2ND EURO-MEDITERRANEAN CONFERENCE FOR ENVIRONMENTAL INTEGRATION
10-13 OCTOBRE 2019, SOUSSE, TUNISIA

Springer
SPRINGER NATURE

Improvement of classroom conditions and CO_2 concentrations through natural ventilation measures reinforced with NBS implementation

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Abstract. This study assessed the relationship between temperature and carbon dioxide concentration and ventilation requirements in classrooms. This assessment has been used to design by modelling proper natural ventilation procedures for ventilation and cooling in educational buildings assisted by Nature-Based Solutions implementation. LIFE myBUILDINGisGREEN aims to contribute to increasing the resilience of these buildings by implementing in them Nature-Based Solutions as prototypes of climate adaptation and improved well-being.

Previous studies have suggested that high temperatures and poor indoor ventilation can result in higher levels of indoor pollutants, which may affect student and teacher health. The study is still ongoing and will completed with the assessment of the NBS implementation and measures proposed in the school using carbon dioxide concentration and building users well-being and health through questionnaires.

Keywords: Carbon dioxide, Temperature, School, Health, Indoor environmental quality.

1 Introduction

The changing climate is creating additional challenges in maintaining a healthy school environment where a large proportion of world population, mostly children, spend approximately a third of their waking hours. Chronic low prioritization of funds and resources to support environmental health in schools and lack of clear regulatory oversight undergird the new risks from Climate Change (CC). LIFE myBUILDINGisGREEN project aims to demonstrate the adaptation measures to CC by Nature-Based Solutions (NBS) in public buildings of education and social services. NBS offer an exciting prospect for resilience building and advancing urban planning to address complex urban challenges simultaneously [1]. NBS can replace or compliment air conditioning for heat risk reduction by reducing outdoor temperature and isolating buildings envelope (green roofs and façades or shading structures) [2-3]. Natural ventilation measures can improve indoor environments, reduce temperature and CO_2 concentration and be cost efficient in combination with NBS implementation.

Classroom temperatures should not exceed 27 °C according to law regulations in many countries. However, indoor temperatures could reach higher values than 38 ºC in the Mediterranean area during last Spring and Summer time.

Apart from temperature, carbon dioxide can provide an indication of the adequacy of ventilation to an indoor environment. Carbon dioxide has been used as a surrogate of exposure to indoor pollutants in studies of occupant reporting of health symptoms. Although ambient outdoor CO_2 is generally around 400 ppm, previous studies have frequently measured school concentrations above 1000 ppm, in some cases reaching as high as 4000 ppm. Those studies suggest that poor ventilation can result in higher levels of indoor pollutants, exposure to which may cause health symptoms [4].

2 Methods

In four classrooms selected in the school carbon dioxide concentration, temperature and relative humidity were monitoring during 5 days.

In classrooms that had been assessed by project staff, IAQ 160 TESTO data loggers were placed to record classroom CO_2 concentration, temperature, relative humidity and barometric pressure. Data loggers were set to collect measurements every 15 min since May 2019. It will keep being monitored until the end of 2021 in order to assess the impact of the NBS implemented in the building. Meteorological parameters temperature, relative humidity, wind speed and wind direction were collected from https://www.adaptecca.es.

Achieved airflow rate was modelled for both buoyancy driven and buoyancy and wind driven at school hours using *OptiVent 2*.0, a simple natural ventilation steady-state tool [5]. A model classroom 10x8x3 m with 30 people was used as reference room. Modelling assessment was carried out in May in Solana de los Barros (Badajoz, Spain).

3 Results

3.1 Results

CO_2 monitoring profiles in the classroom show several peaks of high concentration around 2,500 ppm. Minimum ventilation requirements to reduce those levels under 1000 ppm for this classroom are 300 L s^{-1}. Modelling assessment has been conducted in order to determine cross ventilation conditions for CO_2 concentration and temperature decreasing (time, indoor and outdoor temperature, effective apertures with windows and door and wind speed and direction). Buoyancy driven ventilation rates depend on the difference between the internal and external air temperature among other factors. It is recommended to assume a temperature difference (outdoor/indoor) between 1 °C and 3 °C for day-time ventilation. Such a conditions allow opening a minimum of 15 % of the time to get recommended ventilation rates. However, outdoor temperatures do not allow this operation in seasons with very low or very high temperatures.

On the other hand, modelling shows that the room can be effectively cooled with buoyancy and wind drive by reducing outdoor temperatures between 5-7 ºC in the air intake area (see Fig.1) and creating effective apertures between 50 and 75 % of the available area. Prevailing winds blow from west, west-south-west and south-west (37 %) and winds higher than 3 m s^{-1} blow 23.5 days in June, so prevailing winds can be useful to assist for ventilation and reduce temperature purposes.

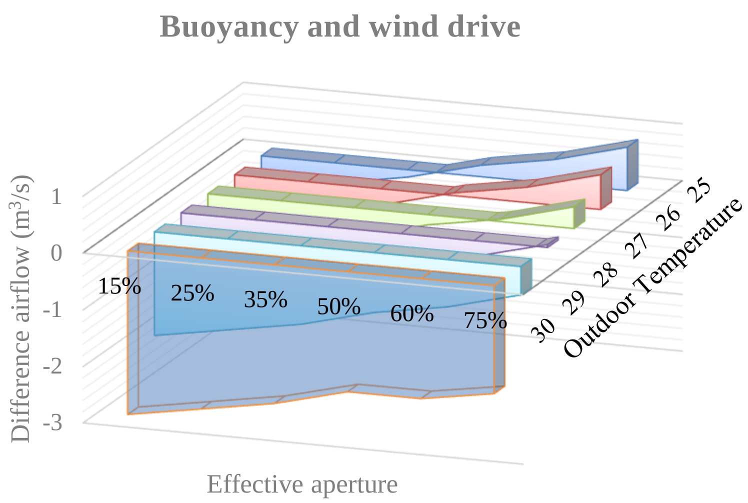

Fig. 1. Difference required airflow for cooling and achieved airflow with different effective apertures (2 m^2 of intake air area) at different outdoor temperatures.

4 Discussion

Ventilation requirements in a model classroom with a high occupation have been assessed by modelling. It is found that with simple windows/door opening measures, carbon dioxide concentration can be maintained below the recommended maximum values. However, at certain seasons such as late spring or summer, with very high outside temperatures, it is necessary to take auxiliary measures in order to cool the intake air.

Intake air and effective apertures have been assessed to create measures for efficient ventilation of the building but also for cooling of the classrooms. It has been found that by creating cross-ventilation formulas and reducing the inlet air temperature these objectives can be achieved. LIFE myBUILDINGisGREEN will implement NBS to improve the thermal behavior of the building and achieve effective formulas to reduce the intake air temperature. Fig. 2 shows a preliminary model for NBS implementation in a school building envelope.

Fig. 2. School rendering with NBS implementation: East façade with green walls and roofs.

5 Conclusions

This study assessed by modelling the relationship between temperature and carbon dioxide concentration and ventilation requirements in classrooms. Furthermore, it has been explored the parameters design for cooling in classrooms by using of NBS. This assessment has been used to design by modelling proper natural ventilation procedures in educational buildings assisted by Nature-Based Solutions implementation. LIFE my-BUILDINGisGREEN aims to contribute to increasing the resilience of these buildings by implementing in them Nature-Based Solutions as prototypes of climate adaptation and improved well-being. The Project is ongoing and in further steps, modelling results will be compared with real implementations.

The authors gratefully acknowledge the support of this work by the LIFE+ Programme under the responsibility of the Directorate General for the Environment of the European Commission through the agreement LIFE17 CCA/ES/00088, LIFE myBUILDINGisGREEN.

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