Simplified CFD Modeling of Air Pollution Reduction by Means of Greenery in Urban Canyons

Stefano Lazzari*[1], Katia Perini[1], Eugenia Rossi di Schio[2], and Enrica Roccotiello[3]
1. University of Genova, Dept. of Architectural Sciences, Stradone S. Agostino 37, Genova, Italy I-16123;
2. University of Bologna, Dept. of Industrial Engineering, Viale Risorgimento 2, Bologna, Italy I-40136;
3. University of Genova, Dept. of Earth Sciences, Environment and Life, Corso Europa 26, Genova, Italy I-16132.

Introduction: a simplified model to evaluate the effect of greenery on the possible reduction of pollution in a straight urban canyon (Figure 1) is presented.

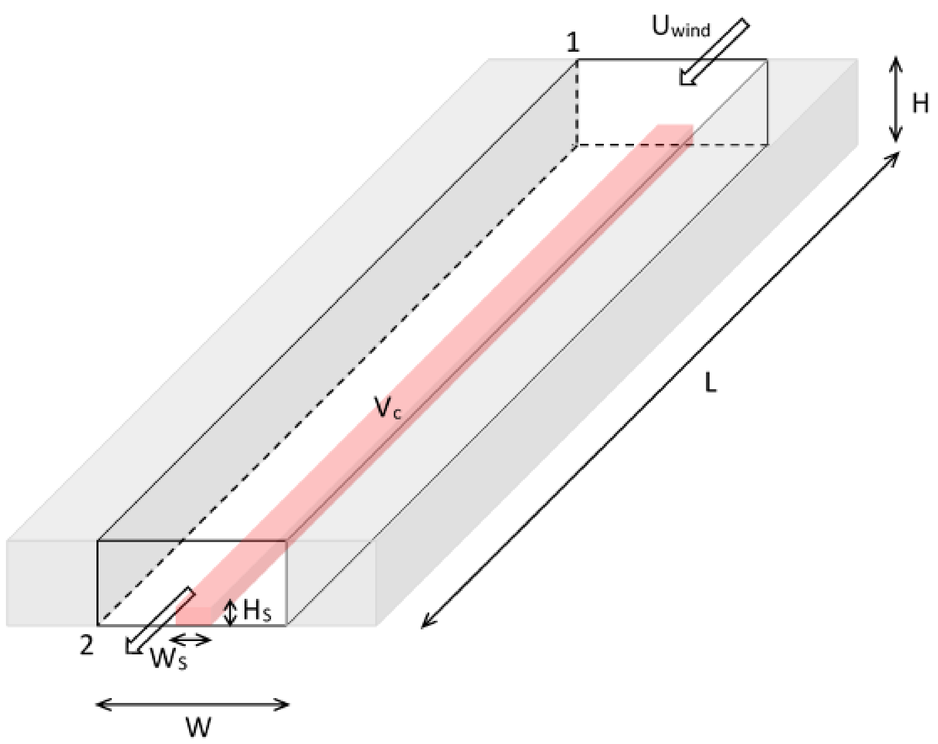

Figure 1. Sketch of the urban canyon.

Computational Method: The governing equations, which are present in the CFD module, are the following ones.

$$\nabla \cdot \mathbf{u} = 0$$

$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot\left\{-p\mathbf{I} + \mu\left[\nabla\mathbf{u} + (\nabla\mathbf{u})^T\right]\right\} + \mathbf{F}$$

$$\frac{\rho}{\varepsilon}\left[(\mathbf{u}\cdot\nabla)\frac{\mathbf{u}}{\varepsilon}\right] = \nabla\cdot\left\{-p\mathbf{I} + \frac{\mu}{\varepsilon}\left[\nabla\mathbf{u} + (\nabla\mathbf{u})^T\right] - \frac{2\mu}{3\varepsilon}(\nabla\cdot\mathbf{u})\mathbf{I}\right\} - \left(\frac{\mu}{\kappa} + \beta|\mathbf{u}| + \frac{Q}{\varepsilon^2}\right)\mathbf{u} + \mathbf{F}$$

$$\nabla\cdot(-D\nabla c) + \mathbf{u}\cdot\nabla c = R$$

Qualitative sketches of the two considered greenery dispositions are shown below (Figure 2).

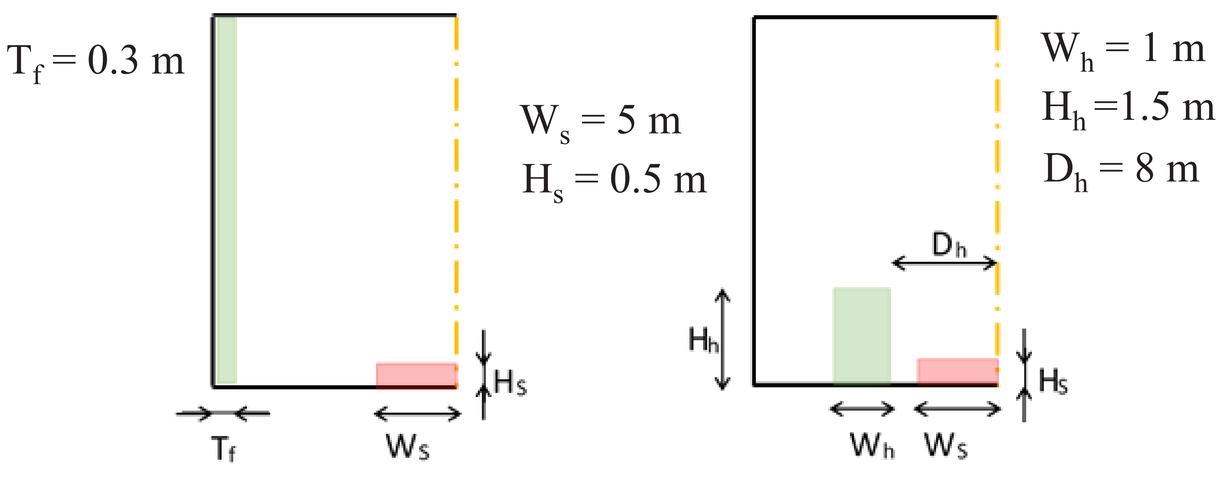

Figure 2. Green façade (left) and green hedge (right)

Greenery is modeled as a Darcian porous medium that absorbs pollutant (diluted specie) according to the reaction:

$$R = -a\,|\mathbf{u}|^{\alpha_1} c^{\alpha_2} \quad \left[\frac{mol}{m^3 s}\right]$$

Pollutant source: cars
Pollutant type: CO_2:

$$S = \frac{n_c}{V_c}\frac{E_c U_c}{M} \quad \left[\frac{mol}{m^3 s}\right]$$

Preliminary results:

Table 1. Effect of greenery for U_{wind}=0.5 ms/s

	pollutant concentration [mol/m^3]		
U_{wind} = 0.5 m/s	clear canyon	green facade	green hedge
plane at 0.3 m from the ground	207.65	184.86	189.87
plane at 1 m from the ground	5.379	0.256	0.272
outlet section of the canyon	14.568	14.472	15.765
overall volume of the canyon	7.107	6.435	6.868

Table 2. Effect of greenery for U_{wind}=3 ms/s

	pollutant concentration [mol/m^3]		
U_{wind} = 3 m/s	clear canyon	green facade	green hedge
plane at 0.3 m from the ground	34.127	27.471	26.862
plane at 1 m from the ground	0.791	0.00489	0.00448
outlet section of the canyon	2.537	1.666	1.860
overall volume of the canyon	1.244	0.832	0.931

Conclusions: The proposed model has been designed to be a flexible tool to predict greenery effect. Indeed, by changing the values of the porosity ε and permeability κ of the porous medium and by tailoring the reduction reaction R (values of a, α_1, α_2), it allows different plant species to be modelled. Planned experimental tests in an innovative chamber will allow the quantification of the "trap-effects" by plants and will help fine-tuning the model.

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