Perfect Mixing or Imperfect Terminology

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ABSTRACT

Air and airborne contaminant mixing in building spaces is important to ventilation system design and performance, tracer gas measurements of ventilation rates, and occupant exposure to indoor pollutants. The physics of air and contaminant mixing have been studied for decades and are fairly well understood. Nevertheless, many discussions of building ventilation, air movement and indoor air quality use the term "perfect mixing" without a clear discussion of what it means or how it applies to the situation being considered. In most cases, the term refers to an idealized situation in which supply air from ventilation systems, entering outdoor air (e.g., via infiltration), air from adjoining space, and indoor-generated contaminants are instantaneously and uniformly mixed with the room or building air volume of interest. This idealized situation is just that, an idealization, which is not achievable in practice, though it is a useful concept for considering metrics and measurements of air distribution and contaminant uniformity. While the existence of perfect mixing within a space is difficult to define and therefore verify; air distribution within a building air volume and the uniformity of contaminant concentrations can be defined and verified through measurement or analysis of modeling (e.g., computational fluid dynamics) results.

The degree of uniformity of indoor air contaminant or tracer gas concentrations in a space are critically important for characterizing indoor air quality and occupant exposure to contaminants, contaminant transport modeling, the application of tracer gas measurement methods, ventilation system design (e.g., air terminal location and discharge velocity), and compliance with ventilation standards (e.g., ASHRAE Standard 62.1). Too often the uniformity issue is dismissed by stating that a space is perfectly mixed, again without a clear discussion of what this means and how this idealization actually applies. In practice, the uniformity of contaminant and tracer gas concentrations depend on the air movement patterns in the space and on the nature of the contaminant (or tracer gas) source including the temperature of the source, air movement associated with the source, and the distribution of the source in the space (i.e., highly localized or distributed throughout the space). For the same air distribution patterns, different sources can in general result in quite different contaminant distributions. Therefore, instead of using the term perfect mixing to describe a space, contaminant or tracer gas concentration uniformity should be used, which is more straightforward to define and quantify.

This presentation will review the history of how air and contaminant mixing has been characterized over the decades and clarify how the important concepts of air distribution and contaminant uniformity can be quantified.