Assessment of industrial contribution and ship emissions at an industrial and coastal site in Northern France

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More than one-year real-time measurements of submicron particulate matter (PM_1) and co-located SO_2 measurements were carried out from 15 July 2013 to 10 September 2014 at an industrial and coastal site (Port Est, Dunkirk, 200,000 inhab.) in Northern France. The sampling site is close to a ship lock and located less than 2 km away from urban (SE-S) and industrial zones (SW-W), and less than 30 meters from the coastline of the North Sea (N). Significant industrial activities include metallurgy, petrochemistry, food processing, power plant, which emit large amounts of sulfur compounds as SO_2 gas and submicron sulfate particles. SO_2 emissions over the region are largely dominated by the industrial sector which represents 95% of the total emissions (Atmo Nord-Pas de Calais 2015). Dunkirk harbor, ranked as the 7th in the North Europe range with ~600 ship movements per day, could also be an important source of air pollution. These emissions are poorly characterized. Long-term studies in such complex multi-influenced environments could help assessing the sources of sulfur compounds, their contribution to PM_1 concentration, and their formation processes.

The non-refractory (NR) submicron particles (organics, sulfate, nitrate, ammonium and chloride) and black carbon were measured by an Aerosol Chemical Speciation Monitor (ACSM) and an Aethalometer, respectively. Collocated measurements included trace gases such as SO_2 and CO_2. Meteorological parameters were provided by an ultrasonic anemometer and a weather station.

Data were classified into four sectors (marine, industrial, urban and industrial-urban) according to the wind direction. The average mass concentration for the four sectors varied from 7.6 (marine) to 14.4 µg m^{-3} (urban) with a distinct chemical composition for each sector. In the industrial sector, sulfate aerosols accounted for more than 60% of the NR-PM_1 mass (Figure 1). SO_2 and SO_4 were almost systematically observed when industrial plumes reached the monitoring site, with a strong influence of relative humidity (Figure 2) and vertical turbulence on the measured concentrations. The ratio of particulate (Sp) to total sulfur (Stot) stays relatively constant at 0.1 when RH ranges from 30-70% but reaches an average of 0.3 at high RH (90-100%), reflecting SO_2 to SO_4 gas-particle conversion processes generally resulting in an increase of aerosol acidity.

A total of ~2,000 ship movements was reported in the nearby lock over the duration of the campaign. Under favorable winds, they could result in concentration increases for SO_2 and PM_1 mass concentration (mainly due to black carbon, organic and sulfate species) up to 50 µg m^{-3} over a 30 min average.

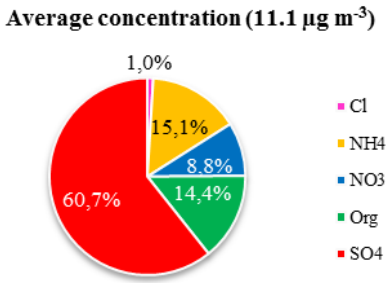

Figure 1. Mass concentration and chemical speciation of NR-PM_1 from the industrial sector

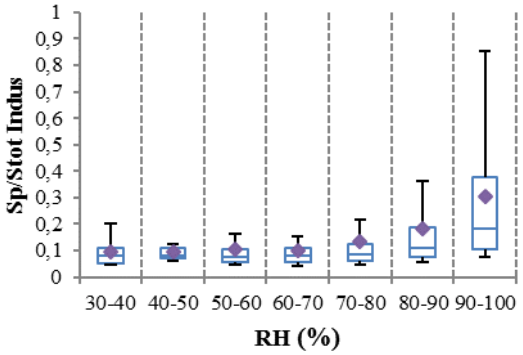

Figure 2. Box plots of the particulate (Sp)-to-total sulfur (Stot) ratio in the industrial sector for different relative humidity (RH) ranges

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Atmo Nord-Pas de Calais (2015). *Annual report 2014* (in French).