Emerging Persistent Organic Pollutants and Their Oxidative Potential in Fine and Coarse Particulate Matter: A Spatial Assessment Across Taiwan

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Abstract

This study investigates the seasonal variation, chemical composition, emission sources, and oxidative potential (OP) of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), and polychlorinated naphthalenes (PCNs) associated with ambient particulate matter ($PM_{1.0}$, $PM_{2.5}$, and TSP) across Taiwan. From 2021 to 2024, PM samples were collected from northern Taiwan (Taoyuan Industrial Station [TYIS: PM], Taipei Municipal Waste Incinerator [TMWI: $PM_{2.5}$]), central Taiwan (Taichung Industrial [TIS: $PM_{2.5}$], Taichung Traffic [TTS: $PM_{2.5}$]), and southern Taiwan (Fengshan and Nanzih: PM_{10}). Wintertime concentrations of PCDD/Fs, PCBs, and PCNs were markedly elevated at TYIS, driven by local industrial activities and stagnant meteorological conditions. PCDD/Fs peaked in winter at TTS and TMWI (7.16 ± 1.64 and 7.53 ± 8.58 fg WHO-TEQ/m³) and in autumn at TIS (8.29 ± 3.21 fg WHO-TEQ/m³). PCBs were highest in summer (TIS: 0.151 ± 0.212; TTS: 0.006 ± 0.013 fg WHO-TEQ/m³), suggesting volatilization under elevated temperatures, while PCNs exhibited no significant seasonal trends. The DTT assay revealed significantly higher OP at TYIS on weekdays (OPv: $PM_{1.0}$: 1.03 ± 0.22, $PM_{2.5}$: 0.99 ± 0.25, TSP: 1.24 ± 0.22 nmol/min/m³; OPm: 86.4 ± 16.1, 46.3 ± 39.9, 14.9 ± 4.98 pmol/min/μg), whereas central sites showed no significant temporal variation ($p > 0.05$). Southern sites displayed elevated OP during daytime. Spearman correlations identified strong associations between OP and NO_3^- across all PM sizes, with OPv linked to Cu and Cr, and OPm to Mn and Cr. These results highlight particle size, source origin, and seasonality as critical factors in PM toxicity, underscoring the need for targeted mitigation strategies.

Keywords: Persistent organic pollutants, Oxidative Potential, Dithiothreitol assay, Taiwan