A MODEL FOR ESTIMATION OF POTENTIAL GENERATION OF WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT IN BRAZIL

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Introduction

Electrical and Electronic market in Brazil

Penetration of EEE in Brazilian households in 2001 and 2008

Estimating stock for non mature EEE

Computer and Cell phone stock in use

A model for WEEE generation

Generation estimates for selected WEEE for 2008 in Brazil

Conclusion
Introduction

• Goal: estimate and validate the volumes of WEEE in Brazil.

• Sales of electrical and electronic equipment are increasing dramatically in developing countries. Usually, there are no reliable data about quantities of the waste generated.

• A new law for solid waste management was enacted in Brazil in 2010, and the infrastructure to treat this waste must be planned.
Electrical and Electronic market in Brazil

- The Brazilian EEE market has been growing strongly. There was a 23% increase in revenues in the electrical and electronic equipment sector from 2007 to 2010 (ABINEE, 2011).

- The Brazilian Institute of Geography and Statistics (IBGE) conducts an annual household survey called the PNAD (IBGE, 2002 and 2009). Among the data gathered is the percentage of households that have various types of electrical and electronic equipment, as shown in Table 1.
Penetration of EEE in Brazilian households in 2001 and 2008

<table>
<thead>
<tr>
<th>Equipments</th>
<th>% Household</th>
<th>Units (million)</th>
<th>Increase</th>
<th>Units (million)</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001</td>
<td>2008</td>
<td>Increase</td>
<td>2001</td>
<td>2008</td>
</tr>
<tr>
<td>Televisions</td>
<td>89%</td>
<td>95%</td>
<td>7%</td>
<td>38,6</td>
<td>54,8</td>
</tr>
<tr>
<td>Refrigerators</td>
<td>85%</td>
<td>92%</td>
<td>8%</td>
<td>36,9</td>
<td>53,0</td>
</tr>
<tr>
<td>Freezers</td>
<td>19%</td>
<td>16%</td>
<td>-16%</td>
<td>8,2</td>
<td>9,2</td>
</tr>
<tr>
<td>Telephones</td>
<td>59%</td>
<td>82%</td>
<td>39%</td>
<td>25,6</td>
<td>47,2</td>
</tr>
<tr>
<td>Washmachines</td>
<td>34%</td>
<td>42%</td>
<td>22%</td>
<td>14,6</td>
<td>23,9</td>
</tr>
<tr>
<td>Audio Systems</td>
<td>88%</td>
<td>89%</td>
<td>1%</td>
<td>38,2</td>
<td>51,2</td>
</tr>
<tr>
<td>Computers</td>
<td>13%</td>
<td>35%</td>
<td>172%</td>
<td>5,5</td>
<td>20,3</td>
</tr>
<tr>
<td>Cell Phones</td>
<td>8%</td>
<td>42%</td>
<td>424%</td>
<td>3,4</td>
<td>24,1</td>
</tr>
</tbody>
</table>

Sources: IBGE 2002 and 2009.
Estimating stock for non mature EEE

- PNAD: number of households that possess the items (household may have more than one device). Does not reflect business usage. PNAD numbers are conservative, particularly for electronic devices like computer and cell.

- Annual survey of households and offices is conducted by Meireles (2010), estimating the stock of computers in use. Cell phone stock is based on the number of cell phone lines in use, obtained from operators (Associação Brasileira de Telecomunicações – TELEBRASIL, 2010).
## Computer and Cell phone stock in use

<table>
<thead>
<tr>
<th></th>
<th>Computer</th>
<th></th>
<th>Cell Phones</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sales (1)</td>
<td>Stock (2)</td>
<td>Sales (1)</td>
<td>Stock (3)</td>
</tr>
<tr>
<td></td>
<td>million units</td>
<td>million units</td>
<td>million units</td>
<td>million units</td>
</tr>
<tr>
<td>2000</td>
<td>2,9</td>
<td>10,0</td>
<td>2,60</td>
<td>23,20</td>
</tr>
<tr>
<td>2001</td>
<td>3,1</td>
<td>13,0</td>
<td>5,20</td>
<td>28,70</td>
</tr>
<tr>
<td>2002</td>
<td>3,1</td>
<td>16,0</td>
<td>11,30</td>
<td>34,90</td>
</tr>
<tr>
<td>2003</td>
<td>3,2</td>
<td>19,0</td>
<td>16,40</td>
<td>46,40</td>
</tr>
<tr>
<td>2004</td>
<td>4,1</td>
<td>23,0</td>
<td>33,30</td>
<td>65,60</td>
</tr>
<tr>
<td>2005</td>
<td>5,6</td>
<td>28,0</td>
<td>36,60</td>
<td>86,20</td>
</tr>
<tr>
<td>2006</td>
<td>8,2</td>
<td>34,0</td>
<td>37,10</td>
<td>99,90</td>
</tr>
<tr>
<td>2007</td>
<td>10,0</td>
<td>41,5</td>
<td>49,70</td>
<td>121,00</td>
</tr>
<tr>
<td>2008</td>
<td>12,0</td>
<td>50,0</td>
<td>55,10</td>
<td>150,60</td>
</tr>
<tr>
<td>2009</td>
<td>12,0</td>
<td>60,0</td>
<td>50,00</td>
<td>174,00</td>
</tr>
</tbody>
</table>

Sources: (1) ABINEE, 2009; (2) Meirelles, 2009, (3) TELEBRASIL, 2010.
A model for WEEE generation

• Different methods since non-mature market products need a different approach.
  – Mature markets are those that are increasing almost at the same rate as the population. Sales are basically for replacement of products after the end of their useful life.
  – Non-mature market products are those where demand is growing faster than population or those that undergo sudden waves of technological change, with the resulting shortening of the lifetime of old technology products. Sales are both to new users and for replacement of old products due to new technological features.
A model for WEEE generation

• A - For mature market products: refrigerators, washing machines, televisions, freezers and audio systems (Consumption and Use Method):

\[ \text{Generation of WEEE}_i = \text{stocks in use}_i / \text{average life time} \]

Stock\(_i\) is the number of devices in use in year \(i\).

• B - For non-mature markets: computers and cell phones (Time-step Method):

\[ \text{Generation of WEEE}_i = \text{sales in year}_i - (\text{stock in year}_i - \text{stock in year}_{i-1}) \]

Sales\(_i\) includes local production and importation during a year. Stock\(_i\) is the number of devices in use.
## Generation estimates for selected WEEE for 2008 in Brazil

<table>
<thead>
<tr>
<th>Equipments</th>
<th>Weight (kg)</th>
<th>Lifetime (years)</th>
<th>WEEE (tonnes/year)</th>
<th>WEEE per capita (kg/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Televisions</td>
<td>30,0</td>
<td>12,0</td>
<td>136.883</td>
<td>0,73</td>
</tr>
<tr>
<td>Refrigerators</td>
<td>65,0</td>
<td>12,0</td>
<td>287.024</td>
<td>1,53</td>
</tr>
<tr>
<td>Freezers</td>
<td>50,0</td>
<td>15,0</td>
<td>30.787</td>
<td>0,16</td>
</tr>
<tr>
<td>Washing machines</td>
<td>40,0</td>
<td>10,0</td>
<td>95.596</td>
<td>0,51</td>
</tr>
<tr>
<td>Audio Systems</td>
<td>10,0</td>
<td>10,0</td>
<td>51.173</td>
<td>0,27</td>
</tr>
<tr>
<td><strong>Mature market Sub total</strong></td>
<td></td>
<td></td>
<td><strong>601.462</strong></td>
<td><strong>3,20</strong></td>
</tr>
<tr>
<td>Computers</td>
<td>30,0</td>
<td>-</td>
<td>105.000</td>
<td>0,56</td>
</tr>
<tr>
<td>Cell phones</td>
<td>0,1</td>
<td>-</td>
<td>2.550</td>
<td>0,01</td>
</tr>
<tr>
<td><strong>Non-mature market Sub total</strong></td>
<td></td>
<td></td>
<td><strong>107.550</strong></td>
<td><strong>0,57</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>709.012</strong></td>
<td><strong>3,77</strong></td>
</tr>
</tbody>
</table>
CONCLUSION

• Need of a different methodology to estimated WEEE generation for non-mature market products, such as computers and cell phones, since average lifetime for such products is not constant

• Total yearly WEEE generation per capita for the seven selected products is 3.77 kg per year. This estimate is a rough indication for 2008 of the generation of selected WEEE items.

• The most important variable is the product lifetime, and that information demands a thorough understanding of consumer behavior.
THANK YOU FOR YOUR ...

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Group of Waste Treatment Studies
ÉAVEL DO RIO
Life cycle assessment on printed matter (paper)  
focus on additives

Henrik Fred Larsen  
QSA, DTU Management Engineering  
Technical University of Denmark, DTU
Outline

- What is LCA: characteristics, elements; goal and scope, inventory, life cycle impact assessment (LCIA)

- LCA impact profile on printed matter
  - Significant contributing chemical emissions
  - Data lack regarding additives, impurities etc.

- Examples on potential “additives” in recycled paper: Hazardous substances found in the Danish printing industry

- Conclusions and further research
The life cycle of printed matter

(Larsen 2004)
The life cycle of printed matter

(Larsen 2004)
What is Life Cycle Assessment, LCA?

Characteristic features of LCA:

- A decision supporting tool
- Focus on services typically represented by a product (the “functional unit”) For example: 1 ton printed matter
- Comparative (relative statements). For example: Distribution of relative impacts from emissions and resource consumption during the life cycle
- Holistic perspective
  - life cycle from cradle to grave
  - all relevant environmental impacts, e.g. Global warming, acidification, ecotoxicity........
  - resource consumption (biotic and abiotic), e.g. Kaolin, Al, Ag, coal....
- Aggregation over time and space
  - life cycle is global
  - life cycle may span over decades or even centuries
Goal and Scope definition
- defining goal: For example *identify the distribution of potential impacts*... defining scope: For example *cradle to grave including recycling*
- decisive for interpretation and use of results: For example *identifying the importance of additives for the impact profile when recycling resources like paper*

Inventory analysis (LCI)
- collecting in- and output data for all processes
Life cycle impact assessment (LCIA)

**Classification:** “What does this emission contribute to?”
- Assignment of emissions to impact categories according to their potential effects
  - Global warming (e.g. CO₂, CH₄)
  - Acidification (e.g. NO₂, SO₃)
  - Ecotoxicity (e.g. phthalates, heavy metals)
  - Human toxicity (e.g. benzene, PAH’s)
  - ………

**Characterisation:** “How much may it contribute?”
- Quantification of contributions to the different impact categories by estimating impact potentials, IPs (e.g. multiplying the characterisation factors (CFs) for each chemical by the emitted amount (Q) per functional unit (fu)):

\[ IP = Q \times CF \]

- Example (GWP):

<table>
<thead>
<tr>
<th>Substance</th>
<th>Q (g/fu)</th>
<th>CF (g CO₂-eq/g)</th>
<th>IP (g CO₂-eq/fu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxid (CO₂)</td>
<td>250</td>
<td>1</td>
<td>250</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>10</td>
<td>25</td>
<td>250</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>500</td>
</tr>
</tbody>
</table>
Life cycle impact assessment (LCIA) and interpretation

Normalisation: "Is that much?"
- Expression of the impact potentials relative to a reference situation (person-equivalence, PE), e.g. normalisation reference (NR) for GWP: 8,700 kg CO₂-eq/pers/year. The normalised impact potential (nIP):

\[ nIP = \frac{IP}{NR} \]

<table>
<thead>
<tr>
<th>Impact category</th>
<th>NR (kg CO₂-eq/pers/year)</th>
<th>IP/fu (kg CO₂-eq/fu)</th>
<th>nIP (mPE/fu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming (GWP)</td>
<td>8700</td>
<td>0,5</td>
<td>0,057</td>
</tr>
</tbody>
</table>

Valuation: "Is it important?"
- Ranking, grouping or assignment of weights (weighting factors, WFs) to the different impact potentials (EDIP: political reduction targets), e.g. for global warming a targeted 10 years reduction of 20% => WF=1/(1-0.2) = 1.3. The weighted impact potential (wIP):

\[ wIP = nIP \times WF \]

<table>
<thead>
<tr>
<th>Impact category</th>
<th>WF</th>
<th>nIP (mPE/fu)</th>
<th>wIP (mPET/fu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming (GWP)</td>
<td>1,3</td>
<td>0,057</td>
<td>0,074</td>
</tr>
</tbody>
</table>

Interpretation: "Where is the hotspots in the life cycle and for what reason?"
- Is paper production a hotspot for printed matter life cycle? Due to energy consumption?
Impact profile on printed matter

Functional unit: 1 ton sheet fed offset printed matter

(Larsen et al. 2006)
Significant contributing chemical emissions to the printed matter impact profile

- Emissions of ink residues (tetradecane) and cleaning agents (hexane, tetradecane) during the printing process and cleaning (35%)
- Emissions (dichlorobenzidine, chloroaniline, cuprous chloride) during pigment production (17-20%)
- Emissions of heavy metals and AOX (as dichlorobenzene) during paper production (>3%)
- Emissions of fountain chemicals (i.e. isopropyl alcohol, IPA) during the printing process (6%)
- Emissions of biocides and hydroquinone from the repro- and plate making process (3%)

(Larsen et al. 2006)
Known additives/impurities/production emissions that might play an important role for the paper/printed matter LCA impact profile but for which knowledge/data is lacking

- Ink components (and their precursors) production: siccatives, antioxidants, pigments, dyes and more
- Water emissions from paper production: softeners (BPA), other phenolic compounds (NPE, APE), other surfactants (LAS), biocides (benzothiazoler, dibromo-compounds), wood extractions (terpenoids, resin acids), fluorescent whitening agents and more
- Recycling of paper: Fate of paper chemicals (wet strength agents, biocides, dyes), ink chemicals (phthalates, hydrocarbons), glue chemicals and more
- Treatment of chemical waste: Fate of (hazardous) waste from printing (ink waste, used cleaning agents, used rinsing water etc.) and from recycling of paper (sludge from repulping)

(Ginebreda et al. 2012, Larsen et al. 2006 and more)
Substances of very high concern (SVHC) appearing on the recently updated EU REACH Annex XIV candidate list and found in the Danish printing industry

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS No.</th>
<th>Annex XIV criteria</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromtrioxide</td>
<td>1333-82-0</td>
<td>Carc 1, mut 2</td>
<td>Chrome plating (gravure)</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>79-01-6</td>
<td>Carc 2</td>
<td></td>
</tr>
<tr>
<td>Cobalt-siccatives *</td>
<td>(10124-43-3)</td>
<td>(Carc 2, rep 2)</td>
<td>Inks (off-set, screen printing)</td>
</tr>
<tr>
<td>Acrylamide</td>
<td>79-06-1</td>
<td>Carc 2, mut 2</td>
<td>Unknown (impurity?)</td>
</tr>
<tr>
<td>Pigment Yellow 34 (lead-chromate)</td>
<td>1344-37-2</td>
<td>Carc 2, rep 1</td>
<td>Inks (screen printing)</td>
</tr>
<tr>
<td>Pigment Red 104 (lead-chromate)</td>
<td>12656-85-8</td>
<td>Carc 2, rep 1</td>
<td>Inks (screen printing)</td>
</tr>
<tr>
<td>2-Methoxy ethanol</td>
<td>109-86-4</td>
<td>Rep 2</td>
<td>Photochemistry</td>
</tr>
<tr>
<td>Di(2-ethylhexyl)phthalate, DEHP</td>
<td>117-81-7</td>
<td>Rep 2, EDS-list</td>
<td>Inks</td>
</tr>
<tr>
<td>Dibutylphthalate, DBP</td>
<td>84-74-2</td>
<td>Rep 2, EDS-list</td>
<td>Inks (screen printing, flexo)</td>
</tr>
<tr>
<td>Benzylbutylphthalate, BBP</td>
<td>85-68-7</td>
<td>Rep 2, EDS-list</td>
<td>Inks</td>
</tr>
<tr>
<td>Boric acid and borax</td>
<td>10043-35-3 and 1303-96-4</td>
<td>Rep 2, EDS-list</td>
<td>Photochemistry</td>
</tr>
</tbody>
</table>

* Possible content of soluble cobalt(II)salts. Cobalt(II)sulphate, cobalt dichloride, cobalt(II)carbonate, cobalt(II)dinitrate and cobalt(II)diacetate all appears on the recently updated REACH Annex XIV candidate list. IARC classify all soluble cobalt(II)salts as possible carcinogenic, i.e. group 2B (http://monographs.iarc.fr/ENG/Monographs/vol86/mono86.pdf)

(Larsen 2012)
Substances meeting Annex XIV candidate list criteria and found in the Danish printing industry (not listed on the REACH Annex XIV candidate list but potential candidates that may be listed in the future)

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS No.</th>
<th>Annex XIV criteria</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>71-43-2</td>
<td>Carc 1, mut 2</td>
<td>Inks, cleaning agents</td>
</tr>
<tr>
<td>Epichlorohydrin</td>
<td>106-89-8</td>
<td>Carc 2, EDS-list</td>
<td>Unknown (impurity?)</td>
</tr>
<tr>
<td>2-Methylaziridine</td>
<td>75-55-8</td>
<td>Carc 2</td>
<td>Inks (flexo)</td>
</tr>
<tr>
<td>Aziridine</td>
<td>151-56-4</td>
<td>Carc 2, mut 2</td>
<td>Inks (flexo, screen printing)</td>
</tr>
<tr>
<td>Propylene oxide</td>
<td>75-56-9</td>
<td>Carc 2, mut 2</td>
<td>Inks, cleaning agents</td>
</tr>
<tr>
<td>2-Methoxy propylacetate</td>
<td>70657-70-4</td>
<td>Rep 2</td>
<td>Inks (screen printing)</td>
</tr>
<tr>
<td>Triethylene glycol dimethylether</td>
<td>112-49-2</td>
<td>Rep 2</td>
<td>Brake fluid</td>
</tr>
<tr>
<td>2-Methoxypropyl-1-ol</td>
<td>1589-47-5</td>
<td>Rep 2</td>
<td>Unknown</td>
</tr>
<tr>
<td>Alkylphenolethoxylates</td>
<td>(25154-52-3)</td>
<td>EDS-list</td>
<td>Inks, cleaning agents</td>
</tr>
<tr>
<td>Chloroalkanes, C14-17</td>
<td>85535-85-9</td>
<td>EDS-list . Possible PBT/vPvB-substance</td>
<td>Chain oil</td>
</tr>
<tr>
<td>Octamethylene tetrasiloxane (polydimethylsiloxane)</td>
<td>556-67-2 (9016-00-6)</td>
<td>Possible PBT/vPvB-substance</td>
<td>Inks</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>80-05-7</td>
<td>EDS-list</td>
<td>Inks, thermal paper</td>
</tr>
<tr>
<td>Resorcinol</td>
<td>108-46-3</td>
<td>EDS-list</td>
<td>Glue</td>
</tr>
<tr>
<td>Styrene</td>
<td>100-42-5</td>
<td>EDS-list</td>
<td>Inks, glue</td>
</tr>
<tr>
<td>Decamethyl-cyclopentasiloxane</td>
<td>541-02-6</td>
<td>Possible PBT/vPvB-substance</td>
<td>Inks</td>
</tr>
<tr>
<td>Stoddard solvent</td>
<td>8052-41-3</td>
<td>Carc 2</td>
<td>Unknown</td>
</tr>
<tr>
<td>Solventnaphtha (crude oil), hydrogen treated light naphthen-(benzene &gt;= 0.1%)</td>
<td>92062-15-2</td>
<td>Carc 2</td>
<td>Cleaning agent</td>
</tr>
</tbody>
</table>

(Larsen 2012)
Conclusions and further research

Conclusions

- There is a general lack of relevant inventory data on e.g. production and fate in products, for almost all additives used in printed matter/paper
- Also characterization factors on additives is to a large degree missing
- However, a few existing case studies indicate that emissions related to the production and use of additives may play an important role for the LCA impact profile of printed matter/paper
- Furthermore, a survey on the use of hazardous chemicals in the printing industry and measurements of additives/impurities in recycled paper indicate that some of these substances may accumulate in the recycled paper and potentially contribute significantly to the printed matter/paper LCA impact profile

Research needs

- Better coverage of upstream processes, e.g.
  - Ink components (and their precursors) production: pigments, softeners, siccatives, antioxidants etc.
  - Water emissions from paper production: softeners (BPA), other phenolic compounds (NPE, APE), other surfactants (LAS), biocides (benzothiazoler, dibromo-compounds), wood extractions (terpenoids, resin acids) and more

- Better coverage of downstream processes including recycling, e.g.
  - Recycling of paper: Fate of paper chemicals, ink chemicals, glue chemicals etc.
  - Treatment of chemical waste: Fate of (hazardous) waste from printing (ink waste, used cleaning agents, used rinsing water etc.) and from recycling of paper (sludge from repulping)
References


Proposed additives/impurities to be included in RiskCycle -USEtox LCIA characterisation factors (CFs)

Thank you for your attention
Assessing Plastics Additives in Life Cycle Assessment

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Content

- Introduction: LCA in RiskCycle
- Method: Life Cycle Assessment
- Results: plastics and additives in LCA
- Conclusions and recommendations
introduction: LCA in Riskcycle

- Life Cycle Assessment: environmental impacts of toxic additives in large context:
  - total of environmental problems
  - total process chain related to the application

- Survey of LCA case studies of plastics:
  - additives do NOT show up as important
  - really unimportant, or not taken into account properly?

- illustration:
  case study on additives (DEHP) in PVC flooring

DEHP: di(2-ethylhexyl)phthalate
Life Cycle Assessment

- Standardized methodology
  - ISO 14040 standard
  - European guide book ILCD

- Methodological steps:
  - Goal and scope definition
  - Life Cycle Inventory
  - Life Cycle Impact Assessment
  - Interpretation

ILCD: International Reference Life Cycle Data System (EC JRC-IES)
plastics and additives in LCA, results from the RiskCycle project

- literature survey of
  - LCI databases,
  - LCIA impact factors and
  - published LCA case studies

- LCA case study on PVC flooring, supplemented with emission data based on SFA studies
literature survey of LCI databases

- 30 LCI databases studied
- focus on plastics and additives
- conclusions:
  - production additives: NOT available
  - production polymers: available
    - aggregated data (Plastics Europe)
    - uncompounded resins, excl. additives
  - use phase: emissions are lacking
  - recycling of plastics: NOT available
  - waste treatment:
    - emission depends on material
    - databases are supplemented by tool
    - coarse models, additives lacking

1. LCA resources directory by JRC-IES
2. Database Registry by UNEP/SETAC
LCIA impact factors

- especially data on toxicity are lacking
- Toxicity: Usetox (Rosenbaum et al., 2008),
  - recommended IA model of ILCD
  - CF based on pathways via environment, so
do not include direct contact (e.g. migration
  from food packaging) or indoor emissions
- characterisation factors are available for some
  additives (e.g. metals, some phthalates)
- however there are many different (plastics)
  additives
- this too makes it difficult to include additives
  in LCA studies
published LCA case studies

- 110 LCA case studies of plastics
- 25 mention additives
- In none of the articles the additives are identified as an important issue
  - waste treatment: only qualitative
  - comparative LCAs:
    - flooring (3) and window frames (1)
    - production (4) and emission (2)
the case study

- cushion vinyl floor covering: PVC and phthalates (DEHP)
- FU: the use of 1 m² cushion vinyl floor covering, with a lifetime of 15 years

<table>
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<th></th>
<th>kg</th>
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<td>cushion vinyl floor covering</td>
<td>1.735</td>
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<td>PVC</td>
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<td>DEHP</td>
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<td>Stabilizer(^1)</td>
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<td>pigment</td>
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<td>other materials (PUR?, flame retardents?)(^1)</td>
<td>0.03</td>
<td>1.73</td>
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<tr>
<td>glass fiber</td>
<td>0.055</td>
<td>3.17</td>
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Table 1 Composition of 1 m² cushion vinyl floor covering (Potter & Blok, 1995).

- cradle-to grave life cycle of product, with 4 different waste treatment scenarios: incineration, land fill (controlled, uncontrolled), recycling
normalised results, aquatic ecotoxicity

Aquatic eco toxicity score for the use of cushion vinyl floor covering broken down into LC stages, based on 4 waste treatment scenarios

- DEHP emissions from landfill
- Emissions from DEHP production
- DEHP emissions during use, not important
normalised results, global warming

Global warming impact score for the use of cushion vinyl floor covering broken down into LC stages, based on 4 waste treatment scenarios

- CO₂ emissions from incinerated plastic waste
- CO₂ emissions from DEHP production

Bars represent:
- Waste treatment
- Emissions during use
- Assemblage cushion vinyl floor covering
- Titanium dioxide production
- Glass fibre production
- Limestone production
- PVC production
- DEHP production
conclusions case study CVFC and DEHP

- additives seem to contribute significantly to Life Cycle Impacts
  - emission in waste treatment
  - production of additive
    (CtG emissions, not only DEHP)

- so additives can not be ignored in case studies on plastics
Approaches used to estimate lacking data

- **LCI data:** emissions based on SFAs
  - e.g. Jenny Westerdahl, Henning Tien
  - the production, use, waste management and emissions of specific substances in a national economy are charted,
  - SFAs are used to derive emission factors

- **LCIA data:** toxicity characterization model
  - Usetox (Rosenbaum et al., 2008)
  - impact factors based on substance characteristics and exposure pathways
  - in the Riskcycle project, Usetox and QSAR models are used to derive characterization factors for 140 additives (Magnus Rahmberg)
general conclusions

- The literature survey shows that additives are by and large neglected in LCA studies:
  - Lack of data: LCI (production, use, waste) and LCIA
  - Scope of LCA study: impact assessment often limited to global warming, notably toxicity impacts are often excluded
  - Failure to recognize additives:
    - Aggregate data for plastics
    - Additives ignored because of its small volume

- The CVFC case study shows that additives may contribute significantly, not just to toxic impacts but also to global warming, not just as emission but also as CtG compound

- Data gaps in LCI and LCIA databases should be mended

- The plastics, together with additives, industry should play a key role in this process
thank you
for your attention
Appendix

Extra information on
1. case study LCA CVFC
2. Literature survey LCI databases and LCA case studies
impact assessment

- baseline characterisation factors of (Dutch) Handbook on LCA (Guinée et al., 2002)
- impact categories toxicity: Usetox model (Rosenbaum et al., 2008)


normalised results, aquatic ecotoxicity

Aquatic eco toxicity score for the use of cushion vinyl floor covering broken down into LC stages, based on 4 waste treatment scenarios

- chromium VI, arsenic, vanadium
- zinc, copper
- chromium VI vanadium nickel
- DEHP to air and water from landfill

- waste treatment
- emissions during use
- assemblage cushion vinyl floor covering
- titanium dioxide production
- glass fibre production
- limestone production
- PVC production
- DEHP production
discussion

- estimated process data for waste treatment
  - no detailed data, models with general characteristics
  - DEHP guestimates
  - data based on ‘high tech’ European processes
  - allocation waste incineration: all to waste treatment
  - landfill site: sewage water treatment IS taken into account

- outdated process data, for PVC and incineration
  - emission during electrolysis NaOH and Cl2 by mercury cell

- impact assessment human toxicity (Usetox)
  - indoor emission pathways not taken into account
conclusions (and remarks)

- waste treatment
  - waste incineration is worst option, others not far apart
  - however, incineration overestimated (allocation), landfill underestimated (if uncontrolled landfill site)

- PVC and phthalates
  - emission of DEHP from an uncontrolled landfill site has a substantial contribution to the environmental impact
  - contribution of DEHP emissions from other processes are negligible
  - however, indoor pathways are not considered
conclusions (and remarks)

- LCA
  - LCA enables to put emissions (of DEHP) in context, total of emissions, total of processes
  - additional to RA: generic global versus actual local
  - process data recycling not available in LCA databases
  - process data ‘low tech’ processes not available in LCA databases
  - process data additives not available in LCA databases
# LCI databases

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Three Journals have been screened on relevant articles:
1) International Journal of Life Cycle Assessment; 265 hits
2) Journal of Industrial Ecology; 118 hits
3) Journal of Cleaner Production; 113 hits