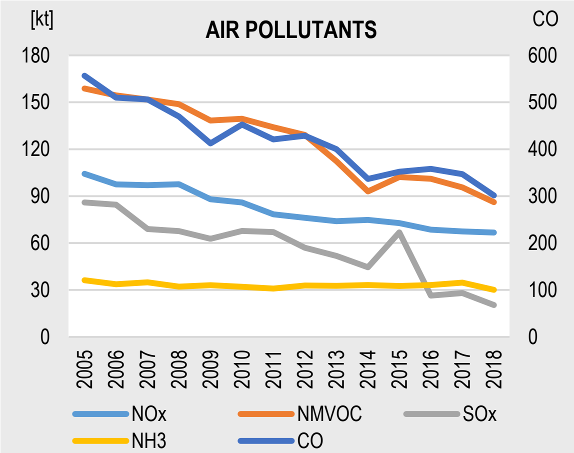


Fig. 6.2 *Emission trends of particulate matter in years 2005 – 2018.*

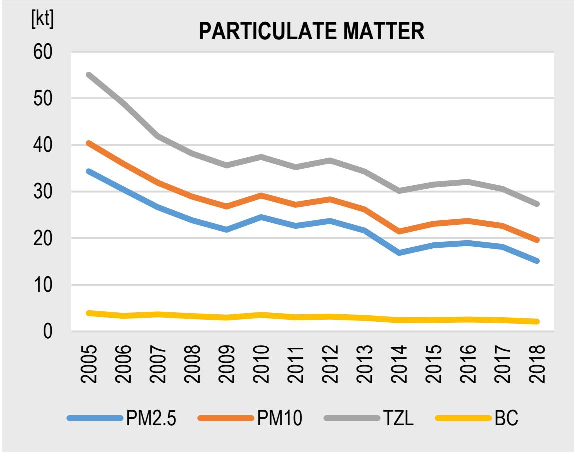


Fig. 6.3 *Emission trends of heavy metals in years 2005 – 2018.*

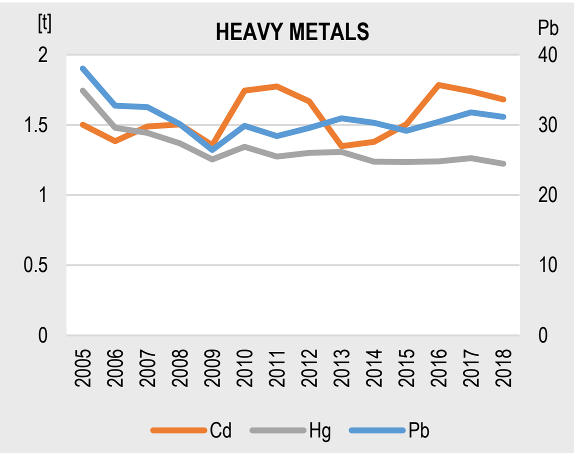


Fig. 6.4 *Emission trends of selected heavy metals in years 2005 – 2018.*

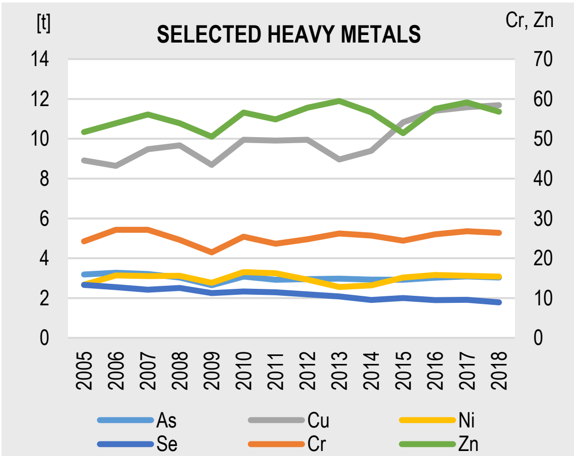


Fig. 6.5 *Emission trends of polycyclic aromatic hydrocarbons(PAH) in years 2005 – 2018.*

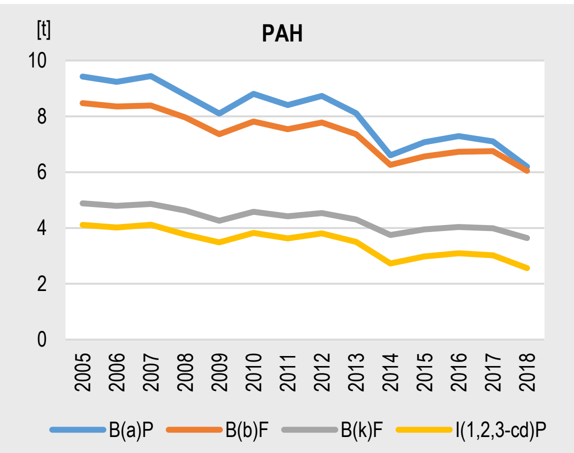
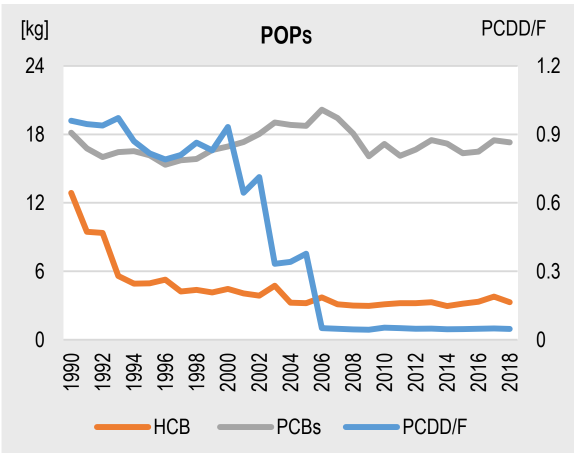


Fig. 6.6 *Emission trends of persistant organic pollutans (POPs) in years 2005 – 2018.*



6.3 SECTORAL OVERVIEW OF EMISSIONS

Division of emissions to sectors is a considerable indicator for policymaking and setting the direction for national strategies and programs. The overview and comparison of individual sectoral shares of the national emission totals of selected air pollutants for the year 2005 and year 2018 are presented on the **Fig. 6.7**.

Fig. 6.7 *The comparison of base year (2005) and the latest available year (2018) of selected air pollutants (NO_X, NMVOC, SO_X, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO) according to their respective sectors. Figures show the percentage share of sectoral emissions in the national balance.*

6.3.1 Energy and stationary fuel combustion activities

Energy and fuel combustion activities are significant sources of emission. Households are the main contributors of particulate matters (their fractions $PM_{2.5}$ and PM_{10}). This sector is also the major contributor of NO_X and SO_X emissions represented by transport and energy industry.

Breakdowns of the energy and stationary fuel combustion activities sector according to NFR 14 structure:

ENERGY AND STATIONARY FUEL COMBUSTION ACTIVITIES

- Fuel combustion (1A)
  - *Energy industries*
  - *Manufacturing industry and construction*
  - *Transport*
  - *Households*
  - *Other sectors*
- Fugitive emissions (1B)

Emission trends in the sector of energy and stationary fuel combustion activities

The energy and stationary fuel combustion activities sector has a declining emission trend, which is shown in **Fig. 6.8** and **Fig. 6.9**. This development is a consequence of the tightening of legislation, and the associated introduction of more modern technologies. The category of fugitive emissions[17] has a declining trend in recent years (**Fig. 6.9**).

Fig. 6.8 *Emission trends of air pollutants in sector energy and stationary fuel combustion activities in years 1990 – 2018.*

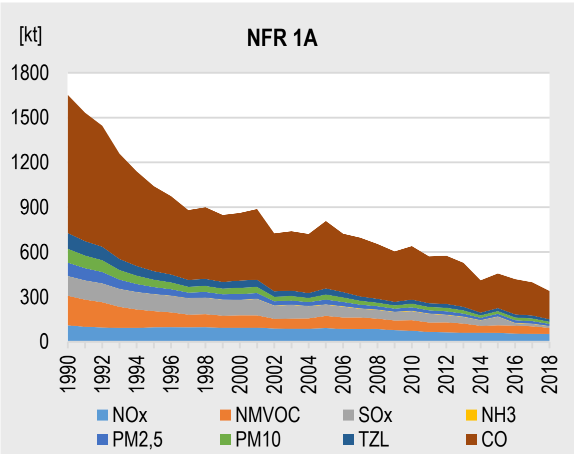
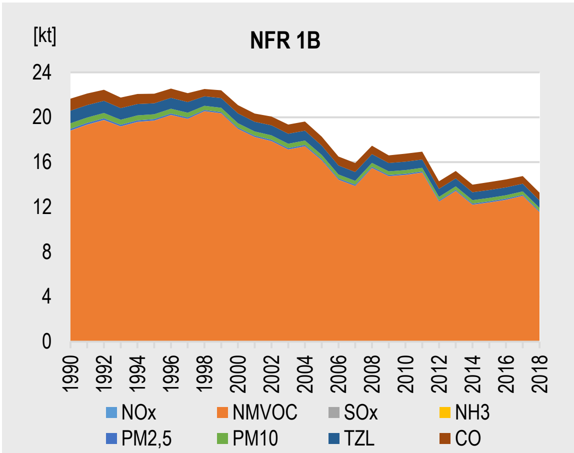


Fig. 6.9 *Emission trends of air pollutants in sector of fugitive emissions in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

[17] *fugitive emissions - emissions of volatile organic compounds, with the exception of waste gases into the air, soil and water, as well as solvents, which are contained in any products. This includes uncaptured emissions that enter the outside environment through windows, doors, vents and similar openings.*

Energy

Energy makes a significant contribution to emissions of most pollutants released into the air. The combustion of brown coal and lignite, currently still used fuels, makes a significant contribution to air pollution, especially through SO_X emissions. These fuels are not envisaged in the future, which will contribute to improving the quality of the environment. Incineration of municipal waste with energy recovery has been one of the main contributors to emissions of heavy metals and persistent organic compounds (POPs) in the past. As a result of the introduction of separation technologies, the amount of these substances released into the atmosphere has gradually been reduced.

In terms of sectoral division, the emission balance is prepared in the following structure of NFR14:

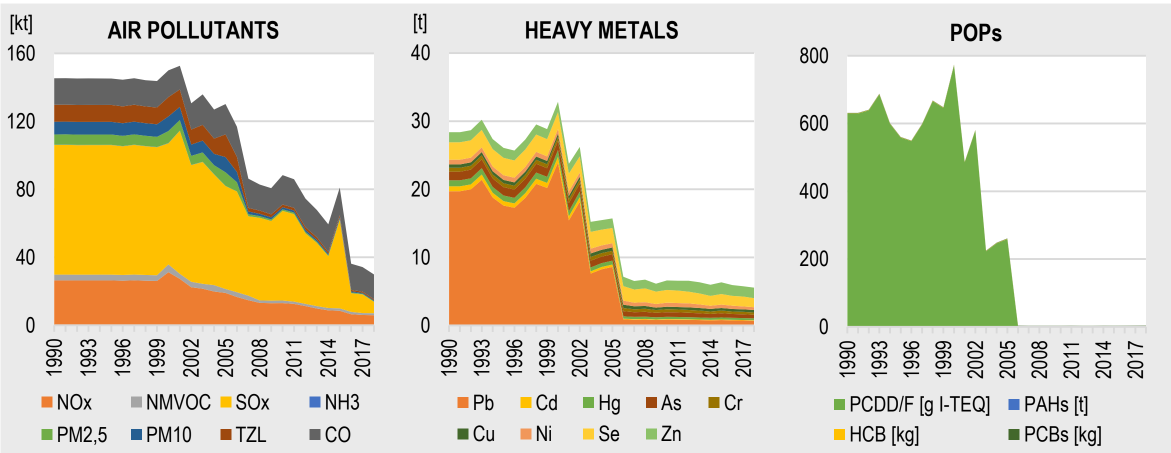
ENERGY (1A1)

- Public electricity and heat production
- Petroleum refining
- Production of solid fuels and other energy industries

Emission trends in the sector of energy

The declining trend is visible in the development charts of the energy sector. The last increase in emissions was recorded in 2015, which was caused by the operation of non-ecological boilers (ENO - Nováky Power Plant - Units 3 and 4) in Slovenské elektrárne (it was the last year of exemption for their operation). During 2015, the source burned a large amount of brown coal, so the most significant increase was recorded in SO_X emissions and extensive reconstruction of other units ENO 1 and 2. In the following year, on the contrary, a significant decrease in emissions was recorded (**Fig. 6.10**).

Fig. 6.10 *Emission trends in energy in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

Fuel combustion in manufacturing and construction

The combustion of fuels in the manufacturing and construction industries contributes to the emissions of all pollutants released into the air, but compared to other categories of the energy sector, the impact of the combustion of these fuels is less significant.

In terms of sectoral division, the emission balance is prepared in the following structure of NFR14:

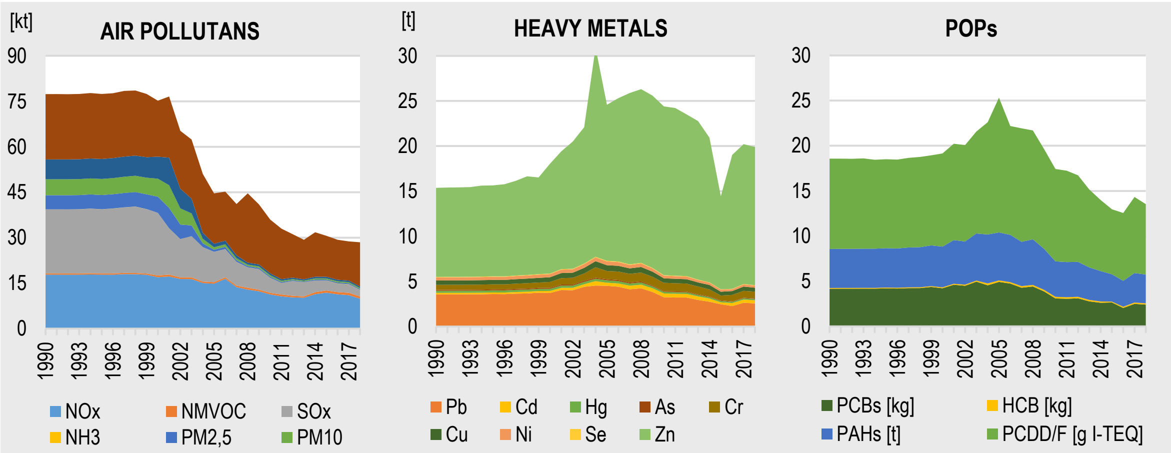
COMBUSTION OF FUELS IN THE MANUFACTURING INDUSTRY AND CONSTRUCTION (1A2)

- Production of iron and steel
- Production of non-ferrous metals
- Production of chemicals
- Pulp, paper and printing production
- Food processing, beverage and tobacco

- Production of non-metallic minerals
- Mobile combustion in the manufacturing and construction industries
- Other stationary combustion in manufacturing industries and construction

Emission trends in the sector of fuel combustion in the manufacturing industry and construction
Most emissions in this category have been slightly declining since 2005. The only exception is zinc (Zn). In 2000, biomass was also used as fuel in the production of pulp and paper, and the increase in its amount caused a gradual increase in Zn emissions until 2009, when the amount of biomass burned began to decrease (**Fig. 6.11**).

Fig. 6.11 *Emission trends in the sector of fuel combustion in the manufacturing industry and construction in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

Transport

Transport sector is the most important source of nitrogen oxide emissions (NO_X) and carbon monoxide emissions (CO). Main share belongs to road transport, in particular the usage of diesel heavy-duty vehicles as well as diesel passenger cars. The sectoral breakdown according to structure of NFR14 and activity kind is following:

TRANSPORT (1A3)

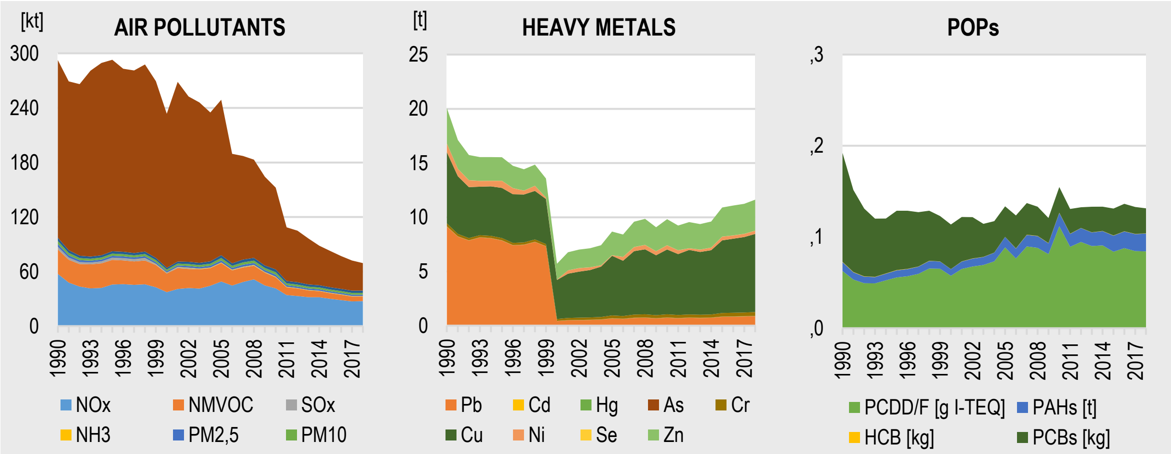
- Civil aviation
- Road transport
  - *Passenger cars*
  - *Light duty vehicles*
  - *Heavy duty vehicles and buses*
  - *Mopeds & motorcycles*
  - *Gasoline evaporation*
  - *Automobile tyre and brake wear*
  - *Automobile road abrasion*
- Railways
- Water transport
- Pipeline transport

Emission trends in the sector of transport
In the recent years, there has been notable change in use of public transport and shift to usage of passenger cars. In addition, the level of transit transport increased (heavy-duty vehicles – HDV). In the fuel consumption by railways is noted an increase compared to the road transport, which has had sharp increase. In comparison with the year 2005, the emissions of air pollutants decreased in range

from 8% (sulphur oxides – SO_X) to 81% (carbon monoxide – CO). Whereas heavy metals has considerable increased by 29%, and POPs by 63% (**Fig. 6.12**).

The majority of heavy metals originate from automobile tyre and brake wear, the activities that are not connected with fuel combustion. The traffic intensity and aggressive driving influence the increase of air pollutants.

Fig. 6.12 *Emission trends in transport in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

Households

Emissions from households (respectively emissions from local heating) are a serious issue in many countries including the Slovak Republic. Large part of households use for heating the individual combustion appliances. In the process of solid fuel combustion in households, besides desired heat, air pollutants are produced in gaseous and solid forms and released into the atmosphere. Total suspended particles can be divided according to their size into PM_{10} and $PM_{2.5}$. Both emission types signify a health risk for humans. Larger particles can cause upper respiratory tract irritation, smaller particles settle deep into the lungs and cause diseases that are more serious. Emissions from domestic heating contribute significantly to the deterioration of local air quality.

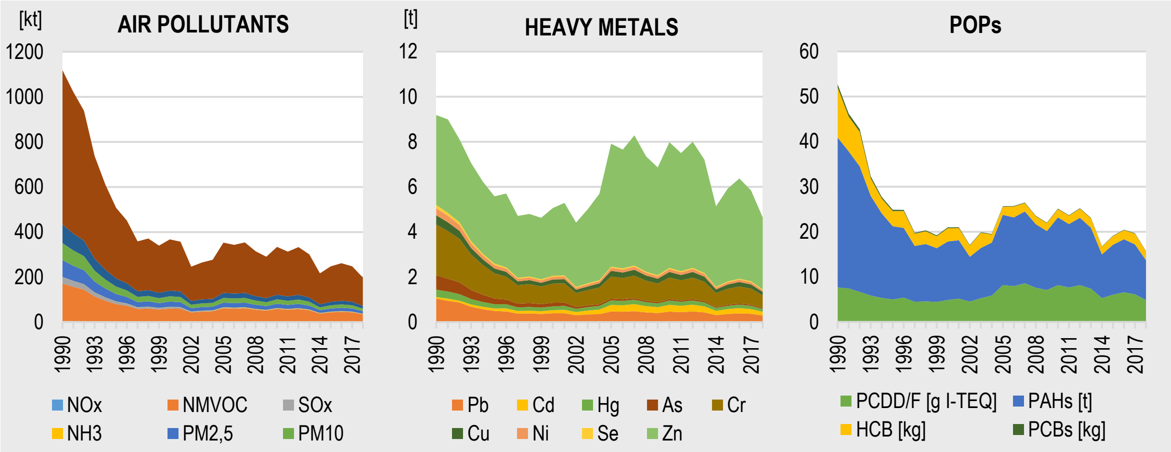
Obsolete, worn and unsuitable combustion appliances, as well as improper heating methods, contribute to increased emission production. Emissions depend on fuel type (with what we heat), type of appliance (which equipment we use: e. g. boilers, ovens, fireplaces) and of course the manner of heating (how we heat and maintain the appliance).

Despite the legal ban of waste burning in households, it is still a current topic without a suitable regulation. Harmful substances are produced if the municipal waste or plastic bottles are combusted in local heating appliances. The composition of emissions depends on the combusted materials. This negligent behaviour leads to emission production of persistent organic pollutants (POPs) and heavy metals, which are often carcinogenic. During winter inversions and poor dispersion conditions, these emissions are concentrated in mountain basins.

Emission trends in households

Since 2005, all monitored emissions from households are rising as a result of the price increase of natural gas. Natural gas was widely used for household until 2005. Currently, the trend of emissions is relatively steady with slight decrease in 2014 and 2016 due to the weather conditions during winters (**Fig. 6.13**).

***Fig. 6.13** Emission trends in households in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

Other

This category is not one of the most important contributors to emissions. It consists mainly of smaller resources operating in services, agriculture, forestry and fishing.

This category includes:

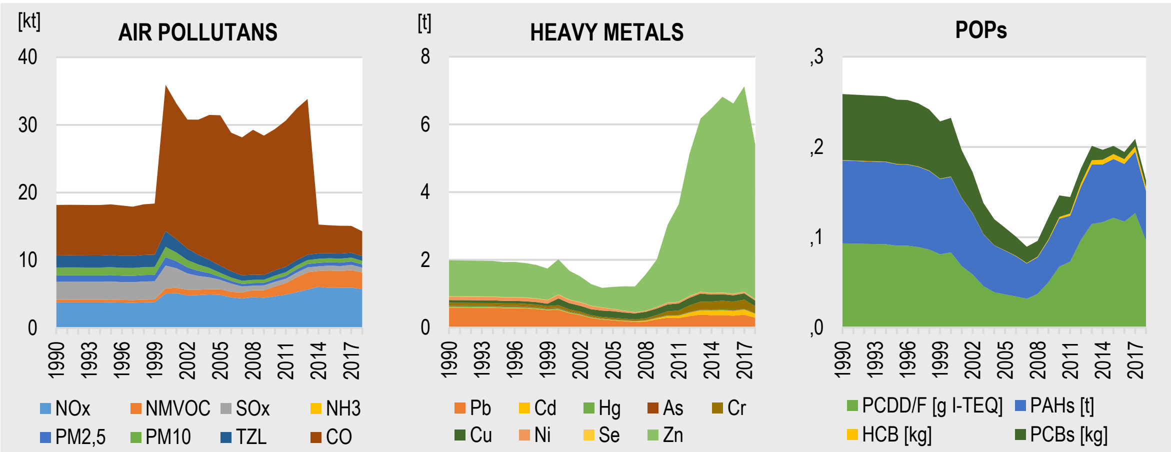
OTHER (1A4, 1A5)

- Combustion of fuels in services
- Combustion of fuels in agriculture, forestry and fishing
- Fuel combustion - other (including military)

Emission trends in other categories

The sources included in these categories are not subject to as strict emission limits and requirements as large sources of pollution, therefore their trend is subject to the structure of the fuels burned and thus does not have a significant declining trend. This category also includes the operation of agricultural, forestry and military equipment (**Fig. 6.14**).

Fig. 6.14 *Emission trends in other categories in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

6.3.2 Industry and product use

Among the member states of EU, the Slovak Republic belongs to the states with the fastest growing economy for recent years. In spite of grow the emissions have a decreasing trend. The share of industrial production on the national GDP of 2017[18] was at the level of 25.7%. In Slovakia, there are traditionally represented industries such as metallurgical production, production of iron and steel, production of coke and refinery products, chemical production, construction industry and others.

The sectoral breakdown according to the structure of NFR14 and activity kind is reported in the following structure:

INDUSTRIAL PROCESSES

- Mineral production (2A)
- Chemical industry (2B)
- Metal production (2C)
- Solvents (2D)
- Other product use (2G)
- Other production industry (2H-2L)

Mineral production

Mineral products in Slovakia are represented by cement production (CRH Slovakia; Považská cementáreň, a.s.; CEMMAC a.s.), lime production (Calmit, spol. s r.o; Mondi scp, a.s.; DOLVAP, s.r.o; Carmeuse Slovakia, s.r.o.), glass production (Johns Manville Slovakia, a.s; RONA, a.s; VETROPACK NEMŠOVÁ s.r.o.; R-GLASS Trade, s.r.o.), mining of minerals, and others. The construction and demolition of buildings and roads is also included in this category.

During the industrial production of mineral products, solid pollutants are released into the air due to the handling of materials, their storage and transport. Other substances are emitted into the air mainly during the combustion of fuels associated with the production itself (included in Chapter **6.3.3**). Heavy metal emissions are associated with glass production (**Fig. 6.15**). POPs emissions do not occur during these activities.

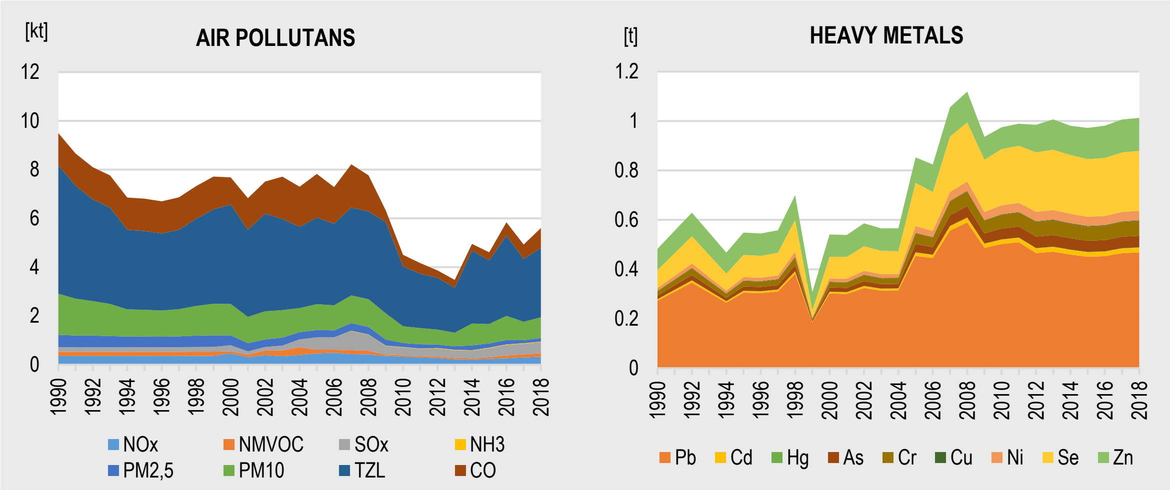
In terms of the NFR structure, the following activities are included in this category:

MINERAL PRODUCTION (2A)

- Cement production
- Lime production
- Glass production
- Mining and quarrying of minerals other than coal
- Construction and demolition
- Storage, handling and transport of mineral products

[18] *Industrial production and its position in the Slovak economy https://www.economy.gov.sk/uploads/files/ezNh8gXF.pdf*

Fig. 6.15 *Emission trends in mineral production in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

Chemical production

Chemical production also has a long-term presence in the Slovak industry, e.g. production of urea, nitric acid, mineral fertilizers (Duslo, a.s.) and various other chemicals (e.g. FORTISCHEM a.s.).

In terms of NFR, we include in this category:

CHEMICAL PRODUCTION (2B)

- Ammonia production
- Nitric acid production
- Production of adipic acid
- Carbide production
- Production of titanium dioxide
- Soda ash production
- Other
- Storage, handling and transport of chemical products

Emission trends in chemical production

For this category, only emissions of basic pollutants are reported in the inventory. Emissions in this category recorded the largest decline in the 1990s, and their trend is now balanced (**Fig. 6.16**).

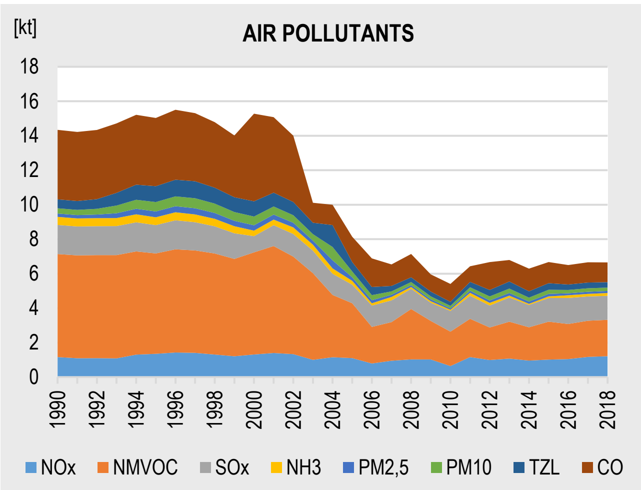


Fig. 6.16 *Emission trends in mineral production in years 1990 – 2018.*

Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

Metal production

A significant industrial activity is the production of metals, specifically the production of iron and steel (U. S. Steel Košice, s.r.o.; ZTS Metalurg, a.s.; Železiarne Podbrezová a.s.), but also metallurgical second-dary production and metal processing (U. S. Steel Košice, a.s.; ZTS Metalurg, a.s.; Železiarne Podbrezová a.s. (KOVOHUTY, a.s.), or aluminum production (Slovalco, a.s.).

According to the NFR structure, the following is included in this category:

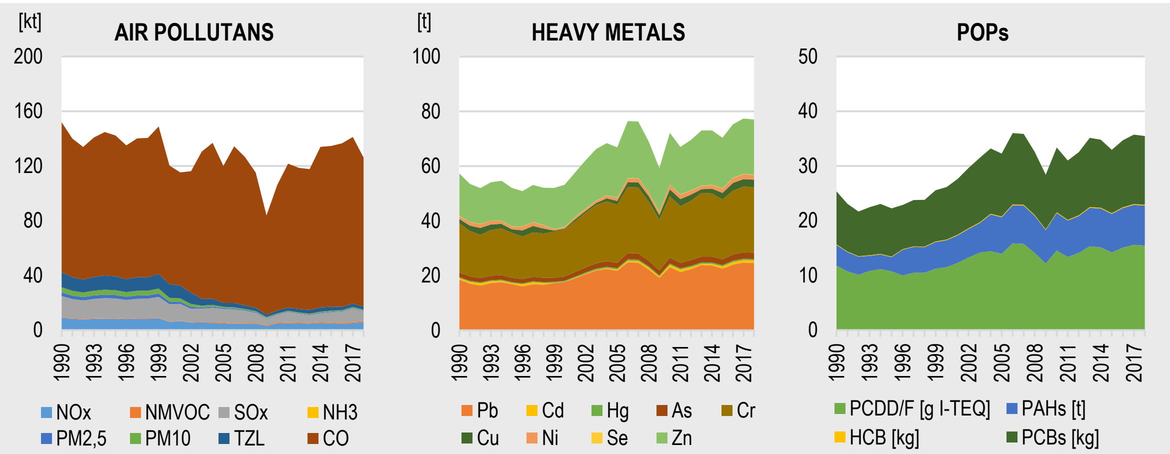
METAL PRODUCTION (2C)

- Production of iron and steel
- Production of ferroalloys
- Aluminum production
- Magnesium production
- Lead production
- Zinc production
- Copper production
- Nickel production
- Production of other metals
- Storage, handling and transport of metal products

Emission trends in metal production

Metal production has long been one of the biggest air pollutants in Slovakia. The most important category is the production of iron and steel. The trend of emissions of basic pollutants in the production of metals is declining, which was most pronounced in the 1990s. Emissions of heavy metals and POPs are rising mainly due to increasing production intensity. Metal production is also sensitive to the economic situation in the country. The decrease in emissions in 2009 was caused by the economic crisis and reduced demand for production products (**Fig. 6.17**).

Fig. 6.17 *Emission trends in metal production in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

Solvents use

The use of solvents is a significant source of emissions. A wide range of substances are used in industry as well as in households, which contain NMVOC (non-methane volatile organic compounds): pure organic solvents or various mixtures used in industry, cleaning agents, paints, thinners, adhesives, cosmetics and toiletries, various products for household or car care.

This also includes emissions from road asphalting. The versatile use of these substances leads to more complex monitoring of their flows. Some of their categories are estimated (especially emissions from substances for domestic use).

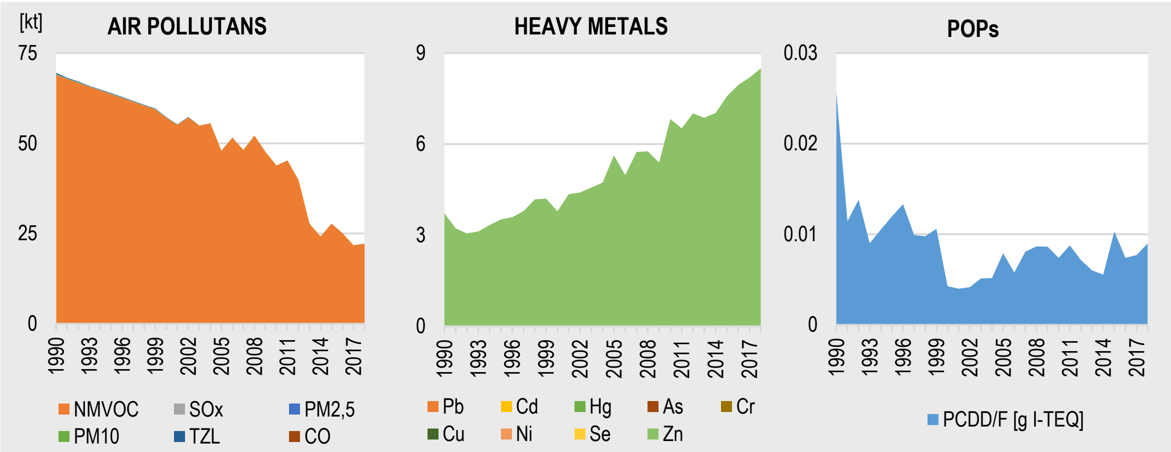
In the NFR structure, this category includes:

SOLVENTS USE (2D)

- Solvents use in households, including fungicides
- Road paving with asphalt
- Asphalt roofing
- Coating application
- Degreasing
- Dry cleaning of textiles
- Chemical products
- Printing
- Other uses of solvents

NMVOC emissions in industry have been significantly reduced in the past and at the same time the solvent content of household products in retail has been regulated. In the long run, these changes are reflected in a decrease in NMVOCs released into the atmosphere, as shown in **Fig. 6.19**. The discharge of heavy metals and POPs is mainly due to the use of lubricants in two- and four-stroke engines.

Fig. 6.18 *Emission trends in solvents use in years 1990 – 2018.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

6.3.3 Agriculture

Anthropogenic activities significantly contribute to the concentration changes of several gases in the atmosphere. The most important and prevailing gas emitted from agriculture regarding the effect to the environment is considered the ammonia. Ammonia reacts with other chemical substances presented in the atmosphere and forms the compounds of the solid phase (NH_4NO_3). Hence, ammonia contributes to the forming of secondary atmospheric aerosols.[19]

Wide emission scale of different gases is originated in agriculture, especially nitric oxide (NO), emissions of particulate matters (PM_{10} and $PM_{2.5}$) and emissions of non-methane volatile organic compounds (NMVOC).

Emissions of nitrogen (NH_3 and NO) can be defined as a loss of nitrogen in the form of the oxides (so-called *volatilisation*). Nitrogen oxides are creating during the entire life cycle, starting by the creating of organic waste (nitrogen excretion in the form of urea and manure of livestock) until its usage at the fertilization of agricultural soils.

[19] *https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/urban-pm25-atlas-air-quality-european-cities*

Nitrogen is essential for animal and crops growing. The substance is presented in feed doses and inorganic fertilizers. Nitrogen is built into plant tissues, muscles and bones of livestock. Unconsumed nitrogen in form of excretion (urea and dung) has to be stored before further use. During this period, the emissions are generated. Manure is used as fertilizer for agricultural soil or input of biogas stations. In the process of crops growing it is necessary to supply the elementary nitrogen in to the agricultural soil in order to better growth of plants also in the form of organic fertilizers. In certain circumstances, the applied nitrogen can be washed out from the agricultural soil. Nitrogen is undergone through chemical reactions with the production of emissions within all mentioned activeties. These emissions have an adverse effect on environments, mainly for the air and water quality.

Emission balance has the following structure NFR 14:

AGRICULTURE

- Manure management (3B)
- Agricultural soils (3D)
- Field burning of agricultural residues (3F)
- Agriculture other (3I)

The percentage of individual categories for ammonia emissions in 2018 is as follows:

- surface application of organic and inorganic waste to agricultural soil: approximately 63%,
- livestock housing and storage of organic waste: approximately 34%,
- grazing: approximately 3%.

The share of the agricultural sector in the national total of NMVOC is approximately 8%. NMVOC are forming in the digestive tract of herbivores as a by-product of enteric (intestinal) fermentation. In this process, the microorganisms cleave the saccharides to simple molecules. The amount of released emission of NMVOC depends on the digestive tract, age and weight of the animal as well as the quality and amount of consumed feed. Another source of emissions is the feed storage, above all the storage of silage.

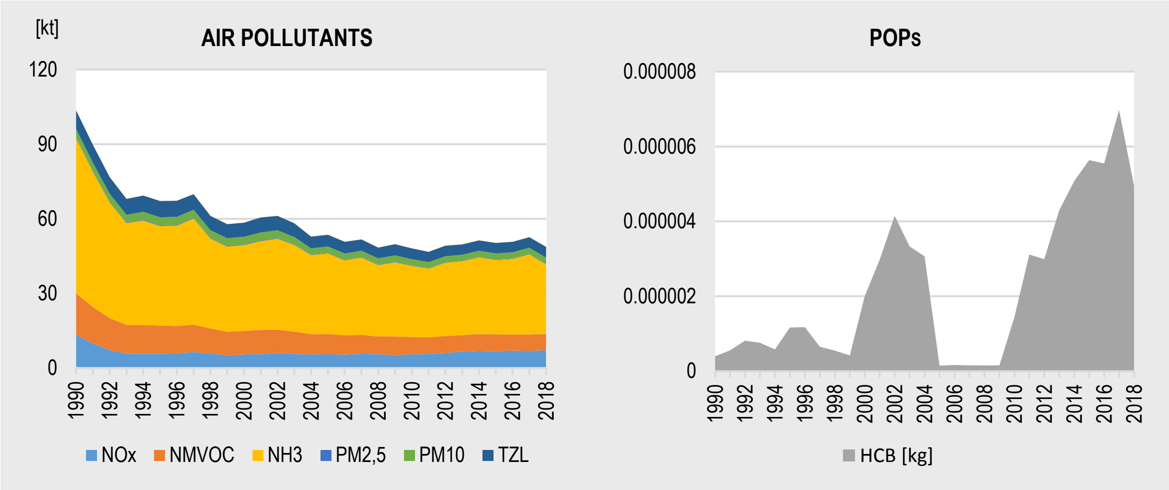
The agriculture is producing the emissions of particulate matters PM_{10} a $PM_{2.5}$. The share of PM_{10} emissions at the national total of PM_{10} is approximately 13%, whilst the share of $PM_{2.5}$ emissions at the national total is only 1.3%. The emissions are creating in agriculture especially during the handling with animal feed, manipulation and drying of agricultural crops, manipulation with bedding animals in stables and in soil cultivation. At the same time, pollutants are produced when the animals are active during their stabling.

Emission trends in the sector of agriculture

During the period 1990 – 2018, livestock numbers in the Slovak Republic has dropped dramatically in the most of the monitored species except goats and poultry. Number of cattle has decreased by 68%, swine by 76% and sheep by 76% over the period. This trend was related to the adverse economic situation in the entire sector. The decline in the number of livestock has had a major impact on the decrease of calculated emissions (**Fig. 6.19**).

Since 2018, several emission reduction measures were implemented into emission inventories (**Tab. 6.5**). Information was taken from the NEIS. This data has influenced the development trend of ammonia emissions despite the annual rising of livestock numbers. Mostly emission from farming of pigs, poultry and goats has decreased. Unfavourable climate conditions, extreme dryness during summer and frosts in spring of the year 2018 caused the crop shortage. Decrease was recorded mainly in the crop of rye (76.9%), oats (12.8%), maize (10.2%), sugar beet (2.1%) and oilseeds (3.5%), which is documented by trends of PM_{10} and $PM_{2.5}$ emissions.

Fig. 6.19 *Emission trends in agriculture.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

6.3.4 Waste managements

In general, the more waste we produce, the greater the amount we have to dispose of. Some waste disposal methods emit pollutants and greenhouse gases into the air. Recycling of waste represents one of the methods for reducing the impact of waste disposal on the air. However, currently there are also more environmentally friendly waste management methods.

The most common methods of disposal are landfills and, to a lesser extent, incineration. When landfill waste decomposes, non-methane volatile organic compounds (NMVOCs) are released into the atmosphere and particulate emissions (PM) are released when handling the waste.

Incineration is the second most common method of waste disposal in the Slovak Republic. It releases a large amount of energy as well as various air pollutants such as heavy metals, polycyclic aromatic hydrocarbons (PAHs) and persistent organic pollutants (POPs). In the past, this energy was not often used and the waste was only disposed of. Nowadays, modern facilities use waste as a fuel for energy production or industrial processes, and waste is also recovered. In this case, the generated emissions are included in the energy sector.

Waste recycling is not the only sustainable manner of waste disposal. One of these is the composting of any organic waste such as food and garden waste. Organic waste is decomposed into mulch in a few weeks and can be used as fertilizer for the soil. Many households have a small-scale composting. But, large-scale composting systems are also being developed to collect organic waste from parks and civic amenities.

Wastewater management also discharges air pollutants. In general, the emissions of persistent organic pollutants (POPs) as well as NMVOC, CO and NH_3 occur in wastewater treatment plants, but in most cases, these are negligible amounts.

From the sectoral point of view, the emission inventory has the following breakdown according to the structure of NFR14:

WASTE MANAGEMENT

- Solid waste disposal on land (5A)
- Biological treatment of waste (5B)
- Incineration of waste (5C)
- Wastewater handling (5D)
- Other waste (5E)

Waste incineration significantly contributes to discharged amounts of dioxins and furans (PCDD/PCDF) into the air. However, dioxins are not degraded in nature at all and they can remain for hundreds of years. By the deposition in the animal tissues, they can enter into the human food chain. The most important way of entering dioxins into the human organism is the intake of food, especially meat, fish, eggs, milk and fats.

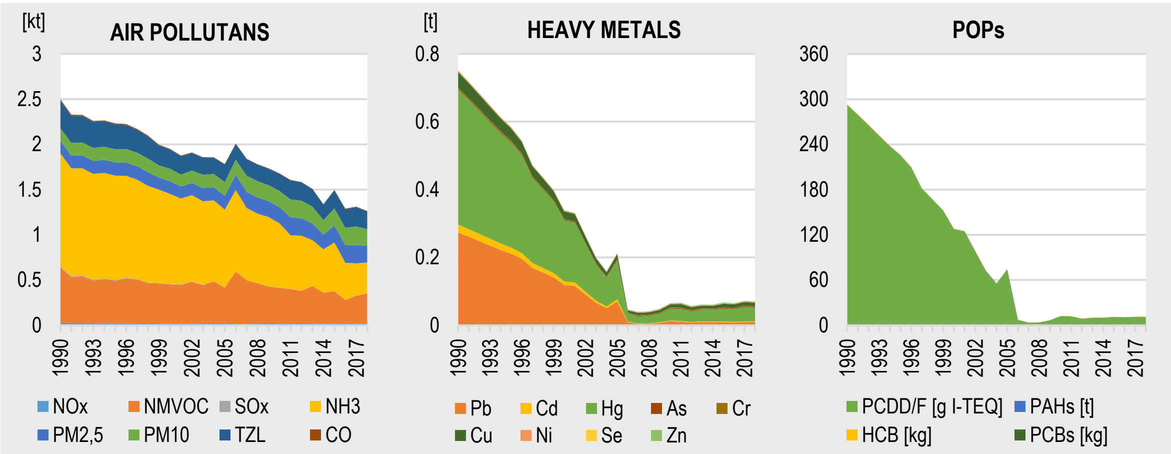
"The most serious adverse health effects of dioxins are carcinogenic – carcinogenic effects. They damage the immune system, their teratogenic effects have been shown (the ability to damage the developing unborn fetus in the mother's body) and they negatively affect sex hormones and thyroid hormones" (Prof. I. Rovný).[20]

Considerable amounts of heavy metals are also discharged into the air during the waste combustion. Modern waste incinerators can effectively capture these substances, but it was not common practice in the past. Heavy metals are deposed into the soil and consequently in the organisms, from which they are very difficult to degrade. Contamination of organisms is gradually increasing because of the food chain, as predatory animals feed on contaminated organisms. In particular, animals at the end of the food chain are in danger and, therefore, humans are at risk from heavy metals. The risk is particularly high in a seaside area where the consumption of marine animals is generally higher.

Emission trends in the waste management

During the period 1990 – 2018, the emissions of all pollutants in the waste sector have dramatically decreased. The decline of dioxins and furans was almost 96%, whilst the amount of disposed waste by the incineration was reduced by almost 77% (**Fig. 6.20**). It was a result of improved technical equipment of existing facilities, the transition to energy recovery of waste, and also a strong reduction in the number of waste incineration plants, which were failing to meet increasingly stringent emission limits. Emissions of heavy metals have significantly dropped, especially in the period 1990 – 2000. Since then, the trend is fluctuating.

Fig. 6.20 *Emission trends in the sector of waste.*



Note: Emissions originated from included activities and processes (AP in legend) can be produces in different amounts. Hence, they might not be fully visible at the figures. However, also small amounts can be important.

[20] *http://www.uvzsr.sk/index.php?option=com_content&view=article&id=1501:dioxiny-a-ich-uinky&catid=56:tlaove-spravy&Itemid=62*

Tab. 6.6 *The complete tree structure of Nomenclature For Reporting (NFR14) – part 1.*

1. ENERGY

1.A STATIONARY FUEL COMBUSTION ACTIVITIES
- 1.A.1 ENERGY INDUSTRIES
  - 1.A.1.a Public electricity and heat production
  - 1.A.1.b Petroleum refining
  - 1.A.1.c Production of solid fuels and other energy industries
- 1.A.2 MANUFACTURING INDUSTRY AND CONSTRUCTION
  - 1.A.2.a Iron and steel
  - 1.A.2.b Non-ferrous metals
  - 1.A.2.c Chemicals
  - 1.A.2.d Pulp, Paper and Print
  - 1.A.2.e Food processing, beverages and tobacco
  - 1.A.2.f Non-metallic minerals
  - 1.A.2.g Other manufacturing industries and construction
    - 1.A.2.g.vii Mobile Combustion in manufacturing industries and construction
    - 1.A.2.g.viii Other stationary combustion in manufacturing industries and construction
- 1.A.3 TRANSPORT
  - 1.A.3.a Civil aviation
    - 1.A.3.a.i(i) International aviation LTO (civil)
    - 1.A.3.a.ii(i) Domestic aviation LTO (civil)
  - 1.A.3.b Road transport
    - 1.A.3.b.i Passenger cars
    - 1.A.3.b.ii Light duty vehicles
    - 1.A.3.b.iii Heavy duty vehicles and buses
    - 1.A.3.b.iv Mopeds & motorcycles
    - 1.A.3.b.v Gasoline evaporation
    - 1.A.3.b.vi Automobile tyre and brake wear
    - 1.A.3.b.vii Automobile road abrasion
  - 1.A.3.c Railways
  - 1.A.3.d Water transport
    - 1.A.3.d.i(ii) International inland waterways
    - 1.A.3.d.ii National navigation (shipping)
  - 1.A.3.e Other transport
    - 1.A.3.e.i Pipeline transport
    - 1.A.3.e.ii Other
- 1.A.4 OTHER SECTORS
  - 1.A.4.a Commercial/Institutional
    - 1.A.4.a.i Commercial/Institutional: Stationary
    - 1.A.4.a.ii Commercial/Institutional: Mobile
  - 1.A.4.b Residential
    - 1.A.4.b.i Residential: Stationary
    - 1.A.4.b.ii Residential: Household and gardening (mobile)
  - 1.A.4.c Agriculture/Forestry/Fishing
    - 1.A.4.c.i Stationary
    - 1.A.4.c.ii Off-road vehicles and other machinery
    - 1.A.4.c.iii National fishing
- 1.A.5 OTHER COMBUSTION
  - 1.A.5.a Other stationary (including military)
  - 1.A.5.b Other, Mobile (including military, land based and recreational boats)

1.B FUGITIVE EMISSIONS
- 1.B.1 FUGITIVE EMISSIONS FROM SOLID FUELS
  - 1.B.1.a Coal mining and handling
  - 1.B.1.b Solid fuel transformation
  - 1.B.1.c Other fugitive emissions from solid fuels
- 1.B.2 FUGITIVE EMISSIONS FROM OIL AND NATURAL GAS
  - 1.B.2.a Fugitive emissions oil
    - 1.B.2.a.i Exploration, production, transport
    - 1.B.2.a.iv Refining / storage
    - 1.B.2.a.v Distribution of oil products
  - 1.B.2.b Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution, other)
  - 1.B.2.c Venting and flaring (oil, gas, combined oil and gas)
  - 1.B.2.d Other fugitive emissions from energy production

Tab. 6.6 The complete tree structure of Nomenclature For Reporting (NFR14) – part 2.

2. INDUSTRY

2.A MINERAL PRODUCTION
- 2.A.1 CEMENT PRODUCTION
- 2.A.2 LIME PRODUCTION
- 2.A.3 GLASS PRODUCTION
- 2.A.5 MINERALS OTHER THAN COAL
  - 2.A.5.a Quarrying and mining of minerals other than coal
  - 2.A.5.b Construction and demolition
  - 2.A.5.c Storage, handling and transport of mineral products
- 2.A.6 OTHER MINERAL PRODUCTS

2.B CHEMICAL INDUSTRY
- 2.B.1 AMMONIA PRODUCTION
- 2.B.2 NITRIC ACID PRODUCTION
- 2.B.3 ADIPIC ACID PRODUCTION
- 2.B.5 CARBIDE PRODUCTION
- 2.B.6 TITANIUM DIOXIDE PRODUCTION
- 2.B.7 SODA ASH PRODUCTION
- 2.B.10 OTHER CHEMICAL INDUSTRY
  - 2.B.10.a Chemical industry: Other
  - 2.B.10.b Storage, handling and transport of chemical products

2.C METAL PRODUCTION
- 2.C.1 IRON AND STEEL PRODUCTION
- 2.C.2 FERROALLOYS PRODUCTION
- 2.C.3 ALUMINIUM PRODUCTION
- 2.C.4 MAGNESIUM PRODUCTION
- 2.C.5 LEAD PRODUCTION
- 2.C.6 ZINC PRODUCTION
- 2.C.7 OTHER METAL PRODUCTION AND HANDLING
  - 2.C.7.a Copper production
  - 2.C.7.b Nickel production
  - 2.C.7.c Other metal production
  - 2.C.7.d Storage, handling and transport of metal products

2.D SOLVENTS
- 2.D.3 SOLVENTS USE
  - 2.D.3.a Domestic solvent use including fungicides
  - 2.D.3.b Road paving with asphalt
  - 2.D.3.c Asphalt roofing
  - 2.D.3.d Coating applications
  - 2.D.3.e Degreasing
  - 2.D.3.f Dry cleaning
  - 2.D.3.g Chemical products
  - 2.D.3.h Printing
  - 2.D.3.i Other solvent use

2.G OTHER PRODUCT USE

2.H OTHER PRODUCTION INDUSTRY
- 2.H.1 PULP AND PAPER INDUSTRY
- 2.H.2 FOOD AND BEVERAGES INDUSTRY
- 2.H.3 OTHER INDUSTRIAL PROCESSES

2.I WOOD PROCESSING

2.J PRODUCTION OF POPs

2.K CONSUMPTION OF POPS AND HEAVY METALS

2.L OTHER PRODUCTION, CONSUMPTION, STORAGE, TRANSPORTATION OR HANDLING OF BULK PRODUCTS

Tab. 6.6 The complete tree struct ure of Nomenclature For Reporting (NFR14) – part 3.

3 AGRICULTURE

3.B MANURE MANAGEMENT
3.B.1 CATTLE
3.B.1.a Dairy cattle
3.B.1.b Non-dairy cattle
3.B.2 SHEEP
3.B.2 SWINE
3.B.4 OTHER
3.B.4.a Buffalo
3.B.4.d Goats
3.B.4.e Horses
3.B.4.f Mules and asses
3.B.4.g Poultry
3.B.4.g.i Laying hens
3.B.4.g.ii Broilers
3.B.4.g.iii Turkeys
3.B.4.g.iv Other poultry
3.B.4.h Other animals
3.D AGRICULTURAL SOILS
3.D.a FERTILIZERS
3.D.a.1 Inorganic N-fertilizers (includes also urea application)
3.D.a.2 Application to soils
3.D.a.2.a Animal manure applied to soils
3.D.a.2.b Sewage sludge applied to soils
3.D.a.2.c Other organic fertilisers applied to soils (including compost)
3.D.a.3 Urine and dung deposited by grazing animals
3.D.a.4 Crop residues applied to soils
3.D.b INDIRECT EMISSIONS FROM MANAGED SOILS
3.D.c FARM-LEVEL AGRICULTURAL OPERATIONS INCLUDING STORAGE, HANDLING AND TRANSPORT OF AGRICULTURAL PRODUCTS
3.D.d OFF-FARM STORAGE, HANDLING AND TRANSPORT OF BULK AGRICULTURAL PRODUCTS
3.D.e CULTIVATED CROPS
3.D.f USE OF PESTICIDES
3.F FIELD BURNING OF AGRICULTURAL RESIDUES
3.I AGRICULTURE OTHER

5. WASTE

5.A SOLID WASTE DISPOSAL ON LAND
5.B BIOLOGICAL TREATMENT OF WASTE
5.B.1 COMPOSTING
5.B.2 ANAEROBIC DIGESTION AT BIOGAS FACILITIES
5.C INCINERATION AND OPEN BURNING OF WASTE
5.C.1 INCINERATION
5.C.1.a Municipal waste incineration
5.C.1.b Industrial waste incineration in total
5.C.1.b.i Industrial waste incineration
5.C.1.b.ii Hazardous waste incineration
5.C.1.b.iii Clinical waste incineration
5.C.1.b.iv Sewage sludge incineration
5.C.1.b.v Cremation
5.C.1.b.vi Other waste incineration
5.C.2 OPEN BURNING OF WASTE
5.D WASTE WATER HANDLING
5.D.1 DOMESTIC WASTEWATER HANDLING
5.D.2 INDUSTRIAL WASTEWATER HANDLING
5.D.3 OTHER WASTEWATER HANDLING
5.E OTHER WASTE

6. OTHER

6. A OTHER
NATIONAL TOTAL

6.4 NATIONAL EMISSION INFORMATION SYSTEM

The basic data from the stationary air pollution sources (hereinafter sources) in SR has began to collect already in 80s of the 20th century. Data were stored in relative simply database of Emission and Air Pollution Source Registry (EAPSR). Radical changes in 90s induced creating a new broader information system for the registering of air pollution sources. Since 2001, the National Emission Information System (NEIS) is used for this purpose. The NEIS was during years regularly extended and updated. The primary scope of the NEIS was mainly the computations of the emissions amounts and air pollution fees for release. At present, this system is used as important (in some cases the only) source of broad-spectrum data (amounts of released air pollutants, amounts of combusted fuels, combustion plant and technology parameters etc.). The Slovak Hydrometeorological Institue (SHMÚ) is delegated by the Ministry of Environment of the Slovak Republic to manage and administrate the NEIS.

Nowadays, system includes module for district offices, portal NEIS PZ WEB for the air pollution source operators (*https://neispz.shmu.sk/*) and central reporting and output module for SHMÚ. Selected data are available on the site *http://neisrep.shmu.sk*, where the user after creating a free account can prepare and dowload customed reports.

Data stored in the NEIS are collected on the base of two main reporting obligations of air pollution source operators:

- obligation as provided in § 4 Act No. 401/1998 on air emission fees, as amended,
- obligation as provided in § 15 section 1 letter e) Act No. 137/2010 on air protection, as amended.

Operators annually report required data thought the portal NEIS PZ WEB. Initial data processing is executed by the district officers at the respective district offices. Summary yearly data evaluation of all large and medium stationary source operators in respective district is submitted by district offices electronically to SHMÚ by 31st May. SHMÚ is processing, analyzing and reviewing data, and also correcting them in collaboration with district officers, if necessary. This centralised review process is running over every year to the end of October. After this internal review process follows the processing of many output reports.

Outputs of the NEIS are used in the preparation process of multiple reports in line with the reporting requirements of the SR (more details in Chapter **6.1**). Also overviews of the most significant stationary air pollution source operators in SR in Chapter **6.4.2** and **6.4.3** were prepared on the base of the NEIS data.

6.4.1 Number of stationary sources listed in NEIS

The term "stationary air pollution source" is defined in the Act No. 137/2010 on the air,[21] as amended, § 3 section 1 letter a). "Source" means a stationary technical unit, stock or fuel storage, landfill, quarry or other area with possibility of steaming up, burning or transfering of pollutants. Source is also other building, object and activity, which could have an effect on emissions and air pollution. Source is allocated as a complex of all parts, components and activities within the functional unit and spatial unit. Section 2 of § 3 states that stationary sources are divided as large, medium or small sources, according to the ratio of their effect on emissions and air pollution. In terms of section 4, the stationary sources are categorized on the base of technology character. The categories and the projected capacity thresholds are listed in the Annex 1 to the Regulation No. 410/2012, as amended.[22]

Number of stationary sources recorded in the NEIS during the year 2018 at regional level is presented in the tables **Tab. 6.7** to **Tab. 6.9**. Total number of sources means the number of large and medium stationary sources. The tables **Tab. 6.8** and **Tab. 6.9** present more detailed numbers in division of scale and operational status. Status out of operation means that sources were not running the whole year,

[21] *https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2010/137/20171201*
[22] *https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2012/410/20171219*

i.e. no emissions were released from these sources. The reasons can be various: temporary suspension of production during a longer reconstruction, termination without liquidation of the installations (e.g. unused or abandoned factories), or other.

Tab. 6.7 *Number of stationary air pollution sources listed in NEIS for the year 2018 at regional level.*

Region	Total number of sources	From this:	
		large sources	medium sources
Bratislava	1 959	89	1 870
Trnava	1 670	115	1 555
Trenčín	1 587	103	1 484
Nitra	1 804	148	1 656
Žilina	1 616	91	1 525
Banská Bystrica	1 889	121	1 768
Prešov	1 618	66	1 552
Košice	1 491	132	1 359
SR	**13 634**	**865**	**12 769**

Tab. 6.8 *Number of large stationary air pollution sources listed in NEIS for the year 2018 at regional level.*

Region	Number of large sources	From this:	
		in operation	out of operation
Bratislava	89	85	4
Trnava	115	102	13
Trenčín	103	92	11
Nitra	148	124	24
Žilina	91	78	13
Banská Bystrica	121	97	24
Prešov	66	55	11
Košice	132	113	19
SR	**865**	**746**	**119**

Tab. 6.9 *Number of medium stationary air pollution sources listed in NEIS for the year 2018 at regional level.*

Region	Number of medium sources	From this:	
		in operation	out of operation
Bratislava	1 870	1 622	248
Trnava	1 555	1 197	358
Trenčín	1 484	1 310	174
Nitra	1 656	1 282	374
Žilina	1 525	1 302	223
Banská Bystrica	1 768	1 383	385
Prešov	1 552	1 348	204
Košice	1 359	1 078	281
SR	**12 769**	**10 522**	**2 247**

6.4.2 Overview of the most significant stationary air pollution source operators in Slovakia listed in database NEIS

Tables **Tab. 6.10** up to **Tab. 6.13** include the list of the most significant operators of stationary air pollution sources (thereinafter "sources") in SR during the year 2018. The emission values are presented in tonnes per year. These total yearly emissions were released from stationary air pollution sources, which are located at the territory of given district and operated by presented operator. The percentual value of Share on total emissions – SR presents the share on total emissions released in given year from large and medium stationary sources in SR listed in NEIS.

Tab. 6.10 *Total suspended particles (TSP) released from the most important sources of operators – 2018.*

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	2 319.01	48.79
2.	Duslo, a.s.	Šaľa	164.65	3.46
3.	Slovalco, a.s.	Žiar nad Hronom	131.91	2.78
4.	FORTISCHEM a. s.	Prievidza	127.32	2.68
5.	Mondi SCP, a.s.	Ružomberok	76.95	1.62
6.	SLOVNAFT, a.s.	Bratislava II	65.95	1.39
7.	DOLVAP, s.r.o.	Žilina	50.62	1.06
8.	BUKOCEL, a.s.	Vranov nad Topľou	48.04	1.01
9.	Považská cementáreň, a.s.	Ilava	44.47	0.94
10.	Ferroenergy s.r.o.	Košice II	42.31	0.89
11.	SLOVNAFT, a.s.	Bratislava II	41.23	0.87
12.	Slovenské elektrárne, a.s.	Michalovce	40.59	0.85
13.	Hornonitrianske bane Prievidza, a.s.	Prievidza	30.12	0.63
14.	Johns Manville Slovakia, a.s.	Trnava	26.92	0.57
15.	Slovenské elektrárne, a.s.	Prievidza	25.38	0.53
16.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	23.71	0.50
17.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	23.27	0.49
18.	Tate & Lyle Boleraz, s.r.o.	Trnava	22.85	0.48
19.	Zvolenská teplárenská, a.s.	Zvolen	22.23	0.47
20.	SLOVMAG a.s. Lubeník	Revúca	22.16	0.47
	TOTAL		**3 349.70**	**70.47**

Tab. 6.11 *Sulphur oxides expressed as SO_2 released from the most important sources of operators – 2018.*

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	4 681.02	24.83
2.	Slovenské elektrárne, a.s.	Prievidza	2 670.64	14.17
3.	SLOVNAFT, a.s.	Bratislava II	2 433.86	12.91
4.	Slovalco, a.s.	Žiar nad Hronom	2 060.54	10.93
5.	Ferroenergy s.r.o.	Košice II	1 329.40	7.05
6.	OFZ, a.s.	Dolný Kubín	720.62	3.82
7.	SLOVNAFT, a.s.	Bratislava II	705.55	3.74
8.	Slovenské elektrárne, a.s.	Michalovce	473.66	2.51
9.	Knauf Insulation, s.r.o.	Žarnovica	422.67	2.24
10.	Zvolenská teplárenská, a.s.	Zvolen	381.03	2.02
11.	Martinská teplárenská, a.s.	Martin	337.97	1.79
12.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	193.87	1.03
13.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	190.96	1.01
14.	Duslo, a.s.	Bratislava III	187.05	0.99
15.	Žilinská teplárenská, a.s.	Žilina	181.81	0.96
16.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	168.71	0.89
17.	KOMPALA a.s.	Banská Bystrica	165.59	0.88
18.	BUKOCEL, a.s.	Vranov nad Topľou	144.64	0.77
19.	Slovenské magnezitové závody, a.s. Jelšava	Košice II	70.19	0.37
20.	SLOVMAG a.s. Lubeník	Revúca	69.62	0.37
	TOTAL		**17 589.40**	**93.30**

Tab. 6.12 *Nitrogen oxides expressed as NO_2 released from the most important sources of operators – 2018.*

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	4 922.22	18.80
2.	Ferroenergy s.r.o.	Košice II	1 689.45	6.45
3.	SLOVNAFT, a.s.	Bratislava II	1 165.03	4.45
4.	Slovenské elektrárne, a.s.	Prievidza	1 128.26	4.31
5.	Mondi SCP, a.s.	Ružomberok	985.59	3.77
6.	CRH (Slovensko) a.s.	Malacky	968.35	3.70
7.	SLOVNAFT, a.s.	Bratislava II	879.08	3.36
8.	Duslo, a.s.	Šaľa	762.61	2.91
9.	CRH (Slovensko) a.s.	Košice - okolie	733.78	2.80
10.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	692.04	2.64
11.	CEMMAC a.s.	Trenčín	550.03	2.10
12.	Slovalco, a.s.	Žiar nad Hronom	538.14	2.06
13.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	513.27	1.96
14.	OFZ, a.s.	Dolný Kubín	499.83	1.91
15.	Považská cementáreň, a.s.	Ilava	494.53	1.89
16.	Carmeuse Slovakia, s.r.o.	Košice II	299.62	1.14
17.	PPC Energy, a.s.	Bratislava III	287.17	1.10
18.	BUKOCEL, a.s.	Vranov nad Topľou	268.03	1.02
19.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	254.68	0.97
20.	Zvolenská teplárenská, a.s.	Zvolen	248.68	0.95
	TOTAL		**17 880.39**	**68.31**

Tab. 6.13 *Carbon monoxide (CO) released from the most important sources of operators – 2018.*

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	101 877.00	71.70
2.	Slovalco, a.s.	Žiar nad Hronom	16 458.36	11.58
3.	CEMMAC a.s.	Trenčín	3 929.66	2.77
4.	CRH (Slovensko) a.s.	Malacky	3 544.55	2.49
5.	Považská cementáreň, a.s.	Ilava	2 143.00	1.51
6.	OFZ, a.s.	Dolný Kubín	1 064.36	0.75
7.	KOVOHUTY, a.s.	Spišská Nová Ves	972.70	0.68
8.	Calmit, spol. s r.o.	Nitra	686.12	0.48
9.	Slovenské elektrárne, a.s.	Michalovce	509.11	0.36
10.	Leier Baustoffe SK s.r.o.	Prešov	450.15	0.32
11.	SLOVNAFT, a.s.	Bratislava II	438.97	0.31
12.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	415.93	0.29
13.	Slovenské elektrárne, a.s.	Prievidza	403.97	0.28
14.	CRH (Slovensko) a.s.	Košice - okolie	400.11	0.28
15.	VUM, a.s.	Žiar nad Hronom	360.62	0.25
16.	Slovenské magnezitové závody, a.s. Jelšava	Košice II	285.03	0.20
17.	Mondi SCP, a.s.	Ružomberok	273.68	0.19
18.	Ferroenergy s.r.o.	Košice II	234.54	0.17
19.	SLOVMAG a.s. Lubeník	Revúca	231.63	0.16
20.	IKEA Industry Slovakia s. r. o.	Malacky	228.20	0.16
	TOTAL		**134 907.67**	**94.95**

6.4.3 Overview of the most significant stationary air pollution source operators in SR at regional level

Tables **Tab. 6.14** up to **Tab. 6.21** represent the most significant operators of large and medium stationary sources listed in NEIS in 2018 at regional level. The emission values are presented in tonnes per year. These total yearly emissions were released from stationary air pollution sources, which are located at the territory of given district and specific region and which are operated by presented operator. The percentual value Share on total emissions - region presents the share on total emissions released from large and medium stationary sources in the given region and year. The percentual value Share on total emissions - SR presents the share on total emissions released in given year from large and medium stationary sources in SR listed in NEIS.

Tab. 6.14 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level –* ***Bratislava region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	SLOVNAFT, a.s.	Bratislava II	107.26	46.22	2.26
	2.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	23.27	10.03	0.49
	3.	CRH (Slovensko) a.s.	Malacky	15.26	6.58	0.32
	4.	PPC Energy, a.s.	Bratislava III	6.79	2.93	0.14
	5.	ALAS SLOVAKIA, s.r.o.	Malacky	5.91	2.54	0.12
	6.	IKEA Industry Slovakia s. r. o.	Malacky	5.85	2.52	0.12
	7.	TERMMING, a.s.	Bratislava II	5.58	2.40	0.12
	8.	TERMMING, a.s.	Pezinok	4.64	2.00	0.10
	9.	Obec Rohožník	Malacky	4.19	1.81	0.09
	10.	Ministerstvo obrany Slovenskej republiky	Pezinok	3.82	1.65	0.08
		TOTAL		**182.58**	**78.68**	**3.84**
Sulphur oxides as SO_2	1.	SLOVNAFT, a.s.	Bratislava II	3 139.42	92.57	16.65
	2.	Duslo, a.s.	Bratislava III	187.05	5.52	0.99
	3.	CRH (Slovensko) a.s.	Malacky	38.87	1.15	0.21
	4.	Ministerstvo obrany Slovenskej republiky	Pezinok	6.21	0.18	0.03
	5.	Pezinské tehelne - Paneláreň, a.s.	Pezinok	5.90	0.17	0.03
	6.	Odvoz a likvidácia odpadu a.s.	Bratislava II	4.05	0.12	0.02
	7.	BIONERGY, a. s.	Bratislava II	2.73	0.08	0.01
	8.	AGROMAČAJ a.s.	Senec	1.48	0.04	0.01
	9.	Ministerstvo vnútra Slovenskej republiky	Bratislava V	0.84	0.02	0.00
	10.	PPC Energy, a.s.	Bratislava III	0.82	0.02	0.00
		TOTAL		**3 387.36**	**99.88**	**17.97**
Nitrogen oxides as NO_2	1.	SLOVNAFT, a.s.	Bratislava II	2 044.19	48.00	7.81
	2.	CRH (Slovensko) a.s.	Malacky	968.35	22.74	3.70
	3.	PPC Energy, a.s.	Bratislava III	287.17	6.74	1.10
	4.	IKEA Industry Slovakia s. r. o.	Malacky	182.17	4.28	0.70
	5.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	91.54	2.15	0.35
	6.	Odvoz a likvidácia odpadu a.s.	Bratislava II	85.19	2.00	0.33
	7.	Veolia Energia Slovensko, a. s.	Bratislava V	78.90	1.85	0.30
	8.	TERMMING, a.s.	Bratislava II	54.38	1.28	0.21
	9.	Bratislavská teplárenská, a.s.	Bratislava III	51.32	1.21	0.20
	10.	Bratislavská teplárenská, a.s.	Bratislava IV	50.00	1.17	0.19
		TOTAL		**3 893.20**	**91.42**	**14.87**
Carbon monoxide	1.	CRH (Slovensko) a.s.	Malacky	3 544.55	73.98	2.49
	2.	SLOVNAFT, a.s.	Bratislava II	449.87	9.39	0.32
	3.	IKEA Industry Slovakia s. r. o.	Malacky	228.20	4.76	0.16
	4.	PPC Energy, a.s.	Bratislava III	112.33	2.34	0.08
	5.	TERMMING, a.s.	Malacky	91.88	1.92	0.06
	6.	Obec Rohožník	Malacky	29.81	0.62	0.02
	7.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	28.71	0.60	0.02
	8.	Veolia Energia Slovensko, a. s.	Bratislava V	27.01	0.56	0.02
	9.	Duslo, a.s.	Bratislava III	26.84	0.56	0.02
	10.	Ministerstvo obrany Slovenskej republiky	Pezinok	23.40	0.49	0.02
		TOTAL		**4 562.59**	**95.23**	**3.21**

Tab. 6.15 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level –* ***Trnava region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	Johns Manville Slovakia, a.s.	Trnava	26.92	15.28	0.57
	2.	Tate & Lyle Boleraz, s.r.o.	Trnava	22.85	12.97	0.48
	3.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	22.00	12.49	0.46
	4.	Agro Boleráz, s.r.o.	Trnava	5.74	3.26	0.12
	5.	Agropodnik a.s. Trnava	Dunajská Streda	5.69	3.23	0.12
	6.	ZLIEVÁREŇ T R N A V A s.r.o.	Trnava	5.41	3.07	0.11
	7.	PCA Slovakia, s.r.o.	Trnava	5.27	2.99	0.11
	8.	Bekaert Slovakia, s.r.o.	Galanta	4.09	2.32	0.09
	9.	ENVIRAL, a.s.	Hlohovec	3.87	2.20	0.08
	10.	ZSE Elektrárne, s.r.o.	Hlohovec	3.32	1.88	0.07
		TOTAL		**105.18**	**59.70**	**2.21**
Sulphur oxides as SO_2	1.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	190.96	49.71	1.01
	2.	Johns Manville Slovakia, a.s.	Trnava	64.13	16.70	0.34
	3.	MACH TRADE, spol. s r.o.	Galanta	30.31	7.89	0.16
	4.	Hornonitrianske bane Prievidza, a.s.	Senica	12.93	3.37	0.07
	5.	RUPOS, s.r.o.	Trnava	12.21	3.18	0.06
	6.	PLYNEX s. r. o.	Galanta	11.84	3.08	0.06
	7.	ECO PWR, s. r. o.	Dunajská Streda	10.32	2.69	0.05
	8.	ZLIEVÁREŇ T R N A V A s.r.o.	Trnava	9.13	2.38	0.05
	9.	BPS Hubice, s. r. o.	Dunajská Streda	4.74	1.23	0.03
	10.	Ing. Peter Horváth - SHR	Galanta	4.48	1.17	0.02
		TOTAL		**351.05**	**91.39**	**1.86**
Nitrogen oxides as NO_2	1.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	139.52	16.41	0.53
	2.	Johns Manville Slovakia, a.s.	Trnava	98.22	11.55	0.38
	3.	ENVIRAL, a.s.	Hlohovec	62.75	7.38	0.24
	4.	Tate & Lyle Boleraz, s.r.o.	Trnava	46.74	5.50	0.18
	5.	Wienerberger slovenské tehelne, spol. s r.o.	Trnava	37.06	4.36	0.14
	6.	Službyt, spol. s r.o.	Senica	36.13	4.25	0.14
	7.	TEPLÁREŇ Považská Bystrica, s.r.o.	Dunajská Streda	25.64	3.01	0.10
	8.	ZSE Elektrárne, s.r.o.	Hlohovec	22.19	2.61	0.08
	9.	Bekaert Hlohovec, a.s.	Hlohovec	21.69	2.55	0.08
	10.	IKEA Industry Slovakia s. r. o.	Trnava	14.26	1.68	0.05
		TOTAL		**504.21**	**59.29**	**1.93**
Carbon monoxide	1.	Službyt, spol. s r.o.	Senica	179.02	29.24	0.13
	2.	Wienerberger slovenské tehelne, spol. s r.o.	Trnava	55.93	9.14	0.04
	3.	ZSE Elektrárne, s.r.o.	Hlohovec	39.33	6.42	0.03
	4.	ZLIEVÁREŇ T R N A V A s.r.o.	Trnava	22.58	3.69	0.02
	5.	ASTOM ND, s. r. o.	Dunajská Streda	21.54	3.52	0.02
	6.	ENVIRAL, a.s.	Hlohovec	21.27	3.47	0.01
	7.	ASTOM V, s.r.o.	Dunajská Streda	20.09	3.28	0.01
	8.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	17.73	2.90	0.01
	9.	IKEA Industry Slovakia s. r. o.	Trnava	16.39	2.68	0.01
	10.	Tate & Lyle Boleraz, s.r.o.	Trnava	16.07	2.62	0.01
		TOTAL		**409.96**	**66.96**	**0.29**

Tab. 6.16 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level –* ***Trenčín region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	FORTISCHEM a. s.	Prievidza	127.32	32.01	2.68
	2.	Považská cementáreň, a.s.	Ilava	44.47	11.18	0.94
	3.	Hornonitrianske bane Prievidza, a.s.	Prievidza	30.12	7.57	0.63
	4.	Slovenské elektrárne, a.s.	Prievidza	25.38	6.38	0.53
	5.	VETROPACK NEMŠOVÁ, s.r.o.	Trenčín	20.66	5.19	0.43
	6.	TERMONOVA, a.s.	Ilava	17.74	4.46	0.37
	7.	Považský cukor a.s.	Trenčín	17.62	4.43	0.37
	8.	CEMMAC a.s.	Trenčín	16.69	4.19	0.35
	9.	KVARTET,a.s.	Partizánske	7.34	1.84	0.15
	10.	KAMEŇOLOMY, s.r.o.	Trenčín	4.62	1.16	0.10
		TOTAL		**311.94**	**78.42**	**6.56**
Sulphur oxides as SO_2	1.	Slovenské elektrárne, a.s.	Prievidza	2 670.64	95.55	14.17
	2.	VETROPACK NEMŠOVÁ, s.r.o.	Trenčín	32.63	1.17	0.17
	3.	Hornonitrianske bane Prievidza, a.s.	Prievidza	11.74	0.42	0.06
	4.	FORTISCHEM a. s.	Prievidza	8.03	0.29	0.04
	5.	BIOPLYN HOROVCE 3, s. r. o.	Púchov	6.99	0.25	0.04
	6.	BIOPLYN HOROVCE 2 s. r. o.	Púchov	6.81	0.24	0.04
	7.	AGROSERVIS-SLUŽBY, spol. s r.o.	Partizánske	6.50	0.23	0.03
	8.	Považská cementáreň, a.s.	Ilava	5.90	0.21	0.03
	9.	Bioplyn Horovce, s. r. o.	Púchov	4.87	0.17	0.03
	10.	BPS Myjava, s. r. o.	Myjava	4.77	0.17	0.03
		TOTAL		**2 758.89**	**98.71**	**14.63**
Nitrogen oxides as NO_2	1.	Slovenské elektrárne, a.s.	Prievidza	1 128.26	35.52	4.31
	2.	CEMMAC a.s.	Trenčín	550.03	17.32	2.10
	3.	Považská cementáreň, a.s.	Ilava	494.53	15.57	1.89
	4.	VETROPACK NEMŠOVÁ, s.r.o.	Trenčín	203.56	6.41	0.78
	5.	RONA, a.s.	Púchov	179.56	5.65	0.69
	6.	FORTISCHEM a. s.	Prievidza	70.92	2.23	0.27
	7.	TEPLÁREŇ Považská Bystrica, s.r.o.	Považská Bystrica	46.71	1.47	0.18
	8.	Výroba tepla, s. r. o.	Trenčín	37.37	1.18	0.14
	9.	TERMONOVA, a.s.	Ilava	37.24	1.17	0.14
	10.	Continental Matador Rubber, s.r.o.	Púchov	34.35	1.08	0.13
		TOTAL		**2 782.54**	**87.59**	**10.63**
Carbon monoxide	1.	CEMMAC a.s.	Trenčín	3 929.66	51.87	2.77
	2.	Považská cementáreň, a.s.	Ilava	2 143.00	28.29	1.51
	3.	Slovenské elektrárne, a.s.	Prievidza	403.97	5.33	0.28
	4.	FORTISCHEM a. s.	Prievidza	193.90	2.56	0.14
	5.	Považský cukor a.s.	Trenčín	175.10	2.31	0.12
	6.	Technické služby mesta Partizánske, s r. o.	Partizánske	99.93	1.32	0.07
	7.	ENGIE Services a.s.	Myjava	75.43	1.00	0.05
	8.	KVARTET,a.s.	Partizánske	41.32	0.55	0.03
	9.	TEPLÁREŇ Považská Bystrica, s.r.o.	Považská Bystrica	40.41	0.53	0.03
	10.	Výroba tepla, s. r. o.	Trenčín	38.72	0.51	0.03
		TOTAL		**7 141.44**	**94.26**	**5.03**

Tab. 6.17 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level –* ***Nitra region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	Duslo, a.s.	Šaľa	164.65	44.56	3.46
	2.	SLOVINCOM, spol. s r.o.	Komárno	13.33	3.61	0.28
	3.	DECODOM, spol. s r. o.	Topoľčany	11.01	2.98	0.23
	4.	Kameňolomy a štrkopieskovne, a.s.	Nitra	7.90	2.14	0.17
	5.	MENERT - THERM, s.r.o.	Šaľa	7.57	2.05	0.16
	6.	P.G.TRADE, spol. s r.o.	Nové Zámky	7.52	2.04	0.16
	7.	Prvá energetická a teplárenská spoločnosť, s.r.o.	Zlaté Moravce	6.91	1.87	0.15
	8.	SLOVINTEGRA ENERGY, a.s.	Levice	6.73	1.82	0.14
	9.	TOP PELET, s.r.o.	Topoľčany	5.74	1.55	0.12
	10.	SLOVENSKÉ ENERGETICKÉ STROJÁRNE a.s.	Levice	5.64	1.53	0.12
		TOTAL		**237.00**	**64.14**	**4.99**
Sulphur oxides as SO_2	1.	P.G.TRADE, spol. s r.o.	Nové Zámky	14.22	13.51	0.08
	2.	Liaharenský podnik Nitra, a.s.	Levice	11.08	10.53	0.06
	3.	GAS PROGRES I., spol. s r.o.	Nitra	9.99	9.49	0.05
	4.	AT GEMER, spol. s r.o.	Nové Zámky	9.85	9.36	0.05
	5.	BIOGAS, s.r.o.	Nitra	8.59	8.16	0.05
	6.	Bioplyn Cetín, s. r. o.	Nitra	8.13	7.72	0.04
	7.	BIONOVES, s.r.o.	Nitra	7.74	7.36	0.04
	8.	BPS Lipová 1 s.r.o.	Nové Zámky	6.09	5.79	0.03
	9.	Ministerstvo obrany Slovenskej republiky	Nitra	3.61	3.43	0.02
	10.	Calmit, spol. s r.o.	Nitra	3.55	3.38	0.02
		TOTAL		**82.87**	**78.72**	**0.44**
Nitrogen oxides as NO_2	1.	Duslo, a.s.	Šaľa	762.61	46.22	2.91
	2.	BIOENERGY TOPOĽČANY s.r.o.	Topoľčany	168.46	10.21	0.64
	3.	SLOVINTEGRA ENERGY, a.s.	Levice	68.67	4.16	0.26
	4.	Bytkomfort, s.r.o.	Nové Zámky	37.97	2.30	0.15
	5.	VICENTE TORNS SLOVAKIA, a.s.	Komárno	30.60	1.85	0.12
	6.	DECODOM, spol. s r. o.	Topoľčany	26.66	1.62	0.10
	7.	TOP PELET, s.r.o.	Topoľčany	26.20	1.59	0.10
	8.	P.G.TRADE, spol. s r.o.	Nové Zámky	21.06	1.28	0.08
	9.	Wienerberger slovenské tehelne, spol. s r.o.	Zlaté Moravce	20.47	1.24	0.08
	10.	Nitrianska teplárenská spoločnosť, a.s.	Nitra	17.10	1.04	0.07
		TOTAL		**1 179.80**	**71.51**	**4.51**
Carbon monoxide	1.	Calmit, spol. s r.o.	Nitra	686.12	44.08	0.48
	2.	Bytkomfort, s.r.o.	Nové Zámky	124.20	7.98	0.09
	3.	Duslo, a.s.	Šaľa	110.62	7.11	0.08
	4.	Wienerberger slovenské tehelne, spol. s r.o.	Zlaté Moravce	92.50	5.94	0.07
	5.	SLOVINTEGRA ENERGY, a.s.	Levice	47.58	3.06	0.03
	6.	Nidec Global Appliance Slovakia s.r.o.	Zlaté Moravce	47.44	3.05	0.03
	7.	WOODPAN SLOVAKIA s.r.o.	Nové Zámky	38.19	2.45	0.03
	8.	SLOVINCOM, spol. s r.o.	Komárno	22.96	1.47	0.02
	9.	VICENTE TORNS SLOVAKIA, a.s.	Komárno	22.28	1.43	0.02
	10.	Bioplyn Cetín, s. r. o.	Nitra	20.45	1.31	0.01
		TOTAL		**1 212.34**	**77.88**	**0.85**

Tab. 6.18 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level –* ***Žilina region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	Mondi SCP, a.s.	Ružomberok	76.95	22.04	1.62
	2.	DOLVAP, s.r.o.	Žilina	50.62	14.50	1.06
	3.	Bekam, s.r.o.	Žilina	13.95	3.99	0.29
	4.	TEHOS, s.r.o.	Dolný Kubín	12.69	3.64	0.27
	5.	D O L K A M Šuja, a.s.	Žilina	12.45	3.57	0.26
	6.	Kia Motors Slovakia s.r.o.	Žilina	10.72	3.07	0.23
	7.	OFZ, a.s.	Dolný Kubín	10.43	2.99	0.22
	8.	Žilinská teplárenská, a.s.	Žilina	10.22	2.93	0.21
	9.	Martinská teplárenská, a.s.	Martin	7.39	2.11	0.16
	10.	LMT, a. s.	Liptovský Mikuláš	6.93	1.98	0.15
		TOTAL		**212.34**	**60.81**	**4.47**
Sulphur oxides as SO_2	1.	OFZ, a.s.	Dolný Kubín	720.62	47.56	3.82
	2.	Martinská teplárenská, a.s.	Martin	337.97	22.31	1.79
	3.	Žilinská teplárenská, a.s.	Žilina	181.81	12.00	0.96
	4.	ŽOS Vrútky a.s.	Martin	67.34	4.44	0.36
	5.	SOTE s.r.o.	Čadca	65.95	4.35	0.35
	6.	Mondi SCP, a.s.	Ružomberok	59.44	3.92	0.32
	7.	AFG s.r.o.	Turčianske Teplice	15.91	1.05	0.08
	8.	BPS BORCOVA, s.r.o.	Turčianske Teplice	7.52	0.50	0.04
	9.	ZDROJ MT, spol. s r.o.	Martin	6.75	0.45	0.04
	10.	Cementáreň Lietavská Lúčka, a.s.	Žilina	4.89	0.32	0.03
		TOTAL		**1 468.21**	**96.91**	**7.79**
Nitrogen oxides as NO_2	1.	Mondi SCP, a.s.	Ružomberok	985.59	37.74	3.77
	2.	OFZ, a.s.	Dolný Kubín	499.83	19.14	1.91
	3.	Martinská teplárenská, a.s.	Martin	235.65	9.02	0.90
	4.	Žilinská teplárenská, a.s.	Žilina	160.57	6.15	0.61
	5.	Rettenmeier Tatra Timber, s.r.o.	Liptovský Mikuláš	147.25	5.64	0.56
	6.	SPECIALTY MINERALS SLOVAKIA, spol. s r.o.	Ružomberok	68.68	2.63	0.26
	7.	Kia Motors Slovakia s.r.o.	Žilina	42.65	1.63	0.16
	8.	LMT, a. s.	Liptovský Mikuláš	36.38	1.39	0.14
	9.	KYSUCA s.r.o.	Kysucké Nové Mesto	30.86	1.18	0.12
	10.	SOTE s.r.o.	Čadca	23.03	0.88	0.09
		TOTAL		**2 230.49**	**85.42**	**8.52**
Carbon monoxide	1.	OFZ, a.s.	Dolný Kubín	1064.36	44.25	0.75
	2.	Mondi SCP, a.s.	Ružomberok	273.68	11.38	0.19
	3.	LMT, a. s.	Liptovský Mikuláš	162.46	6.75	0.11
	4.	SOTE s.r.o.	Čadca	95.90	3.99	0.07
	5.	SPECIALTY MINERALS SLOVAKIA, spol. s r.o.	Ružomberok	70.40	2.93	0.05
	6.	Rettenmeier Tatra Timber, s.r.o.	Liptovský Mikuláš	63.52	2.64	0.04
	7.	ŽOS Vrútky a.s.	Martin	53.33	2.22	0.04
	8.	TURZOVSKÁ DREVÁRSKA FABRIKA s.r.o.	Čadca	48.81	2.03	0.03
	9.	LEHOTSKY CAPITAL s.r.o.	Liptovský Mikuláš	39.95	1.66	0.03
	10.	Žilinská teplárenská, a.s.	Žilina	33.88	1.41	0.02
		TOTAL		**1 906.29**	**79.26**	**1.34**

Tab. 6.19 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level –* ***Banská Bystrica region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	Slovalco, a.s.	Žiar nad Hronom	131.91	29.10	2.78
	2.	Zvolenská teplárenská, a.s.	Zvolen	22.23	4.90	0.47
	3.	SLOVMAG a.s. Lubeník	Revúca	22.16	4.89	0.47
	4.	Nemak Slovakia s.r.o.	Žiar nad Hronom	14.85	3.28	0.31
	5.	Energy Edge ZC s. r. o.	Žarnovica	13.71	3.03	0.29
	6.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	9.96	2.20	0.21
	7.	Hontianska energetická, s. r. o.	Veľký Krtíš	9.94	2.19	0.21
	8.	BYTES, s.r.o.	Detva	9.66	2.13	0.20
	9.	BUČINA ZVOLEN, a.s.	Zvolen	8.71	1.92	0.18
	10.	Železiarne Podbrezová a.s.	Brezno	8.25	1.82	0.17
		TOTAL		**251.40**	**55.47**	**5.29**
Sulphur oxides as SO_2	1.	Slovalco, a.s.	Žiar nad Hronom	2 060.54	61.39	10.93
	2.	Knauf Insulation, s.r.o.	Žarnovica	422.67	12.59	2.24
	3.	Zvolenská teplárenská, a.s.	Zvolen	381.03	11.35	2.02
	4.	KOMPALA a.s.	Banská Bystrica	165.59	4.93	0.88
	5.	SLOVMAG a.s. Lubeník	Revúca	69.62	2.07	0.37
	6.	Veolia Utilities Žiar nad Hronom, a.s.	Žiar nad Hronom	60.53	1.80	0.32
	7.	VUM, a.s.	Žiar nad Hronom	49.05	1.46	0.26
	8.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	31.51	0.94	0.17
	9.	Železiarne Podbrezová a.s.	Brezno	23.64	0.70	0.13
	10.	Calmit, spol. s r.o.	Rimavská Sobota	12.95	0.39	0.07
		TOTAL		**3 277.12**	**97.64**	**17.38**
Nitrogen oxides as NO_2	1.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	692.04	20.63	2.64
	2.	Slovalco, a.s.	Žiar nad Hronom	538.14	16.04	2.06
	3.	Zvolenská teplárenská, a.s.	Zvolen	248.68	7.41	0.95
	4.	KOMPALA a.s.	Banská Bystrica	212.55	6.34	0.81
	5.	Železiarne Podbrezová a.s.	Brezno	193.29	5.76	0.74
	6.	SLOVMAG a.s. Lubeník	Revúca	156.75	4.67	0.60
	7.	Bučina DDD, spol. s r.o.	Zvolen	142.84	4.26	0.55
	8.	Veolia Utilities Žiar nad Hronom, a.s.	Žiar nad Hronom	135.25	4.03	0.52
	9.	Energy Edge ZC s. r. o.	Žarnovica	102.78	3.06	0.39
	10.	BUČINA ZVOLEN, a.s.	Zvolen	94.82	2.83	0.36
		TOTAL		**2 517.16**	**75.03**	**9.62**
Carbon monoxide	1.	Slovalco, a.s.	Žiar nad Hronom	16 458.36	87.63	11.58
	2.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	415.93	2.21	0.29
	3.	VUM, a.s.	Žiar nad Hronom	360.62	1.92	0.25
	4.	SLOVMAG a.s. Lubeník	Revúca	231.63	1.23	0.16
	5.	Železiarne Podbrezová a.s.	Brezno	176.90	0.94	0.12
	6.	Calmit, spol. s r.o.	Rimavská Sobota	99.80	0.53	0.07
	7.	Bučina DDD, spol. s r.o.	Zvolen	73.65	0.39	0.05
	8.	TUBEX SLOVAKIA, s.r.o.	Žarnovica	62.70	0.33	0.04
	9.	IPEĽSKÉ TEHELNE a.s.	Poltár	57.11	0.30	0.04
	10.	Energy Edge ZC s. r. o.	Žarnovica	54.28	0.29	0.04
		TOTAL		**17 990.97**	**95.79**	**12.66**

***Tab. 6.20** Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level – **Prešov region**.*

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	BUKOCEL, a.s.	Vranov nad Topľou	48.04	25.54	1.01
	2.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	23.71	12.61	0.50
	3.	BIOENERGY BARDEJOV, s.r.o.	Bardejov	8.34	4.44	0.18
	4.	VSK MINERAL s.r.o.	Vranov nad Topľou	7.50	3.99	0.16
	5.	BYTENERG spol. s r.o.	Medzilaborce	5.92	3.15	0.12
	6.	IS-LOM s.r.o., Maglovec	Prešov	5.66	3.01	0.12
	7.	TATRAVAGÓNKA a.s.	Poprad	5.17	2.75	0.11
	8.	LOMY, s. r. o.	Prešov	3.50	1.86	0.07
	9.	SPRAVBYTKOMFORT a.s. Prešov	Prešov	3.38	1.80	0.07
	10.	Centrum sociálnych služieb Dúbrava	Snina	2.77	1.47	0.06
		TOTAL		**114.00**	**60.61**	**2.40**
Sulphur oxides *as SO_2*	1.	BUKÓZA ENERGO. a. s.	Vranov nad Topľou	168.71	47.43	0.89
	2.	BUKOCEL. a.s.	Vranov nad Topľou	144.64	40.66	0.77
	3.	CHEMES. a.s. Humenné	Humenné	16.32	4.59	0.09
	4.	AGROKOMPLEX. spol. s r.o. Humenné	Humenné	5.29	1.49	0.03
	5.	Centrum sociálnych služieb Spišský Štvrtok. n.o.	Levoča	4.26	1.20	0.02
	6.	Leier Baustoffe SK s.r.o.	Prešov	3.92	1.10	0.02
	7.	Ministerstvo obrany Slovenskej republiky	Humenné	2.08	0.59	0.01
	8.	Základná škola v Malcove	Bardejov	1.62	0.46	0.01
	9.	IKA TRANS. spol. s r.o.	Kežmarok	1.09	0.31	0.01
	10.	Základná škola Krajná Poľana	Svidník	1.05	0.29	0.01
		TOTAL		**348.97**	**98.10**	**1.85**
Nitrogen oxides *as NO_2*	1.	BUKÓZA ENERGO. a. s.	Vranov nad Topľou	513.27	38.41	1.96
	2.	BUKOCEL. a.s.	Vranov nad Topľou	268.03	20.05	1.02
	3.	BIOENERGY BARDEJOV. s.r.o.	Bardejov	95.61	7.15	0.37
	4.	SPRAVBYTKOMFORT a.s. Prešov	Prešov	85.24	6.38	0.33
	5.	Leier Baustoffe SK s.r.o.	Prešov	32.37	2.42	0.12
	6.	CHEMOSVIT ENERGOCHEM. a.s.	Poprad	27.26	2.04	0.10
	7.	CHEMES. a.s. Humenné	Humenné	27.08	2.03	0.10
	8.	Popradská energetická spoločnosť. s.r.o.	Poprad	16.86	1.26	0.06
	9.	AGROKOMPLEX. spol. s r.o. Humenné	Humenné	12.63	0.94	0.05
	10.	BPS Huncovce. s.r.o.	Kežmarok	10.42	0.78	0.04
		TOTAL		**1 088.77**	**81.47**	**4.16**
Carbon monoxide	1.	Leier Baustoffe SK s.r.o.	Prešov	450.15	35.78	0.32
	2.	BUKÓZA ENERGO. a. s.	Vranov nad Topľou	216.55	17.21	0.15
	3.	BUKOCEL. a.s.	Vranov nad Topľou	153.60	12.21	0.11
	4.	Schüle Slovakia. s.r.o.	Poprad	98.42	7.82	0.07
	5.	SPRAVBYTKOMFORT a.s. Prešov	Prešov	29.98	2.38	0.02
	6.	Teplo GGE s. r. o.	Snina	29.09	2.31	0.02
	7.	Spravbytherm s.r.o.	Kežmarok	21.24	1.69	0.01
	8.	BIOENERGY BARDEJOV. s.r.o.	Bardejov	19.53	1.55	0.01
	9.	PRO POPULO PP a.s.	Levoča	13.69	1.09	0.01
	10.	Centrum sociálnych služieb Spišský Štvrtok. n.o.	Levoča	11.52	0.92	0.01
		TOTAL		**1 043.76**	**82.95**	**0.73**

***Tab. 6.21** Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2018 at regional level – **Košice region**.*

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	U. S. Steel Košice, s.r.o.	Košice II	2 319.01	89.63	48.79
	2.	Ferroenergy s.r.o.	Košice II	42.31	1.64	0.89
	3.	Slovenské elektrárne, a.s.	Michalovce	40.59	1.57	0.85
	4.	Carmeuse Slovakia, s.r.o.	Košice - okolie	21.88	0.85	0.46
	5.	SYRÁREŇ BEL SLOVENSKO a.s.	Michalovce	21.17	0.82	0.45
	6.	CRH (Slovensko) a.s.	Košice - okolie	18.16	0.70	0.38
	7.	Carmeuse Slovakia, s.r.o.	Košice II	11.16	0.43	0.23
	8.	EUROCAST Košice, s.r.o.	Košice II	9.93	0.38	0.21
	9.	AMETYS s.r.o. Košice	Košice - okolie	8.67	0.34	0.18
	10.	Tepelné hospodárstvo Moldava, a.s.	Košice - okolie	5.10	0.20	0.11
		TOTAL		**2 497.97**	**96.55**	**52.55**
Sulphur oxides as SO_2	1.	U. S. Steel Košice, s.r.o.	Košice II	4 681.02	67.36	24.83
	2.	Ferroenergy s.r.o.	Košice II	1 329.40	19.13	7.05
	3.	Slovenské elektrárne, a.s.	Michalovce	473.66	6.82	2.51
	4.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	193.87	2.79	1.03
	5.	Slovenské magnezitové závody, a.s. Jelšava	Košice II	70.19	1.01	0.37
	6.	TP 2, s.r.o.	Michalovce	60.48	0.87	0.32
	7.	CRH (Slovensko) a.s.	Košice - okolie	25.64	0.37	0.14
	8.	KOVOHUTY, a.s.	Spišská Nová Ves	20.93	0.30	0.11
	9.	Carmeuse Slovakia, s.r.o.	Košice II	13.36	0.19	0.07
	10.	RMS, a.s. Košice	Košice II	10.86	0.16	0.06
		TOTAL		**6 879.41**	**98.99**	**36.49**
Nitrogen oxides as NO_2	1.	U. S. Steel Košice, s.r.o.	Košice II	4 922.22	55.06	18.80
	2.	Ferroenergy s.r.o.	Košice II	1 689.45	18.90	6.45
	3.	CRH (Slovensko) a.s.	Košice - okolie	733.78	8.21	2.80
	4.	Carmeuse Slovakia, s.r.o.	Košice II	299.62	3.35	1.14
	5.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	254.68	2.85	0.97
	6.	eustream, a. s.	Michalovce	190.04	2.13	0.73
	7.	Slovenské elektrárne, a.s.	Michalovce	186.98	2.09	0.71
	8.	KOSIT a.s.	Košice IV	69.05	0.77	0.26
	9.	Košická energetická spoločnosť, a.s.	Košice IV	54.89	0.61	0.21
	10.	Duslo, a.s.	Michalovce	54.26	0.61	0.21
		TOTAL		**8 454.97**	**94.58**	**32.30**
Carbon monoxide	1.	U. S. Steel Košice, s.r.o.	Košice II	101 877.00	96.93	71.70
	2.	KOVOHUTY, a.s.	Spišská Nová Ves	972.70	0.93	0.68
	3.	Slovenské elektrárne, a.s.	Michalovce	509.11	0.48	0.36
	4.	CRH (Slovensko) a.s.	Košice - okolie	400.11	0.38	0.28
	5.	Slovenské magnezitové závody, a.s. Jelšava	Košice II	285.03	0.27	0.20
	6.	Ferroenergy s.r.o.	Košice II	234.54	0.22	0.17
	7.	Duslo, a.s.	Michalovce	107.52	0.10	0.08
	8.	eustream, a. s.	Michalovce	104.07	0.10	0.07
	9.	Embraco Slovakia s.r.o.	Spišská Nová Ves	84.20	0.08	0.06
	10.	Carmeuse Slovakia, s.r.o.	Košice II	75.15	0.07	0.05
		TOTAL		**104 649.42**	**99.57**	**73.65**

6.4.4 Emissions from stationary sources in SR

Tab. 6.22 includes emissions of basic air pollutants in tonnes, which were released from large and medium stationary sources (except small sources and households) in SR in given year. Specific territorial emissions in given year (**Tab. 6.22**) are representing the amount of emissions in tonnes, which were released from large and medium stationary sources and falls on one square km of given district.

Tab. 6.22 *Emissions [t] and Specific territorial emissions [t.km^{-2}] of basic pollutants released from large and medium stationary sources in 2018 at district level - part 1.*

District	Emissions [t]				Specific territorial emissions [t.km^{-2}]			
	TSP	SO_2	NO_2	CO	TSP	SO_2	NO_2	CO
Bratislava	174.604	3 338.379	2 971.091	788.346	0.47	9.08	8.08	2.14
Malacky	41.054	39.384	1 225.049	3 922.490	0.04	0.04	1.29	4.13
Pezinok	10.327	12.232	35.287	57.226	0.03	0.03	0.09	0.15
Senec	6.076	1.564	27.170	23.235	0.02	0.00	0.08	0.06
Dunajská Streda	18.815	18.138	114.531	67.803	0.02	0.02	0.11	0.06
Galanta	37.635	247.743	232.814	77.444	0.06	0.39	0.36	0.12
Hlohovec	13.444	3.882	136.550	80.351	0.05	0.01	0.51	0.30
Piešťany	4.000	4.842	34.879	13.714	0.01	0.01	0.09	0.04
Senica	8.291	18.137	50.555	197.230	0.01	0.03	0.07	0.29
Skalica	6.063	0.493	25.227	10.944	0.02	0.00	0.07	0.03
Trnava	87.919	90.891	255.829	164.758	0.12	0.12	0.35	0.22
Bánovce nad Bebravou	4.358	0.881	16.603	15.115	0.01	0.00	0.04	0.03
Ilava	67.941	8.679	568.632	2 211.099	0.19	0.02	1.59	6.17
Myjava	3.551	5.017	33.169	80.310	0.01	0.02	0.10	0.25
Nové Mesto nad Váhom	8.203	1.739	32.154	21.821	0.01	0.00	0.06	0.04
Partizánske	12.702	10.093	71.393	180.273	0.04	0.03	0.24	0.60
Považská Bystrica	10.266	1.914	54.708	52.019	0.02	0.00	0.12	0.11
Prievidza	210.010	2 694.062	1 253.602	697.979	0.22	2.81	1.31	0.73
Púchov	10.285	27.115	265.620	64.377	0.03	0.07	0.71	0.17
Trenčín	70.451	45.391	880.727	4 252.976	0.10	0.07	1.31	6.30
Komárno	26.268	0.661	104.509	98.133	0.02	0.00	0.09	0.09
Levice	47.075	14.816	151.137	102.546	0.03	0.01	0.10	0.07
Nitra	49.994	47.431	177.858	829.595	0.06	0.05	0.20	0.95
Nové Zámky	25.513	34.471	120.498	200.148	0.02	0.03	0.09	0.15
Šaľa	178.166	5.250	793.634	127.895	0.50	0.01	2.23	0.36
Topoľčany	29.309	0.830	264.015	37.593	0.05	0.00	0.44	0.06
Zlaté Moravce	13.185	1.810	38.198	160.677	0.03	0.00	0.07	0.31
Bytča	2.318	1.262	8.952	6.915	0.01	0.00	0.03	0.02
Čadca	5.183	67.552	45.793	160.654	0.01	0.09	0.06	0.21
Dolný Kubín	34.095	721.801	533.789	1 122.536	0.07	1.47	1.09	2.28
Kysucké Nové Mesto	10.110	0.830	46.320	27.420	0.06	0.00	0.27	0.16
Liptovský Mikuláš	34.203	3.028	242.837	325.220	0.03	0.00	0.18	0.24
Martin	23.745	414.964	276.968	109.353	0.03	0.56	0.38	0.15
Námestovo	15.882	13.681	20.833	61.982	0.02	0.02	0.03	0.09
Ružomberok	87.572	62.303	1 090.410	408.386	0.14	0.10	1.69	0.63
Turčianske Teplice	1.999	29.956	36.325	29.859	0.01	0.08	0.09	0.08
Tvrdošín	12.311	2.648	29.226	12.217	0.03	0.01	0.06	0.03
Žilina	121.756	197.035	279.741	140.663	0.15	0.24	0.34	0.17

***Tab. 6.22** Emissions [t] and Specific territorial emissions [t.km^{-2}] of basic pollutants released from large and medium stationary sources in 2018 at district level - part 2.*

District	Emissions [t]				Specific territorial emissions [t.km^{-2}]			
	TSP	SO_2	NO_2	CO	TSP	SO_2	NO_2	CO
Banská Bystrica	23.929	172.442	350.098	125.463	0.03	0.21	0.43	0.16
Banská Štiavnica	6.247	0.022	4.556	6.116	0.02	0.00	0.02	0.02
Brezno	27.075	26.692	227.202	271.475	0.02	0.02	0.18	0.21
Detva	28.228	0.450	89.076	65.673	0.06	0.00	0.20	0.15
Krupina	4.261	12.970	23.482	20.619	0.01	0.02	0.04	0.04
Lučenec	15.291	6.031	38.082	24.173	0.02	0.01	0.05	0.03
Poltár	4.381	6.149	29.101	70.204	0.01	0.01	0.06	0.15
Revúca	38.995	112.068	900.668	704.860	0.05	0.15	1.23	0.97
Rimavská Sobota	17.787	15.528	168.424	168.142	0.01	0.01	0.11	0.11
Veľký Krtíš	17.423	7.119	63.176	55.490	0.02	0.01	0.07	0.07
Zvolen	54.773	394.518	529.917	192.630	0.07	0.52	0.70	0.25
Žarnovica	20.796	424.863	198.351	138.757	0.05	1.00	0.47	0.33
Žiar nad Hronom	194.060	2 177.367	732.598	16 937.874	0.37	4.21	1.42	32.72
Bardejov	10.906	2.477	109.854	25.210	0.01	0.00	0.12	0.03
Humenné	7.263	23.751	50.779	31.958	0.01	0.03	0.07	0.04
Kežmarok	6.196	1.622	37.220	36.131	0.01	0.00	0.06	0.06
Levoča	3.918	4.353	8.500	27.588	0.01	0.01	0.02	0.07
Medzilaborce	6.158	0.006	9.710	2.054	0.01	0.00	0.02	0.00
Poprad	17.042	1.473	93.339	153.392	0.02	0.00	0.08	0.14
Prešov	29.262	5.534	153.272	508.551	0.03	0.01	0.16	0.54
Sabinov	3.068	0.359	14.166	10.664	0.01	0.00	0.03	0.02
Snina	12.761	0.207	33.032	65.928	0.02	0.00	0.04	0.08
Stará Ľubovňa	2.737	0.239	20.445	6.732	0.00	0.00	0.03	0.01
Stropkov	0.354	0.070	3.147	1.216	0.00	0.00	0.01	0.00
Svidník	3.858	2.014	7.961	7.177	0.01	0.00	0.01	0.01
Vranov nad Topľou	84.580	313.629	795.053	381.661	0.11	0.41	1.03	0.50
Gelnica	4.552	1.401	6.929	12.183	0.01	0.00	0.01	0.02
Košice	2 398.708	6 310.258	7 376.157	102 585.466	9.84	25.89	30.26	420.88
Košice-okolie	64.638	48.321	810.157	501.855	0.04	0.03	0.53	0.33
Michalovce	72.746	534.678	517.578	769.871	0.07	0.52	0.51	0.76
Rožňava	17.943	5.559	40.644	66.947	0.02	0.00	0.03	0.06
Sobrance	5.392	14.243	28.251	33.680	0.01	0.03	0.05	0.06
Spišská Nová Ves	10.969	24.430	86.244	1 093.978	0.02	0.04	0.15	1.86
Trebišov	12.415	10.612	73.299	39.847	0.01	0.01	0.07	0.04
SLOVAKIA	**4 753.393**	**18 852.361**	**26 177.098**	**142 084.865**	**0.10**	**0.38**	**0.53**	**2.90**

LIST OF ANNEXES