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

A PROPOSAL TO OVERCOME THE AMBIGUITY OF THE AEROSOL AND COMMUNICATE IT MORE EASILY, WITH THE HELP OF CAPTAIN SANKEY

Giovanni Bonafè[1] and Michele Stortini[2]

[1]Agenzia Regionale per la Protezione dell'Ambiente del Friuli Venezia Giulia, Palmanova, Italy
[2]Agenzia regionale per la prevenzione, l'ambiente e l'energia dell'Emilia-Romagna, Bologna, Italy

Abstract: In order to give a simple and straight answer to the question "who is to blame for air pollution?", a screening approach is proposed, expressing the emission of each anthropogenic precursor in terms of "PM10 equivalent". The anthropogenic aerosol formation factor (AFs) is estimated, starting from de Leeuw (2002) and Johansson et al. (2003) and introducing corrections based on chemistry-transport model simulations, in order to better express the local dynamics of the Po Valley.

Key words: *PM10, Po Valley, emissions, chemistry-transport model, communication.*

INTRODUCTION

In order to communicate, to a generic public, which are the main human activities affecting the air quality, in terms of aerosol concentration, in most of the cases primary particulate matter (PM) emissions are shown. Sometimes also the emissions of some gaseous precursors are considered. While the first approach is misleading, since it implicitly excludes the formation of secondary aerosol, the latter can be confusing, since emissions of primary PM and emissions of the precursors (NOx, VOCs, NH3, SOx) are not commensurable. Chemistry-transport models (CTMs) are the solution to fill this knowledge gap, but often the plenty of information they give is complex and not so easy to condense in a straight answer – possibly a ranking - to the simple question "who is to blame for air pollution?".

In this work, we propose a method which is a compromise between the emission-ranking approach, simple and easy to communicate but possibly misleading, and the chemistry-transport-model approach, accurate but complex.

METHOD

The method proposed by de Leeuw (2002) and Johansson et al. (2003) is helpful, since the emission of each precursor can be expressed in terms of "PM10 equivalent", using their aerosol formation factor (AFs). This approach is similar to the "carbon-dioxide-tons-equivalent", widely used to assess and to communicate the contribution of single human activities or single countries to the greenhouse gases emissions.

The AF is defined as

$$AF = \frac{M_S}{M_P} \cdot Y \cdot F \qquad (1)$$

where M_P is the molecular mass of the precursor, M_S is the molecular mass of the corresponding secondary molecule in the aerosol, Y describes the fraction of emission potentially leading to aerosol formation, F denotes the fraction of emitted mass converted into secondary aerosol. The AFs estimated for the European scale are shown in Table 1 (2nd column).

Table 1. Aerosol formation factors

emission component	AF	
	European scale	Emilia-Romagna scale
primary PM	1	1
SO_2	0.54	0.14
NO_2	0.88	0.23
NH_3	0.64	0.17
VOC	0.02	0.0055

This is our starting point. However, the AFs suggested by de Leeuw (2002) and Johansson et al. (2003) are suitable for continental scale analysis, not for regional. Therefore we need to calculate regional scale AFs. We decided to rescale the European-scale AFs, assuming their proportions are constant.

In order to rescale the European-scale AFs, we need specific knowledge of the Po Valley air pollution dynamics, provided by a CTM. Therefore, the CHIMERE model (Menut *et al.*, 2014) was run on a domain covering northern Italy with a resolution of 5km (Stortini *et al.*, 2007). Meteorological input is provided by the COSMO-I7 non-hydrostatic model (Steppeler *et al.*, 2003; Jongen and Bonafè, 2006), while emission input refers to year 2010 and is provided by ISPRA Italian national emission inventory (De Lauretis *et al.*, 2009) and Emilia-Romagna regional emission inventory (Tugnoli and Rumberti, 2010). Chemical boundary conditions come from PREV'AIR (Rouil *et al.*, 2009), the continental scale implementation of CHIMERE, run by INERIS. This operational modelling suite - called NINFA – uses the MELCHIOR chemical module and simulate separately primary and secondary aerosol.

Through an annual simulation with the NINFA modelling system we estimated the following partition of the PM in the Emilia-Romagna region: 23% anthropogenic primary, 61% anthropogenic secondary, 16% natural primary. Assuming the same proportion in the emissions of the "PM10-equivalent", since the emissions of anthropogenic primary PM10 are 13,638 Mg/y, we expect 36,170 Mg/y of anthropogenic secondary.

On the other hand, if we use the European-scale AFs as they are, we would get 138,340 Mg/y of PM10-equivalent anthropogenic secondary. Therefore, in order to apply the AFs approach to the Emilia-Romagna domain, we need to rescale AFs by a factor of 138,340/36,170=3.8. The rescaled AFs are shown in Table 1 (3rd column). Natural emissions of primary PM10 (soil erosion, re-suspension, volcanic dust, sea spray) are not included in the analysis.

RESULTS

The definition of the AF, suitable for the Emilia-Romagna regional scale for an annual period, allows us to express the emissions of the precursors of PM10 in terms of "PM10 equivalent" (for a different domain or at more local scales or for shorter time intervals, different AFs might be found). Therefore we can represent the PM10 dynamic as a continuous flow where the PM10 equivalent mass is preserved. In the "Sankey diagram" shown in Fig.1 the width of the connections is proportional to this flow of PM10 equivalent mass in the Emilia-Romagna region. This seems to us to be an effective and fairly accurate way to answer to the question "who is to blame for air pollution?", and lead to the ranking shown in Table 2.

If one only considers primary PM10 emissions, domestic wood heating would stand out as the worst polluter. On the other hand, the industrial sector emits 82% of the SO_2 and 55% of the VOCs total regional emissions. But considering the sum of all the precursors, each weighted with its own AF, we can get a more accurate overview, concluding that the road freight is indeed the prevailing anthropogenic source, but not overwhelmingly, representing about a quarter of the total. Therefore, this is a straightforward way to show the need to act on many sectors, in order to reduce the air pollution in the Po Valley.

Table 2. Emissions in the Emilia-Romagna region, expressed in terms of PM10 equivalent (Mg/year).

source	primary PM10	NH_3	NO_2	SO_2	VOCs	total PM10
road freight	2636	9	10396	24	17	13082
agriculture/livestock	418	8381	147	0	0.3	8946
industry	1614	188	3519	2004	283	7608
domestic wood heating	5316	26	349	28	143	5862
light vehicles	1842	132	3470	27	21	5492
other sources	1646	23	2831	167	38	4705
energy production	86	0	2181	60	8	2335
domestic heating (not wood)	80	0	1659	139	4.4	1882

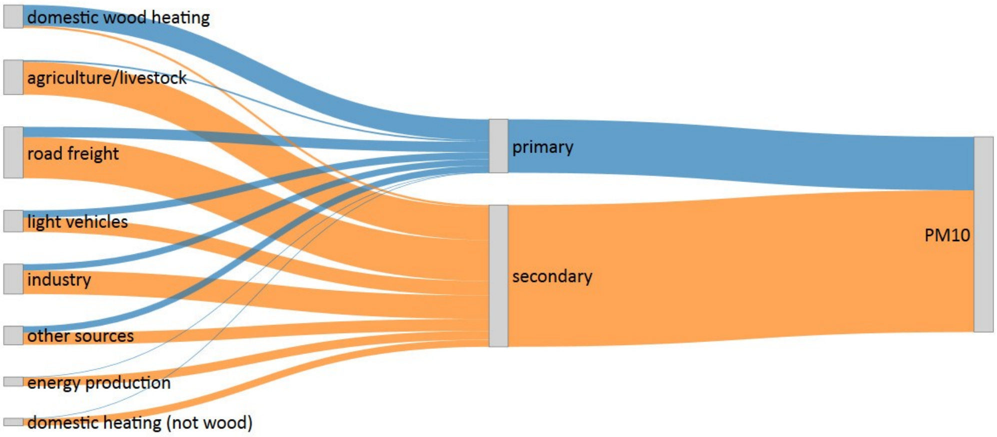

Figure 1. The aerosol formation factor allows expressing anthropogenic PM10 precursors in terms of "PM10 equivalent" in the domain. Therefore we can represent the PM10 dynamic as a continuous flow where the PM10 equivalent mass is preserved. In this "Sankey diagram" (Sankey, 1896) the width of the connections is proportional to this flow of PM10 equivalent mass in the Emilia-Romagna region. On the left side, emissions are aggregated by emission sector; in the centre, aggregated by category. An interactive version of this plot is available at http://rpubs.com/gbonafe/origin-ant-pm10-er

REFERENCES

De Lauretis, R. *et al.* (2009). La disaggregazione a livello provinciale dell'inventario nazionale delle emissioni. Institute for Environmental Protection and Research—ISPRA, Technical report, 92, 2009.

de Leeuw, F. A. (2002). A set of emission indicators for long-range transboundary air pollution. Environmental Science & Policy, **5**(2), 135-145.

Johansson, M., Karvosenoja, N., Porvari, P., & Kupiainen, K. (2003). Emission scenarios for particulate matter research and policy assessment in Finland. In *12th International Emission Inventory Conference. Emission inventories-applying new technologies* (Vol. 28).

Jongen, S., & Bonafè, G. (2006). LAMI verification for air quality forecast and assessment purposes: case studies, special measurement campaigns, long-term evaluation. ARPA-SIM Internal Report.

Menut, L., *et al.* (2014). CHIMERE 2013: a model for regional atmospheric composition modelling. Geoscientific model development, **6**(4), 981-1028.

Rouil, L., *et al.* (2009). PREV'AIR: an operational forecasting and mapping system for air quality in Europe. Bulletin of the American Meteorological Society, **90**(1), 73-83.

Sankey, H. R. (1896). The thermal efficiency of steam-engines (including appendixes). In *Minutes of the Proceedings of the Institution of Civil Engineers* (Vol. 125, No. 1896, pp. 182-212). Thomas Telford-ICE Virtual Library.

Steppeler, J., Doms, G., Schättler, U., Bitzer, H. W., Gassmann, A., Damrath, U., & Gregoric, G. (2003). Meso-gamma scale forecasts using the nonhydrostatic model LM. Meteorology and atmospheric Physics, **82**(1), 75-96.

Stortini, M., Deserti, M., Bonafe, G., & Minguzzi, E. (2007). Long-term simulation and validation of ozone and aerosol in the Po Valley. Developments in Environmental Science, **6**, 768-770.

Tugnoli, S., & Rumberti, V. (2010). Inventario delle emissioni in atmosfera. Technical report, ARPA Emilia Romagna. http://goo.gl/e017Q.