Residential exposure to highway traffic exhaust 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 residential air pollution exposure and its impact on respiratory health. A previous questionnaire study with schoolchildren in Canton Uri, Switzerland, found significant associations between dispersion estimates for particulate matter <10µm (PM_{10}) from trucks and wheezing in the chest (OR=1.24, 95%CI: 1.01-1.52) and hay fever (OR=1.26, 95%CI: 1.05-1.52). Significant associations were also found between PM_{10} from cars and wheezing (OR=1.30, 95% CI: 1.02-1.67) (results not published). This pediatric asthma panel study is aimed 1. to develop spatial land-use regression (LUR) models for residential outdoor exposure, 2. to estimate the contribution of different sources of PM_{10} using receptor modeling methods, and 3. to examine the relationship between spatially refined exposure estimates and respiratory heath.

Methods

This work is part of an asthma panel study done in Erstfeld, Switzerland. This Alpine community is located in a narrow valley (about 1km wide) crossed by a major highway. From November 2007 to June 2009 13 children (ages 7–13) with asthma participated in monthly monitoring of respiratory health indicators including exhaled NO and oxidative stress markers in exhaled breath condensate. Prior to each health monitoring 14-day passive NO_2 was measured indoors and outdoors of the children's homes with Passam tubes (www.passam.ag). During the last year of the study three PM_{10} and $PM_{2.5}$ measurements spread over different seasons were taken outside of 9 homes and the highway site. We measured 14-day averages of PM_{10} and $PM_{2.5}$ collected on Teflon filters using Harvard Impactors (Air Diagnostics and Engineering, Inc., Naples, ME) with a flow rate of 4L/min by running the pump for 10 minutes per hour for 14 days.

During the whole study period 14-day passive NO_2 was measured with Passam tubes at one highway and one background station in addition to seven mobile and 9 fixed sites spread over the community. Continuous NO_2, NO_x, particle number concentrations (PN) and meteorological parameters such as wind speed and direction, relative humidity and temperature were measured at the fixed highway and background sites as well as the mobile site, which was moved every four weeks to a new location covering all four seasons per site. At the highway and mobile sites daily PM_{10} was collected on quartz filters with a high volume sampler (Digitel KHA-80) with a flow rate of 500 L/min and analyzed for elemental (EC) and organic carbon (OC) with the EUSAAR2 protocol. At the mobile station daily PM_{10} was also collected on

Teflon filters using a partisol sampler (Thermo Partisol Low Volume Sampler) with a flow rate of 16.7 L/min and analyzed for 48 trace elements, the diesel marker 1-Nitropyrene and the wood smoke marker levoglucosan.

Analysis

Continuous measurements were averaged over the day and summary statistics were calculated for all pollutants at the highway, background and mobile sites. A land-use regression model for daily NO_2 was built using the measurements at the highway and mobile sites together with selected land-use, traffic, and meteorological parameters. The model was then used to predict daily NO_2 at all fixed and home sites. Passive NO_2 measurements at all sites were then compared with matched 14-day averages of the predicted daily concentrations. All statistical analyses were performed with SAS9.2 (SAS Institute Inc., Cary, NC).

Results

A. Summary of air pollution monitoring:

Mean daily concentration ranged from 22.6µg/m^3 (± 11.8µg/m^3) to 32.7µg/m^3 (± 12.6µg/m^3), 1.2µg/m^3 (± 0.7µg/m^3) to 1.6µg/m^3 (± 0.8µg/m^3), and 8187#/cm^3 (± 4014#/cm^3) to 16094#/cm^3 (± 8192#/cm^3) for NO_2, EC and PN, respectively. These traffic related pollutants showed a negative gradient with increasing distance to the highway. PM_{10} and OC were more homogeneously distributed with ranges of 16.6µg/m^3 (± 10.8ug/m^3) to 17.7µg/m^3 (± 10.6µg/m^3), and 3.4ug/m^3 (± 1.7ug/m^3) to 3.5ug/m^3 (± 1.6ug/m^3), respectively. All pollutants showed a seasonal pattern with significantly higher concentrations in winter.

B. LUR model (NO_2):

The LUR model for daily NO_2 (R^2=0.91) was dominated by the background NO_2 concentrations (part. R^2=0.77) and the distance weighted heavy duty vehicle traffic counts from the highway (part. R^2=0.11). Validation of the model with passive measurements from all sites showed R^2's between 0.76 and 0.93 for passive sampler sites and between 0.66 and 0.96 for most home locations. However, the model was not able to estimate accurate concentrations for two homes located ca. 120m and 550m above the city (R2's of 0.25 and -0.01, respectively).

Work in progress

- Land-use regression modeling for PN and PM_{10}.
- Estimation of source contributions to PM_{10} with Positive Matrix Factorization and validation using diesel and wood smoke markers. (Variations of the trace metals are described in the poster of Harish C. Phuleria: "Trace metal composition of ambient $PM_{2.5}$ and PM_{10} and their spatio-temporal variation near a major highway in an Alpine valley in Switzerland")
- Assessing levels of changes in upper airway inflammation marker, NO in exhaled breath, with levels of exposure to highway traffic.
- Assessing associations of levels of oxidative stress markers with exposure to highway traffic exhaust.

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INTRODUCTION

Although trans-Alpine highway traffic exhaust is a major source of air pollution along the Alpine highway valleys, little is known about residential air pollution exposure and its impact on respiratory health. This pediatric asthma panel study is aimed 1. to develop spatial land-use regression (LUR) models for residential outdoor exposure, 2. to estimate the contribution of different sources of PM_{10} using receptor modeling methods, and 3. to examine the relationship between spatially refined exposure estimates and respiratory heath.

METHODS

Monitoring

- Monthly monitoring of respiratory health indicators including exhaled NO and oxidative stress markers in exhaled breath condensate of 13 children (ages 7–13) with asthma from November 2007 to June 2009.
- Air pollution monitoring during the whole study period (Figure 1).
- PM_{10} filters analyzed for elemental (EC) and organic carbon (OC), 48 trace elements, diesel marker 1-nitropyrene and wood smoke marker levoglucosan.

Analysis method

- Land-use regression (LUR) models to estimate daily home outdoor exposures using air pollution measurements together with selected land-use, traffic, and meteorological parameters. Validation with 14-day measurements outside children's homes.
- Estimating contributions of diesel trucks, passenger cars, biomass burning, road dust and urban background sources using Positive Matrix Factorization.
- Assessing short-term impact of general air pollution and diesel truck exhaust on respiratory health using model estimates and source apportionment results.

METHODS (cont.)

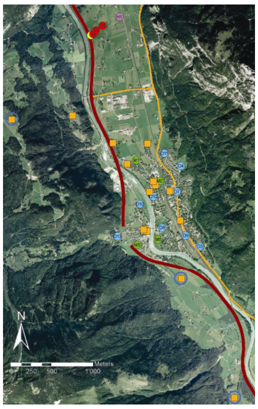

Figure 1: Air pollution monitoring in Erstfeld

- **Highway**
- **Main street**
- **Subject homes**
  - 14-day passive NO_2 indoors and outdoors, each month prior to health monitoring
  - 14-day PM_{10} and $PM_{2.5}$ outdoor homes in 3 seasons
- **Passive sampler sites**
  - 14-day NO_2
- **Highway site** (B1)
- **Background site** (H1)
- **Mobile sites**
  - 14-day passive NO_2
  - Continuous NO, NO_2, NO_x and particle number (PN)
  - Daily PM_{10}, elemental carbon (EC) and organic carbon (OC) (not for H1)

RESULTS

A. Summary of air pollution monitoring

Traffic related pollutants such as NO_2, EC and PN show decreasing concentrations with increasing distance to the highway (Figure 2a-c) while PM_{10} and OC are more homogeneously distributed (Figure 2d-e).
Concentrations are higher in winter than in summer for all pollutants.

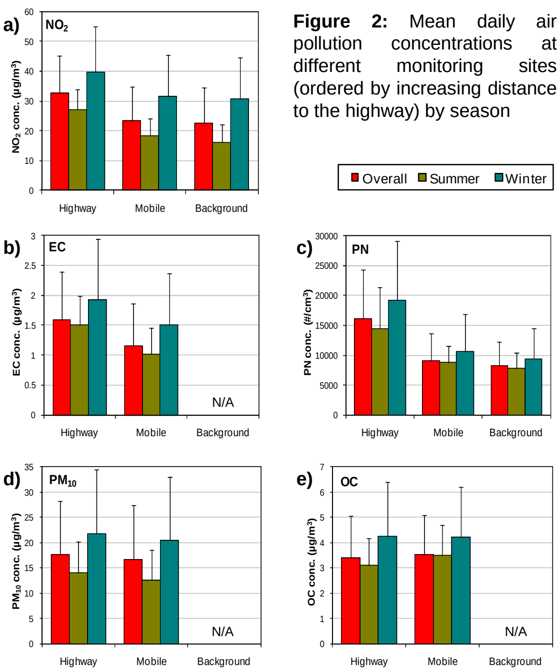

Figure 2: Mean daily air pollution concentrations at different monitoring sites (ordered by increasing distance to the highway) by season

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B. Land-use Regression Model (NO_2)

For the LUR model (R^2=0.91), which was built using continuous NO_2 measurements at mobile sites, background NO_2 concentrations (part. R^2=0.77) and distance weighted heavy duty vehicle traffic counts on the highway (part. R^2=0.11) were the most important predictors (Table 1).
Comparison between measured passive 14-day NO_2 and matched 14-day averages of predicted daily NO_2 resulted in R^2's between 0.76 and 0.93 for passive sampler sites and between 0.66 and 0.96 for most home locations. For two homes located ca. 120m and 550m above the city the model was inadequate (R^2's of 0.25 and -0.01, respectively).

Table 1: Land-use regression model for daily NO_2 concentrations

Variable	Estimate		SE	Partial R^2	Adj. Model R^2
Background NO_2 measurement (μg/m³)	0.70	**	0.03	0.77	**0.91**
Heavy duty vehicle traffic count at highway (distance weighted)	0.36	**	0.02	0.11	
Light duty vehicle traffic count at highway (distance weighted)	0.05	**	4.1E-03	0.02	
Temperature (°C)	-0.17	**	0.02	0.01	
Average wind speed (m/s)	-0.56	**	0.07	4.6E-03	
Background NO_x measurement (μg/m³)	0.09	**	0.01	4.3E-03	
Elevation (m)	-0.12	**	0.02	2.1E-03	
Pressure (hPa)	-0.04	**	0.01	7.0E-04	
Average wind direction	2.2E-03	*	1.1E-03	3.0E-04	
Weekly time term (sin)	0.34		0.19	2.0E-04	

* p<0.05; ** p<0.01; SE: Standard error

CURRENT WORK

- Land-use regression modeling for PN and PM_{10} within the city
- Estimation of source contributions to PM_{10} with Positive Matrix Factorization and validation using diesel and wood smoke markers
- Assessing levels of changes in upper airway inflammation marker, NO in exhaled breath, with levels of exposure to highway traffic.
- Assessing associations of levels of oxidative stress markers with exposure to highway traffic exhaust.

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