Phosphorus Management & Circular Economy

From Discussion to Implementation for the case of sewage sludge management

by Christian Kabbe
AGENDA

01 Introduction & why P?
02 Germany 2017+
03 Recovery and Market issues
04 Outlook

Joseph Wright of Derby: Henning Brand discovering phosphorus in 1669
Life’s bottleneck! Limits the biomass potential of the planet!

Isaac Asimov 1959

1. Phosphorus is essential to life, non-renewable
   - Phosphate rock limited availability

2. Geostrategic dependency of EU on few countries
   - EU import dependency 92% of fossil-based P (Germany 100%)
   - Phosphate rock on EU list of 20 Critical Raw Materials since 2014
   - $P_4$ at CRM list since 2017

3. Environmental impact of active phosphorus (surplus coming from waste)

Presented by Christian Kabbe @ 5th PROMETIA Seminar, 14 Dec 2018 in Berlin
Why Phosphorus?

https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html
The broken cycle

- Increase crop yield
- Compensate dissipation and losses

Adapted from: [http://www.nhm.ac.uk/research-curation/research/projects/phosphate-recovery/ceep11.htm](http://www.nhm.ac.uk/research-curation/research/projects/phosphate-recovery/ceep11.htm)

263 million tons fossil P rock (global mining 2017, USGS 2018)
## Relevant Renewables

<table>
<thead>
<tr>
<th>[kton P/year]</th>
<th>Total</th>
<th>Recycled</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage sludge</td>
<td>297</td>
<td>115</td>
<td>182</td>
</tr>
<tr>
<td>Biodegradable solid waste</td>
<td>130</td>
<td>38</td>
<td>92</td>
</tr>
<tr>
<td>Meat &amp; bone meal</td>
<td>128</td>
<td>6</td>
<td>122</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>427-555</td>
<td>153-160</td>
<td>274-396</td>
</tr>
<tr>
<td>Manure recycling =</td>
<td>1 736</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral fertiliser use =</td>
<td>1 448</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Van Dijk & Oenema “Overview of phosphorus flows in wastes in Europe”, 2013, Fertilisers Europe seminar, 6 Feb. 2013. Updated Van Dijk et al. 2015

Sewage (sludge) is the second most relevant renewable P source in Europe!
Sewage (sludge) is a renewable nutrient resource still waiting to be tapped to it’s full potential
Challenges: Enabling techn. alternatives to complement /compensate traditional route!
Sewage Sludge - Destinations in Europe - Diversity

Total sludge quantity covered: appr. 10 million tons of dry solids per year!

Germany 2017+: a template to adapt, but not just to copy as is

- 2017 – new fertilising ordinance (DÜV) limits nutrient loads applied to land and acutely reduces sludge disposal capacities -> cost explosion!
- new fertiliser ordinance (DÜMV) sets stricter quality criteria (less sludge conform) – monitoring cost
- 2017 – new sewage sludge ordinance (AbfKlärV) enters into force
  - 2023 – all WWTP have to submit sludge management concepts considering P recovery
  - 2029 – P recovery oblig. for all plants > 100,000 p.e. (ban from land application)
  - 2032 – P recovery oblig. for all plants > 50,000 p.e.
    - Even smaller WWTP forced to recover P, if no land application possible
    - On-site WWTP have to deplete below 20 g P/kg DM or at least by 50%
    - After thermal pretreatment recoverable separate storage of ash/concentrate or recovery process with >80% recovery rate
- What is missing?
  - No marketable recycling concepts included
  - No measure to secure proper ash quality (all sludge can be inc. in mono-inc.)
  - Reverence value for P should refer to mineral sludge phase, not to DS
  - Who pays for what? (Inc. and recovery from ash monopoly?)
Hotspots for P recovery & Recycling for WWTP > 50.000 p.e.

2029/32+
- Land appl. prohibited
- Co-incineration only for sludge with < 2% P
- Mono-incineration allowed without restriction, but P recovery from ash afterwards required

Priority for utilities:
- Long term disposal security
- Cost control
- Lowest financial risk

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Sewage Sludge - Destinations in Germany 2016

Total municipal sludge quantity: 1.77 million tons of dry solids per year!
Germany 2017+ substantial increase of mono-incineration

- Currently appr. 668 kt DS mono-incineration capacity 2017 (municipal sludge)

- After 2029/32 at least 1.200.000 Mg DS capacity needed to comply with sludge reg (Ecoprog 2017) … likely more

- Most new capacities between 2022 and 2027 (already +600 kt DS in prep. announced)

  -> future SSA quantity > 500.000 Mg/a (>45.000 Mg P/a)
More than 100 full-scale plants operational world-wide! > 80 recover Struvite (> 60 are municipal)

Global implementation – without law enforcement just to recover as such?
Availability of Solutions? ... Yes! there are ...

Where?
- Integrated recovery at WWTP
- Down-stream recovery from sewage sludge

Re-dissolution modules
- Without enforced re-diss.
- Poly-phosphate re-diss. prior digestion
- Thermal hydrolysis
- Chemical re-dissolution

Recovery modules
- Crystallization in sludge matrix
  - AirPrex
  - EloPhos
  - STRUVEX
- Crystallization in sludge liquor or adsorption at CSH after dewatering
  - Pearl
  - Phosnix
  - AD-HAP

Pre-treatment
- Sewage sludge mono-incineration
- Thermal alternatives
- Direct application

P recovery & recycling
- Chemically
  - Conv. Fertiliser Manufact.
  - Glatt® SERAPLANT
  - METAWATER
- Thermally
  - AshDec, EuPhoRe
  - RecoPhos (InduCarb)
  - EcoRin

Agriculture
- Full-scale
- Demo/Pilot
- Landscaping

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Amended from P-REX® and Kraus
Challenges and **keys to Success and Sustainability?**

Only technologies, yielding **homogenous products** or raw materials, **independent from input material quality** and mutually meeting both criteria, **energy efficiency** and **resource efficiency** will have a chance for wide-spread application under sustainability aspects.

**Keys:**
- ✓ Heavy metal depletion *(high quality products)*
- ✓ Moderate energy (and chemicals) consumption *(cost)*
- ✓ Market for “known” recovered P *(commercial products)* *(real value and price)*
Today:
60% mono-inc.
40% co-inc.
Some struvite

Tomorrow:
100% mono-inc.
Some struvite

From 2024/25 100% mono-incineration in 2 incinerators

http://www.stadtentwicklung.berlin.de/umwelt/abfall/klaerschlamm/ressource.shtml
No Recycling without **Value Chains**

**Commodities**

- Sludge – organic fertiliser
- Struvite – NP fertiliser in some MS (proven good fert. eff.)
- DCP – approved P fertiliser (component)
- Ash – generally barely plant available, rather raw material – processing needed
- MAP/DAP – main N&P components in fertiliser production (commodities)
- MGP / $P_4$ – commercial products with broad application (commodities)

(Biochar) – actually Pyrochar! No fertiliser! Maybe soil improver?

Waste, raw material or product? -> Question of volume, homogeneity and still of origin!

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OSTARA’s – Value Chain Solution (on-site WWTP recovery)

Solves operational problems
Provides operational benefits, reduces opex
Improves overall WWTP performance
Offtake guarantee takes burden from operator
Creates real value out of struvite

Source: OSTARA

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Commercial HQ products as renew. raw materials
Commercial HQ by-products
Independent of Fe/Al and ash moisture
Real Heavy Metal decontamination
Robust and simple!!!
Substantially reduces waste!

Source: http://www.easymining.se/our-technologies/ash2phos/
Wrap-up & Outlook

- Would there be any change without law enforcement?

- New German legislation fosters sludge mono-incineration and therefore drying as well -> co-incineration capacities declining ... as capacities for imported sludge

- Site-by-site P recovery on-site WWTP needs to be linked with operational needs and benefits and will play a limited complementary role

- Ash-based route will become the major route for P recovery from sewage in Germany (>500,000 Mg SSA, > 45,000 Mg P) -> lowest risk for invest. and sludge disposal route

- Known materials easier to integrate in market! Recyclates need to fit into existing markets, not the other way around!

- Recovery and recycling of P contributes to CE and sustainability
Thank you

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