HEALTH RISKS OF AIR POLLUTION IN THE CZECH REPUBLIC

Environmental health monitoring in CR includes the monitoring of selected quality indicators of outdoor and indoor air quality. 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) within the Automated Immission Monitoring (AIM). In 2016, data from 94 urban measuring stations which fulfil the requirements of the monitoring system were processed. A total of 77 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.

1. 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). 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. 1.1. Usefulness of the data from the station network operated by the Health Institute in Ustí nad Labem was influenced by its ongoing reconstruction.

Tab. 1.1 The number of measuring stations included in the assessments, 2016

Pollutant	*No. of stations*	*Pollutant*	*No. of stations*
PM_{10}	118	NO	63
$PM_{2,5}$	70	NO_X	65
NO_2	65	CO	13
PAHs	43	O_3	48
Benzene	34	SO_2	42
Metals in PM_{10} (As, Cr, Cd, Mn, Ni, Pb)			46

Air quality is processed on two levels. The first level 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. 1.2. 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. 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.

Tab. 1.2 Categories (types) of urban measurement stations by the pattern of pollution sources

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*

1.1 Primary measured substances

In comparison with the previous year, the level of air pollution in 2016 improved slightly in most of the monitored parameters; nevertheless the measured values do not deviate from the long-term 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; compared to 2012, trend of reducing the number of winter inversions has been continuing. Pursuant to the heating seasons 2012 - 2015 the winter 2016 can be considered as very mild. Airborne pollution in cities and urban

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

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 6 $\mu g/m^3$ at EMEP background stations; the mean annual value in cities, depending on the intensity of local traffic, ranged from 16 $\mu g/m^3$ in by pollution not significantly burdened areas, over 20 - 30 $\mu g/m^3$ in medium load areas and up to an annual mean of 45 $\mu g/m^3$ 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 60 $\mu g/m^3$ (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.

Exposure to elevated values of **PM_{10} suspended aerosol fractions** in cities is of a non-point character and an estimated 16% of the 4.5 million inhabitants of the residential areas under study lived in locations where at least one of the criteria of exceeded limits is confirmed. 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 (17% of measuring stations from a total of 115 evaluations). The annual limit (40 $\mu g/m^3$) was exceeded at single station in Ostrava-Radvanice, where the highest urban value of the annual arithmetical mean was recorded (41.1 $\mu g/m^3$). Increased burden with PM_{10} aerosol fractions in the MSR Region is highlighted by a difference of roughly 7 $\mu g/m^3$ of the annual mean between estimates of average annual values for common urban environment 28 $\mu g/m^3$ in MSR and 21 $\mu g/m^3$ in other areas in the Czech Republic.

In individual types of urban areas, depending on the intensity of local traffic, the PM_{10} mean annual value ranged:

- on the level about 21 $\mu g/m^3$ (26 $\mu g/m^3$ in MSR) in localities with not direct traffic load (categories 2 and 3);

- between 18 and 21 $\mu g/m^3$ (34 $\mu g/m^3$ in MSR) of the annual mean in heavily traffic areas (categories 4 and 6);

- up to 21 – 27 $\mu g/m^3$ (41 $\mu g/m^3$ in MSR) of the annual mean in localities heavily burdened by industry (categories 8 to 10).

In 2016, the WHO recommended PM_{10} limit value of 20 $\mu g/m^3$/year was exceeded in 80 out of 104 evaluated measuring stations. Environmental load caused by PM_{10} aerosol fractions has a tendency to be stable in the long-term in the last decade. The annual arithmetic mean at nationwide and regional background CHMI stations (Košetice, Rudolice v Horách and

Jeseník) ranged from 7 to 19 μg/m^3. The daily limit was exceeded only once at the station in Košetice and two times at Jeseník station.

The processing of $PM_{2.5}$ suspended particulate matter included 59 stations, six stations in Prague, five stations in Brno and Ostrava, two in Jihlava, Plzen, Hradec Kralove, Pardubice, Olomouc and in Karvina and one station in another 34 settlements. The annual limit of 25 μg/m^3 was exceeded at 8 municipal stations in the MSK (Karviná, Ostrava, Český Těšín, Havířov, Rychvald and Věřňovice). The 10 μg/m^3 annual average, recommended by the WHO as a limit, has been exceeded at all measuring stations, including the republic background station Košetice (11.3 μg/m^3). The proportion of $PM_{2.5}$ fraction in PM_{10} ranged from 64% (station in Brno) to 89% (station in Opava). This ratio is primarily determined by the composition of concur sources. It shows significant seasonal dependence - higher $PM_{2.5}$ values in the heating season. In the period 2007 - 2015, the average $PM_{2,5}/PM_{10}$ ratio ranged between 72% and 76%. This share grew by less than 3%, from 75% in 2015 to 77.9% in 2016.

1.2 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 five years.

Concentrations of As, Cd, Ni and Pb in residential areas are roughly about 2 – 3 fold higher than natural rural background values recorded at the EMEP stations in Košetice and Bílý Kříž. 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.

1.3 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 downward trend.

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 2016, the limit value for **benzo[α]pyrene** (BaP) was exceeded in 31 of the 41 measuring stations (58%). The limit value of 1 ng/m^3/year was exceeded threefold and more in a suburban station in Řeporyje, a rural suburban station in Kladno Švermov and five stations in the Moravian-Silesian Region (three stations in Ostrava, one station in Karviná and Český Těšín). More than double the annual limit value was measured at five other stations. The lowest values obtained in settlements (in Ústí nad Labem and in Brno - 0.59 to 0.60 ng/m^3/year) are comparable to the values at the national background stations (0.4 to 0.5 ng/m^3/year).

Annual average concentrations of benzo[*a*]pyrene in urban non-industrial and transport localities ranged between 0.5-3.3 ng/m^3, with a mean value of 1.46 ng/m^3. In traffic-loaded localities, values in the summer period were below 0.1 ng/m^3, the annual mean value for this type of site was 1.56 ng/m^3. In industrially exposed locations (chemical industry, metallurgy, etc.), especially in the Ostrava-Karviná basin, the annual mean values were two and more times higher (1.3 to 9 ng/m^3). In addition, they are accompanied by a 24-hour winter maxima in the order of dozens of ng/m^3. In the summer, the measured values there ranged most frequently from 0.1 to 5 ng/m^3, with the exception of two stations near the ArcelorMittal industrial complex in Radvanice-Bartovice with higher BaP values. The average annual value in 2016 for the category of urban areas affected by the industry was estimated at 3.4 ng/m^3.

The importance of small energy sources and long-distance transport at the Košetice national background station (JKOSP) reflects the concentration differences in the order of magnitude between the seasons of the year with higher values measured in heating and in the transition seasons. At moderately traffic loaded urban station in Prague 10 (ASROP), annual averages decreased from 2.5 ng/m^3 in 2006 to 0.71 ng/m^3 in 2015. The decrease is particularly noticeable in the heating and transition seasons. Although the values measured in the non-heating season are comparable to the values in Košetice, they were more than double in the transition and heating seasons. At stations representing different levels of industrial load in the MSK, i.e. in Karviná (TKAOP) and in Ostrava-Radvanice (TOREP - stations in the ArcelorMittal emission plume), the concentrations do not decrease under the value of 0.5 ng/m^3 in the non-heating season, and they reach tens of ng/m^3 in the heating season.

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 (Tab. 1.3.1) and the concentrations measured.

Tab. 1.3.1 Toxic equivalent factors (TEF) for carcinogenic polycyclic aromatic hydrocarbons

	TEF		TEF		TEF
Benzo[a]pyrene	1	*Benzo[b]fluoranthene*	0.1	*Dibenz[ah]anthracene*	1
Benzo[k]fluoranthene	0.01	*Benzo[a]anthracene*	0.1	*Indeno[1.2.3-c.d]pyrene*	0.1
Chrysene	0.01	*Benzo[j]fluoranthene*	0.1		

TEQ BaP values show large differences between measured areas. The highest values (13 ng TEQ/m3/year in 2016) have been found at the Ostrava-Radvanice (TOREP) station, representing the vicinity of a major industrial resource. Also higher values (≥ 5 ng/m3/year of TEQ BaP) were found in the other four industrial districts in Ostrava and the Moravian-Silesian Region than in another urban stations, where annual TEQ BaP values ranged from 0.7 to 3.0 ng/m3. The potential impact of small local solid fuel sources in small settlements is illustrated by the values between 3 to 6 ng TEQ/m3/ year at stations in Kladno - Švermov, Brandýs n/L and in Prague 5 at the suburb station in Řeporyje. The annual arithmetic mean of TEQ BaP at the background urban localities was 0.84 ng TEQ/m3 in 2016.

1.4 Volatile organic compounds

The concentration of benzene was monitored at 32 stations in the CHMI network in 2016. The annual benzene limit amount to 5 $\mu g/m^3$. 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.

The level of air pollution with benzene in the measured urban areas ranged between 0.7-3.3 $\mu g/m^3$/year in 2016, with an annual average of 2 to 3.3 $\mu g/m^3$ at five stations (in the Moravian-Silesian Region). The annual arithmetic mean value at the background stations amounted to 0.6 $\mu g/m^3$. At urban stations not loaded by industry or transport as well as in traffic-loaded areas, the annual average levels ranged from 0.8 to 2.4 $\mu g/m^3$ with a mean value of 1.2-1.3 $\mu g/m^3$/year. In industrially loaded locations (chemical industry, metallurgy, etc.), the highest values in the range of 0.7 to 3.3 $\mu g/m^3$/year have been detected in the long term.

1.5 The evaluation of air quality

The highest exceeding rate of the air pollution limit value was found for benzo[*a*]pyrene (BaP); the average annual concentration in any type of urban area did not fall below the annual limit value, the median values ranged from 113% in urban background transport and industry unloaded sites to the highest (medium) value of 345% valid for Ostrava's urban industrial areas). The average annual PM_{10} concentration draws the limit at the lowest level in urban backgrounds and on the contrary most notably in urban industrial or village localities in MSCs. The same applies to nitrogen dioxide with the extension of traffic-exposed sites.

For a similar description of the situation in small settlements there is still insufficient data, however, the most significant are suspended particles (PM_{10} and $PM_{2.5}$), BaP and arsenic, which sources are predominantly small local sources using solid fuels.

2 HEALTH IMPACTS OF AIR POLLUTION

2.1 The population exposure

Manifestation of the effects of air pollutants on health is dependent on their concentration in the atmosphere and time for which people are exposed to these substances. The real exposure during the day, year and during the life of the individual varies greatly and differs depending on the occupation, lifestyle, and concentrations of substances in various locations and environments.

Concentration ranges characterizing the size of urban air pollution by PM_{10} and nitrogen dioxide (NO_2), and thus the potential exposure of the population is shown in Tab. 2.1.1.

Tab. 2.1.1 The range of PM_{10} and NO_2 annual mean concentrations at the monitoring stations, 2016 (in µg/m^3)

Pollutant	*Rural background*	*Urban environment*		
		Minimum value	*Mean value*	*Maximum value*
Nitrogen dioxide (NO_2)	5.7	11.0	25.6	53.7
Aerosol particles PM_{10}	13.0	15.0	22.4	41.7

2.2 Health effects of air pollution

Particulate matter

Aerosol particles are considered the most significant environmental factor associated with mortality not only due to their carcinogenicity, but also because of their systemic proinflammatory action, creation of oxidative stress, changes of electrical processes in cardiac tissue, role in development of atherosclerosis including calcification of cardiac arteries and other effects. There is sufficient evidence that exposure to air pollution causes development of lung cancer. PM aerosol fractions, as the major components of air pollution, were evaluated by IARC separately leading the same conclusion that they represent proven Class 1 human carcinogens. In 2013, the WHO International Agency for Research on Cancer (IARC) based on an independent review of more than thousand studies classified a mixture of substances that are implicated in air pollution as Class 1 human carcinogens [1].

Long-term exposure to PM air pollution results in increased mortality from cardiovascular and respiratory diseases, including lung cancer, chronic bronchitis, decreased pulmonary function in adults and children, and in other health problems. A limit value of $PM_{2.5}$ that might be considered as safe for human health remains a subject of debate amongst specialists. A recent evaluation of epidemiological studies [2] has failed to reveal such a limit, whereas increased mortality has been correlated with very low $PM_{2.5}$ fractions of e.g. 8.5 µg/m^3 [3]. Additionally, there is a growing body of evidence linking exposure to particulate matter and type 2 diabetes, impaired neurological development in children and neurological dysfunction among adults [2]. Short-term exposure to elevated concentrations of PM plays a role in development of morbidity and mortality namely in cases of cardiovascular and pulmonary disease and associated hospitalization, infant mortality, increased incidence of respiratory symptoms aggravation, particularly among asthma sufferers.

Quantitative estimate of health effect caused by air pollution have been performed as regards to particulate matter exposure. The basic indicator of health effects from long-term exposure is an estimate of premature deaths in adult population aged over 30 years, excluding external death causes (accident, suicide etc.). This indicator therefore includes premature deaths from particular causes (cardiovascular or respiratory disease, lung cancer etc.) as well as deaths resulting from short-term exposure to PM. Estimates were based on the concentration-response function recommended in the WHO HRAPIE project [4].

Using the mean ratio of the $PM_{2.5}$ fraction contained in PM_{10} during the 2011 – 2016 period at a 75% level enables estimation of the increase in (natural) mortality among the exposed adult population as 4.5% for each 10 µg/m^3 of the mean annual concentration in excess of the defined counterfactual level of 13.3 µg/m^3 of PM_{10} fraction. The mean concentration of urban

PM_{10} in 2016 reached 22.4 µg/m^3. The overall mortality rate for the CR population aged over 30 years was therefore increased by 4.11% due to long-term PM_{10} exposure. In view of the range of mean annual concentrations of this pollutant from 13.6 µg/m^3 to 41.1 µg/m^3 at sites in different types of localities, the estimate of the ratio of premature deaths from PM_{10} exposure against overall mortality (natural) ranged from values of less than 1% in urban localities with no traffic load to 13% in the most industrially and traffic burdened localities.

Because at the time of elaborating this report were not available a detailed demographic data for 2016, it was impossible to employ standard procedure using attributive cases method to estimate premature deaths caused by exposure to aerosol particles. The estimate was therefore made using aggregate data on death counts from the Czech Statistical Office database and the estimate of deaths up to 30 years of age and deaths for external causes. An estimation of four thousand premature deaths in 2016 caused by long-term exposure to PM was performed.

Nitrogen dioxide

Nitrogen dioxide as a component of emission from combustion processes is highly correlated with other primary and secondary pollutants, therefore, it cannot be clearly determined whether the observed health impairment arise from independent effect of NO_2 or rather the effect of the whole mixture of substances, in particular aerosol, [5], hydrocarbons, ozone and other substances [6]. The main outcome of short-term exposure to high concentrations of NO_2 is an increase in airway responsiveness; based on the impact on changes in the reactivity in the most sensitive asthmatics the WHO recommended value of 1-hour NO_2 concentration of 200 µg/m^3 was derived. The residents of large urban areas affected by transit and targeted traffic have been highly exposed. The recorded annual average values show that in areas heavily burdened by traffic e.g. in Prague agglomeration, reduced lung function, increased incidence of respiratory diseases, increased incidence of asthmatic aggravation and allergies can be expected both in adults and children.

Although quantitative relationships of exposure and health effects of NO_2 (e.g. on total, cardiovascular and respiratory mortality) have been established, there cannot by clearly determine the degree of overlap between these effects with the effects of other outdoor air pollutants. That's why experts recommend assessing the health impact of air pollution on the basis of relations of suspended particles in which the effects of other pollutants has been involved [4].

Ozone

Ground-level ozone is not emitted directly into the atmosphere. It results from photochemical reactions between oxides of nitrogen and volatile organic compounds. Ozone, which is a typical part of the so-called summer smog episodes, can in the warm season reach the levels affecting health. Ozone has strong irritating effect on the conjunctiva and respiratory tract and at higher concentrations causes breathing problems and mucosal inflammatory response in the airways. Increasingly sensitive to ozone exposure are people with chronic obstructive pulmonary disease and asthma. Short-term and long-term exposure to ozone affects the respiratory morbidity and mortality. Chronic exposure to ozone increases the frequency of hospitalization for asthma exacerbation in children and acute worsening of cardiovascular and respiratory diseases in the elderly [4].

Increase in the daily maximum 8-hour concentration for every 10 µg/m^3 above the level of 70 µg/m^3 results in an increase in overall mortality of 0.3%. The impact on respiratory mortality in the population over 30 years of age is estimated at 1.4% for every 10 µg/m^3 of daily maximum 8-hour average concentrations above 70 µg/m^3 during the period from April to September [4].

Carbon monoxide and sulphur dioxide

Levels of carbon monoxide and sulphur dioxide in outdoor air do not constitute a significant health risk in the measured municipalities, although in the case of sulphur dioxide the threshold effect for 24-h concentration has not been yet detected in epidemiological studies. Sulphur dioxide concentrations occur only occasionally over 40 µg/m^3, which is twice the target value recommended by the WHO with a high degree of precaution.

Metals

There is insufficient scientific evidence concerning the health effects of exposure to airborne heavy metals. Epidemiological studies show the possible influence on the effects of PM_{10} on the cardiovascular system via contained heavy metals including chrome, nickel, cadmium, manganese or mercury [2]. Lead detected in aerosol samples is no longer a health risk in terms of direct exposure since the blanket introduction of lead-free petrol. In terms of carcinogenic effects the detected concentrations of cadmium and arsenic do not represent significant health risks in most areas.

Evaluation of health risks from carcinogens

An estimate of the theoretical increase of cancer risk caused by long-term exposure to pollutants from outdoor air was carried out for arsenic, nickel, BaP and benzene. The estimate is based on the theory of non-threshold effect of carcinogens and takes into account the linear relationship of dose and effect. For the calculation, unit cancer risk values (UCR) were used, these being the magnitude of the risk of increased probability of oncological disease at a life-long exposure to 1 µg/m^3 of the carcinogens in ambient air. The UCR values for the assessment of carcinogens (Tab. 2.2.3.1) were taken from WHO materials (Air Quality Guidelines for Europe, Air Quality Guidelines, Global Update 2005 - Particulate Matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide and other sources (US EPA, HEAST).

Tab. 2.2.1 Unit cancer risk values for the monitored carcinogens

Pollutant	*Arsenic*	*Nickel*	*Benzo[a]pyrene*	*Benzo[a]anthracene*
UCR	1.5E-03	3.8E-04	8.7E-02	1.0E-04
Pollutant	*Benzo[b]fluoranthene*	*Benzo[k]fluoranthene*	*Benzo[ghi]perylene*	*Dibenz[ah]anthracene*
UCR	1.0E-04	1.0E-05	1.0E-06	1.0E-03
Pollutant	*Chrysene*	*Indeno[1.2.3-cd]pyrene*	*Cadmium*	*Benzene*
UCR	1.0E-06	1.0E-04	1.74E-04	6.0E-6

For inhabitants of individual types of urban localities, lifelong exposure to monitored substances was considered and expressed as annual arithmetic means for 2016, allowing calculation of the extent of individual risk.

Tab. 2.2.2 summarizes the results on the individual risk for evaluated chemicals based on recorded concentrations from rural background stations, minimum values of health risk for inhabitants of urban localities with minimal load and maximum values for inhabitants of maximum load urban areas. Mean values of individual risk were calculated on the basis of carcinogen concentrations in all types of the monitored urban localities.

Tab. 2.2.2 The estimate of the individual risk from exposure to airborne carcinogens, in number of cancer cases per 1 mil. population, 2016

Pollutant	*Rural background*	*Urban environment*		
		Minimum value	*Mean value*	*Maximum value*
Arsenic	0.86	0.74	1.95	7.61
Nickel	0.09	0.12	0.27	1.30
Cadmium	0.02	0.02	0.06	0.66
Benzene	3.60	4.20	7.80	19.80
Benzo[a]pyrene	41.76	51.33	155.73	783.00

The theoretical increase of cancer risk caused by exposure to pollutants from the outdoor air has not essentially changed for several years and is in the range of 10^{-7} - 10^{-3} for the different carcinogens (one incremental cancer case per 10 million to 1 thousand population). The greatest long-term contribution is from exposure to carcinogenic polycyclic aromatic hydrocarbons (BaP): in the most burdened industrial urban areas the values attained represent an incremental lifelong cancer risk by almost one case per 1,000 of the population.

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