BUILD SIMUL (2011) 4: 227 – 244
DOI 10.1007/s12273-011-0035-6

Impact of non-uniform urban surface temperature on pollution dispersion in urban areas

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Research Article

Abstract

Airflow pattern through street canyons has been widely studied to understand the nature of pollution dispersion in order to develop guidelines for urban planners. One of the major contributing parameters in pollution dispersion is thermal-induced flow caused by surface and air temperature difference. However, most of the previous studies assumed isothermal condition for street canyons. Those addressed the thermal-induced flow, have assumed a uniform wall surface temperature distribution. The external building wall surface temperature distribution is not uniform, and is influenced by many factors including the wall surface characteristics, and shading. The non-uniform temperature distribution significantly impacts on 3-dimensional airflow within street canyons. Moreover, effect of intersection is barely considered in the literature where $L/H<3$ (L and H are respectively length and height of street canyon). This Paper reports the development of a 3-dimensional model to study the effect of non-uniform wall surface temperature distribution on the pollution dispersion and flow pattern within the short street canyons ($L/H<3$). For this purpose, a computational fluid dynamics (CFD) model is developed to investigate these effects on pollution dispersion in various prevailing wind velocities and directions. Moreover, active and passive techniques to reduce the level of concentration are examined. The study clearly shows that thermal-induced flow dominates during fair-weather condition.

Keywords

city ventilation,
airflow,
street canyon,
pollution dispersion,
thermal-induced flow,
CFD

Article History

Received: 21 December 2010
Revised: 6 April 2011
Accepted: 11 April 2011

1 Introduction

It is expected the world population to reach over 9 billion by 2050 (Population Reference Bureau 2005). This information indicates that more mega cities packed with densely high-rise buildings will be built to accommodate this population. The highly packed built urban environment influences the heat dissipation (Urban Heat Island) and pollution (Urban Pollution Island) due to the reduction of airflow, city ventilation. The city urban environment is ventilated mainly by rural air which is mainly done by wind and thermal buoyancy forces: the ventilation helps to dissipate the heat and dilute the contaminants concentration. The reduction of city ventilation impacts the building energy consumption, outdoor air quality, pedestrians' health and comfort, as well as indoor air quality, building occupants' health and building energy consumption.

The building height has complex role in the city ventilation. It can improve the ventilation by improving thermal convection boundary layer flows along the exterior wall surface, or it can reduce it by altering the airflow direction. Previous research using the concept of effective ventilation rate (air change per hour) quantified the impact of aspect ratio (AR) on the urban heat island (Mirzaie and Haghighat 2010a). Many studies show that the pollution dispersion correspondingly changes in magnitude and direction with the alteration of the thermal stability (Huang et al. 2009; Mirzaei and Haghighat 2010a, 2011). This is mostly due to creation, weakening, or strengthening of small/large circulations within street canyons (Li et al. 2006). These circulations have complex patterns because of the difference in temperature of street canyon's surfaces. The temperature difference between urban surfaces changes the airflow regime through street canyons (Xie et al. 2006).

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