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Characterization and Cytotoxicity of POPs and Heavy Metals in TSP and $PM_{2.5}$ from an Electronic Waste Recycling Site, Compared with Five Urban Sites in SE China

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ABSTRACT

This study aims to investigate characteristics of elements, heavy metals / metalloid (Cd, Cr, Cu, Pb, Zn, Mn, Ni, As), persistent organic pollutants (PAHs, PBDEs, PCDD/Fs) in the air from an electronic-waste recycling site and other five urban sites of Guangzhou and Hong Kong in South China, and also the cytotoxicity of air particles on human health.

Air samples of total suspended particles (TSP), and particles with aerodynamic diameter smaller than 2.5 μm ($PM_{2.5}$) were collected simultaneously at Guiyu (an e-waste recycling site), two urban sites in Guangzhou (Li Wan, Tian He) and three urban sites in Hong Kong (Yuen Long, Tsuen Wan, Hok Tsui) in summer (from 16 August to 17 September 2004) and winter (from 1 February to 7 March 2005). The total concentration of $PM_{2.5}$ ranked in the order of two urban sites in Guangzhou (LW and TH) (52.8-76.6 μg m^{-3}) > e-waste site (GY) (50.5 μg m^{-3}) > two urban sites in Hong Kong (YL and TW) (44.0-49.6 μg m^{-3}) > the background site in Hong Kong (HT) (31.5 μg m^{-3}). The same order was found for TSP concentrations.

In terms of elemental species in the $PM_{2.5}$, Guiyu contained high S (3204 ng m^{-3}), Cl (1175 ng m^{-3}), Guangzhou contained high S (5434-7522 ng m^{-3}), K (1038-1555 ng m^{-3}), and Si (696-935 ng m^{-3}), while Hong Kong contained high S (4463-5086 ng m^{-3}).

Concentrations of Cr, Cu and Zn (especially Cr and Zn) in Guiyu in $PM_{2.5}$ were 4-33 times higher than other Asian metropolitan cities, such as Tokyo, Shanghai, Ho Chi Ming, Taichung and Seoul. In general, the concentrations of heavy metals in both TSP and $PM_{2.5}$ followed the order of [Cr]>[Zn]>[Pb]≈[Cu]>[Mn]>[Cd]≈[Ni]≈[As]. There were

significant correlations between Cd, Cr, Cu, Pb, Zn, Mn concentrations in TSP and those in $PM_{2.5}$, except Ni and As. In general, there were significant correlations between concentrations of individual contaminants in TSP with $PM_{2.5}$ (i.e. PAHs, Cd, Cr, Cu, Pb, Zn, Mn except Ni and As).

The total sum of 16 USEPA priority polycyclic aromatic hydrocarbons (PAHs) associated with TSP and $PM_{2.5}$ in Guiyu ranged from 40.0 to 347 and 22.7 to 263 ng m^{-3}, respectively. Five-ring and six-ring PAHs accounted for 73% of total PAHs. The average concentration of BaP in Guiyu (8.85 in $PM_{2.5}$, 15.4 ng m^{-3} in TSP) was 2-20 times higher than other Asian cities, such as Guangzhou (1.89 ng m^{-3} in TSP) and Hong Kong (0.59 ng m^{-3} in TSP), Tehran (4.02 ng m^{-3}), Delhi (4.99-9.56 ng m^{-3}), Bombay (5.6 ng m^{-3}), Tokyo (2.0-2.9 ng m^{-3}), and Singapore.

Twenty-two polybrominated diphenyl ethers (PBDE) congeners (BDE-3, -7, -15, -17, -28, -49, -71, -47, -66, -77, -100, -119, -99, -85, -126, -154, -153, -138, -156, -184, -183, -191) in TSP and $PM_{2.5}$ were selected. The results showed that the monthly concentrations of the sum of 22 BDE congeners contained in TSP and $PM_{2.5}$ at Guiyu were 21.5 and 16.6 ng m^{-3}, with 74.5 and 84.3%, contributed by nine congeners (BDE-28, -47, -66, -100, -99, -154, -153, -183 and -191 respectively). The two urban sites of Guangzhou and Tsuen Wan of Hong Kong had a similar congener pattern, but not Yuen Long and Hok Tsui of Hong Kong. The results also showed that mono-penta brominated congeners, which are more toxic, accounted for 79.4-95.6% of Σ_{22}PBDEs from all sites. All congeners tested in Guiyu were up to 58-691 times higher than the studied urban sites of the present study and more than 100 times higher than elsewhere (the continent of Europe and Asia, Canadian Arctic and Siberia).

Ambient air concentrations of the 17 polychlorinated dibenzo-p-dioxins /dibenzofurans (PCDD/Fs) which sampled simultaneously on September 10th 2004 in Guiyu, Guangzhou and Hong Kong were measured. The concentration of PCDD/Fs in Guiyu was 6521 fg/m^3, which was 1.5 times of Guangzhou and 3.1 times of Hong Kong. Total TEQ of Guiyu, Guangzhou and Hong Kong air samples were 590, 202 and 137 fg I-TEQ/m^3, respectively. The concentration of 2,3,7,8-TCDD in Guiyu was up to 54 fg/m^3, which exceeded the whole year standard (30 fg/m^3) of USA (Indiana, Kansas and Washington).

Thus Guiyu was ranked as the most polluted site in terms of PBDEs, PCDD/Fs, PAHs and heavy metals contents in TSP and $PM_{2.5}$ among all the studied sites of the present study. Cytotoxicity of the extract of TSP and $PM_{2.5}$ (ten 24 h samples collected) against human promonocytic leukemia cell line U937 (ATCC 1593.2) was determined by MTT (3-(4,5-dimethylthiazol-2-yl) -2,5-diphenyltetrazolium bromide) cytotoxicity assay. The results showed that under the same concentrations of extract, $PM_{2.5}$ cytotoxicity was 2-4 times higher than TSP.

The higher concentrations of heavy metals and POPs in the air of Guiyu were due to heating or opening burning of electronic waste, while the air of other urban sites in Southeast China contained relatively high concentrations of heavy metals and POPs, resulted in high cytotoxicity.

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