DOCTORAL THESIS

Hazardous air pollutants from the waste incineration industry: formation mechanisms, distribution characteristics, and potential environmental risks

Wang, Chen

Date of Award:
2020

Abstract

In this study, the formation mechanisms, distribution characteristics, and potential environmental risks of hazardous air pollutants from industrial-scale waste incineration processes were investigated.

First, to clarify the dominant formation mechanism of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) in a hazardous waste (HW) incinerator, three tests were designed by adding different precursors in phenol-containing raw materials. With the addition of p-dichlorobenzene, PCDD/F levels at the quenching tower outlet were ten times higher than levels observed at the inlet. This indicates that the quenching tower failed to suppress the formation of PCDD/Fs and surface-mediated precursor reaction is the dominant formation mechanism in low-temperature stages. Besides, adsoprtive memory effect in air pollution control devices (APCDs) also led to high PCDD/F emissions. These findings suggest that to control PCDD/F emissions, strict regulation of chlorine contents in feed materials and frequent cleaning of APCDs are necessary.

Meanwhile, single particles and solid residues were collected from the same HW incinerator. Morphologies and elemental compositions of particles in flue gas and indoor air were characterized by transmission electron microscopy-energy dispersive X-ray spectrometry (TEM-EDS). Eight types of single particles were classified, as organic, soot, K-rich, S-rich, Na-rich, Fe-rich, mineral and fly ash particles. The heavy metal partitioning behavior study suggested that Hg, Cd and Pb were mainly enriched in fly ash through evaporation, condensation, and adsorption; while Cr, Cu, Mn, and Ni were mostly remained in the bottom ash due to their low volatilities.

In addition, the study also investigated environmental behaviors of certain characteristic pollutants. Thrity-two soil samples surrounding a cement plant co-processing HW were collected and analyzed for the presence of 16 polycyclic aromatic hydrocarbons (PAHs) and 12 heavy metals. Ten samples were selected for PCDD/Fs analysis. The highest concentration of PCDD/Fs occurred 1200 meters downwind from the cement plant. Levels of $\sum 16$ PAHs ranged from 130.6 to 1134.3 μg/kg in soil. Source identification analysis suggested that the cement plant was the most likely source of PAH contamination. The concentrations of Cd and Hg were on average two times and six times higher than background values, respectively. Both incremental lifetime cancer risk model (ILCR) for PAHs and potential ecological risk index (RI) for heavy metals indicate potential risks to the population and the environment surrounding the cement plant.

Last, to identify whether waste incineration is a major source for airborne environmentally persistent free radicals (EPFRs), tree leaf samples were collected from 120 sites surrounding four waste incinerators and one urban area. EPFR concentrations on leaves ranged from 7.5×10^{16} to 4.5×10^{19} spins/g. For the 10 N.D. samples, they were all collected from areas inaccessible by vehicles. Although previous work has linked atmospheric EPFRs to waste incineration, the evidence in this study suggests that vehicle emissions, especially from heavy-duty vehicles, are the main sources. According to our estimation, over 90% of the EPFRs deposited on tree leaves might be attributed to automotive exhaust emissions, as a synergistic effect of primary exhausts and degradation of aromatic compounds in road dust.

Keywords: Waste incineration, PCDD/Fs, PAHs, Heavy metals, EPFRs, Primary particles, Formation Mechanism, Spatial distribution, Environmental risk assessment.

Table of Contents