SIMULATION OF INDOOR AIR QUALITY IN AN OFFICE BUILDING FLOOR : A FIRST CASE STUDY

S. Parey

Electricité de France, Research & Development Division, Environment Branch

ABSTRACT

In order to evaluate the impact on indoor air quality of different installation and ventilation strategies, the modeling of indoor air pollutant transfer has been developed in the CLIM2000 software (thermal and airflow code). Then, these models have been used to simulate the evolution of indoor air pollution in an office building floor for a week in winter under different ventilation strategies. The selected pollutants are CO2, CO, NO2 and HCHO and the sources are outdoor pollution for all pollutants and occupancy for CO2. So far, humidity has not been taken into account. This first simplified study pointed out the importance of post-occupation ventilation and allowed to identify the main ways of modeling improvement.

INTRODUCTION

Numerical calculations allow a great number of applications, from dimensioning to impact studies. Therefore, modeling of indoor air pollutants evolution has been introduced in the temperature and pressure evolution models of the CLIM2000 software. Then, as a preliminary application, the evolution of pollutants in an office building floor has been simulated for one working week in winter, considering heating, lighting, ventilation and occupation scenarios. The pollution sources are outdoor air pollution and CO2 produced by occupants. The configuration representing the office building floor is simplified, modeled as three air areas with all doors open and without taking into account solar radiation and wind effects. The impact of three different ventilation strategies on indoor pollutant concentrations have then been compared.

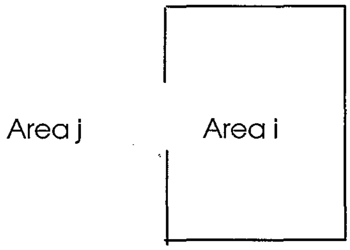
METHODS

Indoor pollution modeling

The concentration is assumed as uniform in each area (perfect mixing) and pollutants are considered as passive and following the airflow convection. The sources are outdoor pollution and occupants. Humidity and material sorption are not taken into account. Five pollutants can be simultaneously considered. Four have been chosen as CO2, CO, NO2 and HCHO.

Schematically, the balance of each pollutant is represented as follows :

if one considers 2 areas (i,j, being either indoor or outdoor air areas), connected through one link, the equation for mass conservation of pollutant in area i can be written :



$$\frac{dm_i}{dt} = \dot{m}_{ji}C_j - \dot{m}_{ij}C_i + S_i + D(C_i - C_j)$$

with m_i pollutant mass in area i
$\dot{m}_{ij}$ airflow from i to j (kg/s)
C_i concentration in area i (kg/kg)
S_i source term in area i (kg/s)
D diffusion coefficient

Case study

The representation of the office building floor is given in the following plot (Figure 1). Area 1 brings together 25 offices, with their dividing walls, area 2 is a meeting room and area 3 corresponds to corridor and toilets. The area at 10°C represents the stairs and is isolated to neglect the exchanges with the other floors. Outside temperature and pressure are taken from meteorological conditions in January near Paris, with temperature between -4°C and 8°C for the days considered.

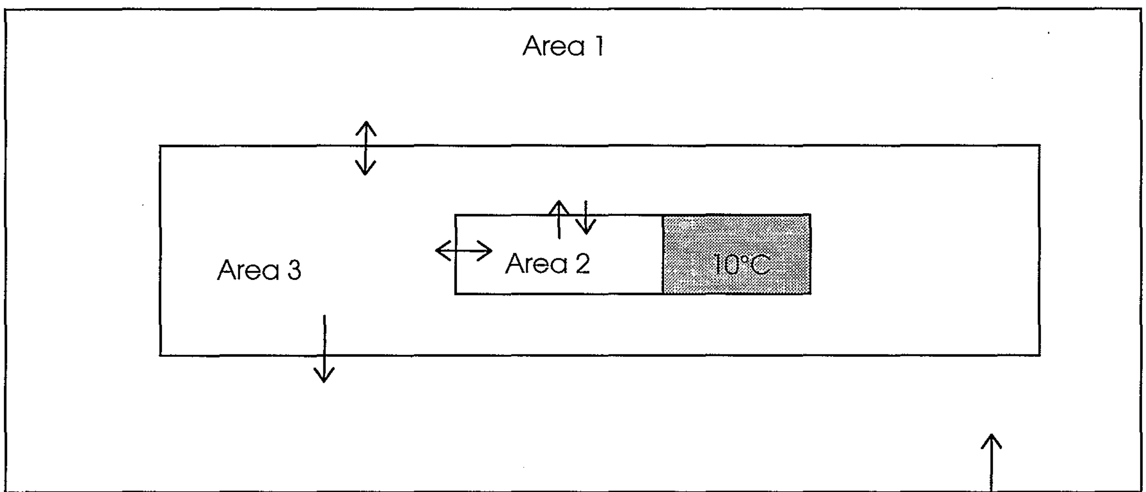


Figure 1 : model representation of the office building floor

Ventilation is insured through one air supply at 20°C in area 1, at a rate of 25 m^3/h/person, one air exhaust in area 3, and one air supply at 20°C in area 2, at a rate of 30 m^3/h/person with an equivalent exhaust. All doors are considered open and all the office doors are represented as a big equivalent door between area 1 and area 3. **Heating** is only installed in office area, with a power of 22000 W.

Occupation scenarios are given as follows, assuming 95W and 9.9 mg/s of CO_2 per person :
Offices (area 1) : 12 m^2/person ➔28 persons maximum.
50% between 8h and 9h, 90% between 9h and 12h, 50% between 12h and 14h, 90% between 14h and 18h, 50% between 18h and 19h
Meeting room (area 2): 3,5 m^2/person ➔10 persons maximum.
5 persons between 9h and 12h and between 14h and 17h
Then, ventilation rates are 700 m^3/h supplied in area 1 and extracted in area 3 and 300 m^3/h supplied and extracted in area 2, between 8h and 19h.
The mass transfers are evaluated considering heat inputs, ventilation and area connections.

Pollution sources are outside air and CO2 produced by occupants. Indoor CO2 production is following the occupation scenarios. Outside air pollution is taken as a typical January day in Paris, repeated identically each simulation day. CO2 concentration varies between 735 and 765 mg/m^3, CO concentration between 0.7 and 1.7 mg/m^3, NO2 concentration between 40 and 70 μg/m^3, and HCHO concentration is constant (12 μg/m^3).
Indoor pollutants evolve following mass transfers and diffusion, with a diffusion coefficient taken to 10^{-4}.

From this case study, which is the reference case, two different ventilation strategies have been tested : Scenario A : 50% increase in ventilation rates, between 7h and 20h
Scenario B : 100% increase in ventilation rates, between 8h and 19h.

RESULTS

Reference case

As the configuration is restricted to three areas, without taking into account radiation and wind effect and with balanced ventilation rates, airflow is negligible during the night. During the day (between 8h and 19h), air entering in area 1 flows to area 3 through the doors, while the meeting room is quite isolated through its own air supply and exhaust.

Considering pollutant concentrations then, the levels reached at the end of the day is kept during the night. For CO, NO2 and HCHO, which are not produced inside, indoor concentration follows outdoor concentration with a light delay. For CO2, the concentration evolves as expected with occupation. Figure 2 and 3 illustrate the evolution of NO2 and CO2 indoors compared to outdoor levels.

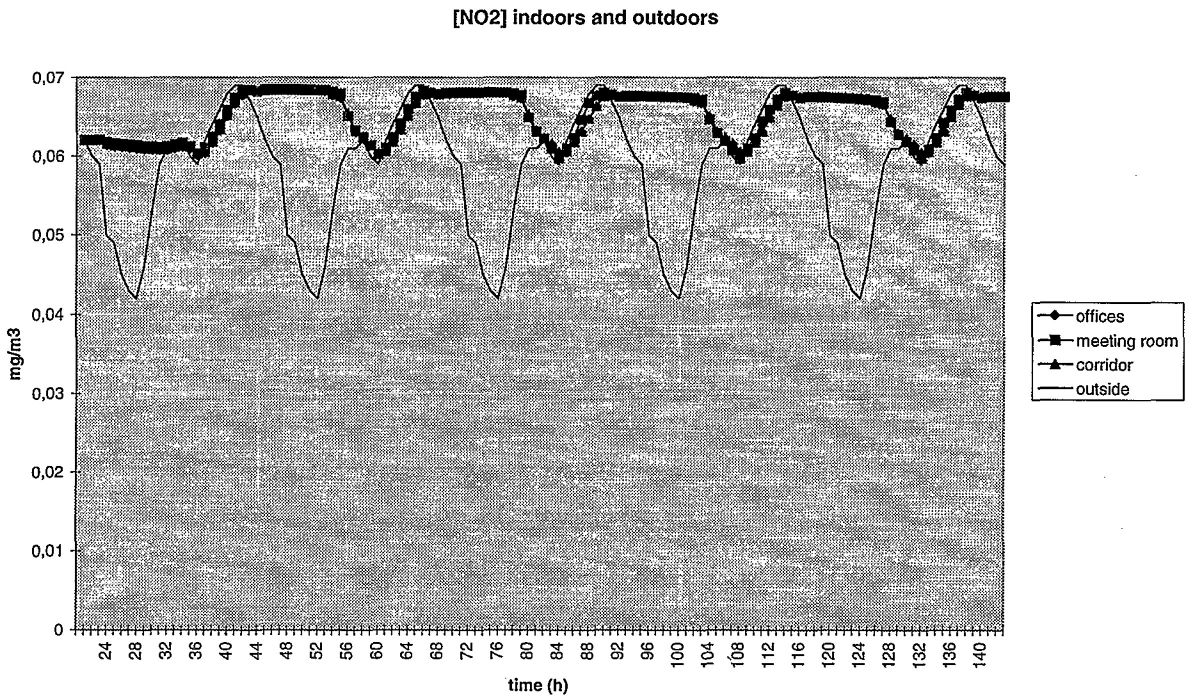


Figure 2 : NO2 concentration indoors and outdoors in the reference case

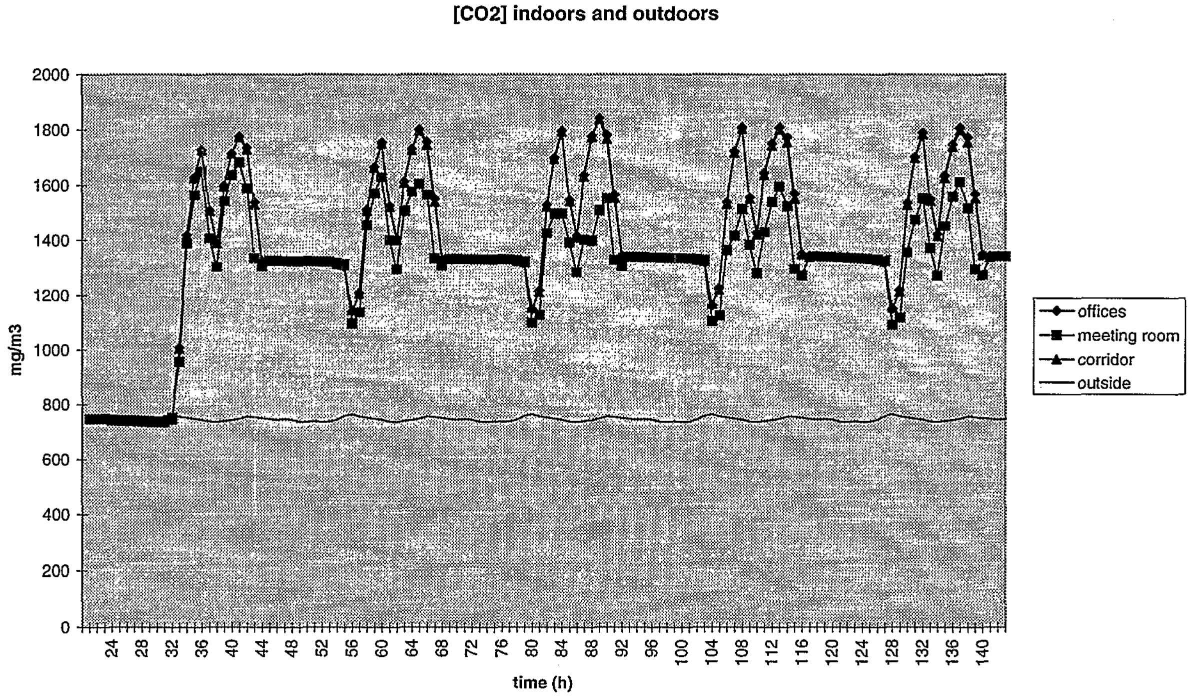


Figure 3 : CO2 concentration indoors and outdoors in the reference case

Ventilation scenarios

From this configuration, two other ventilation strategies have been tested regarding the indoor pollutant concentration induced, compared to reference case:

Scenario A : 50% increase in ventilation rates with longer duration of ventilation (beginning one hour sooner and ending one hour later). This leads to 36 m^3/h/person in the office area (1008 m^3/h) and 45 m^3/h/person in the meeting room (450 m^3/h), between 7h and 20h

Scenario B : 100% increase in ventilation rates during the same period as in the reference case (between 8h and 19h). This leads to 50 m^3/h/person in the office area (1400 m^3/h) and 60 m^3/h/person in the meeting room (600 m^3/h).

The results are mostly interesting for CO2, which is the only pollutant produced indoors. As expected, concentration decreases as ventilation rate increases. As outside concentration is well lower than inside concentration, ventilating one hour more after occupation leads to reduced indoor concentration during the night, even compared to the level reached with higher ventilation rates. This can be seen from figure 4 for the office area, at day 3 of the simulation.

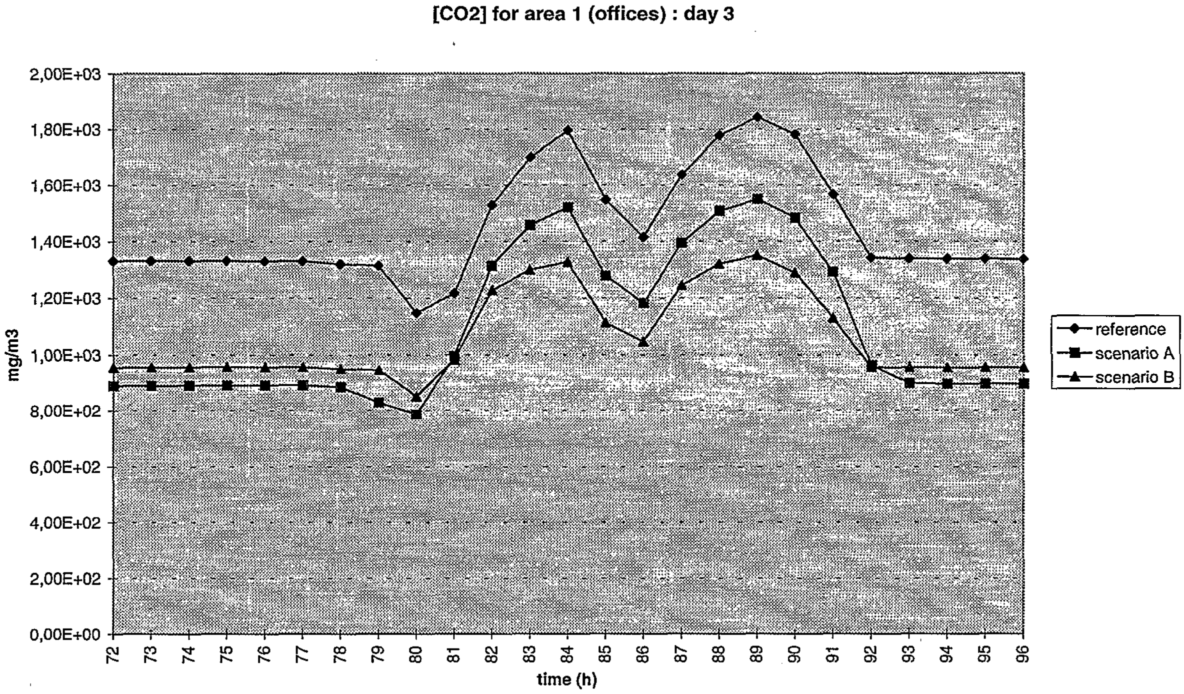


Figure 4 : CO2 concentration in area 1 according different ventilation scenarios

DISCUSSION

This study is a preliminary calculation and allowed to test the simulation of indoor pollution in a realistic configuration. In this simplified case, only CO2 is emitted indoors and other pollutants come from outside, without any sink or source inside. Moreover, there are practically no exchanges during the night, because infiltration is negligible (excepted when heating begins which induces low "exfiltration"). The results for different ventilation strategies show however an impact of the ventilation duration.

Further ways of improvement can be identified. First of all, the models will be more systematically validated against experimental data in simplified configurations. Then, the influence of radiation and wind effect should be taken into account, which will necessitate at least a six areas representation. Then, humidity and material sorption will be included in the modeling. Furthermore, the analysis of ventilation strategies should include energy consumption consideration.

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