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SPATIAL VARIABILITY OF POLLUTION INDUCED BY TRAFFIC IN STREET CANYON

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1. Introduction

Concentration of pollutants produced by car traffic in a street below the roof level has large spatial variations. In a street, pollutants are diluted by the turbulent air flow which is induced by the wind speed above the roof level, and also produced by car displacement. The airflow structure is in relation with street size and building shape. Particularly strong gradients of concentrations can be observed vertically and also horizontally in front and along buildings where are set up ventilation inlets and windows. So it is necessary to take into account this variability to consider the influence of outdoor air upon indoor air quality.

The street canyon case has been studied extensively last years by C.S.T.B. and many other authors. A bibliographical synthesis is presented, including results from field measurements, wind tunnel experiments and numerical simulation.

2. General pattern of pollution in urban area

At the level of a town, background pollution and local pollution must be considered. Industrial sources contribute mainly to create a background level of pollution covering uniformly at least quarters of towns. Chimney exhausts from domestic heating come in addition to this background concentration as the sources are also generally regularly disseminated on the roofs. Car traffic at the opposite acts locally as the source is usually confined in town at the ground level in the streets between buildings. This leads to great differences in spatial distribution of pollutant concentration both between different streets or inside a street. Concentration field in a street will be the result of pollutant dispersion by the mean air flow and by turbulence diffusion from the source. The mean air flow is mainly resulting from general wind conditions above street and turbulence is principally created by the traffic.

3. Airflow structure in the street, influence of wind characteristics

The structure of air flow in the street is function of street geometry and wind direction above roofs. When passing above with a given angle from street axis there is creation of a vortex occupying more or less the volume between building as it is illustrated in the figure n° 1 , taken from Hertel and Berkowicz (1989). This vortex is easily reproduced in wind tunnel and by numerical simulation but fields observations shows important fluctuations in form and intensity of this vortex due to instationary characteristics of incident wind. This vortex allows, through the vertical wind component created, the elimination of pollutant by convection above the roofs. The figure n°2 gives an example of measured vortex (Baranger 1986). At the opposite when the wind blows in the axis of the street the decrease of pollution above the roofs is due only to turbulent diffusion, which may lead to situation of higher concentration in the street. (Hertel, Berkowicz 1989)

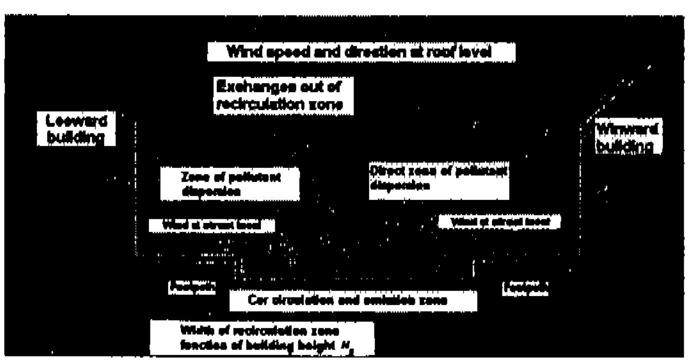

Figure n° 1 – Geometry of wind structure in canyon street according the OSPM model of Hertel and Berkowicz

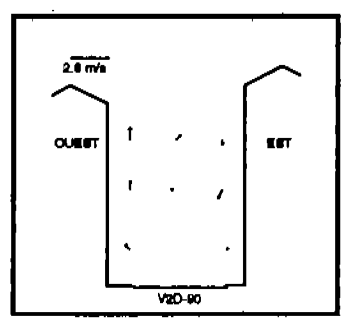

Figure n° 2 – Measured vortex in a canyon street for a wind perpendicular to the street (Baranger, 1986)

4. Concentration field and influence of street geometry

The concentration field in the street is dependent of the form of the vortex, which is dependent of geometrical characteristics of the streets. For example the roof geometry may change considerably the form of the vortex. For similar street dimension, changing from flat terrace roof to normal inclined tile roof changes the simple vortex to a double vortex in the street. The second one will be turning opposite to the first one. The ratio between height and width will determine if the vortex will take all the volume of the street or not and thus the general level of concentration which will be lower. Wind tunnel measurements shows that the critical value where there is a notorious change in street concentration level when the ratio height/width is greater than one (Meroney and Al. 1994). The figure n°3 reproduce numerically an example of pollutant concentration distribution under vortex condition in a canyon street (Delaunay 1997).

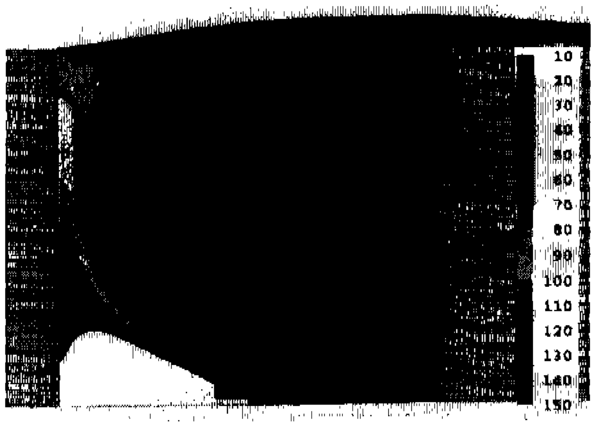

Figure n° 3 – Pollutant concentration repartition under vortex conditions in a canyon street obtained by numerical modelling (Delaunay, 1997)

5. Vertical Variability of concentration level

So when the structure of the wind flow in the street presents the form of a vortex, especially when the wind arrives perpendicular to the street, it may leads to concentration pattern and level different from one side to the other and which is illustrated on the following figure n°4 issued from measurements (Baranger, 1986).

As the source is at ground level, there is a vertical decreasing gradient of the concentration level along the building facades. The order of magnitude of the difference in concentration between bottom and top of the building can be up to a factor 15 in severe configuration, but turns usually around 5.

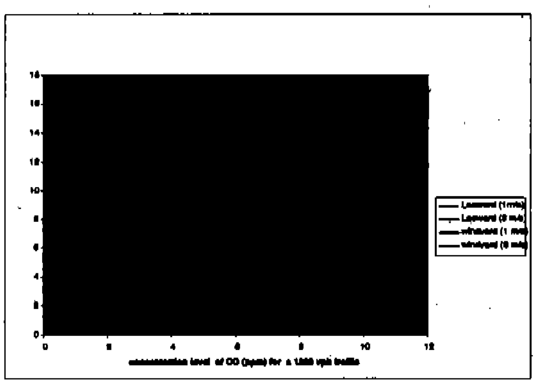

Figure n° 4 – Mean pollution concentration gradient on the leeward and the wind ward side of a canyon street for two classes of wind speed and wind direction perpendicular to the street (Baranger, 1986)

6. Lateral variability of concentration level

Along facades inside the street, differences of concentration level also occur. due to lateral streets which permit evacuation of pollutant if the traffic in lateral street is reduced compared to main street the figure n° 5 presents example of measurements made in Wind Tunnel (Hoydysh, Dabbert 1986). Differences also appear in the case of existence of a nearby particular source as a tunnel or ventilation outlet diffusing concentrated exhaust gases from a confined volume. figure n°6 presents the site of measurements and figure n°7 the results of measurements compared to numerical simulation (Flori and al 1995).

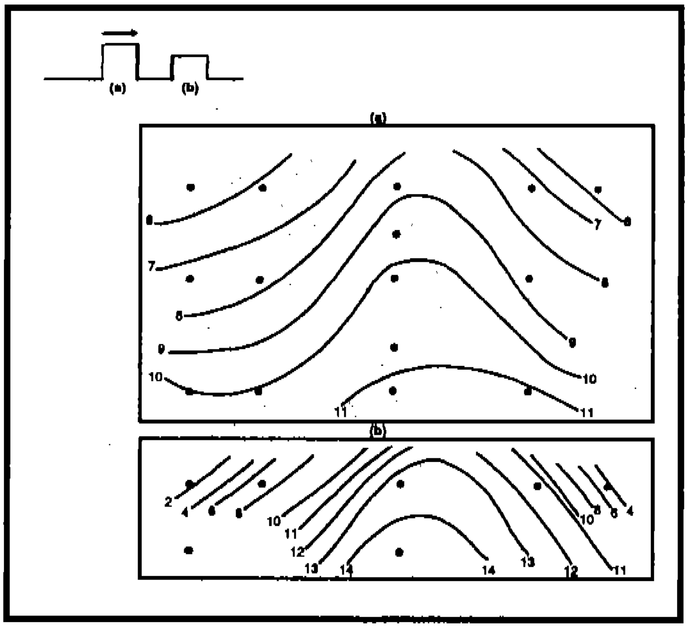

Figure n° 5 – Concentrations level on windward (a) and leeward (b) facades of two buildings with lateral crossing streets (Hoydysh, Dabbert, 1986)

Figure n° 6 – Measurement site for determination of the influence of a tunnel outlet in a canyon street (Flori and al, 1995)

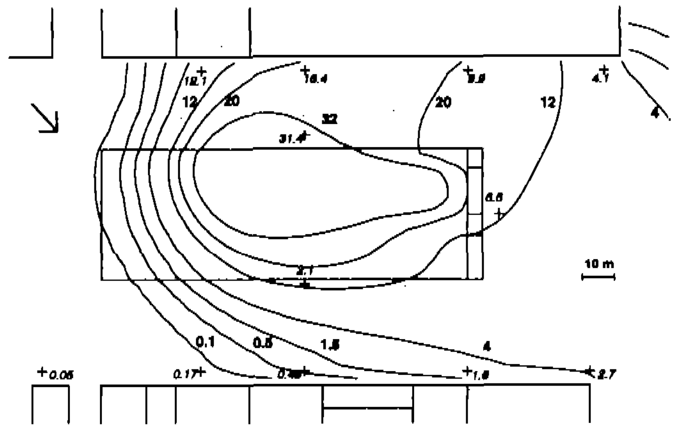

Figure n° 7 – Comparison of numerical simulation and measurements in a canyon street with a tunnel outlet (Flori and al, 1995)

7. Conclusion

Spatial variability of concentration level in a street canyon is strongly dependent of wind characteristics (speed and direction) which can induce particular distribution of concentration along building facades.

Other factors, as geometrical characteristics of the street, can be of influence, in the spatial variability of pollution concentration in a street canyon. Sometimes these factors may have correcting effects on the above mentioned action of wind.

Following factors can be mentioned: the street height/width ratio and the form of roofs but also the localisation and periodicity of traffic lights.

All these factors should be taken in account or at least kept in mind during the ventilation system conception phase.

Acknowledgements

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