5.41 APLICATION OF ATMOSPHERIC DISPERSION MODELS TO EVALUATE POPULATION EXPOSURE TO NO_2 CONCENTRATION IN BUENOS AIRES

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INTRODUCTION

The activities of a human society - the economy, production of goods, transport and consumption - all affect the environment. All stages of these activities contribute directly or indirectly to creating air pollution. Air pollution causes health effects when the population is exposed. Therefore, exposure may be considered as the intersection between the ambient pollution concentrations and the location of the population. Urban areas are the major sources of pollution and population. Pollutant emissions affecting air quality in cities are considered to have consequences for human health. A vast majority of urban and suburban population in different parts of the world is exposed to conditions that exceed Air Quality Standards. Population exposure summarises the exposure of everyone in the population. However, the true population exposure distribution cannot easily be measured because individual behaviour is complex. An indicator of population exposure can be obtained through the analysis of the spatial and temporal features of air pollution and population density distributions. The word indicator is used to reflect the complexities between outdoor air quality and the true population exposure. Estimating reliably the exposure profiles of an urban population requires complete information regarding temporal variability of pollutant concentrations at representative locations at which the population is exposed. Since achieving this goal through monitoring alone is difficult for both technical and practical reasons, modelling methods are necessary to indirectly generate a more comprehensive profile of concentrations relevant to the pollutant-specific health impact assessment being evaluated.

Buenos Aires City (Argentina) has approximately three million inhabitants and $200km^2$ of extension. Several times, measurements of air pollution concentrations have revealed that the air quality standards can be exceeded. In this paper, we calculate the horizontal distribution of nitrogen oxides (expressed as NO_2) concentration in the city applying atmospheric dispersion models: the DAUMOD model for urban area sources and the ISCST3 model for point sources. The estimated concentration levels are related with the possible exposed population. We estimated hourly and annual concentrations of NO_2 and evaluated the occurrence of concentrations greater than the Guidelines for Air Quality recommended by the World Health Organization (WHO). Finally, we obtained the population exposure to NO_2 in the city.

AIR QUALITY STANDARDS AND HEALTH EFFECTS OF NO_2

Nitrogen oxides usually enter the air as the result of high-temperature combustion processes, such as those occurring in automobiles, aircrafts and power plants. Nitrogen dioxide (NO_2) is a light brown gas with a characteristic pungent odour. It is highly reactive and plays an important role in the atmospheric reactions that generate ozone. It is corrosive and a strong oxidising agent. It combines with water to form nitric acid and nitric oxide. Sources of NO_2 also include home heaters and gas stoves.

Nitrogen dioxide may cause significant toxicity because of its ability to form nitric acid with water in the eye, lung, mucous membranes and skin. Healthy individuals experience respiratory problems when exposed to high levels of NO_2 for short-time exposures. Asthmatics are especially sensitive and changes in airway responsiveness have been observed in some studies of exercising asthmatics exposed to relatively low levels of NO_2. The primary aim of Air Quality Standards is to protect public health from the effects of air pollution with an adequate margin of safety and to eliminate or minimize exposure to hazardous pollutants. Based on human clinical data, the WHO (2000) proposed a one-hour Guideline of 0.2mg/m^3 for NO_2. At double this recommended Guideline (0.4mg/m^3), there is evidence to suggest possible small effects in pulmonary function of asthmatics. Should the asthmatics be exposed either simultaneously or sequentially to NO_2 and an aeroallergen, the risk of an exaggerated response to the allergen is increased. To protect the public from chronic NO_2 exposures WHO (2000) recommended an annual Guideline of 0.04mg/m^3. Available results suggest respiratory effects in children at annual average NO_2 concentrations in the range of 0.050-0.075 mg/m^3 or higher.

THE MODELS

The Urban Atmospheric Dispersion Model (DAUMOD) has been developed, evaluated and presented in former papers (Mazzeo, N. and L. Venegas, 1991; Venegas, L. and N. Mazzeo, 1998, 2001, 2002, 2003). DAUMOD model estimates the concentration from urban area source emissions. In this model the background air pollution concentration (C) at each centre grid in which the urban area is divided, is given by:

$$C(x,\ 0) = \frac{a\left[Q_0\, x^b + \sum_{i=1}^{N} (Q_i - Q_{i-1})(x - x_i)^b\right]}{\left(\left|A_1\right| k\, z_0^b\, u_*\right)} \tag{1}$$

where x is in the mean wind direction; a, b and A_1 are parameters that depend on atmospheric stability (Venegas, L. and N. Mazzeo, 2002), Q_i (i=0, 1, 2, …, N) are the emission strengths in each of the square grid cells upwind, k is von Kárman´s constant, z_0 is the surface roughness length and u_* is the friction velocity. Eq.(1) must be applied to different lines of grid cells located at downwind. In former papers (Mazzeo, N. and L. Venegas, 1991; Venegas, L. and N. Mazzeo, 1998, 2001, 2002, 2003) we have compared successfully the results of DAUMOD with data of air pollution concentrations obtained at Bremen and Frankfurt (Germany), Nashville (USA), Copenhagen (Denmark) and Buenos Aires (Argentina).

We use the well-known ISCST3 dispersion model to estimate the concentrations from point source emissions (Power Plants located in the city). It is a gaussian code widely employed for pollutant dispersion assessment and is recommended by US.EPA and by the Environmental Authority of Argentina. A detailed description of the model and references on the evaluation of its performance can be found in U.S.EPA (1995).

RESULTS AND DISCUSSION

The DAUMOD and ISCST3 models are applied to area and point sources, respectively, to calculate NO_2 hourly and annual concentrations at Buenos Aires city for 2002. We used an emission inventory of NO_X (expressed as NO_2) with 1km x 1km of resolution (Mazzeo, N and L Venegas, 2003). As an example, Figure 1 shows NO_2 concentration distribution during rush hour in the evening (08:00pm). The concentration pattern shows a large variability that is related to the distribution of emission sources. Higher concentration values are related to higher traffic density areas. Annual concentration values are greater than 0.04 mg/m^3 in the entire city.

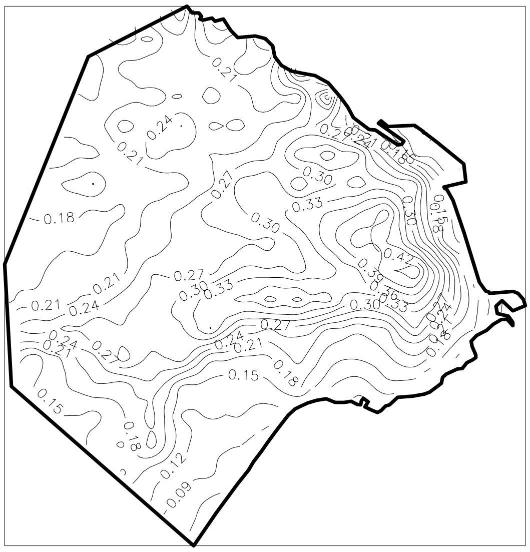

Figure 1. Spatial distribution of hourly NO_2 concentration in Buenos Aires during rush hour in the evening (08:00 pm)

Figures 2 (a) and 2(b) show the spatial distributions of population density of children up to14 years old and adults with more than 65 years old, respectively. In the city, 19% of the inhabitants are children up to 14 years old (62580 of them are asthmatics) and 16.3% is more than 65 years old and 120000 adults are asthmatics.

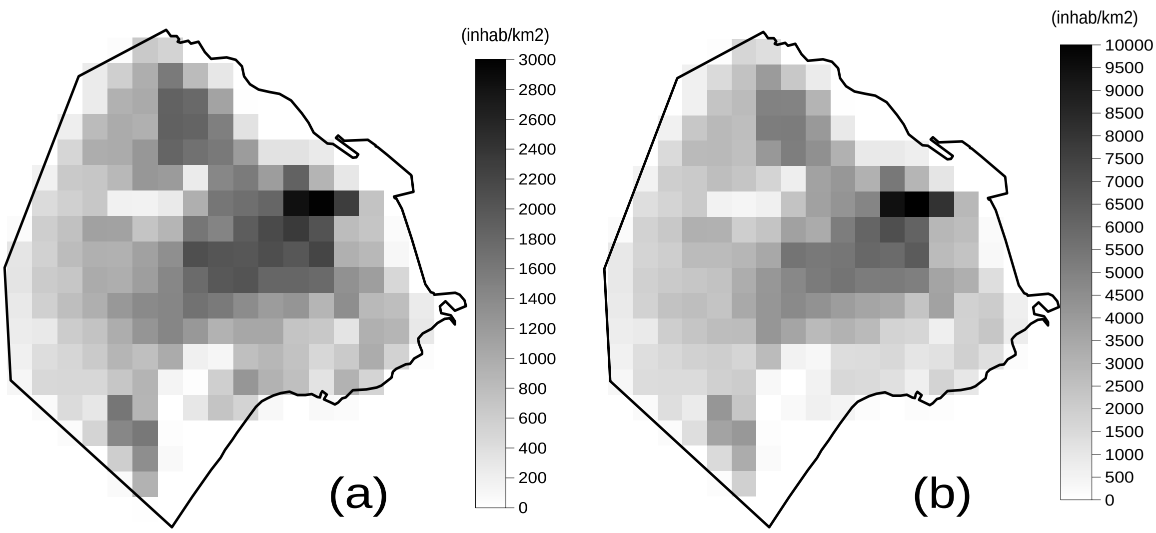

Figure 2. Distribution of population density (inhab/km^2). (a) children (0-14 years old), (b) adults (> 65 years old)

We evaluated the spatial distribution of occurrence of NO_2 hourly concentrations greater than the one-hour Guideline (0.2mg/m^3) (Figure 3). In the 13% of the city hourly concentrations are greater than 0.2mg/m^3 during 20-30% of the year. From Figures 2 and 3, it can be found that 30% of the population (900000 inhabitants) is exposed to NO_2 hourly concentrations that exceed the WHO Guideline. The exposed population that lives in the grid cell that shows more cases of hourly concentrations greater than the Guideline is composed by: 18.4% children up to 14 years old and 16.9% adults (more than 65 years old).

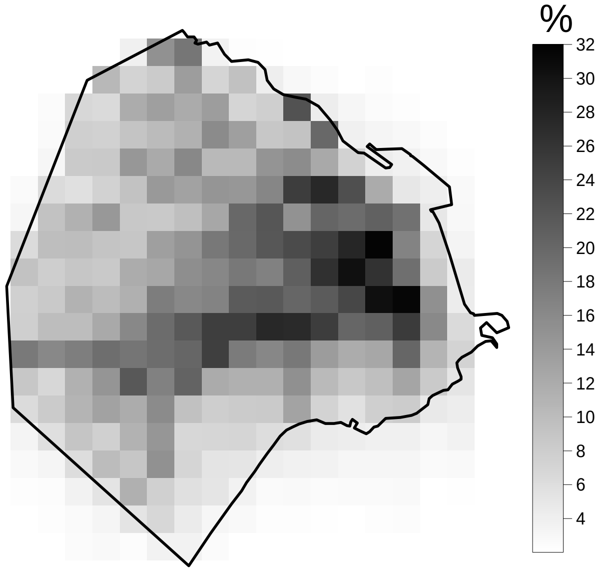

Figure 3. Annual frequency (%) of hourly concentration greater than 0.2mg/m^3 at each grid cell.

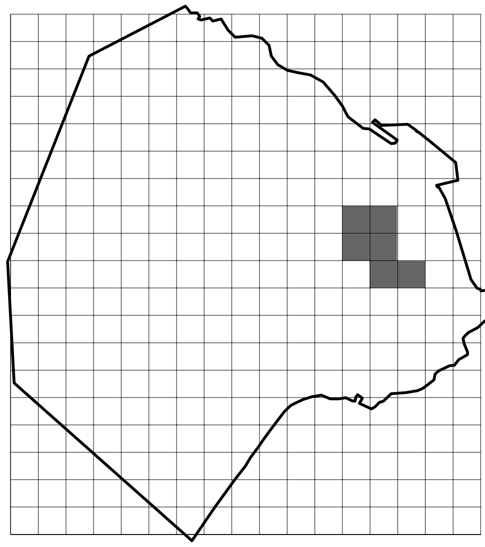

Figure 4.Grid cells where NO_2 hourly concentration may be greater than the WHO Guideline value during more than 36 consecutive hours.

The grid cells where NO_2 hourly concentrations greater than 0.2mg/m^3 persisted during more than 36 hours are shown in Figure 4. People living in this part of the city (6km^2), which represent the 4% of the children (0-14 years old) and the 5.1% of the adults (more than 65 years old) can be exposed to this risky condition.

Figure 5 shows population exposure for different ages, presented as the cumulative percentage of inhabitants versus the number of hours with concentration greater than 0.2 mg/m^3 at which they could be exposed during 2000.

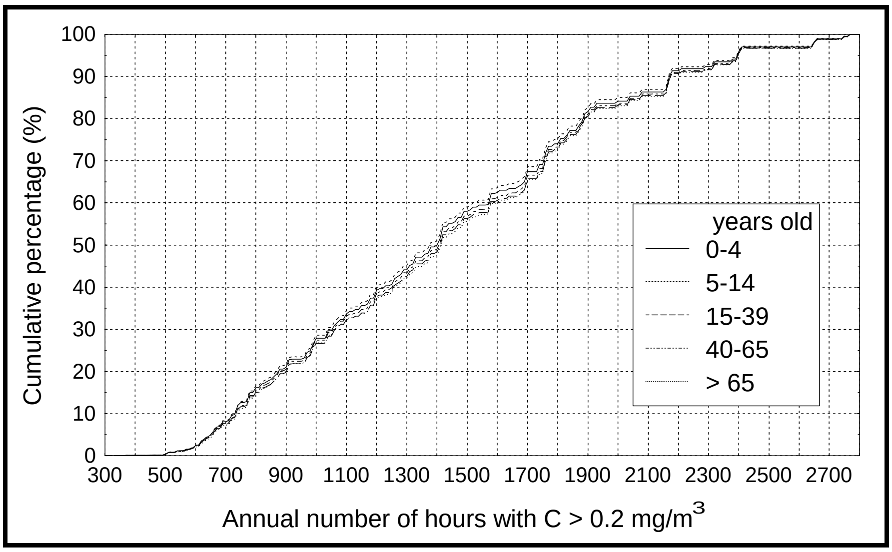

Figure 5. Population exposure for different ages.

CONCLUSIONS

Chronic or repeated exposure to low concentrations of NO_2 may exacerbate pre-existing respiratory conditions, or increase the incidence of respiratory infections, especially in the most sensitive persons. Temporal and spatial distributions of the concentration of NO_X (expressed as NO_2) in Buenos Aires City obtained applying DAUMOD and ISCST3 models were related with the possible exposed population. Hourly and annual NO_2 concentrations were estimated. The analysis of occurrences of hourly concentrations greater than the WHO Guideline revealed that: 13% of the grid cells showed 1h-concentrations greater than the Guideline during 20-30% of the year, exposing 30% of the population (900000inhab). The study of the persistence of 1h-concentration greater than the Guideline value showed that in 6km^2 of the Buenos Aires city, where 4% of the children up to 14 years old and 5.1% of people with more than 65 years old live, could be exposed to this adverse condition during periods longer than 36 hours. 50% of the population could be exposed to concentrations greater than the Guideline value during 300 to 1400 hours/year. Annual concentration in the city exceeded the WHO Guideline value.

ACKNOWLEDGEMENTS

This work was supported by the Projects: UBACYT-X093 and FONCYT PICT2000 Nº 13-09544.

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