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Favorable Street Canyon Aspect Ratios for Pollutant Removal- a Large-Eddy Simulation Approach

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Given the limited land resource, urbanization is one of the solutions to the current rapid economic development and population growth. Narrow streets flanked by high-rise buildings, also known as street canyons, are commonly found in metropolises nowadays. In recent years, this issue has been aroused the public awareness that the air pollutants from domestic sources and vehicular emissions are unable to be removed but trapped inside the street canopy level threatening human health and our living environment. A thorough understanding of the pollutant removal mechanism is the key step to rectify the current poor urban air quality. This study is therefore conceived to examine how the pollutant removal is related to the street width and building height.

Large-eddy simulation (LES) with the one-equation subgrid-scale (SGS) turbulence model is employed to investigate the characteristic ventilation and pollutant transport in idealized two-dimensional (2D) street canyons of different building-height-to-street-width (aspect) ratios (ARs) h/b. Model validation is performed by comparing the LES results with those of k-ε turbulence model and laboratory experiments. A consistent trend of the pollutant exchange rate (PCH) among the LES, k-ε turbulence model, and experimental results is obtained. While its drag is largest, the street canyon of AR = 0.5 is found to be most favorable in the pollutant removal perspective. This finding seems contradict with the presumption that the smaller the AR (wider the street), the more efficient the pollutants removal.

In the isolated roughness regime the flows in (wider) street canyons, the entrainment from the prevailing flow aloft down into the ground level purging pollutant away. On the contrary in the skimming flow regime, in (narrower) street canyons, the recirculating flows inside the street canyon are isolated from the prevailing flow in which the (vertical) pollutant removal is governed by roof-level intermittency. Unexpectedly, in the wake interference regime, lying between isolated roughness and skimming flow regimes, the PCH is found to be the least among the three flow regimes. This is likely caused by the shallow purging air stream together with the pollutant re-entrainment from the roof level back into the street canyon. These LES results suggest that the pollutant removal is not simply proportional to the street width. Indeed, the turbulent transport processes should not be overlooked that plays a crucial role in the pollutant removal mechanisms. Hence more ARs should be considered generating a comprehensive picture for the favorable street canyon aspect ratios for better air quality.