18th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
9-12 October 2017, Bologna, Italy

USING THE SHERPA TOOL TO SUPPORT THE AIR QUALITY PLAN OF BUDAPEST

Emese Homolya[1] and Zita Ferenczi[1]

[1] Hungarian Meteorological Service, Budapest, Hungary

Abstract: Air quality models differ in their complexity, computer requirements and application, however, a common feature is their role to describe the connection between the emission of pollutants and the concentrations that evolve in the environment. Due to the models' complexity in general, the calculations are typically time consuming, and therefore enable a limited number of simulations at once. It is possible to develop simplified models based on source-receptor relationships in order to decrease computation time. These models reproduce the behaviour of the full air quality model in a simplified way.

In our analysis to assess the possible effects of emission reduction measures on the air quality of Hungary and Budapest we used the SHERPA software, developed by the European Commission Joint Research Centre. Calculations in SHERPA are based on the combination of the gridded emission inventory devised by INERIS and results of simulations calculated using the CHIMERE chemical transport model.

Our aim in this work was to determine, how concentrations in the air would change as a consequence of certain decreases in emissions of particulate matter and nitrogen-dioxide. Accordingly, we can identify the extent to which emissions should be reduced in order to attain a particular improvement in air quality. Apart from considering the country as a whole, we focused on the air quality of the surroundings of some of the major cities as well, with special attention to Budapest.

Results suggest that the primal anthropogenic source of particulate matter in Hungary is residential combustion, however, regarding nitrogen-dioxide emission, road transport is dominant. Consequently, in order to reduce PM_{10} concentrations, it is most effective to decrease emissions from residential combustion. Concentrations of NO_2, on the other hand, can be reduced to the largest extent by limiting road transport.

In addition to the expected changes in air pollution concentrations, we examined, how large-scale transport processes contribute to local air quality. According to results, local air pollution is highly dependent on transport from the neighbouring areas, especially in the case of particulate matter.

Key words: *air quality assessment, chemical transport modelling, emission reduction.*

INTRODUCTION

Due to the endeavour to reduce emission rates of many kinds of pollutants in the latest decades the air quality of Europe has improved significantly. Measuring sites are operating all over Europe and provide a continuous sequence of valuable in-situ measurements, however, a complex assessment of air quality requires the involvement of air quality models as well. Air quality models comprise mathematical schemes describing the physical and chemical processes responsible for the dispersion, transformation and deposition of pollutants in the air. Calculations are based on pre-defined emission and real meteorological data and yield information about the air quality that evolves in the environment. While air quality models were used only by research institutions mainly for research purposes a few decades ago, now they are commonly applied in the assessment of air quality issues.

Air quality models are diverse in their complexity and IT requirements and their applying depends on the specific purposes of an analysis. Generally, we differentiate between two types of air quality models depending on whether we base our evaluation on the emission sources or the receptors. Source-oriented – mostly referred to as chemical transport – models use emission data and are based on the mathematical interpretation of dispersion, chemical processes, deposition and the interactions between the different processes. They are applied in several fields of atmospheric chemistry research and enable the assessment of the consequences of certain emission reduction activities as well. Receptor-oriented models take into account conditions and the changes in the conditions in the vicinity of certain grid points (receptor points) in the first place. Via the calculation of a mass-consistent equation they relate measured concentrations to

emission sources. These models are most frequently used to determine the extent by which separate emission sources contribute to the evolving air concentrations of pollutants.
Due to their general complexity air quality models are fairly demanding calculation-wise, therefore enable a limited number of simulations at the same time. In order to overcome this limitation, the construction of simplified models is possible that reproduce the behaviour of the original air quality model (Clappier et al., 2015). The simplified models require a more modest amount of calculation capacity and therefore enable the carrying out of multiple simulations in a relatively short time. Such methods applies the SHERPA (Screening for High Emission Reduction Potential on Air) tool, constructed by the European Commission Joint Research Centre, which has been developed to provide support for the design of regional scale measures aimed at air quality improvement.

METHODS

SHERPA provides an opportunity to estimate how a certain extent of emission reduction might affect air quality, which emission sectors and pollutants should be treated primarily when designing measures and in what proportions the neighbouring regions contribute to local air pollution. Calculations are based on the gridded emission inventory provided by INERIS (Institut National de l'Environnement Industriel et des Risques) and results of calculations carried out using the CHIMERE chemical transport model. The flexibility of the program makes it possible to use locally produced high quality data as well.

As for the spatial coverage, the tool covers the area of Europe with a resolution of roughly 7x7 km and enables the detailed examination of the air quality of any European region in a local scale. The process of air quality assessment is organized via individual modules including *source allocation* to investigate how the air quality in a certain area is affected by different emission sources, *governance* to analyse and find the way in which the optimal improvement in air quality can be attained by taking into account the effects of the surrounding regions and *scenario analysis* to simulate the impact of a certain emission reduction scenario on air quality. Additionally, SHERPA is equipped with a RIAT+ first guess module (The Regional Integrated Assessment Tool) to provide input data for RIAT+ (Carnevale et al., 2012).

Emission reduction for individual emission sectors and precursors is freely defined by the user. Reduction rates are required in percentage. SHERPA uses the SNAP (Nomenclature of Territorial Units for Statistics) sectors (EMEP, 2013) – summarized in Table 1 – to group emission of different origin.

Table 1. Emission sectors in SHERPA (SNAP)

Sector code	Sector name
MS1	Combustion in energy and transformation industries
MS2	Non-industrial combustion plants
MS3	Combustion in manufacturing industry
MS4	Production processes
MS5	Extraction and distribution of fossil fuels and geothermal energy
MS6	Solvent and other product use
MS7	Road transport
MS8	Other mobile sources and machinery
MS9	Waste treatment and disposal
MS10	Agriculture

One of our aims in our work was to determine how a certain rate of emission reduction concerning PM_{10} and NO_2 pollutants from different origin might affect air quality in Hungary. We defined reduction rates to be 10% in each case and chose road transport and residential combustion as sources of pollutants, which concern emission macro sectors MS7 and MS2, respectively. Secondly, we carried out an investigation to determine the extent by which the individual emission sectors contribute to the overall pollution in the country. All the analyses were made using SHERPA.

RESULTS

Emission reduction rates in SHERPA are defined to definite regions, which in Hungary correspond to the different counties in the country. Investigation in higher resolution, such as for cities, is not possible, except for the capital, Budapest, which itself represents an individual region. Therefore, we chose

Budapest to be the target area in the analysis of the effects of emission reduction. Figure 1 represents the expected effects of a 10% emission reduction of particulate matter concerning road transport (MS7) and residential combustion (MS2) in the area of Budapest, with the maximum values on the scales being 0,34% and 0,58% regarding road transport and residential combustion, respectively.

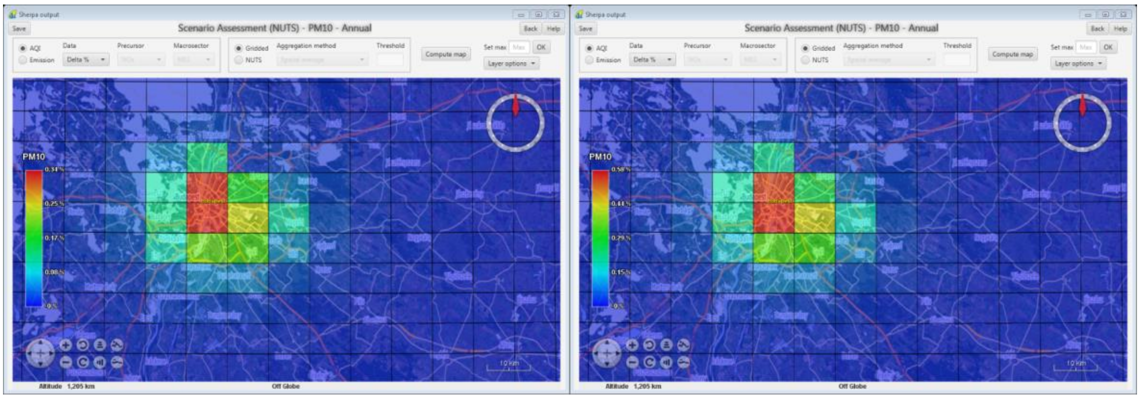

Figure 1. The effects of reduced PM_{10} emission originating in road transport (on the left) and residential combustion (on the right) by 10% on the air quality of Budapest

Results illustrated in Figure 1 suggest that the effects of emission reduction are in terms of spatial distribution very similar concerning both emission sectors, the city centre is more affected than the outer regions, however, the scale of the decrease in concentration values is different. We can conclude that – although emission from road transport clearly contributes to the total amount of anthropogenic particulate matter emission to a large extent – residential combustion appears to be even more significant. Consequently, in the case of Budapest, we can reduce PM_{10} concentrations more effectively by restricting residential combustion. Figure 2 shows results related to NO_2, with the maximum values on the scales being 2,04% and 0,79% regarding road transport and residential combustion, respectively.

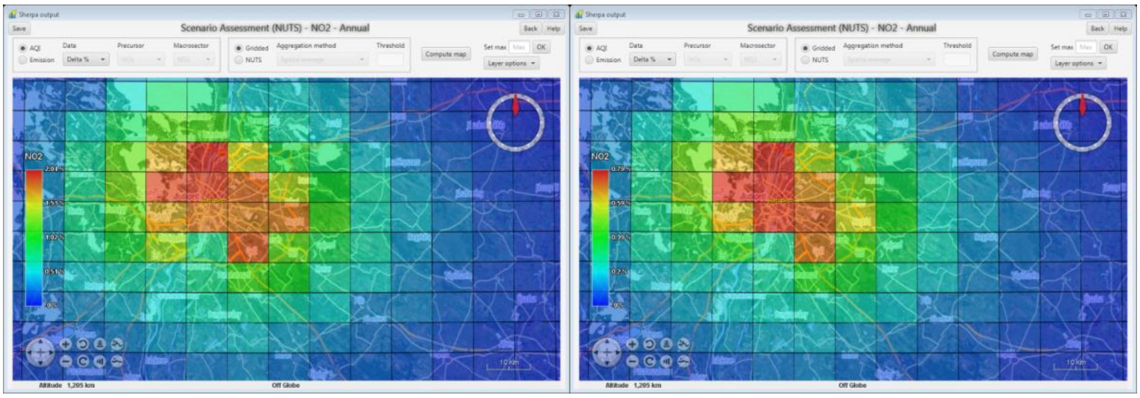

Figure 2. The effect of reduced NO_2 emission originating in road transport (on the left) and residential combustion (on the right) by 10% on the air quality of Budapest

According to results, NO_2 concentrations can more effectively be reduced by the limitation of road transport. The same rate of emission reduction result in an observably larger scale change in the concentration values than in the case of particulate matter.

An important indication of the results is that a relatively high – 10% – emission reduction leads to only 1-2% improvement in air quality in all of the examined cases. This is due to the fact that air pollution evolving in a particular area depends not only on local emissions but on long-range transport processes as well. Local measures affect local emissions, the quantity of pollutants arriving from farther areas cannot be regulated this way. However, as a consequence of the limitation of local emissions in one place the quantity of pollutants transported to the neighbouring areas is reduced, therefore the place in question contributes less to environmental pollution.

SHERPA enables the determination of the extent by which emissions from different origin (emission sectors) contribute to the total pollution. Information of such helps decision makers in identifying the emission sectors to concentrate on primarily when introducing measures with the purpose of reducing air pollution in general, therefore it is essential in the planning and designing strategies aiming to improve air quality. In this analysis we chose the target area to be the whole country and – similarly to the previous examinations – addressed PM_{10} and NO_2 pollution. The relevant module in SHERPA differentiates between the uncontrollable emission with transborder origin and local emissions. Sectoral division is only determined to the latter type of emission.

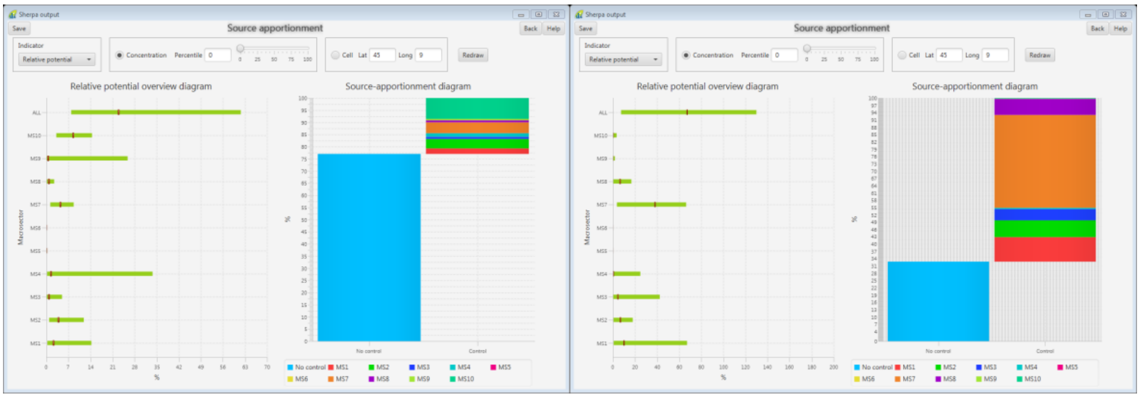

Figure 3. Identification of the sources mainly determining PM_{10} (on the left) and NO_2 (on the right) pollution in Hungary

Figure 3 shows the average contribution of the different emission sectors to PM_{10} and NO_2 pollution, in percentage, for the area of Hungary. On the diagrams there appears a column with the sign 'no control', indicating the proportion of the total pollution that originates from farther places, therefore it is beyond what can be affected by local regulations. This proportion in Hungary – according to results – is in average 33% for NO_2 and 77% for PM_{10}, meaning that 77% of PM_{10} and 33% of NO_2 pollution has transborder origin. Naturally, these values show a considerable spatial variability throughout the area of the country. Generally, in Hungary, the majority of local emission concerning either of the pollutants in examination arises from road transport and combustion, with agriculture also playing a significant role in PM_{10} pollution.

The background emission database of SHERPA is expected to be updated in the near future, for the construction of gridded emission databases for the year 2015 is an obligation for all European countries. Previously, the majority of the states in Europe had not reported data on a regular grid but national totals for each pollutant and emission sector, which implied difficulties in the production of European-scale gridded emission inventories. Reporting emission data having been calculated separately by each country for a unified grid, where the local specialities are taken into account, enables the production of more accurate emission inventories. Therefore, updating the emission database of SHERPA with the new inventories is expected to result in the calculations being more accurate and more usefully applicable in the design of air quality plans.

SUMMARY

Air quality models are based on the relationship between emissions and concentrations of pollutants evolving in the environment as a consequence. Therefore, they provide an opportunity to analyse the extent to which a certain degree of emission reduction might affect air quality.

In our study we used the SHERPA tool to examine the possible effects of reduced emission relating to particular emission sectors and pollutants on the air quality of Hungary and the capital, Budapest. SHERPA provides a tool for the analysis of the effects of measures aiming at the improvement of air quality in any region inside Europe. Calculations are based on a pre-defined input emission database that comprises the gridded emission inventory prepared by INERIS and results of simulations having been carried out using the CHIMERE chemistry transport model.

For the analysis of the expected effects of emission reduction we chose the examined pollutants to be PM_{10} and NO_2 in relation to road transport and residential combustion and defined a 10% reduction rate in all cases. We addressed Budapest as the target area. Additionally, we examined, in what proportion emissions from different emission sectors contribute to the total PM_{10} and NO_2 pollution throughout the area of the whole country.

Results suggest that the main source of PM_{10} in Hungary is residential combustion, however, concerning NO_2, road transport is more determining. Therefore, the most effective way to reduce PM_{10} pollution is likely to lie in the restriction of residential combustion, while in order to moderate NO_2 pollution, limiting road transport would probably be more productive. Based on the analysis of source apportionment it is evident that long-range transport contributes to local pollution to a considerable extent. Regarding local emission sources country-wise, concentrations of the examined pollutants originate mainly in road transport and combustion, with agriculture also being important in the case of particulate matter.

REFERENCES

Carnevale, C., G. Finzi, E. Pisoni, M. Volta, G. Guariso, R. Gianfreda, G. Maffeis, P. Thunis, L. White and G. Triacchini, 2012: An integrated assessment tool to define effective air quality policies at regional scale. *Environmental Modelling & Software*, **38**, 306–315.

Regional Integrated Assessment Tool PLUS web: http://www.riatplus.eu/html/eng/home.html

Clappier, A., E. Pisoni and P. Thunis, 2015: A new approach to design source-receptor relationships for air quality modelling. *Environmental Modelling & Software*, **74**, 66–74.

EMEP/EEA air pollutant emission inventory guidebook, 2013, EEA Technical report, No 12/2013, ISSN 1725–2237.