Case study
„Phosphorus recovery from sewage sludge - Results of the European FP6- and FP7-projects SUSAN and SUSYPHOS“

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Devison 4.3 Waste Treatment and Remedial Engineering
About Phosphorus (P)

- P is essential for all living organisms due to its important functions (DNA, RNA, ATP,…,bones,…)
- P is a main element for plant nutrition and essential for crop production
- P is taken up by plants and removed from the fields by harvest. It is required for plant and animal production. In Germany around 150,000 Mg P/a leave the agricultural sector in form of market products
- Phosphate rock is a non-renewable resource and its utilisation for fertiliser production bears some environmental disadvantages (current global reserves depleted in 50-100 years)
- Phosphate rock often contains toxic elements like cadmium and uranium
- Waste water is the municipal waste flow with the highest potential for P-recovery (Germany: approx. 60,000 – 70,000 t P/a)
About Phosphorus (P) - World Wide Production and Consumption

Location of Phosphate Reserves (18 billion Mg)

- China, 37%
- Morocco, 32%
- South Africa, 8%
- USA, 7%
- Jordan, 5%
- Brazil, 1%
- Russia, 1%
- Israel, 1%
- Other countries, 8%

North America: 20% 20%
Western Europe: 6% 0%
Eastern Europe/GUS: 8% 7%
Asia: 41%
Oceania: 2% 2%


Modified from: Elsner 2008

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Evolution of the Pathways for Sewage Sludge in Germany

- Agricultural utilisation decreases due to controversy discussions about organic pollutants
- Thermal treatment increases and makes more than 50% today
- Interest in utilisation of sewage sludge ashes increases in Germany
Sewage sludge ashes are permitted as raw material for fertilisers since Dec. 2008 according to the new German Fertiliser Ordinance (DüMV, Dec. 2008)

P-fertiliser consumption in Germany ca. 138,000 t P/a (business year 2007/2008; BMELV, 2010)

Potential for substitution - sewage sludge: ca. 44 % (theoretic potential)
- sewage sludge ash: ca. 11 % (ashes from mono-incineration)
The EU-Project SUSAN

„Sustainable and Safe Re-use of Municipal Sewage Sludge for Nutrient Recovery“

EU-project 6th Framework Programme
EU-funding: ca. 1.2 Mio. EUR

The SUSAN-consortium

- **TU WEN**: Coordination, Technological development
- **BAM**: Operator of the largest mono-incineration facility for sewage sludge in Europe
- **SNB**: Technological development, Pilot plant operation
- **ASH DEC**: Planning of industrial plants
- **YARA**: Fertiliser company, Conditioning of fertilisers, Market analysis
- **JKI**: Agricultural investigations with the ash based fertilisers

Investigations into sustainability of different sludge management options

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Principle of the SUSAN-strategy for P-Recovery

1. Mono-incineration
   - sewage sludge
   - organic pollutants
   - heavy metals

2. Thermochemical treatment
   - sewage sludge ash
   - heavy metals
   - chlorine donor (e.g. MgCl₂ / CaCl₂ / HCl)
   - e.g. in a rotary kiln 850-1000 °C
   - separation of heavy metal chlorides

3. Secondary raw material for P-fertiliser production
   - low pollutants concentrations
   - high P-bioavailability

4. Destruction of organic pollutants

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Thermochemical Treatment of Sewage Sludge Ashes

- Addition of a Cl-donor (MgCl₂) to sewage sludge ash
- Treatment of the mixture at 850-1000°C
  1. Formation and evaporation of heavy metal chlorides
  2. Formation of new P-bearing mineral phases

Addition of a Cl-donor (MgCl₂) to sewage sludge ash

Treatment of the mixture at 850-1000°C

1. Formation and evaporation of heavy metal chlorides
2. Formation of new P-bearing mineral phases
Equipment and Methodology

**Furnaces**

Lab-scale: 0.5 kg (batch)
Medium-scale: ~ 20 kg/h
Technical-scale: ~ 300 kg/h (project partner ASHDEC)

**Screening**

with 8 sewage sludge ashes was carried out with the lab-scale furnace

**Systematic investigation**

with 3 “basic ashes” carried out in the lab-scale furnace

Influence of operational parameters on heavy metals removal and P-bioavailability

- **SNB**: high Fe-conc.
- **SNB**: low Fe-conc.
- **SINDL**: low Fe-conc. but high Al-conc.

Systematic variation of
- temperature 750-1000°C
- retention time 20-120 min
- type of Cl-donor MgCl₂ and CaCl₂
- Cl-conc. 50-200 g Cl/ kg ash
Heavy Metal Removal by Thermochemical Treatment

Similar results were obtained for further Cl-donors (CaCl$_2$, gaseous HCl) and for other types of ashes.
Mineral Phases formed by the Thermochemical Treatment

Treatment with CaCl$_2$
- destruction of whitlockite and AlPO$_4$
- intermediate compound chlorspodiosite
- final product contains (Rietveld):
  - 41.9% chlorapatite
  - 5.7% whitlockite
  - ~2% AlPO$_4$

Treatment with MgCl$_2$
- destruction of whitlockite and AlPO$_4$
- intermediate compound chlorspodiosite
- final product contains (Rietveld):
  - 29.3% stanfieldite
  - 15.6% chlorapatite
  - (5.2% whitlockite)
  - 4.4% farringtonite
Agricultural Investigations with Thermochemically Treated Ashes

Trials with thermochemically treated ashes, ash based fertilisers and conventional fertilisers in the greenhouse and the field

August 2006

July 2007

June 2008

Ash based P-, PK- und NPK-fertilisers
Control fertilisers SSP/ Thomasphosphate
Results of pot trials in 2006 - P-uptake

P-uptake maize (mg/pot) at a P-level of 50 mg P per pot (PK-variants) (significant differences between groups were determined by Tukey post-hoc test, p<0.05 and are denoted by different letters)

MgCl₂-variants

CaCl₂-variants

August 2006
Results of pot trials in 2007 - Dry Matter Yield

Figure 3: Dry matter yield maize (g/pot) at a P-level of 500 mg P per pot
(different letters denote significant differences between groups as determined by Tukey post-hoc test (P<0.05))
Pilot Plant Operation and Industrial Scale Perspective

Pilot-plant operation 2008-2010:
capacity: **300 kg/h**, location: **Leoben (AT)**

took over ASH DEC in 2011
and currently plans
the first industrial plant with a **capacity of 32,000 tpy**
Developments in the FP7-Eurostars Project  **SUSYPHOS**

**Sustainable Sybiotic Phosphorus**
Fertiliser Production from Two Renewable Raw Materials

02/2009 – 10/2011

⇒ Investigate potentials for energy and cost savings
⇒ Utilisation of further P-rich waste materials

⇒ Development of a **FLOX burner** for solid matter
   by the German company e-flox GmbH
   homogenous temperature distribution
   in the reactor ⇒ less NOx-emissions

⇒ Utilisation of **Meat and Bone Meal** (MBM) and **dryed sewage sludge** as alternative energy- and P-source at the same time

⇒ Utilisation of **PVC** as an energy- and Cl-source at the same time
Summary

- Phosphorus is a limited resource. Western Europe has no P-reserves and is completely dependent on the world market which is dominated by a few countries.

- P-recycling from sewage sludge is one promising option to substitute and save primary natural resources.

- Incineration of sewage sludge destroys organic pollutants and concentrates phosphorus in the resulting ashes.

- In the European project SUSAN a thermochemical treatment was developed that removes heavy metals from the ashes and transfers stable phosphates into plant-available compounds.

- A pilot plant (300 kg/h) was successfully operated by the ASH DEC Umwelt AG.

- Recent investigations in the European project SUSYPHOS are focused on energy saving and economic operation.

- The first industrial plant with a capacity of 32,000 tpy is currently planned by OUTOTEC.
Thank you very much for your attention!

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