is project focused on the pollutant transport in idealized three-dimensional (3D) street canyons using computational fluid dynamics (CFD). A series of sensitivity tests were performed to examine the effects of building-width-to-street-width ratio (WR) on the pollutant removal behaviours. The results reveal the pollutant dispersion characteristics in 3D building configuration, and how WR affects the upward and sideward pollutant removal. Based on the current findings, it is suggested that the CFD results for idealized 2D street canyons should be interpreted with caution.

**Methodology**

**CFD code:** OpenFOAM-1.6  
**Turbulence Model:** Unsteady Reynolds-averaged Navier-Stokes Renormalization group k-ε turbulence model

**Parameters for the Street Canyon:**
- Building length in x direction: \( w (1 \text{ m}, 2 \text{ m}) \)  
- Building length in y direction: \( a (1 \text{ m}) \)  
- Building height: \( h (1 \text{ m}) \)  
- Street width in x direction: \( b (1 \text{ m}) \)  
- Building-width-to-street-width ratio (WR): \( \frac{w}{b} \)  
- Domain height: \( 8 \times h \)  
- Number of buildings in x direction: 8  
- Number of buildings in y direction: 5

**Parameters for the Flows:**
- Characteristic length: \( h (1 \text{ m}) \)  
- Characteristic velocity: \( U_0 (0.15 \text{ m/s}) \)  
- Reynolds number: \( U_0 \times h / v = 1.5 \times 10^4 \)  
- Number of grid points: about 10 million

**Parameters for the Pollutant Transport:**
- Pollutant concentration: \( c \)  
- Average pollutant concentration inside the canyon: \( c^* \)  
- Pollutant exchange rate through an interface of area \( A \): \( \text{PCH} \)  

The total \( \text{PCH} \) is divided into two components:

\[
\text{PCH} = \int_A \gamma c \, dA \quad \text{PCH} = \int_A \rho c \, D_t \, \frac{\partial c}{\partial t} \, dA
\]

\( \gamma \) is the velocity normal to the interface, \( D_t \) is the turbulent pollutant diffusivity. The mean part \( \text{PCH} \) represents the pollutant transport by mean flow. The fluctuating part \( \text{PCH} \) represents the pollutant transported by turbulence.

**Results and Discussions**

**WR = 1**

The contours of \( \text{PCH} \) and \( \text{PCH}^* \) exhibit similar patterns, implying the dominance of \( \text{PCH} \) in the pollutant entrainment (most contours are negative). On the other hand, \( \text{PCH}^* \) is positive (upward transport) and large, dominating the pollutant removal from the street canyon.

**WR = 2**

The dominance of pollutant removal (positive contours) through the sideward interface near the ground level is a result of the street-level area pollutant source. Though \( \text{TKE} \) is peaked at the windward roof level, pollutant accumulates near the leeward building leading to the elevated \( \text{PCH} \).

**Fig. 4** Contours on the upward interface of Canyon B of WR = 1

The peaks of \( \text{PCH}^* \) and \( \text{TKE} \) locate closely to each other on the sideward interface, signifying the stronger influence of turbulence on \( \text{PCH}^* \).

**Fig. 5** Contours on the sideward interface of Canyon B of WR = 1

The pollutant from Canyon A is carried to the sideward interfaces of Canyon B. It enters into Canyon B following the mean flow (negative contours), recirculation inside the street canyon and is finally removed from Canyon B through the upward interface by turbulence (positive contours in Fig. 4).

**Fig. 6** Contours on the upward interface of Canyon A of WR = 2

1. Unlike WR = 1, the average \( \text{PCH} \) on the upward interface is positive, demonstrating the importance of mean flow in pollutant removal from a wider street canyon.
2. Similar to WR = 1, the pollutant removal on the upward interface by \( \text{PCH}^* \) (positive contours) peak near the sides of the street canyon which is likely the result of the recirculating flow inside the street canyon.

**Fig. 7** Contours on the sideward interface of Canyon A&B of WR = 2

Compare Fig. 3, 5, 7, the pollutant removal in WR = 1 is distributed evenly at the ground level while in WR = 2 is shifted toward the leeward ground level. These dissimilar pollutant transport behaviours are caused by the recirculation of different nature (Fig. 8).

**Fig. 8** Vector profile sampled in \( \beta = 0.5 \) for WR = 2

In fact the pollutant could be transported opposite to the free-stream flow that goes into the upstream along the street below the roof level. This re-entrainment mainly takes place through the sideward interfaces that is less significant in street canyons of larger WRs.

**Conclusions**

1. Generally, pollutant entrainment is dominated by mean flow while pollutant removal is dominated by turbulence.
2. When WR is increased from 1 to 2, the wider canyon enhances the performance of \( \text{PCH}^* \) while \( \text{PCH}^* \) remains the same pattern. Hence, \( \text{PCH} \) is improved.
3. In the roof level of Canyon A, the contribution of \( \text{PCH}^* \) is mainly attributed to the peaks near the sideward interfaces. When the street is widened, these peaks affect less within a smaller region, the overall \( \text{PCH}^* \) performance is weakened.
4. Pollutant could be carried into the upstream canyons which is a process governed by the sideward pollutant removal and entrainment.

**Corresponding Author:** Chun-Ho LIU  
Department of Mechanical Engineering, 7/F Haking Wong Building, The University of Hong Kong, Pokfulam Road, Hong Kong, CHINA  
Tel: (852) 2859 7901; Fax: (852) 2858 5415; liuchunho@graduate.hku.hk

---

**HARMONiS**

13th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes  
Paris, France, 1–4 June 2010