Towards zero-waste valorisation of fresh and landfilled wastes and residues

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Raw material supply faces major challenges: "Europe, the poorest continent in the world"
EU therefore needs to excel in substitution and recycling - From urban to landfill mining:

1. *End-of-Life products*
2. *Enhanced Landfill Mining*
3. *Secondary resources*
SIM² KU Leuven Philosophy: Closing the loop through urban & landfill mining

K. Binnemans, P.T. Jones, et al., *Journal of Cleaner Production*, 2015
1. **EoL products**: Efficient recycling/urban mining requires holistic approach

![Diagram showing the process of recycling/urban mining with stages: collectie, ontmanteling, scheiding, voorbehandelen, eindverwerking, recyclaat](image)

**Formal**
- (e.g. Europe, UNU 2008, Chancerel et al. 2009)
  - 60%: formal take-back system
  - 25%: mainly mechanical processes
  - 95%: integrated smelter
  - 15%

**Informal**
- (e.g. India, Keller 2006)
  - 80%: individual collectors
  - 50%: manual sorting and dismantling
  - 50%: backyard leaching
  - 20%
Example: Selective recuperation of Eu and Y from End-of-Life CFLs (using ionometallurgy)


**Key advantages:**
- Selective dissolution of $\text{Y}_2\text{O}_3: \text{Eu}^{3+}$ (70% of the total value in the powders)
- Regeneration of new red YOX phosphor
- Short 3-step process
- Very basic chemical operations (no purification or solvent extraction)
- Only oxalic acid is consumed (stoichiometric amounts to make YOX)
- Zero (additional) waste generation (except $\text{CO}_2$)
- Mild conditions ($< 100 \, ^\circ\text{C}$, pH $> 1$)
SIM² KU Leuven covers more than REE’s – strong focus also on Sb, In, Ge etc.

Processing of critical metals is a technological challenge
2. Enhanced Landfill Mining
[of MSW/industrial residue landfills]

- 150,000 - 500,000 landfills in Europe
  - From MSW, mixed to industrial landfills
  - From waste dumps to state-of-the-art landfills
- Do-nothing scenario is not an option
  - Remediation costs for EU-28 projected to be 0.1-1 trillion euro in the next 5 decades
- ELFM targets recovery of metals, materials, energy and land) & preserves drinking water
- Prioritisation is required: remediation need, content, location and size are key parameters
3. Industrial Process Residues (fresh/landfilled flows/stocks)

K. Binnemans et al., *Journal of Cleaner Production*, 2015

Zero-waste valorisation principle!
Flemish MaRes Programme: Materials from Secondary Resources

• Flanders has no primary ores containing critical metals
• BUT… Flanders has:
  o Large volumes of secondary (industrial) process residues: tailings, sludges, slags and ashes (e.g. phosphogypsum, goethite)
  o Leading metallurgical companies and research institutes
MaRes Rationale: metals and minerals from residues - towards new metallurgical systems

Fig. C5 - Toolbox for treatment of industrial residues by combining different innovative technologies

MaRes aims at creating and demonstrating an operational, flexible toolbox combining pyro-, hydro-, electro-, bio-, solvo- and ionometallurgy technologies to recover metals and to hot stage engineer and valorise the residual matrix into highly innovative low-carbon building materials and other mineral materials.
MaRes Roadmap Flanders: binders from secondary resources (case: MetalloChimique)

Table produced from cleaned fayalitic slag (97% slag in product)

IWT O&O COZIRAS MetalloChimique & KU Leuven → 36 M€ investment in new fumer to clean fayalite slag → new binders

Fig. E2 – Industrial roadmap for Flanders with respect to production of OPC-replacing, low-carbon binders from freshly produced and stockpiled residues.
MaRes ICON SUPERMEX project: valorising CM containing sludges (Nyrstar) and slags (Umicore) with mineral valorisation into geopolymers (CRH) (KU Leuven)

Nyrstar Balen/Overpelt – Belgium

<table>
<thead>
<tr>
<th>Composition Nyrstar's goethite sludge</th>
<th>Fe (wt%)</th>
<th>SiO₂ (wt%)</th>
<th>CaO (wt%)</th>
<th>Zn (wt%)</th>
<th>Pb (wt%)</th>
<th>In (g/t, dry basis)</th>
<th>Ge (g/t, dry basis)</th>
<th>Other elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshly produced (80,000 tonnes/year)</td>
<td>24-36</td>
<td>3.7-8.4</td>
<td>0.7-6.1</td>
<td>5.9-12.9</td>
<td>1.5-3.7</td>
<td>100-500</td>
<td>50-100</td>
<td>S, Ag, As, Tl, Cd, Cu, Mn,..</td>
</tr>
<tr>
<td>Stockpiled goethite (&gt; 1 million tonnes)</td>
<td>24-36</td>
<td>3.7-8.4</td>
<td>0.7-6.1</td>
<td>5.9-12.9</td>
<td>1.5-3.7</td>
<td>100-900</td>
<td>50-180</td>
<td>S, Ag, As, Tl, Cd, Cu, Mn,..</td>
</tr>
</tbody>
</table>

Jones/Urban Mining
KU Leuven & Flemish cooperation on the EU level: a world to win!
Flagship KU Leuven project: H2020 MSCA-ETN REDMUD: zero-waste valorisation bauxite residue

WP1. Fe and Al removal

WP2. Ti & REE removal and recovery

WP3. Cementitious binders

ESR5 (RWTH), ESR6 (NTUA), ESR7 (KU Leuven), ESR8 (KU Leuven) ESR9 (UHelsinki), ESR10 (MEAB)

ReEs incl. Sc

Residue

Bauxite residue

WP4. NORM and Characterisation of diverse BO’s, BRs and residues from WPs 1-4

ESR1 (RWTH) ESR2 (NTUA) ESR3 (KU Leuven)

WP5. Training

ESR13 (AoG), ESR14 (KTH) ESR15 (UTartu), ESRs 1-12

WP6. Dissemination and outreach

Bauxite Ore

WP7. Management

E22/10/2015
Pan-European collaboration to develop and implement the “New metallurgical system” toolbox

**METGROW+ “New Metallurgical Systems” Toolbox**

Primary and secondary resources containing base and critical metals
1. Low Grade Ores & Tailings
2. End-of-Life Waste
3. Sludges, slags, and dusts

**Existing & New Unit Operations**

- Pretreatment (WP2)
  - 1. COMMINUTION BENEFICIATION
  - 2. FEED PREPARATION
- Metal Extraction (WP3)
  - 3. HYDRO-FLEX
  - 4. BIOLEACHING
  - 5. SOLVO-IONO LEACHING
  - 6. PLASMA-PYRO
- Metal Recovery (WP4)
  - 7. SOLVO-IONO RECOVERY
  - 8. BIOSORPTION & PRECIPITATION
  - 9. (BIO)ELECTRO-WINNING
- Matrix conversion (WPS)
  - 10. SCM
  - 11. GEO-POL

**Residue Matrix Valorisation**

**EU**

**KU LEUVEN**

**H2020 METGROW+**

**SIM**
Circular economy and KU Leuven-Belgian participation in EIT KIC Raw Materials

Co-location centre “West” in Leuven

Belgian core partners:

1. Sustainable Mining
   - Natural resources
   - Historic wastes (tailings, landfills)

2. Materials Management
   - New scrap
   - Metals, alloys & compounds

3. Recycling Technologies
   - Historic wastes (tailings, landfills)
   - Natural resources

4. Substitution
   - from industrial minerals
   - from concentrates & ores

Raw Materials Production
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