HEALTH RISKS OF AIR POLLUTION IN THE CZECH REPUBLIC IN 2017

Concentrations of airborne pollutants have been obtained from a network of 21 measuring stations operated by health institutes (CSMON) in the monitored cities, and from measuring stations supervised by the Czech Hydrometeorological Institute (CHMI) which correspond to the health monitoring requirements. In 2017, data of 80 urban measuring stations from a total of 63 municipalities and 8 Prague districts were covered for the assessments by the Monitoring System.

For comparison, the evaluation included also data on rural background levels acquired from measurement programmes at two EMEP stations (Co-operative programme for the monitoring and evaluation of the long-range transboundary air pollution in Europe) operated by CHMI in Košetice and Bílý Kříž, data from three background stations with regional significance in Jeseník, Svratouch, and Rudolice v Horách as well as data from traffic 'hot-spots' in Prague, Brno, Ústí n/L, and Ostrava.

Urban airborne pollution

In towns and urban agglomerations, the major long-term sources of airborne pollution are traffic and its associated processes (primary combustion and non-combustion emissions - re-suspension, abrasion, corrosion, etc.) and emissions from small sources. Traffic is a major source of nitrogen oxide, aerosol $PM_{10,}$ $PM_{2.5,}$ and fine particulate matter ($PM_{1.0}$ and other fractions of ultrafine particles), chrome, nickel, lead (resuspended), volatile organic compounds - VOCs (petrol engines), polycyclic aromatic hydrocarbons - PAHs (diesel engines) and, of high importance when considered as a sum, greenhouse gases carbon monoxide and carbon dioxide (approx. 10^2 - 10^3g CO^2/1 km/vehicle). Small/locally significant sources of solid and liquid fossil fuel combustion are or may be non-negligible sources of nitrogen oxide, carbon monoxide, PAHs and particulate matter. A separate issue is presented by the environs of large-scale industrial and power sources or areas loaded by significant long-distance pollution transport such as the Ostrava-Karvina and northern Bohemia agglomeration. The issue remains also the load from secondary pollutants including ozone from emitted precursors (VOCs).

These facts correspond to the level of drawing of the average annual concentration limit values of pollutants in the basic types of urban localities (background, traffic and industrial). While in national rural background measuring stations the levels of the monitored substances were up to 50% of their limit values in 2017, in urban and industrial locations the limits were exceeded even more than doubled in case of PM_{10}, $PM_{2.5}$, benzo[*a*]pyrene and locally also nitrogen dioxide. In 2017, the course of levels in cities was considerably influenced by multi-day smog situation in January and February.

Data on mass concentration are available namely for basic substances which are aerosol PM_{10} and nitrogen dioxide NO_2. According to the equipment of the involved measuring stations the evaluation is supplemented with data on other pollutants. The number of measuring stations, data of which were used to assess the potential population exposure and health impacts is shown for individual pollutants in Tab. 1. Usefulness of the data from the station network operated by the Health Institute in Ustí nad Labem was still influenced by its ongoing reconstruction.

Air quality is processed on two ways. One is aimed at the evaluation as related to the annual limits (AL) as stipulated in Annex no.1 of Act no. 201/2012 Coll. on air protection, and to the reference concentrations (RfK)[1]. The second level targets the air quality assessment in defined types (categories) of urban areas. The assessment criterion included not only the intensity of surrounding traffic, but also the relative proportions of different types of heating systems and possible burden from significant industrial source. Distribution of the location types according to these criteria is presented in Tab. 2. Air quality in the different types of locations is evaluated for health most relevant pollutants NO_2, PM_{10}, As, Cd, Ni, Pb, benzene and BaP.

Tab. 1 The number of measuring stations included in the assessment, 2017

Pollutant	*No. of stations*	*Pollutant*	*No. of stations*
PM_{10}	83	NO	57
$PM_{2,5}$	53	NO_X	60
NO_2	59	CO	11
PAHs	44	O_3	46
Benzene	33	SO_2	38
Metals in $PM_{10-2,5}$ (As, Cr, Cd, Mn, Ni, Pb)			46/5

Tab.2 Categories (types) of urban measurement stations by the source pattern

Category	Description
1	Urban background without major sources (parks, sport grounds etc)
2	Urban residential with local sources REZZO 3, traffic up to 2 thous. vehicles/24h
3	Urban residential without local sources, district heating, traffic up to 2 thous. vehicles/24h
4	Urban residential with both local and district heating, traffic 2-5 thous. vehicles /24h
5	Urban residential with both local and district heating, traffic 5-10 thous. vehicles/24h
6	Urban residential with both local and district heating, traffic over 10 thous. vehicles/24h
7	Urban residential with more than 10 thous. vehicles/24h, transit roads (hot spots)
8	Urban industrial with significant effect of industry, traffic up to 10 thous. vehicles/24h
9	Urban industrial with significant effect of traffic(10 – 25 thous. vehicles/24h)
10	Urban industrial with highly significant effect of traffic (over 25 thous. vehicles/24h)
11	Rural background - forests, parks (out of intravilan), grasslands, uncultivated grounds, water areas, meadows etc)
12	Rural agricultural – impact of agricultural source – cultivated grounds
13	Rural industrial – influence of industry outweigh the effect of traffic
14	Rural industrial with traffic load - influence of traffic outweighing industry
15	Rural residential with low-level effect of traffic (up to 2 thous. vehicles/24 h)
16	Rural residential with medium traffic load (2 – 10 thous.vehicles/24h)
17	Rural residential with high traffic load ((> 10 thous. vehicles/24h)
18	Rural non residential with traffic load (> 10 thous. vehicles/24h), no residential buildings

In addition, the estimate of the burden of the common urban environment (ie. the urban "background", without an extremely heavy transport and industry) was performed. This estimate is based on average annual concentration data obtained from urban monitoring stations in categories 2 – 5. The data of similar urban stations in the Moravian-Silesian region were not included to this estimate due to the higher area burden compared with stations in other regions of the country, and they are evaluated separately.

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[1] actual authorization is set in Act No. 201/2012 Sb., Para. 27.

Primary measured substances

In comparison with 2016, the level of air pollution in 2017 has worsened in most of the monitored parameters; the smog episode at the beginning of the year influenced also the long-term downward trend. Ambient air quality in the residential areas under monitoring is to a great degree influenced by meteorological conditions. They can be characterised by a higher rate of extreme and rapid weather changes including more long-term periods of dry weather with high temperatures, short periods of intense precipitation. Pursuant to 2012 - 2016 the temperature in winter months 2017 was above the average. Airborne pollution in cities and urban agglomerations is primarily caused by traffic as a major and effectively non-point source. Other sources (heating plants, domestic heating and industry) have a more local significance. Extensively burdened by industry Moravian-Silesian Region (MSR), where crucial emissions stem from large industrial sources and the long-range pollution transport, has been showing increased measured values of air pollutants. This is confirmed by annual air pollution characteristics of nitrogen dioxide, PM_{10}, $PM_{2.5}$ and benzo[*a*]pyrene, which not only in urban locations with heavy traffic, but also in industry burdened areas MSR exceed the WHO recommended values and the limit values. On the other hand, the measured values of carbon monoxide and sulphur dioxide at urban stations rarely exceeded the level of 5% of the short-term air pollution limits; insignificantly increased concentrations of sulphur dioxide can be observed at some stations in the MSR. Together with a higher frequency of sunny and tropical days the number of days and areas with elevated concentrations of ground-level ozone has been gradually rising.

Annual arithmetic means of **nitrogen dioxide** did not exceed 8 $\mu g/m^3$ at EMEP background stations; the mean annual value in cities, depending on the intensity of local traffic, ranged from 17 $\mu g/m^3$ in by pollution not significantly burdened areas, over 17 - 30 $\mu g/m^3$ in medium load areas and up to an annual mean of 42 $\mu g/m^3$ in areas heavily burdened by traffic. The highest values have been recorded in 'hot-spots' (in Prague, Ostrava, Brno and Ústí n/L) where mean annual values ranged between 40 and 50 $\mu g/m^3$ (>125% of annual limit 40 $\mu g/m^3$). Resulting nitrogen dioxide pollution in urban areas is associated with traffic, heating plants, domestic heating and namely in the Ostrava-Karviná area also large industrial sources. The situation remains stable on a long-term basis.

The long-term enhanced exposure to suspended particulate matter PM_{10} significantly affected the smog situation in January and February. In 2017, at least 80% of roughly 4.5 million inhabitants of the residential areas under study lived in locations where at least one of exceeding limit criteria was confirmed (in 2016 it was 16%). The annual limit value of 40 $\mu g/m^3$ was exceeded at two measuring stations in Ostrava at Radvanice station (TOREK), where the highest urban value of the annual arithmetic mean (44.4 $\mu g/m^3$) was reached and the station in Věřňovice (TVERA) (41 $\mu g/m^3$). The higher PM_{10} burden in the MSK shows a difference of approximately 8 $\mu g/m^3$ between the estimated annual average concentration for the urban environment: 31.3 $\mu g/m^3$ for the MSK municipalities vs. 23.2 $\mu g/m^3$ for other Czech settlements.

While in 2016 over 35 cases of exceedance of the short-term 24h emission limit (50 $\mu g/m^3$/24h) were detected at 20 stations, this limit was exceeded at 43 stations in 2017. The PM_{10} aerosol particulate matter concentrations in the settlements have fluctuated in the last 10 years without a noticeable trend.

The assessment of exposure to $PM_{2.5}$ suspended particulate matter included 53 stations. The annual limit of 25 µg/m^3 was exceeded at 8 urban stations: in Karviná, Ostrava, Český Těšín, Havířov, Rychvald and Věřňovice. The WHO recommended annual value margin 10 µg/m^3 was exceeded at all measuring stations, including the national background station Košetice (11 µg/m^3). The proportion of $PM_{2.5}$ fraction in PM_{10} ranged from 63% (station in Brno) to 89% (station in Jihlava); the average proportion value reached 77%. This ratio is primarily determined by the composition of concurred sources. It shows significant seasonal dependence - higher $PM_{2.5}$ values in the heating season or during atmospheric inversion ($PM_{2,5} \approx 90\%$). In the period 2007 - 2015, the average $PM_{2,5}/PM_{10}$ ratio ranged between 72% and 76%.

Heavy metals in PM_{10} suspended fractions

The levels of airborne pollution by heavy metals were without significant fluctuation in the majority of the monitored urban localities. Good correlation of annual arithmetical and geometrical means of Pb, As, Cd, Cr, and Mn in most areas denotes a relative stability and homogeneity of the emission values measured in cities without great seasonal, climactic or other variations. The nickel concentrations have been steadily declining in the last years.

Concentrations of As, Cd, Ni and Pb in residential areas are roughly about 2 – 3 fold higher than natural rural background values. Elevated As values occurs near major industrial sources at the measuring stations in Ostrava (metallurgic plants) and localities prone to large-scale combustion of solid fossil fuels. Higher concentrations of other heavy metals usually are of restricted local incidence and significance. Industrial heavy-load localities in the Ostrava region are characterised by higher levels of Ni, Mn, Cd and Pb, Tanvald and surrounding Cd and Pb. Elevated values are found in areas with old toxic load (Kutná Hora, Příbram) or close to new small and middle-sized metal-industry facilities.

Polycyclic aromatic hydrocarbons

Amongst the organic pollutants monitored in selected localities were compounds having serious health effects - polycyclic aromatic hydrocarbons (PAHs). Although their high-molecular fractions are bound to fine aerosol particles ($PM_{2.5}$ and smaller fractions) they may also occur as vapour. A number of them are classified as mutagens and carcinogens. The estimation of the benzo[*a*]pyrene annual mean values in settlements is fluctuating around 1 to 1.5 ng/m^3 with an insignificant increasing trend in the last 10 years.

Comparison of PAH characteristics collected at measuring stations in different types of urban localities reveals the ongoing combination of effects from two major types of PAHs sources (household heating and traffic). A case in point is the Ostrava-Karviná agglomeration which moreover suffers from emissions of large industrial complexes and by the significant effects of long-range air pollution. The winter period is characterized by the occurrence of episodes of higher concentrations, both due to the increased requirements for energy, and their slower removal from the atmosphere by physical-chemical processes as well.

In 2017, the limit value for **benzo[*a*]pyrene** (BaP) was exceeded in 29 of the 44 measuring stations (66%). The limit value of 1 ng/m^3/year was exceeded two or threefold in a suburban station in Řeporyje, a rural suburban station in Kladno Švermov. By more than 50% the limit was exceeded in all stations in the Moravian-Silesian Region, of those almost fivefold in station in Ostrava and in Český Těšín, and more than ninefold in Ostrava-Radvanice. The lowest values obtained in settlements (in Ústí nad Labem - Kočkov and in Brno – Líšeň 0.6

ng/m^3/year) are comparable to the values at the national background stations (0.5 to 0.6 ng/m^3/year).

PAH compounds comprise a number of substances of which some are classified as probable carcinogens with health effects of diverse impact. Estimates of the overall carcinogenic potential of airborne PAH compounds are based on comparison of potential carcinogenic effects of monitored substances with that of the most toxic and best known representative - benzo[*a*]pyrene (BaP). The estimate is therefore expressed as the **toxic equivalent of benzo[α]pyrene (TEQ BaP)** and is calculated as the sum of products of toxic equivalent factors (TEF), as determined by US EPA and the concentrations measured.

TEQ BaP values show large differences between measurement coverage areas. The level of the burden of the source-directly not affected background sites in the Czech Republic can be estimated from the TEQ BaP annual arithmetic mean value at background stations - 0.77 ng TEQ/m^3 in 2017. The highest annual values above10 ng/m^3 (13.34 ng TEQ/m^3 in 2017) have been found in the long term at the Ostrava-Radvanice (TOREP) station, representing the vicinity of a major industrial source. Also at four other industry-affected stations in the Moravian-Silesian Region (Karviná, Ostrava, Český Těšín) several times higher values (≥ 5 ng/m^3/year TEQ BaP) were found than in other urban stations where the TEQ BaP annual values reached 3.6 ng/m^3, independently of the traffic burden level. The potential impact of small local solid fuel sources in small settlements is well illustrated by values between 3.2 to 6 ng TEQ/m^3/year at stations in Kladno - Švermov, Brandýs n/L and at suburban station in Prague 5 Řeporyje.

Volatile organic compounds

The concentration of benzene was monitored at 33 stations in the CHMI network in 2017. The annual benzene limit amount to 5 µg/m^3. The data confirm the crucial importance of industrial production and secondary transport (despite a significant reduction in the benzene content of motor gasoline) as the largest sources of volatile organic compounds and, in particular, benzene into the air. In 2017, the annual levels of benzene in the measured urban areas were in the range of 0.7 - 3.8 µg/m^3; the highest values were measured at three stations in Ostrava where the annual average ranged between 2 and 3.8 µg/m^3.