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EDMS MODEL VERIFICATION CONSIDERING REMARKABLE CHANGES IN AIRPORT TRAFFIC SYSTEM

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Abstract: This paper presents the verification process of the Emission and Dispersion Modeling System adapted to evaluate the air quality of Liszt Ferenc International Airport. One receptor point was selected at the Airport, at Terminal Building 2 for the analysis, where an air quality monitoring station has been operating. Modeling results completed with background concentrations generated from another suburban monitoring station were compared with measured hourly concentrations using statistical indicators for three compounds (CO, NO_X and PM_{10}). Acceptable correlation coefficients (0.53-0.76) were obtained, however modeled PM_{10} concentrations were significantly underestimated. Pollution roses were generated that highlighted the areal distribution of the pollution sources influencing air quality at the receptor point. The contribution of aircraft movement and apron area emission was found to be well rated, but in case of CO and NO_X small (17%) deficiency was found for ground vehicles emission, moreover a much higher (65%) difference was obtained for PM_{10}.

***Key words**: airport air quality, dispersion modeling, EDMS modeling system*

INTRODUCTION

Airport air pollution related early mortality is not negligible. One of the most important topics of health effect studies is a suitable dispersion model combined with a detailed emission inventory. Numerical modeling tools give the opportunity to forecast and plan air quality supporting decision making. There are a number of dispersion models, some of which are investigated in detail in case studies and compared at specific airport sites.

This paper presents a verification study of EDMS (Version 4.5) adapted to Liszt Ferenc International Airport (Budapest, Hungary), by comparing simulation results with air quality monitoring data. The EDMS system is a combined emission and dispersion model, which can be used to produce an inventory of emission generated at airport site, as well as to calculate pollutant dispersion inside and around the airport. Steib et al. (2008) showed that meteorological situation intensively affects air quality at airport region, the influence of distant sources can be commensurable with the contribution of local sources depending on wind direction.

The traffic at Budapest Airport show significant activity growth in accordance with global trends, thus developments connected to airport service were realized. Furthermore, due to economic crisis, the Hungarian Airlines (MALÉV) became bankrupt in 2011 that again entailed changes in airport operation. As a result, the operational principles changed notably, especially the traffic at terminal buildings (T1 and T2) at Budapest Airport: Terminal Building 1 (T1) was closed in 2012 so that all aircraft traffic is transferred to Terminal Building 2 (T2), which was rebuilt to be able to serve even more passengers. This also means that the route of the passenger related cars and the use of parking facilities have been changed significantly. Furthermore, the section of city close to the Airport showed remarkable developments, which infers the growth of vehicle traffic. Therefore, our first aim was to study long term datasets to find out the contribution of the airport related emission sources to overall air quality situations and follow the changes in air quality due to Airport operational alteration. Secondly, the applicability of default emission parameters is studied in order to verify the assumptions made for the time and spatial description of relevant pollution sources.

EXPERIMENTAL

For our selected model EDMS, the system architecture and input data requirements were already described in detail in our previous article (Steib et al., 2008). Since the emission factors vary in a wide range, especially for ground vehicles, where the vehicle types are very diverse, mostly EDMS default values were used. The runway usage of aircrafts is registered by the operators, so that the timing and aircraft type of landing and takeoff operations could be simulated in accordance with the reality. All other aircraft movement (taxiing, Auxiliary Power Unit - APU) and aircraft operation related vehicle traffic were chosen as the default values from EDMS. Taxiing time was set to 12 minutes. Aircraft types were divided into three categories, for each of them a representative aircraft was chosen in order to simplify input data generation: Heavy - Boeing 767, Medium - Boeing 737, Light - Citation I. Simulations were made for daily averages on an 8,000 m × 8,000 m grid, with 200 m spatial resolution, for compounds CO, NO_X and PM_{10}. Emissions of significant point sources were also taken into account.

In 2008, a monitoring station was installed on the terrace of T2, since then it has been continuously measuring hourly average concentrations of various compounds (CO, NO_X, PM_{10}, SO_2, O_3, CH_4). These data are used to verify model results for statistically acceptable periods. On the area of T2 apron, emissions of aircrafts APU and taxi of Ground Support Equipment (hereafter GSE) and ground supporting vehicles (catering, passenger transporting buses), and of employees cars should be taken into account as well. In addition Airport operation related emission sources positioned far from T2 (like takeoff, point sources) can have demonstrable effect depending on the meteorological situation.

Since EDMS calculates the concentration distribution of specified compounds originating only from sources defined by the Airport, one has to determine background concentrations to be able to compare measurement and modeling results. Determination of the background concentrations is not straightforward, since due to the closeness of the city, it can be supposed that the urban pollution plume might also affect the air quality of the airport. To overcome this, a dataset of a nearby monitoring station was used. The closest station of the Hungarian Air Quality Network is located ca. 3 km west from the Airport at Gilice tér (hereafter GT). The station registers hourly average concentrations of all three compounds (CO, NO_X, PM_{10}) chosen for the model verification study. However, this station is at a suburban location, the effect of local sources must be taken into account. There exists a road with important traffic, but the measured concentration data shows characteristic daily and weekly time structure. Beside this, point sources can be found in the vicinity of GT (like Budapest Power Plant and smaller workshops), which have significant effect on local air quality. Therefore, background concentrations at the Airport were determined in two steps. First, because the tendency of the minimum values of 00h-06h periods (when vehicle and aircraft traffic is negligible) during the entire year showed great similarity but significantly higher at GT than at the Airport, an f_k (where k stands for the given pollutant) linear regression factor was calculated. This significant difference can be explained on one hand with the unbuilt environment at Airport, which ensures favorable conditions for pollutants dilution. On the other hand, it is due to the influence of local sources (power plant, households, etc.). The obtained factors are f_{CO}=0.7, f_{NOX}=0.6, and f_{PM10}=0.4.

In the second step, our aim was to remove the effect of emissions related to local traffic, for which a method introduced by Balczó et al. (2011) was used with small modifications. The principle of this method is that components calculated with Fourier analysis of the dataset are filtered above a frequency threshold ($\nu > 0.056\ h^{-1}$). In our case the Fourier spectra of the day-of-week averaged hourly concentrations were calculated for every pollutant. The results confirm the previously expected trends, that beside the daily cycle, a significant component with 12 h periodic time is detectable for CO and NO_X pollutants, which can be identified with the effect of typical suburban vehicle traffic. The correction is defined by the ratio of the 12 h Fourier component amplitude and the averaged measured maximum daily difference in the concentration time series. As the traffic is much lower at weekends, the contribution of vehicle sources can be neglected for these days. Therefore, weekdays and weekends were treated separately, so that on weekends no corrections were done. Daily averaged corrected background concentrations for a certain k pollutant for the i-th day ($c_{bg,k}^{i}$) could be calculated from $c_{l,k}^{i}$ hourly averaged measured concentrations as

$$c_{bg,k}^{i} = \begin{cases} f_k \frac{1}{24}\left[\sum_{l \in \bar{H}} c_{l,k}^{i} + \sum_{l \in H}\left(1 - \frac{A_k}{\frac{1}{7}\sum_{j=1}^{7} \overline{c(\max)_{j,k}} - \overline{c(\min)_{j,k}}}\right) c_{l,k}^{i}\right] & if\ weekday \\ f_k \frac{1}{24}\sum_{l=1}^{24} c_{l,k}^{i} & if\ weekend \end{cases} \quad (1)$$

where A_k is the amplitude of the Fourier component with 12h periodic time (A_{CO}=78.29 μgm^{-3}, A_{NOX}=17.32 μgm^{-3}, A_{PM10}=1.04 μgm^{-3}), $\overline{c(\max)_{j,k}}$ and $\overline{c(\min)_{j,k}}$ are the averages of the *j*-th day minimum and maximum concentrations (*j*=1…7). H is the set of peak hours: $H = \{7, 8, 9, 18, 19, 20\}$.

Modeled concentrations at the defined receptor point were added to background values determined using the method described above. As a consequence, measured concentrations close to the receptor point were expected to be comparable with these values. An example period of measured versus the sum of modeled and background concentration time trend of NO_X is presented in Figure 1.

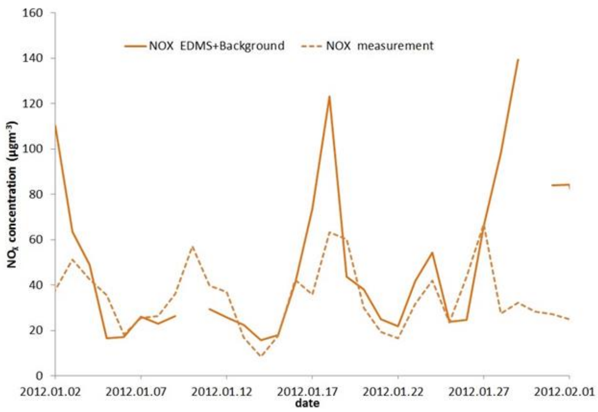

Figure 1. Daily averages of measured and simulated NO_X concentrations at T2 site in January 2012

RESULTS

Emission and meteorological input files were generated based on data of on-site measurements. The simulation process consists of two parts, first a preprocessor (EDMS) generates emission values for the different sources, then the second part (AERMOD system) calculates dispersion. As a result, concentration fields for daily averages on a certain domain for the selected compounds as well as meteorological parameters are calculated. Two periods were chosen for the analysis: years 2006 and 2012. The obtained distributional difference for NO_X in annual averages (grid values for 2012 were subtracted from the ones calculated for 2006) is presented in Figure 2.

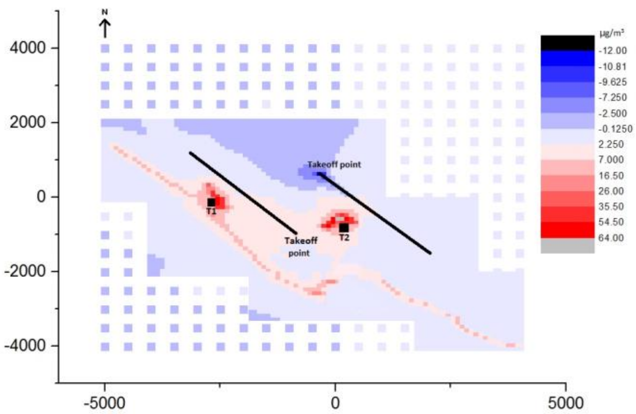

Figure 2. Difference between yearly average of NO_X concentration distribution for 2006 and 2012

Previous concentration distribution results showed that areas of T2 and roadways beside Airport area have highest concentration (Steib et al., 2008). Due to the decrease of aircraft traffic annual average CO and PM_{10} concentrations were lower in 2012 at the entire Airport area. Though CO emissions of point sources showed a great increase in some cases, the annual quantities were orders of magnitude less than aircraft LTO emissions. A notable difference could be found for NO_X concentrations at takeoff starting points, northern takeoff point showed remarkable NO_X contribution in 2012. This was due to meteorological and operational causes. For situations with no wind, Airport operators directed the aircrafts to closer takeoff point to reduce taxiing time. In 2006, Terminal Building 1 (T1) was in operation during the total period, so that starting point between the Terminal buildings was used dominantly, resulting in much lower NO_X load at the northern takeoff point. After the closure of T1, the usage of starting points was changed, thus the ratio between the two takeoff starting points have been equalized. As it is shown later, it has had significant effect on T2 apron air quality.

Long term monitoring data gives us the opportunity to verify modeling results. Though EDMS predict concentrations for every grid point of the Airport, only one receptor point could be used for the verification due to availability of air quality monitoring site. Concentration monitoring was performed at the most contaminated area of Airport, where the considerable emission sources are the most diverse (APU, GSE, handling and passenger related cars and buses, etc.). Our aim was to study the accuracy of modeling results at this point, principally focusing on the time tendencies of pollutant concentrations that were compared for daily averages of measured and simulated results for the closest receptor point. Background values, which were the corrected values of GT site using the method described above, were added to the output values of EDMS. Statistical indicators (correlation coefficient, BIAS, relative BIAS, root-mean-square error (RMSE)) were calculated to check the quality of simulation results. The joint analysis of these markers can show the accuracy of modeling output values added to background values. Statistical indicators of this comparison (for year 2012) are presented in Table 1.

Table 1. Statistical indicators of the difference between measured and modeled daily average CO, NO_X and PM_{10} concentrations for 2012

	Correlation coefficient	**BIAS**	**Relative BIAS**	**RMSE**	**Concentration span (μg/m³)**
CO	0.71	-0.29	-8.38×10^{-4}	142.16	1234
NO_X	0.53	13.73	0.555	24.59	103
PM_{10}	0.76	-2.31	-0.44	5.11	43

The best agreement was found for CO, only the negative value of BIAS indicate that a small but significant underestimation exists. Modeling of PM_{10} concentration is usually a weak point of air quality models. Our data have shown surprisingly good agreement, however BIAS and RMSE values indicate incompleteness in EDMS results or/and in background determination. The correlation between measured and modeled NO_X concentrations is the weakest. Since background values are typically small compared to daily average values, the discrepancy should originate from modeling. This can be partly due to the fact that no chemical reaction or sink of NO_X is considered during the dispersion calculation.

Beside time trend analysis bivariate pollution roses were drawn to identify emission sources which affect local air quality at a certain point. Bivariate pollution rose is a graphical data analysis technique, where concentration distribution is shown in the function of wind vector on radar chart. Bivariate pollution roses were generated for (i) EDMS results added to corrected background concentrations, (ii) measured concentrations and (iii) EDMS results only. Our aim was to identify the sources responsible for the extreme discrepancies in time series.

As a result of comparing the bivariate pollution roses for CO generated from measurement and EDMS + background results it was found that emissions originating from the apron area are slightly underestimated. Remarkable difference occurs in the direction of south from receptor point, which area contains the parking places for passenger cars. This amount of shortcoming can be partly explained with the incomplete data of parking usage (only those cars were registered, which entered into the parking area, those passed through, or stopped for few minutes were not taken into account). Previous studies (Celikel et al., 2005) showed the weakness of EDMS built-in emission parameters for passenger cars, since they are characteristic for operations in the USA, but do not reflect the conditions of European airports, which should be present in our case as well. To quantify this effect, we need to have detailed information about the actual vehicle fleet parameters (types, age, etc.).

For NO_X, similar effects can be identified (see Figure 3). The apron and the passenger parking area's emission is underestimated by a factor of 0.3. At the same time, the influence of aircraft emission during takeoff is demonstrable (segment from north to northeast), since concentration distribution shows local maximum in that direction as well. It is important to note, that the clear appearance of runway emission is not expected, since takeoff time is a short part of an hour, whereupon takeoff emission contribution might not be detectable in all cases. Increasing the time resolution of EDMS results could correct this effect, but this high time resolved analysis exceeds our purposes.

In case of PM_{10}, whereas correlation coefficient show good agreement, a significant underestimation is demonstrated from statistical indicators, however apron area and passenger parking emission shows similar magnitude of emission in EDMS results, which corresponds to the reality. Although background values are determined with assumable uncertainty, the magnitude of PM_{10} concentrations is certainly underestimated by EDMS.

Figure 3. Pollution roses for measurement (left), EDMS + background (up, right) and EDMS (down, right) results of daily average NO_X concentration, at T2 site in 2012

In general, air quality at Airport area became better between the period of 2006 and 2012, while the number of passengers slightly increased, which means that the operational optimization was successful from the environmental aspects. However, as a result of rearrangement of aircraft movements, the effect of NO_X contribution due to takeoff emission at Terminal Building 2 depending on meteorological situation can be detectable.

CONCLUSION

In this study, a comparison of measured data and modeled concentration distribution calculated by EDMS for three compounds (CO, NO_X and PM_{10}) was presented. A statistically acceptable 1-year (2012) period was studied to analyze the accuracy of input data, and to study the effect of change in aircraft traffic on local air quality. A monitoring site was operated continuously during this period, which was chosen as the nearest receptor point of the model for comparison. Background values were generated from the closest air quality measurement station (Gilice tér), which was found to be expressive in case of CO and especially PM_{10}. Statistical indicators and pollution roses were generated to analyze the accuracy and weaknesses of emission parameters.

EDMS gives reliable and realistic results for long term data and applicable for air quality management for Budapest Airport. Correlation between measurement and simulation values were acceptable for all 3 compounds, however a slight underestimation is noticeable, especially in case of PM_{10}. This is basically due to the uncertain determination of ground vehicle emissions since at present such data are only available for the registered cars. These observed discrepancies should be corrected by a more precise determination of ground vehicle traffic.

In general, air quality at Airport area became better between the period of 2006 and 2012, while the number of passengers slightly increased, which means that the operational optimization was successful from the environmental aspects. However, as a result of rearrangement of aircraft movements, the effect of NO_X contribution due to takeoff emission at Terminal Building 2 depending on meteorological situation can be detectable. Taking these findings into consideration, the contribution to Budapest city contamination can be determined by EDMS, especially in critical meteorological situations, when Airport operation related emission cannot be neglected.

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