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AIR POLLUTION MODELLING SOFTWARE PERFORMANCE COMPARISON - A CASE STUDY OF KOMÁROM ROAD

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Abstract: *Recent economic development in many countries has shown an increase in the number of vehicles in urban areas, which further results in an increase in pollutant emissions. This paper presents the results of modelling the simulation of carbon monoxide (CO) distribution in ambient air on roads in Komárom inHungary. The modelling was performed in two modelling software in ADMS and IMMI software. This paper presents a case study of air pollution of bypass road No. 131 in Komárom, Hungary. Modelling in IMMI software was done before and after the construction of the bypass road, based on the simulation in IMMI software, the new bypass helps reduce pollutant emissions in the city. To compare the modelled concentrations from the IMMI software, a comparative analysis was performed with ADMS software. The analysis showed that there is a difference between the concentrations from both software.*

Keywords: *ADMS, IMMI, air pollution, carbon monoxide*

NTRODUCTION

Clean air is essential for our health and the environment. But since the beginning of the industrial revolution, the quality of the air we breathe has deteriorated significantly, mainly due to human activities. Although, the last decades of care for the environment and human health have led to a significant improvement in air quality, people are constantly exposed to pollution in urban areas. Air quality can be determined based on basic emissions that are emitted into the air from both stationary sources (industry) and mobile sources (mainly road traffic). It often happens that the emissions of pollutants are above the prescribed limit values. [1]
Motor vehicles were the single largest source of ambient carbon monoxide during the 1960s and 1970s, even in the most developed countries of the world carbon monoxide is one of the most present and most toxic pollutants. It causes widespread physiological dysfunction in humans mainly due to its haemoglobin binding affinity. Low levels and long-term human exposure to carbon monoxide cause headaches, fatigue and exhaustion, and higher human exposure to carbon monoxide significantly reduces oxyhaemoglobin in the blood, which can endanger human life by reducing the oxygen supply to vital organs, especially the brain and heart. [2].
To prevent high concentration of this pollutant in ambient air, limit values (LV) are defined by various institutions. Hence, according to the United States Environmental Protection Agency (US EPA)national ambient air quality standards for carbon monoxide intakes must not exceed an average of 10 mg/m^3 over a period of eight hours or an average of 40 mg/m^3 over a one-hour period once a calendar year [3]. According to the World Health Organisation (WHO) guidelines, defined LV for CO [4] are lower in comparison to the US EPA standards for one-hour CO concentration. Limit values for CO in ambient air in legislation of Republic of Serbia [5] were defined in more details, defining LV for

different averaging times (1h, 24h and 1year). However, LV for CO defined in EU directives, referring only for maximum daily 8 hour mean [6] (Table 1).

Table 1. Limit Values for CO

Agency	Situation	Maximum CO	Duration
US EPA	Outdoor/Ambient air	10 mg/m³	8 hours
WHO		40 mg/ m³ 10 mg/m³ 30 mg/m³	1 hour 8 hours 1 hour
Serbia		10 mg/m³ 5 mg/m³ 3 mg/m³	8 hours 24 hours 1 year
EU		10 mg/m³	8 hours

The air quality assessment should involve detailed procedures that are approved by the national authority. Very often it includes complex the processes, techniques and steps that leads to the valid and reliable data. Hence, the most reliable technique is appropriate measurement of pollutant concentration, but very often it is time and finance consuming process. However, modelling of the pollutant distribution and its concentration in ambient air is sometimes approved in order to obtain indicative information on pollutant levels in environment. The reference modelling techniques is not defined by Serbian legislation in this moment but at the same time Serbian legislative defines modelling uncertainty for different pollutants.

In this paper, a modelling distribution CO was done by the ADMS Urban model to make a comparative analysis with concentration obtained by IMMI presented the master thesis "Environmental impact assessment of air pollution using a dispersion model", Eötvös Loránd University, Faculty of Natural Sciences, Centre for Environmental Science, Budapest 2018 performed by Bushra Afteh [7]. The thesis deals with the influence of the bypass road construction in the vicinity of the city of Komárom, Hungary on air quality.

MATERIALS AND METHODS

Study area and Sensitive Receptors

Komárom a small town in northern Hungary has nearly 20,000 inhabitants. The town is located on the right bank of Danube River close to the border with Slovakia. The subjects of this paper are influence of 3 roads located in the town Komárom on air quality. Road 3 is a bypass road, recently built, and has the task of relieving the amount of traffic through the town by Road 1 and Road 2 (Figure 1).

To achieve a full perception of the influence of CO on the surrounding area, sensitive and vulnerable receptors are selected for calculation of CO concentration (Figure 1 and Table 2).

Figure 1. Research area

Table 2. Sensitive receptors

	Name	Description
R1	Petőfi Sándor Általános Iskol	School
R2	Egressy Béni Elementary Art School	School
R3	Helen Doron Early English Nyelviskola	Kindergarten
R4	Komáromi Gesztenyés Óvoda	Kindergarten
R5	Komáromi Tóparti Óvoda	Kindergarten
R6	Extra-med Health and Sport Kft	Medical
R7	Selye János Hospital - Clinic	Medical

Modelling software

The IMMI pollutants module calculates the dispersion of gas, dust, and odour, according to both the particle model (TA Luft 2002/AUSTAL2000) and to the Gaussian model (TA Luft 1986). IMMI also allows for the combining of the calculation of air pollutants with the forecast of noise, two environmental impacts which often have the same cause. IMMI integrates data from the dispersion of air pollutants and noise out in the open (traffic, industrial and recreational noise) into a universal software for emission forecasting. [8]. In this paper, IMMI output data were used for comparative analysis with ADMSS Urban software.

ADMS-Urban is the most comprehensive version of the atmospheric modelling system. ADMS-Urban is an improved Gaussian model (Figure 2) that is intended for modelling the dispersion of pollutants in the atmosphere released from industry, households, as well as road traffic in urban areas. Unlike other

Gaussian models that use the classification of atmospheric stability using the Pasquil-Gifford empirical curve, ADMS-Urban defines the structure of the boundary layer over the Monin-Obuch boundary layer length and height. The ADMS-Urban software package is required in terms of finding data. In addition to defining the source of pollution (surface, point, line) and the interest of pollution, for real conditions and obtaining the most reliable data, it is necessary to define additional parameters. This includes terrain data (terrain roughness, geometry - width and height of the road, etc.) [9].

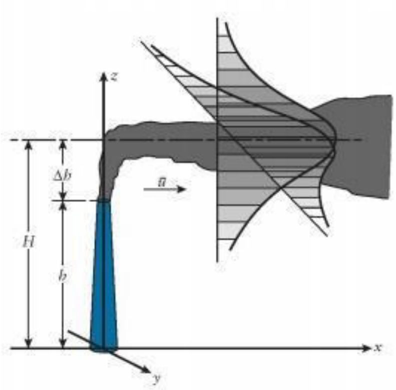

Figure 2. Gaussian dispersion model [10]

Gaussian model dispersion is expressed with following equation:

$$c(x,y,z) = \frac{Q}{\pi u \sigma_y \sigma_z} \exp\left(-\frac{1}{2}\left[\frac{y^2}{\sigma_y^2} + \frac{(z-H)^2}{\sigma_z^2}\right]\right)$$

where: Q-continual emission from point source (g/m^3), σ_z- dispersion coefficients (m), y- average wind speed (m/s), H- point source height (m).

RESULTS AND DISCUSSION

To obtain modelled concentration of CO from ADMS Urban software, following input data were processed:

Meteorology - Meteorological data (temperature, wind speed and direction) for the period of 1st July to 1st August 2019, were used for model development. In that period, the maximum measured temperature was 40.7°C, while the minimum value was 14.2 °C. The observed period was characterized as a dry season with no precipitation. In June of 2019, the most dominant wind direction was SW, reaching the speed ranging from 1 to 15m/s. Wind speeds below 1m/s, ADMS Urban recognize as "silence" (Figure 3).

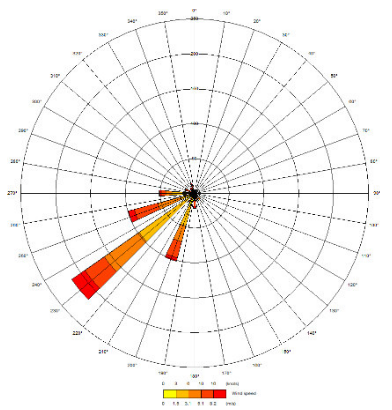

Figure 3. Wind rose

Emission factor for CO – ADMS urban model calculates emission rate from traffic according to the traffic flow and fleet composition. According to the data on traffic flow from Afteh (2018), the emission rate was defined for all three roads, including both light vehicles and heavy vehicles (Table 3).

Table 3. Emission factors (in g/km) for cars and heavy trucks for speed 50 km/h

Source	EF [7]	EF [11]
Light vehicle	0,170	0,753
Heavy vehicle	0,800	0,697

After defining the emission factors for all three roads as well as for light and heavy vehicles, and defining meteorological data, a modelling was performed. The CO concentrations obtained by modelling ranged from 17 $\mu g/m^3$ to 172 $\mu g/m^3$ (Figure 4).

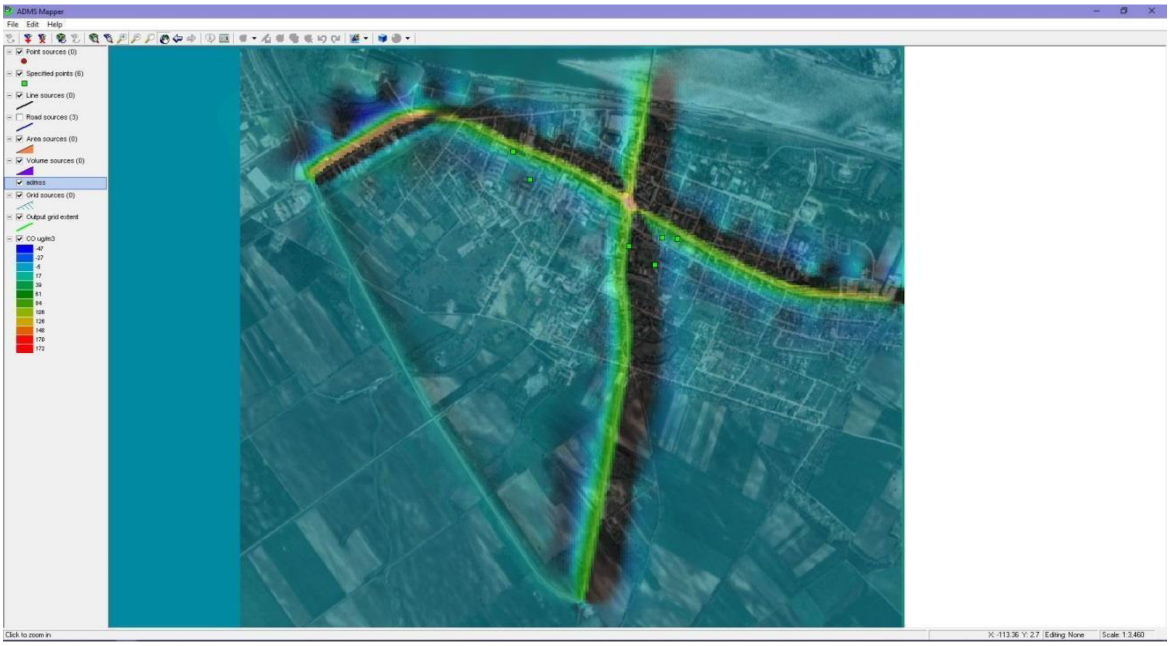

Figure 4. Modelled CO concentration for defined domain of research

Since the dispersion concentrations of the carbon-monoxide for the whole domain were not available in the Afteh (2018), for the comparative analysis, additionally modelling of CO concentrations in the sensitive receptors was performed. Table 4. shows modelled concentration by ADMS Urban software, that were calculated according to the available hourly data on meteorology.

Table 4. Modelled concentration (µg/m^3) by ADMS Urban software using hourly meteorological data

Receptor	CO (IMMI)	CO (ADMS Urban)
R1	19,132	0,0121
R2	6,65	0,0080
R3	5,351	0,0117
R4	17,822	0,0707
R5	3,599	0,0115
R6	3,86	0,0017

Although we deal with models based on Gaussian distribution, the obtained results by ADMS were significantly lower than those obtained by IMMI. One of the reasons could be attributed to the different types of input data needed for each model, especially meteorological data, and emission rat from vehicles as well (Table 3). To avoid that, the most probable scenarios for modelling were selected as performed in Afteh (2018) [7] results.
Since the ADMS Urban defines the structure of the boundary layer over the Monin-Obuch boundary layer length and height, instead of Pasquil-Gifford classes, daytime solar insolation (W/m^2) was used for D class of stability sed in Afteh (2018) [7]. Hence, the D class of stability, were defined as slight daytime solar insolation (> 300 W/m^2). Concerning dominant wind direction and speed, given in Afteh (2018) [7], two scenarios were selected: S1 for SW wind direction and S2 for SSE wind direction. Wind speed of 1.5 m/s was used for both scenarios. The emission factors were not possibleto predefine in ADMS Urban software.
Comparative analysis of modelled CO concentration, calculated for sensitive receptors, obtained by IMMI and ADMS, in case of scenarios S1 and S2, are presented in Table 5.

Table 5. Modelled CO concentration (μg/m^3) in sensitive receptors by IMMI and by ADMS for two scenarios.

Receptor	CO (IMMI)	CO for S1 (ADMS)	CO for S2 (ADMS)
R1	19,132	0,013	0,0023
R2	6,65	0,011	0,0006
R3	5,351	0,005	0,0037
R4	17,822	0,029	0,0490
R5	3,599	0,002	0,0045
R6	3,86	0,002	0,0002

The obtained modelled CO concentration by ADMS Urban for S1 and S2 scenario were still much lower in comparison to the modelled concentration obtained by IMMI. That leads to the conclusionthat the performance mostly depends on availability of adequate meteorological data.

CONCLUSION

This paper shows modelled CO concentrations, obtained by dispersion simulation of pollution from vehicles. The case study covered 3 roads near sensitive facilities in town Komárom, Hungary with the goal to identify CO concentration levels and the impact on vulnerable facilities. The modelling was performed initially in IMMI software and after that, for comparative analysis, the modelling was performed in ADMS-Urban software. The concentrations obtained from the ADMS-Urban software are significantly lower than the concentrations obtained by the IMMI software. Although each software operates by the Gaussian modelling method, the differences in the obtained concentrationsare reflected due to different types of input data especially data on prevailing meteorological conditions.

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