Using dispersion models to account for secondary $PM_{2.5}$ formation in health impact assessment

C. Mangia[1], M.Cervino[1] and E.A.L. Gianicolo[2,3]

[1] CNR, ISAC, Institute of Atmospheric Sciences and Climate, National Research Council, Italy
[2] CNR, IFC, Institute of Clinical Physiology, Italy
[3] University of Mainz, Institute of Medical Biostatistics, Epidemiology and Informatics, Mainz, Germany,
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Presenting author email: c.mangia@isac.cnr.it

Several epidemiological studies have reported adverse associations between exposure to ambient particulate matter (PM) and mortality and morbidity for several causes. A crucial issue in the integrated environmental health impact assessment is the prognosis of PM pollution and, in particular, the way to account for secondary $PM_{2.5}$ formation in presence of large emissions of SO_2 and NO_x.

Due to the complex non-linear gas-particle chemistry, modelling the formation of secondary $PM_{2.5}$ from a single point source would require the implementation of complex photochemical grid models, which need as input all the emissions of the area and contributions from external sources. These data are almost never available. Consequently, the estimation of the impact of a single point source in forming secondary $PM_{2.5}$ is often disregarded in environmental and health impact assessments.

The aim of this work was to estimate primary and secondary $PM_{2.5}$ originating from a single source using the dispersion model CALPUFF (Scire at al., 2000) in two different simplified configurations and to assess the impact in terms of attributable deaths. In Case A the chemical mechanism MESOPUFF was activated. Under this chemical five species scheme (SO2, SO4+, NOx, HNO3, NO3-), daytime SO2 and NOx oxidation are hourly varying functions of background ozone concentration, solar radiation, atmospheric stability and plume NOx concentration. In Case B specific SO_2 and NO_x offset ratios (10:1 for SO_2 and 100:1 for NO_2) were considered (Guerra et al. 2014), converting emissions of precursors into equivalent amounts of direct $PM_{2.5}$ emissions.

As case of study, we considered the emissions of the coal power plant located in the municipality of Brindisi in southern Italy (Figure 1). The study area is 105x135 km^2 wide and comprises two towns (Brindisi and Lecce) and 125 villages with a total population of 1,152,000 individuals. We considered a 105 km x 135 km Calmet/Calpuff modelling domain with a resolution of 1.5 km x 1.5 km. Simulations were performed for the year 2006.

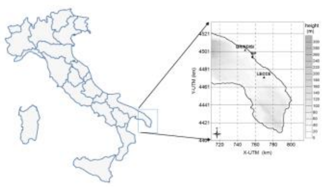

Figure 1. The area of study

The estimated annual average and annual local maximum values of primary $PM_{2.5}$ were 0.02 and 0.22 $\mu g/m^3$ respectively. Primary $PM_{2.5}$ decreases at half of its maximum values within 10 km from the source. In Case A the estimated total (primary plus secondary) $PM_{2.5}$ extended over a larger area with annual average and annual spatial maximum values of 0.09 µg/m3 and 0.43 µg/m3, respectively. In Case B the total $PM_{2.5}$ pattern resembles that of the primary $PM_{2.5}$; the estimated annual average and maximum values of total $PM_{2.5}$ become 0.04 µg/m3 and 0.55 µg/m3, respectively.

The number of estimated natural deaths potentially attributable to annual increased $PM_{2.5}$ levels was derived by a three-step procedure (Künzli et al., 1999, Beelen et al. 2014). This resulted in 4 deaths (95% CI 1-7) attributable to primary $PM_{2.5}$ and increased respectively to 19 (95% CI 6 – 29) and to 9 (95% CI 3 – 14) attributable deaths in Case A e B, respectively, when the secondary $PM_{2.5}$ was also considered.

Both Cases A and B showed that neglecting the contribution of secondary $PM_{2.5}$ leads to underestimate the potential impacts of such industrial emissions on air quality and human health. The Cases disjoined as of the impacted area (larger in Case A) and of the maximum value (higher in Case B). This could inform policies intended to preserve both air quality with respect to law thresholds, and human health with respect to risk abatement.

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