Impact of residential exposure to highway traffic exhaust on respiratory health of children in an Alpine valley in Switzerland

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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. Previous questionnaire studies along the highway A2 found wheezing positively associated with proximity to the highway in adults (Hazenkamp-von Arx *et al.*, 2011) and with traffic related PM_{10} (particulate matter <10 micrometer) in children (not published). 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} (see source apportionment poster "Source apportionment of ambient PM_{10} near a major highway in a Swiss Alpine valley") and (3) the relationship between spatially refined exposure estimates and respiratory heath. This paper focuses on aim (3).

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 (eNO) as an upper airway inflammation marker and oxidative stress markers in exhaled breath condensate. Exhaled breath was collected in mylar balloons followed by NO analysis within 2-3 hours after collecting (Sievers Chemiluminescence NO Analyser). Exhaled breath condensate (eBC) was collected during tidal breathing for 10 minutes through an R-Tube covered by a cooling sleeve and stored (-80℃) until analysis for pH (micro electrode pH meter) and for Nitrite (eBC NO) (Griess reaction assay). At each visit records were taken about asthma symptoms, medication use, allergies, exposure to tobacco smoke, and a time-activity diary of the child for the day before the health monitoring.

Measurements of NO_2 (nitrogen dioxide) at 13 locations in the community were used to model the home outdoor exposures with a land-use regression model (LUR). In addition different source contributions (e.g. diesel trucks, gasoline cars, biomass burning, etc.) to PM_{10} are quantified by source apportionment methods (see source apportionment poster "Source apportionment of ambient PM_{10} near a major highway in a Swiss Alpine valley").

Statistical Analysis

Mixed models (random intercept) were used to assess the short-term impact of different pollutants (total PM_{10} and EC at highway site, home outdoor NO_2 estimates from LUR-model, traffic PM_{10} from source apportionment) with various lag times on the eNO levels. Covariates included asthma symptoms, medication use, allergies, presence of cold or flue, exposure to tobacco smoke, relative humidity, temperature, ambient NO, eBC PH, eBC NO, seasonal term, weekday term. They were selected on a significance level of 0.2. Two-pollutant models (incl. ozone) were also studied. All statistical analyses were performed with SAS 9.2 (SAS Institute Inc., Cary, NC).

Results

In the one-pollutant models only traffic PM_{10} showed significant effects for the 2-day average (3.8%; CI: 0.04-7.64%) and the lag1-3 average (5.2%; CI: 0.5-10.1%). All other pollutants showed no significant effects. Inclusion of ozone only influenced EC and NO_2. For EC effects got significant for several lags after inclusion of ozone. We can see a trend of increasing effects in eNO from the general to the more specific air pollutant (total PM_{10} to NO_2 to EC to traffic PM_{10}). Averages over several lag days seem to have a greater influence than single lag days.

Work in progress

- Estimation of diesel and gasoline contributions to PM_{10} with Positive Matrix Factorization and validation using diesel markers.
- Association between biomarkers (eBC and eNO) and different air pollutants and sources will be investigated further.

References

Hazenkamp-von Arx M.E., Schindler C., Ragettli M.S., Künzli N., Braun-Fahrländer C., Liu S.L.J. (2011): Impacts of highway traffic exhaust in alpine valleys on the respiratory health in adults: a cross-sectional study. Environmental Health 10:13. Doi:10.1186/1476-069X-10-13

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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} (see source apportionment poster "Source apportionment of ambient PM10 near a major highway in a Swiss Alpine valley")
3. relationship between spatially refined exposure estimates and respiratory heath.

METHODS

Health Monitoring
- Monthly monitoring of respiratory health indicators of 13 children (ages 7-13) with asthma from November 2007 to June 2009.
  - *Exhaled NO (eNO)*: Flow controlled collection of exhaled breath in mylar balloons (Figure 1a) followed by NO analysis within 2-3 hours after collecting with a Sievers Chemiluminescence NO Analyser
  - *Exhaled breath condensate (eBC)*: Collection during tidal breathing for 10 minutes through an R-Tube covered by a cooling sleeve (Figure 1b).
    - Analysis for *pH* with a micro electrode pH meter
    - Analysis for Nitrate (eBC NO) with Griess reaction assay
- Monthly questionnaires (for the 24 hours prior health measurements) about symptoms, health status, inhalator and medication use, exposure to smoking, home ventilation and a time activity diary.
- Baseline questionnaires about age, sex, socioeconomic status, birth history, health history, home characteristics, living environment and pets.
- Skin prick test for 22 allergens (different pollen, animals, molds, dust mites).

METHODS cont.

Air Pollution Monitoring and Modeling
- Air pollution monitoring during the whole study period:
  - 14-day passive NO_2 at children's homes and 13 sites in the village
  - Continuous NO, NO_2, NO_x and particle number at background, highway and 4 mobile sites
  - Daily PM_{10}, EC and OC at highway and mobile sites
- PM_{10} filters from mobile sites used for source apportionment with Positive Matrix Factorization.
- Daily home outdoor NO2 exposures estimates using land-use regression (LUR) models.

Statistical Analysis
Mixed models (random intercept) were used to assess the short-term impact of different pollutants with various lag times on the eNO levels. Covariates were selected on a significance level of 0.2. Two-pollutant models (incl. ozone) were tested.

a) 

b) 

Figure 1: Collection of a) exhaled NO (eNO) and b) exhaled breath condensate (eBC)

RESULTS

A. Summary of health measurements

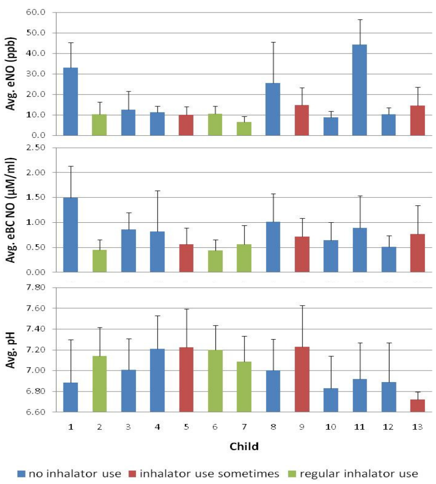

Figure 3: Average values of eNO, eBC NO and pH for each child with indication of inhalator use

Children with regular inhalator use have in average lower eNO and eBC NO than children who are not using an inhalator (Figure 3). We also observed higher eNO for children with allergies to pollen or grass during allergy season.

B. Short-term effects of eNO

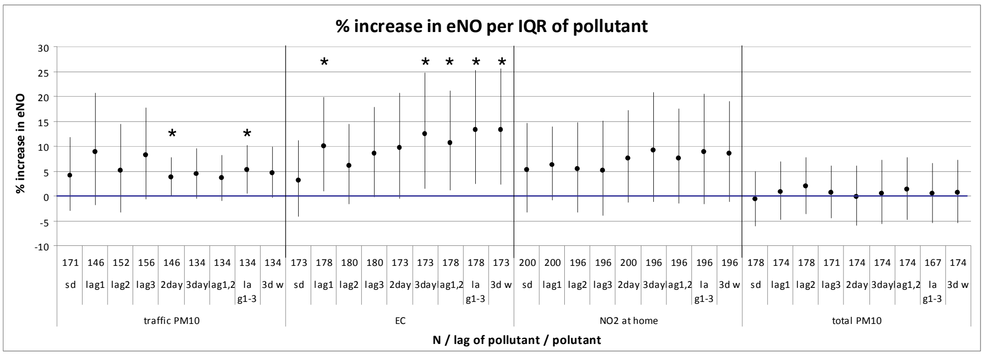

Figure 4: Percent increase in eNO levels per interquartile range (IQR) of pollutant (two-pollutant models). Total PM_{10} and EC were measured at the highway site, NO_2 was estimated with LUR-model and traffic PM_{10} comes from preliminary source apportionment. IQR of traffic PM_{10}=1.6µg/m^3, EC=0.9µg/m^3, NO_2=15.8µg/m^3, and total PM_{10}=11.5µg/m^3. All models were adjusted for asthma status, inhalator use, presence of a cold or flu, current allergies, and day of measurement. Additional covariates were included for EC (PH, season and lag1 ozone), NO_2 (season and same day ozone) and total PM_{10} (PH, eBC NO and season).
(*) significant effects. Time lags: sd=same day, lag1, lag2, lag3, 2day=2 day average, 3day=3 day average, lag1,2=average of lag1 and lag2, lag1-3=average of lag1, lag2 and lag3, 3d w=weighted average (0.25*sd+0.5*lag1+0.25*lag3).

In the one-pollutant models only traffic PM_{10} showed significant effects for the 2-day average and the lag1-3 average. Significant effects for EC were only seen after inclusion of ozone. We can see a trend of increasing effects in eNO from the general to the more specific air pollutant. Averages over several lag days seem to have a greater influence than single lag days.

CONCLUSION & FUTURE WORK

- We found significant short-term effects between eNO and the traffic PM_{10} and EC.
- Source apportionment is being refined to separate HDV diesel exhaust from gasoline cars using fractionated EC and OC.
- Association of biomarkers (eBC ad eNO) and different air pollutants and sources will be investigated further.

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