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Global approaches to environmental exposure – assessment of e-waste

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INTRODUCTION & OBJECTIVES

The waste stream of obsolete electronic equipment grows exponentially, creating a worldwide problem.

e-waste issues are complex, multi-faceted and can only be successfully tackled via a multidisciplinary, trans-boundary approach that involves all stakeholders that include amongst others: manufacturers, scientists, economists, policy makers, waste professionals and consumers.

The e-waste project aims to highlight:

- i) discrepancies in the provision and enforcement of regulations between developed and emerging countries;
- ii) complexity in the analysis of e-waste contaminants in environmental and biological samples; and
- iii) A harmonised approach should be taken to use compound-specific trace analysis

METHODOLOGY

- A systematic literature review on four key aspects: a) chemical analysis; b) environmental and health impacts; c) recycling and treatment of e-waste and d) governance. The review using databases such as: ISI Proceedings, JSTOR Search, Scopus, Web of Science, PubMed
- Case study analysis from many different countries

RESULTS & DISCUSSION

The e-waste stream comprises of a heterogeneous mix of different metals, metalloid, glass, plastics, flame retardants and valuable materials such as gold, silver, copper and aluminium (Fig. 1). A sizeable amount of e-waste has been discarded in developing countries due to the high cost of safe recycling processes and stringent regulations in developed countries (Fig. 2).

In developed countries, e-waste management revolved around two major strategies: recycling or disposal in their own countries, or exportation to other countries (developed and developing).

In developing countries, the management of e-waste is rudimentary (e.g. dismantling, chipping, melting and burning are often used by the informal sector to recover valuable materials from different e-waste components) and hazardous (Table 1, Fig. 2). These unofficial recycling practices contribute to the release of toxic metals and persistent pollutants that affect both the environment and human health. It is further complicated by illegal import of the waste, hindered by lack of technology, undermined by weak environmental regulations and constrained by inadequate organizational structure.

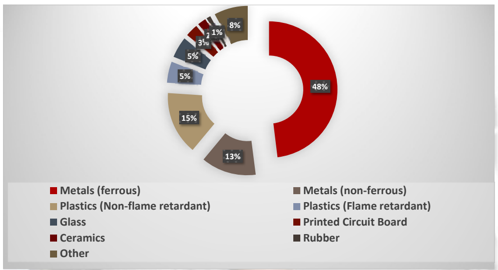

Fig. 1: Material constituent of some equipment that end up as e-waste

Fig. 2: Transboundary routes of e-waste transport[1]

Table 1. Examples of informal recycling activities around the world.

Activities	Country										
	China	Egypt	Ghana	India	Indonesia	Nigeria	Pakistan	Philippines	South Africa	Uruguay	Vietnam
Physical dismantling using bare hands and simple hand tools such as hammers, chisels screw drivers to separate different material	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Removing components from printed circuit boards by burning	✓	✓	✓	✓		✓	✓				
Printed circuit boards sold to informal exporters for further treatment		✓	✓		✓		✓	✓		✓	✓
Stripping of metals in acid baths	✓			✓					✓		
Crushing and/or melting plastics	✓		✓		✓		✓	✓		✓	✓
Burning cables to recover precious metals	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Manual stripping of wires					✓			✓			✓
Burning unwanted materials in open air	✓		✓			✓					
Disposing unsalvageable materials in fields/landfill/riverbanks	✓		✓	✓		✓		✓		✓	
Refilling of toner cartridges	✓					✓					

Over the last decade, a large body of knowledge has emerged on the risk posed to the environment in e-waste recycling sites (Table 2). It is apparent that there is a lack of harmonisation of tools or indices to assess risk in environment and health, particularly in soil.

Default risk assessment methods frequently **overestimate** exposure by assuming that a chemical will be equally bioavailable in all media, irrespective of the properties of the environmental media or the chemical form of the contaminant.

Using total pollutant concentration in health risk models like to overestimate the potential daily intake of contaminants from informal e-waste recycling sites. Whereas, bioavailability and bioaccessibility data provide more accurate assessment of the risk.

Fig. 3: Informal recycling activities in developing countries

Table 2. Criteria used in literature to assess risk in e-waste recycling sites.

Criteria	Examples
Pollutant's total concentration	Heavy metals in surface dust in India[2]
Considering the bioavailability of the pollutants	Heavy metals in soils from Nigeria[3], dechlorane plus in soil from China[4], heavy metals in soil from Ghana[5]
Considering the bioaccessibility (physiological based extraction test)	Pb in Philippines[6], heavy metals in China[7,8]
Compare with Regulatory benchmarks and control sites	Heavy metals in groundwater[9] and well water[10] in China, soil in India[11]
Using pollution indices	PAHs in soil in China[12], PCB and BFRs in dust in Vietnam[13], heavy metals in soil in China[14] and Ghana[15]
Using risk models to examine exposure pathways	Dioxin/PCDD/Fs in soil[16] and heavy metals in air in China[17,18]

PAHs = Polycyclic aromatic hydrocarbons; PCB = Polychlorinated biphenyl; BFRs = Brominated flame retardants; PCDD/F = Polychlorinated dibenzo-*p*-dioxins and dibenzofurans

CONCLUSION

i) Significant discrepancies exist in the provision and enforcement of regulations between developed and emerging countries.
ii) The analysis of e-waste contaminants in environmental and biological samples is complex and challenging.
iii) Conceptual models should be used to ascertain the source-pathways-receptors route of the pollutants
iv) Currently, there is lack of harmonisation of tools or indices to assess risk in environment and health, particularly in soil.
v) It is proposed that a harmonised approach should be taken to use appropriate speciation analysis (e.g. to assess bioavailable or bioaccessible fractions) to evaluate e-waste contaminant risk.

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IUPAC project webpage: https://iupac.org/projects/project-details/?project_nr=2014-031-3-600

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