A METHOD FOR SELECTION OF BACKGROUND AIR QUALITY MONITORING SITES IN AN URBAN AREA

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INTRODUCTION

Most cities worldwide suffer from serious air-quality problems, which have received increasing attention since the 1970-decade. A major probable reason for the urban air quality problems is population growth, combined with an increasing emission of air pollutants from different sources: motor vehicles, industries, power plants, domestic.

The monitoring of pollution levels in the atmosphere is of fundamental importance because it enables us to measure the extent to which pollution is actually occurring; it provides us a guide as to how effective our controls are proving: it also indicates where greater effort is needed. Air-quality monitoring networks are identified according to the particular monitoring objectives planned. Essentially the objective may be broken down into one of the three classes: determination of facts, diagnosis or prediction.

The design of a pollution monitoring network depends on the purpose for which the information concerning pollution levels are to be used, the degree of accuracy required, and the economics of establishing and operating a network. Various techniques to design an optimum air monitoring network have been cited in the literature. Among these, spatial correlation (*Elsom,* 1978; *Handicombe and Elsom,* 1982), Monte-Carlo variance reduction approach (*Nakamori et al.,* 1979), population dosage product and statistical technique based on Fisher's information measures (*Husain and Khan,* 1983) have commonly been applied in the past. Other classifications are presented by *Shindo et al.* (1990) and *Wu and Chan* (1997). Different authors have presented methodologies for designing of air pollution monitoring network using atmospheric diffusion models (*Seinfeld,* 1972; *Noll et al.,* 1977, *Noll and Mitsutomi,* 1983, *Mazzeo and Venegas*, 2000).

In this paper we present a method for selection of the number and location of background air pollution monitoring sites in an urban area. We use the urban atmospheric dispersion model DAUMOD to obtain surface distributions of mean background concentrations (*Venegas and Mazzeo,* 2002). The methodology is based on the analysis of the number of times the estimated mean concentration value at each grid cell is greater than a chosen level and the identification of the grid cells with more cases. As an example, we applied this methodology to NO_x emissions in the city of Copenhagen (Denmark).

BRIEF DESCRIPTION OF THE SITE SELECTION PROCEDURE

The first step is to estimate the surface distribution of background hourly air pollution concentration in the urban area. This is done running an urban atmospheric dispersion model, considering at least one year of hourly input data. It is recommended to include regional background concentration if it is available.

In the second step, a reference concentration level (C_L) is chosen. Afterwards, the next step is to identify the hourly cases with at least one grid cell with estimated concentration greater than C_L. The grid cells with more exceedances can be identified. Assuming a limitation on the number of sites as determined by the resources available, the minimum number of monitoring stations needed to register the occurrence of $C > C_L$ is determined from these grid cells. The pre-selected grid cells are ranked according to the number of exceedances. Once the grid cell with the highest score is identified as a site location the rest of grid cells that simultaneously show concentration greater than C_L are excluded to be chosen. This procedure continues until a minimum number of sites locations is finally determined. The efficiency of this network design procedure depends on the accuracy of model predictions. In the case of the DAUMOD model, the bias of model predictions is: ± 50% for hourly concentrations and ± 20% for daily concentrations (*Mazzeo and Venegas,* 1991; *Venegas and Mazzeo*, 2002).

Once the network is operating, the measurements can be applied to "calibrate" the network design. This "feedback" procedure is beyond the scope of this paper.

EXAMPLE OF THE SITE SELECTION USING THE PROPOSED METHODOLOGY

We present an application to select the number and site location of sensors to support an air pollution control system to register the occurrence of hourly and daily concentrations greater than a given value in an urban area. In this example, we used a typical diurnal variation of NO_x emissions data for the city of Copenhagen (Denmark). The emission data were subdivided into a grid net with a resolution of 2km x 2km (*Berkowicz,* 2000). Hourly meteorological data were taken at a station located on the roof of a building at the centre of the grid. The contribution from regional sources was obtained from measured concentrations at a rural monitoring station located at about 25 km west of Copenhagen. We used one year (1994) of information.

We chose the reference concentration levels for hourly ($C_{L1\text{-}h}$) and daily ($C_{L24\text{-}h}$) mean values taking into account the standard concentration values for NO_x. The World Health Organisation recommends the following air quality standard for NO_x (*Murley,* 1995): 0.40 mg/m³ (for 1-h averaging time) and 0.15 mg/m³ (for 24-h averaging time). Having in mind the bias of DAUMOD results, we consider the following values: $C_{L1\text{-}h}$=0.20 mg/m³ and $C_{L24\text{-}h}$=0.12 mg/m³.

Figure 1 includes the cases (date and time) with estimated hourly concentrations of NO_x greater than $C_{L1\text{-}h}$= 0.20 mg/m³ and Figure 2 includes the estimated daily concentrations of NO_x greater than $C_{L24\text{-}h}$= 0.12 mg/m³. It can be seen that the grid cell (5,4) shows the highest number of cases in both.

Which should be the minimum number of monitoring stations needed to register the occurrence of concentrations greater than the reference values C_L? The analysis of the cases included in Figures 1 and 2 leads to the following results (site locations are shown in Figure 3):

Averaging	Percentage (%) of cases with $C > C_L$ that could be detected		
Time	Sites: (1), (2), (3), (4)	Sites: (1), (2), (3)	Sites: (1), (2)
1-h	100%	98%	97.0%
24-h	100%	100%	95.2%

Coordinates of the grid cell

DATE	22	32	42	52	62	72	82	23	33	43	53	63	73	83	24	34	44	54	64	74	84	25	35	45	55	65	75	85	26	36	46	56	66	76	86	27	37	47	57	67	77	87	28	38	48	58	68	78	88
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94012919	x	x	x	x	x			x	x	x	x	x			x	x	x	x	x			x	x	x	x	x			x	x	x	x				x	x	x	x				x	x	x				
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94113018	x	x		x				x	x	x	x	x			x	x	x	x	x			x	x	x	x	x			x	x	x	x				x	x	x	x				x	x	x				
94113019	x	x	x	x	x			x	x	x	x	x			x	x	x	x	x			x	x	x	x	x			x	x	x	x				x			x				x	x	x				
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Figure 1. Cases with hourly concentration greater than $C_{L1\text{-}h}$= 0.20 mg/m³ at each grid cell. Each grid cell is identified as IJ (I: column; J: row) on top of the Figure. The date is YYMMDDHH

Coordinates of the grid cells

DATE	22	32	42	52	62	72	82	23	33	43	53	63	73	83	24	34	44	54	64	74	84	25	35	45	55	65	75	85	26	36	46	56	66	76	86	27	37	47	57	67	77	87	28	38	48	58	68	78	88
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Figure 1. (cont.) Cases with hourly concentration greater than $C_{L1\text{-}h}$= 0.20 mg/m³ at each grid cell. Each grid cell is identified as IJ (I: column; J: row) on top of the Figure. The date is YYMMDDHH.

Coordinates of the grid cells

DATE	22	32	42	52	62	72	82	23	33	43	53	63	73	83	24	34	44	54	64	74	84	25	35	45	55	65	75	85	26	36	46	56	66	76	86	27	37	47	57	67	77	87	28	38	48	58	68	78	88
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Figure 2. Cases with daily concentration greater than $C_{L24\text{-}h}$= 0.12 mg/m³ at each grid cell. Each grid cell is identified as IJ (I: column; J: row) on top of the Figure. The date is YYMMDD24.

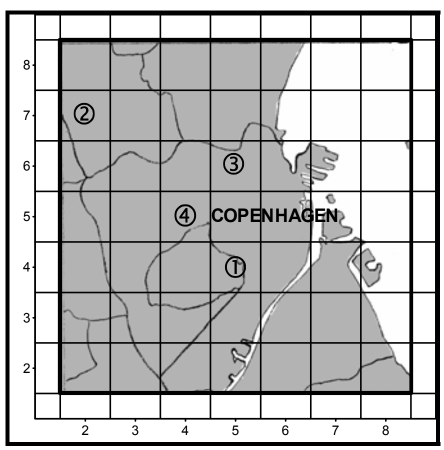

Figure 3. Monitoring site locations selected to register the occurrence of concentrations greater than the reference values in the urban area. (grid step: 2km).

SUMMARY

This paper presents a methodology for designing an air quality monitoring network to control highest background concentration values generated from area sources in an urban area, using the DAUMOD urban atmospheric dispersion model.

The application of this procedure can be summarised as follows:

- the use of an urban atmospheric dispersion model to grid-cell emissions
- the selection of a reference concentration value (C_L)
- the identification of the cases with $C > C_L$ in each grid-cell,
- the selection of the monitoring sites needed to register the occurrence of situations with $C > C_L$ in at least one grid-cell.

ACKNOWLEDGEMENTS

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