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Air quality assessment based on road traffic pollutants dispersion modelling: Giurgiu – Ruse Bridge Case study

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Abstract: *The paper presents a case study related to air quality assessment along an important high traffic bridge (Giurgiu - Ruse), by dispersion modelling of the main pollutants. In order to estimate the level of pollution caused by bridge road traffic in the closest urban areas, Giurgiu and Ruse and based on the traffic data, four scenarios for the air quality assessment have been carried out according to different meteorological conditions. The dispersion modeling was realized on specialized environmental pollution software, which features a fully operational Gauss model in its base module. There are presented dispersion maps for the main road traffic pollutants (NO_x, CO, SO_2, THC), aiming to evaluate their impact on the urban areas vicinity, in four different wind directions scenarios, at a constant temperature. Conclusions are presented according to available European Legislation and future scenarios are proposed, for other different meteorological conditions.*

Key Words: *Air pollution, Dispersion maps, Modelling, Scenario, Road Traffic*

1. INTRODUCTION

Road Traffic, both for people and goods, is the most used mode of transport in present. Cars are a very convenient means of transportation with relatively low costs. But the true cost of using cars is very high if we consider the pollution and its environmental effects [1], [2].

Cars are a linear source of low altitude emissions of pollutants such as carbon dioxide, carbon monoxide, nitrogen oxides, sulfur oxides, particulate maters, lead, volatile organic compounds, all having a negative impact on the environment and on the human health [3], [4], [5], [6]. The traffic impact on human health is quantified through a higher incidence of cancer and heart diseases, more breathing issues/ and especially a continuous increase in the severity of diseases [7], [8]. Technological improvements that reduced emissions [9] were offset by a high traffic increasing, so that emissions are still growing. Emissions of pollutants from vehicles have two main features: first, elimination is very close to the ground, leading to the development of very high concentrations at ground level, even for lower density gases with large diffusion capacity in the atmosphere. Secondly, emissions are realized on the entire adjacent road surface, the concentration differences depending on the traffic intensity and the road ventilation possibilities [1]. The air pollution in urban areas due to the traffic from the inside of city or its vicinity is obviously influenced by specific geographical and urban factors and of course by weather conditions [10], [11].

As an alternative to or in conjunction with direct monitoring, computer models are often used to predict the levels of pollutants emitted from various types of sources, and how these emissions eventually impact ambient air quality over time. Models are available for estimating emissions from mobile and stationary sources. [11], [12]. Mathematical modelling of pollutant dispersion in the atmosphere means estimating pollutant concentrations at ground-level and above ground, depending on characteristics of pollution sources, meteorological and orographic conditions, physical and chemical transformation processes that may release pollutants in the atmosphere and their interaction with the ground surface. This is one of the least expensive ways of action against pollution.

2. ATMOSPHERIC DISPERSION MODELLING – IMMI SOFTWARE

The atmospheric dispersion modelling is the mathematical simulation of how air pollutants disperse in the ambient atmosphere. It is performed with computer programs that solve the mathematical equations and algorithms which simulate the pollutant dispersion. The dispersion models are used to estimate or to predict the downwind concentration of air pollutants or toxins emitted from sources such as industrial plants, vehicular traffic or accidental chemical releases.

Dispersion modelling is a method for estimating the ground-level concentration of pollutants at various distances from a source. Modelling refers to a general technique that uses mathematical representations of the factors affecting the pollutant dispersion. [13] The selection of an air quality model for a particular air quality analysis depends on the type of pollutants being emitted, the complexity of the source, and the type of the topography surrounding the facility.

The IMMI software by Wölfel is a reference tool in the air pollution modeling research field. IMMI is a software package for Environmental Pollution Mapping that integrates the air dispersion modelling (gases, dust, odours), outdoors sound propagation (road, traffic, railway, industrial and recreational noise) and inter-faces to CAD and GIS packages. IMMI is used by professionals working with public authorities, consulting engineering companies and industry [14].

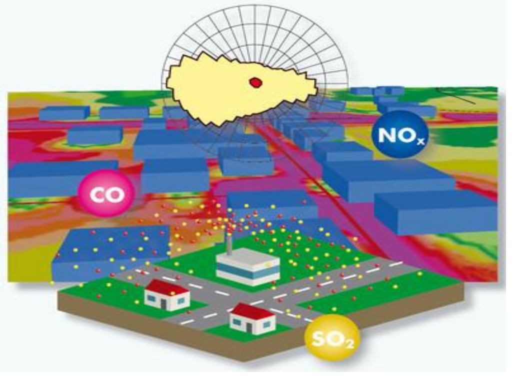


Fig. 1 - General idea of the IMMI air polluting software - Gaussian model

Source: http://www.woelfel.de/en/products/modelling-software/immi-air-pollution-mapping.html

Features:

- Dispersion calculation for gaseous and odorous pollutants and dust, e.g. SO_2, NO_x, NO_2, NH_3, CO, CO_2 ...
- Point, line and area sources
- Effective source height for cold and warm exhaust gases
- Odors: Percentage of hours of a year with odor perception
- Calculation of receptor grids or single user-defined receivers
- Calculation of odour streams for livestock

The dispersion models can predict concentrations at selected downwind receptor locations. IMMI dispersion model for estimation of plume contaminant concentration at a point in space is based on the Gaussian Dispersion Equation (1), according to the proven German TA-Luft, Annex C of 1986 [15].

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

where:
C = point concentration at receptor, in μg/m3;
(x, y, z) = ground level coordinates of the receptor relative to the source and wind direction, in m;
H = effective release height of emissions, in meters (m);
Q = mass flow of a given pollutant from a source located at the origin, in μg/s;
u = wind speed, in m/s;
σ_y = standard deviation of plume concentration distribution in y plane, in m;
σ_z = standard deviation of plume concentration distribution in z plane, in m.
Gaussian model was chosen because provides accurate information for distances between 10 m - 30 km, for which the dispersion coefficients have been experimentally determined.

The assumptions made in the development of the above mentioned equation are:

- The plume spread has a Gaussian (normal) distribution in both horizontal and vertical planes, with standard deviations of plume concentration distribution in the horizontal and vertical directions;
- Uniform emission rate of pollutants;
- Total reflection of the plume at ground;
- The plume moves downstream (horizontally in the x direction) with mean wind spread;
- The stack gases emitted from the mobile source (traffic) in the atmosphere are not reactive i.e. there is no form of reaction between the pollutants. [16], [17].

This paper presents a case study that aims to assess the rate of air pollution due to a heavy road traffic on Giurgiu – Ruse Bridge and the possible impairment of its two neighboring urban areas, Giurgiu and Ruse, in four wind directions scenarios, using IMMI software. The parameters considered in this study are Nitrogen Oxides (NOx), Sulphur Dioxide (SO_2), Carbon Monoxide (CO)and CH_4 (Methane).

The air quality profile consequences of emissions are predicted using the Gaussian Plume Dispersion Model.

Its advantages are the followings:

- This kind of dispersion did not require significant computer resources
- It's easy to use – it comes with user-friendly graphical user interfaces (GUIs) and a relatively small number of input variables is required
- It's widely used – well developed knowledge due to many users and also the results of different studies can easily be compared.
- It has simple meteorological data requirements – as input data set

The main objective of such a modelling study is usually to determine the significance of the effects of pollutants discharged from a particular mobile source (in our particular case the road traffic).

The results must therefore be reported effectively and concisely in a manner suitable to the purpose for which they were produced. This means the results must be communicated in a way that can be understood by other people who may not be experienced in interpreting the model output.

This involves two steps: first, to report themselves the modelling results in an easy-to-understand manner; and second, to evaluate the implications of the results in terms of the potential effects of the predicted ground-level concentrations on people's health and on the environment, according to existing legislation (also in an easy-to-understand manner).

3. INFORMATION ABOUT TRANSBORDER TRANSPORT IN GIURGIU - RUSE REGION

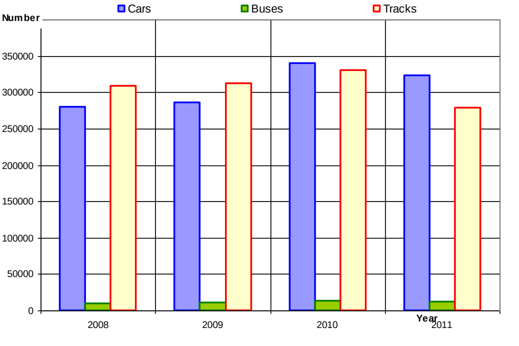
For performing this case study, we used yearly traffic data (Table 1) received from Bulgarian Police Border and Bulgarian Customs for period 2008 – 2011 [18], [19], as well as traffic data measured during 07 – 13 November 2011, in four different hourly intervals (Table 3).

We used IMMI for dispersion calculation of gaseous, odorous and dust pollutants, version IMMI 6.3 software package, model based on the proven German TA-Luft, Annex C of 1986.

Table 1 Number of cars on Giurgiu Ruse Bridge (Total, annual)

	2008	***2009***	***2010***	***2011 (9months)***
Cars	279405	286390	339602	323209
Buses	9860	10396	12798	12294
Tracks	309128	311960	329862	278512

Fig. 2 - Percentages for the means of transportation for the Giurgiu –Ruse border



As the received data are not fully available for the entire year 2011 (Table 1), we chose for this study the year 2010 (Table2) and having real counting data for the week 07 – 13. 11.2011:

Table 2: Distribution of cars in 2010 – Official data

	2010	
Cars	339602	49.8%
Buses	12798	50.2%
Trucks	329862	
Total	682262	100%

Real average value:
682262/365 days/24 hours =
78 cars/hour
(according to official data)

Distribution of cars at four higher traffic hourly interval in each day from week 07 – 13.11.2011 can be seen in Table 3:

Table 3: Distribution of cars for week 07 – 13.11.2011, at four higher traffic hourly intervals – Real hourly data

07.11.11	08.11.11	09.11.11	10.11.11	11.11.11	12.11.11	13.11.11	**Hourly Interval**
Mo	**Tu**	**W**	**Th**	**Fr**	**Sa**	**Su**	
111	111	112	126	117	76	65	7 - 12
100	94	96	96	100	100	95	12- 20
66	78	71	82	82	75	68	20 -23
57	54	57	58	58	55	60	23 - 7

Higher value: 126 cars/hour
(according to measured data)

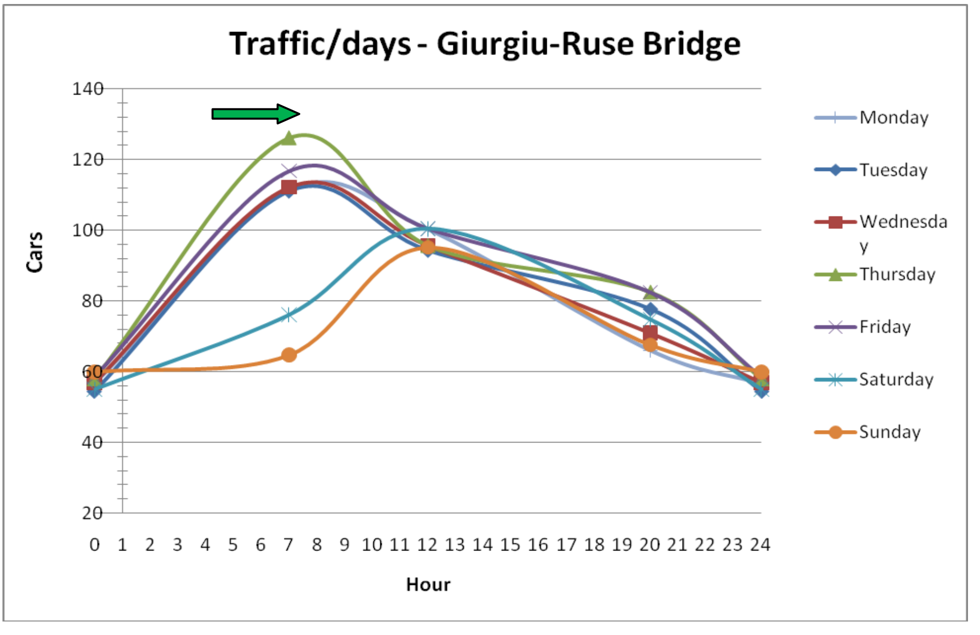


Fig. 3 - Giurgiu – Ruse Bridge Traffic (week 07. – 13.11.2011)

We chosen for dispersion the interval 07 – 11 a.m., as the higher values are in this period of the day, and from this interval, the highest value from the entire week, 126 cars/hour - Thursday, 10.11.2011 (Table 3, Fig. 3).

Four reference scenarios were estimated, according to different main predominant wind directions in Giurgiu region. These predominant wind direction have been taken into account according to data registered at Giurgiu meteo station [20], [21], as can be seen in Fig. 4 and Table 4:

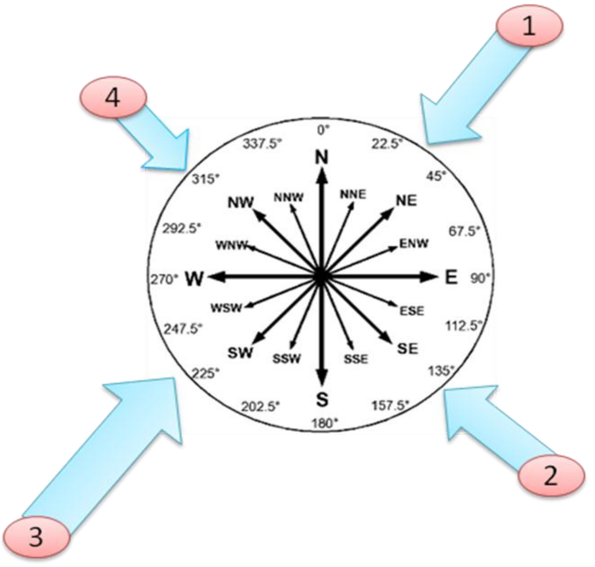


Fig. 4 - Four main wind directions scenarios for Giurgiu – Ruse Bridge road traffic pollutants

Input data for simulations:

- Constant temperature, 10 Celsius degrees
- Anemometer height = 10m
- Average wind velocity ua = 2 m/s
- Stability class (TA Luft) = III/1: neutral
- Angular step size = reference sectors (2°)
- Grid calculation:

	Step size	Points
dx/m	100	229
dy/m	100	133

Total grid calculation points = 30457

Table 4: Annual Wind Directions registered at Giurgiu meteo station

Meteorological station	Annual Wind Direction Percentages								
	N	**NE**	E	**SE**	S	**SV**	V	**NV**	Calm
Suceava	3.0	1.4	2.8	10.1	8.0	7.1	4.7	26.5	36.4
....									
Calaraşi	9.2	16.6	10.2	8.7	5.7	9.6	17.4	5.7	16.9
Giurgiu	4.9	**18.7**	9	**10.5**	6.4	**20.5**	5.3	**10.1**	14.6
Ploieşti	14.6	16.0	9.5	2.8	2.5	7.8	9.2	5.6	32.0
Bucureşti Băneasa	3.4	16.4	10.3	1.8	1.5	11.7	9.2	2.3	43.4
Vf. Omu	6.9	9.3	4.5	2.9	6.6	20.8	20.9	17.8	10.3
....									

4. MAIN SCENARIOS FOR ROAD TRAFFIC POLLUTANTS DISPERSION MODELLING ON GIURGIU – RUSE BRIDGE

In Fig. 5 – 20 can be seen the simulated Gaussian Plumes for pollutants in each of the four scenarios:

Scenario 1 (wind from N-E):

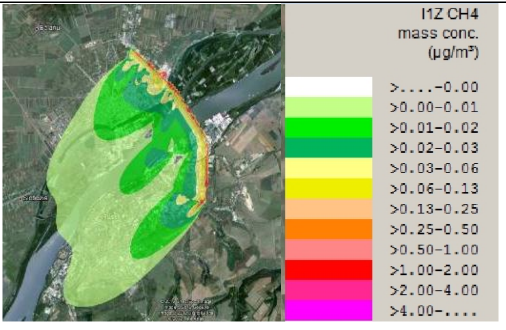


Fig. 5. CH_4 dispersion

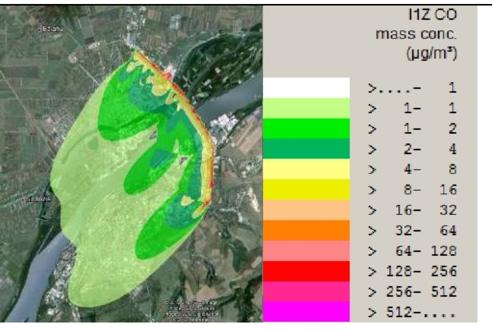


Fig. 6. CO dispersion

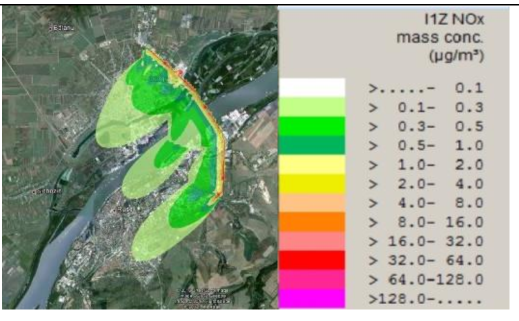


Fig. 7. NO_x dispersion

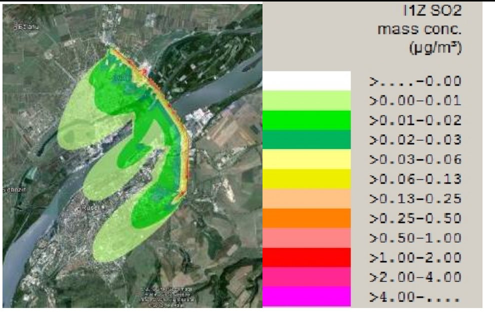


Fig. 8. SO_2 dispersion

Scenario 2 (wind from S-E):

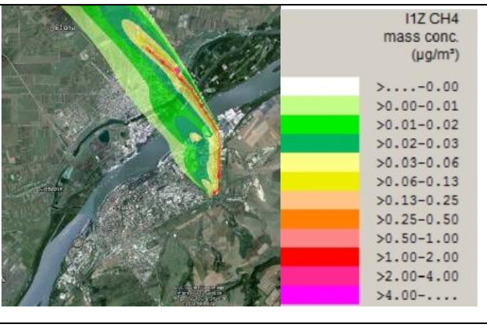


Fig. 9. CH_4 dispersion

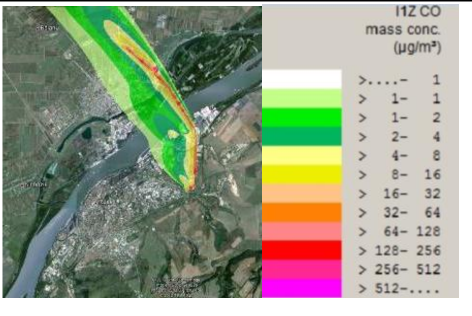


Fig. 10. CO dispersion

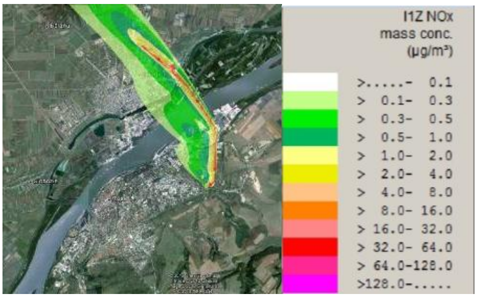


Fig. 11. NO_x dispersion

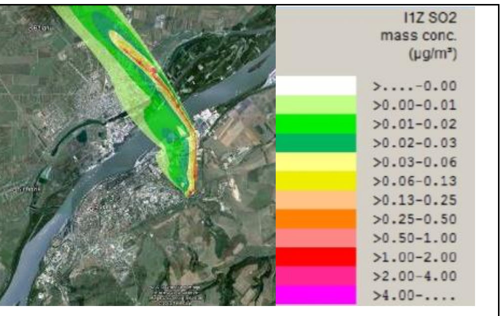


Fig. 12. SO_2 dispersion

Scenario 3 (wind from S-V) :

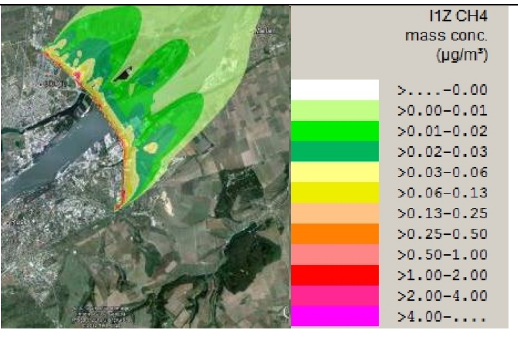


Fig. 13. CH_4 dispersion

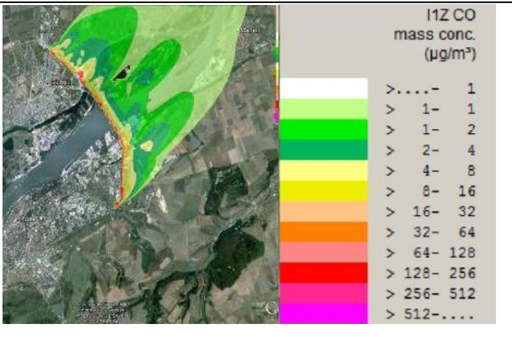


Fig. 14. CO dispersion

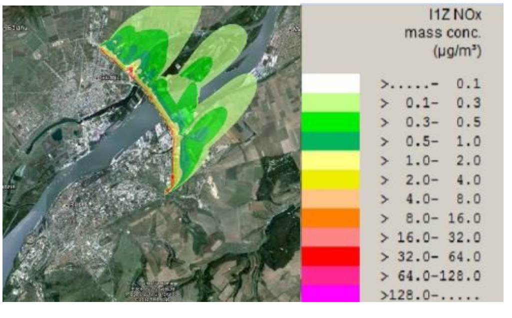


Fig. 15. NO_x dispersion

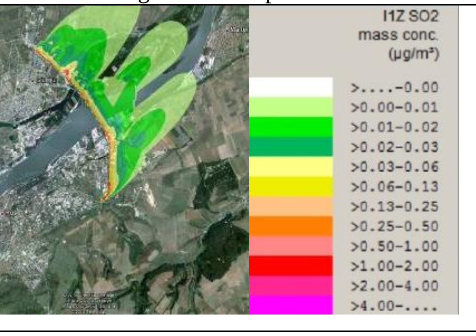


Fig. 16. SO_2 dispersion

Scenario 4 (wind from N-V):

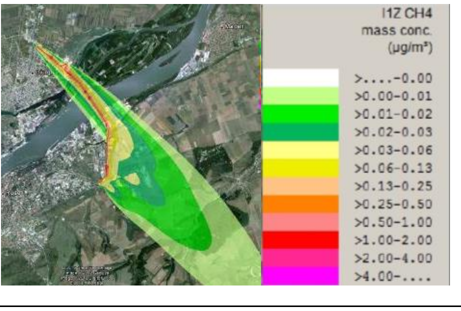


Fig. 17. CH_4 dispersion

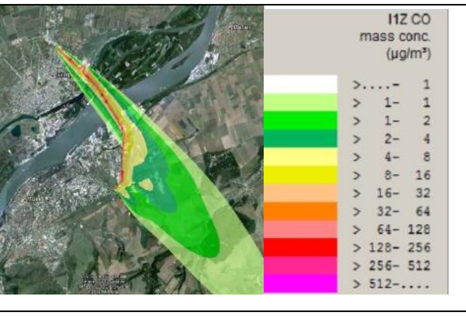


Fig. 18. CO dispersion

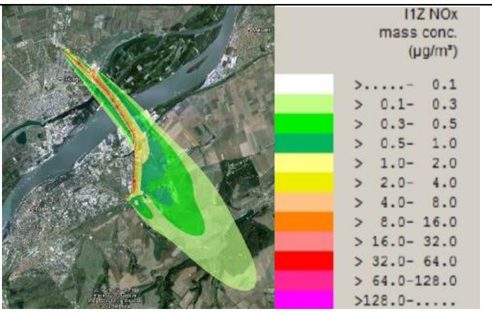


Fig. 19. NO_x dispersion

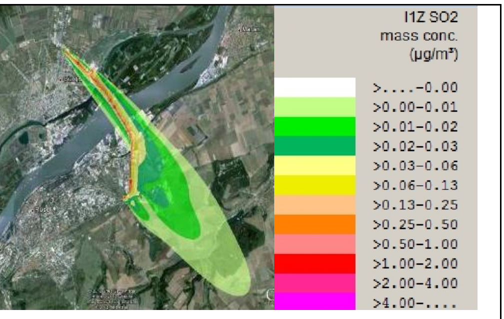


Fig. 20. SO_2 dispersion

On the European level the air quality is governed by a series of initiatives and directives to reduce emissions and improve the air quality (see links section). The 6th Environmental Action Plan and its thematic strategies is the policy response to address these pressing societal problems.

The Clean Air for Europe Programme (CAFE) within the 6th Environmental Action Plan has developed the thematic strategy for further reduction of air pollution and its effects and has prepared the ground for a new Air Quality Directive [22]. The so-called CAFE Directive (2008/50/EC) was published on 21st May 2008 and merges earlier directives into single directive on air quality.

However, it gives Member States a greater flexibility in meeting some of these standards in areas where they have difficulty to comply.

The CAFE Directive addresses regular assessment of air quality through monitoring and modelling in agglomerations with more than 250.000 inhabitants, requires the development of Action Plans for the improvement of air quality and defines obligations to inform the public on the air quality situation.

For a good interpretation of all scenarios, it is important to know and understand the limit imposed by the European legislation – Directive 2008/50/CE on ambient air quality and cleaner air for Europe – see Table 5 [23], transposed both in Romania and Bulgaria: Law no.104/15.06.2011 on environmental air quality (published in MO 452/28.06.2011) in Romania [24] and Clean Air Act and Ordinance No.12 of 15 July 2010 in Bulgaria [25].

Table 5: Limit values for main pollutants, according to Directive 2008/50/CE

	Requirement	**Averaging**	**Limit Value**
SO_2	Hourly limit value for human health protection	1 h	350 $\mu g/m^3$
	Daily limit value for human health protection	24 h	125 $\mu g/m^3$
	Limit value for eco-systems protection	Calendar Year -	20 $\mu g/m^3$
NO_x	Hourly limit value for human health protection	1 h	200 $\mu g/m^3$ NO_2
	Yearly limit value for human health protection	Calendar Year -	40 $\mu g/m^3$ NO_2
	Yearly limit value for eco-systems protection	Calendar Year	30 $\mu g/m^3$ NO_x
CO	Daily (8 hours) limit value for human health protection	24 h, at every 8h	10 mg/m^3

As it can be observed from the legends analysis for each scenario simulation, in no situation the simulated values are over the legal limit values, for main pollutants (SO_2, NOx and CO). This is very important mainly for scenario 1, which involves moving the cloud of pollutants through both cities (Giurgiu and Ruse) from the vicinity of the bridge (Table 6):

Table 6: Simulated hourly values, versus limit values according to Directive 2008/50/CE

Scenario	**SO_2,** µg/m^3	**NO_x,** µg/m^3	**CO,** µg/m^3
1	0 – 4 < 350	0,5 – 128 < 200	1 – 512 µg/m^3< 10 mg/m^3
2	0 – 4 < 350	0,1 – 128 < 200	1 – 512 µg/m^3< 10 mg/m^3
3	0 – 4 < 350	0,1 – 128 < 200	1 – 512 µg/m^3< 10 mg/m^3
4	0 – 4 < 350	0,1 – 128 < 200	1 – 512 µg/m^3< 10 mg/m^3

Therefore we can conclude that the Bridge road traffic is not a danger for air pollution in the main two cities from trans-border area, the values of pollutants concentration being much under the imposed values. This conclusion is available only in temperature, average wind velocity, stability class and traffic conditions assumed as input data in this study.

4. CONCLUSIONS AND FUTURE WORK

The characteristics of Gaussian models make them convenient tools to determine the significance of the effects of pollutants discharged from a particular source, fixed or mobile – in our case Giurgiu Ruse Bridge road traffic.

Having in view the main annual wind directions frequency in Giurgiu region, the traffic consistency on the Giurgiu Ruse Bridge and temperature, average wind velocity, stability class and traffic conditions assumed as input data in this study, we can conclude that this pollution source (the bridge road traffic) is not dangerous for Giurgiu, or Ruse, in any situation of simulated scenarios, the values of main pollutants being much under the legal limit values.

Future scenarios can be modelled in some other various temperature conditions and future air quality measurements from the vicinity of the bridge and also in Giurgiu and Ruse towns can be performed, in order to evaluate the share of traffic pollution within the general pollution of each city.

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REFERENCES

[1] R.N. Colvile, E.J. Hutchinson, J.S. Mindell, R.A. Warren, *The Transport Sector as a Source of Air Pollution,* available at: http://eprints.ucl.ac.uk/894/1/Millennium_rvw_final_october.pdf

[2] *** OECD-Greening Transport: *Globalisation, Transport and the E nvironment* available at: http://www.oecd.org/env/transportandenvironment/45095528.pdf.

[3] Alois Krasenbrink, Giorgio Martini, Urban Wass, Edward Jobson, Jens Borken, Reinhard Kuehne, Leonidas Ntziachristos, Zissis Samaras and Menno Keuken, *Factors Determining Emissions in the WHO European Region,* available at: http://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf.

[4] Menno Keuken, Eric Sanderson, Roel van Aalst, Jens Borken and Jurgen Schneider, *Contribution of Traffic to Levels of Ambient Air Pollution in Europe,* available at: http://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf.

[5] *** *Sources of Pollutants in the Ambient Air - Mobile Sources*, available at: http://www.epa.gov/apti/course422/ap3a.html.

[6] Roger Gorhan, *Air Pollution from Ground Transportation*, available at: http://www.globalcitizen.net/data/topic/knowledge/uploads/20110302143644705.pdf.

[7] John Wargo, Linda Wargo, Nancy Alderman, *The Harmful Effects pf Vehicle Exhaust – A Case for Policy Change*, available at: http://www.ehhi.org/reports/exhaust/exhaust06.pdf.
[8] Janice J, Svetlana Smorodinsky, Michael Lipsett, Brett C. Singer, AlfredT. Hodgson, Bart Ostro, *Traffic-related Air Pollution near Busy Roads*, American Journal of Respiratory and Critical care Medicine, 2004, *vol. 170 no. 5 520-526*, available at: http://ajrccm.atsjournals.org/content/170/5/520.full.
[9] *** European Commission, *Transport&Environment, Road Vehicles*), available at: http://ec.europa.eu/environment/air/transport/road.htm
[10] U.S. Environmental Protectiona Agency – *Air Pollution Control Orientation Course – Control Emmissions Technologies – Transport and Dispersion of Air Pollutants*, available at: http://www.epa.gov/apti/course422/ce1.html.
[11] Mario G. Cora and Yung-Tse Hung, *Air Dispersion Modeling: A Tool for Environmental Evaluation and Improvement*, Environmental Quality Management/Spring 2003, published online in Willey InterScience, pag. 75-86.
[12] *** *Air quality modeling*, available at: http://www.cleanairworld.org/TopicDetails.asp?parent=21
[13] *** *Atmospheric dispersion modeling*, available at : http://en.wikipedia.org/wiki/Atmospheric_dispersion_modeling.
[14] *** *Wölfel - IMMI software for dispersion calculation of gaseous, odorous and dust pollutants*, available at: http://www.woelfel.de/en/products/modelling-software/immi-air-pollution-mapping.html
[15] *** *Excerpt of the Technical Instructions on Air Quality Control, Annex C : Model Calculation*, available at: http://www.soundplan.eu/fileadmin/user_upload/pdf/soundplan_luft/gauss/2009-08-13_en_---_ta_luft_86_annex_c.pdf.
[16] Maudood N. Khan, William L. Crosson, and Maurice G. Estes, Jr. Universities Space Research Association (USRA), *Land Use and Land Cover Characterization within Air Quality Management Decision Support Systems: Limitations and Opportunities*, NASA Applications Program Lead Program Manager for Air Quality Applications NASA Headquarters Washington, DC 20546, February 23rd 2007.
[17] Mihaiella Cretu, Victoria Teleaba, Silviu Ionescu, Adina Ionescu, *Case study on pollution prediction through atmospheric dispersion modeling*, WSEAS Environment And Development, Issue 8, Volume **6**, August 2010, ISSN 1790-5079.
[18] *** *Bulgarian Police Border, petition no. 16764 / 05.09.2011*.
[19] *** *Bulgarian Customs, petition no. 16764 / 05.09.2011*.
[20] ***Scoala Nationala de Meteorologie – INMH, *Suport de curs: Vantul*, available at: http://193.26.129.71, http://snm.inmh.ro/scoala/index.php/.
http://www.google.ro/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CCgQFjAA&url=http%3A%2F%2F193.26.129.71%2Fscoala%2Fclaroline%2Fbackends%2Fdownload.php%3Furl%3DL0NMSU1BVE9MT0dJRS9zdXBvcnRfY3Vyc19fVmFudC5kb2M%253D%26cidReset%3Dtrue%26cidReq%3DDOCUM&ei=4CGyUPudCtGRswbmx4HQCg&usg=AFQjCNE8k3MWxQp3OvZjaFislGh3VjDUCw&sig2=W5y0LWAI-vZ6wzIKfA5vQQ.
[21] *** *Memoriu de prezentare al judetului Giurgiu - Documente planuri judetene*, available at: http://www.rowater.ro/daarges/Documente%20Planuri%20Judetene/Planuri%20de%20aparare%20judetul%20Giurgiu/5.%20Memoriu%20de%20prezentare%20a%20judetului%20Giurgiu.pdf.
[22] *** Clean Air for Europe (CAFÉ) Programme, available at: http://europa.eu/legislation_summaries/other/l28026_en.htm.
[23] *** European Commission – *Environment – Existing Legislation*, available at: http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm.
[24] *** Ministerul mediului si padurilor, *Calitatea Aerului, Legislatie nationala*, available at: *http://www.mmediu.ro/beta/domenii/protectia-atmosferei/calitatea-aerului/legislatie-calitatea-aerului/*
[25] *** Ministry of Environment and Water from Bulgaria, *Harmonization of National Environment Legislation with Acquis, Air quality*, available at: http://www2.moew.government.bg/index_e.html.