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AIR POLLUTION IN THE SLOVAK REPUBLIC

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FOREWORD

Air quality issue is a part of sophisticated system of relations in the Earth environment. Substances releasing from the sources of pollution undergo to atmospheric transport, scattering and chemical changes. Part of these substances deposits on the Earth ground and penetrates into the underground waters, soil and sediments, from where they can be released back into the ambient air. In any part of cycle they can enter into the chemical reactions. Ambient air reacts quickest on the different changes. In case the source of pollution fades, the ambient air becomes usually quickly clean. In the contrary the polluted substances persist longest in soil and sediments.

Obviously, the problems of environment are not possible to constrain by political boundaries. Since decades, the transboundary character of air pollution was acknowledged by the international communities, resulting in signing of several international conventions. In 1979 was signed one of the basic documents in this field, Convention on Long-range Transboundary Air Pollution – CLRTAP.

Among the alarming problems of environment which accompanied development of industry and growth of living level belonged smog episodes in industrial regions and acid rain originated mainly as a consequence of releasing oxides of sulphur and nitrogen from large energetic and industrial sources at burning of fossil fuel with high content of sulphur. Appearance of photochemical smog was also disquieting. On this situation reacted European and consequently Slovakian legislation. At the end of last century, the rigid legislative measures entered into force aiming at large and medium-sized sources of air pollution. The most significant consequence was outstanding decrease of sulphur dioxide emissions resulting in decrease of sulphur dioxide concentrations and mitigation of acid rain. At the territory of Slovakia, the concentrations of sulphur dioxide do not exceed the limit values set by legislation. Measures concerning road transport resulted in cutting down the share of lead additives in petrol up to the elimination of lead petrol production at all. Lead emissions from road transport decreased and lead concentrations in ambient air of Slovakia do not exceed limit value for the time being. Measures in road transport, including the strict emission limits also contributed to the decreasing of oxides of nitrogen concentrations.

Application of strict emission limits guided to: implementation of separators for solid pollutants at large and middle air pollution sources; change of fuel base; gradual implementation of best available techniques. Emissions of solid pollutants decreased significantly as compared to the last decades of the 20th century and their concentrations decreased in breathing zone, as well.

Upon the evolution of knowing the mechanisms how the solid pollutants affect the human health, the attention was shifted on the smaller size fractions. Present legislation contains the limit values for solid pollutants with aerodynamic diameter less than 10 and 2.5 micrometres (PM_{10}, $PM_{2.5}$). These limit values are exceeded in Slovakia for the time being, similarly like in other European countries. However, the responsibility for high concentrations of solid pollutants in majority of regions was shifted from large industrial sources to the emissions released from burning of solid fuels to the households and emissions related road transport. With these sources are connected also high concentrations of further dangerous substance, benzo(a)pyrene, releasing into the atmosphere as a product of imperfect burning. Target value of benzo(a)pyrene is exceeded in more locations. Apart from the largest sources of benzo(a)pyrene – heating of households by solid fuels and traffic – in some locations contribute to its concentrations also industrial sources, such as coke production and thermal plants.

For air pollution sources are generally applied, the higher over the Earth are they located, the better their emissions are scattered. For example, high industrial chimneys in its vicinity usually contribute very little to the high concentrations of solid matter in breathing zone. However, these matters are transported on long-range distances and contribute to regional and transboundary transport of pollution. In such a way, they become a part of the so-called regional background, which shares significant part in total measured concentrations of solid matter. On the contrary, the effect of low chimneys becomes evident in their vicinity. By effective emission mitigation of low situated pollution sources, such are local heating and traffic, the significant decrease of PM and benzo(a)pyrene is possible to reach, predominantly in outstanding polluted regions, where these sources dominate. However, for full-area of ambient air quality improvement is necessary to think also on emissions from other sources.

Open problem remains also the question of tropospheric ozone, which is not emitted directly into the atmosphere, but originates by photochemical reactions of other substances, natural and anthropogenic, the so-called ozone precursors. Situation is complicated by the fact the precursors as well as tropospheric ozone undergo to the long-range transport in regional scale. Even though the emissions of anthropogenic ozone precursors decreased, the result is only decrease of concentrations during smog episodes. Within the last years, similarly like in other European countries of our geographical latitudes, the annual average concentrations are not changing significantly and reflect more extent of photochemical activity throughout the summer time.

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.

INTRODUCTION

Ambient air quality in general is defined by the presence of pollutants in the atmosphere. Base point of origin for their assessment in Slovakia is measurement of pollutant concentrations, which is performed by the Slovak Hydrometeorological Institute (SHMÚ) at the stations of National monitoring network of air quality (NMSKO). Its part are also four stations of Cooperative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe (EMEP). For full-area air quality assessment in Slovakia are used also methods of mathematical modelling apart from measurements. Criteria for air quality assessment are set in Regulation of Ministry of Environment of the Slovak Republic on ambient air quality No. 244/2016 Coll. of Acts in wording the Regulation No. 296/2017 Coll. of Acts.

In following text will often appear two basic expressions – emissions and air quality

Under the expression emission is perceived each direct or indirect releasing of pollutant into the ambient air. It is introduced in volume units within the certain period, e.g. in tons per year. Chapter 6 is dedicated to the emissions of pollutants into the ambient air.

Air quality is characterized by the concentrations of pollutants (in older literature is sometimes used the expression imissions), expressed e.g. by weight mass of pollutant per one cubic meter of air. Their value is determined by measurements in breathing zone (monitoring stations of air quality), or it is calculated by the support of mathematical modelling. Chapter **5** is dedicated to the assessment of air quality upon the base of measurements.

Mathematical model connects causes with consequences upon the base of mathematical relationships describing physical and chemical processes in the atmosphere. Geographical distribution of emissions and meteorological data are input data for model. Spatial distribution of pollutant concentrations is output of model. Methods used at mathematical modelling of air quality and their results are described in Chapter **4**.

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 chimneys 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 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 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 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 $m.s^{-1}$. 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 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

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 Regulation No. 296/2017 Coll. of Acts), 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 Regulation No. 296/2017 Coll. of Acts) and is published on the SHMÚ webpage.

1.1.1 Allocation of the territory into zones and agglomerations 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 Košice)

Zones: Banská Bystrica region (territory of region), Bratislava region (territory of region apart from territory of capital of the Slovak Republic, Bratislava), Košice region (territory of region apart from territory of city Košice), Nitra region (territory of region), Prešov region (territory of region), Trenčín region (territory of region), Trnava region (territory of region) and Žilina region (territory of region).

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

- **BRATISLAVA AGGLOMERATION**

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.

KOŠICE AGLOMERATION

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 interferes 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 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 city)

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 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 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.

[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*

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.

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.

[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*

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 Tetras, West Tetras and Belianske Tatras, Skorušinské vrchy (hills), Oravské Beskydy, Oravská Magura, Oravská vrchovina (uplands), Chočské vrchy (hills), Krivánska Fatra, Kysucké Beskydy, Kysucká vrchovina (uplands) and Javorník, in south part the Low Tatras, Veľká Fatra, Lúčanská Fatra a Strážovské vrchy (hills). 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, 2534 long distance lories 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].

[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*

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

ZONE PREŠOV REGION

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

Air pollution sources in zone Prešov region

Dominant source of air pollution in Prešov region is household heating, mainly in smaller districts of mountainous part of area, where the highest share of fuel wood is using as compared to the other districts of region. Further emission source is road transport. Upon the all-country traffic counting in 2015 is known the daily average 30 731 vehicles (4 025 long distance lorries and 26 528 passenger vehicles) – the most in region – passing via road No. 18 in Prešov district. Very frequented in this district is also road No. 3450 (23 597 vehicles, 3 009 long distance lorries and 20 518 passenger vehicles). For comparing – loaded highway D1 in region is lower, with maximum 16 560 vehicles (4 002 long distance lorries and 12 527 passenger vehicles) in Prešov district. The other among roads with heavy traffic – in Poprad district is road No. 3 080 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 city)

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 (hills). 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.

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

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 passenger vehicles) and road No. 3710 in district Trebišov with 9 328 vehicles (614 long distance lorries and 8 686 passenger vehicles) [10].

In **Tab. 1.1** are summarized data about the area and settlements of respective regions according to data accessible on pages of ŠÚ SR (Statistical Office of SR).

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

	Area [km^2]	**Number*** **of inhabitants**
Bratislava region	2 053	659 597
Trnava region	4 146	563 591
Trenčín region	4 502	585 883
Nitra region	6 344	676 672
Žilina region	6 809	691 368
Banská Bystrica region	9 454	647 874
Prešov region	8 973	825 022
Košice region	6 754	800 414

** Status to 31. 12. 2018* *Source: Statistical office of SR*

1.1.2 Allocation of the territory into zones and agglomerations 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 (territory of the Slovak Republic apart from the territory of the capital city of the Slovak Republic, Bratislava)

For the time being heavy metals As, Cd, Ni, Pb and Hg 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 – 2018, p. 52). 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.

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

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 – 2018, p. 48), 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, 2018). 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, mercury and ozone, the whole territory of SR without Bratislava was chosen for simplification and Bratislava was allocated as agglomeration.

1.2 THE LIST OF AIR QUALITY MANAGEMENT AREAS FOR YEAR 2018

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 exceeded 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 locality 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.

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 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.

Areas of air quality management in SR for 2018, proposed by SHMÚ upon the base of air quality assessment in zones and agglomerations in years 2015 – 2017, 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 2015 – 2017 (with respect to measurement results in previous years in case of not sufficient number of valid measurements).*

AGGLOMERATION Zone	Delimited air quality management area	Pollutant	Area [km²]	Number of inhabitants*
BRATISLAVA	Territory of capital of SR, Bratislava	PM_{10}, NO_2, BaP	368	432 863
KOŠICE Košice region	Territories of Košice city and municipalities Veľká Ida, Sokoľany, Bočiar	PM_{10}, BaP	296	244 890
Banská Bystrica region	Territory of Banská Bystrica city	PM_{10}, BaP	103	78 327
	Terittory of Jelšava city and municipaliies Lubeník, Chyžné, Magnezitovce, Mokrá Lúka, Revúcka Lehota	PM_{10}, $PM_{2.5}$	109	6 248
	Territory of Hnúšťa city and its parts Brádno, Hačava, Likier, Polom, municipality Rimavské Brezovo, Tisovec city and its part Rimavská Píla	PM_{10}	206	12 112
Košice region	Territory of Krompachy city	PM_{10}, BaP	23	8 763
Prešov region	Territory of Prešov city and Ľubotice municipality	PM_{10}, NO_2	79	92 160
Trenčín region	Territory of Prievidza city	BaP	43	46 408
	Territory of municipalities Bystričany, Zemianske Kostoľany, Kamenec pod Vtáčnikom, Čereňany and Nováky city	PM_{10}	114	11 279
	Territory of Trenčín city	PM_{10}	82	55 333
Trnava region	Territory of Trnava city	NO_2	72	65 207
Žilina region	Territory of Ružomberok city and Likavka municipality	PM_{10}	145	29 734
	Territory of Žilina city	PM_{10}, $PM_{2.5}$	80	80 810

** Status to 31. 12. 2018*

Remark: On monitoring station Bystričany, Rozvodňa SSE, the limit value for average 24-hour PM_{10} concentration was exceeded in years 2012 and 2013 and even though in years 2014 – 2017 the limit PM_{10} value on this monitoring station was not exceeded, in years 2014 – 2016 the number of valid measurements was not reached. Therefore the station Bystričany was proposed to let it as area of air pollution management and to be even enlarged about Nováky, Zemianske Kostoľany, Kamenec pod Vtáčnikom and Čereňany due to the similar emission sources (influence of the heating power station and household heating) as well as similar dispersion conditions.

In contrary, though on monitoring station Humenné, Nám. Slobody, the limit PM_{10} value was exceeded in 2017 (with 36 exceedances of annual average 24-hour concentration 50 $\mu g.m^{-3}$, while legislation allows 35 exceedances), the territory of city Humenné was not proposed to be included among the areas of air quality management, because the limit value exceedance was caused by construction activity, which is finished for the time being.

2 AIR QUALITY MONITORING NETWORK

Despite of the fact, the first air pollutant measurements were performed in the second half of the fifties in last century, systematic monitoring in our territory began 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 more times. Present version is implementation of EU legislation (directions of European parliament and Council 2008/50/EC on ambient air quality and cleaner air in Europe).

As the aim of monitoring is to characterize air quality as best as possible, taking into account human health protection, the structure of monitoring network was proposed in such a way as the individual stations characterize the extent of pollution in most loaded areas – in past those were mainly locations in vicinity of large industrial air pollution sources. These stations are also now a part of monitoring network, similarly as locations loaded by emissions from road transport. Plan of monitoring is gradually enlarging also on measurements in the 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 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 are “covered” by the influence of 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 and at present it comprises continual measurements by automatic instruments and manual measurements based on the sampling and chemical analysis in Testing laboratory of SHMÚ. Manual monitoring cover air measurements of heavy metal concentrations, volatile organic compounds VOC and polycyclic aromatic hydrocarbons – PAH and also air quality monitoring and analysis 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 2018 is presented in **Fig. 2.1**.

Detailed list of monitoring instruments and methods used for individual stations is in Annex A – Measurement stations of monitoring air quality networks – 2018

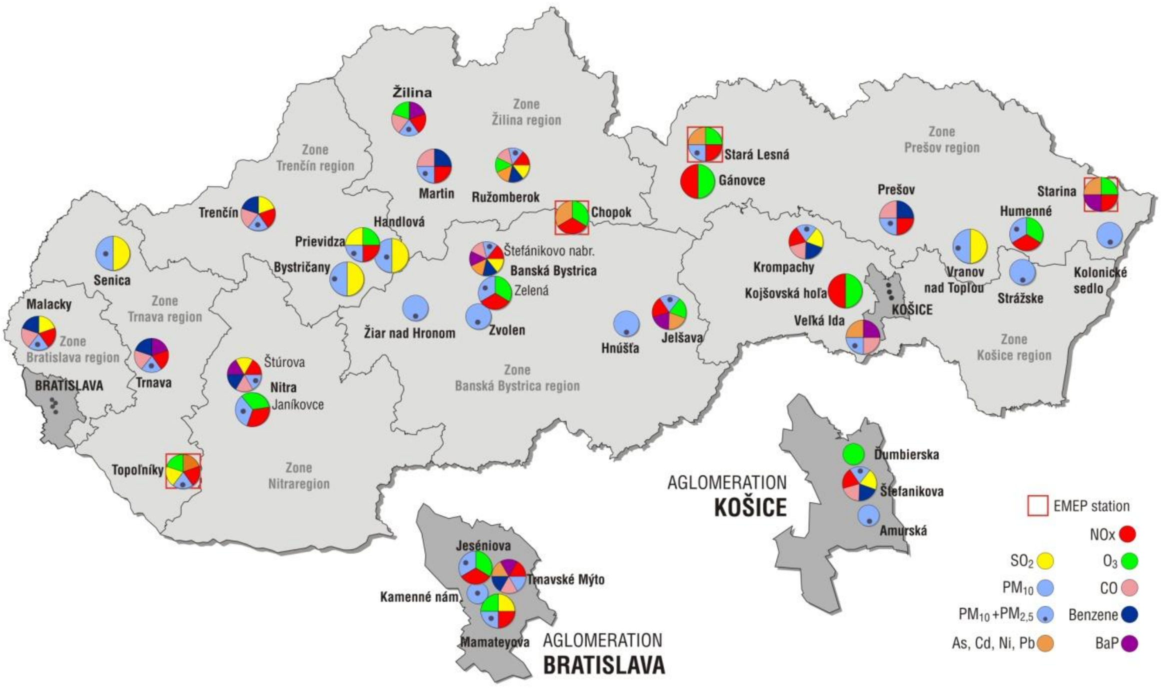
The UN ECE Convention on Long Range Transboundary Air Pollution (CLRTAP) was signed in Geneva in 1979. In frame of Convention was signed eight protocols until now. The first one among them was Protocol on Long-term Financing of the Co-operative Programme for Monitoring and Evaluation of the Long-range 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 more than 200 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) and persistent organic pollutants (POPs) have been included into the measurement programme.

Fig. 2.1 *National air quality monitoring network in year 2018.*



Tab. 2.1 contains the list of air quality monitoring stations, which do belong into the monitoring network of NMSKO, introduce 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, background/regional), which the respective station monitor.

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, Štefánik. 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, Mierove 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 – countryside (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 Testing laboratory of SHMÚ analyses heavy metals and polycyclic aromatic hydrocarbon. 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 – 2018.

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
	Bratislava, Jeséniova	x	x	x		x				
	Bratislava, Mamateyova	x	x	x	x	x				
	Together 4 stations	4	3	3	1	2	1	1	1	1
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				
	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	2
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		
	Together 4 stations	3	3	2	1	1	2	1	1	1
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				
	Gánovce, Meteo. st.			x		x				
	Prešov, Arm. gen. L. Svobodu	x	x	x			x	x		
	Starina, Vodná nádrž, EMEP			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		1
Trenčín region	Prievidza, Malonecpalská	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		
Trnava region	Topoľníky, Aszód, EMEP	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
Žilina region	Chopok, EMEP			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	1	1
NMSKO altogether 38 monitoring stations		33	32	25	14	16	13	11	5	8

Air quality monitoring programme on EMEP stations in year 2018 is listed in **Tab. 2.3**. Ozone is measured continuously. Sampling interval for PM_{10}/TSP and heavy metals is one week, 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, nitric acid, chlorides, and ammonium and alkali ions) is analysed from samples collected on EMEP stations according to monitoring programme listed in **Tab. 2.4**, either upon daily base (Chopok, Starina) or weekly (Topoľníky, Stará Lesná). Results of analysis 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 analysis are therefore longer (one month apart from 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 performed on Chopok, 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 14 stations. Minimum required extent of monitoring[11] was fulfilled. Sulphur dioxide monitoring was secured on all 14 stations continuously by reference method. Required number of valid measured data (90%) was reached on 13 monitoring stations. (Note: Percentage of valid measurements was 86% on AMS Prievidza, Malonecpalská and failure of measurement was caused by breakdown of analyser).

- **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 instrument 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 32 stations. Minimum required extent of monitoring 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 31 monitoring stations. (Note: failure of measurement on AMS Trnava, Kollárova was caused by technical breakdown of analyser).

- **Carbon monoxide CO**

This pollutant was monitored on 13 monitoring stations. Minimum required extent of monitoring[1] was fulfilled. CO monitoring was secured on 13 stations, continuously by reference method. Required number of valid measured data (90%) was reached on 12 monitoring stations. (Note: failure of measurement on AMS Ružomberok, Riadok was caused by technical breakdown). 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[1] was fulfilled. Ozone monitoring was secured on all 16 stations, continuously by reference method. Required number of valid measured data (90%) was reached on 14 monitoring stations. (Note: failure of measurement on AMS Gánovce, Meteorological station and AMS Stará Lesná AÚ SAV, EMEP was caused by technical breakdown).

- **Benzene**

Benzene was monitored on 11 monitoring stations. Minimum required extent of monitoring[1] 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.

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[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 analysis are collected on nitrocellulose filter each second day during 24 hours and consequently are analysed in Testing laboratory of SHMÚ by the ICP MS (inducted coupled plasma mass spectrometer). In 2018 the samples for heavy metal analysis (Pb, As, Cd, Ni) were collected on one suburban, four urban and four EMEP stations (Pb, As, Cd, Ni, Cr, Zn, Cu).

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

  In 2018 the benzo(a)pyrene monitoring was provided on eight monitoring stations. Collection of samples was realized on quartz filter each third day 24 hours. Samples are analysed after extraction in Testing laboratory of SHMÚ by the method of GC MS (gas chromatography mass spectrometer).

- **VOC**

  Volatile organic compounds $C_2 – C_7$ or the so called light hydrocarbons began to be sampled on station Starina in autumn in 1994. Starina is one of 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.

- **Air quality monitoring on EMEP stations**

  Air quality measurements were realized on four EMEP monitoring stations in coincidence with EMEP monitoring strategy (**Tab. 2.3**) according to approved monitoring programme.

- **Atmospheric precipitation monitoring on EMEP stations**

  Precipitation quality measurements were realized on four EMEP monitoring stations in coincidence with EMEP monitoring strategy (**Tab. 2.4**) according to 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. VZZO data from monitoring stations, which passed through function tests (**Tab. 2.5**) serve as supplementing data to the measurements from NMSKO network for the air quality assessment in cases, the data were gained by 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
Type of station: B – background, I – industrial

3 AIR QUALITY ASSESSMENT IN AGGLOMERATIONS AND ZONES OF SLOVAKIA

3.1 INTRODUCTION

Problems concerning environment accompanied technological progress of mankind since 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 as well as in European legislation, implemented consequently into the legislation of SR.

Air quality assessment according to 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** process the results of measurements from monitoring stations with monitoring programme EMEP according to limit values for vegetation protection. Programme EMEP comprises also atmospheric precipitation quality analysis.

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 – later only Air act) is considered for good, if the air pollution level is lower than limit value or target value.

Limit value is (in coincidence with § 5 section 5 of Air act) air pollution level determined upon the base of scientific knowledge with 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 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 accidence of warning threshold is necessary to issue the warning in front of the serious smog situation. Warning thresholds are determined by 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 knowledge, 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 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 limit values for human health protection and critical levels for vegetation protection, upper and low limits for ambient air pollution level assessment of SO_2, NO_2, NO_X, PM_{10}, $PM_{2.5}$, Pb, CO and benzene. **Tab. 3.2** presents 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	(-)
Benzén	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 2018.*

AGGLOMERATION Zone	Pollutant	SO_2	NO_2	PM_{10}	$PM_{2.5}$	CO	Benzene	O_3
BRATISLAVA	Bratislava, Kamenné nám.			100	98			
	Bratislava, Trnavské mýto		99	99		100	99	
	Bratislava, Jeséniova		97	98	98			94
	Bratislava, Mamateyova	95	96	99	98			95
KOŠICE	Košice, Štefánikova	99	96	99	99	98	99	
	Košice, Amurská			96	96			
	Košice, Dumbierska							100
Banská Bystrica region	Banská Bystrica, Štefánik. nábr.	94	96	99	99	96	99	
	Banská Bystrica, Zelená		95	98	97			91
	Jelšava, Jesenského		98	97	97			93
	Hnúšťa, Hlavná			97	97			
	Zvolen, J. Alexyho			99	99			
	Žiar n/H, Jilemnického			99	99			
Bratislava region	Malacky, Mierove nám.	98	96	98	98	99	99	
Košice region	Kojšovská hola		97					95
	Veľká Ida, Letná			98	98	96		
	Strážske, Mierová			99	98			
	Krompachy, SNP	96	98	99	98	98	99	
Nitra region	Nitra, Janíkovce		98	98	98			95
	Nitra, Štúrova	97	97	96	91	96	98	
Prešov region	Gánovce, Meteo. st.		98					89
	Humenné, Nám. Slobody		98	99	99			93
	Prešov, Arm. gen. L. Svobodu		98	99	99	95	99	
	Vranov n/T, M. R. Štefánika	97		99	99			
	Stará Lesná, AÚ SAV, EMEP		98	99	99			86
	Starina, Vodná nádrž, EMEP		96					92
	Kolonické sedlo, Hvezdáreň			98	98			
Trenčín region	Prievidza, Malonecpalská	85	96	99	98			93
	Bystričany, Rozvodňa SSE	94		99	99			
	Handlová, Morovianska cesta	95		99	99			
	Trenčín, Hasičská	98	98	99	99	94	99	
Trnava region	Senica, Hviezdoslavova	98		98	98			
	Trnava, Kollárova		99	99	89	98	99	
	Topoľníky, Aszód, EMEP	93	97	96	96			93
Žilina region	Chopok, EMEP		95					93
	Martin, Jesenského		95	98	98	95	97	
	Ružomberok, Riadok	93	96	94	97	89	97	91
	Žilina, Obežná		96	99	99	95		92

** ≥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 2018 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 thresholds exceedances – 2018.

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.					19	26	19				
	Bratislava, Trnavské mýto			0	**41**	19	29		1 286	1.4		0
	Bratislava, Jeséniova			0	12	20	24	16				0
	Bratislava, Mamateyova	0	0	0	22	21	26	17			0	0
KOŠICE	Košice, Štefánikova	0	0	0	28	**44**	33	20	1 834	0.8	0	0
	Košice, Amurská					9	24	15				
Banská Bystrica region	Banská Bystrica, Štefánik.nábr.	0	0	0	34	**39**	30	20	1453	1.2	0	0
	Banská Bystrica, Zelená			0	10	11	21	14				0
	Jelšava, Jesenského			0	10	**74**	36	24				0
	Hnúšťa, Hlavná					24	26	19				
	Zvolen, J. Alexyho					8	20	16				
	Žiar n/H, Jilemnického					7	19	16				
Bratislava region	Malacky, Mierové nám.	0	0	0	27	21	27	18	976	1.9	0	0
Košice region	Kojšovská hola			0	3							0
	Veľká Ida, Letná					**63**	38	24	2 246			
	Strážske, Mierová					15	25	19				
	Krompachy, SNP	0	0	0	18	19	24	19	1 884	2.7	0	0
Nitra region	Nitra, Janíkovce			0	11	13	24	18				0
	Nitra, Štúrova	0	0	0	34	19	28	16	1 457	0.7	0	0
Prešov region	Gánovce, Meteo. st.			0	9							0
	Humenné, Nám. slobody			0	9	6	22	19				0
	Prešov, Arm. gen. L. Svobodu			0	**41**	32	30	20	1 421	1.4		0
	Vranov n/T, M. R. Štefánika	0	0			9	23	19			0	
	Stará Lesná, AÚ SAV, EMEP			0	4	1	15	12				0
	Starina, Vodná nádrž, EMEP			0	3							0
	Kolonické sedlo, Hvezdáreň					0	18	10				
Trenčín region	Prievidza, Malonecpalská	0	0	0	16	11	23	18			0	0
	Bystričany, Rozvodňa SSE	**2**	0			13	23	17			0	
	Handlová, Morovianska cesta	0	0			6	22	16			0	
	Trenčín, Hasičská	0	0	0	27	**37**	29	20	1 196	1.5	0	0
Trnava region	Senica, Hviezdoslavova	0	0			18	27	16			0	
	Trnava, Kollárova			0	35	27	29	20	1 423	1.6		0
	Topoľníky, Aszód, EMEP	0	0	0	7	20	26	18			0	0
Žilina region	Chopok, EMEP			0	2							0
	Martin, Jesenského			0	26	33	28	18	1 634	1.0		0
	Ružomberok, Riadok	0	0	0	20	35	27	21	2 220	1.2	0	0
	Žilina, Obežná			0	25	29	27	22	1 591			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) – 2018.

			As	Cd	Ni	Pb
AGGLOMERATION Zone	Pollutant	[ng.m-3]	**As**	**Cd**	**Ni**	**Pb**
	Target value	[ng.m-3]	6.0	5	20	-
	Limit value	[ng.m-3]	-	-	-	500
	Upper limit for assessment	[ng.m-3]	3.6	3	14	350
	Low limit for assessment	[ng.m-3]	2.4	2	10	250
BRATISLAVA	Bratislava, Trnavské mýto		0.5	0.5	2.1	7.2
Slovakia	Banská Bystrica, Štefánik. náb.		0.5	0.5	1.1	9.6
	Jelšava, Jesenského		1.3	0.6	0.2	15.4
	Ružomberok, Riadok		0.4	0.2	0.9	6.5
	Velká Ida, Letná		0.7	0.7	1.6	163.9

In **Tab. 3.6** are quoted annual average concentrations of benzo(a)pyrene (BaP) in air according to measurements in years 2014 – 2018. Monitoring of BaP began on EMEP station Starina in year 2018, and covered November and December. Average value calculated from the whole year measurements would be lower than average concentration from last two months. In warm half of year the BaP concentrations pretend only split of values measured in winter also in background stations. Upon the above written is possible to deduce, that annual average value on Starina station not exceeded target BaP value. Measurement of BaP in Žilina station, Obežná covered the cool half of year (January – March, November – December). Taking into account the high measured values, also by including the low summer values on this station, the annual BaP average concentration exceeded the target value. Measurements of BaP on station Trnava, Kollárova were performed in period August – December and on monitoring station Bratislava, Trnavské mýto the BaP was monitored in period January – February and July – December. Therefore is possible, that the annual average concentrations would not exceed the target BaP value on stations Trnava, Kollárova and Bratislava, Trnavské mýto at the whole year of measurements.

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

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

Limit value exceedance is marked by red colour

Occurrence and period of pollution duration at the level of warning thresholds for SO_2 during last 6 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 this period.

Tab. 3.7 *Assessment of air pollution by SO_2 according to the occurrence and duration of warning threshold exceedance within the years 2013 – 2018 on station Bystričany, Rozvodňa SSE.*

Year	2013	2014	2015	2016	2017	2018
Number of warning threshold exceedances	2	0	0	0	0	0
Duration in hours	7	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 Regulation of MoE SR No. 296/2017 Coll. of Acts, 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 air pollution development and upon the base of meteorological forecast is not reasonable to assume the decreasing of concentration 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 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 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}.*

Station	Duration of exceedance [h]		Station	Duration of exceedance [h]	
	information threshold	warning threshold		information threshold	warning threshold
Banská Bystrica, Štefánik. náb.	41	3	Prešov, Arm. gen. L. Svobodu	85	0
Bratislava, Jeséniova	10	0	Prievidza, Malonecpalská	9	0
Bratislava, Mamateyova	3	0	Ružomberok, Riadok	97	6
Hnúšťa, Hlavná	39	17	Senica, Hviezdoslavova	8	0
Jelšava, Jesenského	206	6	Topoľníky, Aszód, EMEP	1	0
Košice, Štefánikova	56	14	Trenčín, Hasičská	17	0
Krompachy, SNP	12	0	Trnava, Kollárova	15	0
Malacky, Mierové nám.	9	0	Veľká Ida, Letná	65	0
Martin, Jesenského	98	0	Žilina, Obežná	38	0
Nitra, Štúrova	13	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 exceedance appears at least over three years from last five years.

In case, the less than five years data are at disposal, 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 Regulation of MoE SR No. 296/2017 Coll. of Acts). Classification of monitoring stations according the upper and low limits for assessment are 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 2014 and 2018.*

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
	Bratislava, Jeséniova						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, Štefánik. 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 2014 – 2018.*

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	
Bratislava	Banská Bystrica, Štefánikovo nábr.			x			x			x			x	x		
	Veľká Ida, Letná			x			x			x			x	x		
	Krompachy, SNP						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		

In **Tab. 3.11** are listed annual average concentrations of tropospheric ozone in years 2008 – 2018 as compared to photochemical extraordinary active year 2003.

Tab. 3.11 *Annual average concentrations of surface ozone (μg.m^{-3}) in years 2003, 2008 – 2018.*

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

≥ 90% requested valid data

Regulation of MoE SR No. 244/2016 Coll. of Acts on air quality in wording of Regulation No. 296/2017 Coll. of Acts 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 since 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	2016	2017	2018	Average 2016 – 18
Bratislava, Jeséniova	11	38	54	**34**
Bratislava, Mamateyova	6	22	33	20
Košice, Ďumbierska	8	10	16	11
Banská Bystrica, Zelená	2	17	20	13
Jelšava, Jesenského	9	11	11	10
Kojšovská hoľa	20	23	41	**28**
Nitra, Janíkovce	17	42	44	**34**
Humenné, Nám. Slobody	3	7	2	4
Stará Lesná, AÚ SAV, EMEP	4	3	33	13
Gánovce, Meteo. st.	0	0	4	1
Starina, Vodná nádrž, EMEP	5	3	7	5
Prievidza, Malonecpalská	*0	19	9	14
Topoľníky, Aszód, EMEP	7	8	6	7
Chopok, EMEP	28	*31	82	**55**
Žilina, Obežná	6	3	12	7
Ružomberok, Riadok	0	0	1	0

** 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}		
	2016	2017	2018	2016	2017	2018
Bratislava, Jeséniova	2	6	1	0	0	0
Bratislava, Mamateyova	0	6	2	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 four stations (i.e. on these stations the average of values AOT40 during years 2014 – 2018 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	2015	2016	2017	2018	Average 2014 – 2018
Bratislava, Jeséniova	28 166	13 612	25 042	25 103	**22 981**
Bratislava, Mamateyova	20 418	4 450	21 525	22 658	17 277
Košice, Ďumbierska	15 111	15 560	11 557	14 384	14 441
Banská Bystrica, Zelená	*2 526	*9 771	17 198	16 982	**20 289**
Jelšava, Jesenského	6 111	*14 597	12 756	6 660	8 509
Kojšovská hoľa	*4 098	18 259	13 056	18 706	16 674
Nitra, Janíkovce	21 800	18 684	25 925	25 036	**22 862**
Humenné, Nám. slobody	315	13 008	14 209	10 833	9 591
Stará Lesná, AÚ SAV, EMEP	9 441	13 151	13 197	22 437	13 021
Gánovce, Meteo. st.	*13 719	2 678	7 020	6 646	7 766
Starina, Vodná nádrž, EMEP	*10 528	10 235	12 154	13 116	11 768
Prievidza, Malonecpalská	*16 823	*5 835	16 167	15 889	16 614
Topoľníky, Aszód, EMEP	9 545	11 812	9 334	15 886	12 920
Chopok, EMEP	15 557	23 014	29 820	32 667	**23 746**
Žilina, Obežná	5 269	14 359	10 956	13 364	11 782
Ružomberok, Riadok		3 875	2 801	3 789	3 338

** 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 2018 from industrial stations of other operators – VZZO.*

AGLOMERATION Zone	Pollutant	Health protection						
		SO_2		NO_2		PM_{10}		CO
	Averaging period	1 h	24 h	1 h	1 rok	24 h	1 rok	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	20	11	24	1 341
	Bratislava, Vlčie Hrdlo (Slovnaft, a.s.)	1	0	0	20	15	24	886
KOŠICE	Košice, Poľov (U.S. Steel, s.r.o.)	0	0	0	9	14	23	4 382
	Košice, Haniska (U.S. Steel, s.r.o.)	0	0	0	16	9	17	4 971
Bratislava region	Rovinka (Slovnaft, a.s.)	0	0	0	15	8	24	1 247
Košice region	Veľká Ida (U.S. Steel, s.r.o.)	0	0	0	13	**57**	39	3 448
	Leles (Slovenské elektrárne, a.s.)	0	0	0	7			
Nitra region	Trnovec nad Váhom (Duslo, a.s.)	0	0	0	12	5	21	
Trenčín region	Oslany (Slovenské elektrárne, a.s.)	0	0	0	10			
Žilina region	Ružomberok (Mondi a.s. - Supra)					7	23	

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

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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 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 monitoring. Those data serve as added information about spatial distribution of 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 2018 the limit values for human health protection for SO_2, PM_{10}, $PM_{2.5}$, benzene and CO were not exceeded in agglomeration Bratislava. Limit value for annual average concentration of NO_2 was 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 2018. Limit values for annual average concentration of PM_{10} as well as SO_2, NO_2 for human health protection were not exceeded. Target value for $PM_{2.5}$ was not exceeded in agglomeration Košice in year 2018.

- **Zone Banská Bystrica region**

Daily average concentrations of PM_{10} exceeded limit value on two AMS: Jelšava, Jesenského and Banská Bystrica, Štefánikovo nábrežie. 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 (74 exceedances of daily limit value) is possible to assign mainly to 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 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 $PM_{2.5}$ were 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 63, in year 2018. 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 2018.

- **Zone Prešov region**

  Limit value for annual average concentration of NO_2 was exceeded in year 2018 on AMS Prešov, Arm. gen. L. Svobodu. Limit value of annual average concentration for PM_{10} was not exceeded in this zone, similarly as limit values for SO_2, benzene and CO and target value for $PM_{2.5}$.

- **Zone Trenčín region**

  Limit value for human health protection concerning daily average concentrations of PM_{10} was exceeded on AMS Trenčín, Hasičská in year 2018. 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 PM2.5 in zone Trnava region was not exceeded in year 2018.

- **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, Hg and O_3 in classification on agglomeration and zones

- **Agglomeration Bratislava**

  Limit value for Pb as well as target values for As, Cd, Ni, BaP were not exceeded in agglomeration Bratislava.

  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 station Bratislava, Jeséniova. In year 2018 the information threshold was exceeded on two stations: Bratislava, Jeséniova and Bratislava, Mamateyova. Warning threshold in agglomeration Bratislava was 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. Annual average concentrations of Hg are at level corresponding to background concentrations.

  Target value of surface ozone was exceeded in zone Slovakia on three monitoring stations: Nitra, Janíkovce; Kojšovská hoľa and Chopok in year 2018. Information and warning thresholds for surface ozone were not exceeded in any station of zone Slovakia.

  Target value for BaP was exceeded on stations Banská Bystrica, Štefánikovo nábrežie; Veľká Ida, Letná; Žilina, Obežná and Jelšava, Jesenského. The high concentrations of BaP in Veľká Ida are caused probably from bigger part of coke production in near metallurgical complex. Main air pollution source in Jelšava is the household heating by solid fuel. The high concentrations of BaP in stations Žilina and Banská Bystrica, Štefánikovo nábrežie are probably caused mostly by high intensity of road transport under the worsened dispersion conditions in cool half of year. Household heating is of smaller influence on these stations. BaP started to be measured on EMEP station Starina in year 2018, average concentration of BaP, measured in year 2018, exceeded target value, but in annual average, when low concentrations from summer months are included into calculations (BaP concentrations in summer are only fraction of winter values), the target value would not be exceeded.

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

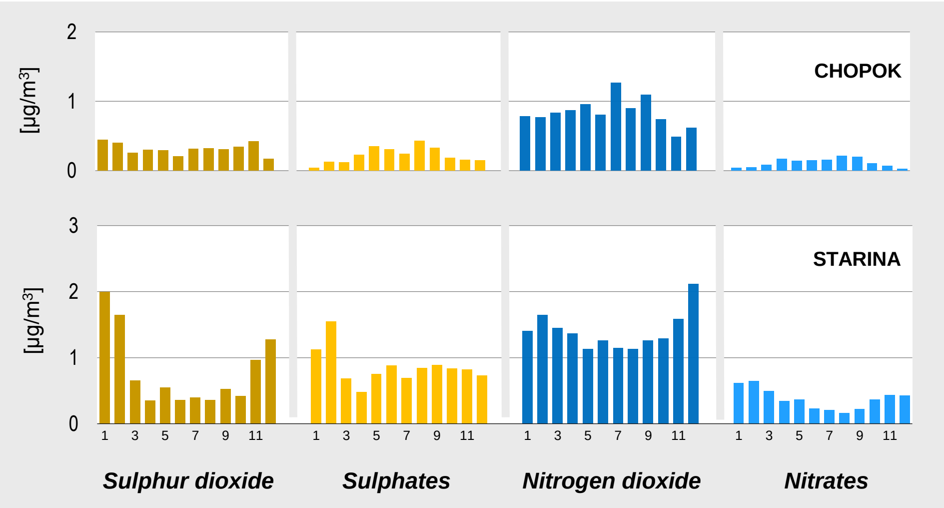
- **Sulphur dioxide, sulphates**

In year 2018 the regional level of sulphur dioxide concentrations recalculated on sulphur was 0.31 µg.m^{-3} on the Chopok station and 0.79 µg.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 Regulation No. 296/2017 Coll. of Acts, the critical value for protection of vegetation is 20 µg SO_2.m^{-3} in calendar year and winter season. This value was exceeded neither at the calendar year (Chopok 0.63 µg SO_2.m^{-3} and Starina 1.58 µg SO_2.m^{-3}), nor in winter season (Chopok 0.6 µg SO_2.m^{-3} and Starina 2.8 µg SO_2.m^{-3}). Annual average concentration of sulphates, recalculated in sulphur, was 0.22 µg.m^{-3} on the Chopok station and 0.85 µg.m^{-3} on the Starina station (**Tab. 3.16**, **Fig. 3.1**).

- **Nitrogen dioxide, nitrates**

Nitrogen dioxide concentrations recalculated on nitrogen on regional stations in year 2018 presented 0.84 µg.m^{-3} on the Chopok station and 1.40 µg.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 Regulation No. 296/2017 Coll. of Acts, the critical value for protection of vegetation is 30 µg NO_X.m^{-3} in calendar year. This level was not exceeded during the calendar year (Chopok 2 .77 µg NO_2.m^{-3} and Starina 4.62 µg 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 – 2018 (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 the measurements 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 2018 are listed in **Tab. 3.16**. Annual concentrations of ammonia represent 0.86 µgN.m^{-3} and ammonium ions 1.48 µgN.m^{-3}.

Tab. 3.16 *Annual average concentrations of pollutants [µg.m^{-3}] in air on EMEP stations – 2018.*

	SO_2	SO_4^{2-}	NO_2	NO_3^-	HNO_3	Cl^-	NH_3	NH_4^+	Na^+	K^+	Mg^{2+}	Ca^{2+}
Chopok	0.31	0.22	0.84	0.12	0.05	0.08	-	-	-	-	-	-
Starina	0.79	0.85	1.40	0.38	0.09	0.22	1.48	0.86	0.26	0.17	0.03	0.12

SO_2, SO_4^{2-} – recalculated on sulphur, NO_X, 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 2018 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 – 2018.*

	O_3	Pb	Cu	Cd	Ni	Cr	Zn	As
Chopok	95	2.33	0.65	0.06	0.26	0.40	4.94	0.12
Topoľníky	54	7.82	2.00	0.15	0.28	0.53	12.95	0.35
Starina	64	3.76	1.08	0.11	0.21	0.51	8.18	0.22
Stará Lesná	67	4.78	1.45	0.12	0.20	0.45	10.10	0.22

Ozone

The longest time series of ozone measurements is in Stará Lesná station, from 1992. The measurements of ozone in Topoľníky, Starina and Chopok began to be carried out later, in 1994. In 2018, the annual ozone average concentration at the Chopok station reached 95 µg.m^{-3}, in Topoľníky 54 µg.m^{-3}, in Stará Lesná 67 µg.m and in Starina 64 µg.m^{-3} (**Tab. 3.17**).

Volatile Organic Compounds

VOCs (Volatile Organic Compounds) C_2–C_7, (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. They are measured and assessed according to the EMEP method elaborated by CCC-NILU. Their concentrations ranged within one order of magnitude from the tenths of ppb up to several ppb. VOCs and NO_X are precursors of ozone formation. The 2018 annual VOC data are listed in **Tab. 3.18**.

Tab. 3.18 *Annual average of volatile organic compound concentrations [ppb] on EMEP station Starina – 2018.*

ethane	ethene	propane	propene	i-butane	n-butane	acetylene	trans-2-butene	1-butene
1.917	1.308	0.774	0.314	0.609	0.210	0.376	0.032	0.357
cis-2-butene	**2-metylbutane**	**n-pentane**	**1.3-butadiene**	**trans-2-pentene**	**1-pentene**	**i-hexane**	**n-hexane**	**isoprene**
0.029	0.129	0.323	0.073	0.011	0.022	0.033	0.115	0.044
n-heptane	**benzene**	**i-octane**	**n-octane**	**toluene**	**ethylbenzene**	**m+p-xylene**	**o-xylene**	
0.039	0.521	0.019	0.044	0.666	0.161	0.396	0.280	

3.4.2 Atmospheric precipitation

Quality of atmospheric precipitation is monitored apart from four EMEP stations also at the Bratislava, Koliba station, which serves as the comparison to the regional stations.

- **Major ions, pH, conductivity**

In 2018 the amount of precipitation recorded at background stations ranged between from 368 to 1418 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 5.26 – 5.58 (**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 sations the range 0.38 – 0.45 $mg.l^{-1}$ (**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 0.23 – 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 0,35 – 0,55 $mg.l^{-1}$ (**Tab. 3.19**).

Fig. 3.2 pH in atmospheric precipitation – Chopok.

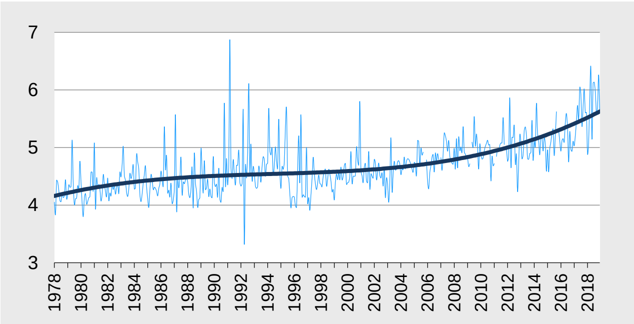
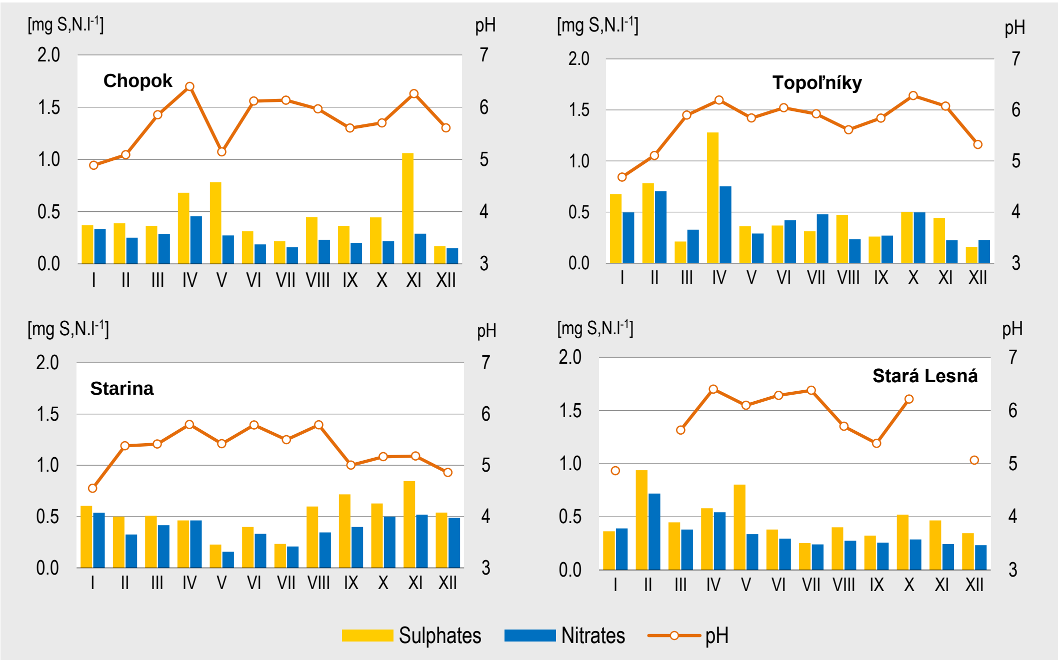


Fig. 3.3 Atmospheric precipitation – 2018.



Tab. 3.19 Annual weighted averages of pollutants in atmospheric precipitation – 2018.

	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	1 418	5.55	11.2	0.381	0.229	0.348	0.171	0.375	0.039	0.020	0.157
Topoľníky	513	5.54	14.3	0.431	0.370	0.546	0.190	0.236	0.045	0.049	0.483
Starina	368	5.26	13.7	0.454	0.351	0.374	0.237	0.605	0.145	0.041	0.294
Stará Lesná	622	5.58	12.7	0.437	0.314	0.401	0.041	0.448	0.059	0.039	0.284
Bratislava, Koliba	738	5.92	25.9	0.611	0.406	1.289	0.354	0.435	0.738	0.231	1.151

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, Koliba 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 2018 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, most distinctive at lead.

Tab. 3.20 Annual weighted averages of heavy metal concentrations in atmospheric precipitation – 2018.

	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	1 301	1.52	0.03	0.27	0.30	1.92	19.38	0.60
Topoľníky	408	0.43	0.00	0.09	0.06	0.74	37.69	0.80
Starina	631	3.03	0.02	0.23	0.42	2.01	6.50	3.41
Stará Lesná	621	0.68	0.01	0.09	0.07	1.29	12.25	1.53
Bratislava, Koliba	776	2.53	0.02	0.26	0.14	4.45	21.13	1.39

3.5 SUMMARY

SO_2

Limit values for average hourly and average daily SO_2 were not exceeded in any agglomeration or zone year 2018. 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 2018 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 exceeded in year 2018 on stations Bratislava, Trnavské mýto and Prešov, Arm. gen. L. Svobodu. Exceeding of limit value for human health protection for hourly concentrations was not recorded on any monitoring station. In year 2018 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 exceeded on any of EMEP stations in year 2018. Values were deeply below 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 2018. Exceedances of limit value for human health protection for 24 hour concentrations were recorded on five AMS: Košice, Štefánikova; Banská Bystrica, Štefánikovo nábrežie; Jelšava, Jesenského; Veľká Ida, Letná and Trenčín, Hasičská.

Upon the base of exceeding of information resp. warning threshold, the announcements were emit 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 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 2018.

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 continuous middle concentration averaging for all sampling places in last three years. According to Annex No. 4 to Regulation No. 244/2016 Coll. of Acts, in wording of Regulation No. 296/2017 Coll. of Acts, in year 2017 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 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
IPE [µg.m^{-3}]	23.8	24.6	24.0	23.2	20.7	19.1	18.4	18.3	18.1

- **CO**

CO limit value was not exceeded on any of monitoring stations in Slovakia in the year 2018 and level of air pollution during previous period of years 2012 – 2018 is below low assessment limit of this level.

- **Benzene**

The major level of benzene was measured on station Krompachy, SNP in year 2018. 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 exceeded in year 2018 on stations Bratislava, Jeséniova and Bratislava, Mamateyova. Warning threshold was not exceeded.

- **Pb, As, Ni, Cd**

  Neither limit nor target values were exceeded in year 2018.

  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 stations Veľká Ida, Letná; Banská Bystrica, Štefánikovo nábrežie; Žilina, Obežná and Jelšava, Jesenského exceeded 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 AIR QUALITY MODELLING

The procedure and the criteria for air quality assessment is given by Act No. 137/2010 Coll. in full compliance with EU legislation. According to its rules, mathematical modelling can be used for air quality assessment as a supplementary method. The basis for the air quality assessment is data measured at the National air quality monitoring network.

Validated emissions from large and medium air pollution sources in 2018 will be available in the last quarter of 2019. Waiting for these data would mean a year-long delay in calculations. Analyses carried out in recent years – after refining emission flows from large and medium-sized sources – have shown only minor differences with the results of the calculations using preliminary emission values from this category of sources. Therefore, in order to ensure that the overall assessment of air quality in Slovakia is kept up to date, non-validated NEIS emission data for the year under review will be used, i.e. year 2018.

CEMOD air quality dispersion model is used for the spatial assessment of SO_2, NO_2, NO_X, CO and benzene, while IDW-A interpolation scheme was used for ozone, PM_{10} and $PM_{2.5}$.

4.1 BRIEF DESCRIPTION OF THE MODELS USED FOR THE AIR QUALITY ASSESSMENT

CEMOD air quality dispersion model

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 based on measurements of 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 installation height is calculated in accordance with the TA-Luft 2002 methodology.

The cited methodology is improved by a correction coefficient to take into account the density and structure of the urban areas (surface roughness) for mobile sources and for the stationary sources with an effective source height less than twice the mean build-up height. CEMOD requires hourly meteorological and emission input data. Model output contains hourly concentrations for each grid point which are used to calculate the eight-hour means, daily and annual concentrations and the respective percentiles corresponding to the hourly and daily limit exceedances.

Input data:

- **Geographic data,** e.g. computational domain, grid node coordinates and altitudes, altitude and coordinates of receptor points, structure of the urban areas, geometry of the selected street.
- **Emissions** from large and medium air pollution sources and the chimney parameters from NEIS database, road traffic intensities and emissions according to vehicles emission standards, velocities and road types.
- **Meteorological data** – hourly meteorological input data measured at the meteorological stations and output of the meteorological model.
- **Background concentrations** – measured data from the EMEP stations. This concentrations are used as long range air pollution.

Model output:

- Concentration of the pollutants in the regular grid and for the reference points (monitoring stations).
- Derived characteristics required by legislation (percentiles used instead of the number of daily or hourly exceedances).

When interpreting the results, it is necessary to keep in mind, that a spatial resolution of 1 km was used – model calculates concentrations in a regular grid with a node distance of 1 km.

- **Anisotropic inverse distance weighted interpolation scheme (IDW-A)**

The IDW-A interpolation scheme was used for those pollutants for which it is difficult or impossible to obtain usable input data for the CEMOD dispersion model. In the interpolation scheme, an environmental anisotropic factor taking into account the impact of orography on the dispersion of pollutants is implemented. The measured concentrations were used as input data for the calculation. Smoothing and exponent of the horizontal representativeness were defined for each input. Regionalization (spatial representativeness) of measurements was introduced. The measured concentrations were interpolated into the reference altitude by the empirically obtained formula – relation between the concentrations and the altitude based on the measurements of EMEP monitoring stations. The IDW-A interpolation scheme thus enables the 3D spatial distribution of the specific derived air pollution characteristics based on the measured data.

Input data:

- Measured and derived data from air quality monitoring stations.
- Anisotropy factors reflecting the impact of the orography on of pollutants dispersion at a given site.
- Attributes for each measuring point – significance of local air pollution sources, geographical parameters, urban areas, smoothing parameters.

Model output:

- Concentration of the pollutants in the regular grid.
- Derived characteristics required by legislation (moving means, AOT40, percentiles used instead of the number of daily or hourly exceedances).

4.2 MODELLING RESULTS

- **Sulphur dioxide – SO_2**

Air quality model CEMOD was used to obtain spatial countrywide distribution of the air quality indicators for SO_2. The model requires hourly emission rates and meteorological characteristics of atmospheric boundary layer. Annual emission rates and stack parameters (co-ordinates, height and diameter, flue gas exist speed and temperature) were obtained from the NEIS database.

Measurements on the EMEP regional stations are used as supplementary data for the spatial air quality assessment. Concentrations measured at the remaining air quality monitoring stations (AMS) are; used for the model validation.

Emissions – Since 1990-ties, SO_2 emissions have been decreasing in Slovakia. ENO (Slovenské elektrárne, Nováky) was responsible for the last significant decrease in 2016. ENO is one of the five dominant sources of air pollution in Slovakia, with the total emissions representing about ¾ of all SO_2 emissions of large and medium-sized sources in the country. Other significant sources are U.S. Steel Košice, Slovnaft Bratislava, Slovalco, Žiar nad Hronom and, to a lesser extent, Ferroenergy, Košice. Stack and vents are represented in the model as point sources. Small sources (mainly household heating) as well as medium and large sources with low emission fluxes are represented as area sources.

Database NEIS contains nearly 9 200 stacks with SO_2 emissions, however, the emissions of the most of them are rather low – less than 1 ton per year. That is why just the selected sources with higher emissions (356 stacks) were selected for the model simulation for the year 2018. The subset of the stacks used for the simulation represents 99.9% of the total SO_2 emissions.

Model results – A slight inter-annual increase of SO_2 concentrations was confirmed, which is in line with the increase in average annual concentrations at the NMSKO measurement stations. The most significant increase was recorded in the stations of Košice, Štefánikova; Malacky, Mierove nam. and Krompachy, SNP.

The complexity of the problem of air quality modelling using a dispersion model such as CEMOD is that it is not easy to capture the vertical profile of the wind speed which is particularly important for SO_2 where the dominant sources are large energy production and industrial sources with high stacks.

The highest values of measured hourly concentrations occurred in the localities influenced by major emission sources, but SO_2 did not exceed the lower limit for the assessment given by the legislation.

No exceedance of the limit value for the mean 24-hour SO_2 concentration occurred at any of the NMSKO monitoring network station in 2018.

However, hourly mean concentration value of 350 $\mu g.m^{-3}$ was exceeded twice at Bystričany, SSE monitoring station (out of 24 of exceedances per year is allowed by legislation).

The underestimation of hourly concentrations in the CEMOD outputs close to the ENO power plant and sources in Vranov nad Topľou is due to the different nature of the upper-air and surface winds. Due to the effective height of the stacks, the smoke plume of these sources is influenced by the upper-air rather than the surface wind entering the model calculations as a one of the input parameters.

Fig. 4.1 *Annual mean SO_2 [µg.m^{-3}] – 2018.*

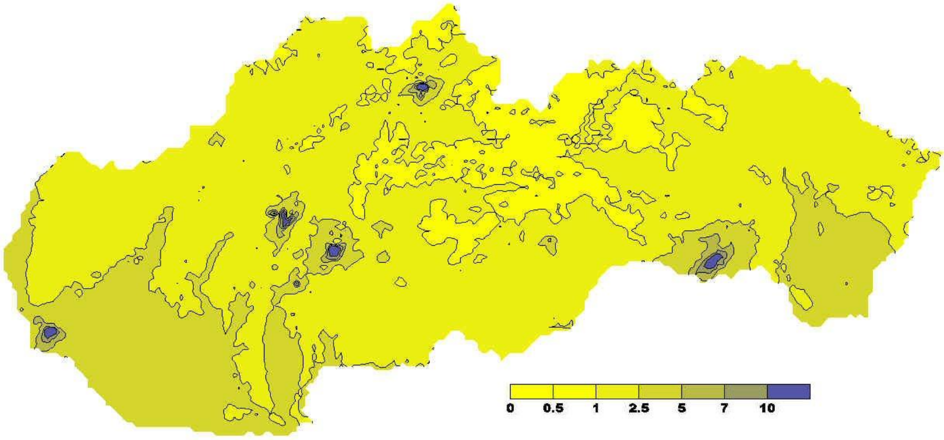


Fig. 4.2 *99,2nd percentile of daily mean SO_2 concentration [µg.m^{-3}] – 2018.*

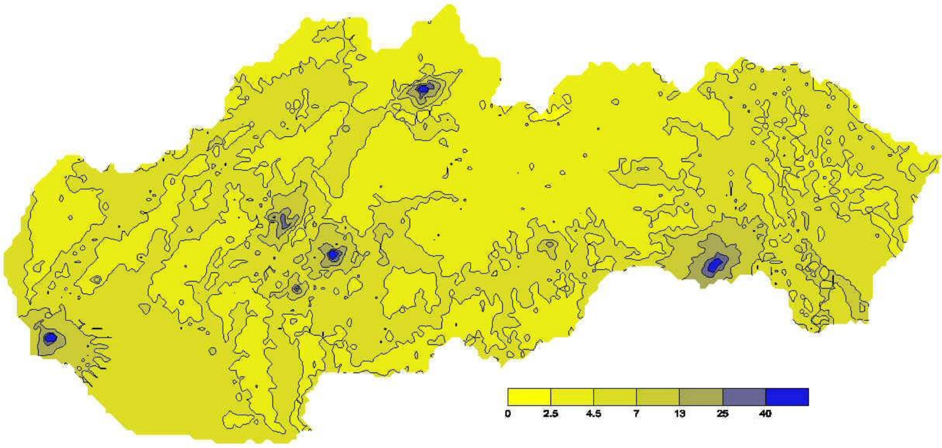
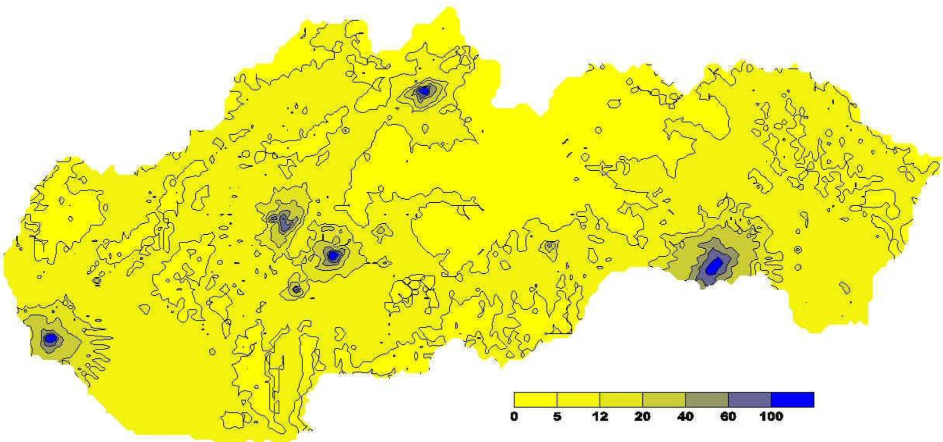


Fig. 4.3 *99,7th percentile of hourly mean SO_2 concentration [µg.m^{-3}] – 2018.*



From **Fig. 4.1**, **Fig. 4.2** and **Fig. 4.3** it is evident that the territory affected by higher SO_2 concentrations is related to the locations of the most important SO_2 emission sources. The location of dominant sources (ENO, U.S. Steel and Slovnaft) is evident from these three maps. Air quality modelling confirmed that the limit value for SO_2 was not exceeded in 2018. It was last exceeded in 2004 at Bystričany monitoring station.

Tab. 4.1 Measured (AMS) and modelled (CEMOD) air quality indicators for the sulphur dioxide (SO_2) – 2018.

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, Mamateyova	8.0	6.8	-15%	17	17	1%	31	42	37%
KOŠICE	Košice, Štefánikova	17.3	11.7	-32%	25	28	11%	41	69	70%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	6.2	5.9	-4%	11	14	30%	17	26	51%
Bratislava region	Malacky, Mierové nám.	11.2	7.9	-29%	21	21	1%	28	39	37%
Košice region	Krompachy, SNP	9.5	6.0	-37%	15	15	0%	20	31	53%
Nitra region	Nitra, Štúrova	9.1	9.2	2%	14	15	7%	18	28	53%
Prešov region	Vranov n/Topľou, M. R. Štefánika	8.0	7.2	-10%	15	21	36%	37	37	1%
Trenčín region	Prievidza, Malonecpalská*	6.5	6.6	2%	15	13	-16%	28	25	-9%
	Bystričany, Rozvodňa SSE	8.7	8.1	-7%	36	22	-39%	47	53	13%
	Handlová, Morovianska cesta	7.9	6.5	-18%	16	16	2%	25	38	50%
	Trenčín, Hasičská	6.1	5.3	-13%	11	10	-9%	17	18	7%
Trnava region	Senica, Hviezdoslavova	10.3	8.4	-19%	20	16	-19%	25	32	29%
Žilina region	Ružomberok, Riadok	6.6	5.7	-13%	12	13	7%	22	27	23%

** Percentage of valid data less than 90%* *Diff – difference*

Tab. 4.1 contains calculated and measured indicators for air quality assessment (99.2nd percentile corresponds to the limit value for 24-hour means and 99.7th percentile corresponds to the limit value for hourly means). It is obvious that the lower the measured value, the more difficult it is to achieve the required accuracy in calculations. This is particularly the case for the mean annual concentrations, where the absolute difference of 1 μg.m^{-3} represents a percentage of up to 15% (which is a common measurement uncertainty of air quality monitoring instruments), while a required model accuracy is 30%. For the mean daily and hourly values, the absolute value of the differences between the measured and modelled concentrations is relatively small.

The locations of high sulphur dioxide concentrations in recent years were, as expected, the areas near the town of Krompachy and ENO power plant close to Nováky.

Comparison of calculation results with measured values in **Tab. 4.1** points in part to the problem of small, unrecorded air pollution sources (residential heating systems) at the site. Until 2016, ENO power plant as the only point source had 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 residential heating by coal is influencing the air quality in Nováky.

Annual mean background concentrations measured at the EMEP monitoring stations were less than 1.6 μg.m^{-3}. Those values are lower than 8% of the limit value for the protection of the vegetation. Annual mean concentration of SO_2 on the Starina EMEP station slightly decreased in the 2018. We can therefore conclude that in the level of regional pollution (including transboundary transport) has not changed significantly but the decreasing industrial emissions are reflected at least in small improvements of the air quality.

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

Air quality model CEMOD was used to obtain spatial countrywide distribution of the air quality indicators for NO_2. The data preprocessing procedure is similar to SO_2. However, the model takes into account the oxidation of NO to NO_2 and is more input intensive. Concentrations measured at EMEP stations were used as supplementary data for the spatial distribution of the background concentrations. The model calibration is based on the measured values (receptor points - AMS - **Tab. 4.2**).

Emissions – Road transport is significant source of nitrogen oxides, representing about 40% of total NO_X emissions from all sectors. The input data on mobile sources, including the structure of road network and transport intensities, are particularly important for this reason.

In the process of input data preparing, the main road network with a total length of f 10 634 km was divided into 3 258 road sections and the corresponding emissions of passenger cars and trucks were calculated. For the calculation in receptor points (**Tab. 4.2**), local communications were included to complete the main road network. 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. In model calculations, fugitive emissions, parking places, fuel filling stations and other known local impacts were represented by area sources.

Annual emissions for large and medium point sources were obtained from the NEIS database, appropriate time profiles according to the source types were applied. Database NEIS contains nearly 9 850 stacks with NO_2 emissions, however, the emissions of the most of them are rather low – only 913 of them had annual emissions of higher than 1 t and only 61 stacks of more than 100 t. That is why just the selected sources with higher emissions (457 stacks) were selected for the model simulation for the year 2018. The subset of the stacks used for the simulation represents more than 90% of the total NO_2 emissions of the large and medium NO_2 emissions sources. Of this total, only four major sources (ENO, U.S. Steel, Mondi SCP and Slovnaft) emit more than 1000 tonnes of NO_2, **with 35% of total emissions of medium and large sources.**

In contrast to sulphur dioxide, emissions of nitrogen oxides is not a matter of several dominant large air pollution sources. The higher number of chimneys (vents) were included in model input compared to modelling CO or benzene. Local heating systems – **heating plants** – account for a larger part of the remaining share of emissions of medium and large air pollution sources. Small sources of air pollution (mainly domestic heating systems) emitted about 10% compared to emissions from medium and large sources. Of this amount, approximately 30% of the fuel wood is combusted.

Small sources (residential heating) and industrial point sources with low emission fluxes from the NEIS database, parking places and road segments with incomplete information on traffic intensities were represented by area sources. 60 such area sources were used in the calculations for the purpose of model calibration at receptor points (AMS stations) The results of the calculations at these points are mainly used to determine the influence of indirect effects (fugitive emissions, short-term economic activities, etc.).

Model results – In 2018, the limit value for the protection of human health for hourly mean concentrations was not exceeded at the monitoring stations. At AMS Bratislava, Trnavské Mýto and Prešov, Arm. gen. Ľ. Svobodu the limit value for the annual mean concentration was slightly exceeded (41 $\mu g.m^{-3}$ at both stations). Annual mean concentrations of nitrogen dioxide exceeded the upper limit for the assessment of air pollution only at three monitoring stations (Banská Bystrica, Štefánikovo nábr.; Nitra, Štúrova and Trnava, Kollárova). All of these AMS are located close to the roads with high traffic intensity. The highest hourly mean concentration was measured at the Bratislava, Trnavské mýto. However, the hourly upper limit for the assessment (140 $\mu g.m^{-3}$) was not exceeded.

In 2018, the values of nitrogen dioxide concentrations across the territory of Slovakia showed a more favourable state of air quality than in 2017. This is probably due to better conditions for dispersion of air pollutants and higher precipitation totals – this is confirmed by a slight decrease of background EMEP with lower altitude (Starina).

In the legislative, the mean annual critical level for NO_X for the protection of vegetation is given. No limit value of NO_X is set for the protection of human health. Model calculations of NO_X are only informative and serve only to verify the functionality of the CEMOD model. The measured data for NO_X are not given because the continuous measuring instruments in the NMSKO network are not intended for vegetation protection purposes.

Tab. 4.2 Measured (AMS) and modelled (CEMOD) air quality indicators for nitrogen dioxide (NO_2) – 2018.

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	41.4	39.0	-6%	120	154	29%
	Bratislava, Jeséniova	11.7	12.4	6%	58	41	-29%
	Bratislava, Mamateyova	21.9	21.2	-3%	88	79	-10%
KOŠICE	Košice, Štefánikova	28.0	26.5	-5%	103	100	-3%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	34.3	32.5	-5%	104	150	44%
	Banská Bystrica, Zelená	10.2	10.3	1%	54	51	-5%
	Jelšava, Jesenského	9.8	9.4	-4%	43	41	-4%
Bratislava region	Malacky, Mierové nám.	26.7	23.0	-14%	84	107	28%
Košice region	Krompachy, SNP	18.0	16.6	-8%	64	64	0%
Nitria region	Nitra, Janíkovce	11.3	11.4	1%	54	36	-33%
	Nitra, Štúrova	34.1	30.6	-10%	103	137	34%
Prešov region	Humenné, nám. slobody	9.5	11.2	18%	57	38	-33%
	Prešov, Arm. gen. L. Svobodu	40.6	37.8	-7%	100	151	52%
Trenčín region	Prievidza, Malonecpalská	16.3	16.5	1%	69	49	-29%
	Trenčín, Hasičská	26.7	29.5	10%	94	102	9%
Trnava region	Trnava, Kollárova	35.3	33.2	-6%	115	134	17%
Žilina region	Martin, Jesenského	25.7	25.4	-1%	78	86	10%
	Ružomberok, Riadok	20.0	18.6	-7%	83	80	-4%
	Žilina, Obežná	25.2	23.3	-8%	91	118	29%

Fig. 4.4 Annual mean NO_X concentration [μg.m^{-3}] – 2018.

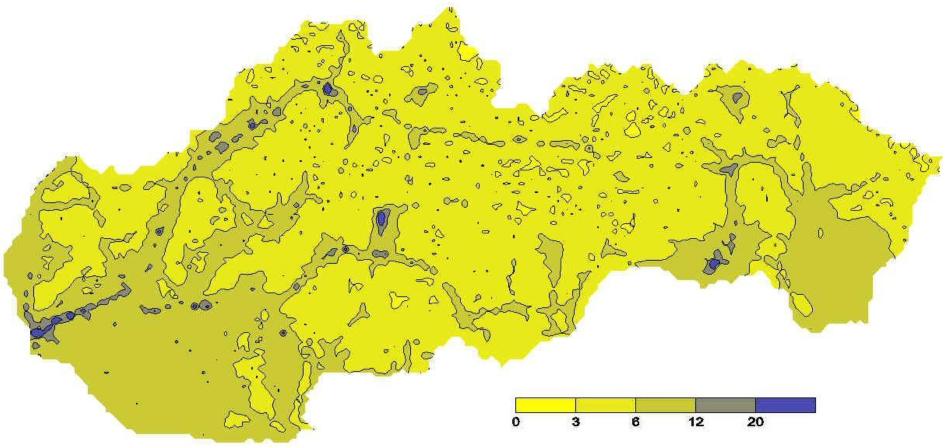


Fig. 4.5 Annual mean NO_2 concentration [μg.m^{-3}] – 2018.

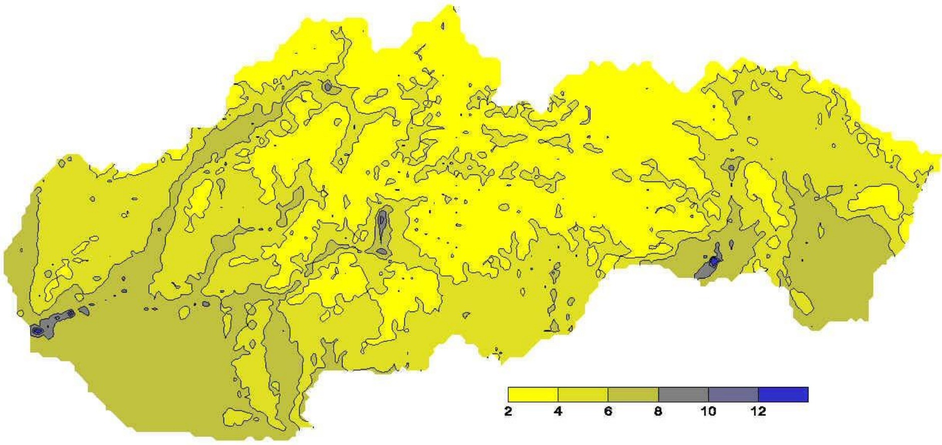


Fig. 4.6 *99.8th percentile of the hourly NO_2 concentrations [µg.m^{-3}] – 2018.*

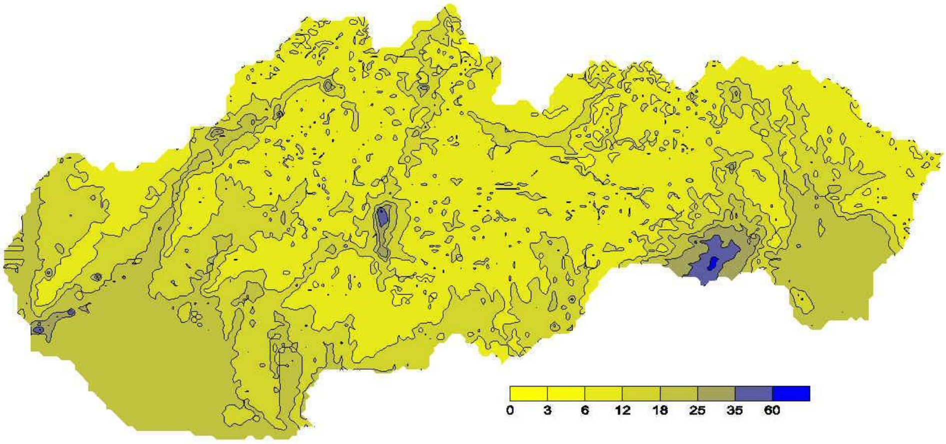


Fig. 4.4 – Fig. 4.6 illustrate the spatial distribution of mean annual concentrations of nitrogen dioxide as well as nitrogen oxides. In the case of nitrogen dioxide (Fig. 4.5, Fig. 4.6), the impact of mobile sources (i.e. the road network) is generally less pronounced due to the gradual transformation of the emitted nitric oxide into nitrogen dioxide (this transformation is a function of time), respectively, due to dispersion and advection as a function of distance. The result is a combination of the effects of the road transport, stationary sources and background concentrations. In the case of CO, the share of automobile transport is more significant – this is due to the fact that only a few dominant stationary air pollution sources are registered, the others are of little importance. The same applies to the mean hourly concentrations of nitrogen dioxide. In the case of NO_X in Fig. 4.4 (immediate chemical transformation of NO to NO_2) we can already see the lines of highways (similarly as it is possible to see in the case of CO)

The annual mean background concentration measured in 2018 at background EMEP stations is 4.6 µg.m^{-3} and less, which represents a slight decrease compared to 2017. The measured value is less than 20% of the limit value for vegetation protection .

Carbon monoxide – CO

Air quality model CEMOD was used to obtain spatial countrywide distribution of the air quality indicators of carbon monoxide. The same procedure for the input data processing was used as for NO_2, but the model calculated a maximum of 8 hour moving means per day.

The concentrations measured in the monitoring network were used to calibrate the model. In 2018, carbon monoxide was monitored at 13 stations of the NMSKO network.

Whereas carbon monoxide is one of the basic pollutants, it is necessary estimate its spatial countrywide distribution, although the limit values for CO are not exceeded in Slovakia.

Emissions – The emissions from road transport (mobile sources) as well as from industrial, energy and heat production stationary sources were used as the model input data. Mobile sources are responsible for about 10% of total carbon monoxide emissions in Slovakia, while emission from domestic heating is estimated to be over 40%. Emissions of large industrial, energy and heat production sources are higher.

The carbon monoxide emissions of mobile sources are more strongly dependent on the engine operating mode, than in the case nitrogen dioxide. Cold start, driving with a cold engine over short distances increases exhaust emissions from road transport, especially in the winter.

Similarly to the procedure with NO_2, emissions were calculated using the traffic intensities per vehicle type and road segments. In the case of trucks, slightly more pessimistic combination of emission factors was used compared to the European standards, taking into account the technical condition of vehicles in Slovakia.

Emissions of carbon monoxide from large and medium stationary sources were obtained from NEIS emission database, and similarly to the procedure of SO_2 and NO_2, only the stacks with higher emissions were used in the model simulation.

Of the total number nearly 9 800 stacks and vents with carbon monoxide emissions, 184 of them were included in the calculations. The subset of the stacks used for the simulation represents nearly 97% of the total carbon monoxide emissions. U.S. Steel Košice and Slovalco, Žiar nad Hronom together produce about 90% of the above emissions of large and medium sources. Another major source of carbon monoxide emissions is metallurgy and cement and lime production.

In the model simulation, stationary air pollution sources with low emission rates, parking places and road segments with incomplete information on the traffic intensities were represented by area sources. The fugitive emissions and other local effects were then represented by 29 area sources.

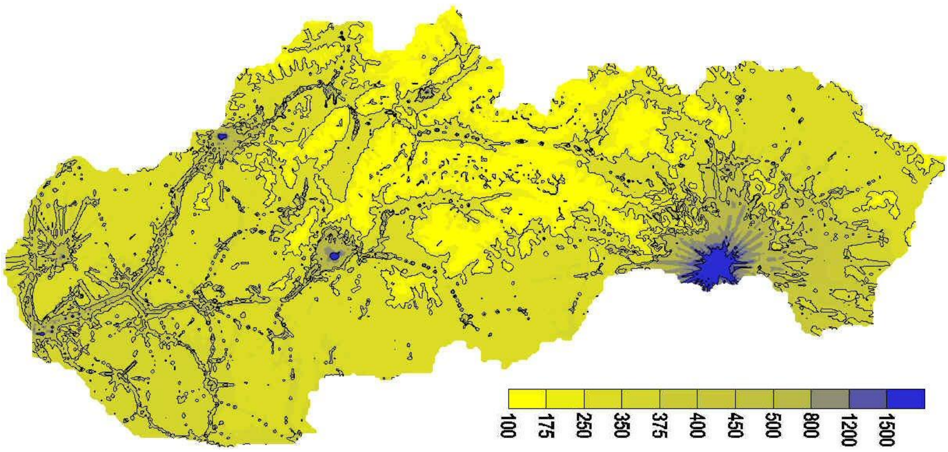
Model results – In 2018, the limit value for the protection of human health and the lower limit for the assessment for carbon monoxide were not exceeded. This pollutant has been unproblematic for several years. The results in 2018 confirm the trend of slight decrease of measured values in the territory of Slovakia. Compared to 2017, a concentrations of carbon monoxide decreased at all stations in the measurement.

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 most traffic measuring stations, with the local character of road traffic being more pronounced, including local problems with traffic flow and parking. Impact of U.S. Steel, Košice dominates near this air pollution source, and influences also the regional background over longer distances. In the surroundings of Žiar nad Hronom, the effect of emissions from the Slovalco (non-ferrous metallurgy – aluminium production) is visible. The annual mean background concentration estimated for 2018 was about 150 to 350 $\mu g.m^{-3}$. 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).

Tab. 4.3 *Measured (AMS) and modelled (CEMOD) air quality indicators for carbon monoxide and their difference in [%] – 2018*

AGGLOMERATION Zone	Monitoring station	CO – 8-hour mean [$\mu g.m^{-3}$]		
		AMS	CEMOD	Difference
BRATISLAVA	Bratislava, Trnavské mýto	1 286	1 259	-2%
KOŠICE	Košice, Štefánikova	1 834	1 774	-3%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	1 453	1 314	-10%
Bratislava region	Malacky, Mierové nám.	976	969	-1%
Košice region	Veľká Ida, Letná	2 246	2 535	13%
	Krompachy, SNP	1 884	1 937	3%
Nitra region	Nitra, Štúrova	1 427	1 604	-2%
Prešov region	Prešov, Arm. gen. L. Svobodu	1 332	2 321	-6%
Trenčín region	Trenčín, Hasičská	1 434	3 421	20%
Trnava region	Trnava, Kollárova	1 589	1 710	12%
Žilina region	Martin, Jesenského	1 697	2 193	4%
	Ružomberok, Riadok	1 983	2 906	-11%
	Žilina, Obežná	1 525	2 234	-4%

Fig. 4.7 Maximum daily 8-hour moving mean [µg.m^{-3}] of CO – 2018.



Benzene

Due to the high potential risk of benzene to human health, the increased attention should be given to this substance. The number of monitoring stations measuring benzene, toluene and xylene in the monitoring network was more than double in 2018 compared to 2005.

The highest value of annual mean benzene concentration was recorded at the AMS in Krompachy. This relatively high level (of 2.7 µg.m^{-3}) is likely to be affected by parking of older vehicles in the area of residential houses near the monitoring station. The nearby petrol station, approximately 200 m away, also has an impact. This situation has practically not changed significantly in recent years (in 2014 the mean annual concentration was 3.2 µg.m^{-3}).

The largest increase in benzene concentrations was recorded at the Malacky monitoring station (up to 1.9 µg.m^{-3}, which represents an increase of up to 0.7 µg.m^{-3} compared to 2017). The increased sulphur dioxide concentrations were also observed at this station.

At the monitoring stations Prešov, Arm. gen. L. Svobodu; Košice, Štefánikova and Martin, Jesenského, annual mean benzene concentrations were significantly lower than in 2017. It is interesting that the Prešov station showed a significant decrease in the level of benzene, similar to the level of carbon monoxide. At the monitoring station Bratislava, Trnavské mýto, the value of 1.4 µg.m^{-3} was measured in 2018, which can be considered satisfactory in view of the increase of benzene emissions from the air pollution source Slovnaft, a.s.

In 2018, the lower limit for the assessment (2 µg.m^{-3}) for benzene was exceeded only at the Krompachy monitoring station, the upper limit for the assessment (3.5 µg.m^{-3}) was not exceeded.

Emissions – The main source of benzene emissions is road transport and combustion processes in the industry. Slovnaft Bratislava and U.S. Steel Košice are dominant sources of benzene emissions.

However, the amount of benzene emissions from road transport is of the order of magnitude higher compared to emissions from industrial sources. We cannot forget about fugitive sources (although petrol contains only about 1% by volume of benzene). The input data on emission from mobile sources were processed by similar procedure to that u of the carbon monoxide and nitrogen oxides. Fugitive emissions and known local activities were represented by 31 area sources in the model simulation.

Model results – Fig. 4.8 shows the spatial distribution of the annual mean benzene concentration. Although the spatial resolution of the model simulation is 1 x1 km, it is possible to recognize the road network fragments in the spatial distribution of the annual mean benzene concentration. Emissions of mobile sources significantly affect air quality close to the roads as they are emitted directly into the human breathing zone.

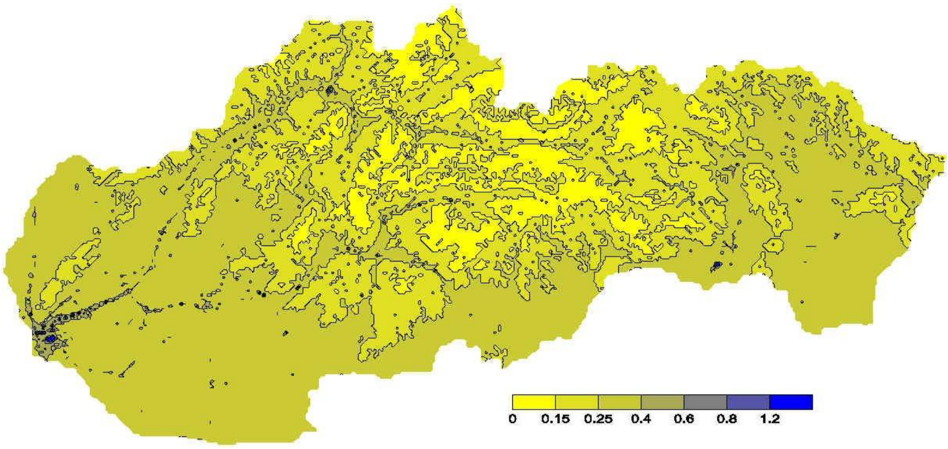
The contribution of road transport outside the city close to roads represents only 0.1 µg.m^{-3} in an annual mean. In the Bratislava agglomeration, the impact of dominant stationary sources (Slovnaft) is apparent in addition to the impact of roads with heavy traffics,

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 concentrations on the background stations decreased in recent years. This seems to be a pan-European trend.

Tab. 4.4 *Measured (AMS) and modelled (CEMOD) air quality indicators for benzene and their difference in % in 2018.*

AGLOMERATION Zone	Monitoring station	Benzene – annual mean concentration [µg.m^{-3}]		
		AMS	CEMOD	Difference
BRATISLAVA	Bratislava, Trnavské mýto	1.4	1.3	-7%
KOŠICE	Košice, Štefánikova	0.8	0.7	-13%
Banská Bystrica region	Banská Bystrica, Štefánikovo nábr.	1.2	1.0	-17%
Bratislava region	Malacky, Mierové nám.	1.9	1.9	0%
Košice region	Krompachy, SNP	2.7	3.1	15%
Nitra region	Nitra, Štúrova	0.7	0.7	0%
Prešov region	Prešov, Arm. gen. L. Svobodu	1.4	1.5	7%
Trenčín region	Trenčín, Hasičská	1.5	1.5	0%
Trnava region	Trnava, Kollárova	1.6	1.3	-19%
Žilina region	Martin, Jesenského	1.0	0.9	-10%
	Ružomberok, Riadok	1.2	1.4	17%

Fig. 4.8 *Annual mean concentration of benzene [µg.m^{-3}] – 2018.*



According to the results of mathematical modelling, the limit value for benzene was not exceeded in Slovakia in 2018.

The level of benzene air pollution in Slovakia has a slightly declining year-on-year trend, which persists in 2018 despite the increase in emission flows from stationary sources.

- **Ground level ozone – O_3**

Ground level ozone is one of the secondary pollutants, it is created as a product of photochemical reactions from other substances – precursors (NO_X, VOC, CO). The transport of ozone from the upper levels of atmosphere (stratosphere) plays an important role mainly in the mountains (**Tab. 3.11**) Annual mean ozone concentrations generally increase with altitude. The maximum values are measured at the sites in the higher mountain while the smaller values are measured at monitoring stations in city centres.

In 2018, there was only a slight increase in annual mean ozone concentrations (4%) compared to the previous year, while in 2017, this interannual increase was 10%. The largest increases in annual mean O_3 concentrations in 2018 were measured in stations Topoľníky, Žilina and Košice, Ďumbierska (on average up to about 15%).

The interpolation model IDW-A was used to obtain spatial countrywide distribution of the air quality indicators for O_3. The measurements from the air quality monitoring network and parameters required by IDW-A methodology were used as model input data. **Fig. 4.9** shows the annual mean ozone concentrations in 2018. **Fig. 4.10** illustrates the number of days in which the average eight-hour concentration of O_3 exceeded 120 $\mu g.m^{-3}$ (the target value for the protection of human health). **Fig. 4.11** shows AOT40 values for the protection of vegetation corrected for the missing values (according to the Decree of the Ministry of Environment SR 244/2016 Coll. on air quality).

The target values for the protection of human health for tropospheric ozone are exceeded in Slovakia. In 2018, exceedances of the limit value were recorded at a larger number of stations than in 2017. In the period 2016 – 2018, the target value for the protection of human health (more than 25 days) was exceeded at four out of sixteen monitoring stations. Two of them are located in the urban areas – Bratislava, Jeséniova and Nitra, Janíkovce and the other two in high altitudes – Kojšovská hoľa and Chopok, EMEP.

The exceedances of AOT40 target values for vegetation protection in May – July (average for 2014 – 2018) occurred at four monitoring stations out of 16 (Bratislava, Jeséniova; Nitra, Janíkovce; Banská Bystrica, Zelená and Chopok). A similar situation was in 2013 – 2017, however, average of AOT40 measured at whole monitoring network in 2014 – 2018 is higher than in 2013 – 2017, the difference is nearly 4%.

Interestingly, exceedances of the AOT40 target value were recorded at the same monitoring stations, where the highest average annual concentrations were measured, respectively, at the same stations that have measured exceedances for the protection of human health. This only underlines the apparent role of ozone precursors, as well as the continental transfer of tropospheric ozone.

The year 2018 was photochemical medium active year. The average monthly deviation of the amounts of solar erythema ultraviolet radiation from the average for the period 2000 – 2018 was 4% at the stations Bratislava, Jeséniova and Gánovce. The average daily deviation of the value of total atmospheric ozone (D.U.) from the long-term average in 1962 – 1990 measured in Hradec Králové in 2018 was –0.1%.

Fig. 4.9 *Annual mean ozone concentrations [µg.m^{-3}] – 2018.*

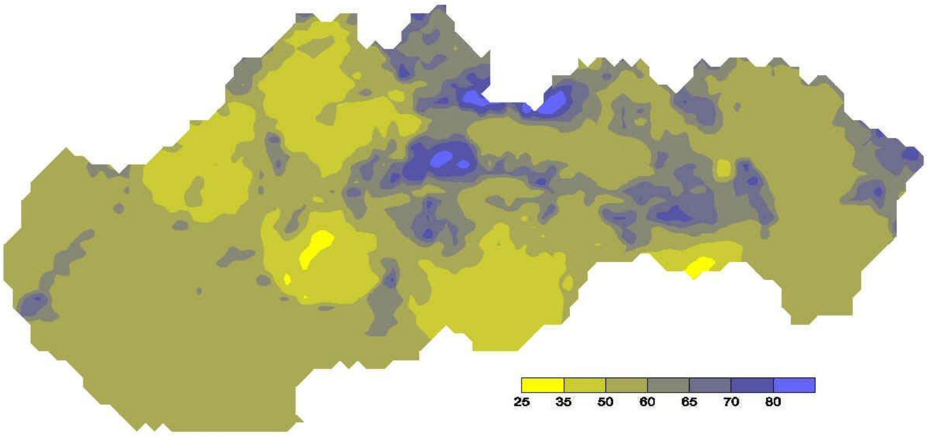


Fig. 4.10 *Number of days with target value for the human health (120 µg.m^{-3}) exceedance in the years 2016 – 2018.*

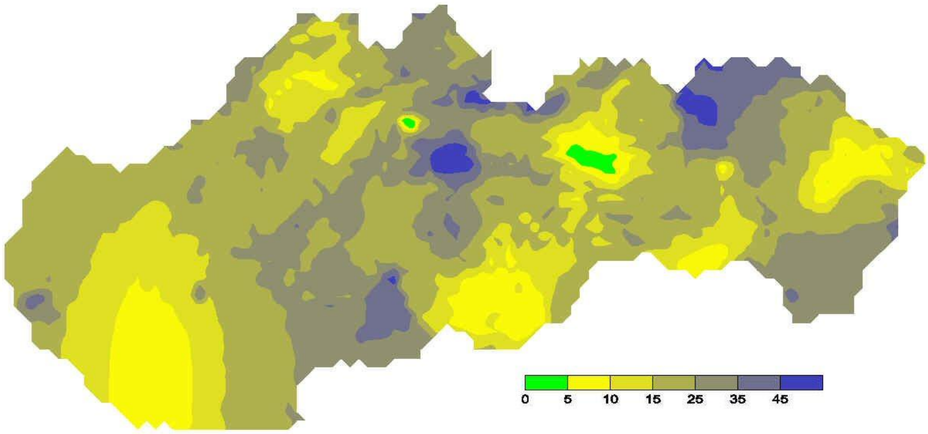
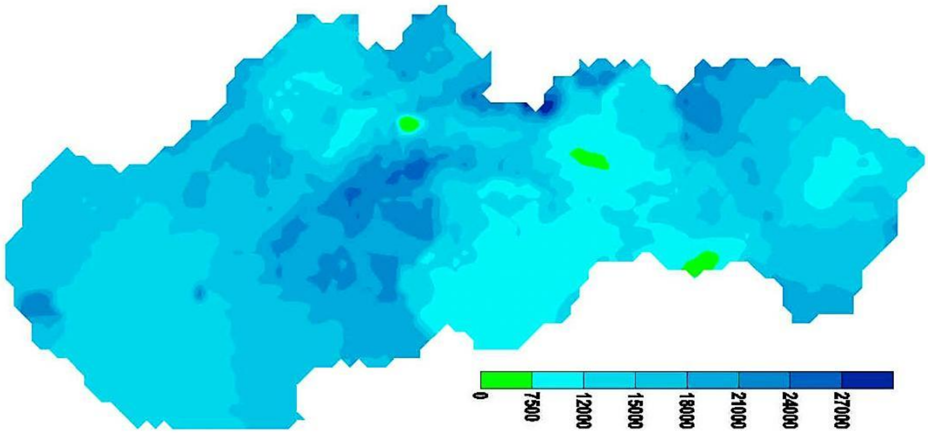


Fig. 4.11 *Mean AOT40 [µg.m^{-3}.h] for a period of five years (2014 – 2018) for the protection of the vegetation, corrected for the missing values.*



- **Particulate matter – PM_{10} a $PM_{2.5}$**

High concentration of PM_{10} in the ambient air is a persistent problem in Slovakia. Exceedances of the daily limit value occur every year. The situation is similar in other European countries. PM_{10} limit exceedances occur mainly in the winter, what is related to the households heating with solid fuels and to the frequent occurrence of adverse dispersion conditions.

In 2018, PM_{10} was continuously measured at 33 air quality monitoring stations, including 11 traffic, 18 urban/suburban background, 3 regional (rural) background and 1 industrial station.

The number of exceedances of the daily limit was above the permitted limit (35 exceedances of the daily mean value 50 $\mu g.m^{-3}$) at 5 monitoring stations, of which 3 were traffic related sites (in 2017 it was 12 stations, of which 5 traffic). The highest number of daily limit exceedances (over 60) was measured at the monitoring stations Jelšava, Jesenského (74) and Veľká Ida, Letná (63). Veľká Ida is influenced by large metallurgical complex, while main source in Jelšava is household heating, and to the lesser extend local industry (magnesite production)

In 2018, $PM_{2.5}$ was continuously monitored at 32 monitoring stations, including two EMEP background stations. (Measurement of $PM_{2.5}$ concentration started in 2005 at three monitoring stations).

Annual limit value for PM_{10} and $PM_{2.5}$ was not exceeded in 2018.

Interpolation model IDW-A was used for the spatial assessment of PM_{10} and $PM_{2.5}$. The concentrations measured at the monitoring stations in the monitoring network and parameters required by IDW-A methodology were used as model input data. PM measurements (direct or derived from TSP) from EMEP stations were used as the additional information in spatial assessment of the area.

Emissions – Residential heating is responsible for the most significant part of total PM_{10} and $PM_{2.5}$ emissions in Slovakia. In the case of PM_{10}, the proportion emissions from household heating is 65 and for $PM_{2.5}$ it is almost 80% from the total emissions.

Road transport is also the important sector. Although the total annual emissions from road transport is lower than those of large and medium air pollution sources, the local impact in the breathing zone is dominant close to the roads with high traffic intensity.

The summary of PM_{10} ($PM_{2.5}$) emissions from large industrial and energy sources represents approximately 30% (15%) of total emissions. While the impact of large sources due to high stacks influence mainly the background concentrations, emissions from the household heating and road transport have a significant impact close to the locations where they enter the air. Small and medium local industrial, energy and heat production sources without proper air pollution abatement technology can influence the air quality significantly in their vicinity.

Agricultural works and the wind erosion from the unpaved soils are responsible mainly for the coarse size fraction of PM, similarly to construction and demolition.

Significant is the role of the secondary fine particles that are formed in the atmosphere by a chemical reaction (e.g. nitrogen oxides from road transport and ammonia from agriculture). The share of secondary PM_{10} may be 30%, with $PM_{2.5}$ even more.

***Model results* (PM_{10}) –** The spatial distribution of PM_{10} is shown in **Fig. 4.12** and **Fig. 4.13**. Based on the measured data, we can conclude that the annual mean concentration in the territory of Slovakia in 2018 slightly decreased compared to 2017. The decrease in daily limit value exceedances is significant. One of the reasons may be that the cold season of 2018 was less heating intensive than in 2017. (January 2017 was extremely cold).

The statistical analysis we have prepared reveals a high statistical significance of the dependence between the measured values from EMEP background stations (located far from air pollution sources) and concentrations measured at other monitoring stations. According to the results of air quality modelling in previous studies, the background PM_{10} concentration in Slovakia is about 20%. It implies, that the problem with PM_{10} needs to be addressed in local scale and regional scale.

Fig. 4.12 *Annual mean concentration of PM_{10} [µg.m^{-3}] – 2018.*

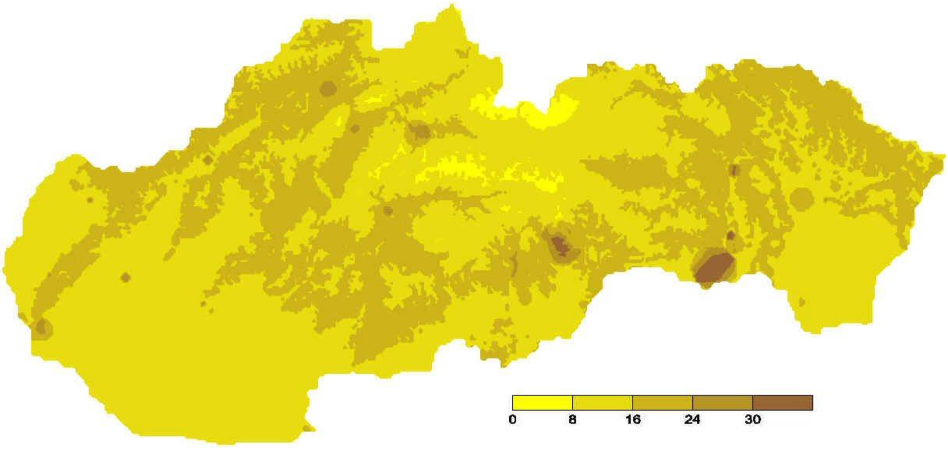


Fig. 4.13 *Number of daily exceedances for PM_{10} – 2018*
(Blue line delimits an area with a limit value exceeded)

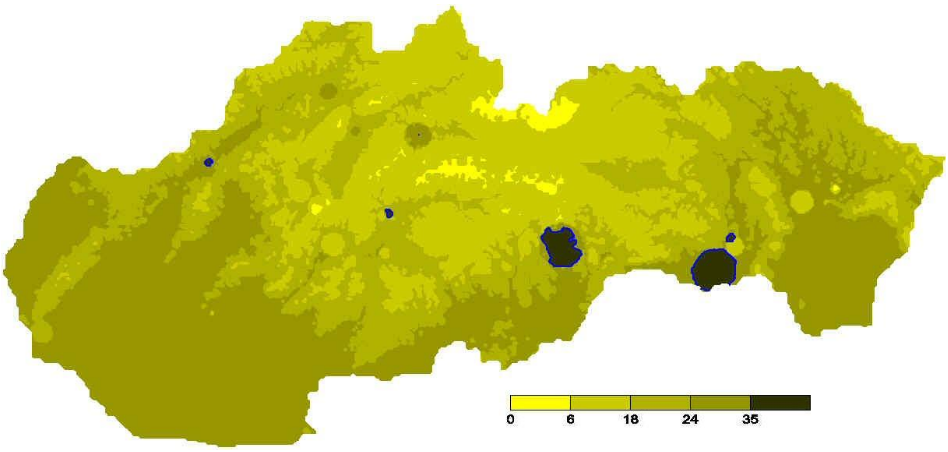
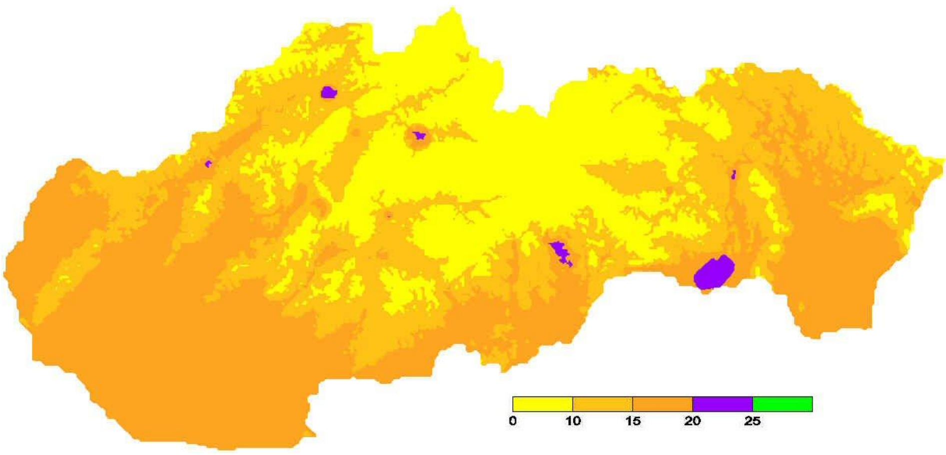


Fig. 4.14 *Annual mean concentration of $PM_{2.5}$ [µg.m^{-3}] – 2018.*



Model results **(**$PM_{2.5}$**)** – In 2015, the limit value for $PM_{2.5}$ came into force. In 2015 and 2016, no exceedance of the annual limit value was measured at any of monitoring station in Slovakia. In 2017, the limit value 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, the target value was not exceeded at any monitoring station. According to the results of interpolation model IDW-A, the limit value for $PM_{2.5}$ was exceeded in 73% of the territory of the Slovakia.

The share of large and medium sources in the measured average annual concentrations in the NMSKO network is less than 5%, with the exception of the surroundings of US Steel, a.s., Košice (in Veľká Ida the monitored share was around 30%).

$PM_{2.5}$ needs more energy to resuspension than PM_{10}, due to the smaller aerodynamic diameter. Consequently, the resuspension of winter sanding/salting and various episodes relevant to resuspension from the uncovered soils or other various fugitive sources are significantly less important for $PM_{2.5}$ than for PM_{10}.

4.3 CONCLUSION

Although the air quality situation was more favourable in 2018 compared to the previous year, the underlying problems persist.

The limit values of NO_2 and PM_{10}, as well as the target value for benzo(a)pyrene were exceeded.

NO_2 slightly exceeded the annual limit value at two monitoring stations.

However, PM_{10} and $PM_{2.5}$ remain the most significant pollutants at the locations where residential heating by solid fuels plays an important role. The worst situation is in mountain where there is a good access to firewood while the orographic features allow for frequent occurrence of adverse dispersion conditions, especially during the heating season.

Road transport has significant impact on the PM_{10} limit value exceedances close to the roads with high traffic intensities. Again, the situation is worse in the winter, and is associated with higher emissions during cold starts of the motors combined with worsened dispersion conditions.

The high impact of small air pollution sources (residential heating) and the road traffic on the air quality compared to the impact of large and medium industrial sources is due to the fact that the emissions are emitted close to the breathing zone, while stack emissions from the large industrial sources are emitted from the high stacks and are usually efficiently dispersed before reaching the breathing zone.

Financial conditions often do not allow the local population to use natural gas for heating or to purchase modern low-emission boilers. However, some improvement can be achieved even by such basic measures as educating people on good practice in operating solid fuel boilers and fireplaces or efficient driving habits.

5 AIR QUALITY ASSESSMENT – CONCLUSION

5.1 AIR QUALITY MANAGEMENT AREAS PROPOSED FOR 2019

The air quality management areas for 2019 were proposed by Slovak Hydrometeorological Institute on the basis of the air quality assessment in zones and agglomerations in 2016 – 2018. (According to § 8 section 3 of Act No. 137/2010 Coll.). The pollutant will be removed from air quality management only when it has been below the limit value for 3 consecutive years.

Tab. 5.1 *The Air Quality Management Areas for 2019 declared on the basis of measurements in 2016 – 2018 (taking into account the measurements in previous years in case of low percentage of valid measurements).*

AGGLOMERATION Zone	Air quality management area	Pollutant
BRATISLAVA	Territory of capital of SR, Bratislava	NO_2, BaP
KOŠICE, Košice region	Territories of Košice city and municipalities Veľká Ida, Sokoľany, Bočiar and Haniska	PM_{10}, BaP
Banská Bystrica region	Territory of Banská Bystrica city	PM_{10}, BaP
	Terittory of Jelšava city and municipaliies 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	Territory of Krompachy city	PM_{10}, BaP
Prešov region	Territory of Prešov city and Ľubotice municipality	NO_2, PM_{10}
Trenčín region	Territory of Prievidza city	BaP
	Territory of Trenčín city	PM_{10}
Nitra region	Territory of Nitra city	BaP
Žilina region	Territory of Ružomberok city and Likavka municipality	PM_{10}
	Territory of Žilina city	PM_{10}, $PM_{2.5}$, BaP

5.2 AIR QUALITY ASSESSMENT BY ZONES AND AGLOMERATIONS ACCORDING TO THE REQUIREMENTS OF DIRECTIVE 2008/50/EC

EU legislation[12] implies an obligation to assess the air quality in each zone and agglomeration. **Tab. 5.2** shows agglomerations and zones where the limit value for PM_{10}, $PM_{2.5}$ or NO_2 has been exceeded in the years under review.

Tab. 5.2 *Zones and agglomerations with exceedances of the limit values of PM_{10}, $PM_{2.5}$ and NO_2 based on measurements in 2016 – 2018 (taking into account data in previous years in case of low percentage of valid measurements).*

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

In the evaluated years 2016 – 2018, the target value for BaP and the target value for the protection of human health for O_3 were exceeded in the Bratislava agglomeration as well as in the Slovakia zone (**Tab. 3.6**, **Tab. 3.12**).

[12] *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 recently published data by the European Environment Agency (EEA) the air pollution caused in the year 2014 in the Slovak Republic 5 416[4] premature deaths. Their number rose in the year 2015 to 5 421.[5] The contribution of individual air pollutants ($PM_{2.5}$ – fine particulate matters with an aero-

[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-2017*
[5] *https://www.eea.europa.eu//publications/air-quality-in-europe-2018*

dynamic diameter equal or 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 deaths are cardiovascular diseases, stroke, lung and respiratory diseases. In addition, air pollution influences other areas of our lives. Work incapacity and high healthcare costs are also attributed to the impacts of air pollution and the environment.

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	$PM_{2.5}$ [b)]		NO_2 [b)]		O_3 [b)]
		$C_0 = 0$ [a)]	$C_0 = 2.5$ [a)]	$C_0 = 20$ [a)]	$C_0 = 10$ [a)]	
2014	5 416	5 160	4 520	100	1 330	160
2015	5 421	5 200	-	240	-	210

a) *The EEA has performed the sensitivity study for health impacts of emissions $PM_{2.5}$ a NO_2. The lowest concentration used to calculate the health impacts of a pollutant in a baseline scenario is referred to as the counterfactual concentration C_0. C_0 represents for instance the pollutant concentration that could be achieved by changes in the environment or the concentration below which the concentration-health response function may not be appropriate, due to the lack of epidemiological data. The value for $PM_{2.5}$ used in previous reports of EEA was $C_0 = 0$ µg.m^{-3}. Taking into account the background pollution concentration in Europe, the availability of risk estimates and sensitivity analysis in 2008, an alternative $C_0 = 2.5$ µg.m^{-3} has also been considered. The calculation of NO_2 has been made by two alternatives: $C_0 = 10$ and $C_0 = 20$ µg.m^{-3}. The data published in report 2018 related to the year 2015 is provided only the values of concentrations $C_0 = 0$ µg.m^{-3} for $PM_{2.5}$ and $C_0 = 20$ µg.m^{-3} for NO_2. The impacts estimated for the different pollutants cannot be simply aggregated because the concentrations (sometimes strongly) correlate.*

b) *The uncertainties in the estimates of premature deaths (expressed as 95% confidence interval) represent the relative risk factors: ±35% ($PM_{2.5}$), ±45% (NO_2) and ±50% (O_3). There might be a bias in the NO_2 estimates due to the correlation with $PM_{2.5}$.*

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).

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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.*

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).

6.1.2 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	Reduction compared with 2005 for any year from 2030		Reduction compared with 2005 for any year from 2020 to 2029	Reduction compared with 2005 for any year from 2030
SR	**SO_2**	57%	***82%***	**NO_X**	36%	***50%***
EÚ 28		59%	***79%***		42%	***63%***
SR	**NMVOC**	18%	***32%***	**NH_3**	36%	***50%***
EÚ 28		28%	***40%***		42%	***63%***
SR	**$PM_{2.5}$**	36%	***49%***			
EÚ 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 2019 includes the period of years 1990 – 2017. 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 with 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.

The overview of selected sectors of nomenclature NFR14:

ENERGY AND STATIONARY FUEL COMBUSTION ACTIVITIES

- Fuel combustion
- Fugitive emissions

INDUSTRY

- Mineral production
- Chemical industry
- Metal production
- Solvents
- Other product use
- Other production industry

AGRICULTURE

- Manure management
- Agricultural soils
- Field burning of agricultural residues
- Agriculture other

WASTE

- Solid waste disposal on land
- Biological treatment of waste
- Incineration and open burning of waste
- Waste water handling
- Other waste

One of the most important data sources in the preparation process of final inventory is the database of **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 for example 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.

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[11] NEIS (National Emission Information System), 2016 http://www.air.sk/neis.php
[12] EMEP/EEA Air pollutant emission inventory guidebook – 2016 (on-line: http://www.eea.europa.eu/publications/emep-eea-guidebook-2016
[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 – 2017.

	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; US 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 long-term development of individual pollutants since 1990 is shown in the figures (**Fig. 6.1** – **Fig. 6.4**). For better transparency, a wide range of values and different scale of units, the figures are divided into four groups on air pollutants, heavy metals, polycyclic aromatic hydrocarbons and persistent organic pollutants.

Fig. 6.1 Emission trends of selected air pollutants in years 1990 – 2017.

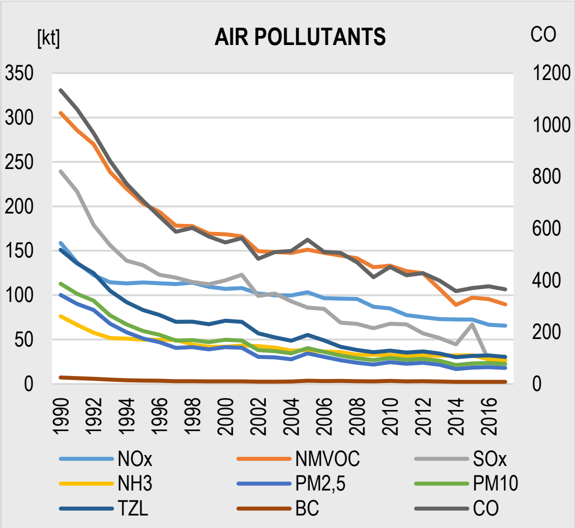


Fig. 6.2 Emission trends of selected heavy metals in years 1990 – 2017.

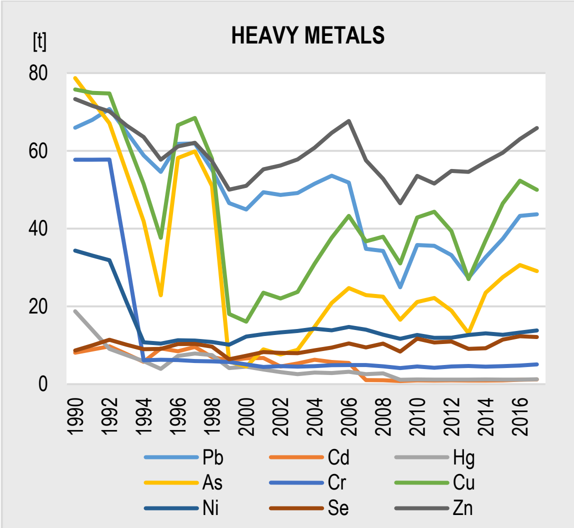


Fig. 6.3 Emission trends of polycyclic aromatic hydrocarbons (PAH) in years 1990 – 2017.

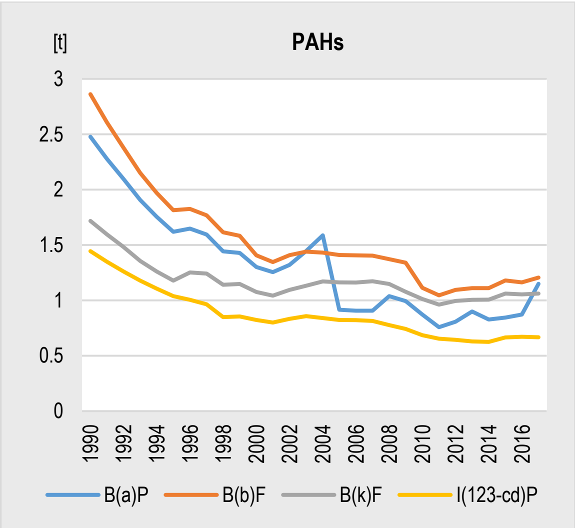
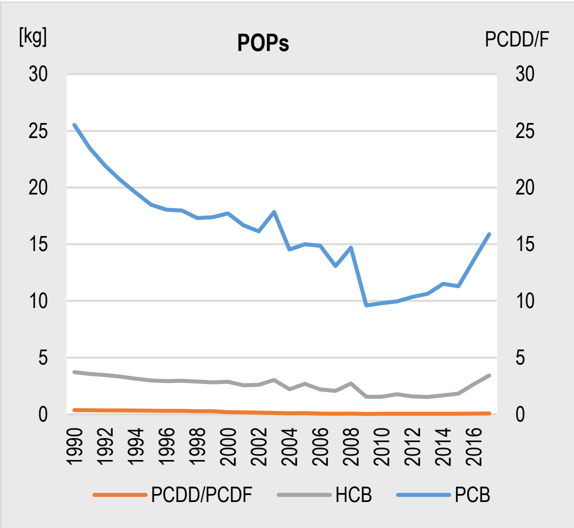


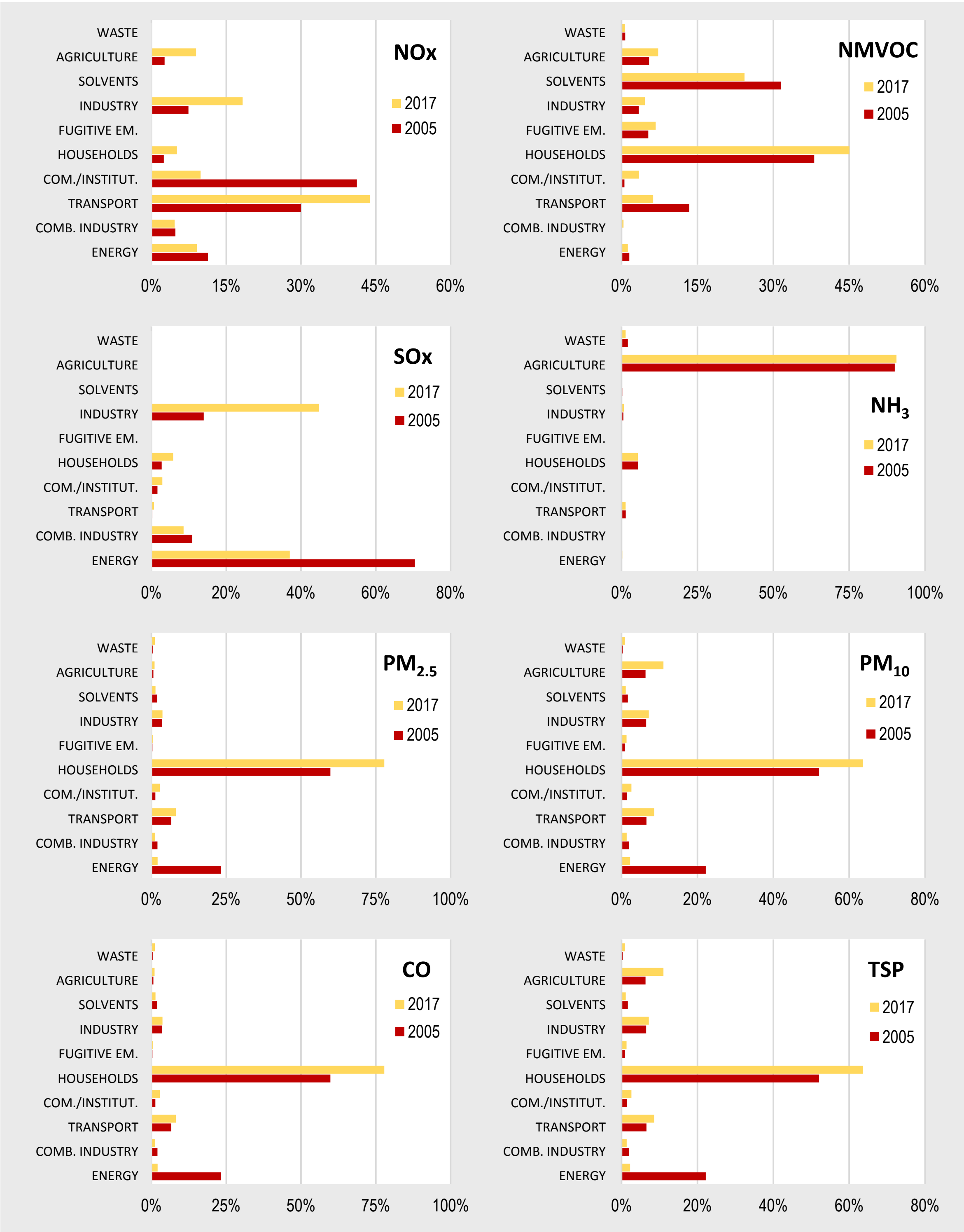
Fig. 6.4 Emission trends of persistent organic pollutants (POPs) in years 1990 – 2017.



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 2017 are presented on the **Fig. 6.5**.

Fig. 6.5 *The comparison of base year (2005) and the latest available year (2017) 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. 6.6** and **Fig. 6.7**. The latest increase was recorded in year 2015. It was the last year of derogation for power plant Nováky (Slovenské elektrárne, a.s) for operation of unabated old boilers (sources ENO B - block 3 and 4). During the year 2015 this source also combusted noticeable higher amount of brown coal compare to previous years. Accordingly, a peak of released emissions of SO_X is visible in trend. The refurbishment of other combustion units ENO 1 and 2 has been conducted, which resulted to considerable drop of emissions in the following year. Categories of fugitive emissions have declining trends in recent years (**Fig. 6.7**).

Fig. 6.6 *Emission trends of air pollutants in sector energy and stationary fuel combustion activities in years 1990 – 2017.*

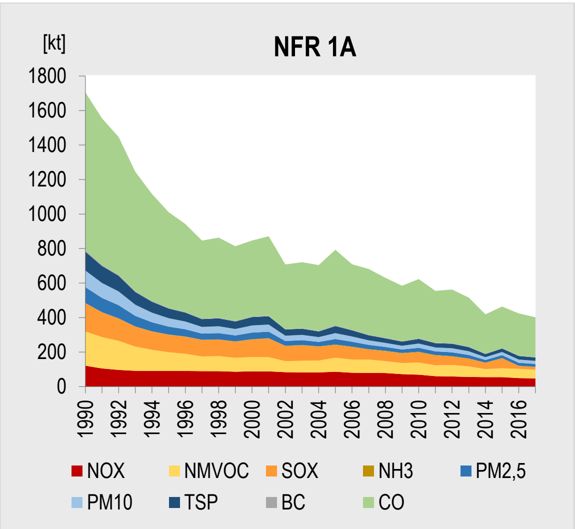
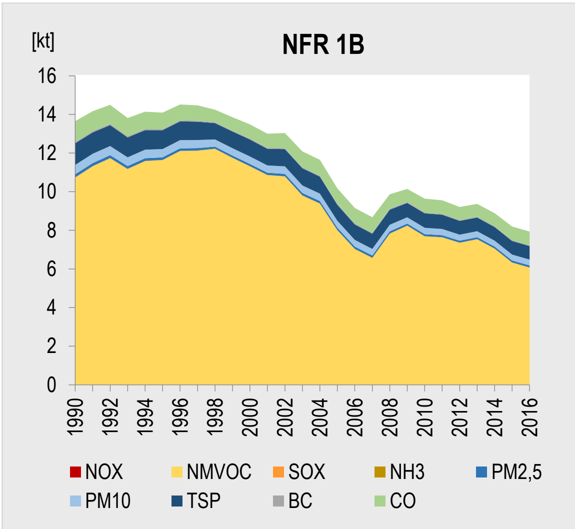


Fig. 6.7 *Emission trends of air pollutants in sector of fugitive emissions in years 1990 – 2017.*



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)

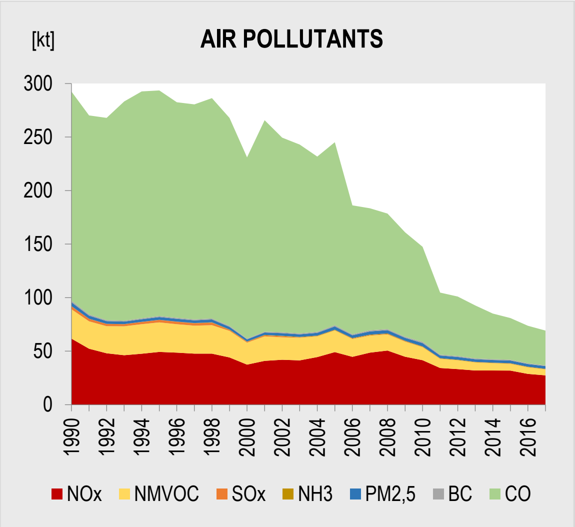
- Civil aviation
- Road transport
  - *Passenger cars*
  - *Light duty vehicles*
  - *Heavy duty vehicles and buses*
  - *Mopeds & motorcycles*
  - *Gasoline evaporation*
  - *Automobile tyre and brake wear*
  - *Automobile road abrasion*
- Railways
- Water transport
- Pipeline transport

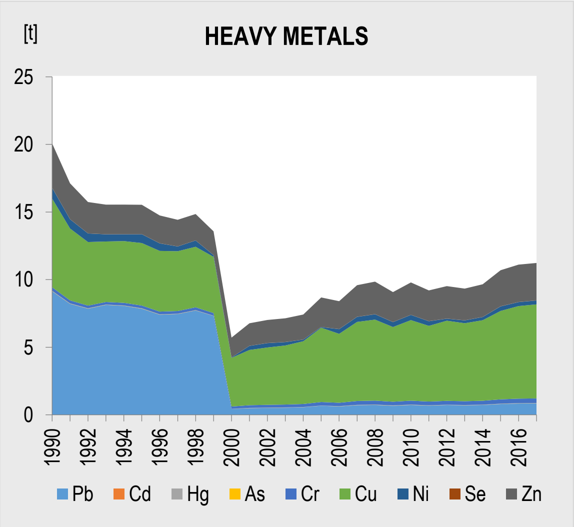
Emission trends in the sector of transport

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%.

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. 6.8 *Emission trends of air pollutants in transport in years 1990 – 2017.*





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. 6.9 *Emission trends of air pollutants in households sector in years 1990 – 2017.*

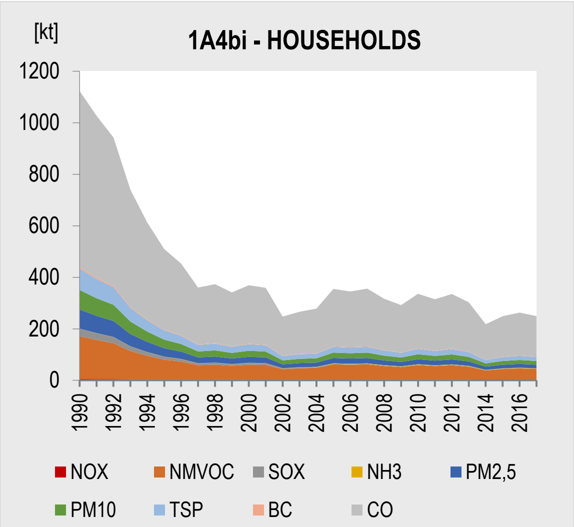
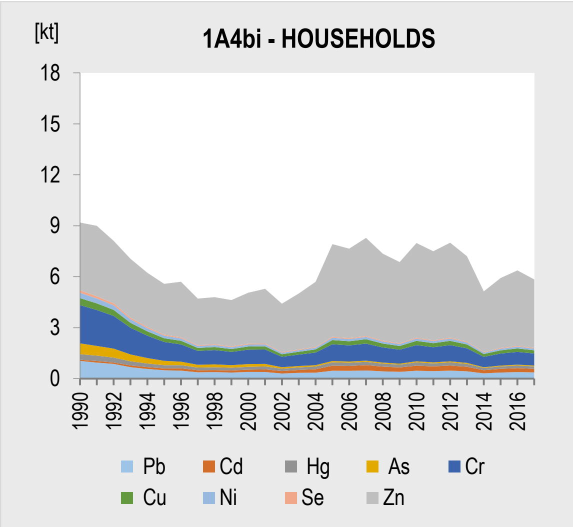


Fig. 6.10 *Emission trends of heavy metals in households sector in years 1990 – 2017.*



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.

Enhanced quality of produced data on households

The statistical survey focused on households´ heating was carried out in cooperation with the Statistical Office of the Slovak Republic. The survey was conducted in the frame of the grant project of SHMÚ funded by Eurostat: *Quality improvements of the air emission accounts and extension of provided time-series*. The sample of households was focused especially on family houses with solid fuels as primary heating fuel.

On the basis of this newly gathered information on appliances structure and types used in the households, types of fuels used, thermal and insulation properties of family houses and their age structure was processed the update of the methodology for households' heating. The improvement of the methodology brought about more precise emissions estimation in households. Emissions were recalculated in the entire time-series since 1990. New emission values for $PM_{2.5}$ slightly declined compared to previous emission data. However, they still form the majority of the national total (78%). The project resulted also into the development of methodologies for historical years to create Air Emission Accounts for years 1990 – 2007.

6.3.2 Industry

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 2016[17] was at the level of 24%. 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)

From mineral production activities presented in the Slovakia are for instance: cement production (CRH Slovensko; 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.), quarrying and mining of minerals and the others. Chemical production has also a long-term tradition in the Slovak industry for instance: production of urea and nitric acid (Duslo, a.s.), and other various chemical substances (e. g. FORTISCHEM a.s., and so on). Important industrial activity is metal production, especially iron and steel production (U.S. Steel Košice, s.r.o.; ZTS Metalurg, a.s.; Železiarne Podbrezová a.s., Slovakia steel mills, a.s.), as well as metallurgical secondary production and processing of metals (U.S. Steel Košice, a.s.; ZTS Metalurg, a.s.; Železiarne Podbrezová, a.s.; Slovakia steel mills, a.s.; Kovohuty, a.s.). Other industries represent for example aluminium production (Slovalco, a.s.).

Concerning the air protection, the most important emissions included in the group of categories, so-called solvents, are non-methane volatile organic compounds (NMVOC). They are part of many different substances, which are used in the industry and human activities. The wide scale of substances contains NMVOC: pure solvents (individual organic compounds) or many different mixtures used in industry, dry cleaning agents, cleaning detergents, paints, paint thinners, glues, cosmetics and toiletries, variety of household products or car care products. Emissions from road paving with asphalt also belong here. Their versatility leads to more difficult tracking the fluxes and some categories are estimated, especially for domestic use. Emissions of NMVOC were significantly limited in the past in the field of industry. In addition, the regulation was applied in the products in retail for domestic use.

The **Fig. 6.11** to **Fig. 6.14** show downward trends of emissions due to the implementation of strict legislative measures in the field of the air protection and technological progress in environmental abatement techniques which reduce the levels of discharged emissions.

[17] *Analýza vývoja priemyselnej výroby https://www.mhsr.sk/uploads/files/w5xfaTOG.pdf*

Fig. 6.11 Emission trends of air pollutants in sector of mineral production in years 1990 – 2017.

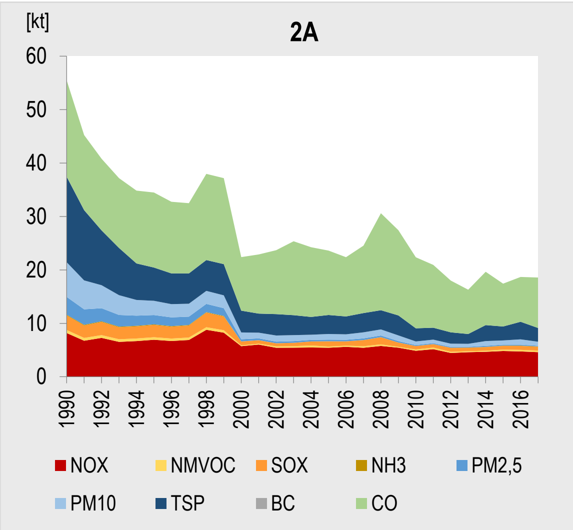


Fig. 6.12 Emission trends of air pollutants in sector of chemical industry in years 1990 – 2017.

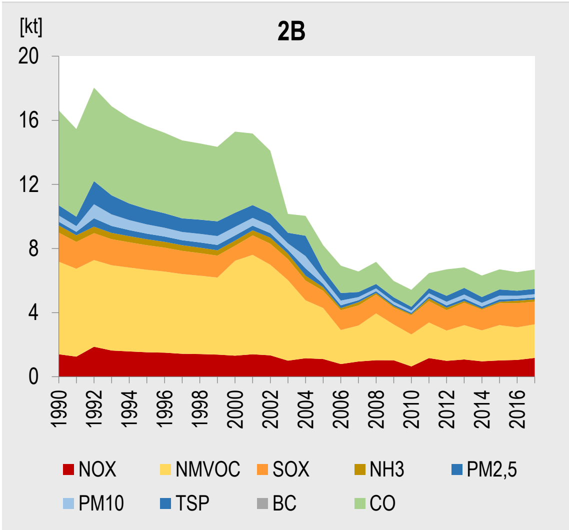


Fig. 6.13 Emission trends of air pollutants in sector of metal production in years 1990 – 2017.

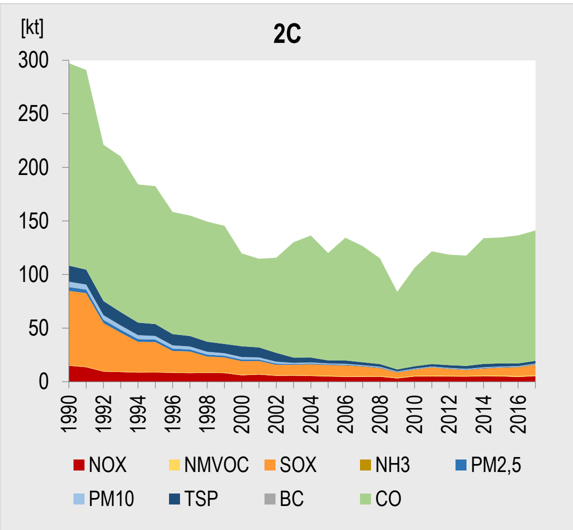
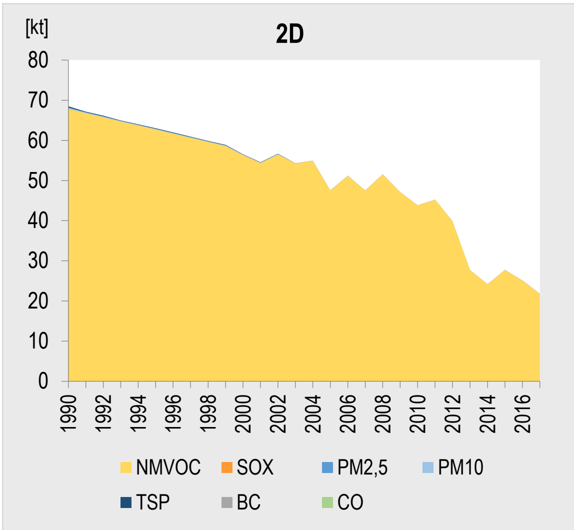


Fig. 6.14 Emission trends of air pollutants in sector of solvents in years 1990 – 2017.



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.[18]

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).

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

Emissions of nitrogen (NH_3 a NO) one can define 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.

Nitrogen is elementary compound 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 live-stock. 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 active-ties. 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)

Percentage determination of individual categories of ammonia emissions are listed below:
- surface application of organic and inorganic waste to agricultural soil: approximately 67%,
- livestock housing and storage of organic waste: approximately 30%,
- grazing: approximately 3%.

The share of the agricultural sector in the national total of NMVOC is approximately 7%. 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.

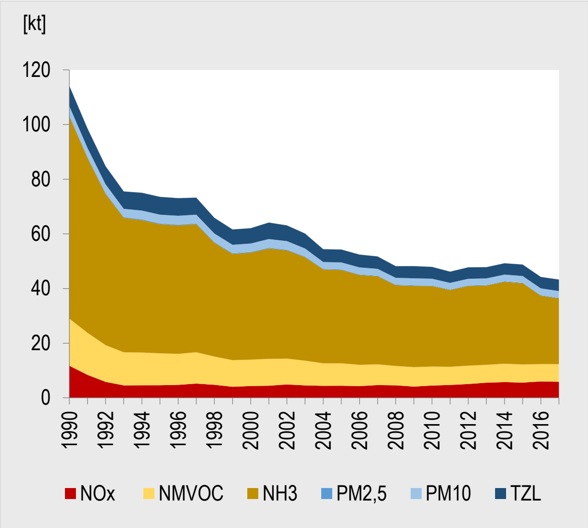
The agriculture is producing the emissions of particulate matters PM_{10} a $PM_{2.5}$. The share of PM_{10} emissions at the national total of PM_{10} is approximately 11%, whilst the share of $PM_{2.5}$ emissions at the national total is only 1%. The emissions are creating in agriculture especially 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 – 2017, 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. 6.15**).

Since 2018, several emission reduction measures were implemented into emission inventories (**Tab. 6.5**). Information was taken from the National Emission Information System. 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 2017 caused the crop shortage. Decrease was recorded mainly in the crop of wheat (27.3%), maize (37.7%), sugar beet (18.3%) potatoes (25.5%) and oilseeds (0.3%), which is documented by trends of PM_{10} and $PM_{2.5}$ emissions.

Fig. 6.15 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. In 2017, 60% of the total emissions of these compounds were released into the atmosphere by waste incineration. 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.

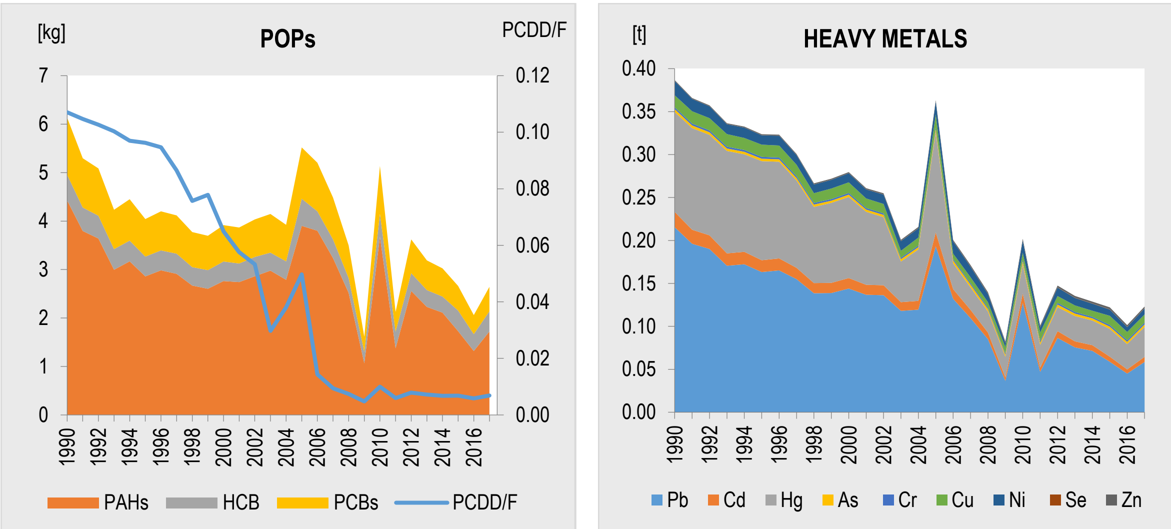
"The most serious adverse health effects of dioxins are carcinogenic – carcinogenic effects. They damage the immune system, their teratogenic effects have been shown (the ability to damage the developing unborn fetus in the mother's body) and they negatively affect sex hormones and thyroid hormones" (Prof. I. Rovný).[19]

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 – 2017, the emissions of all pollutants in the waste sector have dramatically decreased. The decline of dioxins and furans was almost 94%, whilst the amount of disposed waste by the incineration was reduced by almost 60%. 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. 6.16 *Emission trends of air pollutants in 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.

[19] 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 Manufacture 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 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[20], 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[21].

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

Number of stationary sources recorded in the NEIS during the year 2017 at regional level is presented in the tables from **Tab. 6.7** to **Tab. 6.9**. Total number of sources means the number of large and medium stationary sources. The tables from **Tab. 6.8** to **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, 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 2017 at regional level.*

Region	Total number of sources	From this:	
		large sources	medium sources
Bratislavský	1 917	90	1 827
Trnavský	1 663	117	1 546
Trenčiansky	1 578	103	1 475
Nitriansky	1 801	145	1 656
Žilinský	1 597	89	1 508
Banskobystrický	1 898	121	1 777
Prešovský	1 644	66	1 578
Košický	1 474	132	1 342
SR	**13 572**	**863**	**12 709**

Tab. 6.8 *Number of large stationary air pollution sources listed in NEIS for the year 2017 at regional level.*

Region	Number of large sources	From this:	
		in operation	out of operation
Bratislavský	90	84	6
Trnavský	117	107	10
Trenčiansky	103	94	9
Nitriansky	145	118	27
Žilinský	89	77	12
Banskobystrický	121	96	25
Prešovský	66	54	12
Košický	132	112	20
SR	**863**	**742**	**121**

Tab. 6.9 *Number of medium stationary air pollution sources listed in NEIS for the year 2017 at regional level.*

Region	Number of medium sources	From this:	
		in operation	out of operation
Bratislavský	1 827	1 577	250
Trnavský	1 546	1 210	336
Trenčiansky	1 475	1 303	172
Nitriansky	1 656	1 296	360
Žilinský	1 508	1 301	207
Banskobystrický	1 777	1 387	390
Prešovský	1 578	1 362	216
Košický	1 342	1 068	274
SR	**12 709**	**10 504**	**2 205**

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

Tables from **Tab. 6.10** to **Tab. 6.13** include the list of most significant operators of stationary air pollution sources (thereinafter "sources") in SR during the year 2017. 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 – 2017.*

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	2 663.83	51.58
2.	Duslo, a.s.	Šaľa	165.93	3.21
3.	FORTISCHEM a. s.	Prievidza	140.58	2.72
4.	Slovalco, a.s.	Žiar nad Hronom	128.09	2.48
5.	Slovenské elektrárne, a.s.	Prievidza	80.87	1.57
6.	Mondi SCP, a.s.	Ružomberok	80.78	1.56
7.	DOLVAP, s.r.o.	Žilina	55.60	1.08
8.	SLOVNAFT, a.s.	Bratislava II	53.37	1.03
9.	Považská cementáreň, a.s.	Ilava	50.80	0.98
10.	BUKOCEL, a.s.	Vranov nad Topľou	44.09	0.85
11.	SLOVNAFT, a.s.	Bratislava II	39.52	0.77
12.	Slovenské elektrárne, a.s.	Michalovce	34.81	0.67
13.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	31.70	0.61
14.	CRH (Slovensko) a.s.	Košice - okolie	31.65	0.61
15.	OFZ, a.s.	Dolný Kubín	27.98	0.54
16.	Tate & Lyle Boleraz, s.r.o.	Trnava	27.64	0.54
17.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	22.76	0.44
18.	Carmeuse Slovakia, s.r.o.	Košice - okolie	21.80	0.42
19.	Johns Manville Slovakia, a.s.	Trnava	21.33	0.41
20.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	21.19	0.41
	TOTAL		**3 744.30**	**72.50**

Tab. 6.11 *Sulphur oxides expressed as SO_2 released from the most important sources of operators – 2017.*

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	8 019.05	31.78
2.	Slovenské elektrárne, a.s.	Prievidza	6 862.37	27.20
3.	Slovalco, a.s.	Žiar nad Hronom	2 441.12	9.67
4.	SLOVNAFT, a.s.	Bratislava II	1 634.06	6.48
5.	OFZ, a.s.	Dolný Kubín	805.85	3.19
6.	SLOVNAFT, a.s.	Bratislava II	725.24	2.87
7.	Knauf Insulation, s.r.o.	Žarnovica	410.27	1.63
8.	Martinská teplárenská, a.s.	Martin	404.24	1.60
9.	Slovenské elektrárne, a.s.	Michalovce	385.89	1.53
10.	Zvolenská teplárenská, a.s.	Zvolen	272.37	1.08
11.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	244.41	0.97
12.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	229.15	0.91
13.	Mondi SCP, a.s.	Ružomberok	200.24	0.79
14.	Žilinská teplárenská, a.s.	Žilina	190.99	0.76
15.	Duslo, a.s.	Bratislava III	185.99	0.74
16.	KOMPALA a.s.	Banská Bystrica	169.27	0.67
17.	Veolia Utilities Žiar nad Hronom, a.s.	Žiar nad Hronom	158.64	0.63
18.	Ferroenergy s.r.o.	Košice II	154.67	0.61
19.	BUKOCEL, a.s.	Vranov nad Topľou	141.40	0.56
20.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	113.52	0.45
	TOTAL		**23 748.74**	**94.12**

Tab. 6.12 Nitrogen oxides expressed as NO_2 released from the most important sources of operators – 2017.

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	5 886.50	22.23
2.	Slovenské elektrárne, a.s.	Prievidza	1 689.44	6.38
3.	CRH (Slovensko) a.s.	Malacky	1 311.08	4.95
4.	SLOVNAFT, a.s.	Bratislava II	1 155.85	4.36
5.	Mondi SCP, a.s.	Ružomberok	1 102.71	4.16
6.	SLOVNAFT, a.s.	Bratislava II	917.29	3.46
7.	CRH (Slovensko) a.s.	Košice - okolie	833.02	3.15
8.	Duslo, a.s.	Šaľa	646.06	2.44
9.	OFZ, a.s.	Dolný Kubín	574.98	2.17
10.	CEMMAC a.s.	Trenčín	567.07	2.14
11.	Považská cementáreň, a.s.	Ilava	565.19	2.13
12.	Slovalco, a.s.	Žiar nad Hronom	551.36	2.08
13.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	516.51	1.95
14.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	325.09	1.23
15.	Carmeuse Slovakia, s.r.o.	Košice II	310.06	1.17
16.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	275.27	1.04
17.	Martinská teplárenská, a.s.	Martin	258.00	0.97
18.	eustream, a. s.	Michalovce	241.47	0.91
19.	RONA, a.s.	Púchov	234.47	0.89
20.	Ferroenergy s.r.o.	Košice II	227.15	0.86
	TOTAL		**18 188.57**	**68.68**

Tab. 6.13 Carbon monoxide (CO) released from the most important sources of operators – 2017.

	Operator	Sources in district	Emissions [t]	Share on total emissions [%]
1.	U. S. Steel Košice, s.r.o.	Košice II	113 587.29	74.38
2.	Slovalco, a.s.	Žiar nad Hronom	16 552.21	10.84
3.	CEMMAC a.s.	Trenčín	3 500.06	2.29
4.	Považská cementáreň, a.s.	Ilava	2 143.56	1.40
5.	CRH (Slovensko) a.s.	Malacky	1 419.41	0.93
6.	Calmit, spol. s r.o.	Nitra	1 339.72	0.88
7.	OFZ, a.s.	Dolný Kubín	1 310.75	0.86
8.	KOVOHUTY, a.s.	Spišská Nová Ves	1 250.67	0.82
9.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	707.98	0.46
10.	Slovenské elektrárne, a.s.	Prievidza	508.06	0.33
11.	Mondi SCP, a.s.	Ružomberok	479.56	0.31
12.	Slovenské elektrárne, a.s.	Michalovce	465.06	0.30
13.	SLOVNAFT, a.s.	Bratislava II	463.12	0.30
14.	Leier Baustoffe SK s.r.o.	Prešov	375.60	0.25
15.	SLOVMAG a.s. Lubeník	Revúca	353.96	0.23
16.	VUM, a.s.	Žiar nad Hronom	277.97	0.18
17.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	232.39	0.15
18.	FORTISCHEM a. s.	Prievidza	218.67	0.14
19.	Slovenské magnezitové závody, a.s. Jelšava	Košice II	213.60	0.14
20.	Železiarne Podbrezová a.s. skrátene ŽP a.s.	Brezno	187.79	0.12
	TOTAL		**145 587.45**	**95.33**

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

Tables from **Tab. 6.14** to **Tab. 6.21** present the most significant operators of large and medium stationary sources listed in NEIS in 2017 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 emission - 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 2017 at regional level –* ***Bratislava region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions region [%]	Share on total emissions SR [%]
Total suspended particles	1.	SLOVNAFT, a.s.	Bratislava II	92.94	41.04	1.80
	2.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	22.76	10.05	0.44
	3.	CRH (Slovensko) a.s.	Malacky	20.82	9.19	0.40
	4.	IKEA Industry Slovakia s. r. o.	Malacky	7.83	3.46	0.15
	5.	PPC Energy, a.s.	Bratislava III	6.83	3.02	0.13
	6.	ALAS SLOVAKIA, s.r.o.	Malacky	6.54	2.89	0.13
	7.	Ministerstvo obrany Slovenskej republiky	Pezinok	4.77	2.10	0.09
	8.	Obec Rohožník	Malacky	4.59	2.03	0.09
	9.	TERMMING, a.s.	Bratislava II	4.18	1.85	0.08
	10.	Veolia Energia Slovensko, a. s.	Bratislava V	3.84	1.70	0.07
		TOTAL		**175.09**	**77.32**	**3.39**
Sulphur oxides as SO_2	1.	SLOVNAFT, a.s.	Bratislava II	2 359.30	90.62	9.35
	2.	Duslo, a.s.	Bratislava III	185.99	7.14	0.74
	3.	CRH (Slovensko) a.s.	Malacky	29.39	1.13	0.12
	4.	Ministerstvo obrany Slovenskej republiky	Pezinok	7.75	0.30	0.03
	5.	Odvoz a likvidácia odpadu a.s.	Bratislava II	7.05	0.27	0.03
	6.	BPS Senec, s. r. o.	Senec	2.87	0.11	0.01
	7.	Pezinské tehelne - Paneláreň, a.s.	Pezinok	1.73	0.07	0.01
	8.	AGROMAČAJ a.s.	Senec	1.49	0.06	0.01
	9.	Bratislavská teplárenská, a.s.	Bratislava II	0.99	0.04	0.00
	10.	PPC Energy, a.s.	Bratislava III	0.82	0.03	0.00
		TOTAL		**2 597.38**	**99.76**	**10.29**
Nitrogen oxides as NO_2	1.	SLOVNAFT, a.s.	Bratislava II	2 073.33	47.32	7.83
	2.	CRH (Slovensko) a.s.	Malacky	1 311.08	29.92	4.95
	3.	PPC Energy, a.s.	Bratislava III	136.78	3.12	0.52
	4.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	93.33	2.13	0.35
	5.	Odvoz a likvidácia odpadu a.s.	Bratislava II	92.29	2.11	0.35
	6.	Veolia Energia Slovensko, a. s.	Bratislava V	79.20	1.81	0.30
	7.	IKEA Industry Slovakia s. r. o.	Malacky	58.70	1.34	0.22
	8.	Bratislavská teplárenská, a.s.	Bratislava III	53.70	1.23	0.20
	9.	Bratislavská teplárenská, a.s.	Bratislava IV	49.48	1.13	0.19
	10.	TERMMING, a.s.	Bratislava II	45.67	1.04	0.17
		TOTAL		**3 993.54**	**91.15**	**15.08**
Carbon monoxide	1.	CRH (Slovensko) a.s.	Malacky	1419.41	54.53	0.93
	2.	SLOVNAFT, a.s.	Bratislava II	472.11	18.14	0.31
	3.	PPC Energy, a.s.	Bratislava III	123.63	4.75	0.08
	4.	TERMMING, a.s.	Malacky	121.37	4.66	0.08
	5.	IKEA Industry Slovakia s. r. o.	Malacky	88.89	3.41	0.06
	6.	Obec Rohožník	Malacky	32.67	1.26	0.02
	7.	Veolia Energia Slovensko, a. s.	Bratislava V	29.42	1.13	0.02
	8.	VOLKSWAGEN SLOVAKIA, a.s.	Bratislava IV	29.24	1.12	0.02
	9.	Ministerstvo obrany Slovenskej republiky	Pezinok	29.18	1.12	0.02
	10.	Duslo, a.s.	Bratislava III	26.69	1.03	0.02
		TOTAL		**2 372.60**	**91.16**	**1.55**

Tab. 6.15 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2017 at regional level –* ***Trnava region.***

		Operator	Sources in district	Emissions [t]	Share on total emissions	
					region [%]	SR [%]
Total suspended particles	1.	Tate & Lyle Boleraz, s.r.o.	Trnava	27.64	15.28	0.54
	2.	Johns Manville Slovakia, a.s.	Trnava	21.33	11.79	0.41
	3.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	21.19	11.71	0.41
	4.	PCA Slovakia, s.r.o.	Trnava	6.56	3.63	0.13
	5.	Bekaert Slovakia, s.r.o.	Galanta	5.77	3.19	0.11
	6.	Agro Boleráz, s.r.o.	Trnava	5.74	3.17	0.11
	7.	Agropodnik a.s. Trnava	Dunajská Streda	5.05	2.79	0.10
	8.	JK Gabčíkovo s.r.o.	Dunajská Streda	4.19	2.32	0.08
	9.	ENVIRAL, a.s.	Hlohovec	3.81	2.11	0.07
	10.	ZLIEVÁREŇ T R N A V A s.r.o.	Trnava	3.62	2.00	0.07
		TOTAL		**104.91**	**57.98**	**2.03**
Sulphur oxides *as SO_2*	1.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	244.41	51.82	0.97
	2.	Johns Manville Slovakia, a.s.	Trnava	88.89	18.85	0.35
	3.	MACH TRADE, spol. s r.o.	Galanta	31.43	6.66	0.12
	4.	Hornonitrianske bane Prievidza, a.s.	Senica	12.17	2.58	0.05
	5.	PLYNEX s. r. o.	Galanta	12.14	2.57	0.05
	6.	RUPOS, s.r.o.	Trnava	11.93	2.53	0.05
	7.	ECO PWR, s. r. o.	Dunajská Streda	9.94	2.11	0.04
	8.	ZLIEVÁREŇ T R N A V A s.r.o.	Trnava	7.92	1.68	0.03
	9.	BPS Hubice, s. r. o.	Dunajská Streda	5.00	1.06	0.02
	10.	BPS Vesele, s. r. o.	Piešťany	4.91	1.04	0.02
		TOTAL		**428.74**	**90.90**	**1.70**
Nitrogen oxides *as NO_2*	1.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	153.74	17.09	0.58
	2.	Johns Manville Slovakia, a.s.	Trnava	108.11	12.02	0.41
	3.	ENVIRAL, a.s.	Hlohovec	62.85	6.99	0.24
	4.	Tate & Lyle Boleraz, s.r.o.	Trnava	50.81	5.65	0.19
	5.	Službyt, spol. s r.o.	Senica	35.96	4.00	0.14
	6.	Wienerberger slovenské tehelne, spol. s r.o.	Trnava	30.15	3.35	0.11
	7.	TEPLÁREŇ Považská Bystrica, s.r.o.	Dunajská Streda	26.36	2.93	0.10
	8.	Bekaert Hlohovec, a.s.	Hlohovec	20.54	2.28	0.08
	9.	IKEA Industry Slovakia s. r. o.	Trnava	14.16	1.57	0.05
	10.	BPS Vesele, s. r. o.	Piešťany	13.34	1.48	0.05
		TOTAL		**516.02**	**57.36**	**1.95**
Carbon monoxide	1.	Službyt, spol. s r.o.	Senica	175.42	31.16	0.11
	2.	Wienerberger slovenské tehelne, spol. s r.o.	Trnava	48.96	8.70	0.03
	3.	ASTOM ND, s. r. o.	Dunajská Streda	22.24	3.95	0.01
	4.	ENVIRAL, a.s.	Hlohovec	21.26	3.78	0.01
	5.	ASTOM V, s.r.o.	Dunajská Streda	20.24	3.60	0.01
	6.	SLOVENSKÉ CUKROVARY, s.r.o.	Galanta	19.57	3.48	0.01
	7.	Tate & Lyle Boleraz, s.r.o.	Trnava	17.42	3.09	0.01
	8.	IKEA Industry Slovakia s. r. o.	Trnava	17.01	3.02	0.01
	9.	I.D.C. Holding, a.s.	Galanta	12.71	2.26	0.01
	10.	Johns Manville Slovakia, a.s.	Trnava	11.71	2.08	0.01
		TOTAL		**366.54**	**65.11**	**0.24**

***Tab. 6.16** Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2017 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	140.58	32.24	2.72
	2.	Slovenské elektrárne, a.s.	Prievidza	80.87	18.54	1.57
	3.	Považská cementáreň, a.s.	Ilava	50.80	11.65	0.98
	4.	Hornonitrianske bane Prievidza, a.s.	Prievidza	19.73	4.52	0.38
	5.	TERMONOVA, a.s.	Ilava	18.41	4.22	0.36
	6.	Považský cukor a.s.	Trenčín	17.20	3.94	0.33
	7.	CEMMAC a.s.	Trenčín	12.24	2.81	0.24
	8.	KVARTET,a.s.	Partizánske	7.24	1.66	0.14
	9.	TEPLÁREŇ Považská Bystrica, s.r.o.	Považská Bystrica	5.47	1.25	0.11
	10.	KAMEŇOLOMY, s.r.o.	Trenčín	3.57	0.82	0.07
		TOTAL		**356.10**	**81.66**	**6.89**
Sulphur oxides as SO_2	1.	Slovenské elektrárne, a.s.	Prievidza	6 862.37	96.87	27.20
	2.	VETROPACK NEMŠOVÁ, s.r.o.	Trenčín	68.99	0.97	0.27
	3.	Považská cementáreň, a.s.	Ilava	35.59	0.50	0.14
	4.	Hornonitrianske bane Prievidza, a.s.	Prievidza	23.77	0.34	0.09
	5.	BIOPLYN HOROVCE 2 s. r. o.	Púchov	9.76	0.14	0.04
	6.	FORTISCHEM a. s.	Prievidza	8.36	0.12	0.03
	7.	BIOPLYN HOROVCE 3, s. r. o.	Púchov	7.04	0.10	0.03
	8.	CEMMAC a.s.	Trenčín	6.34	0.09	0.03
	9.	Bioplyn Horovce, s. r. o.	Púchov	6.02	0.09	0.02
	10.	BPS Myjava, s. r. o.	Myjava	5.13	0.07	0.02
		TOTAL		**7 033.37**	**99.28**	**27.87**
Nitrogen oxides as NO_2	1.	Slovenské elektrárne, a.s.	Prievidza	1 689.44	43.08	6.38
	2.	CEMMAC a.s.	Trenčín	567.07	14.46	2.14
	3.	Považská cementáreň, a.s.	Ilava	565.19	14.41	2.13
	4.	RONA, a.s.	Púchov	234.47	5.98	0.89
	5.	VETROPACK NEMŠOVÁ, s.r.o.	Trenčín	197.08	5.03	0.74
	6.	FORTISCHEM a. s.	Prievidza	75.05	1.91	0.28
	7.	TEPLÁREŇ Považská Bystrica, s.r.o.	Považská Bystrica	58.27	1.49	0.22
	8.	Výroba tepla, s. r. o.	Trenčín	46.00	1.17	0.17
	9.	TERMONOVA, a.s.	Ilava	38.77	0.99	0.15
	10.	Continental Matador Rubber, s.r.o.	Púchov	38.03	0.97	0.14
		TOTAL		**3 509.38**	**89.49**	**13.25**
Carbon monoxide	1.	CEMMAC a.s.	Trenčín	3 500.06	47.97	2.29
	2.	Považská cementáreň, a.s.	Ilava	2 143.56	29.38	1.40
	3.	Slovenské elektrárne, a.s.	Prievidza	508.06	6.96	0.33
	4.	FORTISCHEM a. s.	Prievidza	218.67	3.00	0.14
	5.	Považský cukor a.s.	Trenčín	172.84	2.37	0.11
	6.	Technické služby mesta Partizánske, s r. o.	Partizánske	113.20	1.55	0.07
	7.	ENGIE Services a.s.	Myjava	80.07	1.10	0.05
	8.	TEPLÁREŇ Považská Bystrica, s.r.o.	Považská Bystrica	70.70	0.97	0.05
	9.	KVARTET,a.s.	Partizánske	40.77	0.56	0.03
	10.	Výroba tepla, s. r. o.	Trenčín	40.63	0.56	0.03
		TOTAL		**6 888.56**	**94.42**	**4.51**

Tab. 6.17 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2017 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	165.93	44.92	3.21
	2.	SLOVINCOM, spol. s r.o.	Komárno	13.52	3.66	0.26
	3.	DECODOM, spol. s r. o.	Topoľčany	10.58	2.86	0.20
	4.	Kameňolomy a štrkopieskovne, a.s.	Nitra	8.98	2.43	0.17
	5.	SLOVENSKÉ ENERGETICKÉ STROJÁRNE a.s.	Levice	8.83	2.39	0.17
	6.	P.G.TRADE, spol. s r.o.	Nové Zámky	7.93	2.15	0.15
	7.	MENERT - THERM, s.r.o.	Šaľa	7.43	2.01	0.14
	8.	Prvá energetická a teplárenská spoločnosť, s.r.o.	Zlaté Moravce	7.14	1.93	0.14
	9.	SLOVINTEGRA ENERGY, a.s.	Levice	6.63	1.79	0.13
	10.	TOP PELET, s.r.o.	Topoľčany	5.74	1.56	0.11
		TOTAL		**242.71**	**65.70**	**4.70**
Sulphur oxides as SO_2	1.	P.G.TRADE, spol. s r.o.	Nové Zámky	14.12	13.22	0.06
	2.	AT GEMER, spol. s r.o.	Nové Zámky	10.39	9.73	0.04
	3.	GAS PROGRES I., spol. s r.o.	Nitra	10.30	9.64	0.04
	4.	BIOGAS, s.r.o.	Nitra	9.48	8.87	0.04
	5.	Liaharenský podnik Nitra, a.s.	Levice	8.38	7.84	0.03
	6.	BIONOVES, s.r.o.	Nitra	8.30	7.77	0.03
	7.	Bioplyn Cetín, s. r. o.	Nitra	8.22	7.70	0.03
	8.	BPS Lipová 1 s.r.o.	Nové Zámky	6.77	6.34	0.03
	9.	BPS Veľké Ripňany s.r.o.	Topoľčany	3.75	3.51	0.01
	10.	Ministerstvo obrany Slovenskej republiky	Nitra	3.04	2.85	0.01
		TOTAL		**82.76**	**77.45**	**0.33**
Nitrogen oxides as NO_2	1.	Duslo, a.s.	Šaľa	646.06	41.72	2.44
	2.	BIOENERGY TOPOĽČANY s.r.o.	Topoľčany	186.73	12.06	0.71
	3.	SLOVINTEGRA ENERGY, a.s.	Levice	76.76	4.96	0.29
	4.	Bytkomfort, s.r.o.	Nové Zámky	44.32	2.86	0.17
	5.	VICENTE TORNS SLOVAKIA, a.s.	Komárno	40.28	2.60	0.15
	6.	TOP PELET, s.r.o.	Topoľčany	26.23	1.69	0.10
	7.	DECODOM, spol. s r. o.	Topoľčany	23.75	1.53	0.09
	8.	Wienerberger slovenské tehelne, spol. s r.o.	Zlaté Moravce	22.16	1.43	0.08
	9.	P.G.TRADE, spol. s r.o.	Nové Zámky	21.53	1.39	0.08
	10.	Nitrianska teplárenská spoločnosť, a.s.	Nitra	18.71	1.21	0.07
		TOTAL		**1 106.52**	**71.46**	**4.18**
Carbon monoxide	1.	Calmit, spol. s r.o.	Nitra	1339.72	60.60	0.88
	2.	Bytkomfort, s.r.o.	Nové Zámky	153.56	6.95	0.10
	3.	Duslo, a.s.	Šaľa	99.16	4.49	0.06
	4.	Secop s.r.o.	Zlaté Moravce	60.12	2.72	0.04
	5.	SLOVINTEGRA ENERGY, a.s.	Levice	51.37	2.32	0.03
	6.	Wienerberger slovenské tehelne, spol. s r.o.	Zlaté Moravce	43.43	1.96	0.03
	7.	WOODPAN SLOVAKIA s.r.o.	Nové Zámky	37.65	1.70	0.02
	8.	VICENTE TORNS SLOVAKIA, a.s.	Komárno	26.19	1.18	0.02
	9.	SLOVINCOM, spol. s r.o.	Komárno	22.96	1.04	0.02
	10.	Bioplyn Cetín, s. r. o.	Nitra	20.69	0.94	0.01
		TOTAL		**1 854.85**	**83.90**	**1.21**

***Tab. 6.18** Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2017 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	80.78	21.04	1.56
	2.	DOLVAP, s.r.o.	Žilina	55.60	14.48	1.08
	3.	OFZ, a.s.	Dolný Kubín	27.98	7.29	0.54
	4.	Bekam, s.r.o.	Žilina	19.87	5.18	0.38
	5.	TEHOS, s.r.o.	Dolný Kubín	13.47	3.51	0.26
	6.	D O L K A M Šuja, a.s.	Žilina	11.34	2.95	0.22
	7.	Kia Motors Slovakia s.r.o.	Žilina	10.42	2.71	0.20
	8.	Žilinská teplárenská, a.s.	Žilina	10.07	2.62	0.20
	9.	Martinská teplárenská, a.s.	Martin	7.74	2.02	0.15
	10.	LMT, a. s.	Liptovský Mikuláš	7.16	1.87	0.14
		TOTAL		**244.44**	**63.66**	**4.73**
Sulphur oxides *as SO_2*	1.	OFZ, a.s.	Dolný Kubín	805.85	43.41	3.19
	2.	Martinská teplárenská, a.s.	Martin	404.24	21.77	1.60
	3.	Mondi SCP, a.s.	Ružomberok	200.24	10.79	0.79
	4.	Žilinská teplárenská, a.s.	Žilina	190.99	10.29	0.76
	5.	ŽOS Vrútky a.s.	Martin	82.55	4.45	0.33
	6.	SOTE s.r.o.	Čadca	82.25	4.43	0.33
	7.	AFG s.r.o.	Turčianske Teplice	12.74	0.69	0.05
	8.	BPS BORCOVA, s.r.o.	Turčianske Teplice	8.02	0.43	0.03
	9.	ZDROJ MT, spol. s r.o.	Martin	7.85	0.42	0.03
	10.	DOLVAP, s.r.o.	Žilina	7.33	0.39	0.03
		TOTAL		**1 802.05**	**97.07**	**7.14**
Nitrogen oxides *as NO_2*	1.	Mondi SCP, a.s.	Ružomberok	1 102.71	38.95	4.16
	2.	OFZ, a.s.	Dolný Kubín	574.98	20.31	2.17
	3.	Martinská teplárenská, a.s.	Martin	258.00	9.11	0.97
	4.	Žilinská teplárenská, a.s.	Žilina	159.58	5.64	0.60
	5.	Rettenmeier Tatra Timber, s.r.o.	Liptovský Mikuláš	149.45	5.28	0.56
	6.	SPECIALTY MINERALS SLOVAKIA, spol. s r.o.	Ružomberok	62.34	2.20	0.24
	7.	Kia Motors Slovakia s.r.o.	Žilina	45.12	1.59	0.17
	8.	LMT, a. s.	Liptovský Mikuláš	40.13	1.42	0.15
	9.	KYSUCA s.r.o.	Kysucké Nové Mesto	28.63	1.01	0.11
	10.	SOTE s.r.o.	Čadca	26.07	0.92	0.10
		TOTAL		**2 447.01**	**86.44**	**9.24**
Carbon monoxide	1.	OFZ, a.s.	Dolný Kubín	1 310.75	45.48	0.86
	2.	Mondi SCP, a.s.	Ružomberok	479.56	16.64	0.31
	3.	LMT, a. s.	Liptovský Mikuláš	178.96	6.21	0.12
	4.	SOTE s.r.o.	Čadca	105.46	3.66	0.07
	5.	Rettenmeier Tatra Timber, s.r.o.	Liptovský Mikuláš	64.47	2.24	0.04
	6.	ŽOS Vrútky a.s.	Martin	61.22	2.12	0.04
	7.	LEHOTSKY CAPITAL s.r.o.	Liptovský Mikuláš	45.75	1.59	0.03
	8.	TURZOVSKÁ DREVÁRSKA FABRIKA s.r.o.	Čadca	44.09	1.53	0.03
	9.	Žilinská teplárenská, a.s.	Žilina	42.19	1.46	0.03
	10.	PELCKO s.r.o.	Ružomberok	29.84	1.04	0.02
		TOTAL		**2 362.28**	**81.96**	**1.55**

Tab. 6.19** Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2017 at regional level – **Banská Bystrica region.

		Operator	Sources in district	Emissions [t]	Share on total emissions region [%]	Share on total emissions SR [%]
Total suspended particles	1.	Slovalco, a.s.	Žiar nad Hronom	128.09	27.36	2.48
	2.	Zvolenská teplárenská, a.s.	Zvolen	20.57	4.39	0.40
	3.	BUČINA ZVOLEN, a.s.	Zvolen	19.84	4.24	0.38
	4.	Energy Edge ZC s. r. o.	Žarnovica	16.98	3.63	0.33
	5.	Nemak Slovakia s.r.o.	Žiar nad Hronom	14.51	3.10	0.28
	6.	SLOVMAG a.s. Lubeník	Revúca	14.19	3.03	0.27
	7.	Veolia Utilities Žiar nad Hronom, a.s.	Žiar nad Hronom	11.14	2.38	0.22
	8.	LBK PERLIT, s.r.o.	Žiar nad Hronom	10.05	2.15	0.19
	9.	Hontianska energetická, s. r. o.	Veľký Krtíš	9.86	2.11	0.19
	10.	Knauf Insulation, s.r.o.	Žarnovica	9.62	2.05	0.19
		TOTAL		**254.86**	**54.44**	**4.93**
Sulphur oxides *as SO_2*	1.	Slovalco, a.s.	Žiar nad Hronom	2 441.12	65.31	9.67
	2.	Knauf Insulation, s.r.o.	Žarnovica	410.27	10.98	1.63
	3.	Zvolenská teplárenská, a.s.	Zvolen	272.37	7.29	1.08
	4.	KOMPALA a.s.	Banská Bystrica	169.27	4.53	0.67
	5.	Veolia Utilities Žiar nad Hronom, a.s.	Žiar nad Hronom	158.64	4.24	0.63
	6.	SLOVMAG a.s. Lubeník	Revúca	91.45	2.45	0.36
	7.	VUM, a.s.	Žiar nad Hronom	32.38	0.87	0.13
	8.	Železiarne Podbrezová a.s. skrátene ŽP a.s.	Brezno	18.58	0.50	0.07
	9.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	16.54	0.44	0.07
	10.	Calmit, spol. s r.o.	Rimavská Sobota	12.60	0.34	0.05
		TOTAL		**3 623.21**	**96.94**	**14.36**
Nitrogen oxides *as NO_2*	1.	Slovalco, a.s.	Žiar nad Hronom	551.36	17.05	2.08
	2.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	516.51	15.97	1.95
	3.	KOMPALA a.s.	Banská Bystrica	217.28	6.72	0.82
	4.	Veolia Utilities Žiar nad Hronom, a.s.	Žiar nad Hronom	202.54	6.26	0.76
	5.	Zvolenská teplárenská, a.s.	Zvolen	196.58	6.08	0.74
	6.	Železiarne Podbrezová a.s. skrátene ŽP a.s.	Brezno	180.03	5.57	0.68
	7.	Bučina DDD, spol. s r.o.	Zvolen	138.21	4.27	0.52
	8.	Energy Edge ZC s. r. o.	Žarnovica	127.29	3.94	0.48
	9.	SLOVMAG a.s. Lubeník	Revúca	120.58	3.73	0.46
	10.	BUČINA ZVOLEN, a.s.	Zvolen	94.31	2.92	0.36
		TOTAL		**2 344.68**	**72.49**	**8.85**
Carbon monoxide	1.	Slovalco, a.s.	Žiar nad Hronom	16 552.21	85.85	10.84
	2.	Slovenské magnezitové závody, a.s. Jelšava	Revúca	707.98	3.67	0.46
	3.	SLOVMAG a.s. Lubeník	Revúca	353.96	1.84	0.23
	4.	VUM, a.s.	Žiar nad Hronom	277.97	1.44	0.18
	5.	Železiarne Podbrezová a.s. skrátene ŽP a.s.	Brezno	187.79	0.97	0.12
	6.	Calmit, spol. s r.o.	Rimavská Sobota	109.28	0.57	0.07
	7.	Veolia Utilities Žiar nad Hronom, a.s.	Žiar nad Hronom	108.51	0.56	0.07
	8.	Bučina DDD, spol. s r.o.	Zvolen	71.36	0.37	0.05
	9.	Energy Edge ZC s. r. o.	Žarnovica	67.22	0.35	0.04
	10.	TUBEX SLOVAKIA, s.r.o.	Žarnovica	46.89	0.24	0.03
		TOTAL		**18 483.18**	**95.87**	**12.10**

***Tab. 6.20** Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2017 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	44.09	22.85	0.85
	2.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	31.70	16.43	0.61
	3.	BIOENERGY BARDEJOV, s.r.o.	Bardejov	9.12	4.72	0.18
	4.	BYTENERG spol. s r.o.	Medzilaborce	7.41	3.84	0.14
	5.	TATRAVAGÓNKA a.s.	Poprad	5.68	2.94	0.11
	6.	IS-LOM s.r.o., Maglovec	Prešov	4.82	2.50	0.09
	7.	LOMY, s. r. o.	Prešov	4.26	2.21	0.08
	8.	VSK MINERAL s.r.o.	Vranov nad Topľou	3.93	2.04	0.08
	9.	SPRAVBYTKOMFORT a.s. Prešov	Prešov	3.49	1.81	0.07
	10.	Ministerstvo obrany Slovenskej republiky	Humenné	2.98	1.54	0.06
		TOTAL		**117.47**	**60.89**	**2.27**
***Sulphur oxides** as SO_2*	1.	BUKOCEL, a.s.	Vranov nad Topľou	141.40	46.49	0.56
	2.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	113.52	37.33	0.45
	3.	CHEMES, a.s. Humenné	Humenné	17.63	5.80	0.07
	4.	AGROKOMPLEX, spol. s r.o. Humenné	Humenné	5.31	1.75	0.02
	5.	Centrum sociálnych služieb Spišský Štvrtok, n.o.	Levoča	3.75	1.23	0.01
	6.	Leier Baustoffe SK s.r.o.	Prešov	3.27	1.07	0.01
	7.	BPS Huncovce, s.r.o.	Kežmarok	2.74	0.90	0.01
	8.	BPS Ladomirová, s. r. o.	Svidník	2.33	0.77	0.01
	9.	ZEOCEM, a.s.	Vranov nad Topľou	2.31	0.76	0.01
	10.	Ministerstvo obrany Slovenskej republiky	Humenné	2.31	0.76	0.01
		TOTAL		**294.58**	**96.86**	**1.17**
***Nitrogen oxides** as NO_2*	1.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	325.09	28.90	1.23
	2.	BUKOCEL, a.s.	Vranov nad Topľou	226.50	20.13	0.86
	3.	BIOENERGY BARDEJOV, s.r.o.	Bardejov	104.46	9.28	0.39
	4.	SPRAVBYTKOMFORT a.s. Prešov	Prešov	87.83	7.81	0.33
	5.	CHEMES, a.s. Humenné	Humenné	29.63	2.63	0.11
	6.	CHEMOSVIT ENERGOCHEM, a.s.	Poprad	27.35	2.43	0.10
	7.	Leier Baustoffe SK s.r.o.	Prešov	26.74	2.38	0.10
	8.	Popradská energetická spoločnosť, s.r.o.	Poprad	18.54	1.65	0.07
	9.	AGROKOMPLEX, spol. s r.o. Humenné	Humenné	12.68	1.13	0.05
	10.	BYTENERG spol. s r.o.	Medzilaborce	11.60	1.03	0.04
		TOTAL		**870.42**	**77.37**	**3.29**
Carbon monoxide	1.	Leier Baustoffe SK s.r.o.	Prešov	375.60	31.61	0.25
	2.	BUKÓZA ENERGO, a. s.	Vranov nad Topľou	232.39	19.56	0.15
	3.	BUKOCEL, a.s.	Vranov nad Topľou	110.26	9.28	0.07
	4.	Schüle Slovakia, s.r.o.	Poprad	85.84	7.22	0.06
	5.	Teplo GGE s. r. o.	Snina	36.90	3.10	0.02
	6.	SPRAVBYTKOMFORT a.s. Prešov	Prešov	30.73	2.59	0.02
	7.	Spravbytherm s.r.o.	Kežmarok	24.42	2.05	0.02
	8.	BYTENERG spol. s r.o.	Medzilaborce	22.12	1.86	0.01
	9.	BIOENERGY BARDEJOV, s.r.o.	Bardejov	21.34	1.80	0.01
	10.	Popradská energetická spoločnosť, s.r.o.	Poprad	13.12	1.10	0.01
		TOTAL		**952.71**	**80.17**	**0.62**

Tab. 6.21 *Total suspended particles, Sulphur oxides, Nitrogen oxides and Carbon monoxide released from stationary sources of most significant operators in 2017 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	2 663.83	91.64	51.58
	2.	Slovenské elektrárne, a.s.	Michalovce	34.81	1.20	0.67
	3.	CRH (Slovensko) a.s.	Košice - okolie	31.65	1.09	0.61
	4.	Carmeuse Slovakia, s.r.o.	Košice - okolie	21.80	0.75	0.42
	5.	SYRÁREŇ BEL SLOVENSKO a.s.	Michalovce	20.58	0.71	0.40
	6.	KOVOHUTY, a.s.	Spišská Nová Ves	9.39	0.32	0.18
	7.	Mesto Sobrance	Sobrance	9.36	0.32	0.18
	8.	Tepelné hospodárstvo Moldava, a.s.	Košice - okolie	9.01	0.31	0.17
	9.	EUROCAST Košice, s.r.o.	Košice II	8.92	0.31	0.17
	10.	Carmeuse Slovakia, s.r.o.	Košice II	8.15	0.28	0.16
		TOTAL		**2 817.50**	**96.92**	**54.55**
Sulphur oxides as SO_2	1.	U. S. Steel Košice, s.r.o.	Košice II	8 019.05	88.43	31.78
	2.	Slovenské elektrárne, a.s.	Michalovce	385.89	4.26	1.53
	3.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	229.15	2.53	0.91
	4.	Ferroenergy s.r.o.	Košice II	154.67	1.71	0.61
	5.	KOVOHUTY, a.s.	Spišská Nová Ves	76.69	0.85	0.30
	6.	TP 2, s.r.o.	Michalovce	63.03	0.70	0.25
	7.	Slovenské magnezitové závody, a.s. Jelšava	Košice II	52.57	0.58	0.21
	8.	Carmeuse Slovakia, s.r.o.	Košice II	9.47	0.10	0.04
	9.	CO.BE.R. spol. s r.o.	Sobrance	8.69	0.10	0.03
	10.	RMS, a.s. Košice	Košice II	8.52	0.09	0.03
		TOTAL		**9 007.73**	**99.34**	**35.70**
Nitrogen oxides as NO_2	1.	U. S. Steel Košice, s.r.o.	Košice II	5 886.50	68.92	22.23
	2.	CRH (Slovensko) a.s.	Košice - okolie	833.02	9.75	3.15
	3.	Carmeuse Slovakia, s.r.o.	Košice II	310.06	3.63	1.17
	4.	Tepláreň Košice, a. s. v skratke TEKO, a. s.	Košice IV	275.27	3.22	1.04
	5.	eustream, a. s.	Michalovce	241.47	2.83	0.91
	6.	Ferroenergy s.r.o.	Košice II	227.15	2.66	0.86
	7.	Slovenské elektrárne, a.s.	Michalovce	132.24	1.55	0.50
	8.	Košická energetická spoločnosť, a.s.	Košice IV	54.71	0.64	0.21
	9.	KOSIT a.s.	Košice IV	52.94	0.62	0.20
	10.	Duslo, a.s.	Michalovce	47.38	0.55	0.18
		TOTAL		**8 060.74**	**94.37**	**30.44**
Carbon monoxide	1.	U. S. Steel Košice, s.r.o.	Košice II	113 587.29	97.34	74.38
	2.	KOVOHUTY, a.s.	Spišská Nová Ves	1250.67	1.07	0.82
	3.	Slovenské elektrárne, a.s.	Michalovce	465.06	0.40	0.30
	4.	Slovenské magnezitové závody, a.s. Jelšava	Košice II	213.60	0.18	0.14
	5.	Duslo, a.s.	Michalovce	176.21	0.15	0.12
	6.	CRH (Slovensko) a.s.	Košice - okolie	162.36	0.14	0.11
	7.	Carmeuse Slovakia, s.r.o.	Košice II	117.01	0.10	0.08
	8.	Tepelné hospodárstvo Moldava, a.s.	Košice - okolie	96.04	0.08	0.06
	9.	Embraco Slovakia s.r.o.	Spišská Nová Ves	84.02	0.07	0.06
	10.	eustream, a. s.	Michalovce	77.11	0.07	0.05
		TOTAL		**116 229.38**	**99.60**	**76.11**

6.4.5 Emissions form 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 2017 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	160.892	2 559.081	2 865.904	830.170	0.44	6.96	7.80	2.26
Malacky	50.096	29.980	1 455.850	1 692.256	0.05	0.03	1.53	1.78
Pezinok	10.049	10.045	26.613	54.184	0.03	0.03	0.07	0.14
Senec	5.407	4.437	33.104	26.210	0.02	0.01	0.09	0.07
Dunajská Streda	20.637	19.078	120.980	70.381	0.02	0.02	0.11	0.07
Galanta	39.469	308.835	278.185	81.040	0.06	0.48	0.43	0.13
Hlohovec	10.595	4.863	114.042	40.767	0.04	0.02	0.43	0.15
Piešťany	5.202	7.606	45.111	20.780	0.01	0.02	0.12	0.05
Senica	9.144	16.784	52.838	197.798	0.01	0.02	0.08	0.29
Skalica	7.840	0.333	25.498	12.378	0.02	0.00	0.07	0.03
Trnava	88.036	114.165	263.008	139.843	0.12	0.15	0.35	0.19
Bánovce nad Bebravou	4.225	0.135	16.902	13.855	0.01	0.00	0.04	0.03
Ilava	75.038	38.619	643.643	2 208.760	0.21	0.11	1.80	6.16
Myjava	3.459	5.681	35.338	85.771	0.01	0.02	0.11	0.26
Nové Mesto nad Váhom	6.600	0.329	33.607	21.538	0.01	0.00	0.06	0.04
Partizánske	11.138	8.682	70.434	177.337	0.04	0.03	0.23	0.59
Považská Bystrica	10.107	2.480	66.936	82.152	0.02	0.01	0.14	0.18
Prievidza	271.658	6 901.634	1 833.075	842.433	0.28	7.19	1.91	0.88
Púchov	11.210	40.093	323.997	79.287	0.03	0.11	0.86	0.21
Trenčín	42.659	86.636	897.425	3 784.840	0.06	0.13	1.33	5.61
Komárno	25.312	0.718	116.973	108.496	0.02	0.00	0.11	0.10
Levice	47.788	12.998	168.394	130.121	0.03	0.01	0.11	0.08
Nitra	45.945	47.666	153.462	1 465.518	0.05	0.05	0.18	1.68
Nové Zámky	23.258	34.509	130.547	237.363	0.02	0.03	0.10	0.18
Šaľa	181.205	3.904	677.128	113.538	0.51	0.01	1.90	0.32
Topoľčany	29.108	5.315	260.200	32.373	0.05	0.01	0.44	0.05
Zlaté Moravce	16.800	1.753	41.698	123.364	0.03	0.00	0.08	0.24
Bytča	3.284	1.452	8.397	5.967	0.01	0.01	0.03	0.02
Čadca	5.098	84.171	48.315	167.776	0.01	0.11	0.06	0.22
Dolný Kubín	51.380	806.834	610.305	1 376.191	0.10	1.64	1.24	2.80
Kysucké Nové Mesto	9.345	0.768	43.022	25.774	0.05	0.00	0.25	0.15
Liptovský Mikuláš	35.049	2.276	250.236	346.710	0.03	0.00	0.19	0.26
Martin	25.745	499.269	303.397	127.963	0.03	0.68	0.41	0.17
Námestovo	19.668	21.974	22.927	78.902	0.03	0.03	0.03	0.11
Ružomberok	92.396	203.778	1 198.917	555.599	0.14	0.32	1.85	0.86
Turčianske Teplice	1.942	23.093	31.773	24.877	0.00	0.06	0.08	0.06
Tvrdošín	11.459	2.820	30.539	13.103	0.02	0.01	0.06	0.03
Žilina	128.589	210.004	282.954	159.275	0.16	0.26	0.35	0.20

***Tab. 6.22** Emissions [t] and Specific territorial emissions [t.km^{-2}] of basic pollutants released from large and medium stationary sources in 2017 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	24.417	181.101	364.571	129.215	0.03	0.22	0.45	0.16
Banská Štiavnica	3.892	0.024	4.977	8.214	0.01	0.00	0.02	0.03
Brezno	31.133	28.887	218.043	282.426	0.02	0.02	0.17	0.22
Detva	24.102	0.476	86.969	67.898	0.05	0.00	0.19	0.15
Krupina	4.382	22.584	33.235	29.414	0.01	0.04	0.06	0.05
Lučenec	17.286	9.076	41.446	31.471	0.02	0.01	0.05	0.04
Poltár	3.870	5.756	25.188	50.195	0.01	0.01	0.05	0.11
Revúca	29.793	115.900	687.712	1 106.691	0.04	0.16	0.94	1.52
Rimavská Sobota	17.539	15.301	184.454	154.611	0.01	0.01	0.13	0.11
Veľký Krtíš	19.428	20.240	78.305	60.405	0.02	0.02	0.09	0.07
Zvolen	62.751	286.028	473.573	186.290	0.08	0.38	0.62	0.25
Žarnovica	30.263	410.387	219.579	134.654	0.07	0.96	0.52	0.32
Žiar nad Hronom	199.251	2 641.868	816.615	17 038.802	0.38	5.10	1.58	32.92
Bardejov	11.040	2.733	110.307	25.560	0.01	0.00	0.12	0.03
Humenné	7.628	25.311	53.427	32.523	0.01	0.03	0.07	0.04
Kežmarok	5.672	4.171	32.726	37.413	0.01	0.01	0.05	0.06
Levoča	3.457	3.842	7.960	17.734	0.01	0.01	0.02	0.04
Medzilaborce	7.489	0.011	12.400	23.219	0.02	0.00	0.03	0.05
Poprad	18.986	1.526	99.640	151.866	0.02	0.00	0.09	0.14
Prešov	27.914	4.932	151.445	433.552	0.03	0.01	0.16	0.46
Sabinov	4.036	0.048	15.979	12.390	0.01	0.00	0.03	0.02
Snina	14.291	0.216	36.622	79.764	0.02	0.00	0.05	0.10
Stará Ľubovňa	2.481	0.243	21.023	6.794	0.00	0.00	0.03	0.01
Stropkov	0.359	0.287	3.856	1.491	0.00	0.00	0.01	0.00
Svidník	3.745	3.341	10.338	9.421	0.01	0.01	0.02	0.02
Vranov nad Topľou	85.832	257.452	569.317	356.598	0.11	0.33	0.74	0.46
Gelnica	5.183	1.441	7.049	16.542	0.01	0.00	0.01	0.03
Košice	2 702.993	8 478.243	6 887.833	114 058.573	11.09	34.78	28.26	467.95
Košice-okolie	76.724	29.475	923.552	330.544	0.05	0.02	0.60	0.22
Michalovce	62.649	449.432	511.347	768.020	0.06	0.44	0.50	0.75
Rožňava	19.083	5.374	45.369	71.258	0.02	0.00	0.04	0.06
Sobrance	10.035	16.173	30.996	38.984	0.02	0.03	0.06	0.07
Spišská Nová Ves	19.557	81.146	58.948	1 371.825	0.03	0.14	0.10	2.34
Trebišov	10.763	6.718	76.168	40.973	0.01	0.01	0.07	0.04
SLOVAKIA	**5 164.859**	**25 232.544**	**26 482.645**	**152 720.016**	**0.11**	**0.51**	**0.54**	**3.11**

LIST OF ANNEXES

ANNEX A Measurement stations of monitoring air quality networks – 2018

ANNEX B Pollutant concentrations from continual measurements in NMSKO network – 2018 (graphs of daily averages and daily maxima)