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A two-step interactive tool to calculate the exposure dose and the infectious risk in indoor compartments

Objective
The idea of creating a computational tool that, with a high degree of interactivity, allows demonstrating both the temporal evolution of the concentrations of a biological contaminant and carbon dioxide (CO2) within an indoor compartment arose during the preparation phase of the modules that the first author taught on a course organised by REHVA about the Safe Operation of Buildings and HVAC Systems during the COVID-19 pandemic. The concept of a high degree of interactivity should be understood as the possibility of the tool allowing the modification of the different parameters that, in some way, influence the temporal evolution of the concentration of contaminants during the occurrence of the simulation process itself, allowing immediate visualisation the effect of the introduced change. In this way, the trainees following the course have a much faster and more complete perception of the impact of each parameter governing the evolution of the studied phenomenon. For a previously defined duration running test, the initially developed tool displays concentrations of CO2 (ppm) and the bio contaminant (Pfu/m3) and the time history of the dose inhaled by a receiver with and without a protective mask. In this initial tool, mainly the physical phenomena related to the emission of the contaminant by an infected agent, its transport, dilution and persistence in the volume of air of the compartment and the reception by the breathing system of a sensible receiver are considered.
In the second phase, the tool was complemented by calculating the infection risk by implementing the Wells-Riley method once the correspondence between the quantity of inhaled contaminant agents and the "quanta" concept was settled. This method considers the infectiousness of the biological contaminant and the resistance of the sensible receivers'immune systems. Thus, the biological characteristics of the sensible receiver and the contaminant agent are considered when calculating the risk of infection once the exposure dose quantity is known.

Methods
The tool has been developed in the LabView programming software and benefits from its good graphical display tools. The tool uses the finite differences formulation for the first step, calculating the concentration variation along equally spaced sampling time instants. It was designed to accept the change of the governing parameters during the simulation of cases, allowing an immediate perception of the effect of the introduced changes. It takes into account the impact of the following variables: emission rate of bio contaminant source, half-life time of bio contaminant, efficiency of protective mask wearied by the emitter, efficiency of protective mask worn by the receiver, fresh air flow rate, volume of the room, number of occupants in the room and respective corpulence data and metabolic rate, flow rate of an indoor installed air cleaner device and individual one-pass purification efficiency. It also allows the simulation of instantaneous high-spread respiratory events like coughing or sneezing.

Results
A parametric study has been conducted for the case of a school room, considering the influence of the air exchange rate and the use of masks by the emitter and the receiver. The values selected for the air exchange rate were defined to cover situations ranging from a closed room, with air exchange assured only by infiltration (0.25 h-1), to a typical mechanical ventilation case (6 h-1) passing through the usual natural ventilation air exchanges (2 to 3 h-1). Between the worst case (a shallow 0.25 h-1, without masks used by the receiver and the emitter) and the best case (6 h-1 and masks used by the emitter and the receiver), the inhaled dose is reduced 63.4 times. Even for the air exchange rates usually achievable with a natural ventilation system, 2 to 3 air exchanges per hour, the reduction is between 25 and 35 times for using masks on both sides of the transmission line.

Conclusions

The developed computational tool proved quite interesting for the knowledge transmission process, allowing a swift demonstration of the effect of each governing parameter due to its highly interactive character. It stimulates the evolution of a biological contaminant and CO2, which is advantageous since CO2 concentrations are much easier to measure in real-time than biological contaminants. The two concentrations usually have good correlations unless a disinfection device is installed in the room or the infected agent has some high airflow rate respiratory events, like coughing or sneezing.

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