Concepts of air purification efficiency tests under realistic conditions with continuous bioaerosol source and evaluation of test results

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ABSTRACT

Air purification technologies have become significantly more relevant since the outbreak of the Sars-CoV-2 pandemic, especially in naturally ventilated but highly frequented indoor environments such as schools and cinemas. In addition to filtering technologies, inactivating air purifiers using e. g. ultraviolet radiation or cold plasma gained higher relevance. The cleaning efficiency of air purification systems is usually tested by measuring an exponential decay under well mixed conditions without dosing during the measuring period. Due to the complexity of real applications, important aspects and properties of the cleaning systems remain unanswered by these simple tests. The test results are often combined with indoor ventilation simulations. In our opinion, there is a lack of studies, particularly for the removal of airborne microorganisms, which divide the leap from such decay measurements to computer-aided simulations of the purification effect under real conditions into several steps. To obtain application conditions as close to reality as possible, tests were carried out with continuous bioaerosol dosing in test rooms and facilities ranging from 12 m³ to 130 m³ under controlled indoor climatic conditions, including office, aircraft cabin, and ventilation duct. Various air purifiers, e.g. standalone devices, wall- and ceiling-mounted units, and induct systems were examined. A suspension containing Phi6 bacteriophages as a surrogate for a pathogen virus was nebulized continuously into the test facilities while air exchange and mixing conditions were modified. To measure the spatial characteristics of the cleaning effect in a room, no additional air mixing was carried out in addition to the cleaning system under analysis. This setting can be used to detect a short-circuit airflow that increase the risk of infection for people in the vicinity of the source of the pathogen. Due to the continuous bioaerosol dosing, it was necessary to develop a mathematical model (named “incremental evaluation model”) to evaluate the data. The main parameters of the model, in addition to the switching times of the devices, are the source term and the exponential loss constant of the air purification system (k_{AC}) and the loss constant without air purification system. The higher the value of the parameter k_{AC}, the better the cleaning effect. Under steady state conditions, the source term can be assumed as constant. For more sophisticated investigations, these parameters were determined temporally and spatially resolved. Based on the test results of selected highly frequented indoor spaces with different ventilation and cleaning scenarios, a calculation tool (VEPZO model) was developed to determine the concentration distribution of active airborne microorganism in real rooms. Advantages, challenges, solutions and outlook of investigations and evaluation tools of air purification systems with continuous bioaerosol source under realistic conditions will be presented.

KEYWORDS

Hygiene concept, air purifier, indoor air quality, evaluation model, bioaerosol