Workshop on good practices and experience in sludge management

Technological Options

6th June 2018, Warsaw
Tools / Resources

- Gravity
- Mechanical force
- Membranes
- Heat
- Pressure
- Biological
  - Anaerobic
  - Aerobic
- Energy
- Time
- Money
- Trust
Sludge Management Options

I Sludge Stabilisation
   I a Anaerobic stabilisation
   I b Aerobic stabilisation
   I c Drying beds / Earthification

II Dewatering
   II a Decanter centrifuges
   II b Filter presses
   II c Screw presses
   II d Mobile versions

III Drying
   III a Convection drying
   III b Contact drying
   III c Solar drying

IV Conversion
   IV a Monovalent incineration
   IV b Co-combustion
   IV c Gasification / Pyrolysis
   IV d Combined waste incineration
   IV e Co-digestion
   IV f Composting

V Final outlets
   V a Phosphorus recovery
   V b Added fuel
   V c Energy generation
   V d Landfill
   V e Land Re-cultivation or reclamation
   V f Agriculture use

06/06/2018
Sewage Sludge Workshop - Warsaw
Anaerobic Digestion (1)

The Basics

- Input: Raw / Thickened sludge
- Stirred & heated tank
- Air tight
- Bacteriological
- 20 – 30 days
- Two versions
  - Mesophilic (30 – 38 °C)
  - Thermophilic (49 – 57 °C)
- Generates methane
  - Gas engine: electricity
  - Heat from combustion: digestor
- Reduces dry solids
- Reduces remaining calorific value

Process

1. Hydrolysis
2. Fermentation
3. Acetogenesis
4. Methanogenesis

> complex organic matter
> carbohydrates, proteins, fats

> soluble organic molecules
> sugars, amino acids, fatty acids

> volatile fatty acids

> acetic acid

> $\text{CH}_4 + \text{CO}_2$

> $H_2, \text{CO}_2$
Anaerobic Digestion (2)

Economics

- Costs
  - Investment - significant
  - Operation – high but ..
- Benefits:
  - Energy
  - Reduced Disposal Volume
- Rule of thumb
  - Economic only for larger volumes
  - >30 - 50 000 p.e.

Other Considerations

- Energy strategy for large plants
- Sludge from other plants
- Changing the tipping point
  - Energy costs
  - Sludge disposal costs
- Thermophilic
  - Quicker (smaller reactor)
  - Heating costs
“Earthification” – Drying Beds

**Drying Beds**

- Close-to-natural method
- Slow dewatering and stabilisation
- Bed or lagoon-like basins
- Dehydration: evaporation and gravity
- Concrete or lined earth
- Space Requirement
  - depth of 1.5–1.7 m
  - 0.25 m²/p.e. - 0.5 m²/p.e.
- Residence time: 5–10 years
- For simple stabilization / drying
  - Filled up to 0.5 m
  - Emptied 1–3 times a year

**Reed Beds**

- Constructed wetland
- Basal layer: Sand-gravel mixture
- Excess filtrate returned to WWTP
- *Phragmites australis*
- Organic components broken down by more than 50 %.
- Winter freezing
Dewatering

- Decanter centrifuges
  - Rapid rotation
  - Flocculants to aid coagulation
  - Sediment continuously removed
  - Final DS ~25%
  - Variant – rotational filtering

- Filter Press
  - Pressure against porous surface
  - Plate filter press
  - Membrane filter press
  - Belt filter press (common)
  - Screw press
  - Mobile versions
  - 12 – 35% DS output
## Comparison

<table>
<thead>
<tr>
<th>Method</th>
<th>m³ sludge /h</th>
<th>kWh/m³ sludge</th>
<th>Polymer kg/t Dry Solids</th>
<th>% DS output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decanter / Centrifuges</td>
<td>1 - 200</td>
<td>1 – 1.6</td>
<td>8 – 12</td>
<td>20 - 32</td>
</tr>
<tr>
<td>Chamber filter press</td>
<td>0.8 – 1</td>
<td>6 – 12</td>
<td>~5</td>
<td>22 - 40</td>
</tr>
<tr>
<td>Membrane filter press</td>
<td>2 – 30</td>
<td>~5</td>
<td>~6</td>
<td>30 - 45</td>
</tr>
<tr>
<td>Belt filter press</td>
<td>2 – 30</td>
<td>0.5 – 0.8</td>
<td>~6</td>
<td>20 - 30</td>
</tr>
<tr>
<td>Screw press</td>
<td>1 - 30</td>
<td>0.2 – 0.3</td>
<td>Low</td>
<td>20 - 35</td>
</tr>
</tbody>
</table>
Drying – Non solar

- Convection Drying
  - Drum dryer
    - Tumble dryer
    - Hot gas of up to 1000 °C
  - Belt dryer
    - 10cm thick layer
    - Temperature: 120 - 150 °C
  - Fluidized bed dryer
    - Upward flow of heated air
    - Inert “bed” entrains liquid

- Contact Drying
  - Disk dryer
    - Stack of disks
    - Central heated column
  - Thin film dryer
    - Rotating blades
    - Heated walls
## Comparison

<table>
<thead>
<tr>
<th>Applied technology</th>
<th>Heating medium</th>
<th>DS sludge input</th>
<th>DS sludge output</th>
<th>Process temperature</th>
<th>Energy_{electr.}</th>
<th>Energy_{therm.}</th>
<th>Heat recovery system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary kiln - direct drying system Maurer</td>
<td>combustion gas</td>
<td>22.5</td>
<td>90</td>
<td>100-130</td>
<td>63</td>
<td>4,250</td>
<td>water and process air heating</td>
</tr>
<tr>
<td>Rotary kiln - indirect drying system Eino</td>
<td>saturated steam</td>
<td>30</td>
<td>95</td>
<td>95-130</td>
<td>50</td>
<td>3,060</td>
<td>water heating and sludge pre-heating</td>
</tr>
<tr>
<td>Direct/indirect belt drying system Sevar</td>
<td>combustion gas thermo oil</td>
<td>25</td>
<td>95</td>
<td>100-140</td>
<td>70</td>
<td>3,300</td>
<td>water heating</td>
</tr>
<tr>
<td>Fluidized bed dryer (direct) system Sulzer</td>
<td>thermo oil</td>
<td>20</td>
<td>95</td>
<td>85-115</td>
<td>110</td>
<td>2,500</td>
<td>water heating and sludge pre-heating</td>
</tr>
<tr>
<td>Linear thin film drying (indirect) system Limus</td>
<td>thermo oil</td>
<td>25</td>
<td>90</td>
<td>115</td>
<td>70</td>
<td>3,000</td>
<td>water heating</td>
</tr>
<tr>
<td>Thin film drying (indirect) system Buss</td>
<td>saturated steam thermo oil</td>
<td>25</td>
<td>50</td>
<td>100-110</td>
<td>75</td>
<td>2,600</td>
<td>water heating and sludge pre-heating</td>
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<tr>
<td>Rotadisc dryer (indirect) Stord type</td>
<td>saturated steam</td>
<td>27.5</td>
<td>95</td>
<td>115-120</td>
<td>125</td>
<td>2,900</td>
<td>water heating and sludge pre-heating</td>
</tr>
<tr>
<td>Mobile disc dryer (indirect) system Babcock</td>
<td>thermo oil saturated steam</td>
<td>25</td>
<td>90</td>
<td>110-120</td>
<td>87</td>
<td>2,900</td>
<td>water heating and sludge pre-heating</td>
</tr>
<tr>
<td>Mobile drum drying (direct) system Amann</td>
<td>combustion gas</td>
<td>25</td>
<td>92.5</td>
<td>120</td>
<td>112</td>
<td>3,000</td>
<td>water heating</td>
</tr>
<tr>
<td>Mobile dryer (direct) system PKA</td>
<td>combustion gas hot air</td>
<td>20</td>
<td>95</td>
<td>110-130</td>
<td>31</td>
<td>3,560</td>
<td>n/a</td>
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<tr>
<td><strong>Mean value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>79</strong></td>
<td><strong>3,107</strong></td>
<td></td>
</tr>
</tbody>
</table>
Solar Drying

• Solar drying
  • Basic (solar only)
    • 70%
  • Assisted (underfloor heat)
    • >85%
    • Waste heat source
    • Heat exchanger (effluent)

• Glasshouse
  • Climate dependent
  • Controlled ventilation
  • Frequent turning
  • Comparatively low cost
Composting

- Process
  - Aerobic – Air Flow
    - Sludge porosity low
    - Bulking agents
    - Turning
  - Moisture control
  - Temperature
- Composting of “green” MSW
- Co-composting: sludge + bio-waste
- Compost output
  - Outlets not guaranteed
  - Financial returns … limited
  - Product standards
  - Eco-label exclusion
- Conclusion
  - Stabilisation
  - Bio-drying
  - Pre-treatment
The role of waste-to-energy in the circular economy (26.1.2017)

• Waste-to-energy processes can play a role in the transition to a circular economy provided that the EU waste hierarchy is used as a guiding principle and that choices made do not prevent higher levels of prevention, reuse and recycling.

• … more consideration .. to those processes, such as anaerobic digestion of biodegradable waste, where material recycling is combined with energy recovery

• …the role of waste incineration needs to be redefined to ensure that increases in recycling and reuse are not hampered and that overcapacities for residual waste treatment are averted

• … ensuring that waste-to-energy capacity planning is consistent with, and supportive of, the waste hierarchy … (new & emerging technologies)

• … ensuring that EU & other public financial support is directed towards waste treatment options that are in line with the waste hierarchy, & that priority is given to waste prevention, reuse, separate collection & recycling.
Incineration Capacity

- Assessment of waste incineration capacity and waste shipments in Europe (EEA, 2017)
  - Mixed municipal waste 2010 - 2014
  - Capacity increased by 6% to 81 million tonnes
  - France, Germany and Netherlands: 50%
    - Plus Italy, Sweden, UK: 6 countries have ~75% of capacity
    - Heavy dependence on landfill elsewhere
  - Specific (per person) capacity high in SE, AT, NL (heating)
  - Some indications of over-capacity

- Trade of waste
  - Stable volumes 2000 – 2007
  - Significant increases from 2008
  - BUT – total trade is very small as a %age (2.3 / 242 mT/a)
Co-Combustion

- Generally – the drier the better!
- Opportunities for fuel substitution – thermal utilization
  - Solid Fuel power plants
  - Cement kilns
  - Other industries – metal furnaces, LECA production
  - Waste incinerators (as a fuel)
- Uses existing infrastructure
- Safe destruction of organics and pathogens
- CO$_2$-neutral

**BUT**

- Industrial Emissions Directive
- Additional drying efforts
- Transportation
- Nutrients not utilized
Co-Combustion in Germany

- Generates about 2 million tonnes DS per annum
- 750,000 t ds/y (34% of all sludge) is burnt in 24 TPPs
- 350,000 t/y (15%) burnt in cement factories
- Rapid increase after 2003 when sludge disposal to landfill was prohibited
- Sludge addition up to 5% of fuel mass viable
- Sludge 25-35% DS
- Lignite: 40 – 55% DS
- Drying and grinding of lignite not affected due to high moisture content
Mono-Incineration

Advantages
- Usually ‘in-house’
- Input sludge quality not important (except moisture)
- Significant reduction in solids and transport costs
- Energy can be recovered

Disadvantages
- High capital and operating costs
- Complex technology requires high operator skill
- Air emissions are expensive to control and monitor
- Energy recovery depends on moisture content
- Residual ash may need special disposal if not recycled
- Flue gas cleaning
- Local opposition can be strong
Breakdown of Alternative Fossil Fuels, EU28, by percent

- Plastics: 37.1%
- Mixed industrial waste: 6.3%
- Tyres: 6.8%
- Other fossil based wastes: 6.5%
- Other biomass: 3.4%
- Animal bone meal, animal meal and animal fats (biomass): 5.2%
- Solvents: 2.1%
- Impregnated sawdust: 17.7%
- Waste oil: 0%

Breakdown of Main Fuel Types, EU28

- Conventional fossil fuels: 63.7%
- Alternative fossil fuels: 31.6%
- Biomass: 4.6%
Pyrolysis

- Process
  - Cf: “Cracking”
  - No oxygen
  - Heat
  - Pressure
  - Outputs
    - Gas
    - Oil
    - Char (solid residue)

- “Char”
  - ...potential to improve agricultural soils’ productivity, remediate contaminated soils, and possible mitigation effects on climate change.

- Not widely used (yet)
Lime stabilization

**Process**
- Quicklime: CaO
- Hydrated (slaked) Lime; CaOH₂
- Strong alkali
  - Increase pH to 12
  - Three months storage
  - Dose rates: 2% - 10%

**Advantages**
- Conditions all types of sludge
- Precipitates heavy metals
- Destroys pathogenic agents
- Eliminates offensive odours
Significantly Reduce Pathogens

- Reduce but not eliminate
  - Aerobic digestion
  - Anaerobic digestion
  - Air drying
  - Composting
  - Lime stabilization

Further Reduce Pathogens

- Hard to detect
  - Composting+
  - Heat drying
  - Heat treatment
  - Thermophilic aerobic digestion
  - Beta ray irradiation
  - Gamma ray irradiation
  - Pasteurization
Phosphorus Recovery

• Phosphorus
  • Essential to life (ATP)
  • Limited resource – “peak phosphorus”
  • Pollutant – eutrophication

• Recovery
  • If sludge to agriculture / land … no need
  • If not then:
    • Removal from the sludge
    • Removal from the ash after incineration
  • Both cases: leaching with acid and base

• European Sustainable Phosphorus Platform
  • [www.p-rex.eu](http://www.p-rex.eu)
    • Seven processes examined in detail
  • RecoPhos
    • Recovery of Phosphorus from Sewage Sludge and Sewage Sludge Ashes with the thermo-reductive RecoPhos Process
Sludge: Example Process

- AirPrex
  - Struvite Crystals
  - Magnesium ammonium phosphate
  - Alkaline conditions
  - Magnesium chloride
  - Collected at bottom of reactor
  - Washing to remove sludge
  - Dried
- End product
  - Berliner Pflanze
  - Fertilizer Approval
  - REACH registration
- Operated in Germany and NL
Ash: Example Process

- **Ashdec**
  - Thermochemical
  - Rotary kiln
  - Reaction with NaSO₄
  - 900 – 1000 °C
  - Output: CaNaPO₄
- **Alternative**
  - MgCl₂ instead of NaSO₄
  - CaMgPO₄
  - Better heavy metal removal
  - P only available in acid soils
Use in Agriculture / Land (1)

Options
• Agriculture
• Land rehabilitation
• Forestry
• Parks & gardens

Advantages
• Nutrients
• Organic matter
• Low cost
• Low technology
• Policy

Disadvantages
• Voluntary
• Vulnerable
• Variable demand
• Quality
• Many stakeholders
• Competition
Use in Agriculture

Considerations

• Demand
  • Suitable arable crops (cereals, industrial and fodder)
  • Attitudes … not to be underestimated … Trust

• Restrictions on sludge use due to natural soil quality

• Restrictions arising from legislation

• Practicalities
  • Quality Control, Quality Assurance
  • Analytical requirements
  • Reporting requirements
  • Farm structure
    • Not well suited to small farms: e.g. manual spreading
    • Better suited to enterprise scale: mechanization …
Landfill – Transitional

- Landfill and Waste Framework Directives effectively prohibit sludge disposal to landfill
- Sludge: stabilised, ≥35% DS & ≤10% of waste mass
- Careful placement in the landfill required
Selecting the Options

**Options Analysis**
- Lifetime Costs
- Capital Costs
- Operational Costs
- Net Present Value

**Risk Analysis**
- Critical Factors
- Sensitivity
- Mitigation

**Sludge generation estimation**
- Present and Future

**Market for sludge-derived products**
- Present and Future

**Legal Constraints**

**Sludge Treatment Technologies**
- Technical Characteristics
- Investment Costs
- Operational Costs
Rules of Thumb

Small WWTPs

Aerobic stabilisation
• Thicken, Drying beds / reed beds / solar drying: transport
No treatment
• Thicken / dewater, transport to central treatment

Medium WWTPs

• Anaerobic digestion
• Dewatering/drying, transport to point of use

Large WWTPs or Waste Treatment Centres

• Medium plus …
• Advanced and additional treatment options may be cost-effective due to large scale
Stand back for a moment

**Perspective**

- 60 g/c/d = ~20 kg/c/a Dry Solids
- Digested and solar dried to 70%: 20 kg/c/a
- Municipal solid waste: 450 kg/c/a
- Organic waste: ~33% = 150 kg/c/a
- 20 versus 150 …
- Municipal solid waste – far bigger issue
- Sewage sludge strategy needs to be part of / integrated into / coordinated with MSW strategy

**National Strategies**

- You have to have one!
- Facilitate application of waste hierarchy: regulatory, advising
  - e.g. setting “appropriate” standards for compost
Factors in option selection

Operational
- Quantity, type and quality of sludge produced
- Internal WWTP operational requirements

Available Options (“the market”)
- End users within “reasonable” distance
- Treatment facilities within reasonable distance (waste managers)
- Desired or specified sludge quality to suit the end use

The Cost Benefit Analysis
- Capital & operational costs of feasible treatment options
- Environmental impact of feasible treatment options
  - Soil quality, Water quality, Air quality, Climate change
- Finding the optimum balance
  - Cost of drying versus increased calorific value & reduced transport costs

06/06/2018 Sewage Sludge Workshop - Warsaw
Technical Guide on the treatment and recycling techniques for sludge from municipal waste water treatment
Thank-you for your attention

Questions and Discussion
More Information

For info or further questions on this seminar and the activities of the JASPERS Networking Platform, please contact the JASPERS Networking and Competence Centre at the following email:

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