# Air quality impact of traffic and point sources in Skopje assessed with dispersion models

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## Abstract

Local scale air quality dispersion models can be used to provide information about the impact of individual emission sources or source categories on the air quality and to predict air quality as a result of changes in emissions such as increase of traffic, emission control measures etc. Dispersion models can be used to complement the data gained by monitoring as the spatial coverage of air quality information provided by monitoring is often limited. They are also an important tool for supporting air quality improvement plans and programmes.

The modelling of the air pollution is one of the techniques that can lead to better planning and making decisions from the authorities on the local, regional or even global scale. In this paper are presenting the first this- kind of study in this area. This study uses measurements for emissions of the NO2 and CO from traffic, and also NO2 and SO2 from point sources in order to produce the general picture of the pollution on annual level.

This modeling study is the first one done for Skopje attempting to assess the air quality impact of major part of the emission sources by dispersion models. Even though the input data required in the dispersion modeling still includes uncertainties, this modeling study can give valuable information on the air quality levels in different parts of Skopje.

## Introduction

The air quality nowadays is one of the most important issues in the ECO World. In most cities air quality has improved (substantially) over the past decades. The visible and noticeable air pollution (smoke, dust, smog) has disappeared from many cities due to local, national and European initiatives. Occasionally air quality poses an immediate threat: during industrial accidents or pollution episodes. Fortunately this is rare. Nevertheless the current air quality still affects people's health. In many European cities, air quality is a concern and it is therefore monitored around the clock. In most cities, industrial air pollution is, or tends to be replaced by traffic related air pollution. Air quality is therefore a common problem to almost all major cities.Air pollution causes health effects and environmental problems. Typical air pollutants that cause immediate concern are listed below.The 3 pollutants of major concern in Europe are: PM10, NO2, O3 and additional that also need to be taken into account are the pollutants (CO, PM2.5 and SO2).

### Overview of the model UDM-FMI

The UDM-FMI is a local scale dispersion model developed at the Finnish Meteorological Institute. The dispersion model is based on Gaussian plume equations for various stationary source categories (point, area and volume sources). The Gaussian plume equations can be mathematically derived from the atmospheric diffusion equation in case of homogeneous and stationary turbulence. The overall structure of the model is presented in Figure 1.

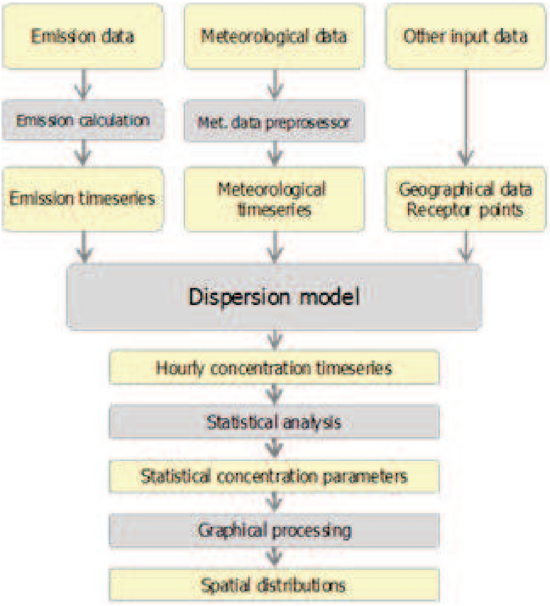


**Figure 1.** The overall structure of the Urban Dispersion Modelling System.

### Overview of the model CAR-FMI

CAR-FMI is a Gaussian finite line source dispersion model i.e. a plume model for an open road network. The model computes an hourly time- series of the pollutant dispersion for CO, NO, NO2, NOx and exhaust PM2.5 concentrations with input information from: -the number and locations of the line sources, -the hourly traffic volumes of the roads, -compounds to be computed and details of statistical interests of the output, -hourly time-series of the meteorology and the background concentration. The meteorological time-series is computed by the meteorological pre- processing model (MPPFMI), developed at the FMI (Karppinen et al., 1997). The background concentrations of gaseous compounds are interpolated from the measurements of the monitoring network of FMI, while the background concentrations of fine particulate matter can be estimated, if local measurements are not available. The technical structure of the refined CAR-FMI model is presented in Figure 2.

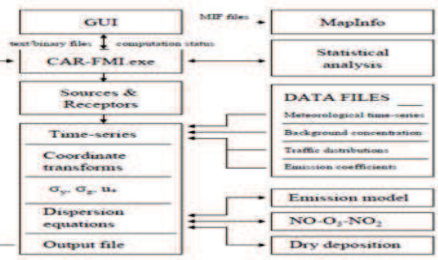


**Figure 2**. Technical structure of the CAR-FMI model, in which dry deposition is associated with PM2.5 concentrations

## Our case study

The dispersion of emissions in Skopje was calculated using this two dispersion models, CAR-FMI (Contaminants in the Air from a Road) and UDM-FMI developed in the Finnish Meteorological Institute. CAR- FMI was used to calculate the dispersion of emissions from traffic and UDM-FMI the emissions from point sources. The pollution generated from traffic is calculated for nitrogen dioxide (NO2) and carbon monoxide (CO) and for the pollution generated from point sources is calculated for nitrogen dioxide (NO2) and sulphur dioxide (SO2).

### *Input data*

*Calculation grid*

With CAR-FMI the concentrations caused by traffic were calculated to a grid of a size 2.3 x 1.3 km covering major part of the Skopje city center. The grid included approximately 900 calculation points. The concentrations were also calculated to a location of an air quality monitoring station “Rektorat” situated close to a busy junction in the north part of the Skopje city center. With UDM-FMI the concentrations from point sources were calculated to over 10000 grid points covering an area of 15×15 km in Skopje valley. The concentrations were also calculated to a location of an air quality monitoring stations in “Lisice”, “Centar”, “Karpos” and “Gazi Baba”.

*Meteorological data*

The dispersion models used in the calculation require hourly time series of those meteorological parameters that affect the distribution of pollutants. The meteorological time series for the year 2008 used in the calculations was compiled using meteorological preprocessor MPP-FMI developed in the Finnish Meteorological Institute. The meteorological observation data used in the calculations was from weather station situated on “Zajcevrid”, in the

Skopje valley. Test calculations were also made with other meteorological data (other stations and years).

*Background concentration data*

The background concentrations data needed for calculations in building the model is from the stations situated in Veles and Lazaropole. Veles is a small town situated approximately 50 kilometers from Skopje and Lazaropole is situated in the mountain area of Mavrovo. Lazaropole station has no local emission sources in the vicinity and Veles station has no major local sources for CO or NO2 emissions. The annual average concentrations for 2008 in Veles were: 17 µg/m3 for NO2, 66 µg/m3 for O3, 2.6 µg/m3 for CO. The annual average concentration for 2008 in Lazaropole was: 1 µg/m3 for NO2, 7 µg/m3 for SO2.

*Traffic data*

The traffic amount data was collected by the Sector of Traffic of the City of Skopje. The data includes traffic amount data separately for passenger cars, motorcycles and heavy duty vehicles for 28 intersections in the Skopje city center. The vehicles were counted during a peak hour in the autumn 2009. The traffic variation during the day was assessed using partially Finnish data and old data from Skopje. In following figure the estimation of daily amounts of cars is presented. There are not available national emission factors for vehicles developed and for the purpose of this first modeling exercise, the Finnish emission factors for year 1995 were used. The year 1995 was selected because it is the oldest year available in the CAR-FMI modeling system, not because it could be estimated that the emission factors represent the current situation in BC. It can be nevertheless estimated that the vehicle fleet in BC is older than in Finland. In 2009 in Skopje the percentage of cars older than 15 years was over 50 % and cars newer than 5 years 18 %.

*Point source emission data*

In the emission calculations 11 major point sources (with 28 individual stacks) were taken into account in the modeling. The major emission point sources that were chosen are: “Cement factory “USJE” – Skopje (Main activity of USJE is cement production), Heat production companies JSC "Toplifikacija"-Skopje [“Toplifikacija ZAPAD”, “Toplifikacija ISTOK” and “Toplifikacija 11 Oktomvri”] (Main activity is production and distribution of heat energy), “Pivara Skopje”-Skopje (Main activity is beer production and production of vinegar, alcoholic and nonalcoholic beverages.) , “Elem-Energetika” (Main activity is electricity production), “Arcelomittal-HRM” (Main activity is production of raw iron, steel and ferro metals), “Arcelomittal-CRM” (Main activity is production of raw iron, steel and ferro metals), “Makstil Valavnica” (Main activity is tin production), “Makstil Celicara” (Main activity is steel production), “MZT Energetika” (Main activity is hot water production). The total amount of SO2 and NOx emissions in tons per year for 2008 were taken into account for each point source as in the following figure. The year 2008 is a reference year in this study because the Cadastre for air emissions is updated every 4 years. The modelling was based on SO2 and NOx annual emission data, annual hours of operation, temperature and outflow of the gases, diameter and height of stacks. Based on this information hourly emission time series was calculated covering the same duration as the meteorological time series.

## Results

### *Traffic*

As the result of the dispersion modeling calculations, the NO2 and CO annual average concentrations caused by the traffic emissions in Skopje city center are shown as dispersion maps in Figure 3 & 4. The maximum annual average concentrations for NO2 occur within and near the most trafficked crossroads and roads in Skopje. According to the dispersion modeling calculations the maximum annual average concentration of the study area for NO2 is 51.4 µg/m3, which exceeds the limit value (40 µg/m3) for annual average concentration of NO2. The highest concentrations occur in and near the crossroads of Boulevard “Goce Delčev” and “Krste Petkov Misirkov” and the crossroad of Boulevard "Kočo Racin" and "Kuzman Josifovski Pitu". According to the dispersion modeling calculations, the concentrations near the busiest roads are between 40 to 50 µg/m3, while in other parts of city center the concentrations are between 25 to 40 µg/m3. The maximum annual average concentrations for CO occur also within and near the most trafficked crossroads and roads in Skopje. According to the dispersion modeling calculations the maximum annual average concentration of the study area for CO is 440 µg/m3. The highest concentrations occur also near the previously mentioned crossroads. According to the dispersion modeling calculations, the concentrations near the busiest roads are between 200 to 440 µg/m3, while in other parts of city centre the concentrations are between 80 to 200 µg/m3. There is no limit value for annual average concentrations of CO. Comparison of the modeled against measured NO2 and CO annual average concentrations was done in one point representing the location of the air quality measurement station Rektorat. This air quality monitoring station is located near the crossroad of Goce Delčev and Krste Petkov Misirkov. The comparison was done with measurement data from 2006 and 2007 as the coverage and the quality of the data from more recent years is not good. The analysis shows that the annual average NO2 and CO concentrations measured in the monitoring station Rektorat are compare well with the modeled ones.

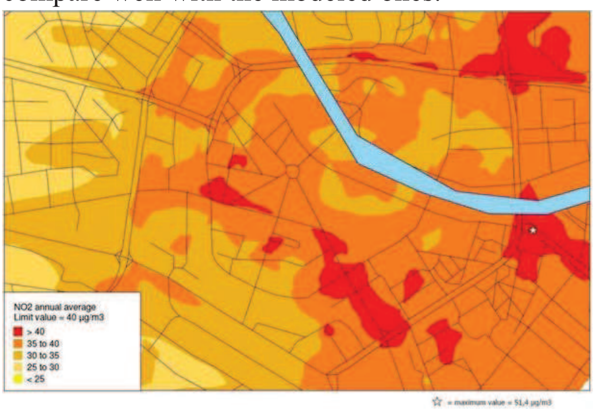


**Figure 3**. Modeled NO2 annual average concentration from road traffic in Skopje


**Figure 4.** Modelled CO annual average concentration from road traffic in Skopje

***Point sources***

As the result of the dispersion modeling calculations, the NO2 and SO2 average concentrations caused by the point source emissions in Skopje are shown as dispersion maps in the figures 9 - 12. In the dispersion maps and in the following text the background concentrations are not taken into account. The NO2 concentrations from the point source emissions in Skopje are very low compared to the concentrations caused by traffic emissions. The annual average is within the range of 0-0.4 µg/m3. The maximum concentrations appear close to the steel production plants "Arcelomittal - CRM" and "Arcelomittal - HRM". The highest SO2 concentrations caused by the point sources in Skopje appear in the vicinity of the energy production plant "Toplifikacija – Zapad". The average annual SO2 concentration from major point sources over the study area is within the range of 0–4.3 µg/m3. The critical value for protection of vegetation for the annual average concentrations of SO2 is 20 µg/m3 and the modeled concentrations do not exceed this. The daily average SO2 concentration (fourth highest daily average according to the limit value) from major point sources over the study area is within the range of 0.6–49 µg/m3. The limit value for the daily average concentrations of SO2 is 125 µg/m3 and the modeled concentrations do not exceed this. The hourly average SO2 concentration (25th highest hourly average according to the limit value) from major point sources over the study area is within the range of 3–343 µg/m3. The limit value for the hourly average concentrations of SO2 is 350 µg/m3 and the modeled concentrations do not exceed this. Comparison between the modeled and measured SO2 concentrations was done in four points that are representing four air quality measurements stations from the State Air Quality Monitoring System – “Karpos”, “Centrar”, “Gazi Baba” and “Lisice”. The regional background concentration is taken into account in the modeled concentrations. The measured annual and daily average SO2 concentrations show higher values than the modeled ones (figure 8-9). This may be due to the fact that in this study the impact of all emissions from point sources (from Skopje valley or larger area) was not taken into account. Other reason might be the unreliability of the emission data that is reported for the point sources.

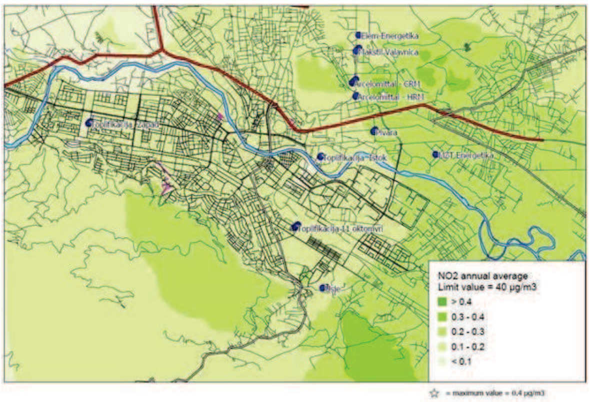


**Figure 9.** Modelled NO2 annual average concentration from point sources in Skopje

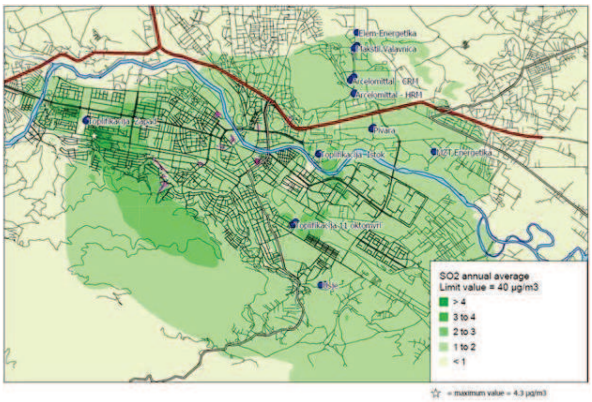


**Figure 5**.Modelled SO2 annual average concentration from point sources in Skopje

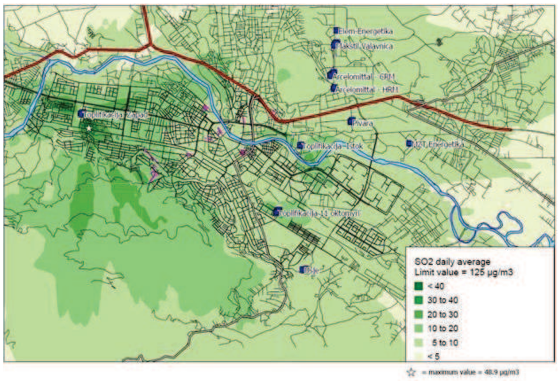


**Figure 6**.Modelled SO2 daily average concentration from point sources in Skopje

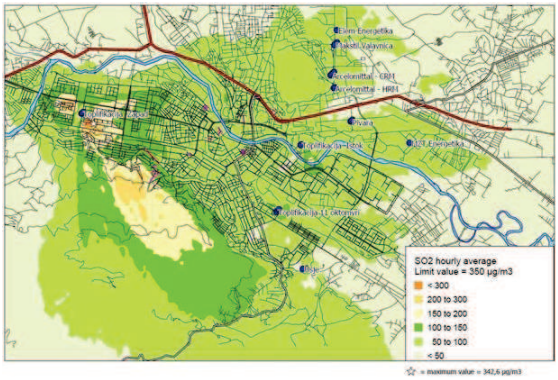


**Figure 7.** Modelled SO2 hourly average concentration from point sources in Skopje

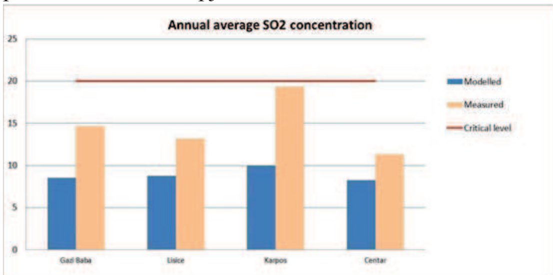


**Figure 8.** The modeled and measured annual average SO2 concentrations in the location of four monitoring stations.

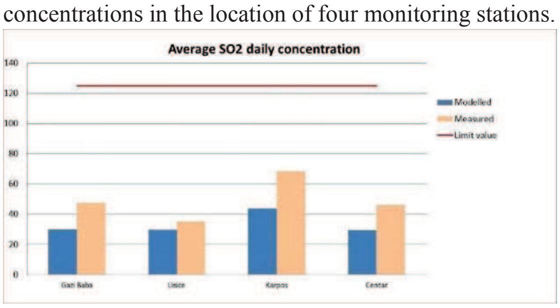


**Figure 9.** The modeled and measured daily average SO2 concentrations in the location of four monitoring stations.

## Conclusions and recommendations

This study was done to assess the air quality impact of major emission sources in Skopje by dispersion models. Two local scale dispersion models were used to assess the impact to air quality caused by emissions from traffic in Skopje city center and all the major industrial and energy production emissions from Skopje valley. For traffic the nitrogen dioxide (NO2) and carbon monoxide (CO) and for point sources nitrogen dioxide and sulphur dioxide (SO2) concentrations were calculated. According to the dispersion modeling calculations, traffic in Skopje is the biggest contributor to the NO2 concentrations with the highest concentrations occurring along the major roads and crossroads. The energy production and industrial point sources have a very small impact to the overall levels of NO2 concentrations. The highest modeled concentrations exceed the limit value for annual average NO2 concentrations. Apart near the busiest roads, the annual average concentrations are below the limit value. The modeled NO2 concentrations were compared to the measured concentrations in the air quality monitoring station in Rektorat. For annual average concentrations there was a difference of 9-16 % between the modeled and measured concentrations, which taking account the uncertainty of the input data can be considered very good. The CO concentrations from traffic occur also near the biggest roads and crossroads. There is no limit value for annual average CO concentration, but it can be estimated that the levels of CO concentrations are not particularly high and level is similar as in many cities in Europe. The modeled CO concentrations were compared to the measured concentrations in the air quality monitoring station in “Rektorat”. For annual average concentrations there was a difference of 15-18 % between the modeled and measured concentrations, which taking account the uncertainty of the input data can be considered good. Point sources can be estimated the main contributor to SO2 concentrations in Skopje. According to the modeling results, the limit values or critical level are not exceeded. However, the measured concentrations in Skopje are higher than modeled ones, which may indicate that not all the emissions were not taken into account in the calculations. The modeling results include some uncertainties that can be estimated to be mainly due to the unreliability of the meteorological data and the limited availability of good quality emission data. Particularly high and level is similar as in many cities in Europe. In order to improve the results of the modeling, following recommendations are given: 1-Improve the quality of meteorological observations, 2-Study in detail the possibility of using other emission factors for traffic, 3-Improve the traffic volume data to cover larger areas and examine the traffic variation during the day, 4-Improve other traffic related data, for example the percentage of cars with catalytic converters, cars using LPG (liquefied petroleum gas) etc. , 5-Improve the reliability of the emission data from point sources, 6-Improve the quality and coverage of the measured concentration data for reliable comparisons with the modeled data. In future, dispersion modeling tools are useful also to assess the air quality impact of other individual sources or source categories, to support emission reduction plans and complement the air quality information from monitoring stations.

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