INDOOR AIR QUALITY IN CLASSROOMS OF RENOVATED SCHOOL BUILDING IN LITHUANIA

Andrius Jurelionis, PhD
Faculty of Civil Engineering and Architecture, Kaunas University of Technology,
Studentu g. 48, LT-3031, Kaunas, Lithuania
E-mail: andrius.jurelionis@ktu.lt

ABSTRACT

The purpose of this study was to assess indoor air quality as well as actual ventilation in renovated school classrooms. A typical naturally ventilated school building was chosen to install different air inlet units in identical classrooms. Later measurements of carbon dioxide concentrations, temperature, relative humidity and air velocity were carried out. Actual measured values were compared with Lithuanian and European standards.
This study gives the evaluation of renovating process in the Lithuanian schools, which began in 1997. The aim of the mentioned process was the reduction of energy consumption in these buildings. Generally such works as modernization of heat substations, replacement of windows, additional thermal insulation of walls and roofs were usually performed. However, the proper attention to indoor air quality and ventilation of classrooms was not paid due to the low budget of these projects as well as underestimation of air quality impact on pupils' health. The results of indoor air analysis in classrooms show that renewal of ventilation systems must be considered more seriously when planning school renovation process in future.

KEYWORDS

School, classroom, ventilation, indoor, air, quality.

1. INTRODUCTION

Most Lithuanian schools are built under the standard projects of 70s and 80s. Great losses of thermal energy is typical of these buildings. In year 1997 "Sponsorship program of sanitary condition improvement in state and municipal educational institutions" was prepared and renovating process of schools started. The purpose was to reduce heating costs and to ensure parameters of thermal comfort in classrooms.
First significant research in evaluating quality of renovation was carried out in year 2001 – 2002. During the course of research some negative effects of renovation were noticed. One of them is insufficient ventilation in classrooms due to sealed windows [1]. Attempts to avoid this negative effect are being made while mounting air inlet units in sealed windows.
At present, valid Lithuanian construction regulations "Heating, ventilation and air conditioning" (STR 2.09.02:1998) [2] require that classrooms were supplied with 21.6 m³/h (6 1/s) of outdoor air for one person. Fixed minimal quantity of outdoor air for one person is 14.4 m³/h (4 1/s).
Although, in renovation projects it is stated that in case of window change air inlets should be mounted, specifications and characteristics of equipment are often not given. Insufficient number or type of air supply equipment is often chosen and the air extraction system is not being reconstructed at all due to financial retrenchment. Therefore, it is not known whether the means that projecting and constructional enterprises undertake are sufficient for the standard air circulation in the classroom.
Therefore, the aim of experimental research was to evaluate the effectiveness of typical ventilation systems that were mounted during school renovating process in Lithuania.

2. OBJECTIVE AND METHOD OF RESEARCH

Parameters' variation in time that characterizes the renovation effect on air circulation and classroom microclimate was analyzed in the process of experimental research. Room air temperature and relative humidity in different places of room, air velocity at 0.1 m, 1.1 m and 1.7 m high above the floor surface and the

concentration of CO_2 were investigated. The research of microclimate parameters was carried out following the standard of Hygiene of Lithuania "Microclimate of residential and public buildings" (HN 42:1999) [3].
In order to compare the effectiveness of ventilation equipment used, classrooms in which the research was carried out had to be similar (geometric similarity, similar width and the same orientation of windows, similar air tightness of partitions and thermal conductivity, similar age of schoolchildren and number of them in lessons etc.). Therefore, classrooms of the same school, on the same floor were chosen that fit all the requirements of similarity. Experiments were carried out in S.Neries secondary school in Vilkaviskis. There were 3 types of air supply equipment, 3 units of each type, mounted in classrooms: "Gecco 3" ("Gealan Clima Control"), "Aereco EMM707" and "Ducoplus 15000" (see figure 1). There were 22-27 schoolchildren in classrooms during lessons (8-10 years old).

a **b** **c**

Figure 1
Air supply equipment that was mounted in investigative school
(a – "Gecco 3", b – "Aereco EMM707", c – "Ducoplus 15000")

"Gecco" and "Aereco" air inlets are fixed to the window frame and "Ducoplus" is the glazed-in air vents. "Aereco" air inlets regulate the supply airflow automatically, according to relative humidity of indoor air. "Gecco" and "Ducoplus" air inlets are controlled manually and have two positions: open and closed. "Aereco" air inlets were set on automatic position during the research. "Gecco" and "Ducoplus" air inlets were open.
The throughput of mentioned air supply units is different. According to manufacturers information and area of cross-section, the largest amount of air can pass through "Ducoplus" air inlet and the smallest - through "Gecco" air inlet.
Systems of natural air extraction were mounted in classrooms during construction of the building, and were not reconstructed during the renovating process.

3. RESULTS OF THE RESEARCH

This section gives the results of measurement of CO_2 concentration, temperature, relative humidity and air velocity in standard classrooms, in which the above mentioned air inlets were mounted. The research was carried out in February – March of year 2004.

3.1. Results of measurement of CO_2 concentration

Despite the type of air supply equipment mounted in classrooms, CO_2 concentration heavily exceeds allowable limit (1000 ppm), as seen in figure 2. Results are very similar for classrooms with "Gecco" and "Aereco" air inlets (standard value was exceeded 3 times during the 4th lesson). Standard value was exceeded 2 times in typical classroom with "Duco" air inlets.

3.2. Results of measurement of relative humidity in the room

According to the previous research, carried out in year 2001 – 2002, relative humidity exceeded standard value in most renovated schools [1] (limits of relative humidity are 40-60%, as set by the standards of Hygiene of

Lithuania [3]). According to the research, relative humidity seldom exceeded 50% during lessons in this particular school. This partially explains the variation of CO_2 concentration in the classroom, in which "Aereco" air inlets are mounted. The humidity sensitive air inlets are adjusted to let in the maximum airflow, in case of 70% of relative humidity in the classroom. In this school this limit was not reached, therefore air inlets were only half open.

Using statistical methods, the existence of correlation between CO_2 concentration and relative humidity level in the classrooms was checked (correlation coefficient of Pearson applied). The results prove the existence of strong relation between these parameters; therefore, there is a linear dependence between them in classrooms.

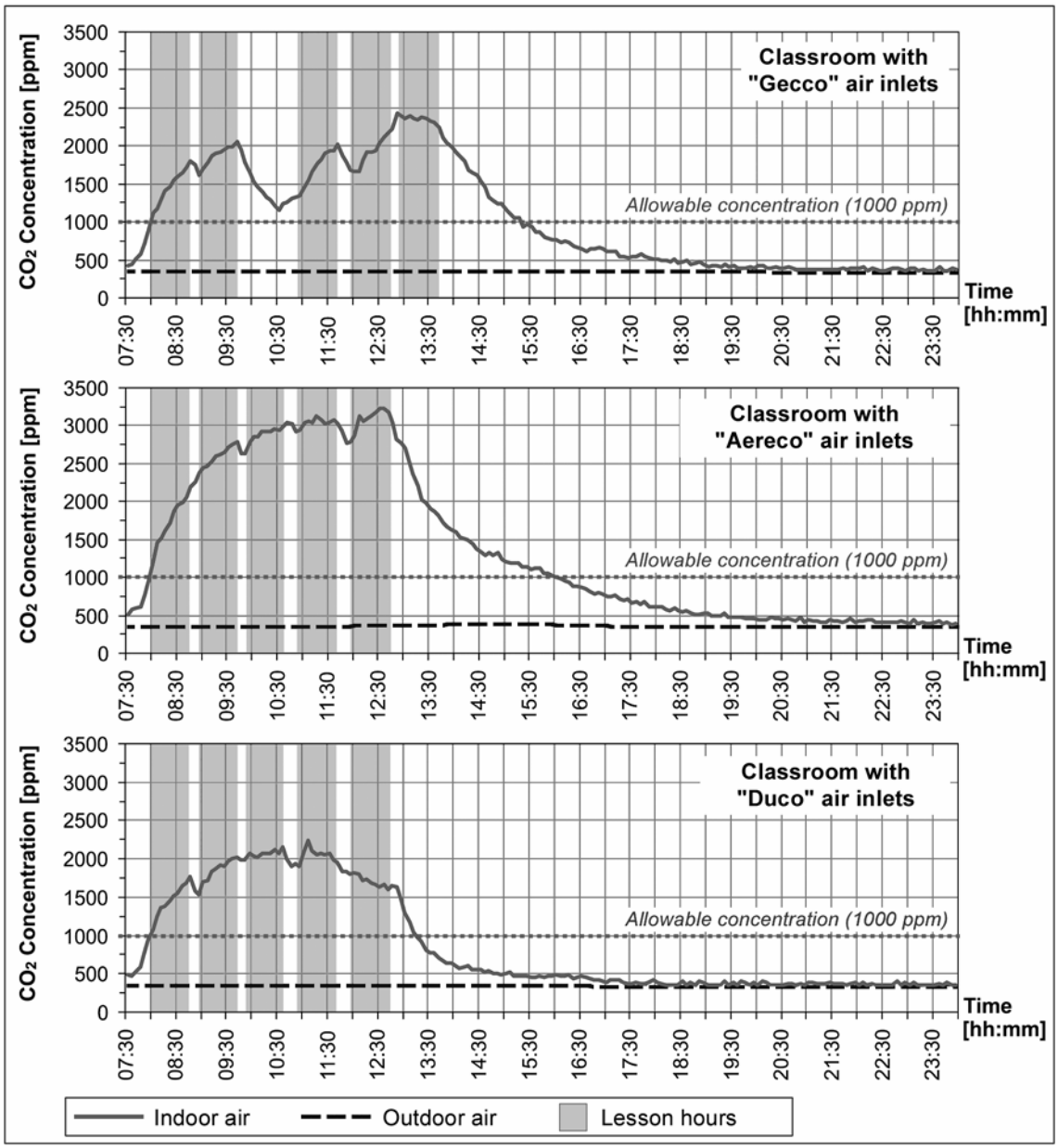

Figure 2
Variation of CO_2 concentration in the center of classrooms, 1.1 m high above the floor surface

3.3. Results of air temperature measurement

Figure 4 shows the variation of air temperature in classrooms. As shown in the figure, this parameter falls into recommended limits of comfort (21-24ºC according to Lithuanian and European standards) only when schoolchildren gather in classrooms. The research also shows that in some classrooms thermal comfort parameters practically are not ensured.

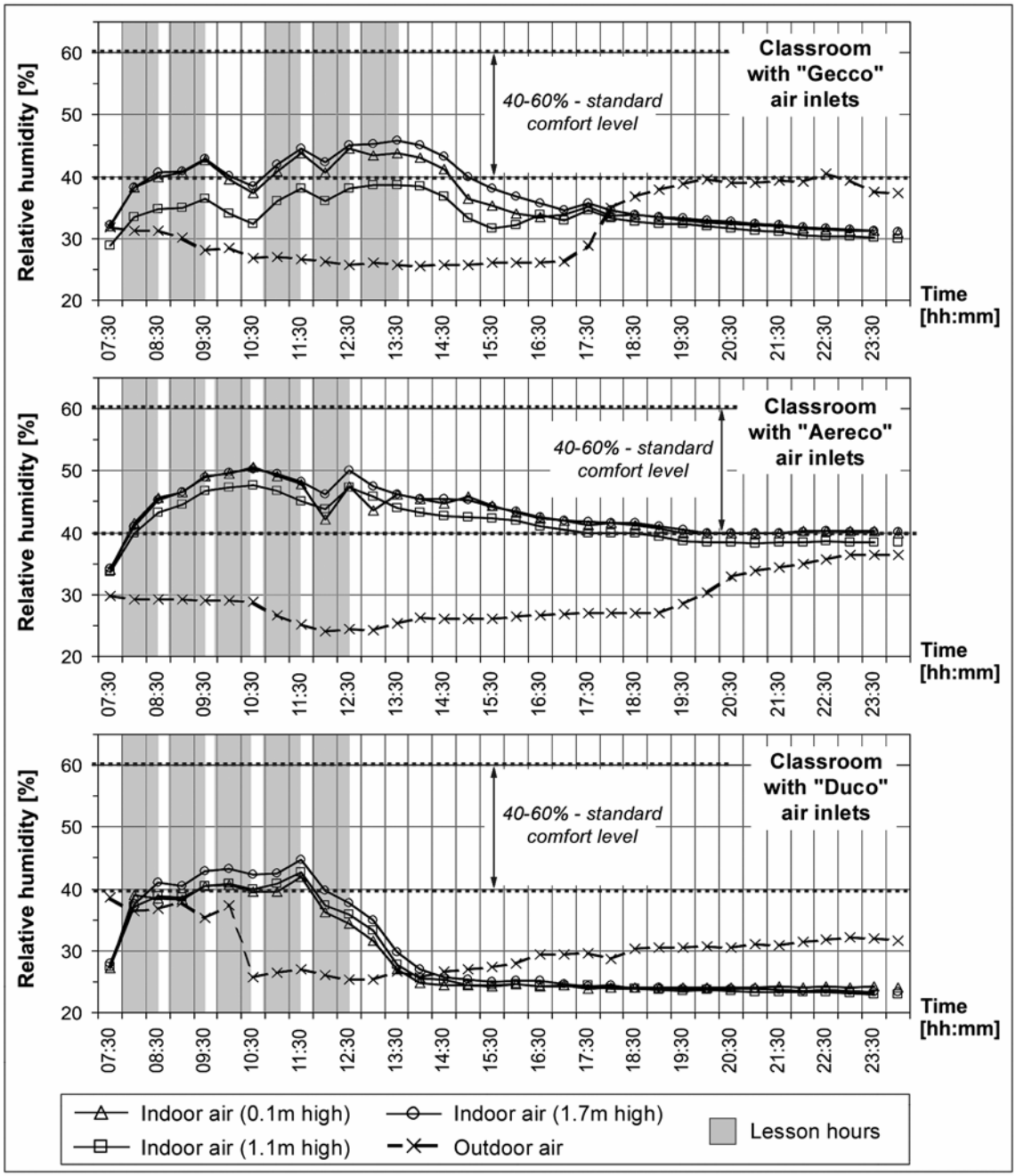

Figure 3
Variation of relative humidity of outdoor air and air in classrooms

3.4. Results of air velocity measurement

While measuring air speed at three different heights (0.1 m, 1.1 m, 1.7 m) of the room, the results were fixed at a one-minute interval. In case of natural ventilation, air velocity in the room is of pulsating nature. All the data was processed by the program of statistics, taking into account the recurrence of air velocity values that exceeds allowable limit (see figure 5). This limit, according to the standard of Hygiene of Lithuania HN 42:1999 [3], standard CR 1752:1998 [4] and standard ASHRAE 62-2001 [5] is set as 0.15 m/s.
According to the type of air supply equipment (i.e. to the airflow rate of supply air), the recurrence of values exceeding the standards is different. As seen in figure 5, supply airflow rate in classrooms influences air speed at lower level most. Air velocity at lower level (0.1 m high) is the slowest in classrooms with “Gecco” air inlets, which ensure the lowest airflow rate. Whereas in classrooms with “Ducoplus” air inlets, that have the highest air throughput of all air supply equipment investigated, air velocity at lower level is the highest and values that exceed the allowable limit recur even in 35,6% of cases.

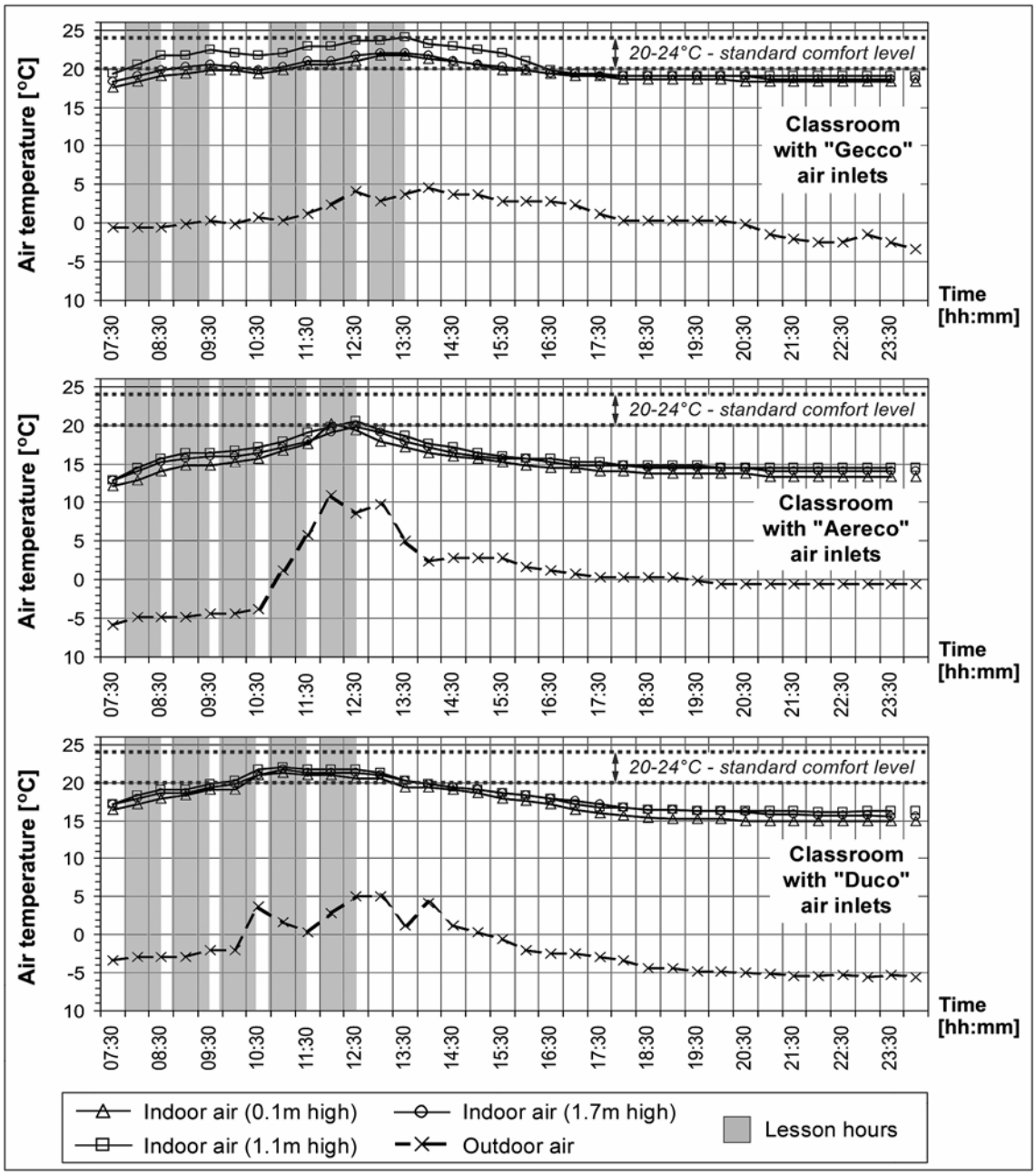

Figure 4
Variation of outdoor air temperature and air temperature in classrooms

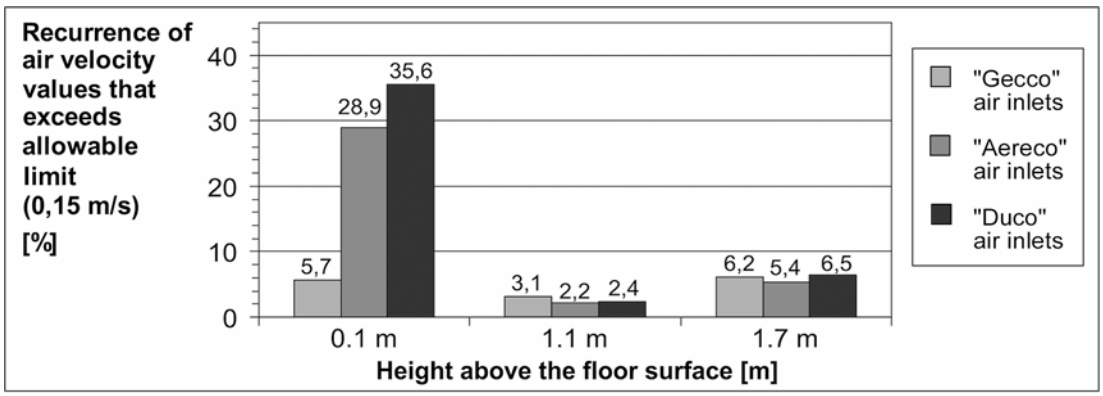

Figure 5

Percentage of a recurrence of air velocity values exceeding allowable limit in classrooms.

3.5. Indirect measurement of extraction airflow

Indirect measurements of extraction airflow were carried out in the investigative classrooms. Duct of a certain width of cross-section was fixed to the exhaust grille; extraction air velocity was measured in the center of the duct. The extraction airflow was counted according to the measured air velocity. This kind of research was possible only in the first floor classrooms, because the direction of air movement in the extraction duct was variable in upper floors, i.e. as outdoor conditions were changing, air was periodically blown inside through the exhaust grille. When calculations were carried out, it became clear that amount of air which is exhausted through the exhaust grilles is smaller than is required by the standards. In order to ensure standard air circulation in investigative classrooms, approximately 560 m^3/h of air should be exhausted [2]. However, passive stack air extraction system exhaust approximately 300 m^3/h (when outdoor temperature is ~0°C). This satisfies only 53% of standard air circulation in investigative classrooms or 79% of allowable air circulation.

4. CONCLUSIONS

In general, it is possible to say that constructional means applied to ensure the standard air circulation in renewable Lithuanian schools are insufficient. In classrooms where the air extraction system was not reconstructed, ventilation becomes insufficient and concentration of CO_2 is exceeded during the lessons. One of the reasons is that passive stack air extraction system do not ensure the standard air circulation in classrooms. In case the outdoor air temperature is ~0°C, the direction of air movement in the ducts of the upper floors is variable. Therefore it is essential to reconstruct air extraction systems while renovating schools.

As Lithuanian schools widely use the air inlets, which directly supply outdoor air to the classroom, the highest air velocity rates emerges at the lower part of the room (0.1 m high) in cold period. It has a pulsating nature (periodically exceeds standard values). The larger amount of supply air passes through the air inlets, the more often air velocity in the lower part of the room exceeds allowable level.

As after evaluating the correlation between CO_2 concentration and relative humidity in the classrooms their linear dependence was set, so ventilation systems with relative humidity sensors can be applied for airflow rate regulation of ventilation systems in school buildings. However, the sensitivity of these sensors must be adjusted for each particular case, taking into account variations of relative humidity in a day course.

In the course of research it was noticed that the air tightness of rooms (especially doors) and the situation of the room in the building layout (distance to staircase) influence air circulation in the classrooms. This must be taken into account while renovating ventilation systems of the classrooms (doors must be impermeable when closed).

References:

1. Ignatavičius, Č., Ignatavičius, G. and Tuomas, E. (2002). *Results of 1997-2000 school renovation.* Homo Liber, Vilnius, Lithuania.
2. STR (1998). *STR 2.09.02:1998, Heating, ventilation and air conditioning. Construction regulation.* Ministry of Environment, Vilnius, Lithuania
3. HN (1999). *Microclimate of residential and public buildings. Standard of Hygiene.* Ministry of Health, Vilnius, Lithuania
4. CEN Report (1998) *CR 1752:1998, Ventilation for Buildings – Design criteria for the indoor environment.* European Committee for Standartisation, Brussels, Belgium.
5. ASHRAE (2001). *ASHRAE Std. Ventilation for acceptable indoor air quality.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.