An integrated comparative technological, environmental and economic assessment of P-recovery technologies

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Introduction

• Progress in development of technologies to recover P from wastewater/sewage sludge/ashes
• Manifold technological approaches are available
• Comparability is often not given

⇒ Integrated comparative technological, environmental and economic assessment
⇒ Todays focus:
  ① P-recovery potential
  ② heavy metal depollution
  ③ costs
  ④ energy demand
Goals for an efficient recycling

- No impairment to the WW treatment process
- High recovery potential (resource efficiency)
- Cost efficient
- Limited resource demand (chemicals & energy) and environmental pollution (emissions)
- Removal of pollutants (heavy metals and organic substances)
- Recycling products for universal use (P-acid), intermediary materials for downstream processing (CaP) or fertilizers with market potential

...BUT there are trade-offs for all technologies.
Comparison of 18 Technologies

<table>
<thead>
<tr>
<th>Liquid Phase</th>
<th>Sewage Sludge (SS)</th>
<th>Sludge Ash (SSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>effluent ion exchange</td>
<td>wet-chemical leaching</td>
<td>wet-chemical leaching</td>
</tr>
<tr>
<td><strong>REM-NUT®</strong></td>
<td><strong>Gifhorn process</strong></td>
<td><strong>PASCH</strong></td>
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<tr>
<td>[effluent precipitation: RAVITA]</td>
<td>Stuttgart process</td>
<td>LEACHPHOS®</td>
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<td>sludge crystallization</td>
<td><strong>PHOXNAN</strong></td>
<td>EcoPhos®</td>
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<tr>
<td><strong>AirPrex®</strong></td>
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<td>[Ash2®Phos]</td>
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<tr>
<td>supernatant crystallization</td>
<td><strong>supercritical water oxidation</strong></td>
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<tr>
<td><strong>Ostara Pearl Reactor®</strong></td>
<td><strong>metallurgic</strong></td>
<td><strong>RecoPhos®</strong></td>
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<td><strong>DHV Crystalactor®</strong></td>
<td></td>
<td>Fertilizer Industry</td>
</tr>
<tr>
<td><strong>P-RoC</strong></td>
<td><strong>MEPHREC®</strong></td>
<td><strong>AshDec®</strong></td>
</tr>
<tr>
<td><strong>PRISA</strong></td>
<td></td>
<td>thermo-electrical</td>
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<tr>
<td>[PhosphoGreen + Eco:P]</td>
<td></td>
<td>Thermphos (P₄)</td>
</tr>
</tbody>
</table>


Method

Life Cycle Assessment

Cost Calculation

Substance Flow Balance

Material Flow Balance

Energy Flow Balance

ecoinvent data base

direct HM emissions

direct gaseous emissions

Product Characterisation

Emissions to atmosphere, water bodies and soil

cumulative energy

modified from Amann et al. (2018)
Method: Reference System & Technology

- WWTP with pollution load of 100,000 PE
- Thermal sludge treatment with co-/monoincineration
- Waste management and treatment of all residues

Egle et al. (2016)
Method: Path of P and heavy metals

Egle et al. (2016)
Results: Removal of pollutants (I)

- Products almost free from heavy metals: recovery from sludge water
- Very good heavy metal removal with almost all recycling technologies from sewage sludge (except MEPHREC®)

- Strongly differing results for technologies to recycling P from sewage sludge ash
Results: Removal of pollutants (II)

RecoPhos®/Fertilizer Industry (wet-chemical extraction)

AshDec® (thermo-chemical)

LEACHPHOS® (wet-chemical leaching)

EcoPhos® (wet-chemical leaching)

Egle et al. (2016)
Results: Costs (I)

Basis of calculation: Running costs **without** savings and revenues

- **Sludge Water/Effluent** and **Sewage sludge**: 100,000 PE
- **Sewage sludge ash**: 30,000 t ash
Results: Costs (II)

**Basis of calculation:** Costs for recycling technologies over the whole process chain with possible savings and revenues.

**Result:** Additional costs for waste water treatment for most technologies

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Egle et al. (2016)
Results: Cumulative Energy Demand

- Benefits with recovery from sludge water
- High energy demand for technologies from sewage sludge
- Recovery from ash beneficial if substitution of P fertilizer considered
Summary and Conclusions (I)

- **Remarkable** but often **unexploited** P-potential
- Manifold available P-recycling technologies, development ongoing
- **Sludge water:** Simple technologies, frequently implemented, operation with financial gains possible, advantages for WWTP, very good final products → but low recycling potential (10–30%) related to WWTP influent
- **Sewage Sludge:** Manifold approaches with varying results: Technologies difficult to control and expensive (wet-chemical), hardly any saving potential, good quality of recycling product (MAP, CaP), need of further research
Summary and Conclusions (II)

Sewage sludge ash:

- Incineration without mixing with P-poor ashes (potential use of additional P-rich wastes e.g., meat and bone meal)
- Different strategies possible:
  - Maximum of heavy metal removal – lower P-recycling – higher costs
  - Maximum of P-Recycling – no or incomplete HM-removal – low costs
- Alternative: Substitution of raw phosphate in Fertilizer industry or P-industry (Thermphos®, EcoPhos®, Ash2®Phos)
- Optimal strategies will always depend on national, regional and site specific contexts
Related publications of the TU Wien Tema

Technological Perspective


Management Perspective


Thank you for your Attention!

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