Occupational risk assessment in E-waste plant: Progress achieved over years †

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‘Electrical and electronic equipment’ or ‘EEE’ means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current;

E-waste is the fastest growing waste stream in the EU and less than 40% is recycled.

✓ an obligation for producers and distributors to finance a system for the recovery and recycling of products placed on the market ("extended producer responsibility" principle)
✓ measures aimed primarily at preventing the production of WEEE and their reuse, recycling and other forms of recovery to reduce the disposed waste volume.
Risks Associated with the End-of-Life Treatment of Electrical and Electronic Equipment

- The major hazards in the recycling chain are associated with the size reduction and separation steps. Shredding, grinding or other size reduction processes lead to generation of dust on which harmful substances can be absorbed.

<table>
<thead>
<tr>
<th>Components</th>
<th>Found in</th>
<th>Substances of concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathode ray tubes</td>
<td>Old TV sets, PC monitors, oscilloscopes</td>
<td>Pb in cone glass, Ba in electron gun getter, Cd in phosphors</td>
</tr>
<tr>
<td>Printed circuit boards</td>
<td>Ubiquitous, from beepers to PCs</td>
<td>Pb, Sb in solder, Cd, Be in contacts, Hg in switches, BFRs in plastics</td>
</tr>
<tr>
<td>Plastics</td>
<td>Wire insulation, plastic housing, circuit boards</td>
<td>Polyvinyl chloride (PVC), Brominated flame retardants (BFR), Polychlorinated biphenyl (PCB)</td>
</tr>
</tbody>
</table>
E-waste recycling can lead to direct or indirect exposure to a variety of hazardous substances that are contained in EEE or formed and released by unsafe recycling practices.

- Individuals who directly engage in e-waste recycling with poor protection are exposed to non-negligible risks.

- Unsafe recycling techniques used to regain valuable materials often increase the risk for hazardous exposures.
Aim of work

- Study of Risk Assessment of Workers Exposed to three different classes of compounds in both settled dust and airborne particulate matter (PM) over the years
Evolution of WEEE plant from 2017 to 2021

1. Weighing
2. Discharge
3. Storage

2017
Disassembling + Shredding

2021
Z1
Shredding
Z2
Disassembling
Sample collection

Dust collection

Dust sieved to 63 µm

PM$_{10}$

→ SKC impactors
37 mm teflon filters

Extraction and purification

Florisil
Sample
Florisil
RC-Filter

HPLC-MS/MS and GC-MS analysis
EXPOSURE PATHWAYS

- Inhalation of particles
- Accident ingestion of dust
- Dermal absorption via particle contact
$\text{CR}_\text{inhalation} = \frac{\text{Ci} \times \text{EF} \times \text{ET} \times \text{ED}}{\text{AT} \times 365 \times 24} \times \text{IUR}$

$\text{CR}_\text{ingestion} = \frac{\text{Ci} \times \text{IngR} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \times \text{SFO}$

$\text{CR}_\text{dermal} = \frac{\text{Ci} \times \text{SA} \times \text{AF} \times \text{ABS} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \times \frac{\text{SFO}}{\text{GIABS}}$

$\text{TCR} = \sum \text{CR}_\text{inhalation} + \text{CR}_\text{ingestion} + \text{CR}_\text{dermal contact}$

$\text{HQ}_\text{inhalation} = \left[ \frac{\text{Ci} \times \text{EF} \times \text{ET} \times \text{ED}}{\text{AT} \times 365 \times 24 \times 1000} \right] / \text{RfC}$

$\text{HQ}_\text{ingestion} = \left[ \frac{\text{Ci} \times \text{IngR} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \right] / \text{RfD}$

$\text{HQ}_\text{dermal} = \left[ \frac{\text{Ci} \times \text{SA} \times \text{AF} \times \text{ABS} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \right] / \text{RfD} \times \text{GIABS}$

$\text{THQ} = \sum \text{HQ}_\text{inhalation} + \text{HQ}_\text{ingestion} + \text{HQ}_\text{dermal contact}$

Ci is the contaminant concentration for each compound in PM (µg/m$^3$) and in settled dust (µg/g).

IngR Ingestion rate (mg/day)

EF Exposure frequency (days/year)

ED Exposure duration (years)

BW Average body weight (kg)

AT Averaging time (days or hours*)

CF Conversion factor (kg/mg)

SFO Oral slope factor (mg/kg/day)$^{-1}$

SA Surface area of the skin that contacts soil (cm$^2$/day)

AF Skin adherence factor for soil (mg/cm$^2$)

ABS Dermal absorption factor (dimensionless)

GIABS Gastrointestinal absorption factor (dimensionless)

ET Daily exposure time (8 h/d)

IUR Inhalation unit risk (mg/m$^3$)$^{-1}$

RfC Reference dose for inhalation (mg/m$^3$)

RfD Reference dose for ingestion/dermal contact

→PRECAUTIONARY APPROACH
In 2017, TCR data exceeded the tolerable values set by USEPA, whereas THQ results were lower than acceptable risk limits. In 2021, both TCR and THQ are lower than recommended values and about 60% below those found in 2017.

Therefore, the plant modifications seem to have resulted in a risk reduction for the workers involved in the treatment of e-waste.