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Calculation of person-weighted average concentrations of No_2, Pm_{10} and $Pm_{2.5}$ in Oslo for 1992-2002

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CALCULATION OF PERSON-WEIGHTED AVERAGE CONCENTRATIONS OF NO_2, PM_{10} AND $PM_{2.5}$ IN OSLO FOR 1992-2002

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ABSTRACT

Person-weighted average concentrations of NO_2, PM_{10} and $PM_{2.5}$, for different averaging periods from 1 hour up to 3 years, have been calculated for all the smallest administrative geographic areas of Oslo for the period 1992 – 2002 (approximately 1000-1500 inhabitants per area). The results of the 3-year averaging generally shows a decline in the air pollution levels for all three compounds during the period. The resulting database of concentrations, for different averaging periods, is currently being used as input for several epidemiological studies of mortality and other health related issues of air pollution exposure in Oslo.

1. INTRODUCTION

The person-weighted average concentration calculations of NO_2, PM_{10} and $PM_{2,5}$ described here are based on earlier dispersion calculations performed in Oslo with NILUs AirQUIS-system for the years 1992-2002 (McInnes, 2004; Denby, 2004; Slørdal et al., 2003). The calculations are based on a Eulerian 22 x 18 km^2 grid model, with sub-grid scale line source modelling of concentrations at buildings close to streets in Oslo with high traffic load. Hourly data of emissions and meteorology for the whole period 1992-2002 is used as input data. The results consists of hourly concentration values of the components in the grid system, and in the building points.

For each of the smallest administrative geographic areas of Oslo, a person-weighted average concentration is calculated by weighting the concentrations in building points (representing buildings) and other receptor points in the area, with the number of persons associated with each point. Different sets of concentration data is then made depending on averaging time, from hour, through day, week, month and year, up to 3-year averages. The idea is to present different person averaged concentrations in the form of a coloured map, for each compound and averaging period, in order to graphically compare the level of air pollution in the different areas, and to use the data as input to different health studies of air pollution in Oslo.

2. METHODOLOGY

Building Points Data and Administrative Areas

The AirQUIS database contains between 5031 and 8275 building points for the period 1992-2002 depending on the year. The number was constant (5031) from 1992-1998, but was increased from 1999 due to increased traffic and change of traffic flow after the opening of the new Oslo main airport late in 1998. For each building point the database stores the number of persons associated with the point as home address.

Only *active* building points are selected to be receptor points in the AirQUIS dispersion calculations. These are points which lies close to streets with heavy traffic. For those building points, sub-grid scale models are used in AirQUIS to calculate concentration values in addition to the grid model (km^2 grid) values. For all other building points only the grid model values are used. The number of active building points (receptor points in the calculations) varies from 3813 points in 1992 to 8009 points in 2002.

The smallest administrative areas in Oslo are in the AirQUIS database defined as polygons with coordinates (x,y). It is therefore possible to calculate which administrative area a certain building point belongs to in a unique way. All in all there are 429 administrative areas in Oslo defined in the AirQUIS database. The total number of persons in the database for Oslo ranges between 502006 (1992) and 507467 (2002) and the number belonging to each administrative area and allocated to each building point is also stored for each year. The number of persons belonging to building points in the areas ranges between 63176 (1992) and 77814 (2002), while the rest of the population in the areas varies between 444291 (1992) and 429653 (2002).

Emissions

The AirQUIS system contains a detailed database of emissions from traffic for each year of the calculation period (1992-2002). The database consists of approximately 1900 individual line sources with data such as location, elevation, width, annual average daily traffic, percentages of different light and heavy duty vehicles etc. The emission factors for NO_2, PM_{10} and $PM_{2,5}$ are based on calculations of emissions from road traffic in Norway (Norwegian Pollution Control Authority, 1999; Torp et al., 1995). The time variations of traffic during each day is partly based on available countings performed on the main roads in Oslo. The percentage of vehicles with studded tyres in the winter season (15 Oct. – 23 Apr.) is set separately for each year based on data from the Norwegian Public Road Administration. It varied from 81% in 1992 to 32% in 2002. Studded tyres contributes significantly to the resuspension of PM_{10}.

In addition to traffic, home heating based on wood- and oil-burning is the main source of air pollution in Oslo. The AirQUIS emission database consists of consumption data and emission factors for NO_2, PM_{10} and $PM_{2,5}$ from such sources, based on a comprehensive emission survey from Statistics Norway.

Meteorology and Boundary Conditions

The meteorological data in the AirQUIS database are based on observations from the stations Valle Hovin, Blindern and Nordahl Brunsgt. in Oslo and consists of data for wind speed, direction, temperature and vertical temperature gradient (stability), and in addition precipitation and relative humidity. The last two parameters are mainly used as input for the PM_{10} emission calculations. A topographical oriented wind field model (MATHEW) is used to generate the wind fields. More details can be found in (McInnes, 2004).

The background level of NO_2 for each hour is based on the minimum daily level found at the stations Prestebakke, Birkenes, Nordmoen and Hurdal. For O_3 the background level for each hour is based on the maximum hourly value found at the stations Jeløya, Prestebakke and Hurdal. In the AirQUIS dispersion model, O_3 is used to transform NO to NO_2. The hourly background concentration of PM_{10} is calculated based on observations of sulphate (SO_4), nitrate (NO_3) and ammonia (NH_4) on station Birkenes for the period 1992-2000, and based on direct observations of PM_{10} in the period 2001-2002.

Calculation of Person-Weighted Averages

For each hour during the calculation period 1992-2002, a person-weighted hourly average concentration is calculated for each of the smallest administrative areas of Oslo in the following manner: First the concentration values in each building point within the area are taken into account. If the building point is an active building point, i.e., a receptor point being used in the dispersion calculations in AirQUIS, the corresponding sub-grid scale receptor point concentration value is used. If the building point is not an active receptor point in AirQUIS, i.e. is outside the buffer-zones around the roads with most traffic, the concentration value for the building point is set equal to the corresponding model grid value in AirQUIS. In both cases the concentration value of the building point is multiplied with the number of persons associated with the building point and subsequently summed.

The rest population in the administrative areas (i.e., the difference between the total number of persons in an area and the number of persons associated with building points in the same area), is then distributed over a certain number of additional points within each area. The additional points are distributed within each area in a uniform way using a Monte Carlo method (random draw) of selecting points. This point distribution is performed once at the beginning of the calculations and remains thereafter the same for all hours. The number of additional points in each area is determined by first choosing a given density for the points, and then multiplying this density with the area. The density is chosen so that the smallest areas get at least 1-2 points each. This corresponds to a density of approximately 1 point per 100 x 100 m^2. The number of persons in each additional point are set equal to the rest population divided by the number of additional points. Concentration values for each additional point are defined as the gridded average concentrations in the grid cell where the additional points are situated.

The concentration values in the additional points within each area are then multiplied with the number of persons associated with each additional point and summed up. This person-weighted sum for each area is then added to the person-weighted sum of concentration values in the building points for the same area, and the total sum is then divided by the total number of persons within the area. This person-weighted average has the same unit as the concentration (µg/m^3). All the hourly values for each area are subsequently summed and averaged in the form of 3-year average concentrations, first for the period 1992-1994, then for 1993-1995, etc., until the last 3-year period 2000-2002.

Mathematically the above described procedure can be summarized using the following expression for the person-weighted average concentration in an administrative area:

$$\overline{C_g} = \frac{1}{N_g}\left\{\sum_{b=1}^{nb} N_b \cdot C_b + \sum_{r=1}^{nr} N_r \cdot C_r\right\} \qquad (1)$$

where N_g represents the total number of persons in the area, N_b og N_r are the number of persons associated with building point b og additional point r respectively, and C_b and C_r represents the hourly average concentration in the same points. In the expression (1), nb represents the number of building points and nr the number of additional points within the area.

The number of persons associated with an additional point r is determined by the following formula:

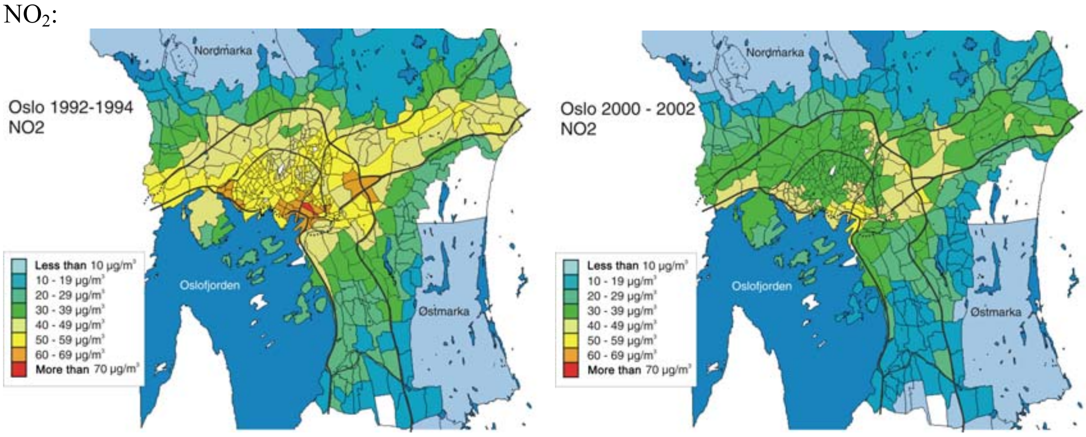
$$N_r = \frac{N_g - \sum_{b=1}^{nb} N_b}{nr} \qquad (2)$$

3. RESULTS AND CONCLUSION

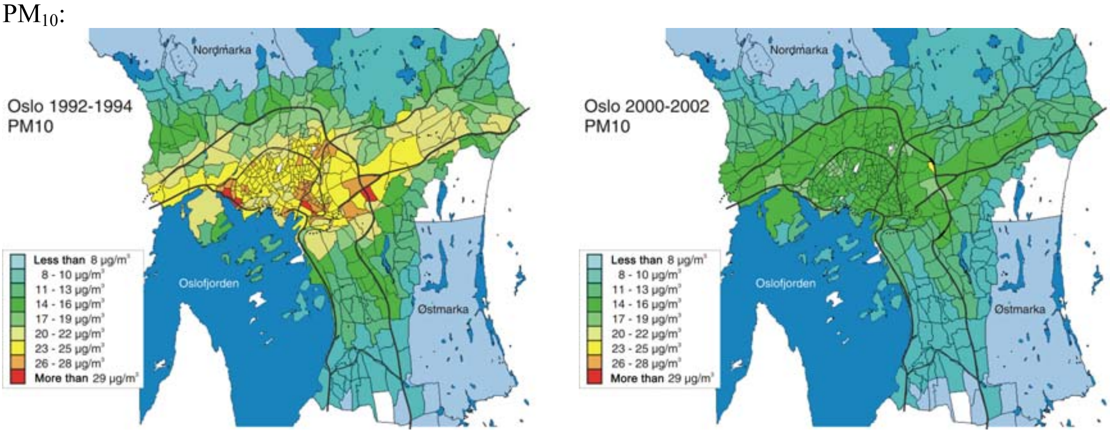
Some results of the 3-year person-weighted average concentration calculations for Oslo are shown in Figure 1. The results generally show that the person-weighted 3-year average concentration level declines throughout the period for all components., which is in accordance with earlier results indicating a similar trend (McInnes, 2004). The geographic areas receiving the highest or lowest levels varies somewhat throughout the years, but if we focus on the last 3-year period, from 2000 to 2002, the administrative areas with the highest averages for NO_2 and PM_{10} were Økern senter and Grønland (Rode 1), while Majorstua, St. Hanshaugen, Fagerborg and Homansbyen have the highest levels for $PM_{2.5}$.

Figure 1: Person-weighted 3-year average concentrations of NO_2 (top) PM_{10} (middle) and $PM_{2.5}$ (bottom) for all the smallest administrative geographic areas of Oslo for 1992-94 (left) and 2000-02 (right). Unit: µg/m^3.

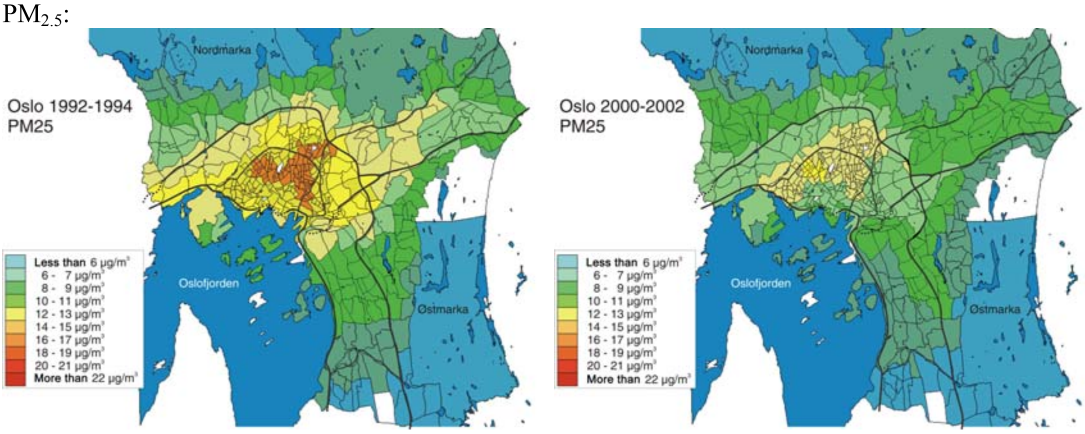
NO_2:



PM_{10}:



$PM_{2.5}$:



It is important to underline that the levels we have analysed for trend are 3-year person-weighted average concentrations, which are also averaged spatially over each administrative area in Oslo. Observational data from a network of monitoring stations in Oslo clearly shows that for some areas, and over short averaging periods (hours and days), there exists quite high levels of air pollution during the winter season (Oslo Department of Public Health, 2004). Their report shows that there are several exceedances of the limit values, to be reached for the years 2005 and 2010, on several of the monitoring stations in Oslo, especially on stations which are situated close to main roads. For example there are some stations which exceed the limit value of 40 $\mu g/m^3$ for NO_2 as a yearly mean which should be reached within 2010, and more than 35 days with daily average values of PM_{10} exceeding 50 $\mu g/m^3$ which should be reached within 2005. Our results do not focus on such hot-spot points, but describes the average concentration over the administrative areas as a whole taking into account where people live (their home addresses). The resulting database of person-weighted concentrations, for different averaging periods, has been found useful as input for several epidemiological studies of mortality and other health related issues of air pollution exposure in Oslo.

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