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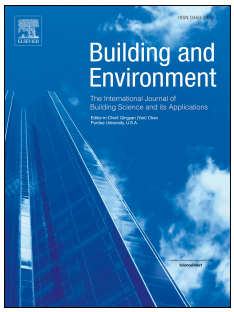

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Anthony D. Fontanini, Umesh Vaidya, Alberto Passalacqua, Baskar Ganapathysubramanian

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Contaminant transport at large Courant numbers using Markov matrices

Anthony D. Fontanini[1], Umesh Vaidya[2], Alberto Passalacqua[1], and Baskar Ganapathysubramanian[*1]

[1]Department of Mechanical Engineering, 2100 Black Engineering, Iowa State University, Ames, IA 50010, USA

[2]Department of Electrical and Computer Engineering, 2215 Coover, Iowa State University, Ames, IA 50010, USA

ABSTRACT

Volatile organic compounds, particulate matter, airborne infectious disease, and harmful chemical or biological agents are examples of gaseous and particulate contaminants affecting human health in indoor environments. Fast and accurate methods are needed for detection, predictive transport, and contaminant source identification. Markov matrices have shown promise for these applications. However, current (Lagrangian and flux based) Markov methods are limited to small time steps and steady-flow fields. We extend the application of Markov matrices by developing a methodology based on Eulerian approaches. This allows construction of Markov matrices with time steps corresponding to very large Courant numbers. We generalize this framework for steady and transient flow fields with constant and time varying contaminant sources. We illustrate this methodology using three published flow fields. The Markov methods show excellent agreement with conventional PDE methods and are up to 100 times faster than the PDE methods. These methods show promise for developing real-time evacuation and containment strategies, demand response control and estimation of contaminant fields of potential harmful particulate or gaseous contaminants in the indoor environment.

1. INTRODUCTION

The human body may be exposed to many different types of potential pollutants, pathogens, or chemical and biological agents. These different gases, particulate matter (PM), and illnesses have many different sources. The products of combustion may be lingering in the air from traffic or industrial emissions. Volatile organic compounds (VOCs) may be evaporating or off-gassing from building materials, paints, or cleaning supplies. As people move around the building, dust, mold, pet hair/dander may be suspended in the air. Chemical or biological warfare (CBW) agents may be released during an attack or an act of terror. People coughing or sneezing in office, hospitals, or public transportation vehicles or terminals could be releasing air bourn infectious diseases into an environment that can affect many people. Some of the health risks related with exposure to these contaminants can be as mild as fatigue, headaches, dizziness, or sinus irritation [1], but could be as severe as aggravated asthma, irregular heartbeat, lung cancer, heart disease, respiratory disease, and in extreme cases can even be fatal [1]. Particulate matter is currently controlled by the National Ambient Air Quality Standards (NAAQS). The particle sizes are generally broken into two classes 1) inhalable particle pollution with diameters < 10 μm (PM_{10}) and 2) fine respirable particle diameters < 2.5 μm ($PM_{2.5}$). Exposure to small diameter PM has been linked to heart disease, lung cancer, cardiovascular and cardiopulmonary diseases [2]. The $PM_{2.5}$ particles are small enough that, when airborne, they experience long suspension times [3], [4], potentially effecting the occupants for long periods of time. The emission of VOCs can have many sources in the indoor environment (paints, adhesives, furnishing, clothing, building materials, combustion materials, and appliances) [5]–[9]. Health effects from VOCs include acute and chronic respiratory problems,