728: Indoor Air Quality in French Educational Buildings

Agota Szucs
LEPTIAB Université de La Rochelle*
agota.szucs@univ-lr.fr

Abstract

Indoor air quality and ventilation rates in educational buildings affect users' health and comfort. The occupational density is high in educational buildings, that is why proper ventilation and suitable indoor air quality have prevailing importance in providing healthy indoor environment which promotes children's concentration and performance. The indoor air quality is function of numerous parameters: the outdoor air quality, the air change rate, the occupancy, the activity, the type and age of furnishing and the used interior building materials.

The aim of the present paper is to characterise the indoor air quality in educational buildings with and without mechanical ventilation system situated in three climatic regions: in the north, in the south and in between, on the west coast of the country. Air change rate, indoor temperature, humidity, CO_2 and VOC concentration have been measured in classrooms for one week during a warm and a mild period. The measurements have been completed by a comfort survey using questionnaires concerning the users' perception of the indoor environment related to ventilation and indoor air quality.

Keywords: indoor air quality, ventilation, school, kindergartens, crèches, comfort

1. Introduction

The energy demand of a building is determined by the following types of heat loss:
- transmission heat loss
- ventilation heat loss
- heat loss due to infiltration

The heat loss due to transmission can be significantly reduced by an adequate choice of insulation and building structure (function of price, embedded energy, chosen load bearing structure). Regarding the ventilation heat loss, the airflow rate has a minimal limit determined by the pollutants' concentration. Studies show that the dominant pollutants when considering outdoor air supply are the CO_2 and the odour from the occupants.

The ventilation heat losses can be reduced by:

- allowing higher pollutant concentration than required for comfort. Too high pollutant concentration leads to comfort, then health problems and can also cause building fabric protection problems (moisture condensation, mould growth etc.)
- preheating the fresh air by the heat recovered from the extracted indoor air
- the fresh air can be preheated by a solar wall, in an atrium or a sunspace

The present study aims after having identified the main pollutant sources in the selected schools and kindergartens, to approach the main issues regarding the effectiveness of the different ventilation techniques.

The ventilation system of a building cannot be considered separately from the building itself. Its effectiveness is affected by the architectural design comprehending the building structure, the building materials, the furniture, the function of the building, the orientation and the disposition of the premises. The number of occupants and the activity practiced in the building premises affect also the quality of the indoor environment [1]. Considering the building at a larger scale, as a part of the urban tissue, it is self intended that the effect of the direct built environment and the climatic factors prevailing on the given geographical site, inclusive the outdoor air quality, can also modify the effectiveness of the ventilation and so the indoor air quality.

The comfort and health requirements have to be dealt with when investigating the indoor air quality.

2. National and international guidelines on indoor air quality

Indoor air quality in educational buildings, such as schools, kindergartens and crèches, represent a subject area of special interest as children spend much time in educational buildings where the occupancy is high and as this part of the population is more vulnerable and sensitive to indoor pollutants than adults [2,3].

Studies carried out in this field study show that improved indoor environmental conditions increase students' productivity [4,5,6]. National guidelines concerning the indoor air quality and the ventilation in educational buildings distinguish different kinds of pollutants. One of the dominant pollutants is the CO_2 whose concentration indicates the bio- effluents which is the result of human metabolism.

Others are the volatile organic compounds (VOC) and the particle pollution. The concentration of the various VOCs depends on the users' activity, the furniture, the building materials, the building service system and self intended the outdoor air quality [7,8].

Particle pollution (also called particulate matter or PM) consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. Some particles, such as dust, dirt or smoke, are large or dark enough to be visible to the naked eye. Others are small and can only be detected using an electron microscope [9]. The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in aerodynamic diameter pose the greatest problems since, when inhaled, they may reach the peripheral regions of the bronchioles and interfere with gas exchange inside the lungs [9,10].

The national guidelines suggest that the CO_2 concentration does not exceed the limit of 1000 ppm and they define a limit of 80 µg/m^3 for particles less than 10 micrometers (PM_{10}) for an exposition period of 24 hours [10]. The WHO recommends for PM_{10}, 50 µg/m^3 as 24-hour mean value, and 20 µg/m^3 as annual mean value. In case of particles less than 2.5 micrometers of diameter, called also fine particles ($PM_{2.5}$) the WHO suggests 10 µg/m^3 as annual mean, and 25 µg/m^3 as 24-hour mean value [11].

The guideline values regarding the VOCs are presented in the Table 1.

Compound	Guide value	Exposition
Acetaldehyde	2000 µg/m^3	24hours
Formaldehyde	100 µg/m^3	30 min.
Styrene	260 µg/m^3	1 week
Toluene	260 µg/m^3	1 week
	1000 µg/m^3	30 min.
Xylene	4800 µg/m^3	24hours

Table 1: Guideline values recommended by the WHO for air quality

3. Indoor air quality measurement campaign

The educational buildings selected are situated in La Rochelle, in the northern region of France and in the vicinity of Lyon. Most of the selected schools are recent buildings and are mechanically ventilated. Some of them have humidity controlled mechanical ventilation system, some heat recovery system and some do not have any ventilation system.

In the frame of the air quality survey CO_2 concentration, relative humidity, temperature, carbonyl, VOCs' and concentration of PM of different size are being measured in the selected classrooms. The outside PM concentration is also being measured. The duration of the measurement campaigns in the selected schools, kindergartens and crèches is 7 days during a mild and a cold period of the year. In this manner the indoor air quality in the selected premises is investigated without and with occupation.

Fig 1.Interior view of an investigated kindergarten

3.1 CO_2 concentration, relative humidity and temperature measurement

The CO_2 concentration, the relative humidity and the temperature in the selected classroom is measured by a portable Q-TRAK 7565 indoor air quality monitor shown on Fig.1.

Fig 1. Q-RAK Indoor air quality monitor

This measurement device logs data at each one minute interval.

3.2 Particle pollution measurement

The particulate matter concentration is measured by a portable GRIMM 1.108 optical aerosol spectrometer (Fig.2).

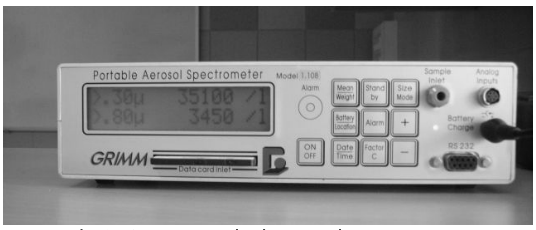

Fig 2. GRIMM optical aerosol spectrometer

The aerosols of size from 0.30 µm to 20 µm are collected on a removable PTFE filter for analysis. The particles are drawn by a sampling head and lead directly into the optical chamber where each particle is counted by a laser ray and classified by size at each 6 second. A second spectrometer measures the outdoor particulate matter concentration.

3.3 VOC concentration

RADIELLO passive air samplers are used to measure volatile organic compound and carbonyl (aldehyde) concentration in the selected classrooms.

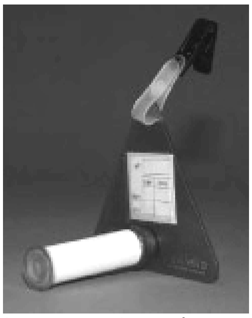

Fig 3. RADIELLO passive sampler

The passive sampler has a cylindrical form. It consists of an outer diffusive layer on microporous polyethylene and a central adsorbing axis charcoal type for VOCs and DNPH-covered for carbonyl compounds [12].
The following VOCs are measured: benzene, toluene, xylene (ortho, meta, para), etylbenzene, styrene, 1,1,1-trichloroethane, trichloroethylene, n-decane, n-undecane.
In parallel to the measurements of volatile organic compounds samples are taken for the analysis of the following carbonyl compounds: formaldehyde, acetaldehyde, acroleine, benzaldehyde, butylaldehyde, hexaldehyde, isopentanal, pentanal, propanal.

A questionnaire regarding the activity patterns during the measurement period, the number of occupants, the ventilation, the architectural parameters, the furnishing, the perceptions of the users and the surrounding outdoor environment completes the measurements.

4. Discussion

The first results of the campaign carried out in a crèche situated in La Rochelle during one and a half day in June show that fine particles are present in a relatively large number indoors. The measurement started at noon on a weekday.
Fig. 4 shows that the concentration of the finest particles is the highest and that of those with a larger aerodynamic diameter is significantly lower. The results representing the highest concentration belong to the particles with an aerodynamic diameter between 0.3 and 0.4 micrometer. The lower curve represents the particles with a diameter between 0.4 and 0.5 micrometer, while the lowest one, those with a diameter between 0.5 and 0.65 micrometer.
The results allow to observe that the concentration of the fine particles decreased significantly during the night. The concentration begins to increase in the morning and it reaches a first peak around 9:30 a.m. then a second peak appears around 3:30 p.m. They can either be due to the activity carried out in the room (painting, drawing etc.) or to the increase of the outdoor particle concentration.

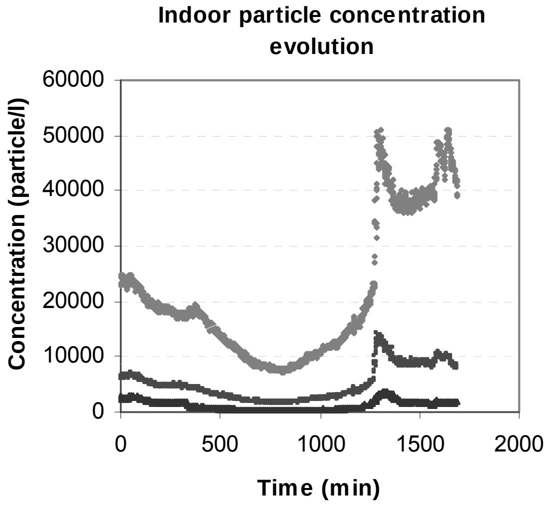

Fig 4. Concentration evolution of fine particles in a selected room of a crèche.

Fig. 5. depicts the concentration variation of the particles with an aerodynamic diameter less than 2 micrometers, indoors (dark curve) and outdoors (light curve). It illustrates the results during a one-day long period started in the afternoon at 4:00 p.m..

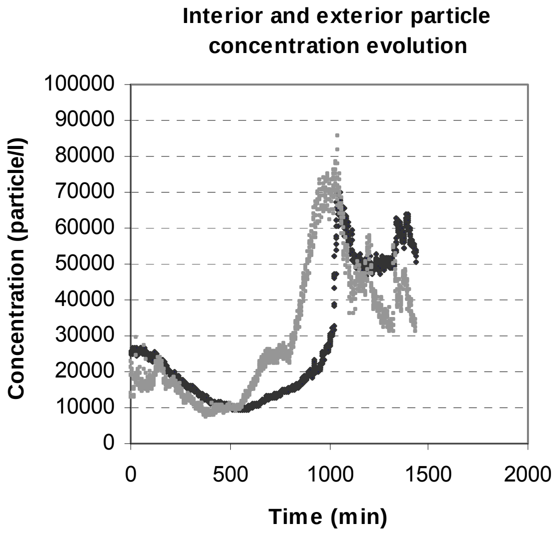

Fig 5. Concentration evolution of fine particles with an aerodynamic diameter less than 2 micrometers outdoors (light curve) and indoors (dark curve) in a selected room of a crèche.

The results show a peak both indoors and outdoors around 9:30 a.m. The crèche is situated between two moderately busy roads and next to a little roundabout. It might be that the peak concentrations are due to the morning rush hours.
The first measurement of the CO_2 concentration were carried out from 8 a.m. till 4 p.m. during a summer day. The CO_2 levels were, in the room, below the recommended level of 1000 ppm with only one exception. The room is ventilated by a humidity sensitive ventilation system and by window opening. Its volume is relatively large compared to the number of occupants: about 140m^3 for about 10 children and 3 nurses, and

the windows are often open in case of good weather conditions.

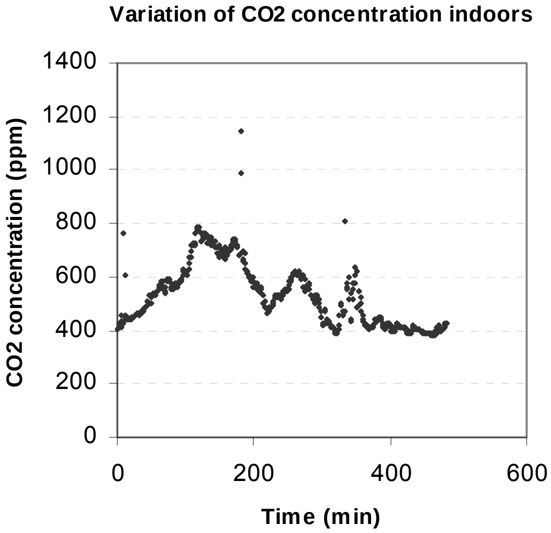

Fig 6. CO_2 concentration variation in the selected room of the crèche

The following interesting question concerning the colder periods of the year that needs to be investigated: "To what extent the air change rate can be reduced in the educational buildings in different climatic conditions in order to find a compromise between energy efficiency and comfort?"
Self intended health requirements have to be complied with and regardless to the ventilation system in crèches, kindergartens and elementary schools a minimal air change rate of 15 m^3/h per person is recommended in France. For the secondary schools and buildings of higher education this value is increased to 18 m^3/h per person [11].

5. Conclusion

The ventilation system of a building affects indoor air quality, the users' health, comfort and the ventilation heat loss represents one of the most important factor affecting the energy demand of a building.
A measurement campaign in progress aims to investigate the effectiveness of different sort of ventilation systems through the indoor air quality in French educational buildings. In the frame of this campaign temperature, CO_2, RH, numerous COV, particulate matter concentration and air change rate are measured indoors and outdoors for a week in a warm/mild and a cold period of the year.
The very first results confirm the presence of significative fine particulate matter concentrations indoors and outdoors at certain times of the day and indicate acceptable CO_2 levels indoors.
The ongoing investigations aim on one hand to support a better architectural conception and ventilation system integration in these kinds of buildings and on the other hand envisage to promote the refinement of indoor air quality and ventilation-related criteria for French educational buildings.

6. References

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