東北風環境下文化大學華岡校園之香菸污染物軌跡追蹤實驗

A numerical simulation and field observation study of tobacco PM2.5 transport for the CCU campus under winter environmental conditions

黃品豪[1](Pin-Hao Huang) 曾文威[1] (Wen-Wei Tseng) 周暉恩[1] (Hui-En Chou)
欒亭蓁[1] (Ting-Chen Luan) 李珮祺[1] (Pei-Chi Lee) 蘇世顯[1] (Shih-Hao Su)

[1]中國文化大學
[1]Chinese Culture University

摘　要

香菸燃燒後的菸煙污染中，細懸浮微粒(PM2.5)為主要的成分之一。本研究透過觀測與數值模擬方法探討冬季東北風環境下，華岡校園內香菸污染物之傳送機制與傳送軌跡。利用可模擬環境風場與障礙物交互作用之計算流體力學 (Computational Fluid Dynamics,CFD)軟體(陳冠儒, 2018)，模擬產出東北風情境下的文化大學華岡校園之超高解析度地面風場數值資料，並透過氣塊軌跡追蹤分析法，探討菸煙污染物在校園中隨空氣平流的特性。我們依據在數值模擬所推估之菸煙污染物的源與匯，設計使用簡易型空氣盒子校園觀測實驗，並與數值模擬之軌跡分析法進行對比。透過比對空氣盒子與空氣品質測站的觀測資料，顯示簡易儀器之觀測資料與空品測站資料呈現出高度正相關的特性。簡易設備具有良好的精確性，且透過儀器之器差修正，可有效的提高觀測準確度。

透過理想化實驗顯示，菸煙污染物透過擴散過程的傳送效率遠低於由平流過程的傳送效率。換句話說，在短時間內的校園菸煙污染物主要是經由風場平流傳送。而在數值模擬的軌跡分析與觀測實驗中都顯示，校園菸煙污染物的主要來源為校園吸菸區，並在污染物生成後數分鐘內向下游傳送。觀測結果顯示在東北風環境下，地面風會由吸菸區北方沿道路向下游吹拂，同時將吸煙區所產生的菸煙污染物往南(大賢館)傳送。此外，觀測結果也顯示降雨事件對於污染物濃度的影響巨大，污染物的雨洗過程顯著，但亦有機會導致污染源因人為因素更為靠近建築物本身。實驗中同時顯示，校園中背景的PM2.5污染物可能與校園車輛活動有關，但大環境背景濃度不會影響菸煙污染物的傳送。

關鍵字：細懸浮微粒，校園觀測，空氣盒子，軌跡追蹤。

Abstract

PM2.5 is one of the major components of tobacco smoking air pollutants. This study used field observations and numerical simulation to inspect the mechanism of cigarette pollutant transportation and the air pollution trajectories in the Hwa-Kang campus under the background northeasterly wind during the wintertime. We used the computational fluid dynamics (CFD) model (Chen, 2018) to simulate the interaction between the background mean flow and the obstacles (campus buildings). According to the model outputs, we can get the ultra-high-resolution surface wind information of Chinese Culture University's Hwa-Kang campus under the background northeasterly environment. Those wind fields were used to discuss the characteristics of tobacco PM2.5 horizontal advection within the campus. Based on the CFD model outputs analysis, we set up a campus observation experiment with airboxes instruments and compared it with the trajectory analysis of the numerical simulation. Those airboxes were compared to the Taiwan Environmental Protection Administration (EPA) air quality monitoring station and show that the airbox observation data have a highly positive correlation with official operational data. The precision and accuracy of the airboxes are up to the level that can provide good measurement data.

We used a stick of burning incense as a particle pollutant source with fan-induced background mean-flow to represent the mechanism of cigarette pollutant transportation. This idealized experiment shows the efficiency of cigarette pollutant transportation through the diffusion process is much slower than the advection (convection) process. It means the horizontal advection is the prime process of tobacco PM2.5 transportation. The observation experiment and the numerical trajectory analysis indicated that the major source of cigarette pollutants is the smoking area. The tobacco pollutants can be transported downstream within a few minutes. Overall, in the Hwa-Kang campus, the wind came from the north and transported the cigarette pollutant produced in the smoking area to the south (Da-Xian Building) in the wintertime. The observation experiment shows that the wash-out process plays an important role in reducing the concentration of PM2.5. However, we also notice that the change of human activities can also let the source of cigarette pollutants be closer to the building on rainy days.

Key words: PM2.5; Campus observation; Air box; Trajectory analysis.