Resource Recovery and Remediation of Alkaline Wastes (R³AW)

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**Alkaline residues**

- Major global waste streams: e.g. steel slags, fly ash, lime spoil, C&D waste, Solvay Process waste, bauxite processing residue
  - Steel slag: 180 million tonnes p.a. globally
  - Fly ash from coal combustion: 415 million tonnes p.a. globally
  - Red mud: 120 million tonnes p.a. globally
Environment: fugitive dusts
Environment:
soils
Environment: water pollution
Long term environmental liabilities

- Long-lived sources: sustained capital input needed
- Conventional management:
  - Acid dosing,
  - Recirculation of waters over spoil, aeration

Water pH in two streams draining the former Consett Steelworks, Co. Durham, UK

Statutory surface water quality limit
Alkaline residues - opportunities

• Generally enriched in a range of e-tech metals and metalloids / CRM (e.g. REE, Co, Cr, Ga, Sb, V)

Typical concentrations of selected metals in alkaline residues (mg/kg)

<table>
<thead>
<tr>
<th></th>
<th>Ga</th>
<th>La</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel slag</td>
<td>30-60</td>
<td>60-100</td>
<td>80-8500</td>
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<tr>
<td>Red mud</td>
<td>70-80</td>
<td>140-300</td>
<td>860-1100</td>
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<tr>
<td>Fly ash</td>
<td>40-60</td>
<td>80-100</td>
<td>50-100</td>
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e.g. Ajka (Hungary) spill material: in the region of **US $0.8 million**
Opportunities - findings from the Catalyst

- Scope for *accelerating* processes
  - Compost cover
  - Minimise dust generation
  - More aggressive leaching
  - Recovery of metals
  - CO₂ offsetting
  - Restoration opportunities
Alkaline residues - the paradigm shift

• Actively accelerate leaching
• Recover the metals
• Remediate waters in low-cost gravity-driven systems
• Minimise the capex and reduce opex of remedial systems:

• £250K per year...>80 years required
<table>
<thead>
<tr>
<th>Challenge to IS</th>
<th>Example</th>
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<tbody>
<tr>
<td>Environmental/economic benefits not fully quantified</td>
<td>Eco-efficiency (assumption that environmental benefits bring economic benefits) seldom interrogated in detail</td>
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<td>Inter-company collaboration</td>
<td>Complex downstream ownership issues for steel by-products and long-standing (decadal) inter-company agreements</td>
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<td>Financial volatility of resource</td>
<td>Volatility of global resource prices may limit attractiveness for investment (e.g. REE since 2011)</td>
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<td>Waste policy</td>
<td>Definitions of waste (by-product, end of waste). Recovery / remediation at legacy sites (ownership, liabilities). Varying implementation across EU</td>
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<td>Scale of operations / power relationships</td>
<td>Large firms operate at a scale that may preclude local IS links</td>
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<td>Geographic constraints to symbiosis</td>
<td>Value of recovered commodity may restrict viable geographic range of re-use.</td>
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<td>Evolving stakeholder relationships / views</td>
<td>Objections to a recovery process may arise late in the development process</td>
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Aim

Develop predictable, passive remediation and e-tech metal recovery technologies for globally significant alkaline waste-streams and develop a framework for their effective deployment

NERC-facing
- Understanding of biogeochemical processes
- Optimise processes
- Develop / adapt recovery technologies
- Ecosystem services in restored analogues
- Identify substrates, test removal rates and upscale

ESRC-facing
- Frameworks for deployment
- Stakeholder engagement
- System boundaries
- Policy constraints
- Overcoming industrial inertia
- Integrated LCA to EU standards
Experimental approach: science elements

- Small scale
- Batch experiments
- Biogeochemical processes
- Lab mesocosms
- Flow through systems
- Leaching and recovery rates
- Buffering processes
- Field pilot
- Combined recovery and remediation
- Ecological endpoints
Systems analysis and LCA

- Systematic stakeholder identification
- Stakeholder interviews
- System analysis
- Policy analysis
- LCA modelled to various future scenarios
Cross-theme links

• Biologically-mediated metal recovery and remediation
• \textit{In situ} recovery
• LCA
• Policy aspects
• Systems analysis – upstream stakeholder engagement

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