INDOOR AIR QUALITY IN RETROFITTING EDUCATIONAL BUILDINGS

Nadine Adra, Richard Cantin, Gérard Guarracino

Ecole Nationale des Travaux publics de l'Etat, Laboratoire des Sciences de l'Habitat, DGCB-CNRS URA 1652, Rue Maurice Audin – 69518 Vaulx-en-Velin, France.
nadine_am@hotmail.com, cantin@entpe.fr, guarracino@entpe.fr

ABSTRACT

For historical and demographical reasons, in many European countries, an important part of educational building must be retrofitted. These retrofitting must be carried out in a context of reduction of greenhouse emissions and energy consumption.
Among different targets for retrofitting, there are the improvement of indoor environment. In fact, educational buildings are particularly vulnerable to indoor environment problems. Studies have indicated a correlation between the way educational buildings are designed, or retrofitted, and student performance. Studies were complicated by the highly systemic nature of education and the range of social, pedagogical and environmental variables involved.
In this study, special aspects of retrofitting educational buildings are set out, and indoor environment requirements are presented. Then, people satisfaction, regarding the indoor environment in four refurbished buildings are studied with an enquiry with provides questionnaires. This includes air and ventilation, heating and temperature, daylight and lighting, sounds and noise, cleanliness and comfort and health aspects.

KEYWORDS

Retrofitting, school, comfort, indoor environment, air quality, questionnaire.

INTRODUCTION

For historical and demographical reasons, a significant stock of educational buildings must be retrofitted in many European countries in the next years. These retrofitting must be carried out in a context of reduction of greenhouse gas emissions and energy consumption. In this context, a group of annex 36 of International Energy Agency aims at promoting, for educational buildings, efficient measurements of retrofitting on energy level. In the same time, in France, an approach named HQE (High Environmental Quality) is developed as a specific action answering to the demand for integration of sustainable building concepts. In this way, the Rhône-Alpes authority leads actions for retrofitting educational buildings.
Among different targets for retrofitting, there are the improvement of comfort and indoor air quality. However, high quality environment must be achieved with reducing energy consumption.
In this paper, indoor air quality and comfort requirements are presented and special aspects of retrofitting educational buildings are set out. Then, in this complex context, a method for collecting information about indoor environmental quality and for identifying problems is proposed. In the last section, an application of this method is exposed in 4 study cases, in order to present an example of indoor environment assessment in retrofitting.

INDOOR AIR QUALITY IN EDUCATIONAL BUILDINGS

Indoor comfort requirements

Children spend a significant portion of their lives in educational buildings. In winter, a child spend, at least, 6 hours, by day, breathing the air inside school buildings. Indoor air pollutants become concentrated with inadequate ventilation in classrooms, and outdoor pollutants enter classrooms through open windows or ventilation system air intakes (Etkin, 1995). Indoor air quality laws, regulations and standards exist (Kumar, 1999). Moreover, the educational process is strongly influenced by thermal, visual and acoustical comfort (High performance schools, 2001). Several comfort requirements for classrooms can be identified, even if the interactions between thermal, visual, acoustic comfort and indoor air quality complicate the identification of a sustainable comfort.

TABLE 1
Some comfort requirements for a classroom (Cantin et al, 2002)

Parameters	Regulations or recommendations
Temperature Winter/Summer	19°C < Temperature < 26 °C (AICVF)
Relative Humidity	35% < HR < 70% (AICVF)
Concentration CO_2	1000 ppm (OMS)
Illuminance tables	325 lux (AFE)
Illuminance blackboard	425 lux (AFE)
Noise	Max 50/55 dB(A)

In fact, professional help is required for diagnosing and investigating indoor air quality and comfort problems in educational buildings. Discomfort, irritation and a variety of short or long term health problems for students, teachers and staff can be manifested in poor indoor environment. However, in numerous cases, it can result from a variety of factors (Etkin, 1995).
Otherwise, children do not have the same performance when they are sick or absent from school. Indoor air quality problems can result in absences because of respiratory infections, allergic diseases from biological contaminants, or irritant reactions to chemicals used in virtually every part of school (Daisey et al, 1999). And what about people who do not have a diagnosable illness, but simply don't feel well? People may report feeling tiredness, having headache, difficulty concentrating or irritation in eyes. Moreover, continued environmental stress can drain children's physical and mental resources and ultimately affect their performance. Evidence from office workers suggests that when individuals experience just two symptoms of discomfort, they begin to perceive a reduction in their own performance (Raw et al. 1990). Furthermore, children are generally more vulnerable to indoor air pollution than adults.
Thus, high requirements can be defined in order to control external environmental impacts and to create a healthy and comfortable indoor environment. They must be integrated during the refurbishment process (Cantin et al. 2002).

Constraints of retrofitting educational buildings

Actually, educational buildings have many special aspects which are considered in the design of retrofitting plans (Cantin et al. 2002). Educational building category includes different types: elementary school, high school, college or university, vocational school, kindergarten, training centres, etc. Educational buildings have different age, size, volume and can contain

various space types with different set-point temperatures and activities. A large diversity of material, construction (structure, facade, glazed wall, insulation, etc.), heating, ventilation and air conditioning systems, or solar and lighting systems, creates various issues which are strains on maintenance staffs. As educational buildings add space, the operation and maintenance of each addition is often different. Occupants are close together having four times as many occupants as office buildings for the same amount of floor space.
The retrofitting projects must be carried out with economical constraints, a limitation of energy consumption and a better indoor comfort. However, in many retrofitting cases, due to a lack of information, decisions made don not sufficiently take into account the indoor air quality.
At the opposite to a new building project, an existing building provides useful information for retrofitting operation. It can helped to determine retrofitting constraints and to provide the possible technical choices for retrofitting. Thus, educational buildings should be retrofitted in a way to minimize and control sources of pollution, and to provide adequate solutions.

METHOD

In spite of complex constraints of retrofitting educational buildings and numerous indoor environment requirements, it is possible to assess the existing situation and to know the wishes of building managers, teachers, students and staff. In order to analyse the existing building, an efficient way is to use a questionnaire. Allowing to investigate the existing physical and sociological problems (Engvall et al, 2000), a variety of questions are identified.

TABLE 2
Structure of an individual questionnaire (Engvall et all, 2000)

Main sections	Examples of questions
Air and ventilation	Have you over the last three months been bothered by air in this classroom? feeling dry, feeling dusty, having a sharp smell, smelling mouldy, etc.
	How often do you air the classroom?
Heating and temperature	Have you over the last three months been bothered by this classroom? Being too warm in the morning, too cold in the morning, in the afternoon, having a cold floor, having draughty door, etc.
Daylight and lighting	What do you think about the overall light in this classroom over the last three months? Very good, quite good, acceptable, rather bad, very bad, etc.
Sounds and noise	Do you think, generally speaking, that it is easy or difficult to hear what is being said in this classroom? Yes, easy, difficult, speech is muffled, etc.
Cleanliness and comfort	What do you think of the cleaning in this classroom over the last three months? Very good, quite good, acceptable, etc.
Health aspects	Do you have or have you had asthma?
	Do you have or have you had hay fever?
	Have you over the last three months had any of the following problems? Say also whether you think that they depend on the school: tiredness, headache, irritation in eyes, runny nose, dry throat, coughing, etc.

This questionnaire is dedicated to students and staff. The main objective of this step is to identify comfort issues.
In the same time, a diagnosis is made in order to identify the main building characteristics and problems related to energy and comfort issues. A visit with monitoring is necessary to complete questionnaire data. Measurements are divided into short term monitoring and spot measurements. The measured parameters concern the building, the thermal, acoustical and lighting conditions, the comfort and the air change rate.

TABLE 3
Examples of measured parameters and the used measuring devices

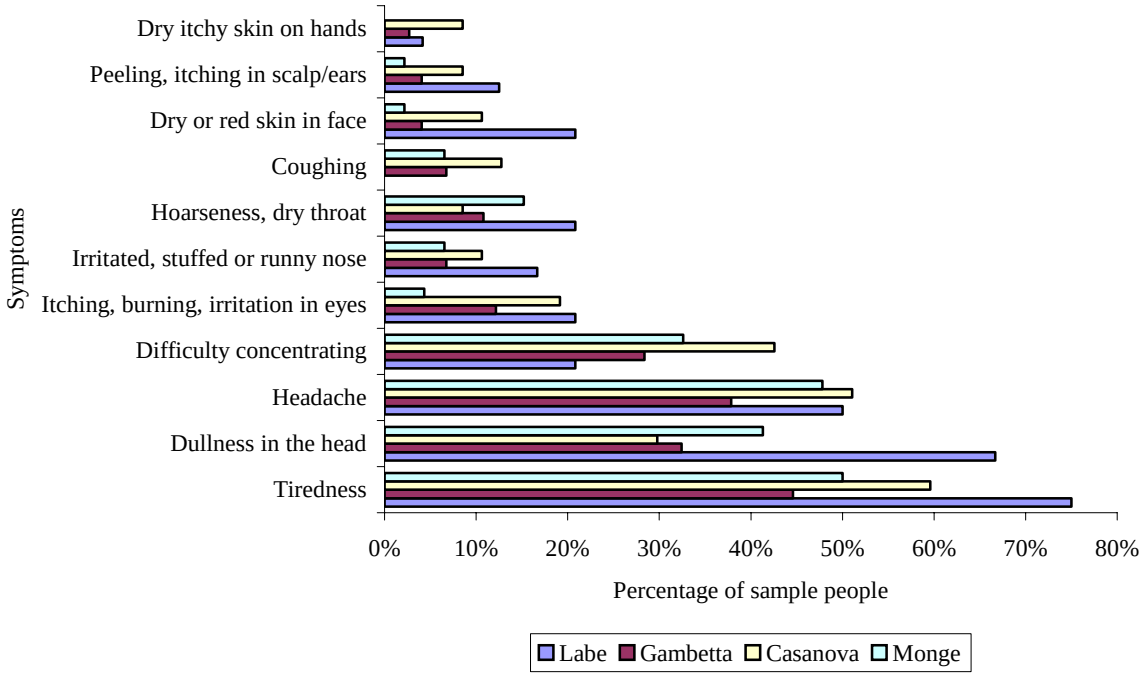
Parameters	Type of measurements	Example of devices
Internal and external temperature	Short term monitoring	Tinytag
Thermal comfort parameters	Spot measurement	Bruel and Kjaer thermal comfort analyser
Relative humidity	Short term monitoring	Tinytag
CO_2 level	Short term monitoring	MultiWarm Drager
Lighting conditions	Spot measurement	Luxmeter, FJ-meter, luminance meter

These two complementary approaches are made in the same time. The questionnaire diagnosis can be correlated with the visit and the monitoring data.
Otherwise, a data collection task involves identifying the characteristics of existing buildings. Some of this information may be already available or easy to obtain i.e. plans and specification documents, previous types of renovation/additions, the operation and maintenance practices and maintenance contract.

CASE STUDIES

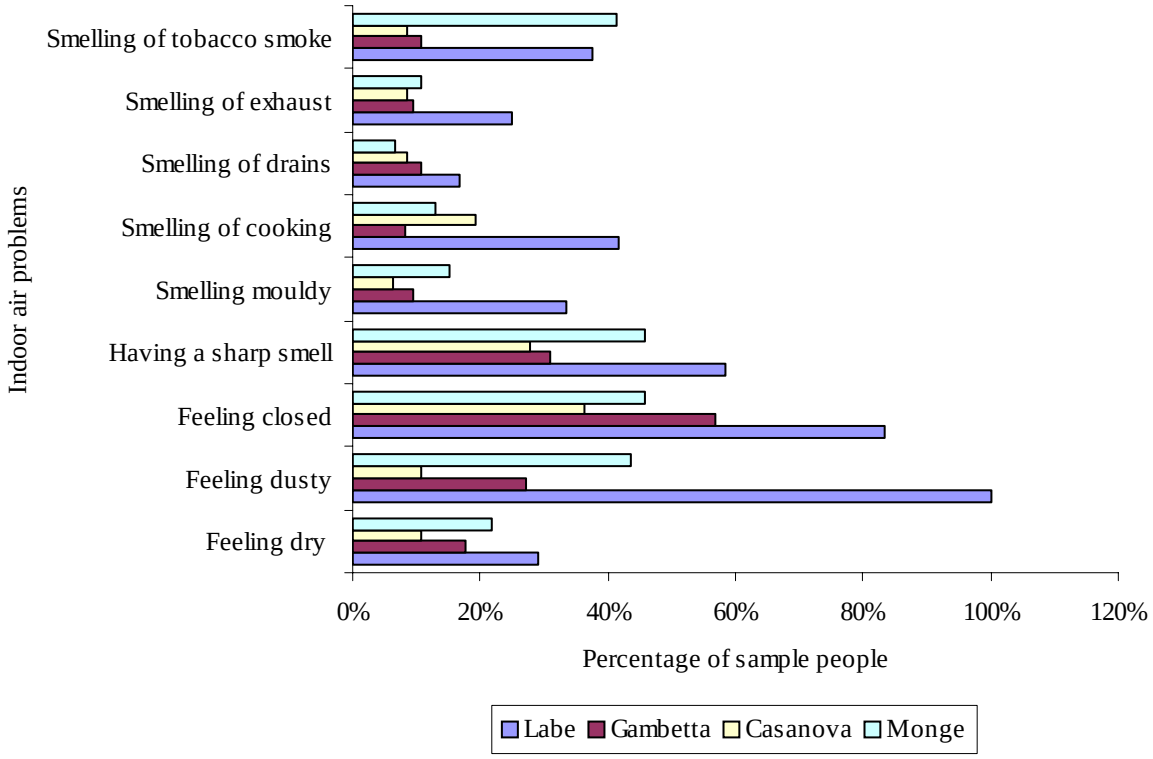
Four French retrofitting educational building have been studied : Casanova high school, Gambetta professional high school, Louise Labe secondary school and Monge secondary school. We distributed the questionnaires in several classrooms in each building. Other data were collected thanks to documents provided by the architect and different actors of these projects.

FIGURE 1
Data for symptoms of discomfort in four schools



In these four schools, a large number of students experience signs of discomfort related to the environment. According to Raw et al. (1990), an estimated loss in performance is about 3% with 3 symptoms, if these symptoms are linked with indoor air quality.

FIGURE 2
Data for significant problems linked to Indoor Air and ventilation



These data about indoor air problems provide complementary indication about indoor environment of existing educational buildings. It can help decision maker in the choice of HVAC systems and in the choice of materials that can act as potent sources of chemical contaminants.
The results were statistically significant and tend to confirm that with an indoor air quality management, including source control and adequate HVAC, student can work in better indoor environment.

CONCLUSION

According to children activities in educational buildings, an assessment of indoor air quality is necessary in retrofitting project. The requirements are numerous and they are in interaction with a variety of factors of indoor comfort. The presented method provides a simple and pragmatic way to assess quickly some issues about indoor air quality. A questionnaire and a visit with a monitoring study allow to understand what are the possible problems for occupants in existing buildings.
The different case studies have shown the efficiency of this method allowing to propose a complementary diagnosis of the building and to justify detailed studies if needed.

The participation of students and staff in this approach has always been appreciated. It is the opportunity for users to understand how their indoor environment can be improved. It is a possible way to improve the educational performance.
Numerous observations have been extracted from these case studies. The developed method provides a contribution for the choice of technical solutions in retrofitting educational buildings.
This work can be completed by taking into account energy and sociological impacts. It is a possible way towards an integration of sustainable concepts in retrofitting buildings.

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