Source apportionment of PM$_{2.5}$ in the harbour–industrial area of Brindisi (Italy): Identification and estimation of the contribution of in-port ship emissions

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**Highlights**

- Source apportionment of PM$_{2.5}$ was performed with PMF in the port-city of Brindisi.
- Brindisi has relevant anthropogenic environmental pressures at National level.
- Receptor model results allowed evaluating ship emission contribution to PM$_{2.5}$.
- Primary ship emission contribution was estimated to be $2.8 \pm 1.1\%$ of PM$_{2.5}$.
- Oil combustion contributes $40\%$ of measured sulphate equivalent to $11\%$ of PM$_{2.5}$.

**Graphical Abstract**

**Abstract**

Harbours are important for economic and social development of coastal areas but they also represent an anthropogenic source of emissions often located near urban centres and industrial areas. This increases the difficulties in distinguishing the harbour contribution with respect to other sources. The aim of this work is the characterisation of main sources of PM$_{2.5}$ acting on the Brindisi harbour–industrial area, trying to pinpoint the contribution of in-port ship emissions to primary and secondary PM$_{2.5}$. Brindisi is an important port-city of the Adriatic Sea considered a hot-spot for anthropogenic environmental pressures at National level. Measurements were performed collecting PM$_{2.5}$ samples and characterising the concentrations of 23 chemical species (water soluble organic and inorganic carbon; major ions: SO$_4^{2-}$, NO$_3^-$, NH$_4^+$, Cl$^-$, CO$_3^{2-}$; Na$^+$, K$^+$, Mg$^{2+}$, Ca$^{2+}$; and elements: Ni, Cu, V, Mn, As, Pb, Cr, Sb, Fe, Al, Zn, and Ti). These species represent, on average, 51.4% of PM$_{2.5}$ and were used for source apportionment via PMF. The contributions of eight sources were estimated: crustal ($16.4 \pm 0.9\%$ of PM$_{2.5}$), aged marine ($2.6 \pm 0.5\%$), crustal carbonates ($7.7 \pm 0.3\%$), ammonium sulphate ($27.3 \pm 0.8\%$), biomass burning-fires ($11.7 \pm 0.7\%$), traffic ($16.4 \pm 1.7\%$), industrial ($0.4 \pm 0.3\%$) and a mixed source oil combustion–industrial including ship emissions in harbour ($15.3 \pm 1.3\%$). The PMF did not separate the in-port ship emission contribution from industrial releases. The correlation of estimated contribution with meteorology showed directionality with an increase of oil combustion and sulphate contribution in the harbour direction with respect to the

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