E-waste: Chemical hazards and policy suggestions for safer management

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Institute for Global Environmental Strategies (IGES)

- **Founded in 1998 by the Government of Japan**
- **Policy research institute working to promote Sustainable Development in the Asia-Pacific region**
- **Focus areas: Climate Change, Natural Resource Management, Sustainable Consumption and Production**
- **Around 80 professional staff**
- **More details at www.iges.or.jp**

Photo: Yasuhiko HOTTA

E-waste related research at IGES

- **E-waste is addressed by the Sustainable Consumption and Production group in its research components dealing with sustainable waste management and chemicals management**

- **"Regional Information Sharing System", a project funded by the Government of Japan in 2008-2011, explored the feasibility of a regional system for sharing information on chemicals in EEE:**
  - **Human health and environmental risks of recycling**
  - **Information needs and benefits of information sharing**

- **IGES is involved in the SAICM/UNEP project on Chemicals in Products (CiP), both as a member of the steering group and as a contributing author of a case study on electronics.**

Outline of the presentation

1. **Chemical hazards associated with e-waste recycling**

   - **End-of-life treatment and hazards involved**

   - **Environmental and human health impact**

2. **Policy suggestions for safer management**

   - **Developing countries**

   - **Developed countries**

2. **Summary**

1. Chemical hazards associated with e-waste recycling

Hazardous content of e-waste

Components	Found in	Substances of concern
Cathode ray tubes	Old TV sets, PC monitors, oscilloscopes	Pb in cone glass Ba in electron gun getter Cd in phosphors
Printed circuit boards	Ubiquitous, from beepers to PCs	Pb, Sb in solder Cd, Be in contacts Hg in switches BFRs in plastics
Batteries	Portable devices	Cd in Ni-Cd batteries Pb in lead acid batteries Hg in Hg batteries
Gas discharge lamps	Backlights of LCDs	Hg
Plastics	Wire insulation, plastic housing, circuit boards	Polyvinylchloride Brominated flame retardants

Formal and informal e-waste recycling

Formal

- **Registered companies**
- **Expected to comply with existing laws and regulations**

Informal

- **Common in developing countries**
- **Unregistered, small scale business**
- **Simple recovery techniques targeting a few valuable substances**
- **No protection of workers/the environment**

There is an emerging formal e-waste recycling sector **in developing countries. However, this industry finds it difficult to compete with the established informal sector due to:**

– **Insufficient access to end-of-life items, lack of collection channels**

– **Higher treatment costs**

Typical e-waste treatment scenarios: developed vs. developing

Developed countries	Developing countries
Formal recycling: • **Manual disassembly** • **Semi-automatic separation** • **Recovery of metals by state-of-the-art methods in smelters and refineries**	Informal recycling: • **Manual disassembly** • **Manual separation** • **Recovery of metals by heating, burning and acid leaching of e-waste scrap in small workshops**
Incineration **with MSW, advanced flue gas treatment, landfill disposal of ashes**	Open burning
Landfill disposal	Open dumping

Chemical hazards are present at all stages of recycling/disposal

Disassembly → **Size reduction and separation** → **Recovery of metals** → **Final treatment**

Disassembly	Size reduction and separation	Recovery of metals	Final treatment
Removal of hazardous components	Shredding	Smelting/ acid leaching	Incineration and landfilling/open burning and dumping

Hazards

Disassembly	Size reduction and separation	Recovery of metals	Final treatment
Leakage and accidental spill of hazardous substances CRTs: Pb, phosphors Hg switches: Hg Backlights: Hg Batteries: Cd, Pb, Hg	Formation of dust particles containing plastics, metals, ceramic and silica	Emission of metal/acid fumes, mixed chlorinated and brominated dioxins and furans (PXDD/Fs)	Emission of metal fumes, PXDD/Fs Leaching of heavy metals and BFRs

Mitigating the hazards of recycling

Disassembly and separation are the crucial steps **that determine the safety of the process and material recovery rate. Hazardous components need to be removed for a separate treatment.**

Further treatment steps require adequate infrastructure and technologies to mitigate the associated hazards:

- **Dust containment systems (in shredding facilities),**
- **Flue gas, fly and bottom ash capture and treatment systems (in smelters and incinerators),**
- **Lining and leachate and gas collection systems (in landfills).**

Negative impact of informal recycling

Well documented and highly convincing scientific evidence*:

- Workplace and environmental pollution

  - Extremely high concentrations of e-waste related chemicals

  - Chemicals detected are those incorporated into EEE (e.g., metals, PBDEs) or generated through processing of e-waste (PXDDs/Fs).

  - Process chemicals used for metals leaching are simply discarded

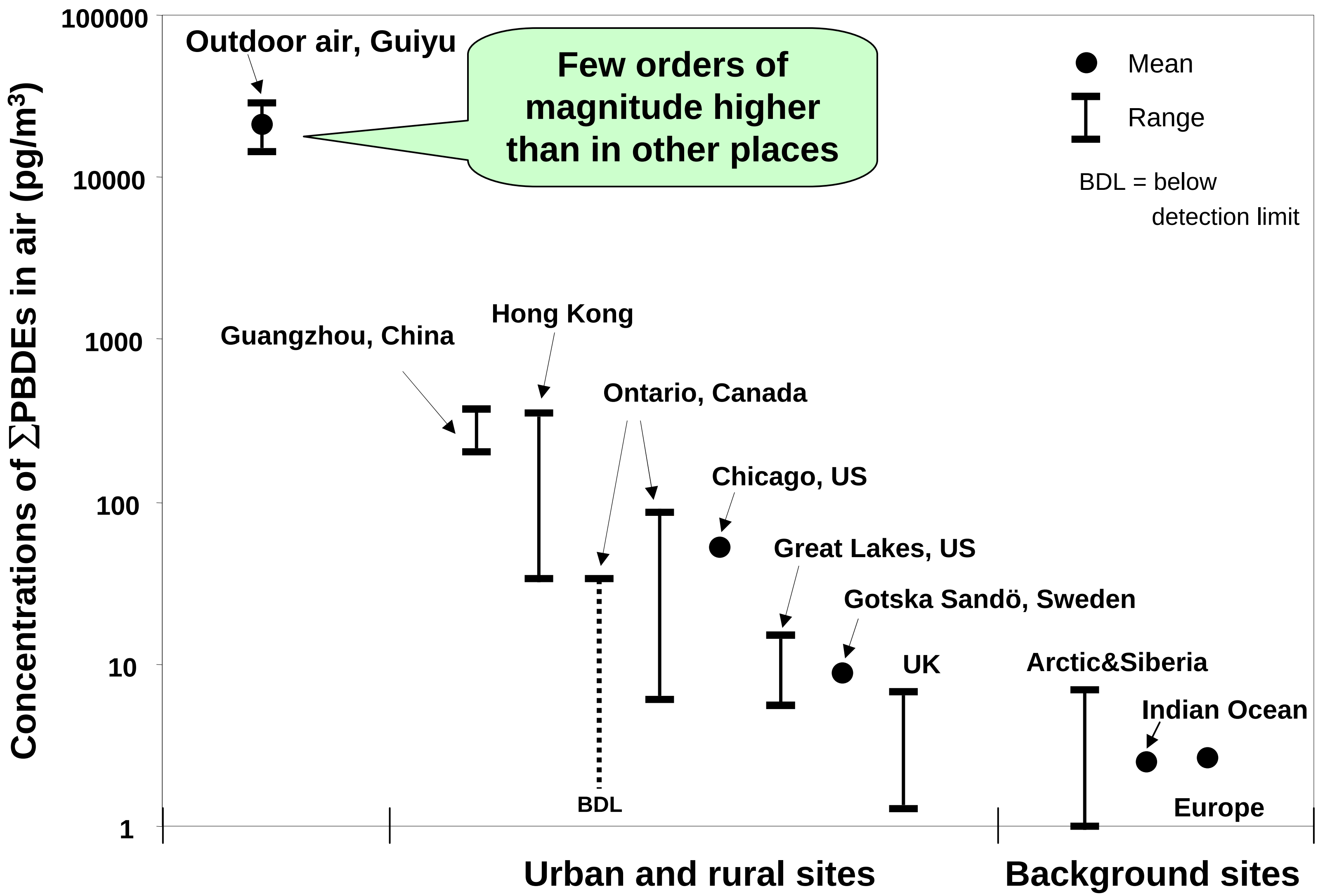
- Human exposure

  - High levels of chemicals observed in e-waste recycling workers and people living close to recycling sites

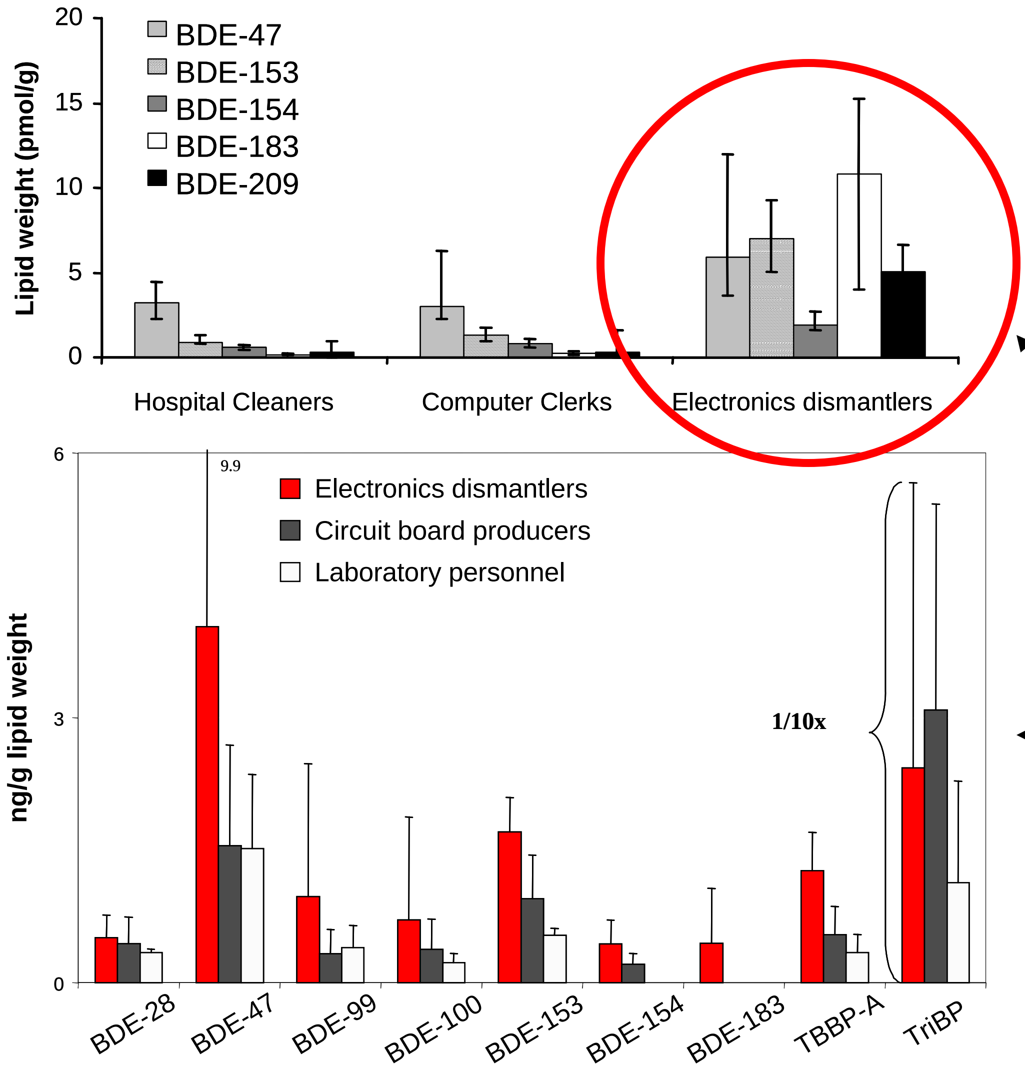
  - Toxic effects (chromosome aberrations, oxidative stress, etc.) observed in affected populations

reviewed in Tsydenova & Bengtsson, Waste Management 31 (2011) 45-58.

PBDEs in outdoor air



“Formal” does not mean “safe”



Brominated flame retardants (additives in plastics) in blood of electronics dismantlers.

E-waste recycling facility in Sweden (Sjodin et al., 1999)

E-waste recycling facility in Norway (Thomsen et al., 2001)

Workplace contamination

	Formal recycling/ Developed countries	Informal recycling/ Developing countries
Risk of workplace contami-nation	**Not well documented, apparently low** **∑PBDEs in indoor air of recycling facilities:** **510 ng/m^3 (Japan)** **96; 98; 260; 310 ng/m^3 (Sweden)** **Sources: Takigami et al., 2006, Sjödin et al., 2001**	**High** **∑PBDEs in outdoor air:** **21.5±7.2 ng/m^3 (Guiyu, China)** **Source: Deng et al., 2007** ***NB: No data on air concentrations in e-waste processing workshops were available for the comparison. However, the high outdoor concentrations are indicative of still higher concentrations in the e-waste workers' immediate environment.***

Occupational exposure

	Formal recycling/ Developed countries	Informal recycling/ Developing countries
Risk of occupational exposure	**Not well documented, apparently low** **∑PBDEs in blood of electronics dismantlers:** **15-75 ng/g lw (Sweden)** **3.8-24 ng/g lw (Norway)** **Sources: Sjödin et al., 1999, Thomsen et al., 2001**	**High** **∑PBDEs in blood of informal e-waste workers:** **140-8500 ng/g lw (Guiyu, China)** **77-8452 ng/g lw (China)** **Sources: Bi et al., 2007 Yuan et al., 2008**

Hazards of incineration and landfilling

Incineration

✓ Emission of metals into flue gas and ash

Low melting point metals (incl. Cd and Pb) easily form fumes.

✓ Emission of mixed chlorinated /brominated dibenzo-*p*-dioxins and dibenzofurans (PXDD/Fs)

If feedstock contains PVC or plastics flame retarded with BFRs and incinerator temperature is not sufficiently high, PXDD/Fs are formed. In the process, Cu may act as catalyst.

Sources: Watanabe et al., 2008; Stewart & Lemieux, 2003.

Landfilling

✓ Leaching of heavy metals and BFRs

Pb was shown to leach from CRTs and PCBs, BFRs were detected in landfill leachate.

✓ Evaporation of toxic substances

Methylmercury was detected in landfill gas.

✓ Formation of more toxic substances due to microbial activity or fires

Hg → methylmercury
BFRs, PVC → PXDD/Fs

Sources: Townsend et al., 2003, 2004; Osako et al., 2004; Lindberg, 2001.

2. Policy suggestions for safer management

Prerequisites for safe and effective e-waste treatment

- Legislation - **Ban of the most problematic hazardous substances, guidelines on recycling/disposal, industry specific health/ environmental guidelines.**
- Technology **– Infrastructure and know-how for safe treatment of components containing hazardous substances**
- Dialogue/knowledge sharing **among producers and the end-of-life community on hazards and improving recycling practices**
- Innovation **– Product design considering the EoL treatment**

2. Policy suggestions for safer management:

Developing countries

Developing countries:
Meeting prerequisites for safe recycling

Major developments in legislation, infrastructure are required to address e-waste issues in developing countries.

- Many countries are in the process of drafting e-waste related legislation. **Effective enforcement will be a challenge.**
- Formal e-waste recycling sector is emerging in a number of countries. **Involves improved methods of recycling and training of staff. Subsidies are likely to be needed to make these formal companies competitive.**
- Many of the measures require international cooperation. **Developed countries need to play a leading role and the major producers need to take a greater responsibility.**

International trade: A special concern

Export of e-waste **from developed to developing countries is still possible due to loopholes in the Basel Convention :**

No clear distinction between “second hand” and “e-waste”

Clear criteria and compliance mechanisms are required**. E.g., an item being imported as “second hand” should not be older than a certain number of years.**

Importing countries have weak institutions and limited enforcement capacity**. Greater responsibility needs to be placed on exporters and exporting countries.**

International EPR system **could be an option.**

The producer could be made responsible for the costs of safe and proper recycling, even if a product is exported from the country where it was originally sold.

2. Policy suggestions for safer management:

Developed countries

Low awareness about hazardous content of e-waste

IGES' survey of recyclers in Japan and the EU:

- **Often NOT aware of the hazards**
- **Experience difficulties in searching, interpreting and effectively utilizing info**
- **Equate "following government regulations" with "safe treatment"**

Lack of industry specific guidelines for e-waste recycling:

- **Follow general OHS/Environmental regulations**
- **Often DO NOT monitor e-waste related chemicals**

Motivation and incentives for safer recycling

Pressure from legislators, producers, consumers or NGOs **to seek information on chemicals in products and use this information for improving recycling practices**

Certification system for recyclers **to ensure responsible recycling. E.g., E2 and E-Stewards certification in the US and WEEELABEX in the EU.**

Sharing information on hazards

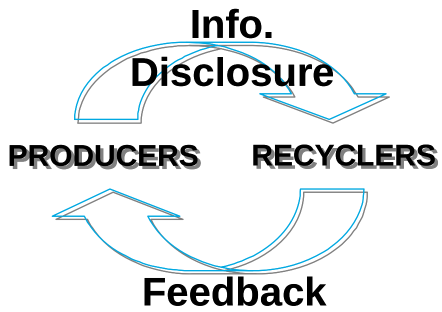
Information on chemicals content, guidance on disassembly and recycling is not readily available from producers.

Some information systems exist but often the information does not reach recyclers.

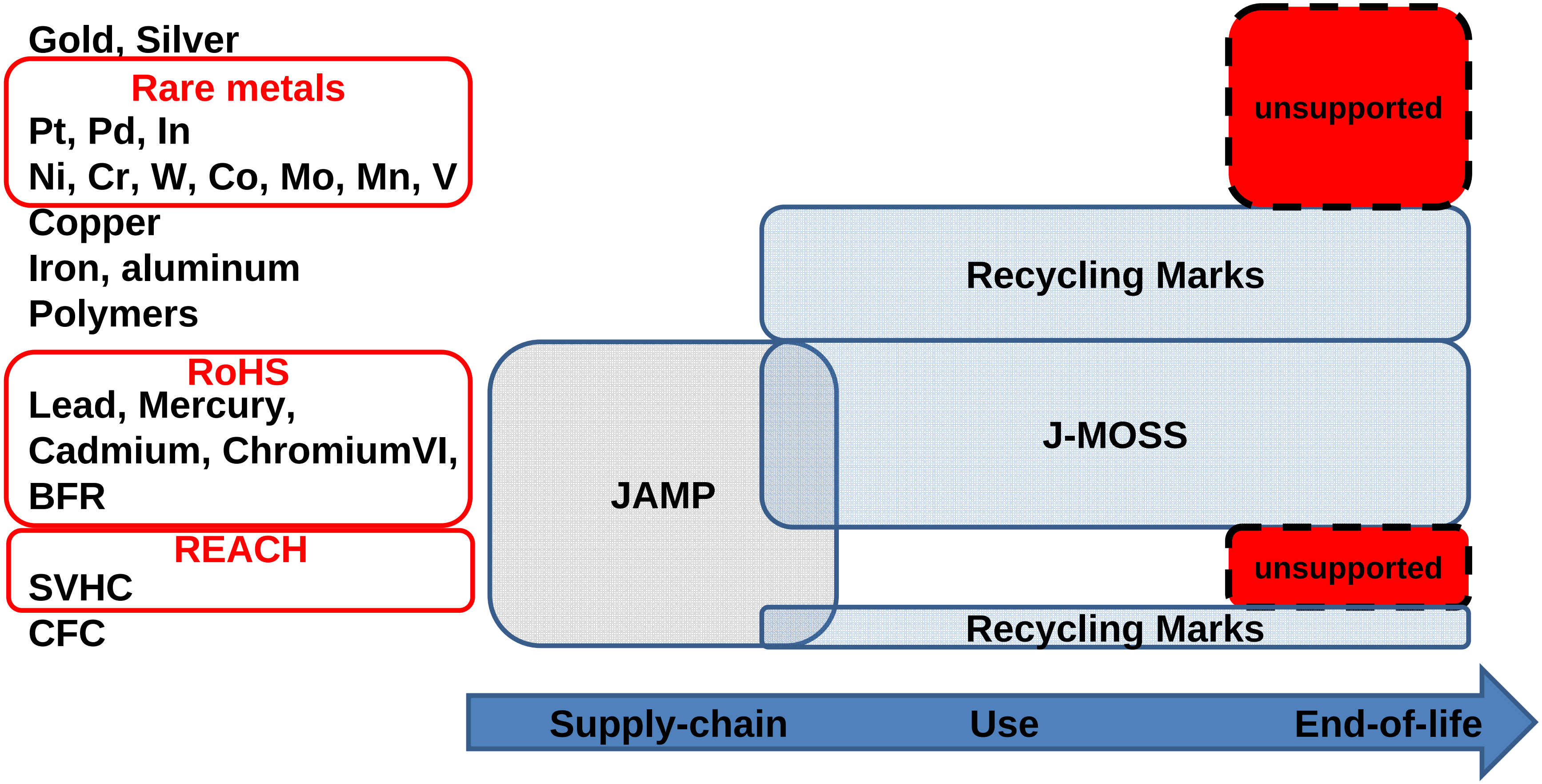
Sharing information within the lifecycle of EEE is imperative for efficient and safe recycling.

Potential benefits of improved information sharing:

- **Safer recycling and waste treatment**
- **Higher material recovery rate**
- **Less contaminated recovered materials**



Japanese system for sharing info on chemicals



- Only limited information reaches the end-of-life stages

  Information on e.g. SVHC and rare metals content is not passed downstream. No formal mechanism to ensure such information transfer.

Prevention vs. Management

- **The presence of hazardous substances in EEE inevitably links its end-of-life treatment with potential risks to human health and the environment.**
- **With the increasing amount of e-waste generated globally, the traditional “end-of-pipe” strategies are not sustainable in the long run.**
- **Green chemistry, design for the environment (DfE) concepts that consider EOL treatment options should be promoted.**
- **The EU RoHS regulation has had global impact on electronics design and some leading producers are extending their lists of restricted substances beyond legal requirements, but stronger pressure – from consumers, NGOs and regulators – is needed.**

Summary (1)

- Chemical hazards exist at each stage of recycling chain/final disposal
  - **Informal e-waste recycling in developing countries results in adverse human health and environmental effects**
  - **Formal recycling is also associated with the risks of workplace contamination and human exposure**

- Dealing with e-waste in developing countries
  - **Clear distinction between “e-waste” and “second hand item” is required (Basel Convention)**
  - **Extension of EPR to include developing countries**
  - **Developing domestic legislation and supporting formal recycling sector**

Summary (2)

- Dealing with e-waste in developed countries
  - **A system to share information on chemicals, guidelines for EOL treatment among producers and recyclers is required.**
  - **Certification system for recyclers could be promoted to ensure responsible recycling. E.g., E2 and E-Stewards Certification in the US and WEEELABEX in the EU.**
  - **Industry specific guidelines are required, e.g. permissible workplace levels of relevant chemicals, occupational exposure limits, etc. need to be established.**
- General considerations
  - **Necessary to consider EOF treatment at the stage of designing a product. E.g., design for environment (DfE), green design.**

Thank you!

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Review

Chemical hazards associated with treatment of waste electrical and electronic equipment

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ABSTRACT

This review paper summarizes the existing knowledge on the chemical hazards associated with recycling and other end-of-life treatment options of waste electrical and electronic equipment (e-waste). The hazards arise from the presence of heavy metals (e.g., mercury, cadmium, lead, etc.), flame retardants (e.g., pentabromophenol, polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol-A (TBBPA), etc.) and other potentially harmful substances in e-waste. If improperly managed, the substances may pose significant human and environmental health risks. The review describes the potentially hazardous content of e-waste, examines the existing e-waste management practices and presents scientific data on human exposure to chemicals, workplace and environmental pollution associated with the three major e-waste management options, i.e., recycling, incineration and landfilling. The existing e-waste management practices and associated hazards are reviewed separately for developed and developing countries. Finally, based on this review, the paper identifies gaps in the existing knowledge and makes some recommendations for future research.

Contents

Hazards CAN BE reasonably managed – Proper disassembly is key

Low risk scenario:
Hazardous components are removed

Removal

Special treatment

Lower risk of pollution and occupational exposure

Disassembly

Shredding and separation

Formation of dust containing particles of metals, plastics, ceramic, silica, etc.

E.g., Circuit board shredding → dust of Pb, Cd, Sb, Be, Hg, plastics

Metallurgical treatment

Emissions of metals, Cl/Br dioxins & furans

Metals → metal fumes (Cd, Pb)

PVC, BFRs in plastics → PXDD/Fs

High risk scenario:
Hazardous components are not removed

Hg switches
Batteries
Plastics, etc.

Higher risk of pollution and occupational exposure