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Environmental and economic evaluation of cathode ray tube (CRT) funnel glass waste management options in the United States

Qingbo Xu [1,2,3], Mengjing Yu [3], Alissa Kendall [4], Wenzhi He [1,2], Guangming Li [1,2], Julie M. Schoenung [3]

[1] College of Environmental Science and Engineering, Tongji University, Shanghai 200092, China
[2] State Key Laboratory of Pollution Control and Resource Reuse, Tongji University, Shanghai 200092, China
[3] Department of Chemical Engineering and Materials Science, University of California, Davis, CA 95616, USA
[4] Department of Civil and Environmental Engineering, University of California, Davis, CA 95616, USA

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Electronic waste (e-waste) contains a wide variety of heavy metals that are detrimental to human and environmental health if they are not disposed of properly. Cathode ray tube (CRT) funnel glass is an important component of the growing volume of end-of-life CRT television and computer monitor waste. CRT glass contains 14-23% of lead (Pb) by weight, which is necessary for protecting monitor users from the cathode ray radiation and for connecting various glass pieces together. However, the large amount of lead contained in the CRT funnel glass creates a serious problem when the CRT glass products reach their end-of-life because lead can escape into the environment and cause severe damage to humans and the environment. Small amounts of lead exposure can result in adverse central nervous system damage that leads to headaches, behavior problems, reproductive issues, and cognitive deficits in children. Despite these well-known health effects, CRT funnel glass still faces improper disposal fates. In recent years, various researchers have investigated the environmental or economic impacts related to CRT glass recycling. These investigations have focused on the collection, dismantling, and materials recovery of various CRT glass recycling processes. Despite these previous investigations, a systematic evaluation of the economic and environmental attributes of various waste management options for CRT funnel glass specifically, especially at the detailed process level, does not exist. In this paper, environmental impacts and economic feasibility of four currently available and one novel CRT funnel glass waste management options are compared and discussed [1].

Five waste management options were evaluated from environmental and economic standpoints: hazardous waste landfill, municipal waste landfill, pyrometallurgy, closed-loop recycling, and hydrometallurgy. Two life-cycle assessment (LCA) methodologies: CML2001 and Eco-Indicator 99, were utilized. With CML2001 the following impact categories were considered: (1) depletion of abiotic resources (abiotic depletion potential, ADP), (2) acidification (acidification potential, AP), (3) eutrophication (eutrophication potential, EP), (4–6) eco-toxicity (marine aquatic, freshwater aquatic and terrestrial eco-toxicity potential; MAETP infinite, FAETP infinite and TETP infinite, respectively), (7) climate change (global warming potential, GWP 100 years), (8) human toxicity (human toxicity potential, HTP infinite), (9) stratospheric ozone depletion (ozone layer depletion potential, ODP steady state) and (10) photo-oxidant formation (photochemical ozone creation potential, POCP). With Eco-Indicator 99, human health, ecosystem and resources depletion impacts were analyzed. Life-cycle assessment is conducted using GaBi 4. Economic feasibility was analyzed using technical cost modeling (TCM). Overall costs for each waste management option consisted of two categories: variable costs and fixed costs. Variable costs included labor, utilities and material costs. Fixed costs included equipment and facility costs. Transportation costs were investigated separately due to variations in transportation distances. Revenues derived from fees charged to customers and sales from recovered materials were considered.

LCA results showed that all five CRT funnel glass waste management options contribute to greenhouse gas emissions because of the need to transport CRT funnel glass to disposal and recycling sites. Sensitivity analysis results highlighted that transportation distances for the three recycling options need to be reduced by approximately 75% for these effects to become negligible. LCA results also show that landfill options have harmful impacts on human health while the recycling options reduce human health impacts. Sensitivity analysis showed that the HTP inf. value for the pyrometallurgy and landfill options exhibit higher sensitivity to key process parameters because of the potential for lead emissions. TCM analysis showed that the transportation cost accounts for approximately 26-45% of the overall waste management cost. The recycling options are more profitable than the landfill options. Sensitivity analysis showed that closed-loop recycling and pyrometallurgy options are more sensitive to changes in transportation distance than the hydrometallurgy option. However, closed-loop recycling and pyrometallurgy options remain profitable across the spectrum of -75% to +75% variations in baseline distance, while hydrometallurgy is no longer profitable after transportation distance increases to more than 75% of the baseline. Overall, landfill options are the least environmentally friendly and least profitable options. Closed-loop recycling is the best option in countries where CRT glass still has a market, but it is not a feasible option for U.S. recyclers. Both environmental and economic evaluation showed that transportation has a large impact on the sustainability and profitability of the CRT funnel glass waste management options. Overall, pyrometallurgy and hydrometallurgy are the most feasible recycling options to implement in the United States. While pyrometallurgy appears to be more sustainable and economical, hydrometallurgy has more opportunities for improvements in process sustainability and for use on-site further improving sustainability and profitability.

[1]. Qingbo Xu, Mengjing Yu, Alissa Kendall, Wenzhi He, Guangming Li, Julie M. Schoenung, "Environmental Life Cycle and Economic Assessment of CRT Funnel Glass Waste Management Options," *Resources, Conservation and Recycling 78 (2013) 92-104; doi:10.1016/j.resconrec.2013.07.001*