DOCTORAL THESIS

Assessment of persistent toxic substances in China and Hong Kong with emphasis on uncontrolled recycling of e-waste

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Assessment of Persistent Toxic Substances in China and Hong Kong with Emphasis on Uncontrolled Recycling of E-Waste

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ABSTRACT

This study involved the participation in a global initiative "Regionally Based Assessment of Persistent Toxic Substances" (RBA PTS) implemented by the United Nations Environment Programme (UNEP) focusing on the identification of sources, fates and impacts of persistent toxic substances (PTS) on environment and human health. For the Central and North East Asia Region, PCDD/Fs, PCBs, PAHs, DDTs and HCH were identified as high priority in terms of sources, especially PCDD/Fs and PAHs which are released into the environment as unintentional byproducts of manufacturing and combustion processes. The open burning of waste, in particular uncontrolled recycling activities involving e-waste, became a clear concern in contributing toxic PTS into the environment. This issue led to the investigation of the concentrations and distribution of PTS and heavy metals in the environment of Guiyu, a small town in northeast Guangdong Province, China, intensely involved in the recycling of electronic waste.

Combusted residue and soil samples collected from Guiyu revealed that PBDE levels were highest in combusted residue of plastic cables and wires and plastic chips nearby a residential area (30000-97400 ng/g, dry wt), soils at an acid leaching site (2720-4250 ng/g, dry wt.), a printer roller dump site (593-2890 ng/g, dry wt.) and at a duck pond (263-604 ng/g, dry wt.). BDE-209 was the most dominant congener and accounted for 35-82% of the total PBDE concentrations among the study sites. The average concentration at the acid leaching site was approximately 638 times higher than the highest reported background concentration (i.e. 5.6 ng/g, UK woodland soil). PCDD/Fs concentrations were also highest at the acid leaching site (12500-89800 pg/g, 203-1096 pg WHO-TEQ/g, dry wt.) and in combusted residue (13500-25300 pg/g, 84.3-174 pg WHO-TEQ/g, dry wt.). The average 2,3,7,8-TCDD equivalent concentration at acid leaching site (506 pg WHO-TEQ/g) exceeded the Canadian soil guidelines by 127 times and the US EPA Region 9

risk-based criteria for the protection of humans by approximately three times. In general, there appeared to be relatively mild contamination by PAHs (<2 mg/kg) in Guiyu with higher levels at open burn sites (11 – 19 mg/kg).

A human health risk assessment using exposure factors based on US EPA's Exposure Factors Handbook indicated that of the three possible exposure pathways to PBDEs, PCDD/Fs and PAHs, namely soil ingestion, dermal absorption and inhalation of fugitive dust from soil, soil ingestion would account for 73-93% of the average daily intake. The maximum potential average dose of PCDD/Fs by a child via soil ingestion at the acid leaching site was calculated to exceed the upper bound of the WHO 1998 advisory for tolerable daily intake by 3.5 times, an indicated a high noncancer toxic health risk. Cancer risk for a child was estimated to be moderate (a 180 in a million chance of getting cancer if the lifetime average intake of PCDD/Fs from soil ingestion was 1.20 pg TEQ/kg-bw/day). Noncancer and cancer risks for adult were found to be low. Calculated hazard indices for the ingestion pathway of penta-, octa- and deca-BDEs and PAH compounds indicated minimal health risks.

Lead concentrations (average 110000 mg/kg) in dust from printed circuit board recycling workshops were 269-2426 times higher than the New Dutch List optimum value. The calculated hazard quotients (HQ) for child scenario dust ingestion exceeded the "safe" reference dose level by 753. For an adult, the HQ was 40.3; 19 times lower than that predicted for a child. Copper, Ni and Zn concentrations in dust also exceeded the New Dutch List optimum values by 31-994, 2-228, and 7-73 times, respectively.

The results of this study indicated that soil in some selected land uses were contaminated with PCDD/Fs, PBDEs and to a lesser extent to PAHs and that the open burning of e-waste was a hotspot for PCDD/Fs and PAHs. Exposure to PCDD/Fs via soil ingestion by children may cause toxic noncancer health effects. Dust from printed circuit

board workshops and from streets in the the printed circuit board recycling district of Guiyu contained highly elevated concentrations of heavy metals, in particular Pb and Cu, and have the potential to pose serious environmental and human health risks.

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