Investigating Informal E-Waste Recycling Methods and Associated Soil Pollution

Key words: environmental pollution, heavy metals, e-waste, recycling, informal, Delhi

Where does your computer go to die? Electric and electronic waste (e-waste) contains hazardous materials and much of it is processed with few environmental controls. Annually, an estimated 20 to 50 million tons of e-waste is produced worldwide[1] and due to the substantial amount of labor involved in the recycling of electronic devices, many e-waste dealers turn to developing economies for processing[2]. Policies designed to address the movement of e-waste recycling increasingly require robust scientific evidence of toxic leaching and the nascent body of evidence describing the environmental effects of unregulated or informal e-waste recycling is largely anecdotal[3, 4]. The few empirical studies have operated at an inappropriate scale to make associations between processing categories and associated levels of pollution[5]; have analyzed policy at a more global scale[2, 6]; or have focused on pollutant leaching in a laboratory setting as a proxy for environmental leaching[7]. The recent US Government Accountability Office report (GAO-08-1044, August 2008) criticizing the US EPA's handling of e-waste highlights the relevance of this research. My study will make a significant contribution to both research and policy by addressing this gap in scale and context and by testing for robust associations between quantified pollutant levels and specific e-waste industrial processes in the field environment.

This investigation will classify and map e-waste recycling operations and quantify associated pollutant levels in the soil. **Hypothesis:** *the concentrations of key pollutants in the soil will increase in association with more destructive recycling processes (e.g. repair and resale will be associated with lower toxin concentrations as compared with smashing cathode ray tubes for the copper yokes).*

Methods: My proposed field site is Delhi, India, due to the city's established e-waste recycling industry and well-documented specialized processing areas[4, 8]. I will collaborate with the following non-governmental organizations in the United States and on-site in India: Silicon Valley Toxics Coalition; Toxics Link, Delhi, India; and Chintan Environmental Research and Action Group, Delhi, India. Base maps of Delhi will be collected from map archives, university departments, and government offices. These will include streets and historical land use to assist in navigation and pollutant baseline controls; elevation for surface/hydrological modeling; and geology, soils, and streams for environmental controls. Additional information will be gathered from public records if historical maps are not available. All data will be translated into geographic space, and digitized in a Geographic Information System, with coordinate systems defined, projected and transformed as necessary. Following this, key individuals from local NGOs, government offices, and universities will be interviewed to provide qualitative data for three critical components: types of e-waste recycling operations in Delhi, site locations, and historical land use not captured in the base map construction.

Combining the results of these interviews with published literature on recycling processes[8, 9], a series of recycling operation categories will be categorized (e.g. one code for gold extraction from printed circuit boards using acid-baths versus another code for cell-phone refurbishment), resulting in approximately 3-5 analytical codes. Information gained in the interviews will be verified and geo-located in the field by surveys assisted by a differentially corrected geographic positioning system (GPS). Using the population of coded recycling operations, a stratified simple random sample of individual recycling sites within each code will be selected. Soil analysis will primarily be performed with a field-portable x-ray fluorescence analyzer (fp-XRF), supplied by Ron Amundson's lab, based in the Department of Environmental Science, Policy and Management at UC Berkeley. The fp-XRF will be calibrated for lead, arsenic, cadmium, bromine, mercury, and chromium, toxic elements most commonly associated with e-waste[2]. All samples collected and fp-XRF readings will be catalogued with geographic coordinates using GPS.

The first sampling phase will define pollutant plumes and concentration strata using transect sampling with the fp-XRF. Systematic random sampling will assign sampling locations within each plume strata. *In situ* soil readings and *ex situ* samples will be collected during the second phase. To aid in precision and bias control, two methods will be employed: 1) one randomly selected site will provide field calibration values by double sampling: *ex situ* soil samples and *in situ* readings 2) 20% of all *in situ* readings will be accompanied by *ex situ* samples at remaining sites as a further control for environmental variations[10].

Potential sources of error include sampling design insensitivity to local variations, sampling obstructions at individual sites, non-soil ground-cover (mitigated by alternate collection protocol for dust using thin-sample), dynamic environmental conditions (mitigated by hydrologic modeling or averaging multiple series), and changing land use at observation sites (mitigated by a study design with more sampling sites than necessary).

After *ex situ* soil samples have been laboratory tested, all soil data will be digitized and geo-referenced. *In situ* readings will be calibrated against quantitative laboratory results producing a measure of estimated bias. Multivariate Analysis of Variance (MANOVA) will be used to assess the combination of toxin concentrations against the categories of recycling processes. Additional variables will be tested for inclusion in the model such as historical land use and environmental features such as slope and soil type. Weights will be applied in the model for the concentration strata and to control for spatial autocorrelation. Covariance will be addressed in the MANOVA model.

Anticipated Results: As the recycling process becomes more destructive, the concentrations of key soil pollutants are expected to increase. The results of this study can aid more precise targeting of particular waste-handling practices for environmental controls, thus facilitating a more nuanced approach to improving e-waste recycling operations. Methods used in this project could also be replicated in other locations to examine environmental contamination associated with formal and informal e-waste recycling.

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