Using SHERPA screening tool for design and assessment of local and regional air quality management

F Popescu¹, B Vujic², A E Cioabla¹, U Marceta², L I Dungan¹, G Trif-Tordai¹ and E A Laza³

¹University Politehnica Timisoara, Faculty of Mechanical Engineering, Mihai Viteazu blvd., no. 1, 300222 Timisoara, Romania
²University of Novi Sad, Technical Faculty “Mihajlo Pupin” Zrenjanin, Djure Djakovic str., bb., Zrenjanin, Serbia
³The National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry, Revolutiei 1989 blvd., no. 15A, Timisoara, Romania

E-mail: francisc/popescu@upt.ro

Abstract. As atmospheric pollution continue to be a significant issue on global level, but with a particular importance at European Union level, the air pollution reduction policies will continue to be enforced in the next decades. At EU level, especially on most developed countries, NO2 and Particulate Matter (fine and coarse fractions) remain an acute problem. To help decision factors to have a better view on entire EU region the SHERPA (Screening for High Emission Reduction Potentials on Air quality) was developed, a tool that was proven helpful in addressing source allocation, governance and the assessment of scenario impacts.

1. Introduction
Good air quality represents an important challenge in Europe. In 2015, about 16 Member States out of 28 failed to comply with the regulations made by the European Union in terms of air quality limit values. The urban population is much more exposed to pollute air that rural inhabitants, situation highlighted by World Health Organization (WHO) that shows that almost 90% of urban population is exposed to high level of pollutants. This aspect poses detrimental influence on health, both in terms of morbidity and mortality. At European Union level authorities starting from cities mayors to government and European Commission act continuously to improve air quality, with an emphasis on urban scale, as urban inhabitants are most exposed to air pollution. Different cities approached the air pollution differently, from supporting renewable energy sources (in heating and transport) to congestion charges or investment in electric public transport, experience shows that in absence of assessment tools the authorities can approach air quality issues with difficulty.

The existing implemented policies, regardless of administrative levels, usually are driven by locally available know-how and at locally available experts, with their inherent limitations. In this context of segregated knowledge and variability of decision JRC-developed tool, SHERPA, can bring a unique approach to support all policy-makers, regardless at their administrative level, to achieve more global (at least European) air quality management strategies [1].

Implementation of regional (EU) based policies for pollution abatement control can only be done with specific tools and models, developed in general to support sustainable development of industries,
starting from life cycle assessment of products from production of raw materials to recycling of the product at the end of usage [2]. Similar approach is used in screening tools for air quality assessment, as air pollutants are not “just molecules”, but they are generated by specific sectors, such as transportation, energy production, a.o, and must be approached specifically.

In Europe there are a multitude of cities which suffer from poor air quality and there is a regularity in the times there are exceeded values defined by European standards and described in the Air Quality Directive and also recommended values made by the World Health Organization. The fine particulate matter PM10 is one of the most important elements which are out of range (made measurements indicate that both the daily and yearly average limit values are regularly exceeded) in several regions in Europe. In the same way, for PM2.5 there are common values in terms of surpassing the existing limits, and only a limited number of urban areas were able to maintain air pollutants concentrations under the admissible limits accepted as tolerable by World Health Organization. Air pollution control actions were imposed at scales from local (urban and county) to national and international, actions imposed in the past decades to governments by society and relevant non-profit environmental organizations. The results are positive, an overall improvement of the air quality over the years being a clear indicator of the undertaken actions, but there are still problems which are localized in specific regions and many cities. In this context, a key issue is to determine at which scale to act to eliminate as well as possible these remaining air pollution problems with the greatest impact on environment and human health [3].

Design of screening tools for assessment of regional (or local) air quality management are similar with already established tools developed for risk management, in general. Just like in risk management, in air quality assessment’s approach must be inter-disciplinary, to allow the identification and understanding of pollution sources not as simple as punctual sources, but as entire activity sectorial sources so that decisions taken to reduce emissions to be efficient at a larger scale, such as European scale.

It is obviously that authorities, local, national or regional, need constant support in terms of scientific information in order to improve their pollution control policy governance and to impose the most effective corrective actions possible. Actions at the local level can only focus on urban scale and are more immediate and easy to enforce. However, at national and international levels the decision making process is more difficult and needs more time and debate to reach final conclusions, SHERPA tool is design specially to bring air quality information’s at EU level in order to support authorities in actions.

The impact of a specific abatement action to improve and control air quality are different from city to city, is only in a small amount country specific and if in one city a measure can have an significant impact in another the same measure may not be effective. There were a multitude of actions taken at different scales or in different activity sectors in order to produce a real impact on air quality that is specific mostly to urban area. Consequently, it is important to develop air quality improvement plans tailored on the local specificity, local road structure, vehicle fleet variability, local heating systems, and quality of public transport, geographical positions and other factors [4].

2. Materials and method
To quantify the impact of cities and the emissions generated by urban activities can be done using chemical transport model that can operate with pollutant transports, diffusion and atmospheric reactions.

Because these models require intensive computational resources they are generally used to perform this detailed analysis for one city or region at the time. To cope with this limitation, the “Screening for High Emission Reduction Potentials for Air quality” tool (SHERPA) has been developed by the Joint Research Centre [3]. This simplified screening tool mimics a chemical transport model, but with a much faster time response.

In the latest air quality study for major EU cities [5] several interesting key points arise regarding the sectorial contribution to air pollution, on the 150 analyzed EU cities:
• The average contribution from the residential sector was 13%, with a largely local contributions in Poland mining areas, and with an observation that in general, the residential sector (heating) has a greater impact in Eastern European countries
• The average contributions from the road transport was 14%, with larger contributions in Western Europe cities. Emissions generated by transportation sector have a major contribution in large, dense cities (Paris, Madrid, London). However, they are also a key contributor in densely populated areas like Belgium and the Netherlands [4].
• The average contribution from agriculture was 23%, with larger contribution in German and Czech cities.
• The average contribution of industry was 20%, with larger contribution in German, French and Austrian cities.
• The average contribution of natural sources was 19%, with PM2.5 peaks in cities in Mediterranean area, associated with episodic atmospheric dust events.

This variability in terms of sectoral impact, even within a single country, illustrates the scope for targeting air quality plans on a city-by-city basis, and the need to supply to local policy makers the tools to support them in better air quality assessments.

SHERPA is a modelling tool, developed for the exploration of potential air quality improvements resulting from national/regional/local emission reduction measures [4]. It is based on source-receptor relationships. These source-receptor relationships are a simplified version of a chemistry transport model, used to simulate the contribution to concentration levels due to all precursor emissions (NOx, NMVOC, PPM, SO2 and NH3) from one particular area of the domain. They are used to estimate the effect of changes in precursor emissions on pollutant concentrations [5].

In SHERPA, concentration changes due to an emission reduction scenario are computed on a cell by cell basis according to the following equation:

\[ \Delta C_n = \sum_{p}^{N_{\text{prec}}} \sum_{m}^{N_{\text{cell}}} a_{n,p,m} \Delta E_{p,m}, \forall n \in [1,N_{\text{cell}}] \] (1)

where the delta concentration \( \Delta C_n \) (change of concentration in comparison to the base case) in a receptor grid cell \( n \) is expressed as a linear combination of the emissions delta \( \Delta E_{p,m} \) (variation in emission when compared to the base case), for each source cell \( m \) and pollutant (i.e. precursor) \( p \). The \( a_{n,p,m} \) coefficients act as weighting factors which apportion the amount of emission variation \( \Delta E_{p,m} \) of precursor \( p \) leaving from cell \( m \) and reaching cell \( n \). As the correlation between \( \Delta C_n \) at receptor cell \( n \) and \( \Delta E_{p,m} \) at sources cell \( m \) decreases with the distance between the cells, it has been assumed that the coefficients \( a_{n,p,m} \) in the previous equation can be approximated by the following distance-function [6]:

\[ a_{n,p,m} = \alpha_{n,p} (1 + d_{n,m})^{-\omega p} \] (2)

where \( d_{n,m} \) is the distance between cells \( n \) and \( m \) and the two unknowns \( \alpha \) and \( \omega \) for each precursor \( p \) and each grid cell \( n \) were estimated from chemical transport model simulation results [6].

The SHERPA tool is distributed with EU-wide data on emissions and source-receptor models (spatial resolution of roughly 7x7 km²), so that it is very easy to start working on any region/local domain in Europe. More specifically, SHERPA logical pathway is implemented through the following steps:
• Source allocation: to understand how the air quality in a given area is influenced by different sources;
• Governance: to analyze how one should coordinate with the surrounding regions to optimally improve air quality;
• Scenario analysis: to simulate the impact on air quality of a specific emission reduction scenario (defined also through the previous two steps)
In this particular study the Romanian Region was taken into account and 3 SHERPA sections were used, Source allocation, Governance and Scenario. One should have in mind that emission factors for PM10 and PM2.5 available on SHERPA servers are not material specific. Numerous studies showed that ability of airborne micrometric particles to travel long distances is given by their elemental composition. As an example, in the past years there were significant numbers of Saharan dust intrusions, especially in Eastern Europe.

3. Results and discussion
Emission reduction rates in SHERPA are defined to definite regions, which in Romania correspond to the different counties in the country. Investigation in higher resolution, such as for cities, is not possible, except for the capital, Bucharest, which itself represents an individual region. Therefore, we chose West Region of Romania (where Timisoara is located) to be the target area in the analysis of the effects of emission reduction. Figure 1 represents the expected effects of an 8.37% emission reduction of particulate matter concerning all sources in western Romania.

One can observe that the maximum range where the local/regional decision makers can work is at maximum 8.37%, suggesting that a large amount of airborne particles in the region are not locally generated.

A better view is given by Figure 2, where the “No control” chart is emphasis in Governance module of SHERPA. However, even if the target area was specifically defined by the GPS coordinates of Timisoara, as SHERPA is not defined at low geographical level in Romania, the uncertainties in this particular study can be significant.

On the larger scale, at country level (entire Romania), the estimations are better due to higher number of data available from national air quality monitoring stations. In Figure 2 one can observe the result of a two-step scenario, one (in the left side) with no emission reduction strategies and second (right side) with emission reduction strategies applied at all emission sources, at 100% potential.

![Figure 1. Western Romania area, PPM-all sectors scenario, governance control area – annual. NUTS 2; Specific area: West / South-West Oltenia.](image-url)
Figure 2. Romania area, all sectors scenario, governance, reduction potential

Obviously the scenario with emission control enforced at 100% is an utopia, but the results shows an interesting fact for Romanian case, that gaseous pollutants emitted are already controlled (as minimum reduction is shown in Figure 2 but PPM (mostly PM10) emissions can be significantly reduced at country level.

Figure 3. Europe-city level, PM10 emission factors, exclusively road transport sector
Other, more source focused scenarios can be analyzed in SHERPA, as the one shown in Figure 3 to 5, where only transportation source was taken into account, at entire Europe level.

Analyzing the results presented in Figures 3 to 5 one can easily notice the major contributors to air pollution in urban levels are the western countries/cities, in respect to PM10 levels, like Nederland, Belgium, Germany and northern (developed) parts of Italy.
4. Conclusions
Governance (urban, national or regional) is difficult and mostly inefficient in absence of supporting scientific information’s and tools specifically developed to impose sustainable and efficient actions in improving air quality in dense inhabited areas. In particular, an appropriate balance between local actions focusing on the urban scale and actions requiring national/international efforts needs to be found. The purpose of this study was to provide information on the potential of SHERPA tool to support researchers and decision making officials on the local, regional and country level to develop and implement better air quality improvement strategies.

References
[1] European Comission, EU Science Hub, SHERPA. A computational model for better air quality in urban areas, 2017, Available at https://ec.europa.eu/jrc/en/news/sherpa-computational-model-better-air-quality-urban-areas
[2] Vorkapic M, Popovic B, Cockalo D, Dordevic D and Minic S G 2015 A model for introducing strategies in sustainable development of small-scale enterprises in Serbia, Journal of Engineering Management and Competitiveness 5(2) 77-83
[3] Thunis P, Degraeuwe B, Pisoni E, Ferrari F and Clappier A 2016 On the Design and Assessment of Regional Air Quality Plans: The SHERPA Approach, Journal of Environmental Management 183(Pt 3) 952-958
[4] Thunis P, Degraeuwe B, Pisoni E, Trombetti M, Peduzzi C, Belis C A, Wilson J and Vignati E 2017 Urban PM2.5 Atlas. Air quality in European cities, European Commission Joint Research Center, Luxembourg: Office for Official Publications of the European Communities
[5] Thunis P, Degraeuwe B, Pisoni E, Trombetti M, Peduzzi C, Belis C A, Wilson J, Clappier A and Vignati E 2018 PM2.5 source allocation in European cities: A SHERPA modelling study, Atmospheric Environment 187 93-106
[6] Pisoni E, Albrecht D, Mara T A, Rosati R, Tarantola S, and Thunis P 2018 Application of uncertainty and sensitivity analysis to the air quality SHERPA modelling tool, Atmospheric Environment 183 84-93