Source apportionment of $PM_{2.5}$ at Abu Dhabi sites

C. Hak and S. López-Aparicio

NILU – Norwegian Institute for Air Research, P.O. Box 100, NO-2027 Kjeller, Norway

Presenting author email: ch@nilu.no

Introduction

Particulate matter (PM) is one of the most concerning pollutants in the United Arab Emirates (Fig. 1).

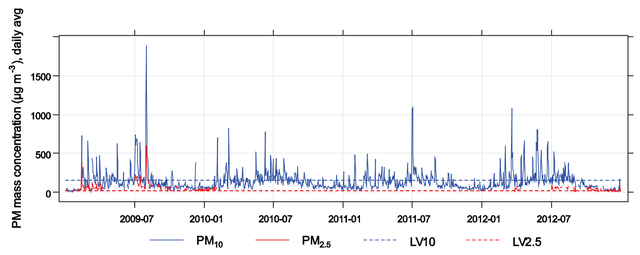


Figure 1: PM_{10} (blue) and $PM_{2.5}$ (red) monitoring data from Hamdan station. Dashed Lines: Limit/guideline values.

To our knowledge, no source apportionment study has been carried out in the area, and it is needed for an efficient abatement strategy.

Objective:

- to identify and quantify the major sources to fine particle mass at two sites in the emirate of Abu Dhabi (Fig. 2).

To reach the objective, Positive Matrix Factorisation (PMF) was applied on chemically speciated data to find multiple sources of particles and possible differences between the sites.

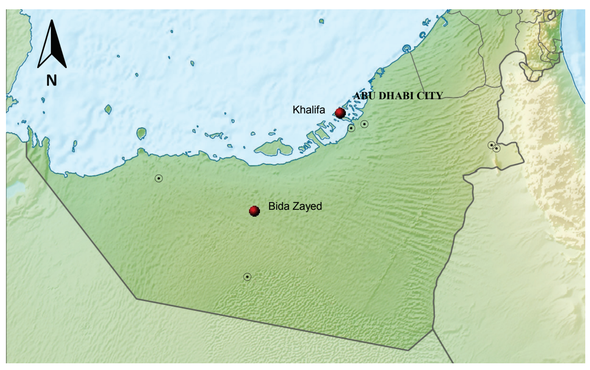


Figure 2: Location of sampling sites (red bullets).

Methodology

Following types of sampling were carried out (March – November 2012):

1) Daily filter samples of $PM_{2.5}$ were collected with sequential filter samplers at two urban background sites, Khalifa and Bida Zayed. Teflon and Quartz filters were analysed gravimetrically and chemically (Table 1).

Table 1: Analytical methods and analysed species.

Elements (ICP-MS) Li, Be, Mg, Al, (Si), K, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Br, Rb, Sr, Y, Mo, Cd, Sn, Sb, Cs, Ba, Tl, Pb, Bi, Th, U
Inorganic ions (IC) SO_4^{2-}, NH_4^+, NO_3^-, Na^+, Cl^-, Mg^{2+}, Ca^{2+}, K^+
Carbonaceous fractions (TOA) OC1, OC2, CO3, OC4, PyrOC, EC1, EC2, EC3, Carbonate

2) Size-resolved samples (0.03 – 10 µm) were collected with a 13-stage cascade impactor and analysed for sulphate. Sulphate size distributions were studied along with air mass back trajectories from the 8-hour sampling time.

Results and discussion

1) Source apportionment using PMF

Five source factors were retrieved at both sites using Positive Matrix Factorisation (PMF EPA 3), Fig. 3.

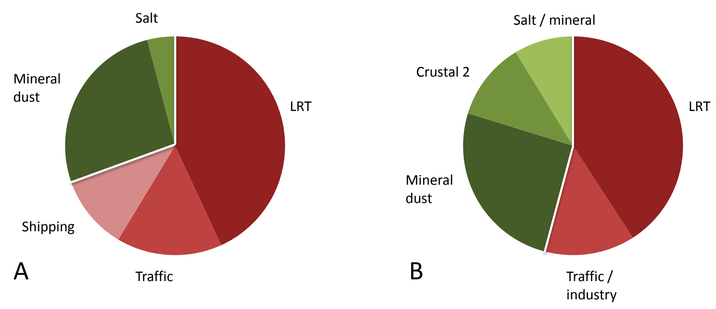


Figure 3: Pie charts showing indicative source contributions for (A) Khalifa, (B) Bida Zayed, obtained by PMF.

- Long-range transport (LRT), with a signature dominated by SO_4^{2-}, NH_4^+, EC, V and Ni, was the largest source factor both at Khalifa and Bida Zayed (Fig. 4).
- The second most important source with similar signatures at both sites was mineral dust, identified by Ti, Al, Fe, Li, Th, etc.
- At Khalifa, located close to the seaside, a shipping factor (Na, V, Ni, Sr) and a salt factor (Cl^-, Na^+, Sr) were found. Local traffic (Zn, Cu, Sb, Bi, EC, OC) also has a considerable contribution.

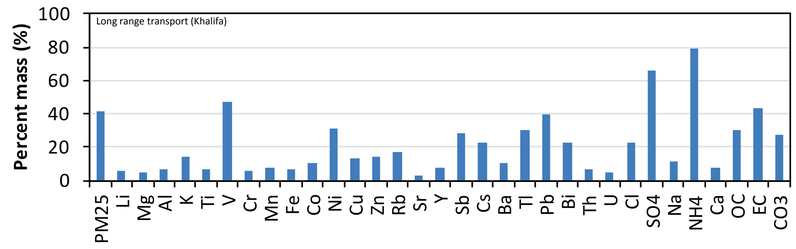


Figure 4: LRT source factor at Khalifa.

- A mixed traffic/industry factor (Pb, Sb, Zn, Cu, Tl) was identified at Bida Zayed, downwind of industrial areas. Two factors of supposedly natural origin (Cl^-, CO_3^{2-}, Sr and NO_3^-, Na^+, Sr) were present at Bida Zayed.

2) Origin of sulphate

Nine size-resolved samples collected at four sites were categorised according to different trajectory patterns. It noteworthy to highlight that:

- Size distributions with accumulation mode only were observed when air masses had spent the past 4 days over the Arabian Gulf (Fig. 5A).

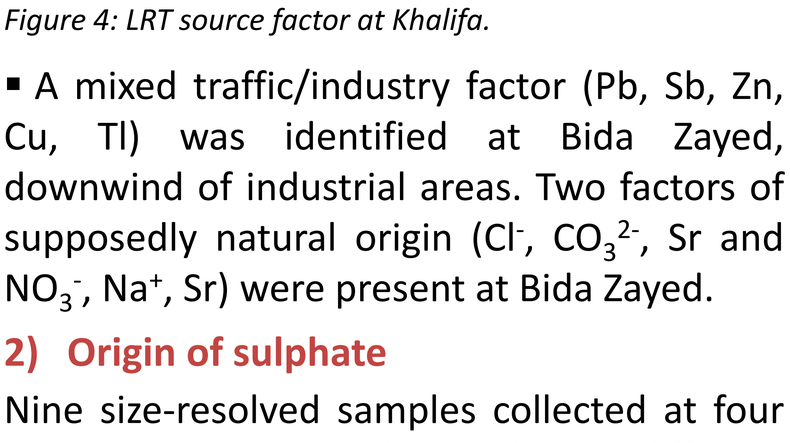


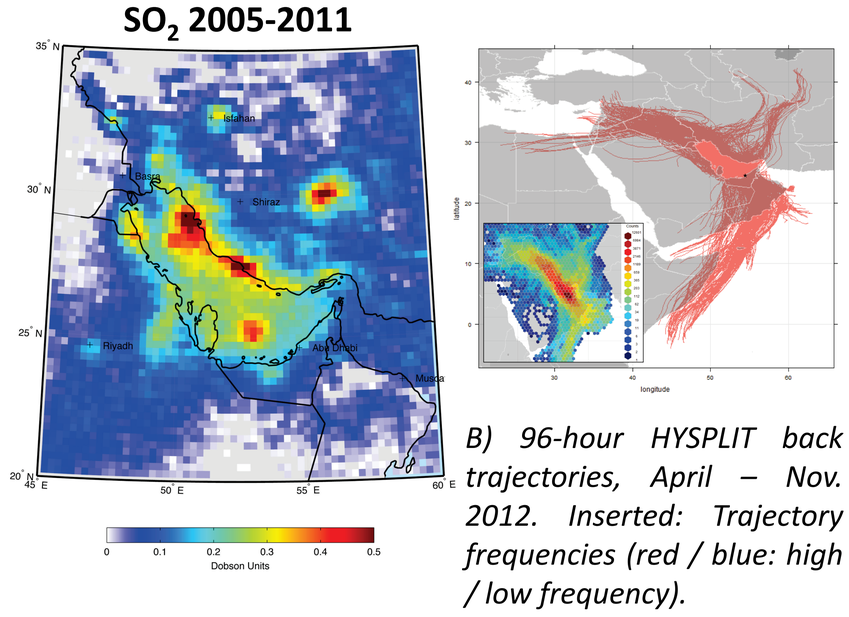
Figure 5: Sulphate mass distribution and air mass back trajectories for two size-resolved samples.

- Accumulation mode and coarse mode of sulphate size distributions were similarly pronounced for trajectories from SW, i.e. passing over Arabian Sea and Oman.

In the case shown in Fig. 5B, the air mass arriving in Abu Dhabi has travelled a long distance (> 4000 km), involving a high wind speed and suspension of dust. The size distribution shows a dominating coarse mode, indicating that mineral sulphate contributes considerably.

Sulphate occurring in the accumulation mode is an important component of secondary inorganic aerosol.

SO_2 sources in the Arabian Gulf, mainly in connection with oil and gas production (Fig. 6A), are expected to contribute greatly to the sulphate levels observed.



B) 96-hour HYSPLIT back trajectories, April – Nov. 2012. Inserted: Trajectory frequencies (red / blue: high / low frequency).

Figure 6: A) Long-term average SO_2 column density over Arabian Gulf.

Passage over the Arabian Gulf was the most frequent track of air masses reaching Abu Dhabi during the sampling period (Fig. 6B). The north-westerly flow is created by the Indian monsoon and is most pronounced during the summer months June – September providing sulphate-rich air masses to Abu Dhabi.

Conclusion

Ambient concentrations of $PM_{2.5}$ and PM_{10} in Abu Dhabi frequently exceed guideline and limit values.

Results from trajectory analysis and receptor modelling indicate that

- the main origin of $PM_{2.5}$ is LRT from anthropogenic sources (~40%)
- the second most relevant contribution is natural mineral dust (~25%)
- local traffic, industry and shipping are also significant sources.

Acknowledgements

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