

Inserting vegetation within cities leads to several benefits, including higher deposition of air pollutants, mitigation of the air temperature, regulation of storm water runoff, and creation of recreational areas. However, the aerodynamic effect of vegetation is not always positive for air quality, especially within urban streets. For example, in tree-lined avenues, wind speeds are low and pollutants accumulate at the pedestrian level. Most experimental studies about the aerodynamic effect of trees on street canyon ventilation focus on two-dimensional isolated canyons perpendicular to the external wind. Other wind directions or more complex urban geometries received less attention. Moreover, velocity and concentration turbulent fluctuations were poorly investigated, even though their importance in the vertical exchange between the urban canopy and the external atmosphere. To fill these gaps, we performed concentration, velocity, and simultaneous concentration-velocity measurements within a street canyon, modeled inside the wind tunnel of École Centrale de Lyon. We analysed the turbulent flow and concentration fields within a canyon, considering different street aspect ratio, wind directions, tree densities, and the presence of street intersections. The aerodynamic effect of trees was simulated by placing two rows of plastic miniatures along the canyon's lateral walls. We used ground-level sources of a passive tracer to simulate traffic pollution.

The results show that, with orthogonal wind direction, the presence of trees hinders the upward mean vertical velocity close to the upwind wall and reduces the turbulent kinetic energy and turbulent mass fluxes inside the canyon, with respect to a non-vegetated case. As a consequence, the increase in tree density leads to a strongly heterogeneous spatial pattern of the mean and turbulent concentration field along the canyon. At the rooftop, with high tree density, the mean concentration increases by 75%, moving from the downwind to the upwind wall. Within a wind-aligned street canyon, high density vegetation with touching crowns reduces the mean longitudinal velocity by 80% and decreases velocity fluctuations by 15%, compared to an empty wind-aligned canyon. At the rooftop, the interaction between the external flow and tree crowns leads to 30% increase in velocity fluctuations. As the height-to-width ratio decreases (i.e., for wider canyons), a vegetation-free corridor between the rows of trees results in 25% decrease in mean longitudinal velocity and 30% increase in velocity fluctuations compared to the empty large canyon. This induces a street ventilation more efficient with respect to the vegetated narrow canyon, especially when pollutants are emitted at pedestrian level. With oblique wind direction, the coexistence of longitudinal flow and transversal recirculation within the non-vegetated canyon promotes the entrainment of fresh air from the external flow into the canyon, along the downwind wall, and the accumulation of pollutants in the canyon central core. The presence of trees hinders the longitudinal and transversal mean flows within the canyon, but it enhances turbulent fluctuations and pollutant mixing in correspondence of the downwind tree. This causes an almost zero mean concentration at the downwind wall and in the canyon centre and 70% higher mean concentration at the upwind wall.

The presence of street intersections causes flow detachment regions, dampens the transversal recirculation, increases flow velocity fluctuations with respect to the laterally-closed canyon, especially with oblique wind direction and in the absence of trees. Conversely, trees alter lateral flow structures and partially re-establish the turbulent flow field typical of a canyon without intersections.

In addition to the innovative experimental results, the detailed dataset collected during this thesis can be exploited to validate analytical models and numerical simulations for better urban air quality management.