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An Assessment of Ambient Air Quality in Győr, Hungary

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Abstract **-** This paper presents an assessment of air quality of the city Győr, located 120 km west to the capital of Hungary. Two urban air monitoring stations are operated by the local Environmental Protection Laboratory in the city. The concentration data of major air pollutants (CO, NO_x, SO_2, C_6H_6, O_3, PM_{10}, $PM_{2.5}$), PM_{10}-bound heavy metals (Pb, Cd, As and Ni) and some polycyclic aromatic hydrocarbons (PAHs) including benzo(a)pyrene (BaP), benzo(a)anthracene, sum of three benzofluoranthene (b, k and j) isomers, indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene are available for the assessment based on the latest published monitoring data of the Hungarian Air Quality Monitoring Network. The levels of pollutants were compared with the Hungarian and EU limit or target values defined for health protection and the WHO air quality guidelines (AQGs) or estimated reference levels (RLs). Moreover, the air quality index values for the pollutants were calculated. The results indicated that the main pollutants were BaP, PM_{10} and $PM_{2.5}$ in the Győr atmosphere. The annual mean concentration of PM_{10} and $PM_{2.5}$ aerosols reached the WHO AQGs (20 and 10 μg/m^3), while that of the BaP it was about 5.5 times higher than the WHO RL value of 0.12 ng/m^3. However, a good or excellent air quality was identified for all examined air pollutants based on the concentration data evaluated by the Hungarian and EU limit or target values.

***Keywords*:** Urban, Air Quality, Monitoring, Air Pollutants.

1. Introduction

Urban air pollution is an environmental problem in many cities around the world that has serious immediate and long-term implications for the health of the population and for the physical environment [1]–[8]. It is well-known that air quality in cities is the result of a complex interaction between natural and anthropogenic environmental conditions [1] and [6]–[8]. Moreover, the air pollution path of the urban atmosphere consists of emission and transmission of air pollutants. Nowadays, emissions from motor traffic or different heating systems are very important source groups throughout the world [8]–[10]. However, there are many other anthropogenic air pollution sources in the cities (e.g. power plants, oil refineries, industrial facilities, factories and wood burning fireplaces). Natural sources such as wind-blown dust, wildfires and volcanoes also have an important influence on air quality. The agricultural sector is also a source of air pollution, but it is also impacted by air pollutants [8]. During transmission, air pollutants are dispersed, diluted and subjected to photochemical reactions [1].

Many air quality standards are used to assess single air pollutants, e.g. NAAQS (National Ambient Air Quality Standards) in USA adopted by the Environmental Protection Agency, WHO AQGs (World Health Organization Air Quality Guidelines), EU-standards in Europe or own standards in the different countries [6]–[8] and [11]. In worldwide, the concentrations of the most important pollutants (mainly CO, NO_2, O_3, particulate matter (PM), Pb and SO_2) are routinely recorded at official air quality monitoring stations because of exposure to elevated concentrations of ambient air pollutants causes adverse human health effects [6]–[8] and [11]. However, it cannot be neglected that human beings in cities are exposed not to a single air pollutant alone, but to a mixture of different substances. Additionally, Air Quality Index (AQI) is also applied for the assessment of the air pollution conditions in cities [11]–[14]. There are many air quality indices in use in the world. Commonly, different countries have their own air quality indices (with different denominations), corresponding to different national air quality standards.

The measurement of the most important air pollutant concentrations in Hungary is importance for number of reasons related to human health, the environment and compliance with EU legislation. The Hungarian Air Quality Monitoring Network (HAQMN) provides current and historical air quality monitoring data nationwide [15] and [16]. The network consists of two mayor parts: automatic monitoring stations with continuous measure of wide range of air pollutants in ambient air, and manual system with sampling points and consecutive laboratory analysis. The air monitoring stations in Hungary are operated by the Environmental Protection Laboratories of County Government Offices. A part of the measured data is registered in the European air quality database maintained by the European Environment Agency [8].

The main objective of this work is to evaluate the air quality in Győr (Hungary) on the bases of the reported air pollutant monitoring data for the year 2016 provided by the Hungarian Meteorological Service (HMS) under the HAQMN. This study gives a brief overview of the measured pollutants, concentration levels and air quality status of the city. The concentrations of the measured pollutants were assessed by the Hungarian and EU air quality standards and WHO AQGs or reference levels (RLs). The Hungarian AQI was also applied for the assessment.

2. Material and Methods

2.1. Study Area

Győr is the most important city in northwest Hungary, the capital of Győr-Moson-Sopron County. It has become one of the largest economic, industrial and traffic areas of Hungary. It has an urban population of 130,000 [17]–[19]. There are two permanent air monitoring stations in Győr under the HAQMN. The location of the sites is shown in Fig. 1. The Site-1 (S1) is located along one of the busiest roads in the centre of the city near the bus and train main stations. The Site-2 (S2) is located approximately 3 km south of the city centre [17]–[19]. It was originally classified as an urban background, but nowadays it can be considered to become an urban traffic site.

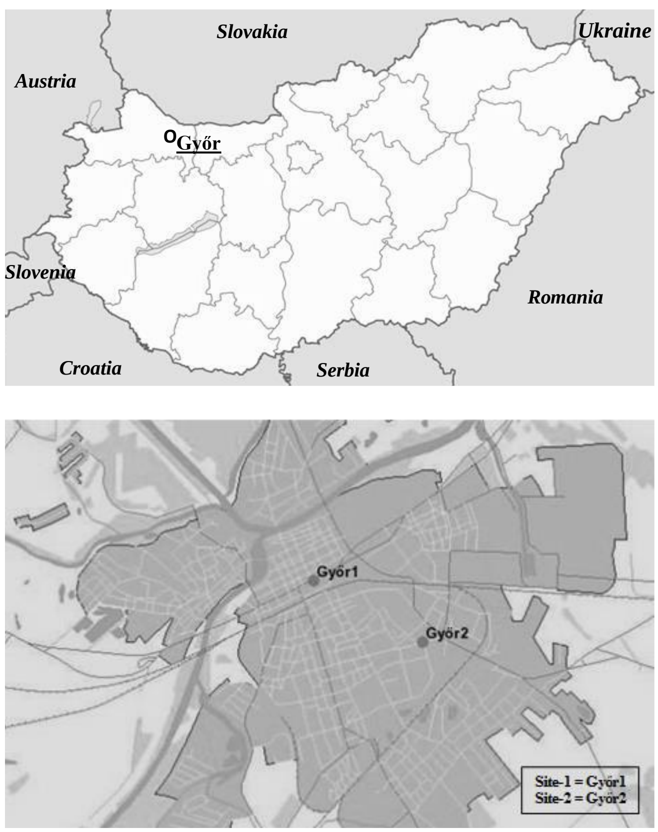

Fig. 1: The location of the monitoring sites in Győr (Hungary).

2.2. Data and Measurements

Table 1 gives an overview on the measured air pollutants in the Győr atmosphere [15] and [16]. Concentration data of NO, NO_2, NO_x (NO + NO_2), SO_2, CO, O_3, PM (with the diameter of 2.5 µm ($PM_{2.5}$) and 10 µm (PM_{10})) and C_6H_6 are collected under the Automatic Monitoring Network (AMN) of the HAQMN. Hourly and 24-hourly concentrations are registered for NO, NO_2, NO_x, SO_2, $PM_{2.5}$, PM_{10}, while hourly and 8-hourly concentrations are provided for CO and O_3 in the database. Annual mean or 8-hour mean concentrations are also reported by the HMS [15].

PM_{10} aerosol sampling is carried out under the Manual Monitoring Network (MMN) of the HAQMN in 4 periods a year for 2 weeks [16]. The concentration of PM_{10} mass and the associated heavy metals (Pb, Cd, As and Ni) and polycyclic aromatic hydrocarbons (PAHs) is monitored. Laboratory analysis are used such as a gravimetric method for PM_{10}, an atomic absorption spectrometry method for heavy metals and a gas chromatography procedure for PAHs including benzo(a)pyrene (BaP), benzo(a)anthracene (BaA), sum of three benzofluoranthene (b, k and j) isomers (BF), indeno(1,2,3-cd)pyrene (IND) and dibenzo(a,h)anthracene (DahA) [17]–[19]. 24-hour sampling was applied in PM_{10} collection procedure. Therefore, the 24-hourly and annual mean concentrations are registered for PM_{10} and the associated measured components in the Hungarian air monitoring database [16]. NO_2 and sediment dust were also monitored in the Győr atmosphere with manual measuring system. However, these data were not evaluated in the present study.

Table 1: The monitoring air pollutants in the Győr atmosphere evaluated in this study.

Pollutants	**Monitoring station**	**Main characteristics**
NO	S1, S2	Automatic continuous measuring system
NO_2	S1, S2	Automatic continuous measuring system
NO_x	S1, S2	Automatic continuous measuring system
SO_2	S1, S2	Automatic continuous measuring system
CO	S1, S2	Automatic continuous measuring system
O_3	S1, S2	Automatic continuous measuring system
$PM_{2.5}$	S1	Automatic continuous measuring system
PM_{10}	S1, S2	Automatic continuous measuring system and 4 periods a year for 2 weeks in MMN[b]
C_6H_6	S2	Automatic continuous measuring system
Pb[a]	S2	4 periods a year for 2 weeks in MMN[c]
Cd[a]	S2	4 periods a year for 2 weeks in MMN[c]
As[a]	S2	4 periods a year for 2 weeks in MMN[c]
Ni[a]	S2	4 periods a year for 2 weeks in MMN[c]
BaA[a]	S2	4 periods a year for 2 weeks in MMN[c]
BbkjF[a]	S2	4 periods a year for 2 weeks in MMN[c]
IND[a]	S2	4 periods a year for 2 weeks in MMN[c]
DahA[a]	S2	4 periods a year for 2 weeks in MMN[c]
BaP[a]	S2	4 periods a year for 2 weeks in MMN[c]

[a] PM_{10}-bound

[b] The collected filter samples (24-hour sampling) were analysed by gravimetric method [17]

[c] Laboratory analysis of PM_{10} filter samples [17]–[19]

3. Results and Discussions

3.1. Concentration Levels of Air Pollutants

The legal standards for the measured pollutants set by the Ambient EU Air Quality Directives and the AQGs or RLs set by the WHO can be found in Table 2 [6]–[8], [20] and [21]. The Hungarian air quality limit and target values are also shown in Table 2 [22]. Most of the Hungarian standards are consistent with the EU standards. Generally, in Hungary the concentration data of air pollutant are assessed by the Hungarian standards [15] and [16]. However, in this study the EU standards and WHO AQGs or RLs are also used for the assessment.

The concentrations of the measured air pollutants in the Győr atmosphere are given in Table 3 [15] and [16]. The percentage of total examined samples exceeded the Hungarian standards is shown in Fig. 2. The concentration levels in only some NO_2, PM_{10} and O_3 samples determined under the AMN were higher than the Hungarian standards at both monitoring sites. Only some samples exceeded the hourly NO_2 limit value of 100 µg/m^3. However, the maximum hourly concentration (120.7 µg/m^3) was under the EU limit and the equal WHO AQG value of 200 µg/m^3. The 24-hourly PM_{10} concentration was above the information threshold value of 75 µg/m^3 in only one day at Site-2.

Table 2: The EU and Hungarian air quality limit or target values and the WHO AQGs or estimated RLs [6]–[8] and [20]–[22].

Pollutants	EU standards	Hungarian standards	WHO recommendations
NO_2	Hourly limit value: 200 µg/m^3 [a] Annual mean limit value: 40 µg/m^3	Hourly limit value: 100 µg/m^3 [a] Daily limit value: 85 µg/m^3 Annual mean limit value: 40 µg/m^3	Hourly AQG: 200 µg/m^3 [a] Annual mean AQG: 40 µg/m^3
SO_2	Hourly limit value: 350 µg/m^3 [b] Daily limit value: 125 µg/m^3 [c]	Hourly limit value: 250 µg/m^3 [b] Daily limit value: 125 µg/m^3 [c] Annual mean limit value: 50 µg/m^3	10 minutely AQG: 500 µg/m^3 [b] Daily AQG: 20 µg/m^3 [c]
CO	Maximum daily 8-hour mean limit value: 10 mg/m^3	Hourly limit value: 10 mg/m^3 Maximum daily 8-hour mean limit value: 5 mg/m^3 Annual mean limit value: 3 mg/m^3	Hourly AQG: 30 mg/m^3 Maximum daily 8-hour mean AQG: 10 mg/m^3
O_3	Maximum daily 8-hour mean target value: 120 µg/m^3 [d]	Maximum daily 8-hour mean target value: 120 µg/m^3 [d]	Maximum daily 8-hour mean AQG: 100 µg/m^3
$PM_{2.5}$	Annual mean limit value: 25 µg/m^3	Annual mean limit value: 25 µg/m^3	Daily AQG: 25 µg/m^3 [g] Annual mean AQG: 10 µg/m^3
PM_{10}	Daily limit value: 50 µg/m^3 [e] Annual mean limit value: 40 µg/m^3	Daily limit value: 50 µg/m^3 [e] Annual mean limit value: 40 µg/m^3	Daily AQG: 50 µg/m^3 [g] Annual mean AQG: 20 µg/m^3
C_6H_6	Annual mean limit value: 5 µg/m^3	Daily limit value: 10 µg/m^3 Annual mean limit value: 5 µg/m^3	Annual mean RL: 1.7 µg/m^3 [h]
Pb	Annual mean limit value: 500 ng/m^3 [f]	Annual mean limit value: 300 ng/m^3	Annual mean AQG: 500 ng/m^3
Cd	Annual mean target value: 5 ng/m^3 [f]	Annual mean limit value: 5 ng/m^3 [f] Annual mean target value: 5 ng/m^3 [f]	Annual mean AQG: 5 ng/m^3 [i]
As	Annual mean target value: 6 ng/m^3 [f]	Annual mean limit value: 10 ng/m^3 [f] Annual mean target value: 6 ng/m^3 [f]	Annual mean RL: 6.6 ng/m^3 [h]
Ni	Annual mean target value: 20 ng/m^3 [f]	Annual mean limit value: 25 ng/m^3 [f] Annual mean target value: 20 ng/m^3 [f]	Annual mean RL: 25 ng/m^3 [h]
BaP	Annual mean target value: 1 ng/m^3 [f]	Daily limit value: 1 ng/m^3 [f] Annual mean limit value: 1.2 ng/m^3 [f] Annual mean target value: 1 ng/m^3 [f]	Annual mean RL: 0.12 ng/m^3 [h]

[a] Not to be exceeded on more than 18 hours per year
[b] Not to be exceeded on more than 24 hours per year
[c] Not to be exceeded on more than 3 days per year
[d] Not to be exceeded on more than 25 days per year, averaged over 3 years
[e] Not to be exceeded on more than 35 days per year
[f] Measured as content in PM_{10}
[g] 99th percentile (3 days per year)
[h] As the WHO has not set an AQG for C_6H_6, As, Ni and BaP, the RL was estimated assuming an acceptable risk of additional lifetime cancer risk of approximately 1 in 100 000
[i] AQG set to prevent any further increase of Cd in agricultural soil, likely to increase the dietary intake of future generations [8]

Table 3: Concentrations of the air pollutants in the Győr atmosphere [15] and [16].

Pollutants	**Site-1**					**Site-2**				
	Annual mean	**1-hour max.**	**24-hour max.**	**8-hour mean**	**8-hour max.**	**Annual mean**	**1-hour max.**	**24-hour max.**	**8-hour mean**	**8-hour max.**
					μg/m^3					
NO_2	29.9	120.7	63.6	–	–	24.8	106.2	52.4	–	–
NO_x	53.1	595.2	214.4	–	–	42.3	623.8	195.5	–	–
SO_2	3.9	17	11	–	–	2.4	30.9	7.6	–	–
CO	523	2132	–	642	1402	455	3005	–	585	1851
O_3	38	127.1	–	55.5	120.7	45.4	137.6	–	65.6	135
$PM_{2.5}$	10	97	33	–	–	–	–	–	–	–
PM_{10}[a]	19	178	52	–	–	21	214	79	–	–
PM_{10}[b]	–	–	–	–	–	16.83	–	49.71	–	–
C_6H_6	–	–	–	–	–	0.5	15.6	9.1	–	–
					ng/m^3					
Pb	–	–	–	–	–	3.54	–	21.31	–	–
Cd	–	–	–	–	–	0.25	–	0.57	–	–
As	–	–	–	–	–	0.83	–	1.54	–	–
Ni	–	–	–	–	–	1.09	–	1.24	–	–
BaA	–	–	–	–	–	0.73	–	4.28	–	–
BF	–	–	–	–	–	2.07	–	8.72	–	–
IND	–	–	–	–	–	1.06	–	5.16	–	–
DahA	–	–	–	–	–	0.15	–	3	–	–
BaP	–	–	–	–	–	0.66	–	4.44	–	–

–: Not measured component at the monitoring site or no data for the pollutant as there is no air quality standard or not measured for the time periods (see also Tables 1 and 2)

[a] Data based on the AMN

[b] Data based on the MMN

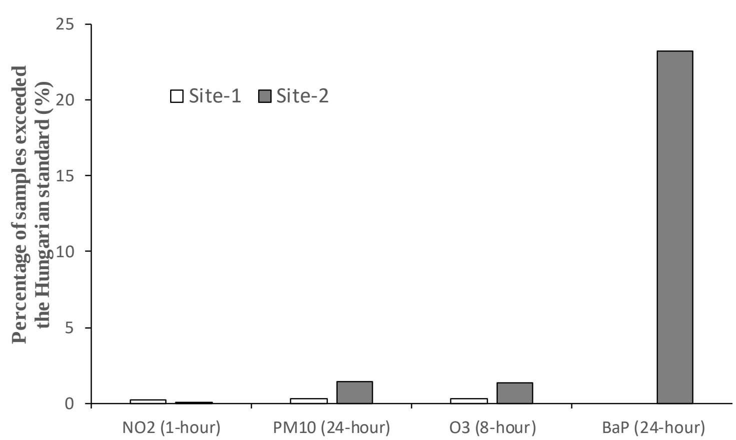

Fig. 2: Percentage of total samples exceeded the Hungarian air quality standards for pollutant.

The annual mean PM_{10} concentration calculated for both sites was 20 μg/m^3, which is equal with the WHO AQG value. However, it is two times less than the EU or Hungarian limit value. The annual mean $PM_{2.5}$ concentration at Site-2 was also reached the WHO AQG value of 10 μg/m^3 (40 % of the EU or Hungarian limit value). The SO_2, CO, C_6H_6 and all heavy metals were observed in low concentration levels. However, 23 % of total samples for BaP exceeded the daily Hungarian limit value of 1 ng/m^3 defined for health protection (Fig. 2). The annual mean concentration of BaP in Győr 2016 was 5.5 times higher than the WHO RL value of 0.12 ng/m^3.

In our previously studies on ambient concentrations of PM10-bound PAHs in the urban atmosphere of Győr we have reported that significantly higher concentrations of PAHs including BaP were detected in samples collected in the heating seasons compared with non-heating periods [17]–[19]. Moreover, our studies have highlighted that the annual average BaP concentrations at the individual urban sites around Hungary often exceeded the EU target value of 1 ng/m^3.

Some other PAH compounds are also monitored. However, there are no air quality standards for them. Therefore, the BaP-equivalent concentrations were calculated in this study according to the BaP-equivalent carcinogenic potency index (BaPE) equation, as in (1) [17] and [18].

$$\mathrm{BaPE} = \mathrm{BaA} \cdot 0.06 + \mathrm{BF} \cdot 0.07 + \mathrm{BaP} + \mathrm{DahA} \cdot 0.6 + \mathrm{IND} \cdot 0.08 \quad (1)$$

This index has been proposed to parameterize aerosol carcinogenicity better than having recourse to the BaP alone. The mean concentration of PAH compounds was multiplied with its carcinogenic factor. The calculated mean BaPE concentration reached the value of 1 ng/m^3. Fig. 3 is illustrated that the highest contribution to BaPE concentration was BaP (0.66 ng/m^3) followed by BF (0.14 ng/m^3), DahA (0.09 ng/m^3), IND (0.08 ng/m^3) and BaA (0.04 ng/m^3).

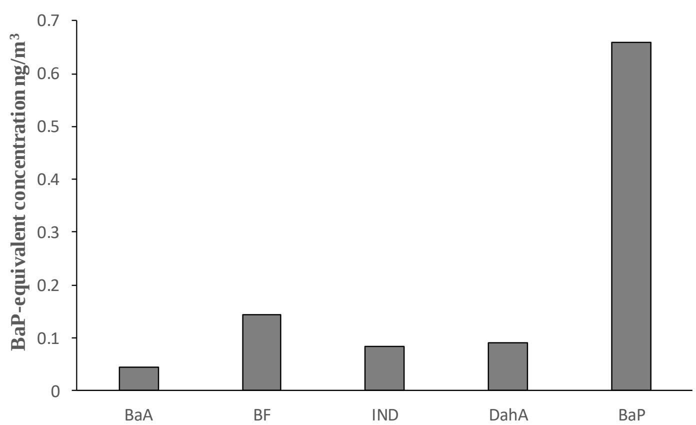

Fig. 3: BaP-equivalent PM10-bound PAH concentrations in Site-2 of Győr.

3.2. Air Quality Index Values

In the present study, AQI values have been calculated using the Hungarian procedure to assess the status of ambient air quality [15] and [16]. This index has a five–step scale and can be expanded by all measured pollutants. The categories can be calculated by the percentage (%) of the air quality standards (1. Excellent 0–40; 2. Good 40–80; 3. Moderate 80–100; 4. Polluted 100–200; 5. Heavily polluted 200–). Originally the Hungarian AQI procedure is based on the Hungarian air quality standards. However, in this study the AQI values were also calculated by the EU standards and the stricter WHO recommendations (Table 4).

The AQI results indicated that the air pollution at the two monitoring stations of Győr can be characterized by the Hungarian and EU standards as excellent (SO_2, CO, C_6H_6, heavy metals) and good (NO_2, O_3, PM_{10}, $PM_{2.5}$, BaP) concentrations in 2016. Also, an excellent (SO_2, CO, C_6H_6 and heavy metals) or good (NO_2 and O_3) air quality was observed by the WHO AQGs or RLs. However, the PM_{10}, $PM_{2.5}$, and especially BaP were under a worse category by using the WHO recommendations compared to the results according to the EU or Hungarian standards.

Table 4: The AQI values in Győr according to the EU and Hungarian air quality standards and the WHO recommendations.

Pollutants	EU			Hungarian			WHO		
	Site-1	**Site-2**	**Both sites**	**Site-1**	**Site-2**	**Both sites**	**Site-1**	**Site-2**	**Both sites**
NO_2	Good[c]	Good[c]	Good[c]	Good[c]	Good[c]	Good[c]	Good[h]	Good[h]	Good[h]
SO_2	Excellent[d]	Excellent[d]	Excellent[d]	Excellent[c]	Excellent[c]	Excellent[c]	Excellent[h]	Excellent[h]	Excellent[h]
CO	Excellent[e]	Excellent[e]	Excellent[e]	Excellent[c]	Excellent[c]	Excellent[c]	Excellent[i]	Excellent[i]	Excellent[i]
O_3	Good[f]	Good[f]	Good[f]	Good[f]	Good[f]	Good[f]	Good[i]	Good[i]	Good[i]
$PM_{2.5}$	Good[c]			Good[c]			Polluted[h,j]		
PM_{10}[a]	Good[c]	Good[c]	Good[c]	Good[c]	Good[c]	Good[c]	Moderate[h]	Polluted[h]	Polluted[h,j]
PM_{10}[b]		Good[c]			Good[c]			Moderate[h]	
C_6H_6		Excellent[c]			Excellent[c]			Excellent[k]	
Pb		Excellent[c]			Excellent[c]			Excellent[k]	
Cd		Excellent[g]			Excellent[c,g]			Excellent[k]	
As		Excellent[g]			Excellent[c,g]			Excellent[k]	
Ni		Excellent[g]			Excellent[c,g]			Excellent[k]	
BaP		Good[g]			Good[c,g]			Heavily polluted[k]	

[a] Data based on the AMN
[b] Data based on the MMN
[c] Based on the annual mean concentration and annual mean limit value
[d] The AQI value was given from the annual mean concentration and daily limit value
[e] The AQI value was given from the 8-hour mean concentration and maximum daily 8-hour mean limit value
[f] The AQI value was given from the 8-hour mean concentration and maximum daily 8-hour mean target value
[g] Based on the annual mean concentration and annual mean target value
[h] Based on the annual mean concentration and annual mean AQG value
[i] The AQI value was given from the 8-hour mean concentration and maximum daily 8-hour mean value
[j] The percentage value is equal with 100 %, the stricter AQI was given
[k] Based on the annual mean concentration and annual mean RL

4. Conclusion

The air quality assessment results reported in this study according to the Hungarian and EU limit or target values show that the city of Győr had a good air quality for the year 2016. The results were based on the concentration data measured by the local accredited Environmental Protection Laboratory. The accredited laboratory conducted measurements by manual sampling methods and by collecting data from two automatic stations. The data have revealed that the least pollutants were heavy metals, SO_2, CO, C_6H_6 and belonged to the category of excellent in the city centre and its catchment area. However, mainly a polluted air quality for the PAH indicator compound and the PM aerosols was identified according to the stricter WHO recommendations. While 23 % of the total samples for BaP exceeded the Hungarian daily limit value of 1 ng/m^3, the annual mean concentration was 66 % of the equal annual EU target value defined for health protection. These data have revealed that seasonally distribution of BaP can be assumed. Despite the annual mean concentrations of NO_2 and O_3 are belonged to category of good, the assessment of seasonal patterns of their distributions (beside BaP or even PM_{10} and $PM_{2.5}$) would also be recommended.

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