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Contaminant ingress into multizone buildings: An analytical state-space approach

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Abstract

The ingress of exterior contaminants into buildings is often assessed by treating the building interior as a single well-mixed space. Multizone modelling provides an alternative way of representing buildings that can estimate concentration time series in different internal locations. A state-space approach is adopted to represent the concentration dynamics within multizone buildings. Analysis based on this approach is used to demonstrate that the exposure in every interior location is limited to the exterior exposure in the absence of removal mechanisms. Estimates are also developed for the short term maximum concentration and exposure in a multizone building in response to a step-change in concentration. These have considerable potential for practical use. The analytical development is demonstrated using a simple two-zone building with an inner zone and a range of existing multizone models of residential buildings. Quantitative measures are provided of the standard deviation of concentration and exposure within a range of residential multizone buildings. Ratios of the maximum short term concentrations and exposures to single zone building estimates are also provided for the same buildings.

Keywords

indoor dispersion,
exposure,
multizone,
shelter-in-place,
state space

Article History

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1 Introduction

1.1 Background and outline

People spend much of their time indoors (Konartit et al. 2010) and understanding the exposure of individuals within buildings to airborne contaminants is a key step in estimating the risks they face. In the case of short term contaminant releases it is necessary to consider the dynamics of the building concentration response. This can be important in the case of intermittent or short term releases within the building or hazards exterior to the building. For example, sheltering within buildings in the event of an accidental or deliberate outdoor release of hazardous airborne material may reduce the likelihood of harmful effects. The benefit from sheltering depends on the concentration time series that building occupants are exposed to. A number of studies have examined the possible benefit of shelter-in-place (SIP) responses, including Casal et al. (1999); Sorensen et al. (2004); Chan et al. (2007a,b, 2008); Kaplan (2009); Bennett (2009); Persily et al. (2009); Parker and Coffey (2011). However, the majority of studies have treated the building as a single well-mixed zone, whilst some (Chan et al. (2008); Bennett (2009); Persily et al. (2009)) have considered additional zones.

The assumption of a single well-mixed zone is useful in order to estimate the broad scale of effects, such as the influence of air change rate. However, further work is needed to understand the variation in concentration and exposure in multiple locations within more realistic buildings to inform emergency response. For example, sheltering within an inner

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