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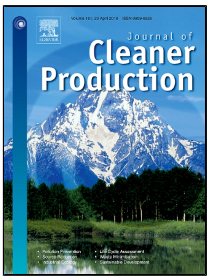

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Two-step pre-processing enrichment of waste printed circuit boards: Mechanical milling and physical separation

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Abstract

Printed circuit boards (PCBs), one of the most complex components of e-waste, contain different metallic and non-metallic components. Recycling of waste PCBs is an important issue, from both aspects of hazardous waste management and recovery of valuable materials. In this study, for the first time, a mechanical-physical separation method for recovery of metallic elements of waste PCBs without any chemical or/and thermal processes was introduced. Two milling stages were applied to enhance the liberation degree, followed by a physical flotation process for enrichment. Based on the elemental analysis, the total metal concentration increased by 75% after the second milling in coarser particle size classifications and ceramic components has decreased significantly. Phase identification techniques confirmed that the ceramic portion is mainly $CaO+SiO_2+Al_2O_3$, which generally exist inside the boards as glass fibres. Using Fourier transform infrared spectroscopy (FTIR) spectra 3 nominees of phenoxy resin, poly vinyl acetate and vinyl chloride were suggested as the major polymer content of the crushed waste PCBs. Scanning electron microscopy (SEM) demonstrated higher degree of liberation in the higher meshes for metallic and non-metallic components but it was lower for fibre glasses. The thermal pyrolysis using infrared gas analyser proved that the most volatile substances are not simple greenhouse gases such as CO, CO_2 and CH_4. Eventually, beneficiation using bromoform+acetone resulted in two