Design and Indoor Air Quality in Kindergartens in Italy

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ABSTRACT

The serious social and health crisis faced as a result of the spread of SARS-Cov 2 has highlighted the weaknesses of human beings but has mainly highlighted the inadequate static response of existing buildings; all those confined spaces characterised by the simultaneous presence of a large number of people, such as classrooms, have shown, over the past two years, how unhealthy are because of the high possibility of contraction of the virus inside them. The following investigation project aims at improving the air quality within the educational spaces by applying strategic solutions of natural ventilation in order to reduce the possible propagation of an airway transmissible virus. To this end, through a defined working methodology, a real monitoring and a data collection campaign has been conducted within two children's institutes located in the province of L'Aquila (Abruzzo, Italy), as a result of which it has been possible to conclude that the optimal values of CO2 concentration within the classrooms under study have been disregarded for almost all of the time. Moreover, natural ventilation alone is not a valid strategic solution to improve air quality inside the classroom and the consequent reduction of the risk of transmission of Covid-19.

KEYWORDS

CO2 concentration, indoor air quality, schools, nursery, comfort

1 INTRODUCTION

The correct ventilation of a circumscribed perimeter and specifically of a school environment implies a high indoor air quality, decisive for the productivity of the subjects who live daily within this space; there is evidence that there is an increase in the quality of the work carried out, a reduction in sick leave and a reduction in related diseases [1,2]. On the contrary, poor air quality within a school can lead to serious health risks, especially among children who are more sensitive to the consequences of pollution than adults. [3]

The dispersion of a pathogen within a confined environment is determined both by humans, who can incubate the virus and release it into the air in the form of aerosols, and by conditioning systems in which pathogens, due to poor maintenance of the installations, can settle and

multiply and then spread in the environment [4,5]. The diseases associated with prolonged stay in confined spaces, the so-called Building Related Illness (BIS), derive from specific chemical, physical or biological substances, the effects of which affect the respiratory system, the cardiovascular system, exposed skin and mucous membranes, nervous system and immunological system [6]. Given the problem of overcrowding in classrooms, it is obvious that the consequence is an increase in the spread of infectious diseases transmitted by air between pupils and teachers.
Pursuing a certain level of air quality within a defined perimeter means substantially diluting the indoor air with air considered "clean", that is, free of contaminants, blowing out the "contaminated" air inside the room [7]. Various parameters, including temperature, humidity, particles and aerosols, formaldehyde or organic compounds [8] can be used to determine the level of air quality within a room; among them, due to the speed of the calculation, the concentration of $CO2$ (carbon dioxide). The concentration of $CO2$ within inhabited spaces is in fact usually used as an indicator of indoor air quality [9]; and it is a clear indicator of whether or not the air we breathe has been previously breathed by other people. [8]
According to the above mentioned factors, the determination of a sufficient level of indoor air quality and the consequent measurement of the $CO2$ level in indoor spaces is a valid indicator for the risk assessment of transmission of COVID 19. Despite the fact that the World Health Organisation (WHO) has established that the concentration of standard $CO2$ within a circumscribed environment should not exceed 1000 ppm, values between 700 and 800 ppm are already considered harmful to the risk of virus propagation. [11]

METHODOLOGY

The project, as described, was conducted through a precise working methodology that allowed to collect and to analyse the environmental data necessary for the development of the final thesis. This strategy was structured as follows:

- identification of the case study
- indoor parameter monitoring
- analysis of results
- strategic interventions

1.1 Identification of the case study

Two kindergartens located in two different countries, both close to L'Aquila (Abruzzo, Italy), have been identified as case studies. (Fig.1 , Fig.2)
L'Aquila, within the classification of climatic zones in the italian territory, is part of ZONE E, with a range of degrees day between 2101 and 3000; located at 714 m above sea level, has a daily average temperature of 11,9 C. Its location, between the Ocre and Velino mountains to the south and the Gran Sasso massif to the north, means that cold air tends to stagnate frequently causing a thermal inversion due to which temperatures often drop below zero during the night, and this happens more easily in the suburbs and in the countryside. The buildings, built in 2009, have the same construction characteristics and both are equipped with an underfloor radiant heating system. Both are developed on the ground floor and are equipped with classrooms, offices, laboratories, toilets, a canteen area with adjoining kitchen and a gym. The buidilngs' structure is entirely in wood, thermally and acoustically insulated, with optimal requirements of safety, static and functional, and a low environmental impact. The day inside the kindergarten is not marked by rigid lessons or hours and frequently the number of pupils present is considerably lower than the number actually enrolled.

Fig.1 Scuola dell'infanzia "IV Novembre", Ocre

Fig.2 Scuola dell'infanzia "Beato Bernardino", Fossa

1.2 Indoor parameter monitoring

Before taking the measurements, data relating to external climatic conditions were recorded in both cases, fundamental to the balancing of the instruments used and to the determination of any discordant phenomena within the classrooms.
The indoor parameters within the classrooms (Co2, temperature and humidity) were monitored by installing two fixed devices in order to monitor the indoor parameters for the next 10 weeks. The Wöhler CDL 210 is used for the continuous monitoring of CO2, temperature and humidity in a confined environment. The device is equipped with an internal memory for the historicization of the sampled data. Through dedicated software it is possible to transfer and store the collected data easily on a PC. The specific sensor of the CO2 molecules allows safe and accurate analysis of carbon dioxide in indoor environments.

1.3 Analysis of results

The data collection campaign at the two institutes lasted a total of 10 weeks during which more than 50.000 measurements were stored. These values have been carefully analysed on the basis of the parameters, within the school time range between 08.30 and 17.30. In general terms, the average occupancy rate of classrooms over the 10-week period was 62%.
The study shows that within the two kindergartens the concentration of CO2 remains below the recommended limit (700 ppm) only for 4 hours out of the total 9 hours of the entire school day, with an average of 45% compared to the interval considered. On the contrary, it exceeds the limit of 900 ppm for an interval equal to 33% of the time. In the remaining 22% the values of CO2 fluctuate between 700 and 900 ppm. This condition is further supported by the calculation of the median value of CO2 concentration which is equal to 862 ppm.
The study of the temperature parameters allows to exclude, in the present case, a possible correlation between the same and the increase of carbon dioxide in the classroom. During the entire period of the data collection campaign this parameter is varied in an irregular way. The analysis of the temperatures reached shows that the measurements taken remain within the recommended range, between 20 and 22 ° C, for an interval equal to 55% of the time, with a median temperature equal to 21°. Values drop below the 20°C threshold for a time frame of 24%, while exceeding the limit of 22°C for the remaining 21% of the time.
The observation of the values related to the moisture analysis finally highlights a mirror situation within the two kindergartens: there are values perfectly contained within the

recommended range (40% -60%) for an interval equal to 50% of the entire school day, humidity rarely exceeds the maximum recommended limit, but for at least 49% of the time there are values below 40%.

Values collected during the data campaign in each of the two kindergartens

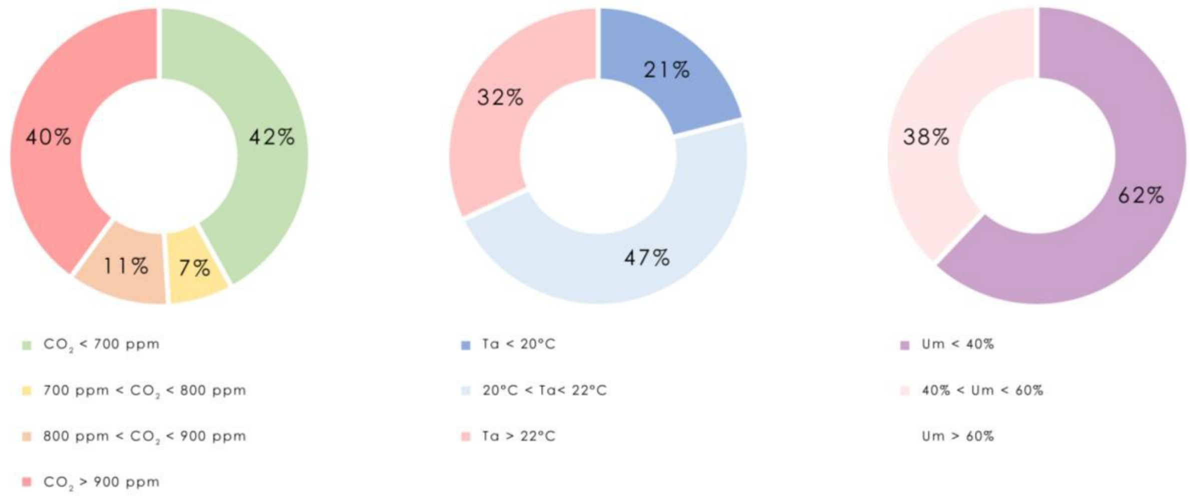

Fig.3 Analysis of CO_2 concentration, temperature and humidity, Scuola dell'infanzia "IV Novembre", Ocre

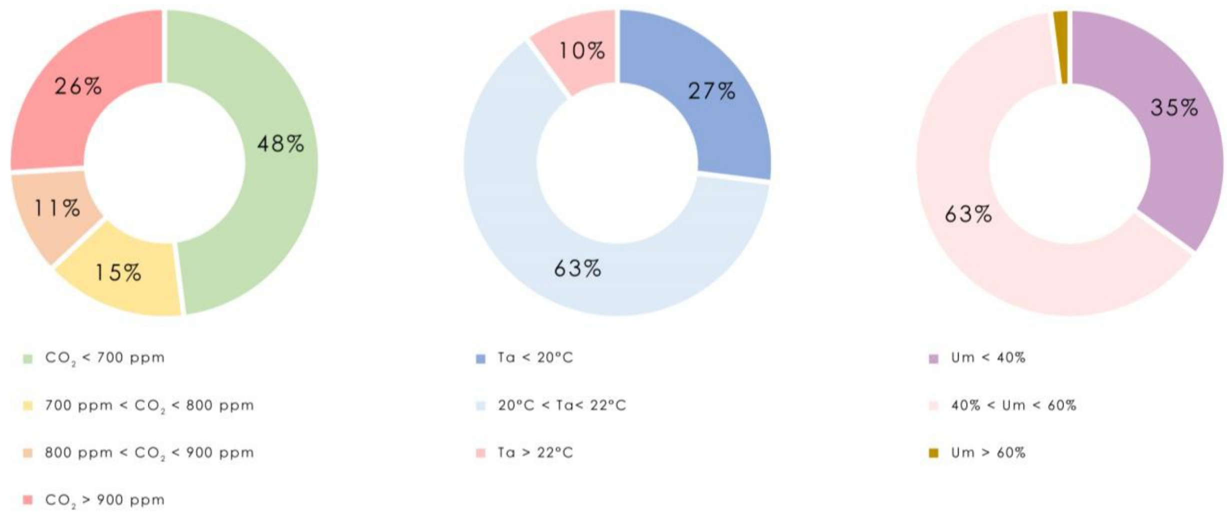

Fig.4 Analysis of CO_2 concentration, temperature and humidity, Scuola dell'infanzia "Beato Bernardino", Fossa

1.4 Strategic interventions

In the final phase of this investigation project, some proposals were launched for strategic interventions aimed at improving air quality in the classroom, monitoring the relevant parameters and analysing the results obtained. During the last eight weeks of work between January and March 2022, intervention strategies to increase the natural ventilation of the classroom and reduce the risk of infection were introduced into the daily practice of the two kindergartens. The solutions presented clearly depend on the study of the outcome of the data collection campaign, therefore closely related to the diagnosis made in relation to the two kindergartens studied, as well as the results obtained from their application. However, this does not hinder their application to different areas of education or work.

The strategies adopted are as follows:
• opening two windows at the beginning of each lesson time for about five minutes;
• reduced opening (a vasistas) of two windows during the whole school day;
• implementation of an air purifier within the classroom (where possible);
• introduction of a 1000 ppm limit overrun alarm system, following which windows had to be opened to reduce CO2 concentration.

The period of application of the first measure appears to be two weeks. The analysis of the collected data shows that the parameters relating to the CO2 concentration continue to reach values indicative high and above 1000 ppm in most of the days considered. Nevertheless, the trend remains broadly contained in a range of 800 to 500 ppm. This information is reflected in the calculation of the median indices of 669 ppm. With the application of the first strategic intervention there is an overall improvement of 13% compared to the values of the CO2 concentration, monitored during the data collection campaign within the two classrooms. The application of this strategy is therefore linked to the effort of the staff and represents a practical solution only within 20 minutes after the opening of the window.

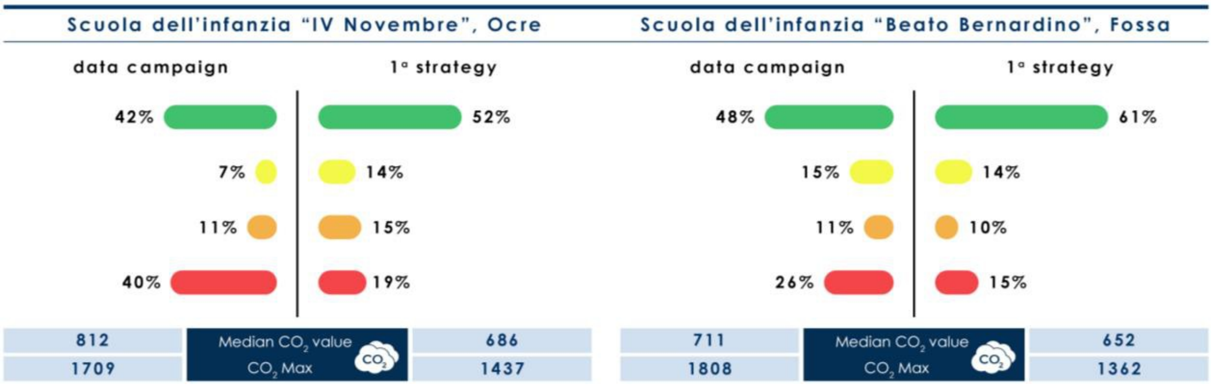

Fig.5 CO_2 concentration comparison before and after application of the first strategy

The second strategic solution proposed has provided, where possible, the constant opening of two potty windows during the entire duration of the school day. Also in this case the parameters were monitored for a total period of about two weeks. Although less than the first strategy adopted, the analysis of CO2 parameters continues to highlight the daily monitoring of high values within the two classrooms. Over a long period of time, values above 1000 ppm continue to be recorded, but by examining the median indices it is possible to observe that the concentration of CO2 remains on average between 600 and 700 ppm. With the application of the second strategic intervention there is an overall improvement of 18% compared to the values of the CO2 concentration, monitored during the data collection campaign within the two classrooms. In this case a fundamental limit is represented by the external climatic conditions that, if unfavorable, do not allow the opening of the windows and the consequent reduction of the CO2 values inside the classroom.

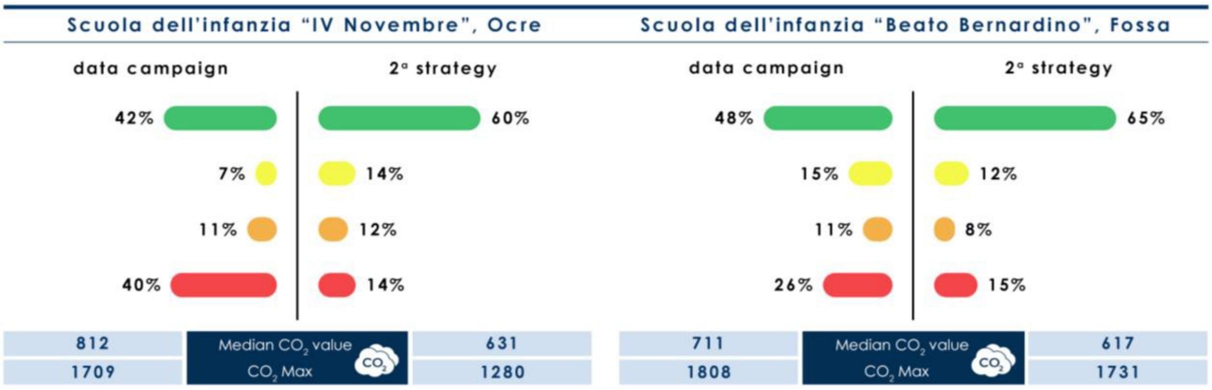

Fig.6 CO_2 concentration comparison before and after application of the second strategy

The third strategy solution provided, in parallel with the maintenance of the windows open to vasistas, the implementation of an air purifier inside the classroom. It should be made clear that the use of this instrument reduces the risk of spreading aerosols and other pathogens, but does not improve indoor air quality. The application of this strategic intervention has led to optimal results within the investigation process. With an improvement of the parameters examined of 21% it has been possible to see a clear reduction in the time span in which, inside the classrooms, values exceeding 900 ppm are reached: percentage that drops to a 15% of the range considered compared to 33% of the data collection campaign. Here too, however, there is an important limitation of application: the impossibility of decreasing the growth of the maximum values. Although drastically reducing the times of the day when the values exceed the recommended limit, there are still extremely high levels of CO2.

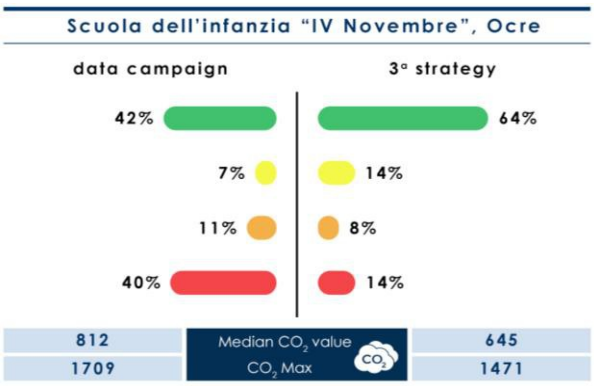

Fig.7 CO_2 concentration comparison before and after application of the third strategy

During the last proposed strategic intervention, an audible alarm system was activated in the Wohler device, exceeding the preset limit of 1000 ppm; as a result of the signal being emitted, users were therefore required to ventilate the classroom more adequately by opening the windows. Observation of the weekly data shows a marked improvement in the maximum levels of CO2, which in fact, in no case exceed 1000 ppm. Nevertheless, it is possible to note that the average of the monitored values is higher than those analysed previously, falling in a range between 700 and 900 ppm. In this case the percentage of improvement compared to the parameters monitored during the data collection campaign is equal to 22%, but the significant limit of the proposed strategy is that its effectiveness is immediate but not prolonged in time. It is clear that the intervention allows to keep the levels below the preset limit but it is only a tool to support the achievement of better air quality. In fact, it emerges the need to implement this strategy with an effective ventilation system.

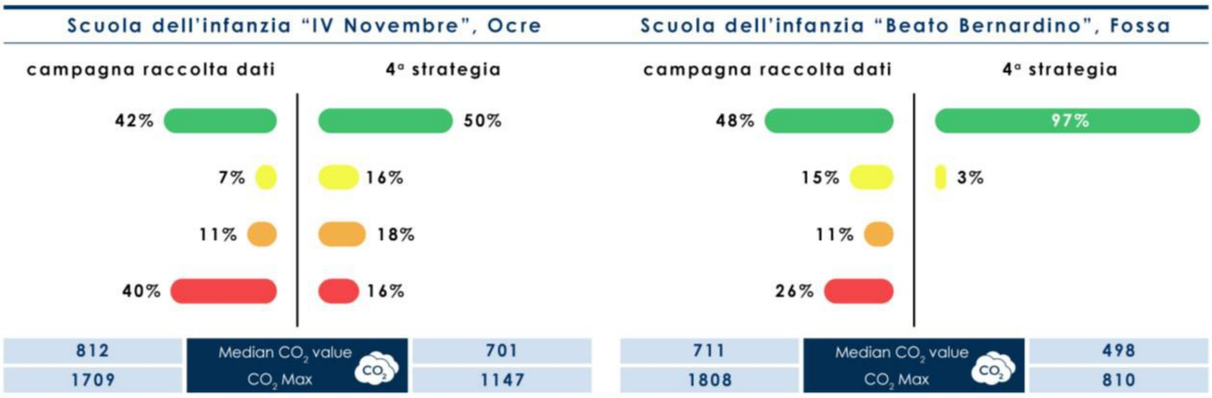

Fig.8 CO_2 concentration comparison before and after application of the fourth strategy

2 CONCLUSIONS

The results obtained in the final phase of the project program, related to the introduction of intervention strategies, have revealed the real extent of the problem related to the theme of air quality and proper ventilation. Each of the interventions adopted, commonly considered of extreme support for the purpose of the cause, has presented important limits of application. The constant opening of the windows to vasistas does not allow to introduce inside the classroom the airflow functional to the precise condition recorded in the enclosure; the use of the purifier, albeit extremely useful in reducing the risk of infection from Covid-19, does not guarantee the reduction of the concentration of CO2. The use of the alarm sound that allows you to keep within a certain threshold levels reached within the class, requires the implementation of additional ventilation strategies that allow to maintain over time that certain standard of quality.

The proposed program highlights that the optimal values of CO2 concentration within the classrooms of a kindergarten are not complied with for almost all time; and through the application of the proposed strategic solutions, clearly establishes the insufficiency of only natural ventilation as a remedy for the improvement of air quality. To endorse this thesis, beyond the analysis conducted, there is the finding that natural ventilation alone cannot guarantee constant air exchange and that it can also promote, through the circulation of indoor air, the transport of viral loads to locations distant from those occupied by infected persons.
Thinking that aerating the environment by natural ventilation can be a valid tool aimed at reducing indoor air pollution and reducing the risk of infection from SARS Cov 2 turns out to be a pure utopian dream: if so, the windows should be opened much more frequently and for a sufficiently long duration. This strategy, as we have seen from the analyses carried out, has, however, obvious practical limitations, including, more importantly, the close relationship with the external environment, which could possibly be characterised by polluted atmosphere, noise or extremely low temperatures. In case of particularly rigid climates such as that of L'Aquila, in fact, the opening of the windows is reduced to a small amount of time compared to the entire duration of school hours, causing not only the loss of accumulated heat but also a sudden lowering of temperatures and the consequent increase of the thermal discomfort inside the classroom.

3 ACKNOWLEDGEMENTS

The results presented were funded by Fondazione Ferdinando Filauro, in collaboration with Università degli Studi de L'Aquila and Escuela Técnica Superior de Arquitectura, Universidad de Sevilla as well as by the Programa Operativo FEDER 2014-2020 of the Consejería de Economía, Conocimiento, Empresas y Universidad de la Junta de Andalucía through the research project UNCOVER (Ref US-1381053).

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