Multi-sectoral wide EU approach for the closure of the loop of a critical raw material: the European phosphorus platform

Anna Laura Eusebi – Università Politecnica delle Marche
Phosphorus importance

Without mineral phosphate fertilisers we could feed maybe $\frac{1}{5}$th of the current world population

Adapted from Dawson et al., Food Policy 2011: http://www.sciencedirect.com/science/journal/03069192

Without Haber-Bosch (mineral nitrogen fertilisers) We could feed half of the world population

Fertilizers Europe / Wageningen University

https://phosphorusalliance.org

Courtesy of C. Thornton European Phosphorus Platform
Requests and final uses

Global phosphate rock market share, by region, 2018 (%)

- Asia Pacific
- Middle East & Africa
- Europe
- North America
- Central & South America

Source: www.grandviewresearch.com

Global Phosphate Market Share, by Application, 2017 (%)

- Fertilizers
- Food & Beverage
- Detergents
- Water Treatment
- Chemicals
- Metal Treatment
- Cosmetics & Personal Care
- Pharmaceuticals
- Others
Location of resources in the world

Where are located the main phosphorus mines?
Location of resources in/for Italy

1. PHOSPHATE ROCKS
   - Italy totally depends from import
   - 64% turnover
   - 475,000 t P2O5 phosphate rock
   - 3% P2O5 in all Europe
   - Mainly from Africa

Source: IFA 2017

www.smart-plant.eu/ENEA
### Impurities of mineral Phosphorous

#### Phosphate Rock - Main Impurities

<table>
<thead>
<tr>
<th>Country</th>
<th>Deposit</th>
<th>P2O5 (wt %)</th>
<th>As (ppm)</th>
<th>Cd (ppm)</th>
<th>Cr (ppm)</th>
<th>Hg (ppb)</th>
<th>U (ppm)</th>
<th>V (ppm)</th>
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Price of mineral Phosphorus
Pressure to recycle phosphorus

Phosphate is on the EU Critical Raw Materials List since 2014 and White Phosphorus since 2017
- Non substitutable
- Non renewable
- Geopolitical resource concentration
- EU 90% dependent on imports

Pressure to reduce phosphorus losses

- Phosphorus is first cause of (non-morphological) quality status failure under the EU Water Framework Directive
- 55% of UK rivers and 74% of lakes exceed P level for good ecological status
- … despite sewage works P discharge reduced 70% 1987 - 1996

- Nitrates Directive 1991/676
Summary...

Recycling potential

- **European Commission** \(^1\)
  STRUBIAS\(^1\) recycled products could replace 25-40% of EU mineral phosphate fertilisers

- **European Commission** \(^2\)
  Phosphorus recycling could replace 30% of EU mineral phosphate fertilisers

- **i.e. market value of recycled phosphates of c. 600 M€** \(^3\)

  [http://dx.doi.org/10.1016/j.scitotenv.2015.08.048](http://dx.doi.org/10.1016/j.scitotenv.2015.08.048)

<table>
<thead>
<tr>
<th>Recycling Sources</th>
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<th>Potential</th>
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<td>115</td>
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<tr>
<td>Meat &amp; bone meal</td>
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<td>6</td>
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<td><strong>274-396</strong></td>
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<td>Manure recycling</td>
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<td>Mineral fertiliser use</td>
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1 = JRC STRUBIAS draft « Market » report 20/12/2017
STRUBIAS products = recovered phosphate salts, ashes, biochars
3 = ESPP estimate
**EU nutrient recycling legal framework**

**EU Fertilising Products Regulation (FPR)**

- Flagship of Commission ‘Circular Economy Package’
- All fertilisers (mineral & organic), plant materials, composts & digestates, soil amendments, growing media, biostimulants, liming materials, etc.
- First EU product legislation to confer “End-of-Waste” status
- Opens European market for recycled fertilisers and for recycling technologies


- **STRUBIAS**: aims to add struvite/phosphate salts, biochars/pyrolysis materials, ash-based materials

*Courtesy of C. Thornton European Platform*
Opportunities to recycle wastewater nutrients?
under new EU Fertilising Products Regulation and STRUBIAS

<table>
<thead>
<tr>
<th>in? or out?</th>
<th>Sewage</th>
<th>Manure</th>
<th>Animal By-Products</th>
<th>Food waste / biowaste</th>
<th>Food industry</th>
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<td></td>
<td></td>
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<td>Cat 2&amp;3</td>
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<tr>
<td>CMC5: digestate</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(X)</td>
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<tr>
<td>CMC6: food-industry by-products</td>
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<td>✗</td>
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<tr>
<td>CMC11: animal by-products (ABPs)</td>
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<tr>
<td><em>Including when used as fertiliser production ingredient</em></td>
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<td>✓ (sterilised ?)</td>
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<tr>
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<td><em>STRUBIAS biochars etc</em></td>
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<td>✓</td>
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</tbody>
</table>

Courtesy of C. Thornton European Phosphorus Platform
Phosphorus load distribution

- **100% P load**
  - Grit chamber
  - Preliminary clarification
  - Aeration
  - Secondary clarification
  - Effluent

- **>90% P load**
  - Anaerobic digestion

- **5-20% of P load**
  - Biogas

- **≤ 25% of P load**
  - Process water

- **≤ 50% of P load**
  - Returned activated sludge

- **40-90% of P load** (solubility, contaminants)

- **> 80% of P load**
  - Ash after incineration
  - Undrained sludge after anaerobic digestion
  - Sludge liquor after dewatering
  - Direct agricultural utilisation of dewatered sludge

*Enhanced P dissolution*
Technical solutions? Several

P-REX

Liquid phase (dissolved P)
- Wet sludge and liquor
- with enhanced P dissolution

Acidic digestion or leaching
- Sludge and sludge ash
- Fertilizer industry
- Mineral fertilizer
- ECOPHOS H₃PO₄
- DCP
- MEPHREC P-slag
- THERMPHOS H₃PO₄/P₄

Thermal
- Electrolysis H₃PO₄
- TetraPhos H₃PO₄
- AshDec (Outotec) P-mineral
- Inducarb FP7 H₃PO₄/P₄
- MEHREC P-slag
- PYREG P-mineral

Full-scale Demo/Pilot Lab-scale
Global Implementation
Global Implementation

Plants to struvite recovery

(Source: O’Callaghan – IFAT 2018)
Struvite – essentially a by-product

- Driven and paid-back by maintenance improvements and savings in EBPR plants
- <10% of European wastewater treatment plants qualify for the current „struvite“ process
- Average P recovery rate from the aqueous phase 8-15% of the potential, up to 40% recovery with sludge pre-treatment
- Plants produce a few hundred to few thousands tons of P-fertilizer. Different shapes, impurities, pollutants and fertilizing efficiency.
- Constant high quality products from Ostara.
P-recycling from sewage sludge ash

> 85% P-recovery rate
  • Several financially sound, industry owned technology suppliers
  • Independent of P-removal process in sewage plant
  • Some processes recover iron/aluminium salts for P-removal in wastewater treatment plants
  • Some processes recover silicates for cement production

But...still no full scale
# Agronomics Characteristics and Depollution Necessity

**Fonte P-Rex**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Recovery potential</th>
<th>Recovery process</th>
<th>TRL</th>
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<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>OM</th>
<th>Recovered material</th>
<th>Solubility</th>
<th>Relative fertilizer efficiency</th>
<th>Pollution potential, handling</th>
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<tbody>
<tr>
<td>REM-NUT®</td>
<td>90%</td>
<td>50-60%</td>
<td>5-6-</td>
<td>ion exchange</td>
<td>(c)</td>
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<td></td>
<td></td>
<td>MAP</td>
<td>&lt;1%</td>
<td>90-100%</td>
<td>90-100%</td>
</tr>
<tr>
<td>AirPres®</td>
<td>85-90%</td>
<td>10-max. 25%</td>
<td>9-9</td>
<td>not necessary</td>
<td>(c)</td>
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**Sewage sludge**

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<th>Recovery potential</th>
<th>Recovery process</th>
<th>TRL</th>
<th>Depollution technology and potential</th>
<th>Heavy metals</th>
<th>As</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
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<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>OM</th>
<th>Recovered material</th>
<th>Solubility</th>
<th>Relative fertilizer efficiency</th>
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**Sewage sludge ash**

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<th>Recovery process</th>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaP</td>
<td>&lt;1%</td>
<td>80-90%</td>
<td>90-100%</td>
</tr>
<tr>
<td>EcolPhos®</td>
<td>95%</td>
<td>~85%</td>
<td>9-9</td>
<td>leaching + organic agent</td>
<td>(c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Phosphoric acid</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>RecPhos®</td>
<td>100%</td>
<td>~87%</td>
<td>9-9</td>
<td>no</td>
<td>(c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mineral fertilizer</td>
<td>75%</td>
<td>100%</td>
<td>75%</td>
</tr>
<tr>
<td>Fertilizer Industry</td>
<td>100%</td>
<td>~87%</td>
<td>9-9</td>
<td>no</td>
<td>(c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mineral fertilizer</td>
<td>40-50%</td>
<td>80-90%</td>
<td>20-40%</td>
</tr>
<tr>
<td>Thermos®</td>
<td>95%</td>
<td>~85%</td>
<td>9-9</td>
<td>Silica slag</td>
<td>(c)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Single Superphosphate**

<table>
<thead>
<tr>
<th>Depollution related to the input flow</th>
<th>Organic Micropollutants (OM)</th>
<th>Handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>no data</td>
<td>+ total destruction of OM</td>
<td>++</td>
</tr>
<tr>
<td>~20%</td>
<td>OM significantly reduced</td>
<td>-</td>
</tr>
<tr>
<td>&gt;40%</td>
<td>OM destruction due to oxidation process</td>
<td>-</td>
</tr>
<tr>
<td>&gt;60%</td>
<td>OM destruction due to sludge incineration</td>
<td>-</td>
</tr>
</tbody>
</table>

**ITalian PHosphorus Platform**

**European Sustainable Phosphorus Platform**

**University Politecnica delle Marche**

**SMART-Plant**
Management costs

Engle et al., 2016
Legislation as driver?
Example Germany 2017+

**National phosphorus recycling legislation**

**Germany**

- **Legislation May 2017**
  - makes phosphorus recovery obligatory
  - within 12/15 years
  - for all wwtp > 50 000 p.e.
  - if sewage sludge P > 2% of dry matter

- **Requires to either recover >50% of P or to reduce sludge P to <2%**
  - *national guidance document under discussion (2019):*
    - %P depends on organics: change with hydrolysis, digestion → may favour mono-incineration (80% of P recovery)

- **Land sewage biosolids use banned for larger sewage WWTP,**
  and lower contaminant limits will reduce spreading for smaller WWTP
National phosphorus recycling legislation

**Switzerland**

- 2016 Decree makes phosphorus recovery obligatory by 2026 from sewage sludge incineration ash* and meat and bone meal ash
  * Switzerland banned land use of sewage biosolids in 2006
- Still under discussion:
  - %P recovery to be required
  - recycled fertiliser criteria
  (Bundesrat decision expected 24/10/2018)
Legislation as driver?

National P-recycling policy developments

Baltic

- **HELCOM:**
  8 EU Member States, plus Russia and the EU

- “Recommendation” March 2017 = obligation
  - maximise phosphorus and other useful substance recycling
  - regular State reporting on measures taken to implement this

- Ministerial Declaration March 2018:
  - define Nutrient Recycling Strategy by 2020
Legislation as driver?

**National P-recycling policy developments**

**Sweden**

- 13 July 2018: Government announces ‘enquiry’ into
  - ban on agricultural use of sewage sludge
  - phosphorus recycling regulation
- Currently working on regulatory proposal - Conclusions mid 2019?

**Austria**

- P-recovery obligation included in Government mandate plan
- Waste Management Plan 2017: P-recovery from 65-85 of sewage sludge by 2030
EU regulation and studies underway

“SAFEMANURE” study
ED ENVI study on recycled nutrient products from manures for the Nitrates Directive (“processed manures”)

REACH contaminants studies
to prepare possible “Restrictions’ under REACH
→ composts and digestates – completed not published
→ mineral and organic fertilisers – tender underway

REACH ‘Registration’ (Annex V) exemption for digestates: regulation expected to be published soon

Legislation as driver?

EU-wide monitoring of manure supporting the development of safe processed manure criteria

In order to promote the sustainable recovery of nutrients from manure, a careful evaluation of agronomic benefit versus possible risks to the environment and health is of pivotal importance. Such an evaluation should be the basis for the development of harmonised criteria that better assess nitrogen fertilisers that are partially or entirely derived from manure.

Within this framework, the role of agricultural application of manure (processed or not) in the propagation of anti-microbial resistance (AMR), interspecies exchange and antibiotic resistant genes as well as the role of veterinary antimicrobial agents is a priority field of research of the European Commission. Indeed, there is a significant data gap on the impacts of antibiotic resistance trends that have been linked with...
European Founding possibilities?

**EU R&D funding**

- **R&D funding:**
  - FP7 (e.g. P-REX project)
  - Horizon 2020
  - Horizon Europe (2021-2028)

- **Agriculture R&D funding**
  - DG ENV: - LIFE
  - DG REGIO: - InterReg
  - National / regional programmes: - e.g. Baltic Bonus

### Upcoming Horizon 2020 calls 22/1/2020

<table>
<thead>
<tr>
<th>Call Code</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE-RUR-08-2018-2019-2020</td>
<td>Closing nutrient cycles - IA Innovation action + RIA Research and Innovation action</td>
</tr>
<tr>
<td>CE-FNR-17-2020</td>
<td>Pilot circular bio-based cities – sustainable production of bio-based products from urban biowaste and wastewater</td>
</tr>
<tr>
<td>CE-FNR-15-2020</td>
<td>A network of European bioeconomy clusters to advance bio-based solutions in the primary production sector</td>
</tr>
<tr>
<td>FNR-18-2020</td>
<td>Sustainability of bio-based products – international governance aspects and market update</td>
</tr>
</tbody>
</table>
ESPP: a coalition for action

• Wide objectives:
  - phosphorus stewardship
  - global food security
  - circular economy
  - environmental protection
  - healthy diet and food safety

• Bringing together:
  - water & waste industries,
  - mineral and organic fertilisers, chemicals,
  - P-recycling technology suppliers,
  - national & regional governments,
  - knowledge institutes …

• Actions:
  - vision & awareness
  - stakeholders & networking
  - dissemination
  - policy and regulation dialogue

More information: www.phosphorusplatform.eu

http://www.phosphorusplatform.eu/members
How ESPP operates

Legally established not-for-profit association → important for transparency, clarity of decision making, representation

- statutes are public  https://www.phosphorusplatform.eu/platform/about-espp
- EU Transparency Register no. 260483415852-40 http://ec.europa.eu/transparencyregister/

100% membership funded
European Phosphorus Platform: Events

**ESPP and research**

- **1\textsuperscript{st} European nutrient research event, Berlin 2015**
  at ESPC2 (European Sustainable Phosphorus Conference)
  with FP7 project P-REX, see ESPP SCOPE Newsletter \textsuperscript{n° 111}
  conclusions published by European Commission

- **2\textsuperscript{nd} European nutrient research event, Basel 2017**
  with InterReg project Phos4You, see ESPP eNews \textsuperscript{n° 16}

- **3\textsuperscript{rd} European nutrient research event, Rimini 2018**
  with Horizon2020 project SMART-Plant, see ESPP eNews \textsuperscript{n° 28}

- **4\textsuperscript{th} European nutrient research event - planned at ESPC4**
  Vienna, 15-17 June 2020  https://www.phosphorusplatform.eu/espc4
Nutrients Platform in the word

**Nutrient platforms and networks worldwide**

- **Netherlands** 2010 [http://www.nutrientplatform.org/](http://www.nutrientplatform.org/)
- **Germany** 2015 [www.deutsche-phosphor-plattform.de](http://www.deutsche-phosphor-plattform.de)
- **Baltic**: ESPP works with Baltic Sea Action Group [www.bsag.fi](http://www.bsag.fi)
- **ESPP** European Sustainable Phosphorus Platform 2013
- **North America**: Sustainable Phosphorus Alliance (SPA) 2017 (launched as NAPPS in 2015) [https://phosphorusalliance.org/](https://phosphorusalliance.org/)
- **Japan**: PIDO 2011 (Phosphorus Industry Development Organization of Japan) [www.pido.or.jp](http://www.pido.or.jp)
Nutrients Platform in the word

Nutrient platform projects

Czech Republic Česká Fosforová Platforma [www.fosforovaplatforma.cz]

Ireland All Ireland Phosphorus Platform [www.nutrientsustainability.ie]

Italy Piattaforma Italiana del Fosforo Contact ENEA [roberta.decarolis@enea.it]

Norway Phosphorus Platform
Contacts [Daniel Mueller](mailto:Daniel.Mueller@ntnu.no) Helen Ann Hamilton [helen.a.hamilton@ntnu.no]

Switzerland
Swiss Phosphorus Network [www.pxch.ch]
AMTP Platform for cooperation on phosphorus recovery technologies [http://www.klaerschlamm.zh.ch/]

United Kingdom Nutrient Platform Contact [r.sakrabani@cranfield.ac.uk]

Canada Phosphorus Hub [https://www.phosphorushub.com]
http://www.phosphorusplatform.eu/members

Thank you for your attention!

a.l.eusebi@univpm.it