Source apportionment of ambient PM_{10} near a major highway in a Swiss Alpine valley

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Background and Objective

Although trans-Alpine highway traffic exhaust is a major source of air pollution along the Alpine highway valleys, little is known about the contribution of trans-alpine highway traffic exhaust to residential exposure and impact on respiratory health. The current pediatric asthma panel study is focusing on the short-term relationship between residential air pollution exposures and respiratory heath outcomes and aims to study 1. residential outdoor exposure using spatial land-use regression (LUR) models, 2. contributions of different sources to PM_{10} and 3. the relationship between spatially refined exposure estimates and respiratory heath (see health assessment poster “Impact of residential exposure to highway traffic exhaust on respiratory health of children in an Alpine valley in Switzerland ”). This paper focuses on aim (2).

Methods

From November 2007 to June 2009 two fixed (background and highway) and four mobile sites were monitored for daily PM_{10} (quartz filters; high volume sampler (Digitel KHA-80)), continuous particle number concentrations and NO_x in Erstfeld, Switzerland. At the mobile locations measurements were taken for one month in each of the four seasons. PM filters were analyzed for elemental (EC) and organic carbon (OC) using TOT-NIOSH700+ protocol. At the mobile station daily PM_{10} was also collected on Teflon filters using a partisol sampler (Thermo Partisol Low Volume Sampler) and analyzed for 48 trace elements using XRF, the diesel marker 1-nitropyrene (1-NP) and the wood smoke marker levoglucosan (LG) using 2D-HPLC-MS/MS. Reconstructed mass (RCM) was calculated using specific trace elements for the contribution of sulphate, soil, organic matter and EC. The resulting missing mass (MM) (difference between PM_{10} and RCM) was used as additional variable in the source apportionment. Positive Matrix Factorization (EPA PMF 3.0) was used to quantify contributions of different local and regional sources. PMF with fractionated EC and OC was also explored with the goal to separate diesel from gasoline exhaust.

Results

For the total of 542 daily measurements mean daily concentrations (± SD) of PM_{10}, sum of trace elements, RCM and MM are summarised in Table1. The sum of total trace elements represented in average 21% of the total PM_{10} concentrations. As expected, PM_{10} levels were higher in winter than summer due to frequent inversion episodes. The amount of MM was also higher in winter than summer with 21% vs. 17% of PM_{10}.

Table 1. Mean (± SD) daily concentrations (µg/m3) for total PM_{10}, sum of trace elements (∑TE), reconstructed mass (RCM) and missing mass (MM) by season.

	overall	spring	summer	fall	winter
PM_{10}	15.5±9.7	12.9±7.2	13.7±6.8	15.7±9.2	19.2±12.3
∑ TE	3.2± 2.5	2.9±1.9	2.6±1.9	3.5±3.1	3.7±2.6
RCM	12.7±7.7	10.6±5.8	11.4±5.9	13.9±8.4	15.0±9.0
MM	2.8±3.9	2.4±2.8	2.3±1.7	1.8±2.6	4.2±5.6

PMF with 7 to 10 factors were explored. About 75% of PM_{10} were explained by secondary pollutants, biomass burning, traffic exhaust, railway and road salt. The contribution of these factors stayed about constant over all approaches. The remaining 25% of PM_{10} were split into soil, road dust, break wear and a NEAT construction factor depending on the predefined number of factors for the PMF.

The 9 factor model provided the most physically reasonable source profiles with secondary pollutants (S, MM, OC), biomass burning (K, EC, OC), railway (Fe, Cu, Cr), soil (Si, Al), road salt (Na, Cl), traffic exhaust (EC, OC, Sb, Zn), road dust (Ca, Si) and break / tire wear (Zn, Fe, Cu). The last factor predominantly contained Mg and Al and concluded to be resuspended dust originating from the excavation material from a nearby big construction site, NEAT (for construction of the longest train tunnel (57km) in the world). The material was transported by train and trucks along the main road.

Seasonal differences were observed for secondary pollutants (higher in summer), biomass burning (higher in winter) and road salt (only winter). Spatial differences were found for different sources, *e.g.* higher railway contributions at D2 (close to rail tracks), higher soil contributions at D1 and D2 (more rural sites).

We found a high agreement (R2 =0.81) between the biomass burning factor and levoglucosan (14-day composites).

Work in progress

Further analysis will be done using fractionated EC and OC data to attempt to split the traffic exhaust factor into a diesel and gasoline exhaust factor. Measured 1-NP and LG levels will be used to validate the diesel exhaust and biomass burning contributions, respectively.

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INTRODUCTION

Trans-Alpine highway traffic exhaust is a major source of air pollution along the Alpine highway valleys, but little is known about its impact on respiratory health. This pediatric asthma panel study aims to study:

1. residential outdoor exposure using spatial land-use regression (LUR) models
2. contribution of different sources to PM_{10}
3. relationship between spatially refined exposure estimates and respiratory heath (see health assessment poster "Impact of residential exposure to highway traffic exhaust on respiratory health of children in an Alpine valley in Switzerland ").

METHODS

Air Pollution Monitoring and Modeling

- Air pollution was monitored at two fixed (B1, H1) and four mobile stations during November 2007 to June 2009 (Figure 1). The mobile locations measured for one month per season.
- PM_{10} filters were analyzed for EC and OC (TOT-NIOSH700+), 48 trace elements (XRF), 1-Nitropyrene (diesel exhaust marker), and levoglucosan (wood smoke marker) (2D-HPLC-MS/MS).
- Reconstructed mass was calculated using specific trace elements for the contribution of sulphate, soil, organic matter and EC. The resulting missing mass (MM) (difference between PM_{10} and RCM) was used as additional variable in the source apportionment. Positive Matrix Factorization (EPA PMF 3.0) was used to quantify contributions of different local and regional sources.

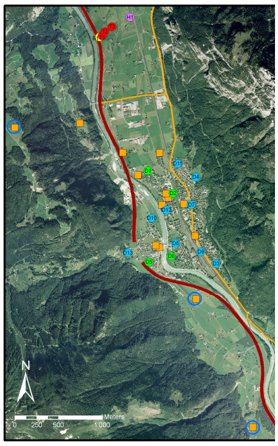

Figure 1: Air pollution monitoring in Erstfeld

RESULTS

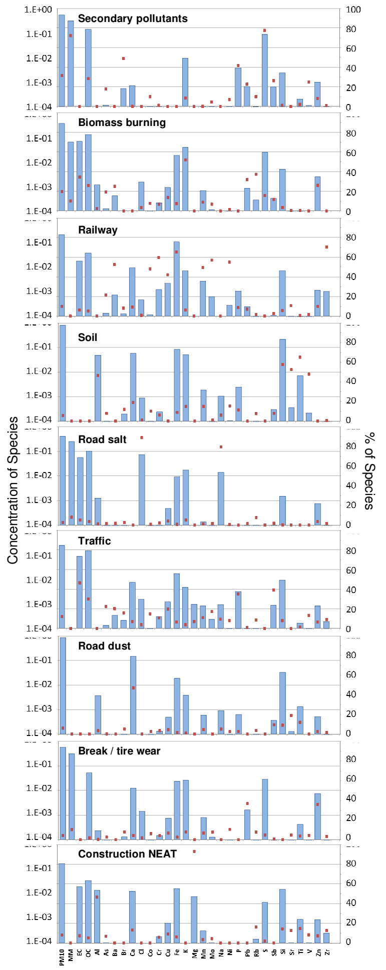

Figure 2: Source apportionment profile for 9 factors. Blue bars correspond to the concentration, red dots to the percentage of species.

A. Source apportionment with total EC and OC (9 factors)

PMF with 7 to 10 factors were explored. The 9 factor model provided the most physically reasonable source profiles (Figure 2) with secondary pollutants (S, MM, OC), biomass burning (K, EC, OC), railway (Fe, Cu, Cr), soil (Si, Al), road salt (Na, Cl), traffic exhaust (EC, OC, Sb, Zn), road dust (Ca, Si) and break / tire wear (Zn, Fe, Cu).

The last factor predominantly contained Mg and Al and concluded to be resuspended dust originating from the excavation material from a nearby big construction site, NEAT (for construction of the longest train tunnel (57km) in the world). The material was transported by train and trucks along the main road.

Main sources contributing to PM_{10} were secondary pollutants, biomass burning, traffic exhaust, railway and wind-blown soil (Figure 3). Seasonal differences were observed for secondary pollutants (higher in summer), biomass burning (higher in winter) and road salt (only winter) (Figure 3a). Spatial differences were found for different sources (Figure 3b), *e.g.* higher railway contributions at D2 (close to rail tracks), higher soil contributions at D1 and D2 (more rural sites).

Comparison of the biomass burning factor with levoglucosan (14-day composites) showed high agreement (R^2 =0.81).

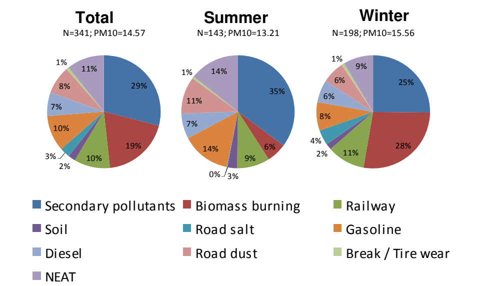

Figure 4: Source contribution to PM_{10} (Jan-Dec 2008) from 10 factor PMF with fractionated EC, OC over the whole year and by season.

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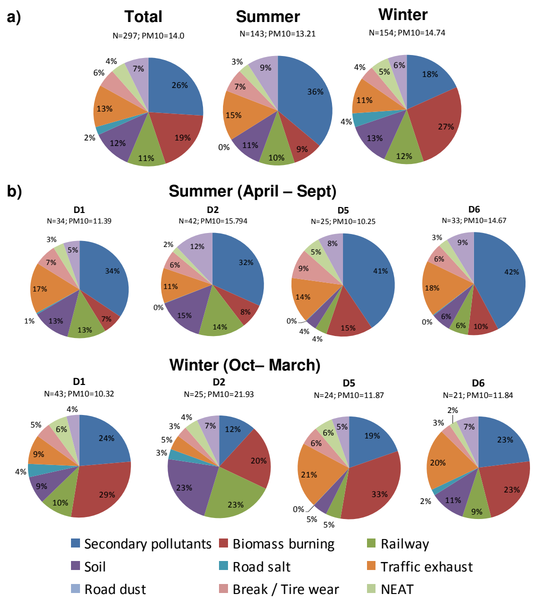

Figure 3: Source contribution to PM_{10} (Jan-Dec 2008) from 9 factor PMF with total EC, OC: (a) over the whole year and by season, (b) by site and season.

B. Source apportionment with fractionated EC and OC (10 factors)

A first attempt to separate diesel and gasoline exhaust using fractionated EC and OC showed similar contributions for secondary pollutants, biomass burning and railway. The traffic and soil related sources got redistributed (Figure 4).

CONCLUSION & FUTURE WORK

- Our first results indicate significant contribution of highway traffic and local biomass burning to residential PM_{10} exposure in the community.
- Further refinement of PMF with fractionated EC and OC to separate diesel from gasoline exhaust is in process.

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