EUROPEAN BEST PRACTICES ON RESOURCE RECOVERY FROM THE WATER CYCLE

ARREAU Review

December 2017
EIP-W Action Group ARREAU

**Accelerating Resource Recovery from the water cycle**

**Objectives**

- Review and exchange current European best practices
  - Success factors for viable and profitable value chains
  - Recommendations to remove policy, financial and legal barriers
- Jointly develop value chains and markets
Working Groups

- Drinking water resources
- Phosphorus from wastewater
- Cellulose from wastewater
- New resources from water

EIP Water

STEERING GROUP

Cross-cutting issues
Working Group
Drinking Water Residuals

Lead: Olaf van der Kolk
(AquaMinerals)
Objectives

• Explore valorisation options for drinking water residuals
• Describe a profitable valorisation governance model
• Contribute to water supply as a zero emission industry
Type of drinking water residuals

<table>
<thead>
<tr>
<th>Processing steps</th>
<th>Main residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softening</td>
<td>Softening pelets</td>
</tr>
<tr>
<td>De-ironing/removal manganese</td>
<td>Lime-sludge</td>
</tr>
<tr>
<td>Coagulation (removal of very fines)</td>
<td>Lime-iron sludge</td>
</tr>
<tr>
<td>De-coloring (removal of humics)</td>
<td>High grade iron-sludge</td>
</tr>
<tr>
<td>Activated coal filtration</td>
<td>Low-grade-Al-/or Fe-sludge</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
</tr>
<tr>
<td></td>
<td>Activated coal sludge</td>
</tr>
</tbody>
</table>
Way of bringing residuals to the market (I)

Tendering

- Company/plant → Residual → Tender → Best Offer → Contractor A, B, C, ...

Application
Way of bringing residuals to the market (II)

Best Practice: shared service center

- Company/Plant 1
- Company/Plant 2
- Company/Plant 3
- Company/Plant X

Shared Service Centre

Residual A
+ buying /sales power  
+ knowledge 
- lower costs tender procedure

Tender

Option/innovation 1

Option/innovation 2

Option/innovation 3

Best Offer

contractor A

contractor B

contractor C

consortium

Application

Residual B

Research Institutes

Option / innovation 2

Shared Service Centre

Service Providers

Suppliers Residuals
Teaming up benefits ....
# PESTEL (organisation)

<table>
<thead>
<tr>
<th>PESTEL</th>
<th>Model: tendering per residual / location</th>
<th>Model: shared service centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political</td>
<td>--</td>
<td>Cooperation is supported</td>
</tr>
<tr>
<td>Economical</td>
<td>Cheapest solution per set service / application</td>
<td>Financial better results than tendering</td>
</tr>
<tr>
<td>Social</td>
<td>Gives competition within PMC</td>
<td>Gives room to innovation from SME’s and therefore quickest road to best performing PMC</td>
</tr>
<tr>
<td>Technology</td>
<td>Often set or at least delimited in tender</td>
<td>Accelerating innovation</td>
</tr>
<tr>
<td>Ecological</td>
<td>Framework set in tender</td>
<td>Better results due to innovative applications</td>
</tr>
<tr>
<td>Legal</td>
<td>In compliance to (EU-) law and policy</td>
<td>Possible challenge in anti-monopoly laws</td>
</tr>
</tbody>
</table>
### Softening pellets: market(s) (1/2)

<table>
<thead>
<tr>
<th>Issue/application</th>
<th>Agricultural</th>
<th>Isolation</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific</td>
<td>Slow releasing neutralizing agent</td>
<td>Avoid evaporation to crawl space</td>
<td>A.o. tiles, structural concrete</td>
</tr>
<tr>
<td>Replaces</td>
<td>Quarry lime</td>
<td>Shells</td>
<td>Sand/gravel</td>
</tr>
<tr>
<td>Quality issues</td>
<td>Water content</td>
<td>--</td>
<td>Size distribution</td>
</tr>
<tr>
<td>Legal issues</td>
<td>Fertilizer act</td>
<td>REACH</td>
<td>REACH Certificates</td>
</tr>
<tr>
<td></td>
<td>REACH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technique</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Maturity market</td>
<td>Grow/mature</td>
<td>Mature/decline</td>
<td>Mature</td>
</tr>
<tr>
<td>Volume market</td>
<td>&gt;&gt; volume DWP</td>
<td>Geography: low situated areas (delta’s)</td>
<td>&gt;&gt; volume DWP</td>
</tr>
<tr>
<td>Number of clients</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Accession market</td>
<td>Moderate</td>
<td>Difficult</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

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## Softening pellets: market(s) (2/2)

<table>
<thead>
<tr>
<th>Issue/application</th>
<th>Excipient for industry</th>
<th>Resource for industry</th>
<th>Food, feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific</td>
<td>A.o. neutralizing waste water, power plants</td>
<td>Production glass, plastics</td>
<td>Additive to food (e.g. diary) and feed</td>
</tr>
<tr>
<td>Replaces</td>
<td>Quarry lime</td>
<td>Quarry lime</td>
<td>Quarry lime</td>
</tr>
<tr>
<td>Quality issues</td>
<td>--</td>
<td>Different and often difficult, calcite core</td>
<td>Hygiene Calcite core</td>
</tr>
<tr>
<td>Legal issues</td>
<td>REACH</td>
<td>REACH</td>
<td>REACH, GMP+</td>
</tr>
<tr>
<td>Technique</td>
<td>--</td>
<td>Drying, seaving, grinding</td>
<td>Drying, seaving, grinding</td>
</tr>
<tr>
<td>Maturity market</td>
<td>Growth</td>
<td>Growth</td>
<td>Growth</td>
</tr>
<tr>
<td>Volume market</td>
<td>Geography: presence specific industry</td>
<td>Potential large, however local</td>
<td>Potential large</td>
</tr>
<tr>
<td>Number of clients</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Accession market</td>
<td>Difficult</td>
<td>Difficult</td>
<td>Difficult</td>
</tr>
</tbody>
</table>
# High grade iron sludge

<table>
<thead>
<tr>
<th>Issue/application</th>
<th>S-binding</th>
<th>P-binding</th>
<th>As-binding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific</td>
<td>Binding sulphur, mainly in digesters</td>
<td>Binding phosphate, surface water, waste water</td>
<td>Binding arsenic. Drinking water</td>
</tr>
<tr>
<td>Replaces</td>
<td>FeCl</td>
<td>FeCl, Al(SO), biological removal</td>
<td>Ion-exchanger, Al-coagulant</td>
</tr>
<tr>
<td>Quality issues</td>
<td>Presence of metals (As in particular)</td>
<td>Presence of metals (As in particular)</td>
<td></td>
</tr>
<tr>
<td>Legal issues</td>
<td>REACH, fertilizer act</td>
<td>REACH, fertilizer act</td>
<td>REACH</td>
</tr>
<tr>
<td>Technique</td>
<td>Dewatering, avoid presence of other substances</td>
<td>Dewatering, avoid presence of other substances</td>
<td>Dewatering, avoid presence of other substances</td>
</tr>
<tr>
<td>Maturity market</td>
<td>Mature</td>
<td>Mature</td>
<td>Introduction</td>
</tr>
<tr>
<td>Volume market</td>
<td>Digesters demand little &gt; than supply</td>
<td>Potential demand &gt;&gt; supply</td>
<td>??</td>
</tr>
<tr>
<td>Number of clients</td>
<td>High</td>
<td>High</td>
<td>Low-moderate</td>
</tr>
<tr>
<td>Accession market</td>
<td>Moderate-Difficult</td>
<td>Moderate-Difficult</td>
<td>Difficult</td>
</tr>
</tbody>
</table>
### Low grade iron/alum sludge

<table>
<thead>
<tr>
<th>Issue/application</th>
<th>Clay brick</th>
<th>Cement clinker</th>
<th>Backfill, sound barrier, cover layer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific</strong></td>
<td>Backing the sludge, using the grain distribution and colour</td>
<td>Fe and Al are an essential component of cement</td>
<td>Cover up waste in waste dump, sound barriers along highways</td>
</tr>
<tr>
<td><strong>Replaces</strong></td>
<td>Clay, Fe and/or Al- additive</td>
<td>Fe and/or Al- additive</td>
<td>Soil</td>
</tr>
<tr>
<td><strong>Quality issues</strong></td>
<td>Presence of CaCO3, coarse material, organic material</td>
<td>Organic substances</td>
<td>Chemical properties</td>
</tr>
<tr>
<td><strong>Legal issues</strong></td>
<td>REACH</td>
<td>REACH</td>
<td>Test is applicable</td>
</tr>
<tr>
<td><strong>Technique</strong></td>
<td>Dewatering</td>
<td>Dewatering</td>
<td>--</td>
</tr>
<tr>
<td><strong>Maturity market</strong></td>
<td>Mature</td>
<td>Mature</td>
<td>Mature</td>
</tr>
<tr>
<td><strong>Volume market</strong></td>
<td>Demand &gt; than supply</td>
<td>?</td>
<td>Local dependent</td>
</tr>
<tr>
<td><strong>Number of clients</strong></td>
<td>Low</td>
<td>Low (geographical)</td>
<td>High</td>
</tr>
<tr>
<td><strong>Accession market</strong></td>
<td>Easy</td>
<td>Easy (after testing)</td>
<td>Easy (after testing)</td>
</tr>
</tbody>
</table>
Brine

<table>
<thead>
<tr>
<th>Issue/application</th>
<th>Salt</th>
<th>Humid acids, fulvic acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific</td>
<td>Reuse salt in process</td>
<td>Removal of humic- and fulvic acids</td>
</tr>
<tr>
<td>Replaces</td>
<td>Primary salt</td>
<td>Humic acids and fulvic acids derived from peat</td>
</tr>
<tr>
<td>Quality issues</td>
<td>Hygiene, purity</td>
<td>Purety, dry matter content,</td>
</tr>
<tr>
<td>Legal issues</td>
<td>Drinking water laws</td>
<td>Fertilizer laws, REACH</td>
</tr>
<tr>
<td>Technique</td>
<td>Diafiltration, nanofiltration</td>
<td>Diafiltration, nanofiltration</td>
</tr>
<tr>
<td>Maturity market</td>
<td>Growth</td>
<td>Growth</td>
</tr>
<tr>
<td>Volume market</td>
<td>Reuse, so balanced</td>
<td>In volume relatively small, but developing</td>
</tr>
<tr>
<td>Number of clients</td>
<td>Small</td>
<td>End users: high</td>
</tr>
<tr>
<td>Accession market</td>
<td>Difficult</td>
<td>Difficult</td>
</tr>
</tbody>
</table>
**Activated (powdered) carbon**

<table>
<thead>
<tr>
<th>Issue/application</th>
<th>Agricultural</th>
<th>Immobilize</th>
<th>Reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific</strong></td>
<td>As structure material, bringing also humic acids</td>
<td>Mix with waste stream immobilizing certain components</td>
<td>Bringing it back to supplier</td>
</tr>
<tr>
<td><strong>Replaces</strong></td>
<td>Organic material</td>
<td>Primary activated carbon</td>
<td>Primary activated carbon</td>
</tr>
<tr>
<td><strong>Quality issues</strong></td>
<td>Metals and pesticides on product</td>
<td>Degree of binding</td>
<td>--</td>
</tr>
<tr>
<td><strong>Legal issues</strong></td>
<td>Fertilizer act</td>
<td>Degree of immobilizing</td>
<td>New product must fit standard</td>
</tr>
<tr>
<td><strong>Technique</strong></td>
<td>Bleeding with other products</td>
<td>Mixing</td>
<td>Manufacturing process activated carbon</td>
</tr>
<tr>
<td><strong>Maturity market</strong></td>
<td>Introduction</td>
<td>Growth</td>
<td>Mature</td>
</tr>
<tr>
<td><strong>Volume market</strong></td>
<td>Demand &gt;&gt; supply</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>Number of clients</strong></td>
<td>High (end-users)</td>
<td>Low-moderate</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Accession market</strong></td>
<td>Moderate</td>
<td>Difficult</td>
<td>?</td>
</tr>
</tbody>
</table>
Examples Products

WWTP: P- and S-control  Digester: S-control
Examples Products
Working Group
Phosphorus

Lead: Fabian Kraus (KWB)
Objectives

Overall objective
• Phosphorus (nutrient) recovery from wastewater
• Including municipal and industrial wastewater (e.g. food industry), not from manure or other bio solids (focus “EIP-Water”)

Specific objectives
• List possibilities for P-recovery and identifying best practice or best available technology (BAT)
• Identifying boundary conditions for BAT, since the local boundaries by infrastructure seems important for implementation
• Legal framework limitations and recommendations for adaptations

Tasks
• Review of Best Practices considering ecological, economical, political and technical information on BAT
• Communicate the results in and outside of the EIP Water Action Group
• **Customer**: fertilizer user, producer or chemical industry

• **Examples of companies existing from Supplier/Producer to Customer:**
  - **Ostara**: WWTP > Fertilizer (Struvite) > Customer
  - **ICL Fertilizer e.g.**: Raw material > Mineral Fertilizer > Customer (Agriculture)
  - **Third parties e.g.**: Mixing component > Organic/organo-mineral fertilizer > Customer (Agriculture)
Examples of existing brands and provider-names (status JAN 2017)

- **Wet sludge/sludge liquor on-site WWTP**
  - Aqueous phase (ortho-P)
  - after enforced P dissolution

- **Thermal sludge or ash route**
  - Slush or ash leaching
  - Thermal (pre)-treatment

- **Fertiliser ind.**
  - Fertiliser
  - ECOPHOS $\text{H}_3\text{PO}_4$/DCP
  - MEPHREC P-slag
  - THERMPHOS $\text{P}_4$

- **Electrodialysis**
  - $\text{H}_3\text{PO}_4$
  - TetraPhos $\text{H}_3\text{PO}_4$
  - AshDec (Outotec) CaNaPO$_4$
  - RecoPhos FP7/ICL $\text{H}_3\text{PO}_4/\text{P}_4$

- **LEACHPHOS**
  - $\text{H}_3\text{PO}_4$
  - RECPHOS DE MCP
  - PYREG P-rich pyrochar
  - KUBOTA P-slag

- **AirPrex**
  - Struvite

- **PHOSPAQ**
  - Struvite

- **ANPHOS**
  - Struvite

- **PHOSPHOS**
  - Struvite

- **NutriTec**
  - Struvite, DAS

- **NuReSys**
  - Struvite

- **RecoPhos**
  - FP7/ICL $\text{H}_3\text{PO}_4/\text{P}_4$

- **ELSTRA**
  - Struvite

- **LySOGEST**
  - Struvite

- **PHORWater**
  - Struvite

- **P-RoC**
  - Struvite, CSH

- **STUGART**
  - Struvite

- **TDH (general)**

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Full-scale Demo Lab/pilot
BAT and their Value Chain

**Resource**
- High quality sewage sludge with sewer control
- Sewage Sludge
- Sludge liquor/centrate from municipal WWTP
- Industrial wastewater (food industry e.g.)

**Product**
- Sewage sludge/Biosolids
- Organic Fertilizer/Biosolids
- Struvite

**Recovery –Rate from Sludge**
*Recovery-Rate from UASB outflow*
- **Case 1**: $\approx 100 \%$
- **Case 2**: $\approx 100 \%$
- **Case 3**: 5-15 \%
- **Case 4**: $\approx 80 \% *$
- **Case 5**: 95-100 \%

**Phosphorus recovery from wastewater**
- Potential for (best) practice (currently in demonstration or full-scale planned)

**Flowchart**
- Influent
- Grit removal
- Primary sedimentation
- Activated sludge tank
- Secondary sedimentation
- Effluent
- Excess sludge
- Process water
- Biogas
- Sludge dewatering
- Digestion tank
- Agriculture
- Incineration
Examples for K.O.-Criteria for other existing Technologies

For defining a technology/ option as best practice...
1. ... it has to be successfully proven in full-scale
2. ... it has the potential to become successful in full-scale near-by

Examples for K.O.-Criteria for technologies (2.):
• Costs e.g. by demand on chemicals or energy
• No valuable product chain with market acceptance for the product
• Unfavorable ratio between produced recyclate and amount of waste (by-products), which has to be disposed off
• Complexity of technology (implementation, operation and finance risks): no demo site available several years after proof of concepts
# PESTEL-Analysis

<table>
<thead>
<tr>
<th>Option/Technology</th>
<th>Political</th>
<th>Economics</th>
<th>Socio-Cultural</th>
<th>Technology</th>
<th>Environment</th>
<th>Legislative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewage sludge in agriculture</td>
<td>-/0 (partly unwanted)</td>
<td>+ (cheap way of sludge disposal)</td>
<td>- (concern regarding human health)</td>
<td>+ (non)</td>
<td>- (concern regarding environment)</td>
<td>+/- (partly forbidden, quality control)</td>
</tr>
<tr>
<td><strong>Case 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic fertilizer from sewage sludge</td>
<td>-/0 (partly unwanted)</td>
<td>+ (cheap way of sludge disposal)</td>
<td>- (concern regarding human health)</td>
<td>+ (simple)</td>
<td>- (concern regarding environment)</td>
<td>+/- (partly forbidden, quality control)</td>
</tr>
<tr>
<td><strong>Case 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Struvite from municipal WWTP</td>
<td>0/+ (unknown, registered as fertilizer in D, NL)</td>
<td>+ (cheap process, market increases)</td>
<td>0</td>
<td>+ (simple)</td>
<td>+ (“clean” fertilizer)</td>
<td>+ (REACH, fertilizer regulation)</td>
</tr>
<tr>
<td><strong>Case 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Struvite from industrial WWTP</td>
<td>0/+ (unknown, registered as fertilizer in D, NL)</td>
<td>+ (cheap process, market increases)</td>
<td>0</td>
<td>+ (simple)</td>
<td>+ (“clean” fertilizer)</td>
<td>+ (REACH, fertilizer regulation)</td>
</tr>
<tr>
<td><strong>Case 5</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphoric acid/Fertilizer from sewage sludge ash</td>
<td>0/+ (unknown, technical solutions preferred?)</td>
<td>+ (by-product selling, market for H$_3$PO$_4$ or MCP/DCP)</td>
<td>0</td>
<td>- (complex)</td>
<td>+ (“clean” raw material, fertilizer)</td>
<td>+ (REACH, fertilizer regulation)</td>
</tr>
</tbody>
</table>
### (PESTEL-) Outcome

<table>
<thead>
<tr>
<th>Option/Technology</th>
<th>Opportunities</th>
<th>Challenges</th>
</tr>
</thead>
</table>
| **Case 1**  
Sewage sludge in agriculture | WWTP in areas without other sludge disposal infrastructure (incineration) or low contaminated wastewater and sludge | Logistics (incl. storage);  
Ensure sludge quality through monitoring in synergy with measures (enhanced sludge treatment or reductions of hazards in the influent) |
| **Case 2**  
Organic fertilizer from sewage sludge | WWTP in areas without other sludge disposal infrastructure (incineration) or low contaminated wastewater and sludge | Ensure sludge quality through monitoring in synergy with measures (enhanced sludge treatment or reductions of hazards in the influent) |
| **Case 3**  
Struvite from municipal WWTP | WWTP with EBPR (and high P-concentrations in sludge liquor), prevention of incrustations, reduced polymer demand, reduced return (and effluent) load, Reduced sludge quantity/disposal cost | Harvesting efficiency of struvite and enable a higher demand on the European market for recycled struvite |
| **Case 4**  
Struvite from industrial WWTP | Industrial WWTP with high N- and P-loads after anaerobic treatment, reduced effluent load | Harvesting efficiency of struvite and enable a higher demand on the European market for recycled struvite |
| **Case 5**  
Phosphoric acid from sewage sludge ash | Existing ashes from mono-incinerations of municipal sewage | Demonstration in full-scale, Selling of by-products, Establishing on the market and competition with established high volume market stakeholders |
All full-scale operating plants are Case 3 and Case 4. Existing Case Studies

Value and Market potential

• What products do you have at the end & at which costs to WWTP operator?
  - Sewage sludge (Case 1, reference): 2-3 €/kg P (equivalent to 120 €/t DS disposal costs)
  - Organic fertilizer (Case 2, reference): < 5 €/kg P (equivalent to disposal costs)
  - Struvite (Cases 3 & 4): 0-5 €/kg P, sludge still needs to be disposed off
  - Phosphoric acid/Fertilizer from ash (Case 5): 0-1 €/kg P
    + approx. 10 €/kg P for new mono-incineration if required

• Why there is success on the market?
  - Recovery-Recycling-processes have synergies with disposal/ maintenance/ by-product production etc...
  - Key driver for on-site WWTP installation: operational benefits (dewaterability and sludge disposal cost)
Green jobs with P-recycling from wastewater

1. Safeguard existing jobs in EU fertilizing industry
   • Today about **20,000 direct employments in N/P/K producers** (source Fertilizer Europe)
   • Under threat of delocalization / external competition (risk of value chain being transferred to countries mining phosphate rock)
     - LOVOCHEMIE (CZ): stopped processing P-rock (apatite) from Russia
     - THERMPHOS (NL): insolvency 2012 due to prize dumping by Kazachstan
     - ICL (NL): **100% green P-fertilizer by 2025** (100% dependent on P₄ imports!)

2. Create new green jobs in Europe
   • P-content in wastewater sludge (EU): 400,000 t P/y
   • P-content in wastewater sludge not used in land spreading: 240,000 tP/y
   • Market generated if P-recycling was enforced by law: 1,200 M€/y (assuming the costs for P-recovery is 5,000 €/tP, ~5 €/pers./a)
   • Potential new green direct job creation (without distribution): **5,000 jobs**, or **10,000 direct + indirect jobs**?
   • In addition, cost saving on P-rock and potentially P₄ imports: 240 M€
Lighthouses (high quality sludge/ biosolids)

Käppala municipal sewage works, Sweden

• REVAQ sewage sludge certification
• 260 t P/year recycled to agriculture
• Reductions in industry & household contaminants
• Sludge mixing with manure for contaminant degradation

Similar lighthouses Brunswick, Germany
Lighthouses (struvite from municipal WWTP)

**AirPrex-Technology by CNP, Germany (digestate)**
- 7 installations recovering P as struvite
- Approx. 1000 t struvite/y recovered, partly recycled to agriculture
- Benefits in Maintenance of the WWTP sludge line
- Savings in Energy and Greenhouse Gases on the WWTP
- Berlin Struvite called „Berliner Pflanze“ – Winner of the GreenTec Award 2015

**Similar lighthouses / technologies: Pearl, Canada; NuReSys, Belgium**
Lighthouses (struvite from municipal WWTP)

PEARL technology by OSTARA, Canada, European branch based in UK (sludge liquor)

- 3 installations in EU, 14 global recovering P as struvite
- Approx. 1000 t struvite/y recovered, partly recycled to agriculture
- Benefits in Maintenance of the WWTP sludge line
- Savings in Energy and Greenhouse Gases on the WWTP
- Struvite called „Crystal Green“ – premium 28-5-0-10Mg fertilizer

Similar lighthouses / technologies: NuReSys, Phospaq, PhosphoGREEN, Struvia, Naskeo, Anphos, EloPhos, eco:P
Lighthouses (struvite from industrial sector)

**NuReSys, Belgium**
- 9 installations recovering P as struvite
- Water sectors: Potato processing, dairy, pharmaceuticals, ...
- Reduction of P and N in UASB outflow

**Similar lighthouses/ technologies: Pearl, Canada; AirPrex, Germany**
Lighthouses (H₃PO₄ from sewage sludge ash)

SNB – HVC Groep – Ecophos, Netherlands, France

• Contract signed 2015/ Start in 2017
• Netherlands / France (Dunkerque)
• Sewage sludge incineration ash
• Production of H₃PO₄/DCP for fertilizers or animal feed
• Treating 60 000 t ash/y for P-recovery

Similar lighthouses/ technologies:
TetraPhos, Germany
Summary

- **Objectives**: Phosphorus recovery from wastewater
- **Value Chain**: Sewage (⇒ Raw material) ⇒ Fertilizer
- **Existing Technologies**: > 20 but only 5 market relevant “Best Practices”
- **Tools for assessment**:
  - *Results WA 4 of P-REX (EU FP7)*: Life-Cycle-Assessment, Costs, Risk Assessment, Plant availability, Toxicity
  - *Results WA 5 of P-REX (EU FP7)*: Market and legislative analysis, regional case studies, strategy development for implementation
- **Existing Case Studies**: many (<20) success-stories in Europe
- **Adding Value especially through synergies**...
- **Ongoing development of other technologies, to be followed-up**...
Conclusion

There is no one-fits-all-solution
There is a manageable number of best practices

Which of this best practices fits best to your plant/ region is...

• ...dependent on regional infrastructure (e.g. EBPR, incineration, drying capacity, fertilizer industry, agriculture)
  • first use existing local infrastructure for P-recovery, then think about additional infrastructure for P-recovery

• ...dependent on regulations in your country and on public discussions
  • regulations can be changed, discussions can be started (agree on realistic P-recycling target for the region, considering local context and trade-off between technical P-recovery and energy efficiency)
Past and Running projects about phosphorus (list not complete)

- BioEcoSIM, [www.bioecosim.eu](http://www.bioecosim.eu)
- FERTIPLUS, [www.fertiplus.eu](http://www.fertiplus.eu)
- ImproveP, [www.improve-p.uni-hohenheim.de](http://www.improve-p.uni-hohenheim.de)
- LIFE PHORWater, [www.phorwater.eu](http://www.phorwater.eu)
- ManureEcoMine, [www.labmet.ugent.be/content/manureecomine](http://www.labmet.ugent.be/content/manureecomine)
- NewFert, [www.newfert.org](http://www.newfert.org)
- nurec4org, [www.kompetenz-wasser.de](http://www.kompetenz-wasser.de)
- Phorwärts, [www.kompetenz-wasser.de](http://www.kompetenz-wasser.de)
- P-REX, [www.p-rex.eu](http://www.p-rex.eu)
- R3Water, [www.r3water.eu](http://www.r3water.eu)
- RecoPhos (Austria), [www.recophos.org](http://www.recophos.org)
- REFERTIL, [www.refertil.info](http://www.refertil.info)
- SmartPlant, [www.smart-plant.eu](http://www.smart-plant.eu)
- TL-BIOFER, [www.life-tlbiofer.eu](http://www.life-tlbiofer.eu)
- KRN-Mephrec, [www.nuernberg.de/internet/km_mephrec/](http://www.nuernberg.de/internet/km_mephrec/)

Full list by ESPP with research projects, initiatives and networks:
Working Group
Cellulose

Lead: Coos Wessels (CirTec)
Facts and figures

- Toilet paper is appr. 30-50% of the Total Suspended Solids (TSS) in sewage.
- Representing 25-45% of the COD in sewage.
- Western Europe average 12-16 kg toilet paper per person.

- NL: 150.000 to 180.000 ton TSS/year
Cellulose from sewage

• Why?

1. Saving energy (reduction of energy for aeration)

2. Reduction of maintenance costs

3. Recovery of valuable resource
Screenings a new side product

• Finescreens, they are of added value!

• Challenges:
  ✓ How do we get the maximum added value from screenings
  ✓ Where can we use the cellulose recovered
An innovative way of maxgrading

Biofuel
- Biogas
- Biodiesel

Basic chemicals

Use as a fiber
- Carton board
- Composite

Bioplastic
Ongoing re-processing routes

Impact on downstream processes

Consumer
Toilet paper sewer system

Waterboard
Screening toilet paper/cellulose from sewage, using finescreen

Cellu2PLA
Use cellulose as carbon source
Production of PLA

CADOS
Use cellulose as fiber
Optimisation sludge dewatering

Cellvation
Use cellulose as fiber
Processing in asphalt

OLAF
Use cellulose as carbon source
Pyrolyses
Speedy composting with Fibral and compost reactor Different WWTP, eg. Kulstad (NO)

- Recirculated newspaper
- Added absorbent (polymer)
- 4-6% additive to sludge
  - (Other composting methods must have 100-150% addition of structural fiber (from trees and bushes/ garden waste)
Optimisation of sludge dewatering
WWTP Ulrum (NL) – started 19-09-2014

Capacity: 20,000 pe
DWF: 107 m³/h
FFT: 457 m³/h
Screenings 30 - 70 kg Ds/h (dewatered)

Improve dewatering to >30% Ds
Reduction polymer consumption to < 3 g/kg Ds
Possible dosage of cellulose from other sources
Production of Bioplastics (PLA)

WWTP Beemster

Capacity: 170,000 pe
DWF: 1,860 m³/h
FFT: 3,600 m³/h

Screenings 770 ton Ds/y

Production 130 ton PLA/y

Challenges:
- Separation of clean cellulose fiber
- Tests for using cellulose in composites
Separation of cellulose fibers
WWTP Uithuizermeeden (NL) – start 01-01-2015

Capacity: 55,000 pe
DWF: 465 m³/h
FFT: 860 m³/h

Screenings 130 ton Ds/y

Focus:
Getting clean cellulosic fibers as raw material for composit
Screencap

- Finescreen supported biological wastewater treatment to enhance plant capacity
- Full scale pilot at Waste Water Treatment Plant Aarle Rixtel (NL)
- Started 1 November 2014, 3 years duration
- Results: Decreased aeration energy needs 15%, reduced sludge production 10%, and increased WWTP’s capacity 10%

Co-funded by the Eco-innovation Initiative of the European Union
Harvesting of cellulosic screenings

- In 9 European countries harvesting cellulosic screenings;
- 33 full-scale installations, from which 16 as primary treatment before activated sludge.
Working Group
Cross Cutting Issues

Lead: Staffan Filipsson (IVL)

A general overview of barriers, constraints, requirements and success factors for implementation of viable and profitable value chains of recovered resources from waste water
Barriers for implementation of viable and profitable value chains

Many water related resource recovery initiatives take place in Europe. All initiatives are challenging existing system structures, which is typical for systemic eco-innovations.

Main regulation- and trade barriers:

• Europe is lacking specific recovery and reuse policies for waste water resources.
• There is lack of clarity in the regulatory framework.
• There is uncertainty regarding future development of regulations.
• There is fear for potential trade barriers for recovered product.
Barriers for implementation of viable and profitable value chains

Main regulation- and trade barriers, continued:

• Policy and decision makers as well as stakeholders are usually uninvolved and unaware of the rapidly growing field of recycling and reuse research and knowledge.

• Too high cost for recovered product / Tax on recovered products.

• Recovered product not seen as a component of integrated product management.

• Big players dominate the market – not interested in new and small volumes.

• Recovered product does not have the same characteristics of traditional product, which is an issue for the process industry as well as for the end user who may be scared off.
Barriers for implementation of viable and profitable value chains

Main barriers depending on lack of knowledge:

- Completeness of assessing and implementing recycling and reuse technologies has been the subject of controversy and debate in the current literature as well as in practice.
- The expertise, data and methods developed are often not in a format useful to the decision-makers who need tools and information they can apply in their day to day activities.
- Negative public perception on the quality of the recovered product.
- Lack of awareness of the multiple benefits of recovery.
- An array of technological solutions does already exist but are either seen as being costly or complex.
- Scientific uncertainties – lack for large scale demonstration plants.
Success factors for implementation of viable and profitable value chains

Ways to underpin the break down of regulation- and trade barriers:

• Create political support for circular economy in water and set proper responsibilities among stakeholders (favorable tax systems for sustainable approaches).

• Create EU-wide quality requirements within and outside of the framework to ensure a high trust for the novel recovered products.

• Introduce mechanisms for distribution of cost and financing models for demonstration projects.

• Introduce incentives like lower taxation for non fossil products, quota of non fossil products in European fertilizer market etc.
Success factors for implementation of viable and profitable value chains

Ways to underpin the break down of regulation- and trade barriers:

• On Member State level we see initiatives to strengthen the regulations such as in Switzerland, Germany and the Netherlands, but a more EU wide policy development is needed to accelerate resource recovery from water and waste water.

• We need rethink regarding established practices and responsibilities of water utilities and other stakeholders.

• We need improved understanding of policies and regulations in combination will manage the lack of clarity in regulations regarding risks associated with reuse and how the policies and regulations can be improved for this purpose.
Success factors for implementation of viable and profitable value chains

Ways to underpin increased knowledge regarding recovered products:

• Introduce combinations of innovation, market analysis, customer collaboration, and new methods for teamwork in the supply chain that creates generic knowledge that can be diffused.

• Communicate the advantages of recovery and reuse:
  - Europe will less dependent on scarce resources.
  - Substantial job opportunities, huge export opportunities outside Europe.
  - Assess the impact on beneficiaries and innovation of the proposed solutions.
  - Resource recovery from water can already be financially profitable (e.g. drinking water residuals) or affordable (e.g. phosphorous <10 €/yr per citizen).
  - Recycling water resources makes Europe less dependent on critical raw materials and offers huge opportunities for new markets and jobs.
Success factors for implementation of viable and profitable value chains

Ways to underpin increased knowledge regarding recovered products:

- Financing for innovation
  - Better knowledge in the value chain will increase the willingness to invest.
  - Establish projects with strong a private-public consortium.
  - Build interfaces between funders, industry, companies, SMEs and research organizations by introduction of a systemic supply chain model combining innovation, market analysis, customer collaboration, lean production and new methods for teamwork in the supply chain:
    - this will lead to concrete business plans for access to finance for involved SMEs which all have potentially disruptive technologies and a high export potential.
    - this will generate generic knowledge for SME`s in the European and OECD countries water cycle.
Success factors for implementation of viable and profitable value chains

Tools to underpin increased knowledge regarding recovered products:

- Increase the knowledge of the environmental and economical impact by both Life Cycle Analysis (LCA) and Life Cycle Cost (LCC).

- Make use of Environmental Technology Verification (ETV) for large scale demonstration projects that support the market uptake of the innovative technologies in Europe and beyond.

- In order to be able to increase the benefits from any reuse and recycling technologies, a larger systemic analysis of the overall environment is needed:
  - the use of Decision Support Systems (DSS) offers an enlargement of the traditional narrow planning and management approaches.
  - a well designed DSS operates on different levels and integrates management of plants with monitoring and support for water governance on a higher organizational level (e.g. pertinent local or regional agencies).
  - a DSS can also be used for evidence based decisions supporting market deployment of new eco-innovative technologies and can be combined with pilot region case studies to demonstrate how reuse effectively can be a component of integrated water management.
Success factors for implementation of viable and profitable value chains

Ways to underpin increased knowledge regarding recovered products

• Stimulate large scale demonstration projects of technologies for reuse of resources.

• Increase the communication and dissemination of results from demonstration projects with the public and the decision makers.

• Involve strategic public customers that has an interest in reuse and introduce training and models for public procurement as well as pre-commercial procurement.

We see incentives for the market to change. Examples are companies that want to diversify their raw sources and companies that want to contribute to circular economy initiatives at local scale.
European best practices on resource recovery from the water cycle

ARREAU review

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