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CASE STUDY OF ENVIRONMENTAL IMPACT ASSESSMENT OF NO_2 CONCENTRATIONS EMITTED FROM LINE SOURCES (TRAFFIC) IN KOMÁROM, HUNGARY

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Abstract

Air pollution after the industrial revolution and the population explosion has increased dramatically. However, air pollution is not a newer phenomenon it starts before the industrial revolution and has taken different forms when people on past used firewood for heating and cooking. Our bodies cannot adopt with contaminations increasing. One of the best solutions to meet the sustainable development goals is the application of Environmental Impact assessment approach (EIA). This study gave an assessment on air quality inside the city of Komárom, Hungary after operating the new bypass road No. 131 in 2015. The differences of air quality between the two years 2010 and 2015 before and after operating the bypass road were investigated during the application of EIA. The EIA study was done by using IMMI software which is a widespread noise and air pollution modelling software provided by the German Wölfel GmbH. Traffic network graphic elements, traffic data (numbers of cars and heavy trucks), emission factors for different pollutants and meteorological data (wind speed, wind direction, and stability categories) were prepared and imported to the software. The modeling was done depending on Gaussian dispersion approach. The average concentrations of NO_2 *were simulated for the whole area and for specific receptor points in case of different wind speed intervals, wind direction, and different stability categories. The obtained results from model showed only small differences in air quality between 2010 and 2015 due to the traffic motion in the bypass road No. 131 but it indicate the changes in traffic and environmental developments on air quality.*

Keywords: *environmental impact assessment, air pollution, Gaussian dispersion model IMMI software.*

1. INTRODUCTION

Air pollution stars before the industrial revolution in different ways when people in past used firewood for heating and cooking [1]. After the industrial revolution and the population explosion, air pollution has increased dramatically [2]. Air pollution is becoming a hot topic in the scientific world since we start seeing lots of changes in weather and the environment. Air pollution and climate change linked to each other. Chaudhuri and Chowdhury [3] stated that air pollution has harmful impacts on the health of the human population and ecosystems, as well as on the earth's climate. Undoubtedly, climate change becoming very fast day after day. More importantly, air quality needs to be understood from two viewpoints the management of air quality and the consequence of the climate change on the community [4]. Definitely true that to achieve the sustainable development goals it is necessarily important to apply Environmental Impact Assessment (EIA) approach. There are several explanations of EIA. In 1992 Turnbull gave a definition for EIA: “A mechanism for all interested parties to be consulted and provide a framework within which agreement may be reached between the developers causing the impacts and those who are affected by the impacts” [5]. Environmental protection Agency defined EIA as a process of examining the anticipated environmental effects of a proposed project - from consideration of environmental aspects at design stage, through consultation and preparation of an Environmental Impact Assessment Report (EIAR), evaluation of the EIAR by a competent authority, the subsequent decision as to whether the project should be permitted to proceed, encompassing public response to that decision [6]. EIA for short-term help the decision makers in making the proper decision. However, EIA not limited only for short term but also important for the long term. For examples, long-term objectives of EIA are to protect human health, preservation of natural sources and keep the environment far away from damages [7]. There are several EIA tools and techniques which can be classified from the simplest one: checklists, matrices, and networks to the most complicated one: map overlays, geographic information systems (GIS) and task-specific computer modeling [8]. Anthropogenic activities by humans caused the increase in greenhouse gases and global warming. Motor vehicles, marine vessels or aircraft (emission of jet fuel) always takes a capacious range of interest. High air pollution levels depend on and vary with the traffic density, rush hours, the urban structure and meteorological circumstances [9] [10]. NOx (nitrogen oxides) emitted to the air by fuel burning at high temperatures and combustion of the engine industries [11]. Recent research shows that how could passenger cars play a negative role in the increasing of the NO_x in 8 European countries and how extreme concentrations form in the city centre due to the high traffic jam [12] [13].

In this study, the main aim was to carry out an EIA study of air pollution of bypass road No. 131 in Komárom, Hungary by measuring the concentrations of air pollutants in 2010 before operating the new bypass road and 2015 after the operating, in order to simulate the effects of the new road on air quality in and around the city of Komárom. The main aim of the construction of the new bypass road in 2015 was to reduce the environmental load in the city caused by traffic.

Technical details for the study area

The new main bypass road No 131 is planned in Komárom city in North-Western Hungary on the south bank of the Danube River in Komárom-Esztergom County. It is branching out of main road No 13 and ends at the roundabout of road No 1. The bypass road is 3.69 km long. Concentration loads have been defined for the breathing zone in z= 2 m height (Figure 1).

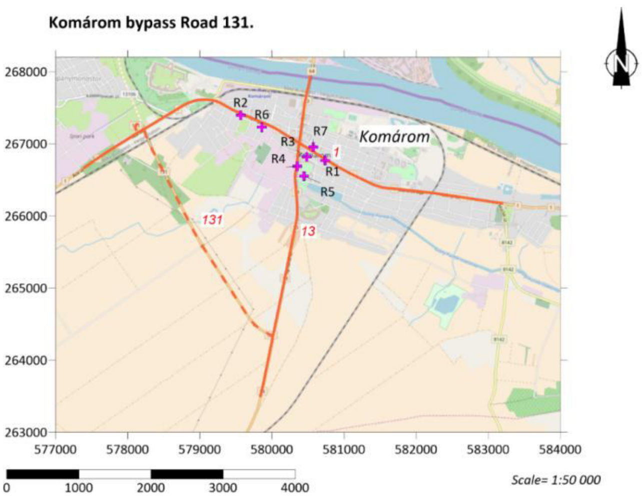

Figure 1: The study area (Komárom city) with receiver points (source: open street map.)

The population of Komárom is around 20 thousand people. The geographical environment of Komárom is threatened by floods. The Komárom Industrial Park was chosen because it is the proper location for large industrial activities. The concentrations of NO_2 pollutant showed high levels inside the city and the main source of air pollution inside the city from traffic especially on the main road No.1., while outside the city, the industrial park is the main emission source. Attention should be also focused on transboundary effects [14].

2. MATERIALS AND METHODS

For modelling the transmission in the air, the IMMI software has been used according to Reiche [15]. The IMMI is a widespread noise and air pollution modelling software provided by the German Wölfel GmbH, which integrates air dispersion models (for gases, dust, odours) and outdoor sound propagation (road, traffic, and railway, industrial and recreational noise) including interfaces to CAD and GIS [16]. The programme calculates the concentration of different air pollutants on EOV (Egységes Országos Vetület - Unified National Projection) coordinates. The immission has been defined within the 268000–263000 and 577000–584000 EOV coordinates (about 7 km × 5 km = 35 km^2). For simulations, traffic network graphic elements, traffic data (v/h) for to classes of cars and heavy trucks, emission factors for different pollutants and meteorological data (wind speed, wind direction, and stability categories) were used.

The average concentration fields of Nitrogen dioxide (NO_2) was simulated for the whole area and for specific receptor points in case of different wind speed intervals and different stability categories by using a Gaussian dispersion model in IMMI software. The Gaussian model was chosen because of its simplicity and fast calculation time, and it does not require sophisticated meteorological data, therefore this tool is suitable for small projects. For simulations, all previous data require importing to IMMI. Calculation reference points have been defined in a 10 × 10 m grid, by the contouring of which graphics on immission have been generated. Concentration loads have been defined for the breathing zone (where people live) in z = 2 m height.

Baseline data collection

- Road network graphics elements, background map: the Komárom–Esztergom County road map obtained by using Open Street Map with the help of MicroStation software and Surfer software. MicroStation was used for preparing a georeferenced background image for the IMMI software and for digitized the roads (segmentation). For the visualization of our results, Surfer software was used, because of this software capable to attach the background map and geo-related dataset.

-Traffic data preparation**:** the traffic data are related to roads No.1 and No.13, and bypass road No.131 which was opened in 2015, and all data sheets were prepared for 2010 [17] and 2015 [18] to import to IMMI software.
Road No. 1, No. 13 and No. 131 were divided into 4, 6 and 1 segments, respectively and each segment represents a few (3–8) km on the roads. From the input database, the following information is required: road number, county, cross section [km+m], codes, and a number of vehicles and heavy trucks per day on each code (Table 1).

The traffic data (traffic factor, and percentage of heavy trucks) were obtained from the previous data (Table 2).
The Traffic factor means the largest hourly traffic, which occurs at least 50 times a year (vehicle/hour). The heavy trucks percent was calculated from the following formula:

$$\text{Heavy trucks percent \%} = \frac{\text{(number of all heavy trucks)/day}}{\text{(number of vehicles per day)/day}} * 100\%$$

Table 1: Number of vehicles and all heavy trucks per day for 2010 and 2015

Road No.	Counter Station code	Number of vehicles per day (2010)	Number of all heavy trucks (2010)	Number of vehicles per day (2015)	Number of all heavy trucks (2015)
1	3816	5456	843	5813	715
1	4561	12201	805	12028	889
1	4562	7931	513	6643	417
1	7948	5615	367	5647	364
13	9	7750	194	10267	263
13	3446	9067	947	10915	281
13	4565	10113	1200	6568	514
13	3349	6842	1257	8130	892
13	6890	5338	819	5703	553
13	3350	3523	455	3409	298
131	2547	-	-	905	110

Table 2: Summary of the traffic data which need to import to the IMMI software

Road No.	Code	Traffic factor 2010	Heavy trucks (%) 2010	Traffic factor 2015	Heavy trucks (%) 2015
1	3816	653	15.0	665	12.0
1	4561	1165	6.6	1266	7.0
1	4562	761	6.0	695	6.0
1	7948	582	6.5	614	6.4
13	9	699	2.5	1020	2.5
13	3446	942	10.4	1092	2.5
13	4565	1064	11.8	696	7.8
13	3349	827	18.3	943	10.9
13	6890	630	15.3	669	9.6
13	3350	403	13.0	411	8.7
131	2547	-	-	108	12

-Emission Factors for Road Traffic from HBEFA database: the emission factor data were imported from the Handbook on Emission Factors for Road Traffic (HBEFA) version 3 German databases [19]. The emission factors were calculated for the two traffic classes, for cars and heavy trucks.

The emission of pollutants can be changed in the function of vehicle speed, but in this study the same speed value (50 km/h) were used for the whole area, but considering the change of emission between 2010 and 2015 due to the change of the fleet composition based on HBEFA (Table 3).

Table 3: Emission factors (in g/km) for cars and heavy trucks for speed of 50 km/h, in 2010, and 2015 (Source of data: HBEFA)

	Cars		**heavy trucks**	
	2010	**2015**	**2010**	**2015**
NO_2	0.090	0.100	0.345	0.260
CO	0.270	0.170	1.110	0.800
PM	0.010	0.004	0.020	0.040
HC	0.020	0.010	0.170	0.070
NOx	0.270	0.300	4.160	2.570

Climate and meteorological data: The site is located on a terraced plain. The climate here is generally temperate. The yearly temperature averages are 10.4°C. The yearly precipitation amount is 531 mm (for period 1982–2012) [20].
For the simulations, meteorological data obtained from Tata Meteorological Station (about 20 km from Komárom) of Hungarian Meteorological Service (HMS). The frequency of wind speed categories for 10-degree resolution of wind direction and for different stability categories for the period 2012–2016 was used in the model. The German and Hungarian stability groups are shown in Table 4.

Table 4: The stability categories

Stability	Klug/Manier	Pasquill/Gifford
		G
Very stable	I	F
stable	II	E
indifferent	III/1	D
indifferent	III/2	C
unstable	IV	B
Very unstable	V	A

For the whole period, the most frequent wind direction is SE. Figure 2 shows the distributions of wind speed and stability categories for the whole dataset.

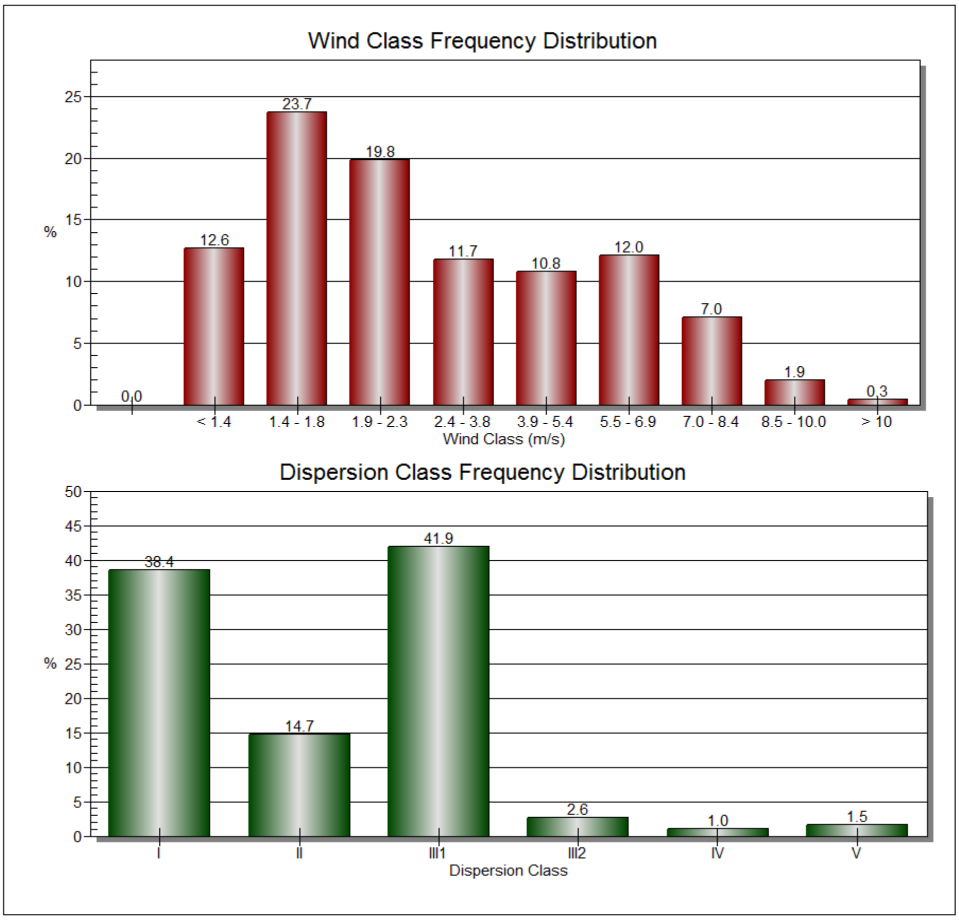

Figure 2: Wind Class Frequency Distribution, Dispersion Class Frequency Dispersion, Source of data: Hungarian Meteorological Service

It was found that the most frequent wind speed interval is between 1.4 and 1.8, while the most frequent categories are III/1 (D - Pasquill) and I (F - Pasquill). Figures 3 and 4 show the wind rose for these two stability categories.
In the case of D stability the most frequented wind direction is north-west and for F stability the south-east.

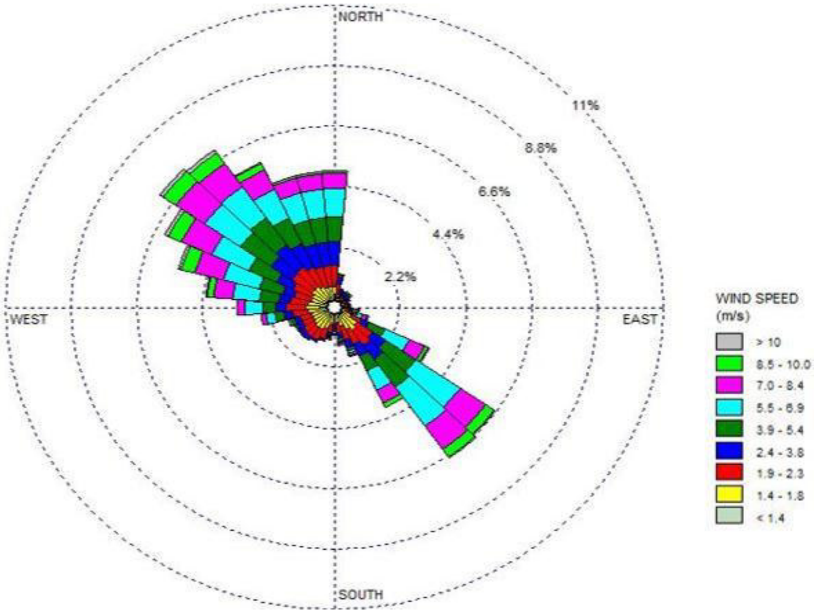

Figure 3: Wind rose for D stability category for Tata Station for the period 2012–2016 with the frequency of wind speed. Source of data: Hungarian Meteorological Service

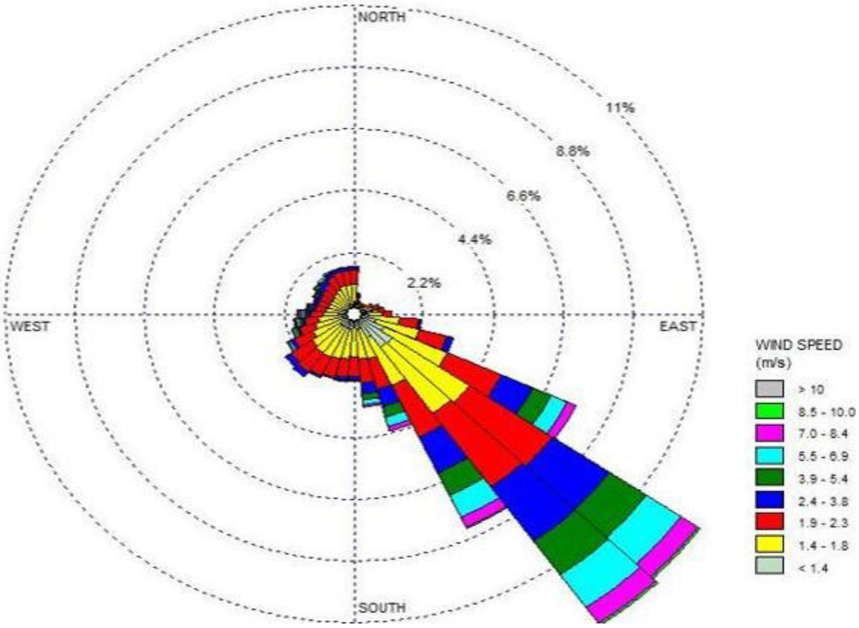

Figure 4: Wind rose for F stability category for Tata Station for the period 2012–2016 with the frequency of wind speed. Source of data: Hungarian Meteorological Service.

Calculation of the transmission: The programme calculates the concentration of different air pollutants on EOV (Egységes Országos Vetület - Unified National Projection) coordinates. The immission has been defined within the 268000–263000 and 577000–584000 EOV coordinates (about 7 km × 5 km = 35 km^2). Calculation reference points have been defined in a 10 × 10 m grid; by the contouring of which graphics on immission have been generated. Concentration loads have been defined for the breathing zone (where people live) in z = 2 m height. Some receiver points, such as school, kindergarten, and medical points were picked. Table 5. consists of the receiver points and the EOV coordinates for each point.

The immission of pollutants (grid calculations) calculated for several scenarios for years 2010 and 2015 for 1.5 m/s wind speed and for D and F stability, the most frequented categories according to Tata station. But the focus was on NO_2 because it is a critical point in Europe. The EU Council Directive 1999/30/EC of 22 April 1999 set the hourly and annual limit values of projection of NO_2 for the protection of human health. The limit value for NO_2 is 100 μg/m³ (in Hungary) not to be exceeded more than 18 hours in a calendar year (that is approximately the 99.8-percentile) [21].

Table 5: Receiver points

Code	Name	Description	x	y
R1	Petőfi Sándor Általános Iskola	School	580734	266770
R2	Egressy Béni Elementary Art School	School	579568	267393
R3	Helen Doron Early English Nyelviskola	Kindergarten	580483	266820
R4	Komáromi Gesztenyés Óvoda	Kindergarten	580351	266689
R5	Komáromi Tóparti Óvoda	Kindergarten	580442	266553
R6	Extra-med Health and Sport Kft	Medical	579861	267229
R7	Selye János Hospital - Clinic	Medical	580571	266953

Several scenarios have been done also for receiver points as sensitive sites. The concentrations of five pollutants for years 2010-2015 were calculated for A, C, D, E, F stability and for 1.5, 2, 3, and 5 m/s wind speed.

3. RESULTS AND DISCUSSION

In the following, we present the model results for NO_2. The figures of the other pollutants showed only very small differences in concentrations. For the presentation, 1.5 m/s wind speed and D and F stability categories were chosen.

Figure 5 and 6 show the concentration field of NO_2 in the area for D stability (neutral stratification) and for the year 2010 and 2015, respectively.
The highest can be found near the main roads.

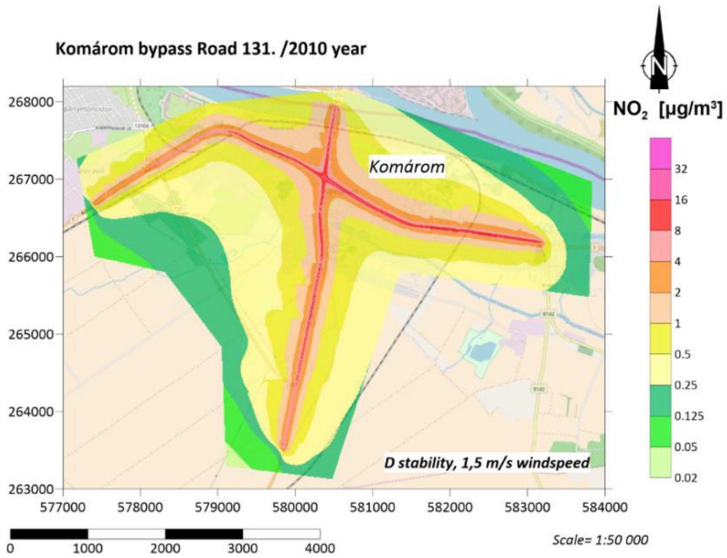

Figure 5: 2010, D stability, 1.5 m/s wind speed, NO_2 immission calculated by IMMI software

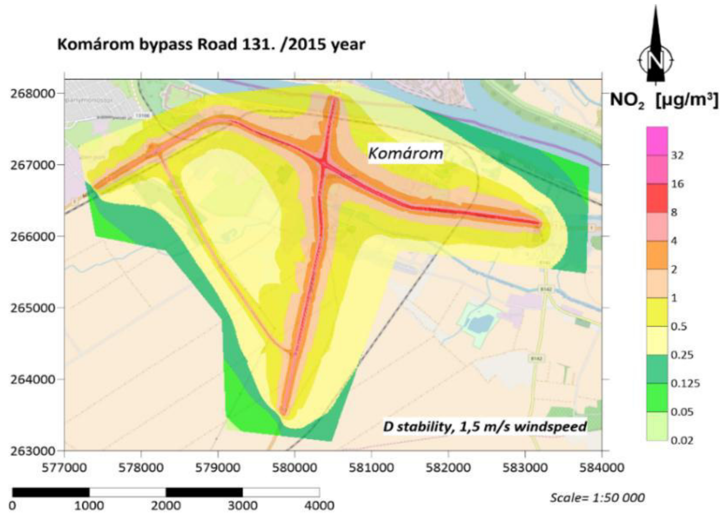

Figure 6: 2015, D stability, 1.5 m/s wind speed, NO_2 immission calculated by IMMI software

In the case of F stability (stable stratification, which is the critical situation for air quality) highest concentration values were noticed (see Figures 7 and 8 for the year 2010 and 2015, respectively).

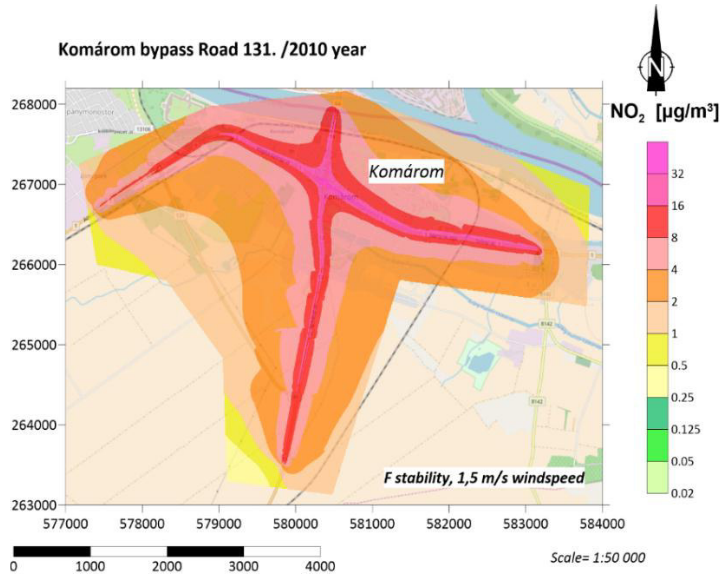

Figure 7: 2010, F stability, 1.5 m/s wind speed, NO_2 immission calculated by IMMI software

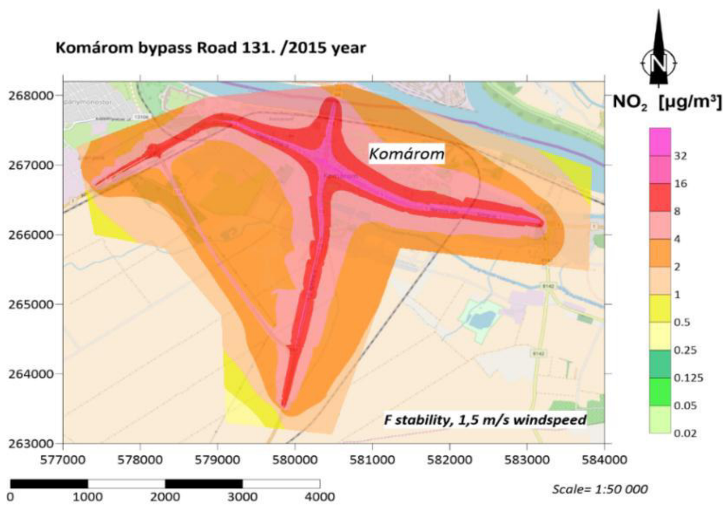

Figure 8: 2015, F stability, 1.5 m/s wind speed, NO_2 immission calculated by IMMI software

The difference maps (see Figures 9 and 10) show the concentration differences between 2010 and 2015. The better air quality could be noticed in the segments of the roads numbers 13 and 1 with D stability and the utmost dissimilarity with the F stability. High immission differences can be found near the new bypass road (No. 131) and around a part of road No.1, the latter is due to the larger traffic in 2015 near the border of Slovakia.

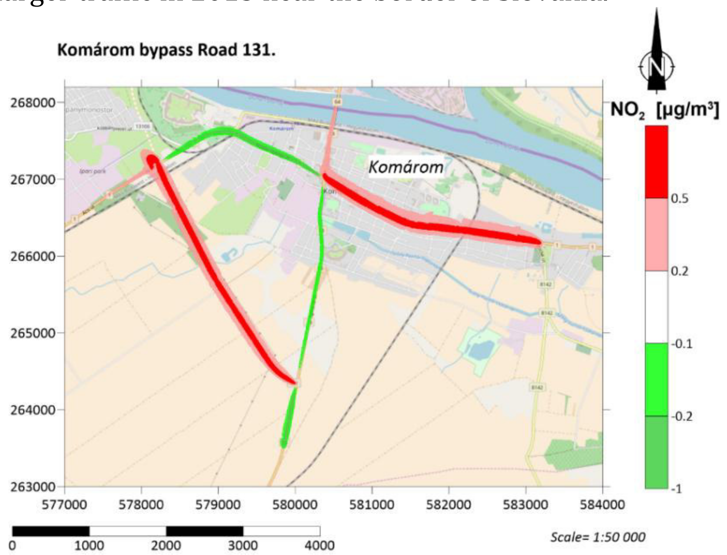

Figure 9: Difference map between 2010- 2015, D stability, 1.5 m/s wind speed, calculated by IMMI software

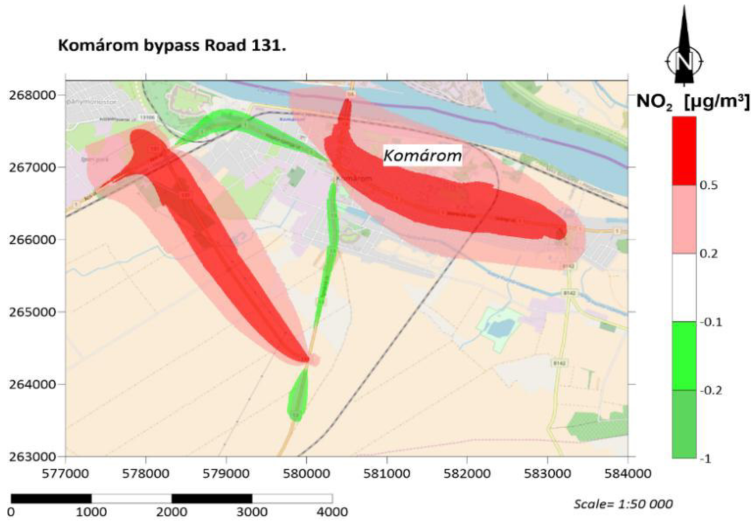

Figure 10: Difference map between 2010- 2015, F stability, 1.5 m/s wind speed, calculated by IMMI software

Concentration values were also calculated for receiver points for different scenarios. Figures 11 and 12 shows the calculated immission data for the year 2010 and 2015, for NO_2 at three receiver's points with different wind speed (1.5, 2, 3, 5 m/s) and same stability D, while Figures 13 and 14 display the same values for stability category F. Lower wind speed (1.5 m/s) showed the high immission concentrations, while the higher wind speed (5 m/s) showed lower concentrations.

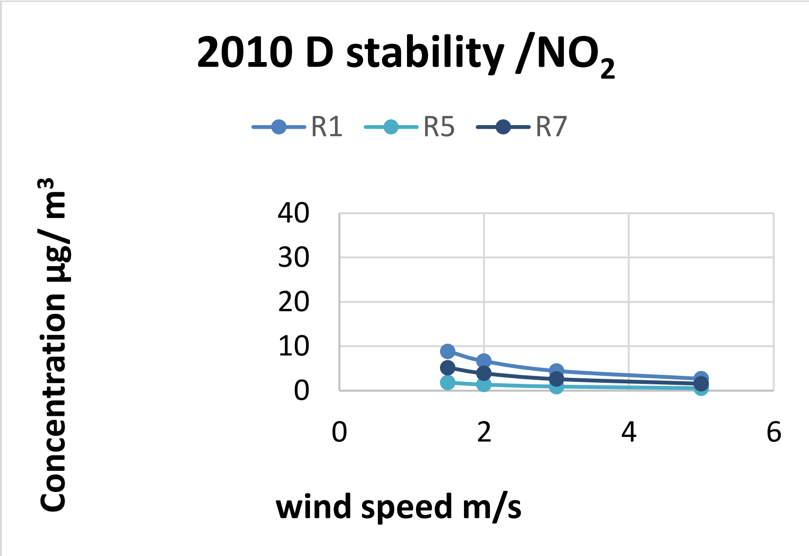

Figure 11: Calculated concentration values for receiver points for 2010 for NO_2, for D stability and for different wind speed

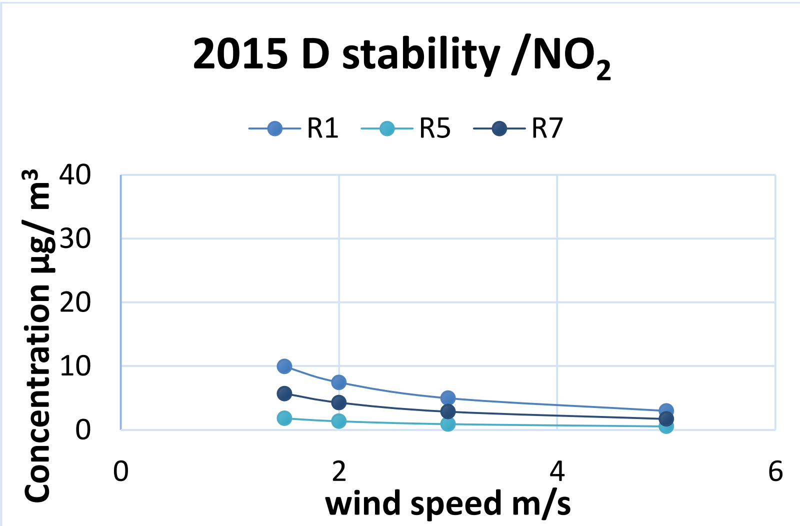

Figure 11: Calculated concentration values for receiver points for 2015 for NO_2, for D stability and for different wind speed

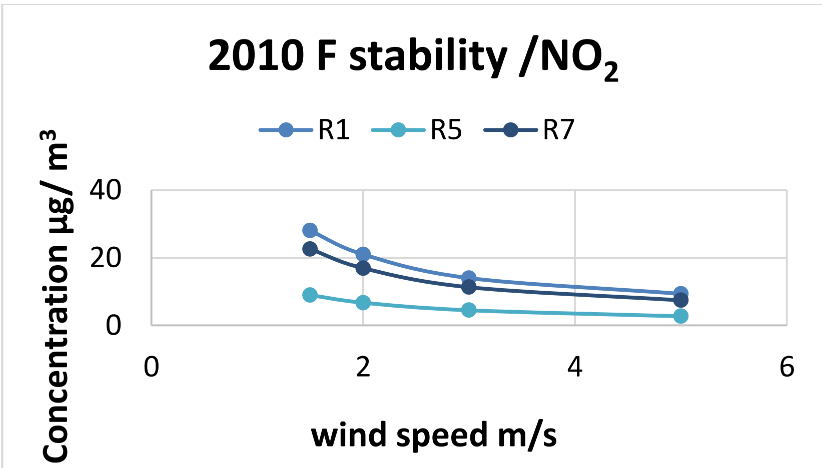

Figure 13: Calculated concentration values for receiver points for 2010 for NO_2, for F stability and for different wind speed

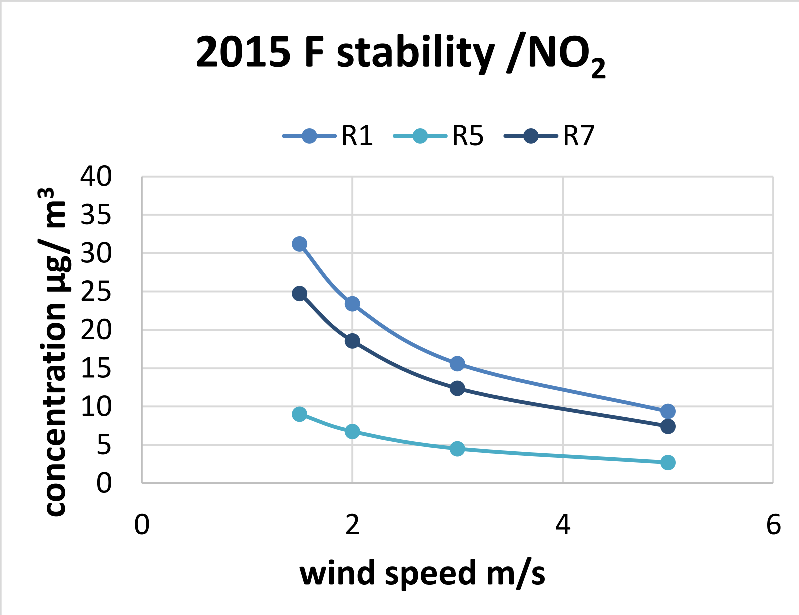

Figure 14: Calculated concentration values for receiver points for 2015 for NO_2, for F stability and for different wind speed

To distinguish the effects of each stability categories, NO_2 concentration values were calculated for A, C, D, E, F categories, where the wind speed was fixed at 1.5 m/s for two years (Fig.15 and Fig.16). The maximum was 31.18 µg/ m³.

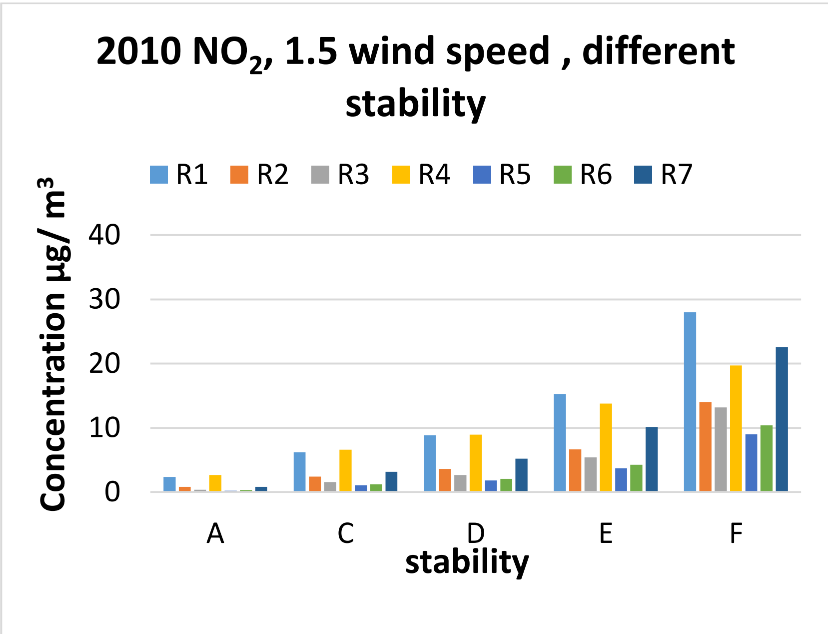

Figure 15: Calculated concentration values for receiver points for 2010 for NO_2 and different stability categories, for 1.5 m/s wind speed

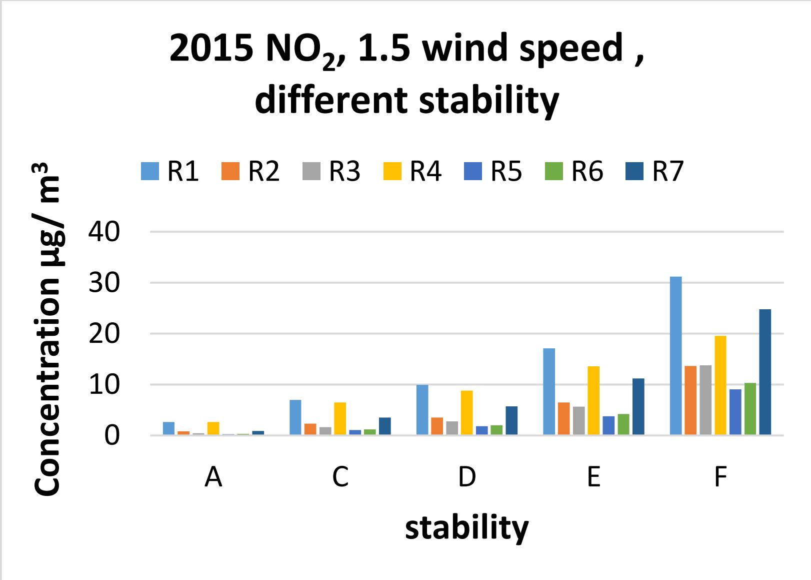

Figure 16: Calculated concentration values for receiver points for 2015 for NO_2 and different stability categories, for 1.5 m/s wind speed

Conclusion

The dispersion model results show only small differences in air quality between 2010 and 2015, but indicate the impacts of the changes in traffic and environmental developments on air quality. In addition, these concentrations were the maximum generated concentrations of NO_2 from one emission source (line sources) and these concentrations shall be added to the background concentration to comply with the immission concentration limits (the max of NO_2 on the scale 32 µg/m^3). Based on the simulations, the new bypass road help in the reduction of the pollutants inside the city, because somehow in segments of the road No.1 and road No. 13 undoubtedly better air quality acquired.

Based on the model simulation we can conclude that for receiver points, R1 school (Petőfi Sándor Általános Iskola - Komárom) and R4 kindergarten (Komáromi Gesztenyés Óvoda) demonstrated the highest immissions in all scenarios. Immissions in some points for the year 2015 show higher concentrations than the year 2010.

No. 131 starts to be in use by heavy trucks and cars instead of the roads No. 1 and 13 to reach the industrial park. However, in one of the segments of road No. 1, high concentrations can be noticed due to the difference of the traffic in the 2 years, wherein 2010 there was a few traffic and in 2015 the traffic increased. In addition, road No.1 is used by traffic to cross to Slovakia.

The meteorological data for simulations were used in the format of annually averaged. Using more detailed input data (e.g. the hourly time series data) could give more precise information and better comparison between the two years and could provide more precise scenarios. For line sources, F stability category (very stable stratification) and low wind speed (1.5 m/s) is the most critical situation for air pollution. Using dispersion models in EIA is an excellent choice for sustainable development. It helps in taking the proper decision by making several scenarios to know the worst situations. Such an example knowing the critical scenarios with the exact occurrence time help the decision makers to take the correct decision and save the health of residents especially the respiratory disease people for example by banning them from going outside till the quality of air getting better. Further investigations are needed especially in schools and kindergartens that located near to the traffic roads to assist the effect of air pollution on the children health and take proper decisions, especially that several studies related the childhood diseases with the exposure to NO_2 air pollutants from traffic such as asthma [22, 23], decrease in cortisol levels and concentrations in adolescents [24], childhood cancer [25]. Finally, in my lovely country, Syria EIA applicable for projects (industrial, residential…etc.) by the Ministry of Local Administration and Environment on the other hand atmospheric dispersion models are not used in assessing the air quality and it is necessarily true that using dispersion models would be beneficial for Syria future especially after the civil war.

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