Natural ventilation as a simple strategy for the improvement of the indoor environmental quality in classrooms

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Presentation Preference: Poster

INTRODUCTION: It now seems clear that the indoor environmental conditions in classrooms, in particular the effect of temperature and indoor air quality (IAQ), influence students' health, attitude and performance. In recent years several studies that evaluate the effects of the classrooms environmental conditions on the learning process were published (Bakó-Biró, Clements-Croome, Kochhar, Awbi, & Williams, 2012; De Giuli, Da Pos, & De Carli, 2012).

In recent years several studies regarding indoor environmental quality (IEQ) were published, covering schools of different levels of education with natural ventilation systems (single façade or cross ventilation), in continuous or purge ventilation. Natural ventilation proved to have great potential, particularly in southern European climate. However, the results, particularly in terms of thermal comfort (air temperature) and ventilation rate or levels of CO_2 concentration, have not always been satisfactory.

OBJECTIVES: Natural ventilation, as other ventilation systems has advantages and disadvantages. However, towards the goals of reducing energy consumption and considering the adaptive possibilities of students, we believe that in Portugal, and in other southern European countries, natural ventilation in schools, both new and refurbished, has great potential for successful implementation. It was on that basis that this study was developed.

MATERIALS AND METHODS: This paper presents the results of part of a research project of broad scope which aims to assess, in an integrated way, several aspects that contribute to IEQ in classrooms. The project comprises 7 schools of different levels of education (from kindergarten to college) located in urban and peri-urban areas of the city of Viseu (within 5 km), installed in buildings of different types and ages, and a total of 28 classrooms are involved, with different orientations and sun exposure. The classrooms had an approximate average area of 50 m^2 and all have bottom-hung windows on the outside and small openings in the interior with adjoining corridors, allowing for the implementation of a cross ventilation strategy.

This part of the research was performed during September and October of 2013 and included the evaluation of the hygrothermal performance, for 4 consecutive days in each school, with occupied classrooms. Air temperature (T), relative humidity (RH) and carbon dioxide (CO_2) concentration were measured. In each school were selected 2 classrooms where specific conditions for cross ventilation were imposed (ventilation protocol). The other 2 classrooms had no control on the window opening.

The sampling interval was of 1 minute and the existing international recommendations were accomplished, in particular, for the location of the sensor, avoiding proximity to windows and heaters. Generally, sensors were positioned next to the teacher desk (approximate height of 0.70 m). The following equipment were used: 1 indoor air quality measurement device Fluke, ref.: 975, that records T, RH and CO_2 concentration (T accuracy ±0.5 ºC; RH accuracy ±2%; CO_2 concentration accuracy 2.75% + 75 ppm), 3 data loggers Hobo U12 for T and RH (T accuracy ±0.35 ºC; RH accuracy ±2.5%) and 3 infrared dispersive measurement devices Telaire 7001 for CO_2 concentration (±50 ppm or ±5% of the reading, whichever is greater).

RESULTS AND DISCUSSION: Previous results revealed that IEQ of the classrooms was poor in terms of IAQ, namely CO_2 concentration (R. Almeida & Freitas, 2010; R. M. S. F. Almeida, Pinho, & Lemos, 2013). From those results the importance of improving classrooms ventilation arises. The next step on this investigation was then to improve the ventilation rates by simple adjustments based on a ventilation protocol that must be implemented in such a manner that the comfort conditions of the classrooms are not neglected.

As an example, Figure1 shows the CO_2 concentration in 8 classrooms of 2 school buildings, 4 with ventilation protocol and the others without ventilation protocol. It is included in the graph the mean concentration and respective standard deviation. For the statistical analysis only the occupied periods of the classrooms were used.

Attending the results shown in Figure 1 it is clear the importance and the positive impact of the ventilation protocol in the classrooms' IAQ. The improvement is observed both in terms of mean values and lower standard deviation, which indicates minor fluctuations and variability of the results and, consequently, lower peak values of CO_2 concentration.

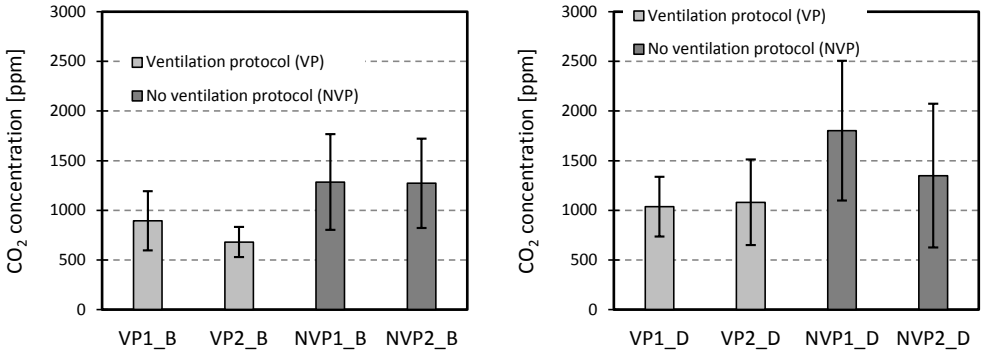

Figure 1 – CO_2 concentration mean value and standard deviation, with and without ventilation protocol: a) school B; b) school D

A more detailed analysis is presented in Table 1, including mean values of T, RH and CO_2 concentration separately for classrooms with and without ventilation protocol. The percent improvement in terms of CO_2 concentration is also indicated, with positive values corresponding to a reduction in concentration.

Table 1 – IEQ mean results for classrooms with and without ventilation protocol

School Id.	T (ºC)		RH (%)		CO_2 (ppm)		
	VP	NVP	VP	NVP	VP	NVP	%
A	24.1	24.7	67	70	978	1436	32
B	27.7	26.6	46	53	788	1279	38
C	26.6	27.0	45	45	1611	1222	-32
D	23.0	24.0	67	66	1059	1576	33
E	26.5	26.6	54	57	768	949	20
F	24.4	24.2	48	51	954	1316	28
G	24.3	22.9	52	64	1370	2485	47

The introduction of a ventilation protocol resulted on an improvement of the IAQ in 6 schools. The only exception was school building C, probably because users (teachers) had the possibility to reject the protocol if they felt uncomfortable. A part from this particular situation, the implementation of the ventilation protocol was very positive: the most interesting performance was obtained in school G with a reduction of 47% in the CO_2 concentration and the even for the less efficient scenario (school E) an improvement of 20% was obtained. Another important result that must be underlined is that the comfort conditions were not neglected with this protocol since no significant difference of temperature between classrooms was found. However, it is important to refer that this results were obtained during autumn, additional measurements must be performed for winter conditions to validate the strategy.

CONCLUSION: A simple ventilation protocol based on a cross ventilation strategy was implemented in several classrooms of Viseu and the IEQ was assessed. Results were very encouraging and globally a significant improvement on the CO_2 concentration was observed. This strategy should continue to be exploited and validated for winter conditions.

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