Modeling exposure of schoolchildren to traffic-related air pollution: short term, medium term and long term exposure

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Background and aims

In the HEAPS-study (Health Effects of Air Pollution in Antwerp Schools) the importance of the school location on children's exposure and health was investigated in Antwerp, Belgium, with a special focus on traffic-related air pollution. 130 children (6 to 12 years old) from 2 schools participated in a human biomonitoring study measuring oxidative stress, inflammation and cardiovascular markers. In this first part of the study detailed exposure estimates are constructed for all members of the cohort. In a second part, acute, subacute and long term health effects will be considered.

Methods

Personal exposure of schoolchildren to traffic-related air pollution is assessed using both measured and modeled concentrations at school and/or at the home address. In the playground of 2 schools, continuous measurements of multiple pollutants were carried out (elemental carbon, black carbon, nitrogen monoxide, nitrogen dioxide, ultrafine particles, and particulate matter (PM2.5, PM10)). Next to the school measurements, air quality was measured on 42 residential locations for black carbon (BC) and on 55 locations for nitrogen dioxide (NO_2). Concentrations were measured for 7 consecutive days in May and June 2011 on each location, and repeated in late autumn 2011. Not all measurements were done simultaneously, but raw measurements were rescaled based on concentration levels at an official monitoring station of the Flemish Environment Agency (Borgerhout, station R801). The BC and NO_2 measurements served as dependent variables in a land use regression (LUR) model. This technique was used to estimate exposure at the children's home address since it was not possible to measure concentrations at 130 locations. LUR is a statistical method that tries to predict concentrations measured at 20 to 100 monitoring stations, by using traffic, land use or population density parameters as explanatory variables in a multiple linear regression model. Time-activity patterns were used in combination with LUR models: concentrations are determined at school and at home, and weighted for the time spent at each of these locations.

Not only air quality estimates were produced, exposure to traffic at home was also assessed directly by calculating relevant traffic parameters in ArcGIS (road length, traffic intensity in different buffers, etc.) and by using traffic counts.

Results

Short term exposure

Concentrations measured at school in the hours before and during the medical examination were used for assessing acute health effects. Over two seasons, short term BC exposure, as measured in the playgrounds ranged from 514 ng/m³ to 6285 ng/m³, and for NO_2 from 10.8 µg/m³ to 35.7 µg/m³. Concentrations measured in the playgrounds of the 2 schools were very similar. In autumn concentrations were elevated compared to concentrations in spring (figure 1) due to a smog episode.

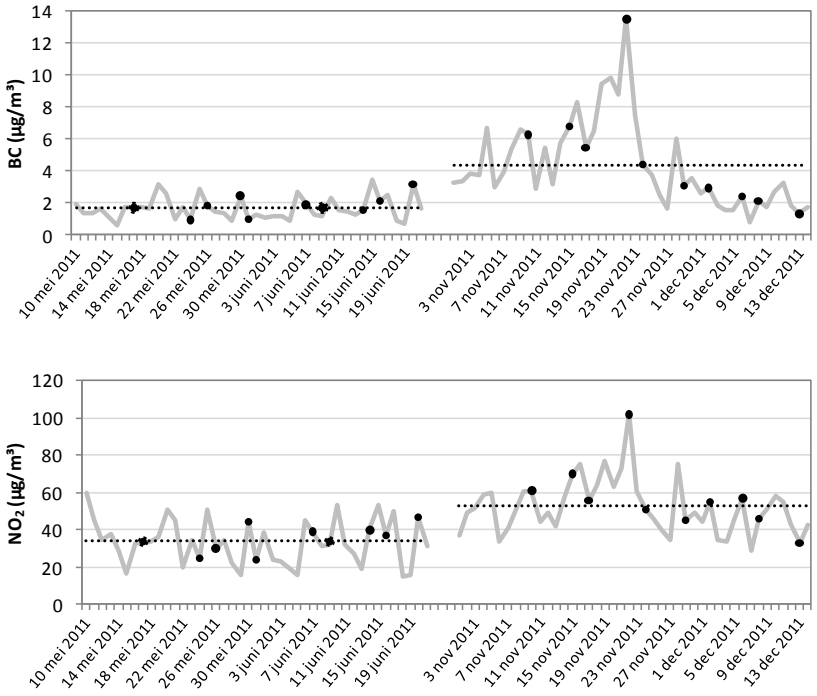

Fig 1, Black Carbon (BC) and Nitrogen Dioxide (NO_2) concentrations measured at the official AQ station in Borgerhout (R801). The black dots indicate days of medical examinations. The dotted line is the period averaged concentration.

Medium term exposure

To determine medium and long term exposure, LUR models were developed. Significant variables in the annual LUR model for BC were heavy traffic in buffers of 50m and 100m, total road length in a 1km buffer, and number of addresses in a buffer with radius 50m. For NO_2, similar variables proved to be significant in the model, with additional variables for traffic intensity of all vehicles in buffers of 50m and 500m, and a negative indicator variable for the presence of green spaces within a 500m radius. The LUR estimates were recalculated into daily concentrations by using the temporal trend observed at a fixed monitor of the official AQ network. Home and school addresses of the study cohort were geocoded and the LUR models for BC and NO_2 were applied. Integrated medium term exposure was determined until 10 days before the child's examination, taking into account exposures at home and at school and the time spent in each of these microenvironments. As an example, one day before the medical examination, the integrated exposure averaged 1492 ng BC/m³ and 26 µg/m³ µg NO_2/m³ in spring; in autumn levels for the same group of children increased to 3157 ng BC/m³ and 43 µg NO_2/m³. Exposures at locations different from the residential or school location are omitted, but they could nevertheless impact personal exposure.

Long term exposure

Seasonal and annual LUR predictions at the children's homes were used to estimate long term exposure (annual average concentration of 2423 ng BC/m³, and 35 µg NO_2/m³). In this specific study, both schools had similar air quality in the playground, and since long term exposure can denote exposure over several years whereas some children only attend this school for 1 or 2 years, the school location was not included in the long term exposure estimate.

Traffic parameters

Traffic parameters are used as an alternative exposure model; they are linked directly to the biomonitoring results without the intermediate air quality estimation. From these additional GIS analyses, we know that for 42 of the 130 children, the distance to the nearest highway or major road was less than 300m; and for only 3 children the distance to the nearest highway or major road was larger than 1500m. 26 children live closer than 75m to a road with over 10000 vehicles per day. Children were also asked to do a traffic count themselves; these counts were recalculated into daily average traffic intensities and used to estimate traffic volume at the home address (useful because for many local streets no modeled traffic counts are available).

Conclusions

The land use regression technique proved to be a fast and accurate means for estimating both long term and daily BC and NO_2 exposure for children living in the Antwerp area. Short term exposure was estimated with measurements in the school's playgrounds. The spatial and temporal resolution was tailored to the needs of the epidemiologists involved in this study.

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