中文摘要

本研究將通風空間內部視為完全混合，推導通風空間中室內氣懸街塵移除機制之動態方程式，其中考慮紊流膠結(turbulent coagulation)、紊流擴散附著(turbulent diffusive deposition）、重力沉降(gravitational sedimentation)及氣流型態等作用，描述室內氣懸街塵之移除動態行為。以台灣北部都市及郊區之街塵為對象，運用環境氣候箱實驗驗證移除動態方程式。環境氣候箱計六組實驗，其中四組採位移式系統(displacement system)和二組採短循環式系統(short-circuiting system)，分別量測兩區間之質量濃度，並以兩種通風量(210±5及105±3 cm^3 s^{-1}, 空氣交換率為1.04±0.02及0.52±0.01 h^{-1})及兩種微粒產生量(0.1±0.02及0.05±0.01 g min^{-1})進行實驗。

實驗結果顯示台灣北部都市(古亭測站)與郊區(菜寮測站)，氣懸街塵之顆粒粒徑分布可以對數常態分布描述，其中幾何平均粒徑分別為1.01±0.03及1.06±0.02 μm，及幾何標準偏差分別為2.59±0.04及2.62±0.03。以均方根誤差(Root Mean Squared Error，RMSE)檢視移除動態模式模擬之準確性，結果顯示平均RMSE值為0.86±0.34 mg m^{-3} (r^2=0.80±0.02)，顯示模擬結果與實測值極為吻合。因此，本移除動態方程式可以平均粒徑預測通風空間中室內氣懸街塵之移除動態行為。

本研究同時進行模式靈敏度分析，當氣動直徑為1.01±0.03 μm時，考慮三種通風量分別為105、210及315 cm^3 s^{-1}(空氣交換率為0.52、1.04及1.56 h^{-1})，對模式參數進行靈敏度分析，分析結果顯示通風量為影響最鉅之參數。當通風量為105、210及315 cm^3 s^{-1}時，紊流膠結對移除影響較大，紊流擴散附著及重力沉降則次之。實驗結果顯示當通風量為210±5及105±3 cm^3 s^{-1}，微粒產生量為0.1±0.01及0.05±0.01 g min^{-1}時，位移式及短循環式通風系統之環境氣候箱內累積氣懸街塵

濃度範圍分別為73.77±3.78~223.71±13.49及97.88±6.49~311.84±18.13 μg m^3。對應比較得知位移式之累積氣懸街塵濃度較短循環式通風系統低，因此位移式較短循環式通風系統能有效移除氣懸街塵。本研究結果，期能作為通風空間中室內移除或控制室內氣懸街塵質量濃度設計之參考。

關鍵詞： 街塵 ；微粒粒徑分布 ；通風 ；紊流膠結 ；紊流擴散附著 ；重力沉降

Abstract

The main purpose of this research is to derive a dynamic equation for describing the removal mechanisms of airborne road dust from a ventilated airspace. This proposed dynamic equation simultaneously takes into account the removal effects of three dimensionless parameters, turbulent coagulation（TC）, turbulent diffusive deposition（TD）, gravitational sedimentation（GS）, and airflow pattern within a ventilated airspace. Two sets of road dust collected from urban and suburban areas situated in northern Taiwan were used in an environmental chamber test to verify the removal dynamics of airborne road dust. Four displacement associated with two short-circuiting ventilation system modes were conducted in the chamber experiment. Two airflow rates（210±5 and 105±3 $cm^3\ s^{-1}$，AC＝1.04±0.02及0.52±0.01 h^{-1}））with two road dust generation rates（0.1±0.02 and 0.05±0.01 g min^{-1}）were employed to perform the experiment to measure the mass concentration of airborne road dose. Results show that there is no significant variation for particle size distributions of those road dust samples obtained from urban and suburban areas in northern Taiwan, whereas both followed a lognormal distribution with average geometric mean diameters of 1.01±0.03 and 1.06±0.02 μm and geometric standard deviations of 2.59±0.04 and 2.62±0.03, respectively. The RMSE (Root Mean Square Error) is applied to verify the simulation performance of the removal dynamic equation. Measured values match well with the simulated values with a RMSE value of 0.86±0.34 mg m^{-3}（r^2 =0.80±0.02）. Results indicate that we can use an average particle size based linear equation to predict the removal dynamics of airborne road dust within a ventilated airspace. Sensitivity analysis of model parameters reveals that airflow is the dominant parameter in the model. Sensitivity analysis shows that TC is the dominant parameter among TC, TD and GS as the airflow rate is 105, 210 and 315 cm^3 s^{-1} （ACH＝0.52、1.04 and 1.56 h^{-1}）. The experimental results also demonstrate that cumulative mass concentrations of airborne road dust in displacement and short-circuiting ventilation systems are 73.77±3.78 ~ 223.71±13.49 and 97.88±6.49 ~ 311.84±18.13 μg m^3 ,respectively, under airflow rate of 210±5 and 105±3 cm^3 s^{-1} with road dust generation rate of 0.1±0.02 and 0.05±0.01 g min^{-1}, indications cumulative mass concentration in displacement system is lower than that in short-circuiting system. Moreover, the cumulative mass concentrations under airflow rate of 210±5 cm^3 s^{-1} are lower than that under 105±3 cm^3 s^{-1}, in both displacement and short-circuiting ventilation systems. Results also demonstrate that the removal efficiency of displacement ventilation system is higher than that of short-circuiting one. Results obtained from this research are expected to offer designers a control strategy for removal of indoor concentrations of airborne road dust from a ventilated airspace.

***Keywords*:** Road dust; Particle size distribution; Ventilation; Turbulent coagulation; Turbulent diffusive deposition; Gravitational sedimentation