Effect of Thermal & Chemical Hydrolysis on Sludge Dewatering, Drying and Incineration

Prof. Dr.-Ing. Peter Hartwig
aqua & waste international GmbH
Hannover, Germany

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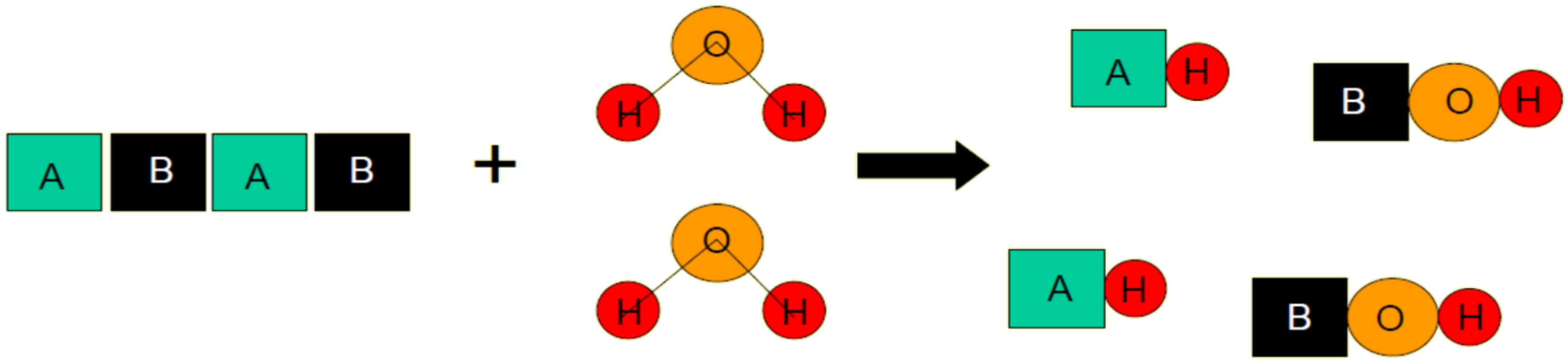
Content

- Basics of hydrolysis
- Thermal hydrolysis for sewage sludge disintegration
- Impacts of hydrolysis on treatment plants operation
- Large scale systems
- Application examples

Hydrolysis

What is hydrolysis?

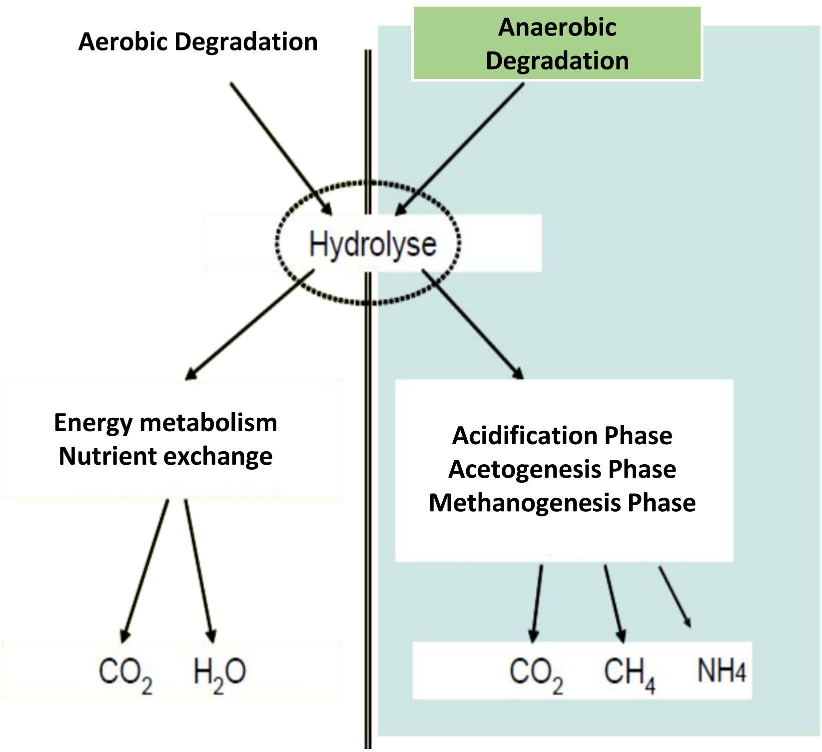
- Decomposition of long-chain, organic molecules into monomeric building blocks by addition of water
- **Physical** (temperature / pressure), **chemical** (acid / Base), **biochemical** by enzymes (aerobic / anaerobic)



Hydrolysis

Biochemical hydrolysis

- High significance in aerobic and anaerobic biodegradation of organic matter
- Enzymatically catalyzed (substrate specific)
- Speed-determining step in the conversion process
- Often limits acidification and methanation in the digester



Hydrolysis

Limitations of biochemical hydrolysis

- Substrates for which no enzymatic matrix is present are not hydrolyzed
- Hydrogels and extracellular polymeric substances (EPS) are either non or hardly degradable
- Consist mainly of polysaccharides and proteins
- Substances have high hydrophilic capacity (high consumption of polymers, poor dewaterability)

Thermal Hydrolysis

Overview (I)

- Disintegration of non or hard degradable substances by application of elevated temperatures and pressures.
- Increasing the degree of degradation of the treated sludge
- Not substrate specific
- Differentiation between processes with T<100 °C and normal pressure as well as T>100 °C and overpressure
- Substrates:
  - excess sludge (ES)
  - primary sludge (PS)
  - raw sludge (RS = ES + PS)
  - co-substrates (CS)

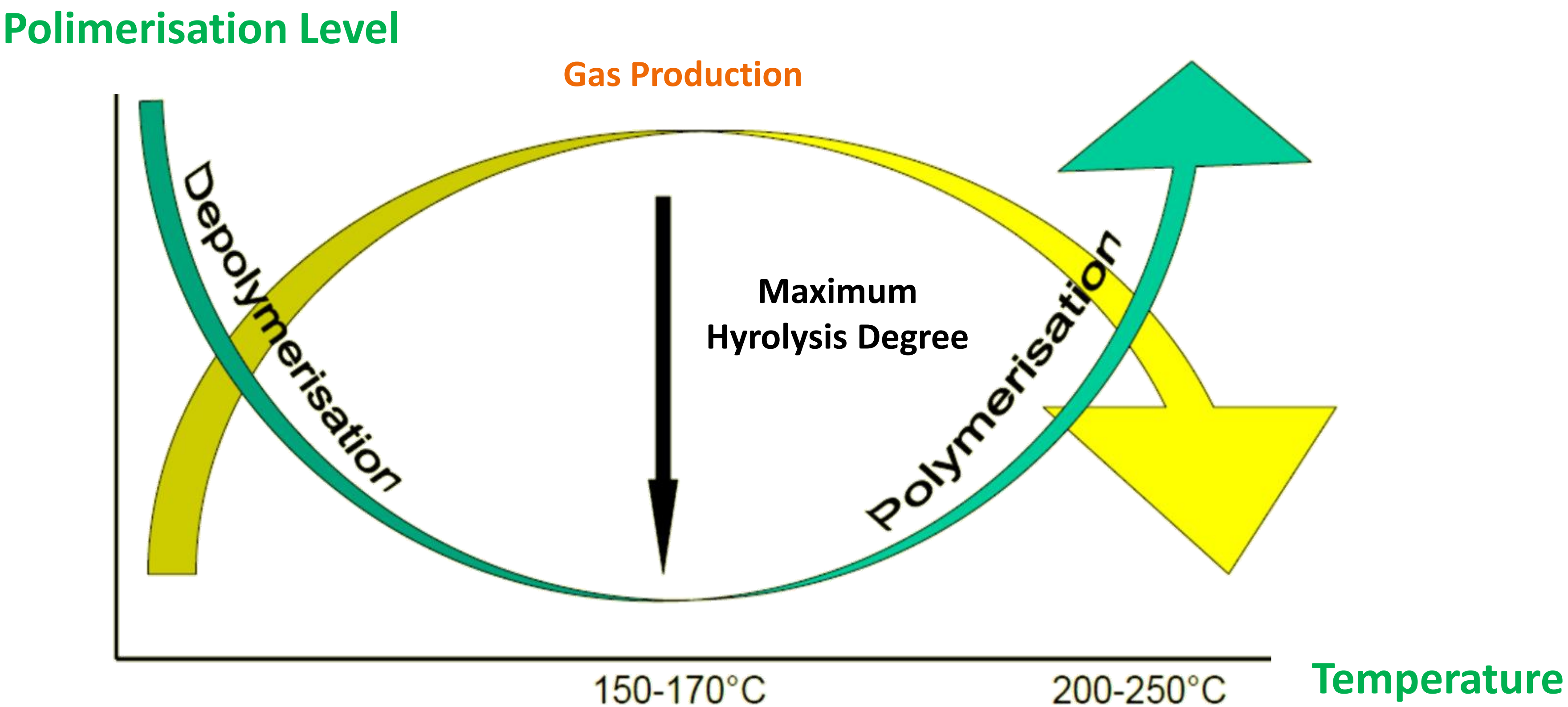
Thermal Hydrolysis

Overview (II)

- Thickening of the sludge before disintegration up to a DS of 6 % to 25% is reached for saving thermal energy
- Sludge heating:
  - **Indirectly** by means of heating medium (for example hot water, thermal oil)
  - **directly** by injection of superheated steam
- For uniform heat supply, processes are usually operated continuously or Semi-continuously

Thermal Hydrolysis

Polymerisation/Depolymerisation



Possible Effects

Advantages

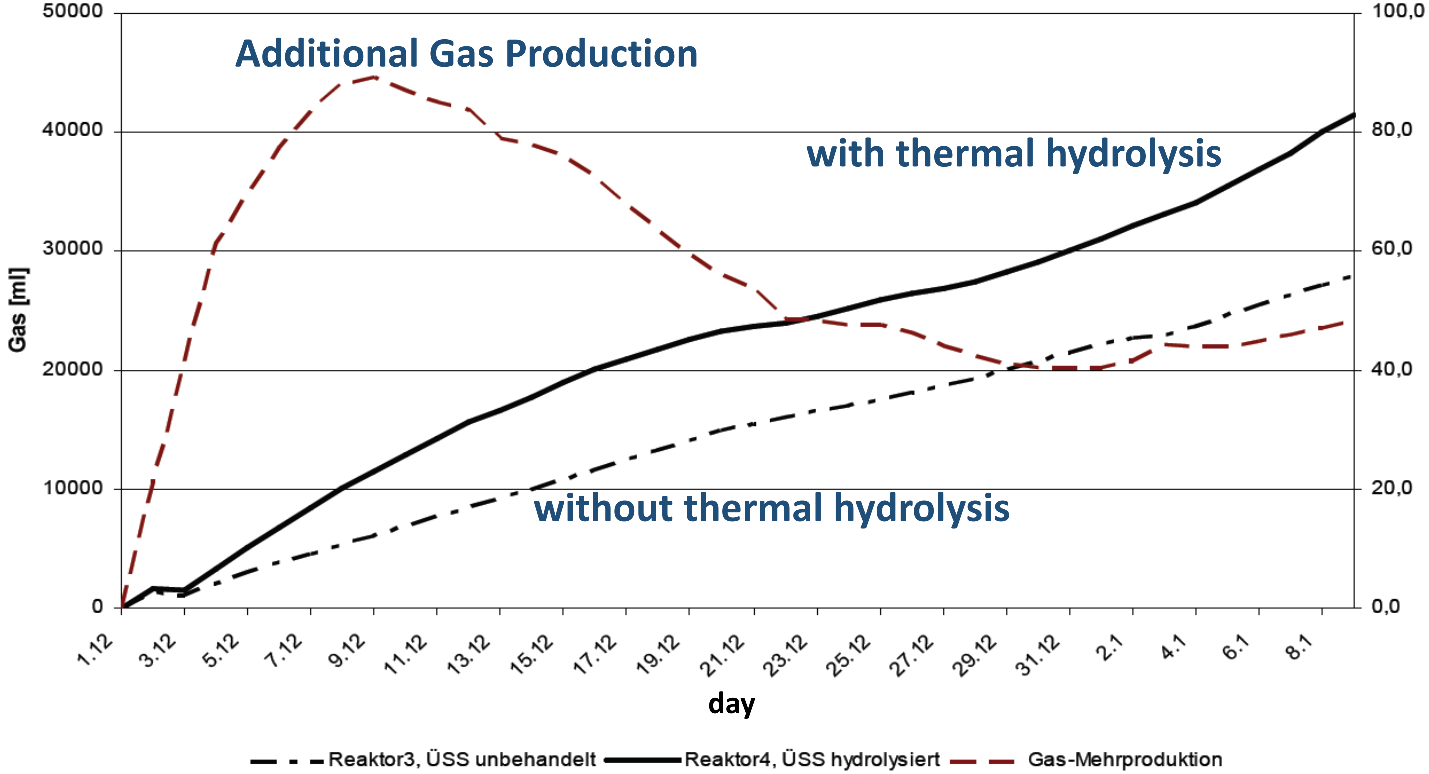
- Higher biological availability of the substrates (increase in technical digestibility degree)
- Higher gas production (up to 50%)
- Reduction in viscosity (pumpable at comparatively high TS concentrations
- Better dewaterability (Less sludge amount and disposal costs)
- Hygienization of the sludge in case of raw sludge treatment
- Reduction of foaming in the digester by destroying the filamentous bacteria
- Capacity expansion (digested hydrolyzed sludge 12 to 15 days)
- Possibility of high load digestion at TS up to 12%
- Increasing the phosphorus recovery potential as MAP

Possible Effects

Influence on gas production

Laboratory digestion test
100% Excess sludge

Gasproduction (ml) **Gasproduction (%)**



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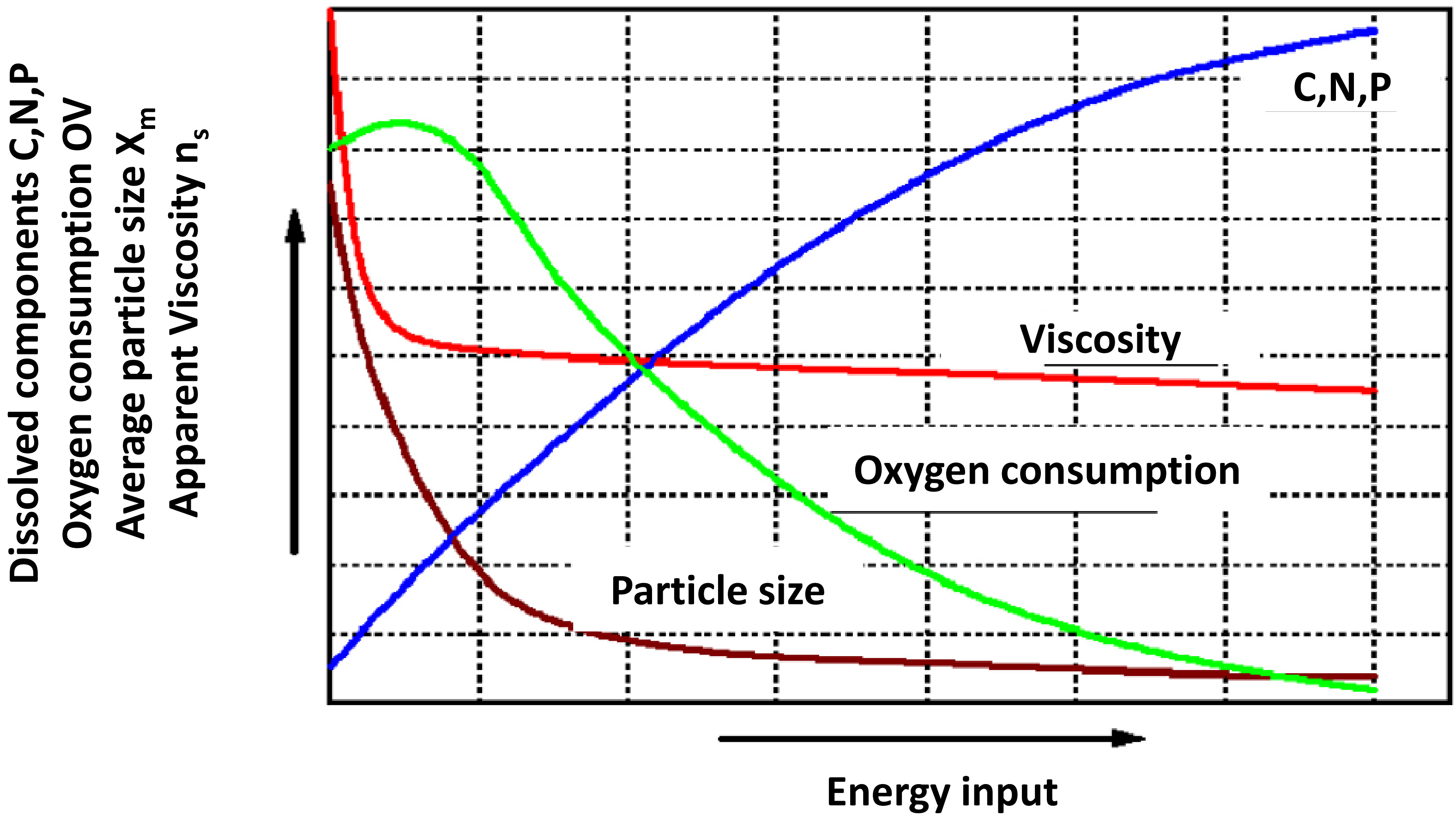
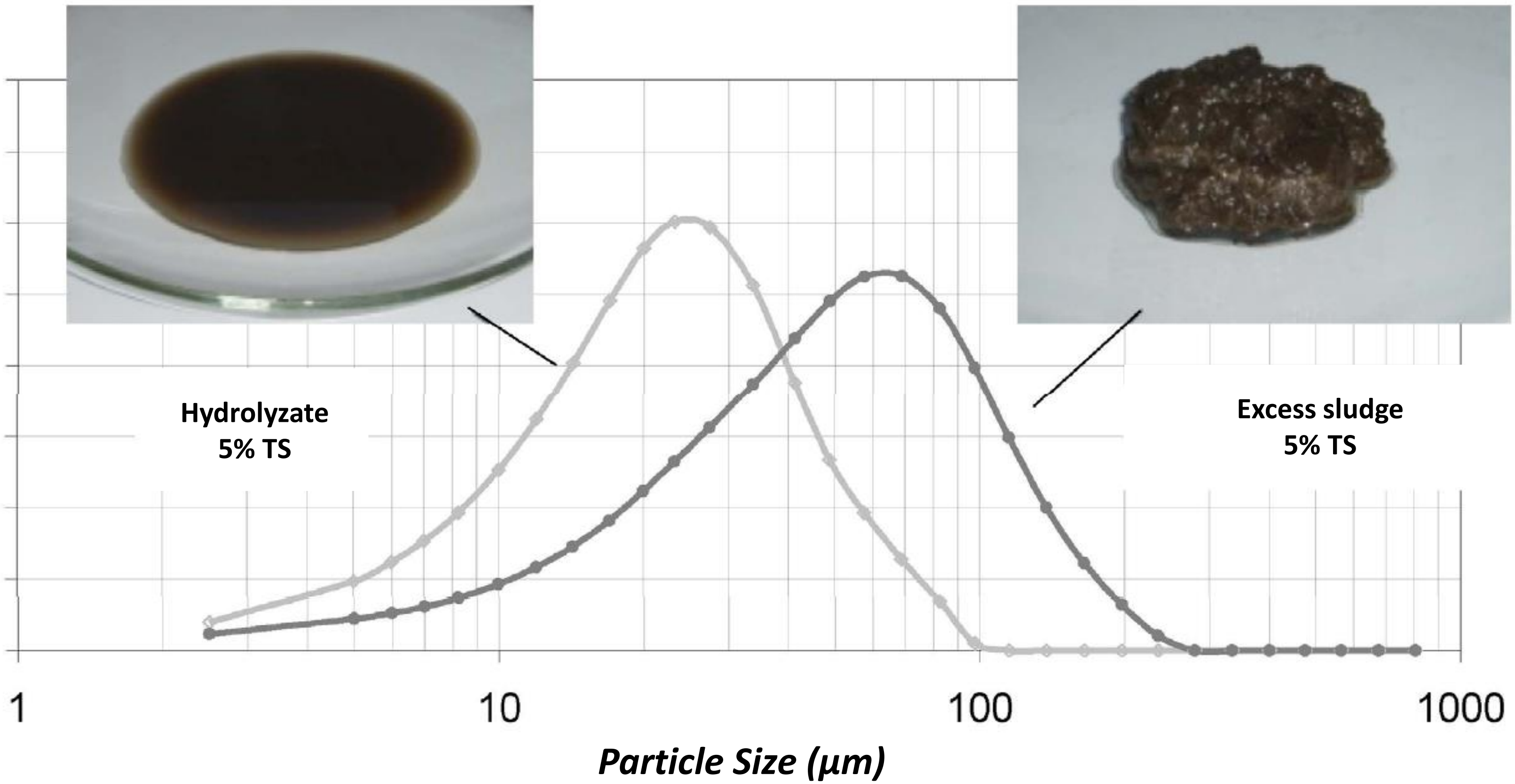
Possible Effects

Influence of energy input on sludge characteristics



Possible Effects
Viscosity change

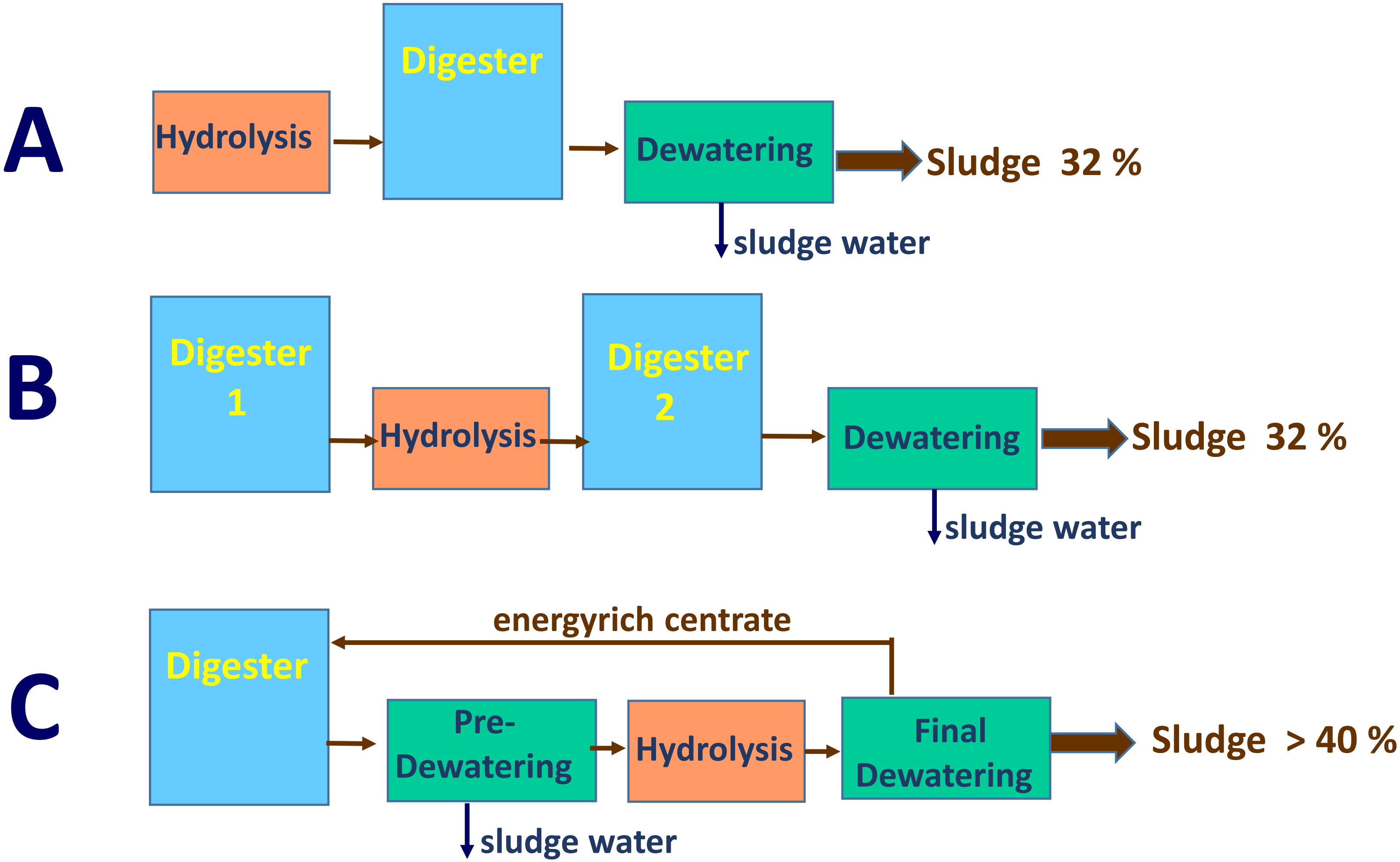


Possible Effects

Disadvantages

- Return load of sludge water
  (inert COD, ammonium, inert organic Nitrogen, Phosphorus)
  to the biological treatment stage of the WWTP
- Separate sludge water treatment may be required / useful
  ….. could be returned into an advantage by N/P-recycling
- Increase COD in the effluent of the WWTP
- Increased operational costs (operation, maintenance)

Process steps for the hydrolysis application



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Available Hydrolysis Technologies (not complete)

Overview

- CAMBI process (CAMBI GROUP AS)
- SolidStream - process (CAMBI GROUP AS)
- PONDUS process (PONDUS Verfahrenstechnik GmbH)
- HCHS process (Harsleev company)
- LysoTherm (ELIQUO STULZ GmbH)
- BIOTHELYS / EXELYS (Veolia Water Technologies)
- TURBOTEC method (Sustec)
- ZERO SLUDGE (NewLisi S.p.A.)

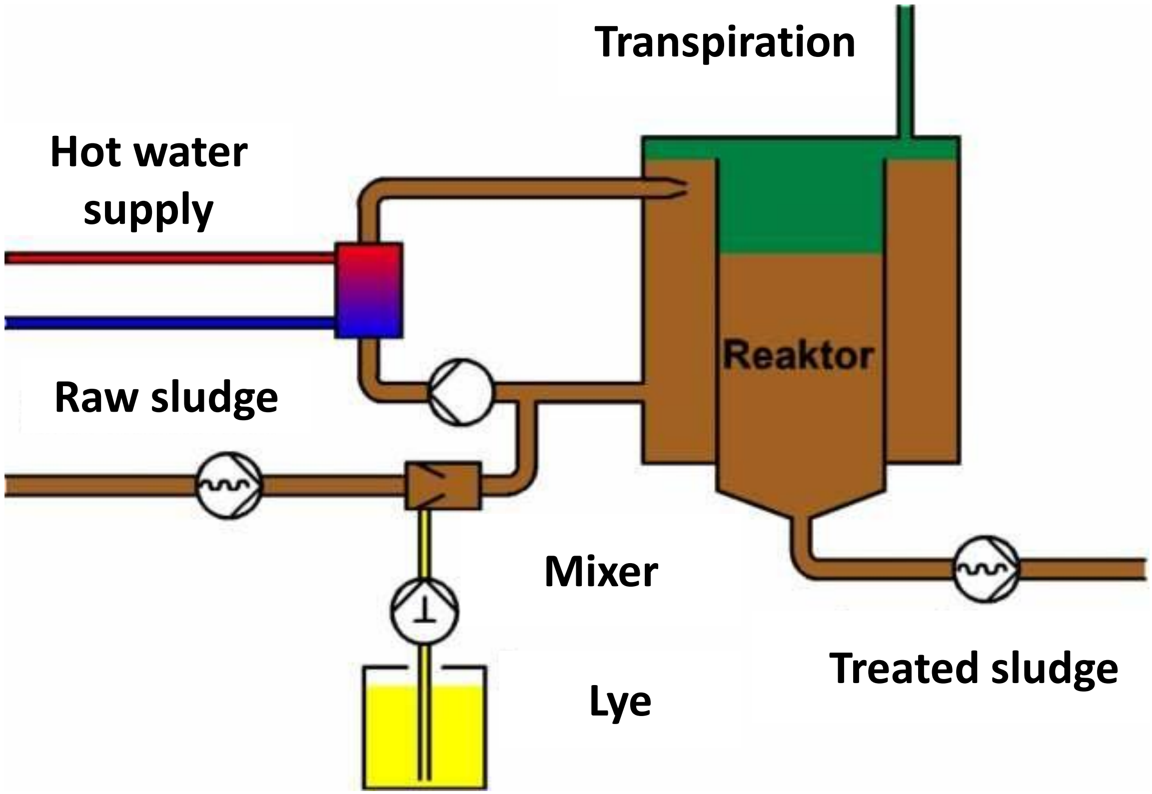
Pondus Process

Short description

- Temperature range **60 to 70 ° C**
- Heat supply indirectly via e.g. **hot water**
- Pressure-free operation of the reactors
- Addition of **lye** (for example 50% sodium hydroxide solution) for a short-term increase in the pH to 10 to 11 (about 1.5 l/m³ of sludge)
- Reaction time of around 2 hours
- Cell membrane destruction by a combination of lye and heat
- Lye is neutralized by excess organic acids
- COD digestibility> 40% possible

Pondus Process

Process Schema



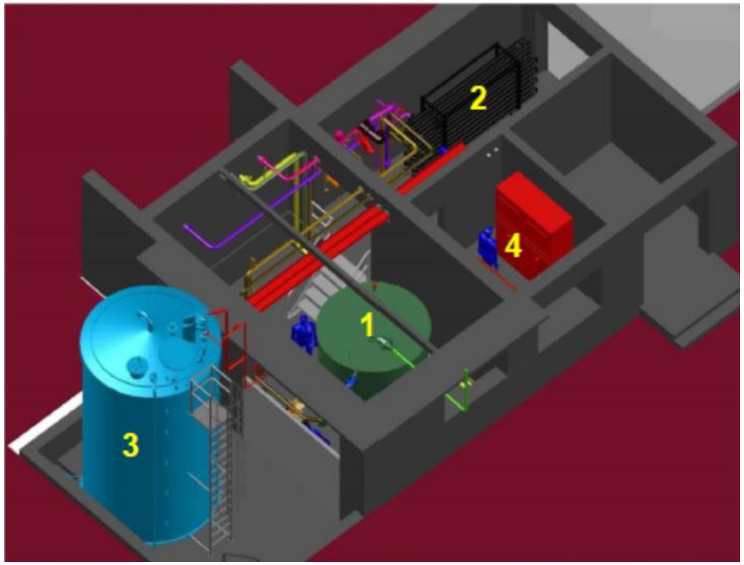
Pondus Process

Application example- WWTP Uelzen

- 83,000 PE, sludge digestion (two-stage, mesophilic), co-fermentation, gas utilization by CHP
- Excess sludge disintegration (2.7 m^3/h Excess sludge)
- Reduction of sludge load from 5,147 to 4,820 kg ODM/d
- Increase in methane production (+ 22% absolute, +31% specific)
- Reduction of ignition loss in digested sludge by 9%
- Dewaterability almost unchanged at 22% TS
- Reduction of polymer dosage by 3 kg WS/t Dry solid content
- Investment costs 400,000 €

Pondus Process

Application example- WWTP Uelzen



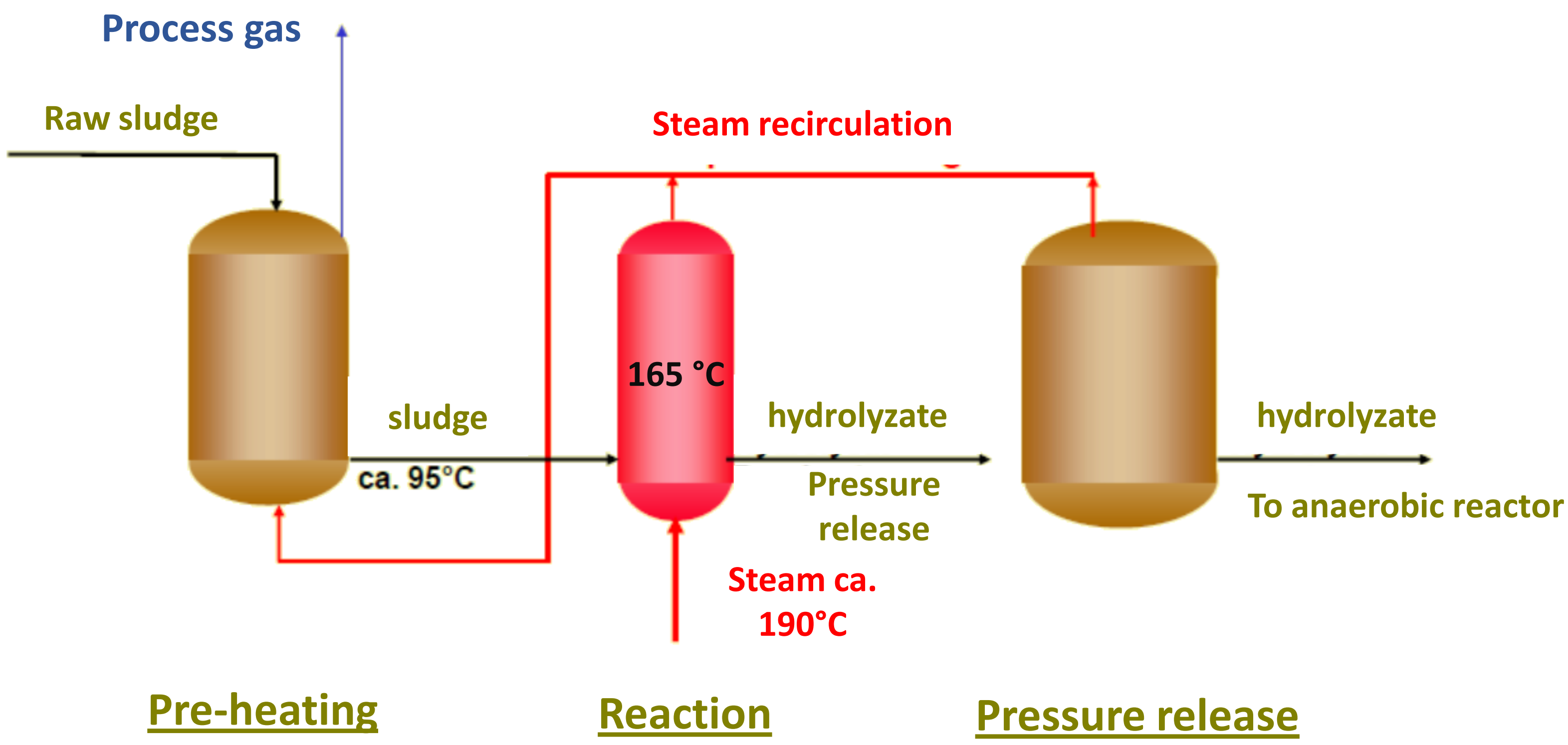
Cambi Process

Short description

- Thickening of the sludge to TS 10 to 15%
- Temperature about **150 to 165 °C**. Direct heat supply via superheated **steam** (about 150 kg steam/m^3 of sludge)
- Pressure: 5 to 6 bar, duration 20 to 30 minutes
- Sudden pressure release
- Hydrolysis Systems: ES or RS (PS + ES)
- Cooling to digestion temperature or mixture of hydrolyzed ES with cold PS
- Digester can be operated after total sludge hydrolysis with a TS content of up to 12% and volume loading rate up to 7 kg ODM / (m^3.d)

Cambi Process

Process schema



Cambi Process

Application example

WWTP Athen

WWTP Fredericia

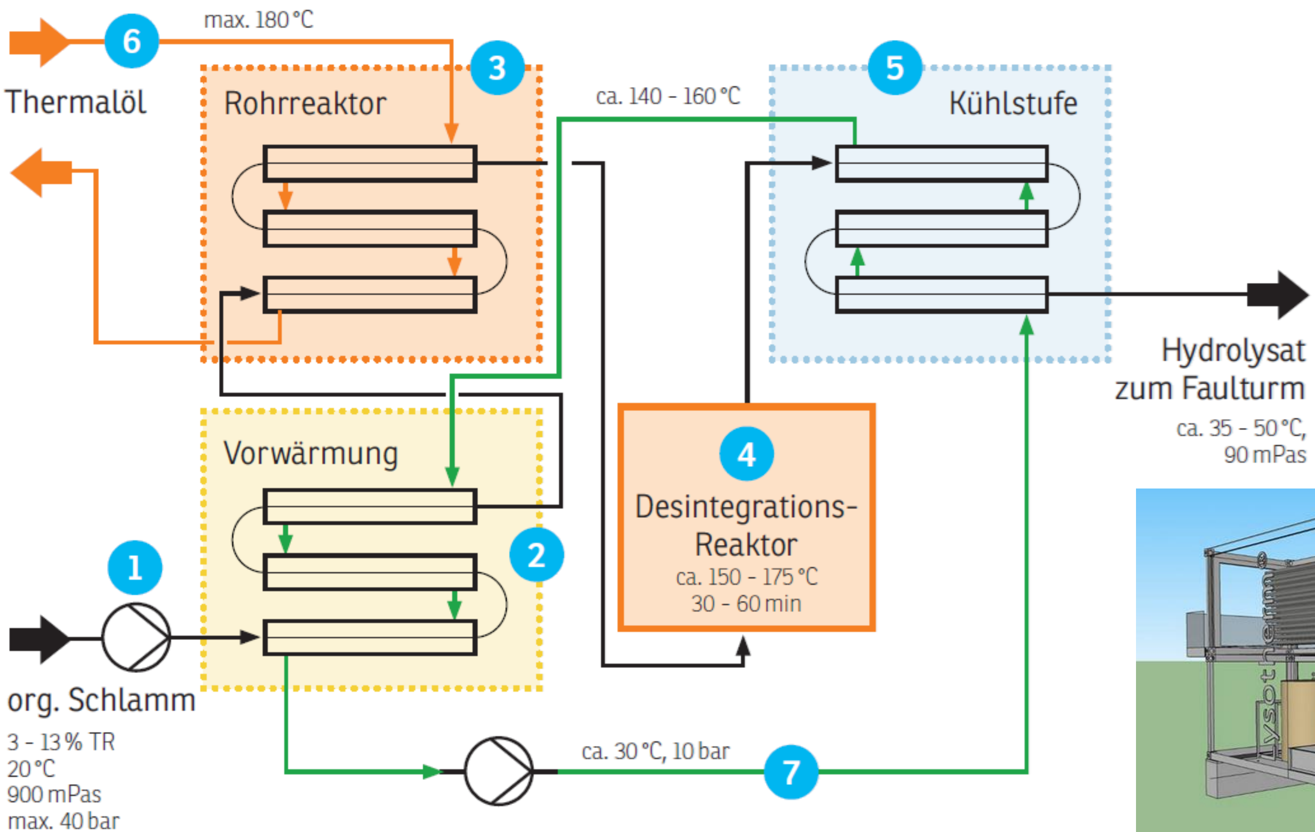
LysoTherm Process

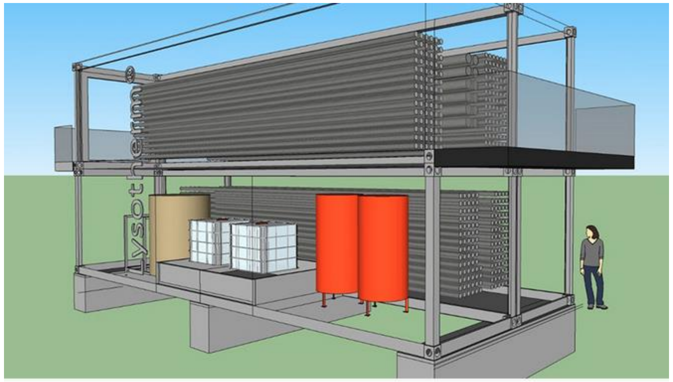
Short description

- Temperature **150 to 175 °C**
- Heat input and recovery via **multi-stage heat exchanger system**
- Thickening of the sludge to up to 6% TS (comparable high sludge volume to be treated)
- Duration: 30 to 60 min
- Preheating, plug-flow reactor, disintegration reactor, cooling stage
- Primary disintegration: sewage sludge disintegration
- Secondary disintegration: digested sludge conditioning

LysoTherm Process

Process schema





LysoTherm Process

Application example- WWTP Lingen

- Design capacity 195,000 PE
- Thermal disintegration of excess sludge
- Capacity of 3,500 kg TS/d
- Phosphorus recovery (MAP precipitation)
- Sludge dewatering
- Period 2012 - 2016

HCHS – Verfahren (Haarslev)

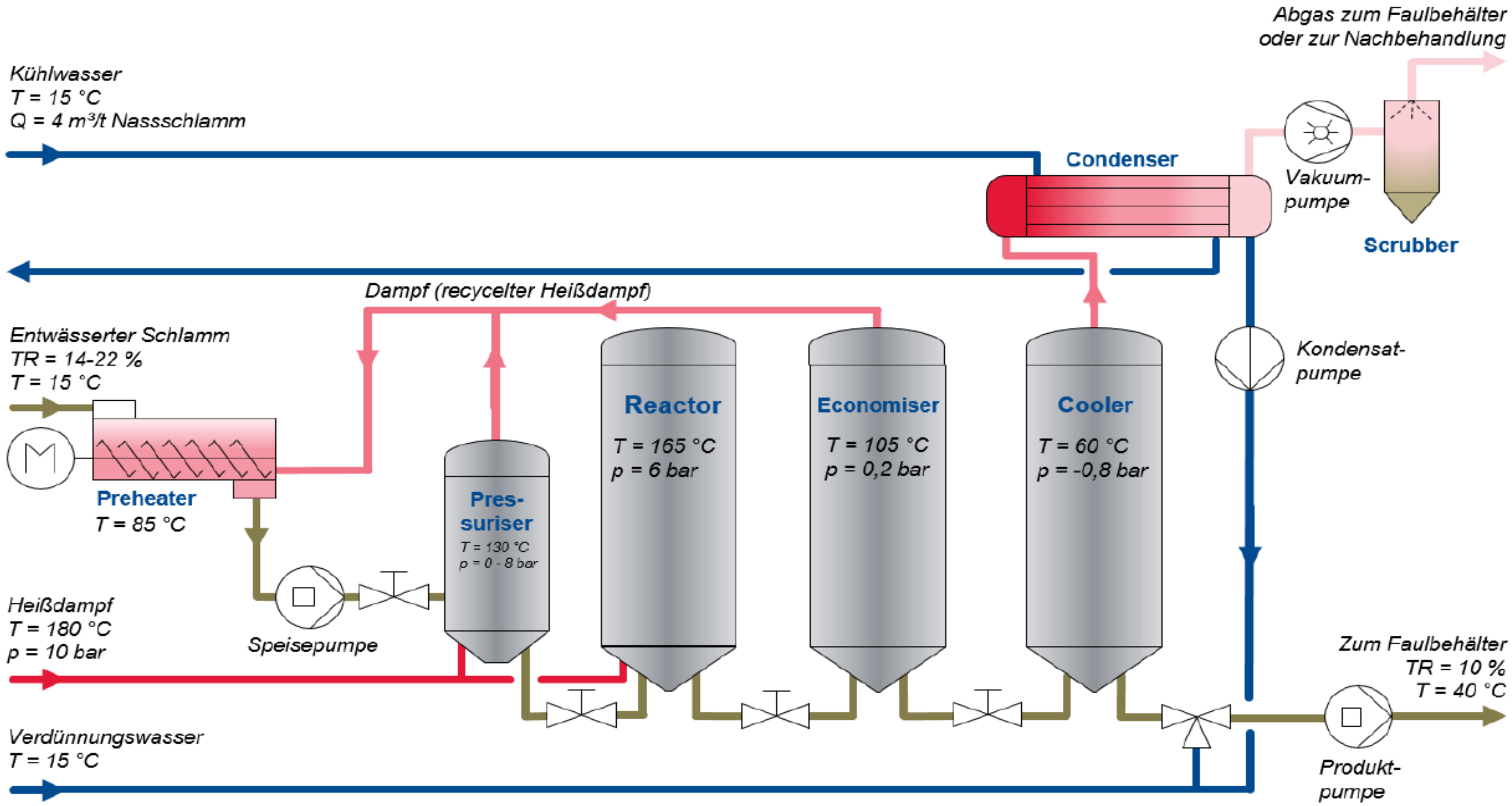
Short description

- Temperature **150 to 170 ° C**
- Pressure about 6 bar
- Direct heating by means of **steam**
- TS content Inlet 17 to 22% TS
- Duration: 30 minutes
- Preheat the sludge by means of steam
- Cooling of the treated sludge in the cooler

WWTP Grevesmühlen
Themal Hydrolysis

HCHS – Verfahren (Haarslev)

Processscheme




Sludge Drying
Anaerobic Sludge Digestion
+ primary sludge storgae
+ thermal hydrolysis
+ Co-Fermentation
= energetic autark operation

Thermal hydrolysis:

- more biogas
- less sludge mass to be dried
- better efficiency of the dewatering (Guarantee value ≥ 32 % DS)

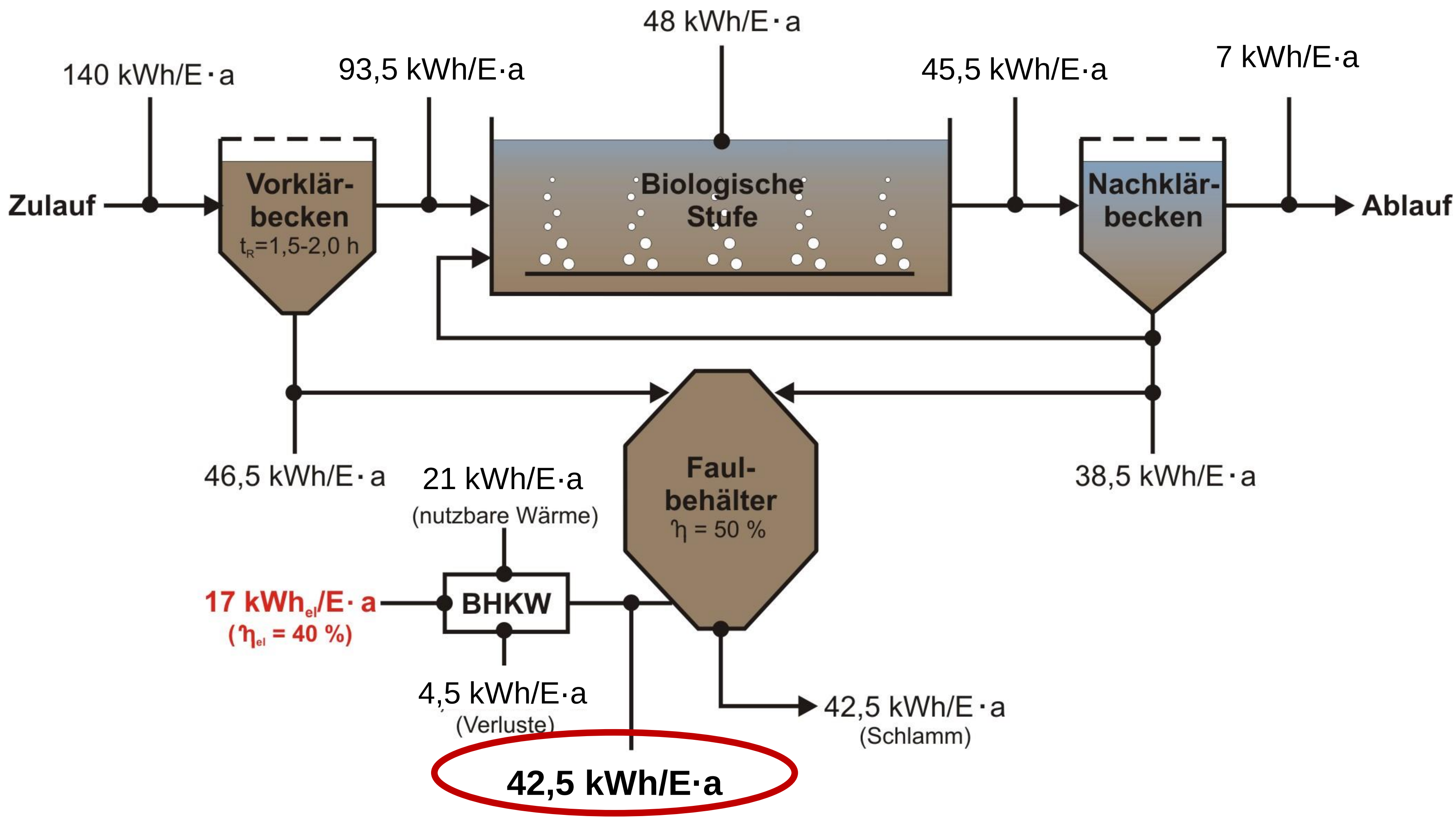
Energy balances on the basis of the COD

- COD-balances are the basis for all simulations
- COD-balances can be used for the operation control
  (Examples: control of a gas flow measurement and analysis)
- Basis of the comparison:

  120 g COD/ PE•day ➔ 140 kWh/ PE • year

  (320 l CH_4 per kg COD, 10 kWh per m^3 CH_4)
- For each separate treatment step a COD-balance is possible

Energy balance on a wastewater treatment plant (Basis:COD)



Effect of Thermal Hydrolysis on Sludge balance

Sludge/ Energy Balance (Example 100,000 PE):

- 6,000 kg BOD_5/day inflow
- Primary sedimentation, 2h retention time, 45 g DS/PE/d PS
- **Primary sludge production: 4,500 kg DS/d**
- Sludge age 15 days, spec. SS-Production 0,71 gg DS/ kg BOD_5 ,
- **Surplus Sludge production: 2,840 kg DS/d**
- **Total sludge production: 7,340 kg DS/d** with 65 % VSS/SS

Without Hydrolysis

- Removal in the digester: 50 % of the VSS ≈ 2,385 kg DS/d.
- **Sludge mass after the digestion: 4.955 kg DS/d.**

With Hydrolysis

- Removal in the digester: **67,5 % of the VSS ≈ 3,220 kg DS/d .**
- **Sludge mass after the digestion: 4.120 kg DS/d.**

Effect of Thermal Hydrolysis on Sludge drying

- The Sludge Drying throughput (kg DS/d) is reduced down to:

  4,120 /4,955 = **83 %**

- The dewaterability of the sludge is increased, rough estimation:

  + 3 % DS until + 5 %DS

- Example 100,000 PE, DS-increase from 27 % up to 32 % DS:

  - 4.955 kg DS/d / 270 kg TS/m^3 = 18,3 m^3/d without Hydrolysis
  - 4.120 kg DS/d / 320 kg TS/m^3 = 12,8 m^3/d with Hydrolysis

- Reduction of the required water evaporation of about 5.5 t/d
- Specific energy demand: 2,26 MJ/kg water evaporation ≈ 0,63 kWh/kg
- Reduction of the energy demand (heat) of **144 kW for 100,000 PE**

Effect of Thermal Hydrolysis on Sludge incineration

Sludge/ Energy Balance (Example 100,000 PE without hydrolysis):

- 6,000 kg BOD_5/day inflow
- Primary sedimentation, 2h retention time, 45 g DS/PE/d PS
- **Primary sludge production: 4,500 kg DS/d**
- Sludge age 15 days, spec. SS-Production 0,71 gg DS/ kg BOD_5 ,
- **Surplus Sludge production: 2,840 kg DS/d**
- Total sludge production: 7,340 kg DS/d with 65 % VSS/SS
- Removal in the digester: 50 % of the VSS ≈ 2,385 kg DS/d.
- **Sludge mass after the digestion: 4,955 kg DS/d.**
- Energy content in the sludge after the digestion: 42,5 kWh/PE/a ≈11,644 kWh/d für 100,000 PE. 1 kWh ≈ 3,6 MJ/kg.
- Energy production per day in the sludge: **41,900 MJ/d**
- Caloric value of the sludge: **8,5 MJ/ kg DS (without hydrolysis)**

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Effect of Thermal Hydrolysis on Sludge incineration

Sludge/ Energy Balance (Example 100,000 PE with hydolysis):

- 6,000 kg BOD_5/day inflow
- Primary sedimentation, 2h retention time, 45 g DS/PE/d PS
- **Primary sludge production: 4,500 kg DS/d**
- Sludge age 15 days, spec. SS-Production 0,71 gg DS/ kg BOD_5 ,
- **Surplus Sludge production: 2,840 kg DS/d**
- Total sludge production: 7,340 kg DS/d with 65 % VSS/SS
- Removal in the digester: **67,5 % of the VSS ≈ 3,220 kg DS/d** .
- **Sludge mass after the digestion: 4,120 kg DS/d.**
- Energy content in the sludge after the digestion (1 Kg SS = 1,2 kg CSB) 28,4 kWh/PE/a ≈7,780 kWh/d für 100,000 PE. 1 kWh ≈ 3,6 MJ/kg.
- Energy production per day in the sludge: **28,008 MJ/d**
- Caloric value of the sludge: **6,8 MJ/ kg DS (with hydrolysis)**
  8,5 MJ/ kg DS (without hydrolysis)

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Simulation Model of Thermal Hydrolysis

Background

- Cooperation with the Zweckverband Grevesmühlen
- Development of a simulation-based decision-making tool
- Pre-treatment, biological treatment, **thermal hydrolysis,** digestion, co-fermentation, deammonification (Plant Wide Modeling)
- Energetic and material optimization of KA Grevesmühlen

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Simulation Model of Thermal Hydrolysis

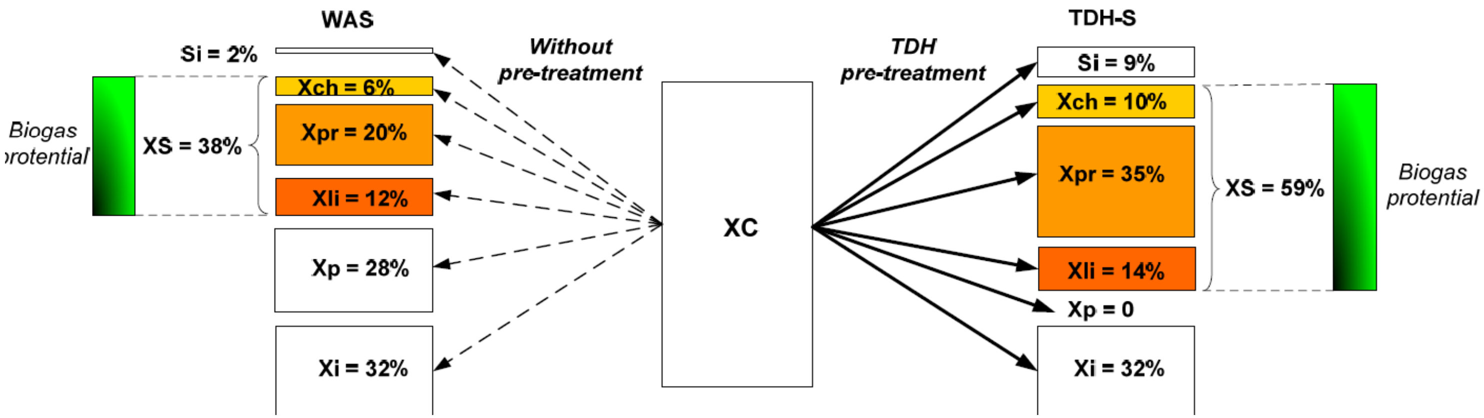
Project phases

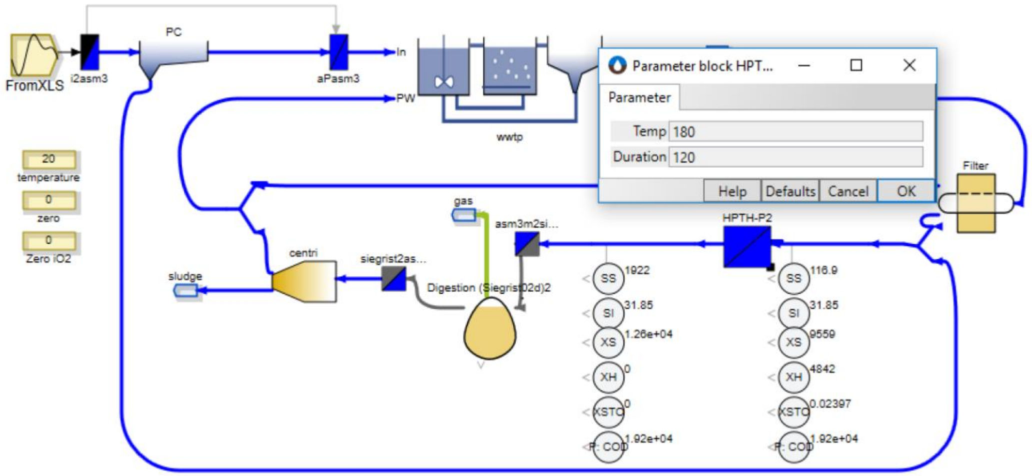
- Development of a simplified simulation model (inventory, operational data analysis, on-site inspection, etc.)
- Detailed modeling of individual components (calibration / validation, thermal hydrolysis, deammonification)
- Creation of a complete model consisting of the individual components
- Application of the complete model for the energetic and mass flow optimization of the sewage treatment plant Grevesmühlen
- Application in plant operation / training of operating personnel/ Application for other IWAMA partners (and outside also)


Zulauf
Belebung
Nachklärung
Gasspeicher
Rechen
Bio-P
Sandfang
Vorklärung
Schlammbehandlung
Faulung
Thermische Hydrolyse
Nach-Gärer
Deammonifikation

Simulation Model of Thermal Hydrolysis

Building the model based on literature research





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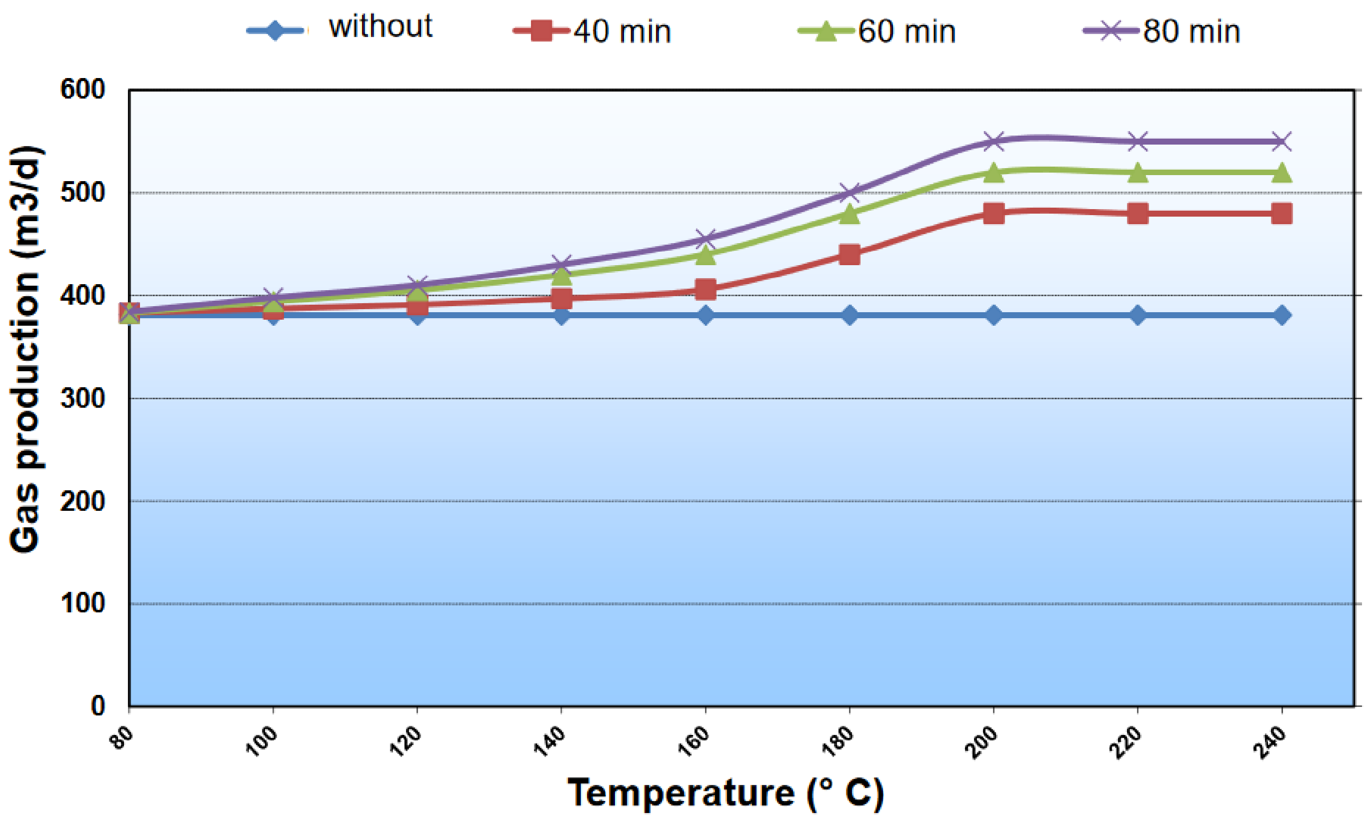
Simulation Model of Thermal Hydrolysis

Intermediate results - gas production



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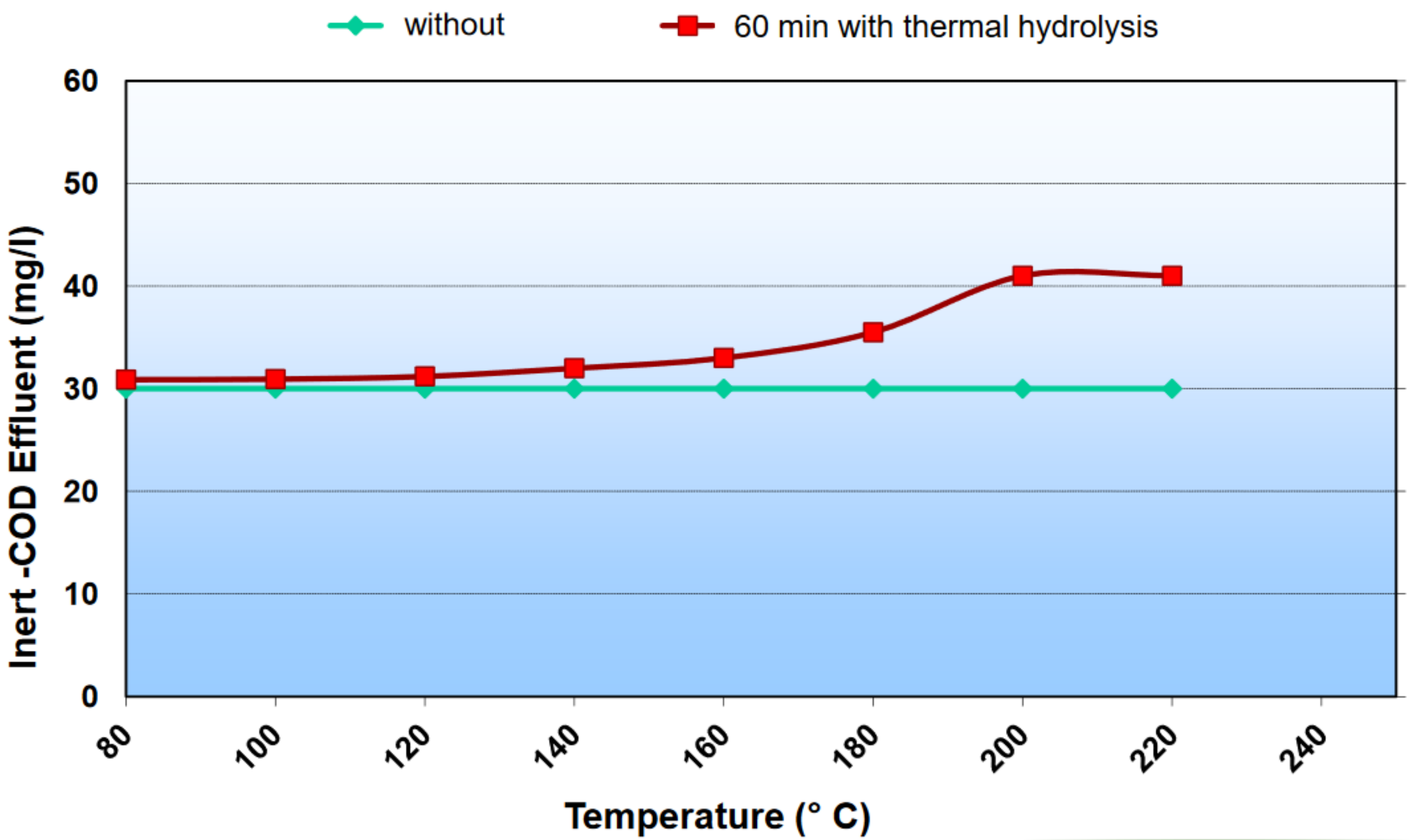
Simulation Model of Thermal Hydrolysis

Intermediate results – Inert COD



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Simulation Model of Thermal Hydrolysis

Batch tests in autoclave for calibration

Conclusion

- Thermal Hydrolysis is useful for energetic optimization of the sludge treatment
- Backloading to be considered, but also as a potential for nutrient recovery

Interreg
Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

IWAMA

Prof. Dr.-Ing. Peter Hartwig
aqua & waste international GmbH
Phone: + 49-511-96251-0
Email: Hartwig@aquawaste.de
www.aquawaste.de

Additional Slides for Discussion

Interreg
Baltic Sea Region

EUROPEAN UNION
EUROPEAN
REGIONAL
DEVELOPMENT
FUND

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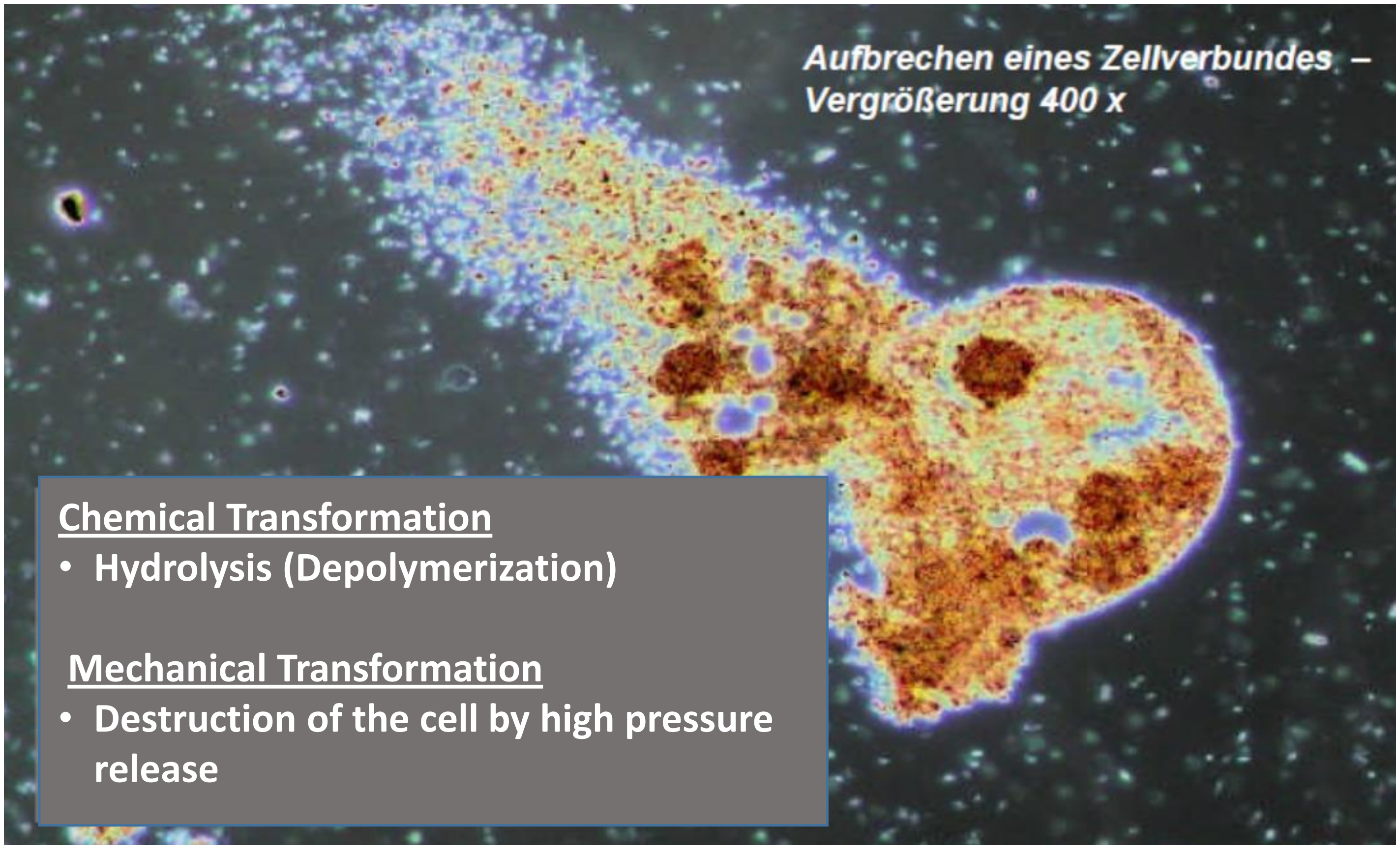
Possible Effects

Cell structure transformation



<u>Chemical Transformation</u>

- Hydrolysis (Depolymerization)

<u>Mechanical Transformation</u>

- Destruction of the cell by high pressure release

Effect of Thermal Hydrolysis on Incineration

- Once treated, sewage sludge becomes a valuable source of nutrients, known as biosolids, which is used in a number of outlets.
- Biosolids are typically used in various energy recovery systems to take advantage of their inherent energy content, which for dried biosolids, is equivalent to lignite.
- Energy recovery systems may include: incineration; co-firing; gasification; pyrolysis or super- and sub-critical wet air oxidation
- Although raw sludge is considered better for incineration due to higher calorific value, a study in Davyhulme, England showed that more energy would be recovered in the overall system when combined with the energy generated from biogas in the digestion facility.

Pondus Process

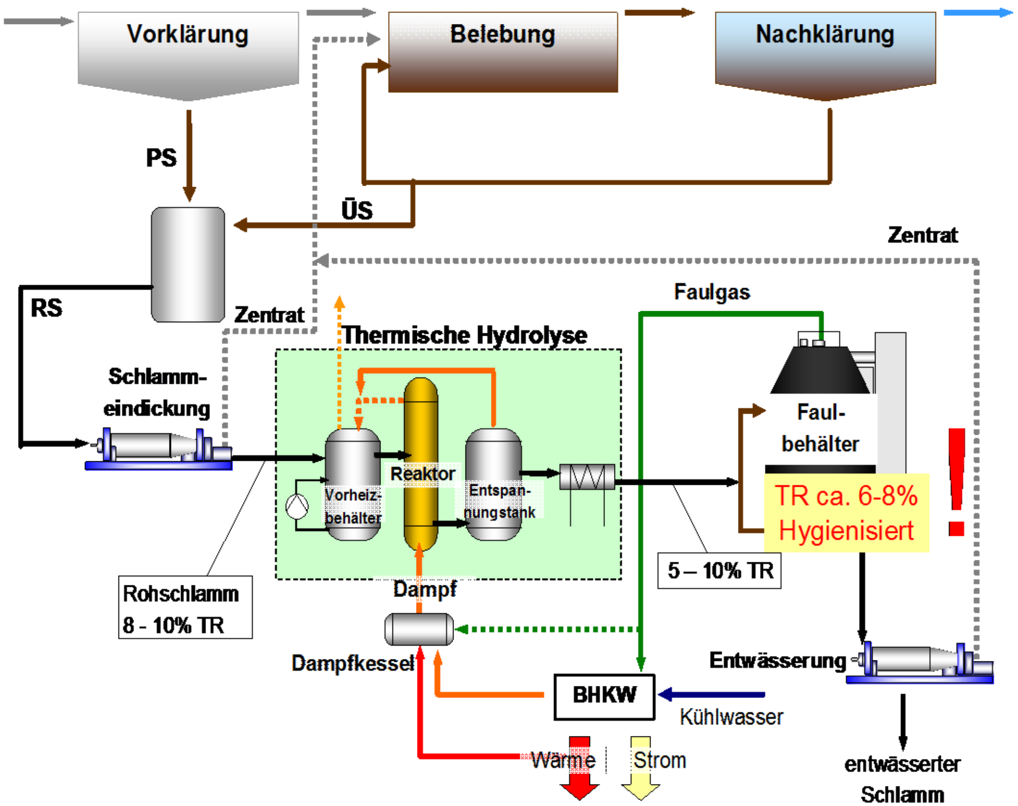
Application example- WWTP Wolfsburg

Pondus Process

Application example- WWTP Gifhorn

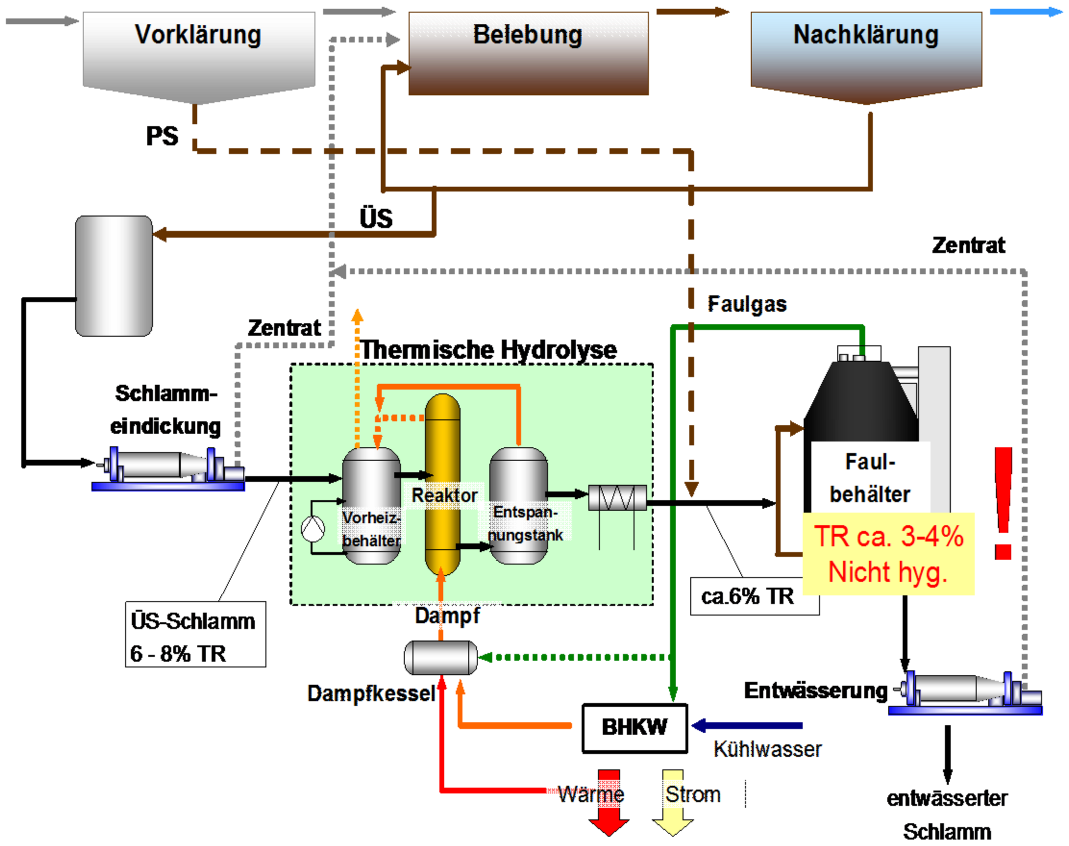
Cambi Process

Raw sludge (RS = PS + ES) - hydrolysis



Cambi Process

Excess sludge(ES) - hydrolysis



LysoTherm Process

Application example- WWTP Amersfoort

- Sludge amount of 12,225 ton TS /year
- Energy surplus of 2,000,000 kWh/year
- PEARL plant (900 ton/year MAP fertilizer)
- DEMON system for nitrogen elimination
- Heat utilization of CHPs
- Project start November 2014, commissioning in March 2016

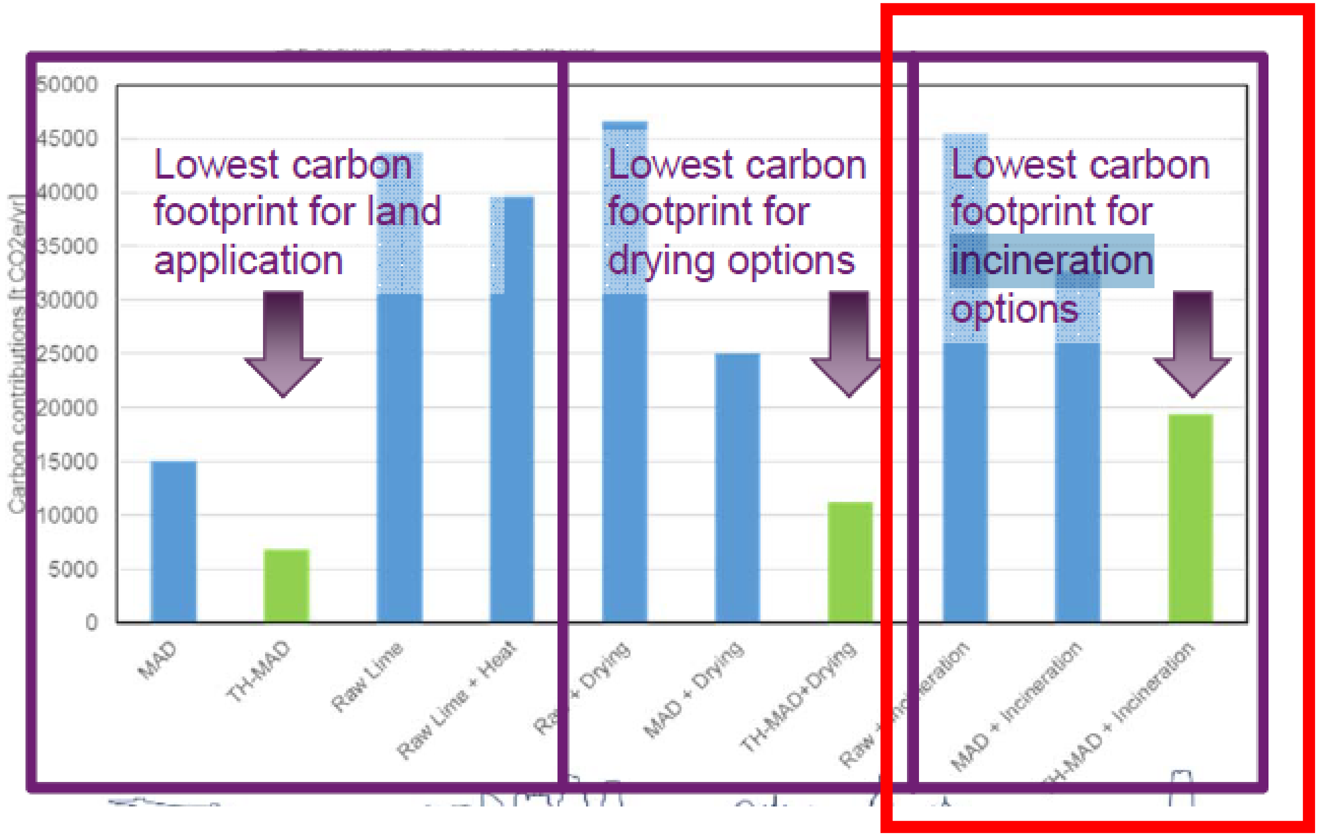
Thermal Hydrolysis

Carbon Footprint

- Provides great carbon footprint savings regardless of endpoint of sludge
- Increased production of renewable energy
- Better volatile solids destruction resulting in less biosolids downstream for transport and further processing
- Better dewatering →reduces biosolids for downstream processing.
- Significant reduction in fossil fuel requirements for downstream drying
- Higher dewaterability→increases energy content in cake →greater energy recovery benefit in downstream incineration, whilst improved volatile solids destruction reduces the quantity of material which needs to be incinerated

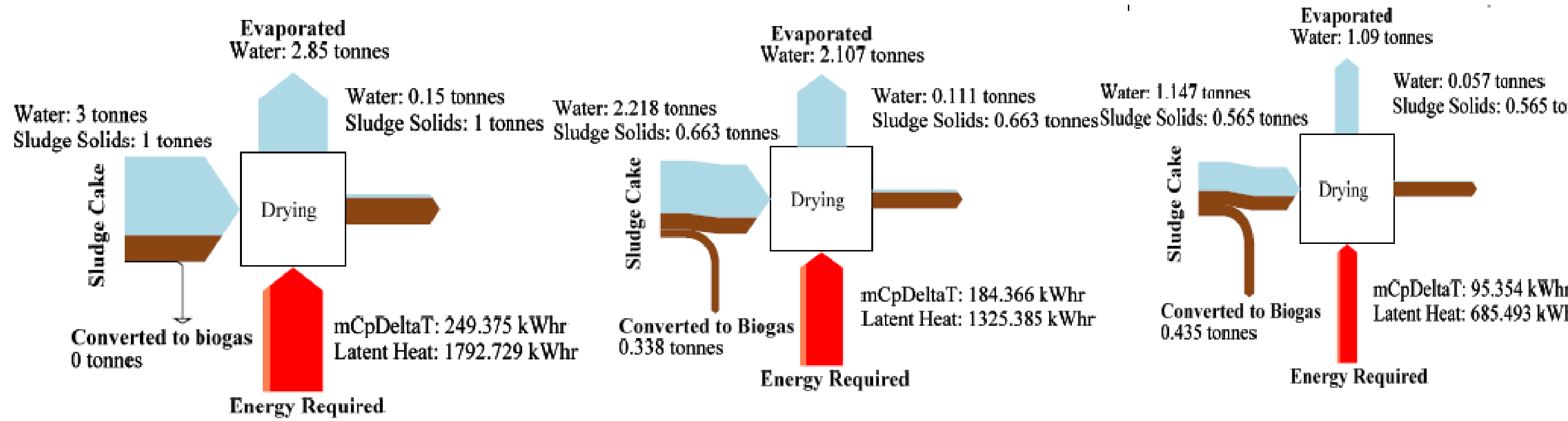
Thermal Hydrolysis

Carbon Footprint



Effect of Thermal Hydrolysis on Drying

Influence on thermal systems



No digestion

MAD

- Less cake to dry
- 25% less energy required than raw

TH + MAD

- Even less cake to dry
- Which also has less water in it per unit volume
- 60%+ less energy required than raw
- 50% less energy required than digested

Simulation Model of Thermal Hydrolysis

Procedures for assessment of the efficiency of thermal hydrolysis

- Determination of optimal operating parameters of thermal disintegration (substrate, temp.)
- Investigation of the influence of disintegration on anaerobic sludge stabilization (degree of degradation, gas production etc.)
- Investigation of the dewaterability behavior of the sludge after anaerobic digestion
- Laboratory scale (130 and 150 °C), large scale (130, 148 and 160 °C)
- Analytic and anaerobic batch tests
- Dewaterability degree assessment by laboratory centrifuge

→ **Basis for calibration of the existing model**

Simulation Model of Thermal Hydrolysis

Pilot plant

- Pressure increase, pressure maintenance and pressure drop
- simulate different temperature and pressure profiles
- Expander
- 2 liter reaction vessel
- Investigation of different material flows and material flow mixtures

Process steps for the hydrolysis application

A) Bevor the digester

- digester retention time can be reduced from 20 to 12 days
- more biogas, better dewaterability

B) Inbetween two digesters (operated in serie)

- In first digester easily degrable organics are already removed (hydrolysis for lower carbon content ≈ less inert COD-production)

C) After the digester and after pre-dewatering

- After final dewatering > 40 % DS possible, good for direct incineration
- sludge water returned to the digester (biogas production)