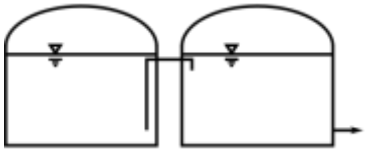
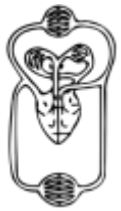
Overview of the Best Available Technology of the main components of an agricultural biogas plant

Michael Köttner

Components of an AD plant

Select the components

1. Pre-storage and feeding system
2. Primary digester (simple digester)
3. Secondary digester
4. Storage volume
5. Pump(s) and mixers
6. Instrumentation & process control unit


Feedstock

Feedstock

www.de.wikipedia.org

www.duden.de

www.de.wikipedia.org

www.fraunhofer-umsicht.de

Feedstock preparation

In general

- Removal of contraries/contaminants
- Reduction of particle size → chopping, grinding
- Dilution, if required

Energy crops

- Preservation → typically ensiling

Feedstock rich in sugar, fat or Feedstock rich in fibers

- Hydrolysis

Feedstock preparation – Ensiling

- Lactic-acid fermentation
  → „Sauerkraut“
- Lactobacilli convert sugar into lactic acid
  → pH-value drops to 4 – 4.5
  → Preservation

Stages:

- Feedstock has to be chopped
- Chopped material will be put into the silo
- Compression is important
  → as little air inside as possible
- Airtight covering of silo stock is mandatory
  → no aerobic bacteria!

Feedstock preparation – Ensiling

Best practice

http://www.vanbockrijck.de/uploads/webimages/projecten/2011/2011_land_(8).jpg

Correct ☺

„Green“ cover

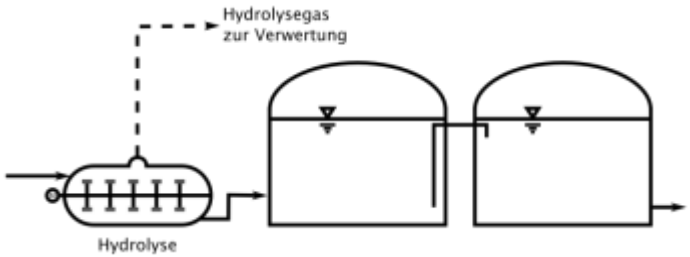
Often done on high silo stocks, but considerable losses, prone to molding

Increased amounts of „dirty“ rainwater

Feedstock preparation – Hydrolysis

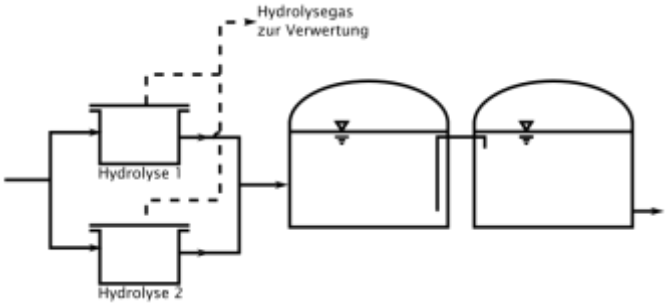
Continuous hydrolysis

- State of the art
- Plug flow with/without downstream digester



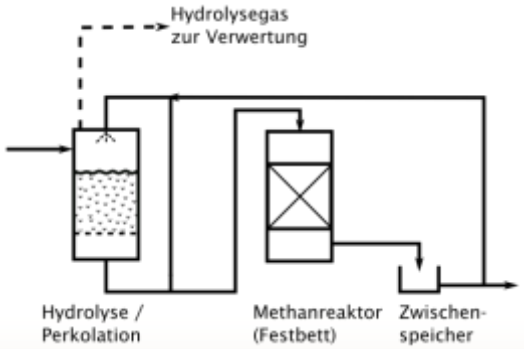
Discontinuous hydrolysis/batch

- State of the art



Fixed bed hydrolysis/percolation

- State of the research
  → for fibrous, stackable material
- Percolate digestion in fixed bed methane reactor



Feeding system

Feeding systems – Typical systems

Reception pit

Solid feeding systems

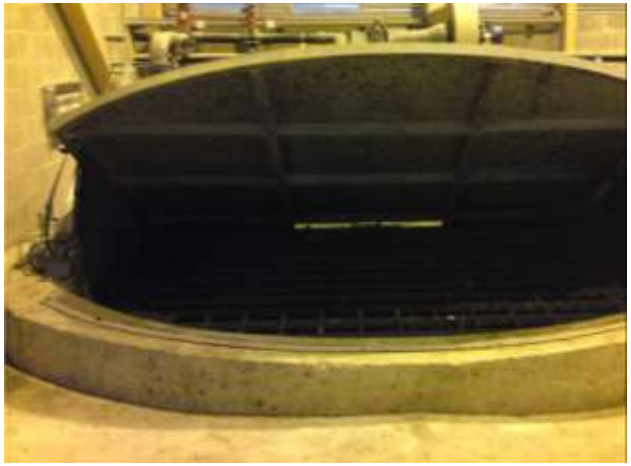
Hopper feed pump

Chute

Feeding systems – Reception pits

- Typically applied at waste digestion plants
- Sometimes for maceration and mixing prior to pre-storage tank
- Sometimes as bunker prior to contaminants removal

Feeding systems – Reception pits



Advantages:

- ✓ Established and reliable system
- ✓ Allow simple discharge of feedstock from trucks
- ✓ Unsusceptible against contraries

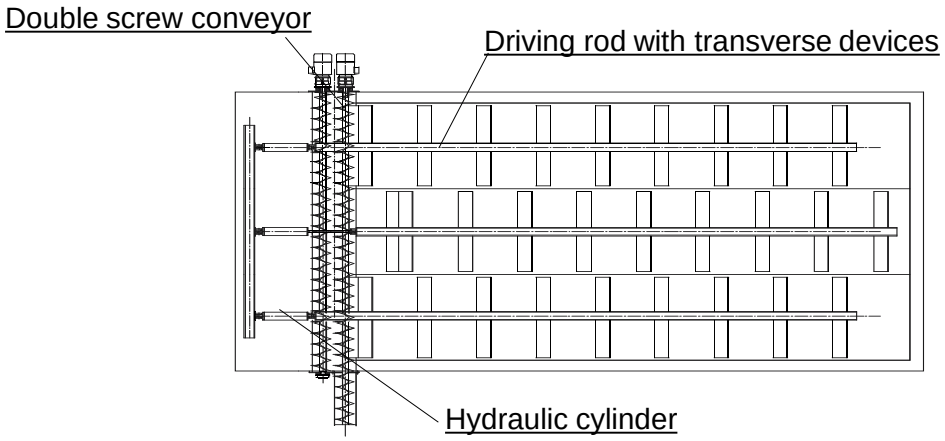
Disadvantages:

- × Dilution of solids < 10 % is necessary (depending on pump design)
- × Capacity of mixer limits throughput
- × Emission during operation
- × Formation of hazardous gases (e.g. H_2S)
  → regular pit emptying + gas detection required

Feeding systems – Solid feeding systems

- Developed to feed solid material directly into the digester
- Always a combination of buffer volume with removal system and conveyor system for the solids
- Rather used in agricultural AD plants
- Typical feedstock: dung, energy crops, vegetables

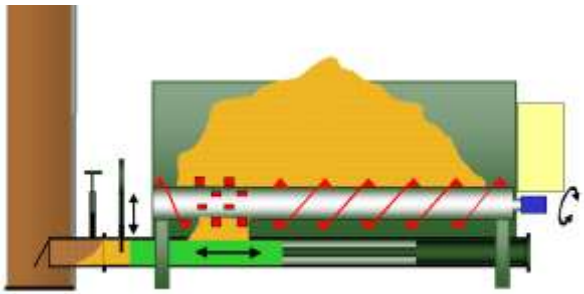
Feeding systems – Buffer tanks



- Should store the feedstock for 1 day
- Chains, augers or hydraulic cylinders are used to transport the feedstock to the conveyor system
- High wear and tear → material selection, doubling of walls

Feeding systems – Buffer tanks

Feeding systems – Conveyors



- Most often screws are used
- Sometimes conveyor belts in combination with screws
- Extremely high wear and tear
- If pistons or press screws are used feedstock will be highly compressed → danger of sedimentation
- Material selection is crucial → with energy crops and organic waste stainless steel (AISI 316)
- Limited to 12 m length / height

Feeding systems – Hopper feed pumps

- Used for mixing solids with liquid
  → alternative to traditional mixing pit
- Suitable for any type of wet digester
- Solids are not compressed
  → fine dosing & quick degradation
- Sensitive towards stones and contaminants
- Requires buffer for solids
- Challenge is the level control of solids

Feeding systems – Chute

- Rather exotic feeding system used in combination with lagoon digesters
- Very simple system
- No moving parts
  → little wear and tear compared with other systems
- Must not be empty → CH_4 emissions

Digester

Digester – Choose the right type

There is no standard recipe. All fits in the right context.

⇨ case specific selection!

Selection criteria:

- Dry matter content of feedstock mix
- Annual feedstock throughput
- Mixability & pumpability → nutrient distribution
- Costs of construction material

Digester types to be discussed

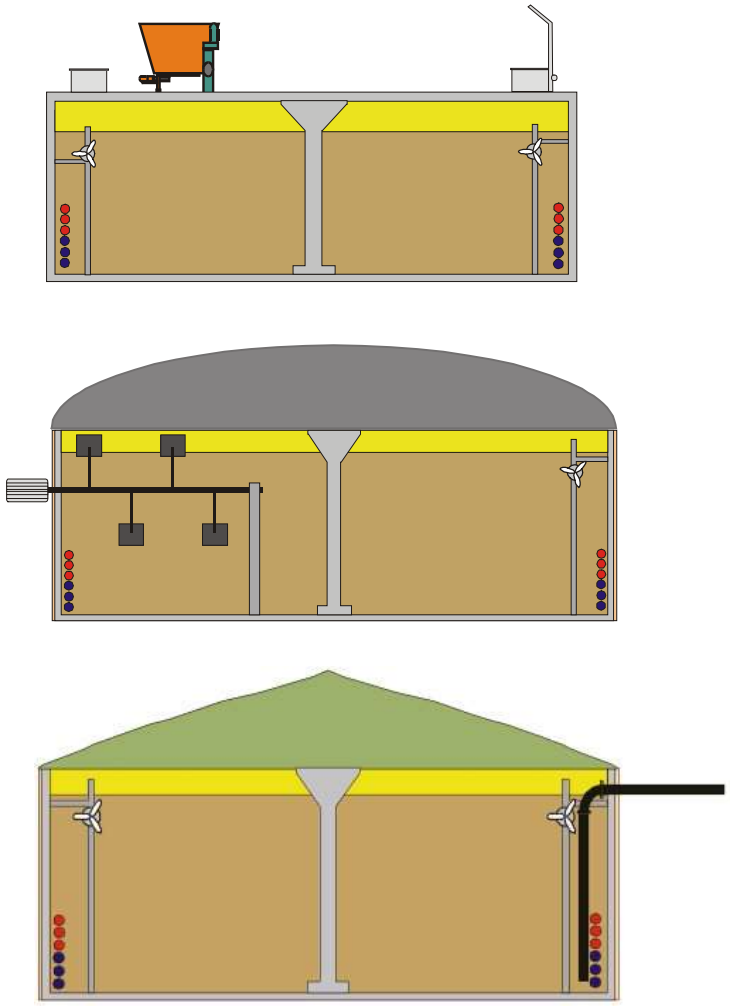
- For „wet“ feedstock:



- For „dry“ feedstock:

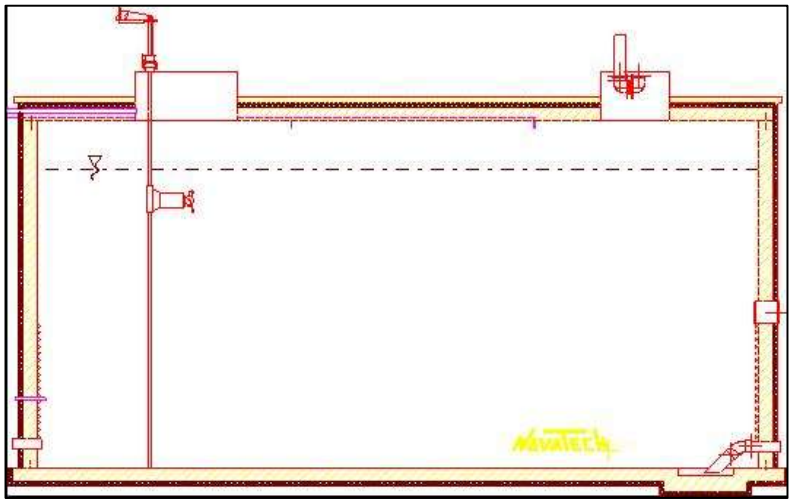

Bioferm

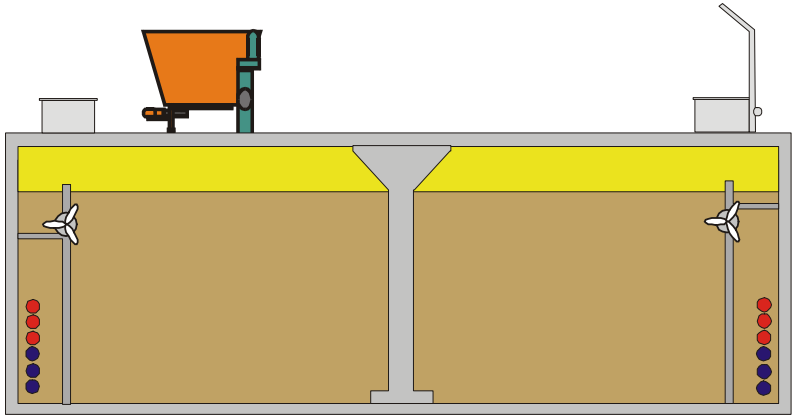
„Wet“ digestion – Flat digesters



- Typically applied in agricultural AD plants
- Typical sizes:
  - h = 6 – 8 m
  - d = up to 32 m
- Suitable for DM-contents up to 12 %
- Ideal for throughputs of up to 20 000 t/a
- Thorough mixing is a challenge
- Zoning possible
- Bypass possible

„Wet“ digestion – Flat digesters with concrete cover





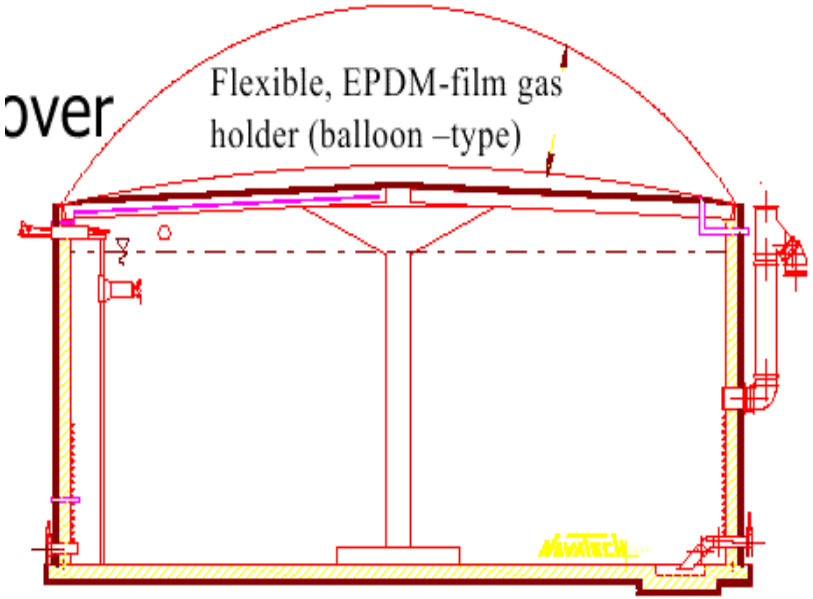
Advantages:

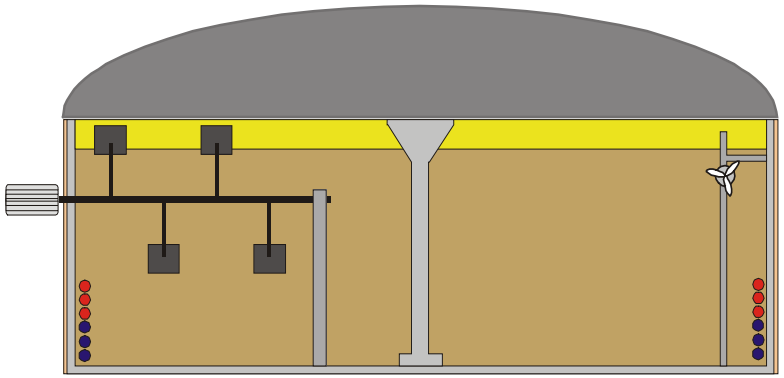
- ✓ Controllable (solid feeding...)
- ✓ Withstand certain pressures (20 mbar)
- ✓ Simple repairing of the stirring system
- ✓ Good insulation → low heat losses
- ✓ Wind protection

Disadvantages:

- × No integrated gas holder
- × Inner digester repair difficult
- × The concrete is not absolutely gas-tight
- × Difficult leak identification

„Wet“ digestion – Flat digesters with simple cover





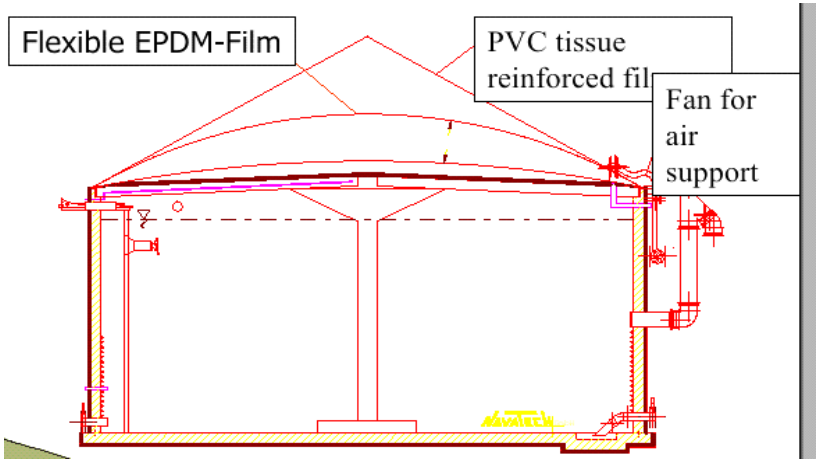
Advantages:

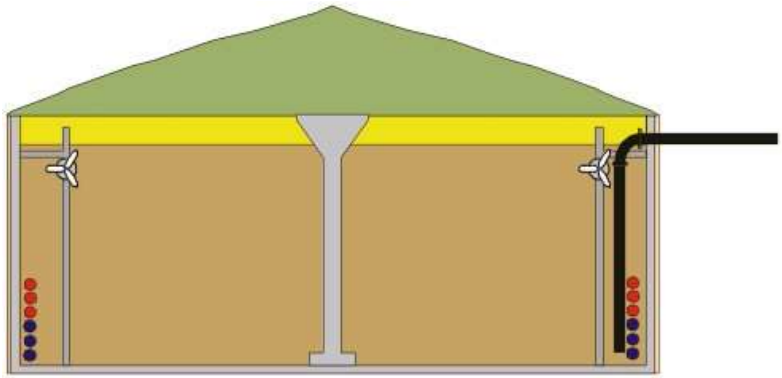
- ✓ Low-price alternative
- ✓ Simple digester revision
- ✓ Integrated gas holder

Disadvantages:

- × Wind and weather sensitive
- × Not 100% gas-tight
- × Difficult to determine gas level

„Wet“ dig. – Flat digesters with double membrane cover





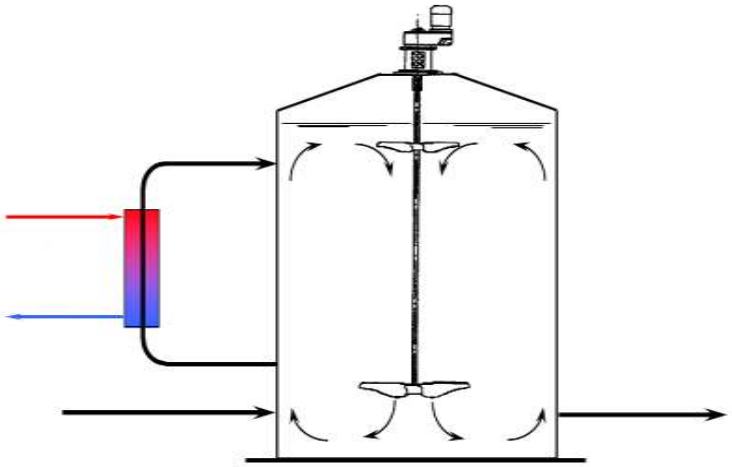
Advantages:

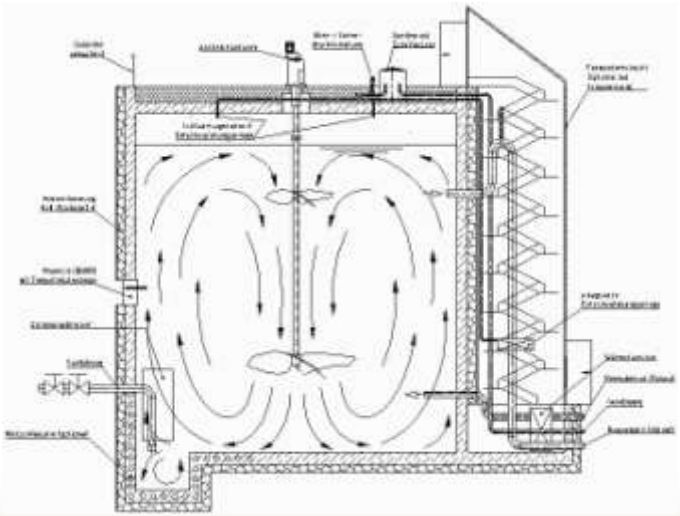
- ✓ Simple digester repair
- ✓ Integrated gas holder
- ✓ Weather proof
- ✓ Easy to determine gas level

Disadvantages:

- × More expensive than one cover
- × Not 100% gas-tight
- × Permanent energy consumption

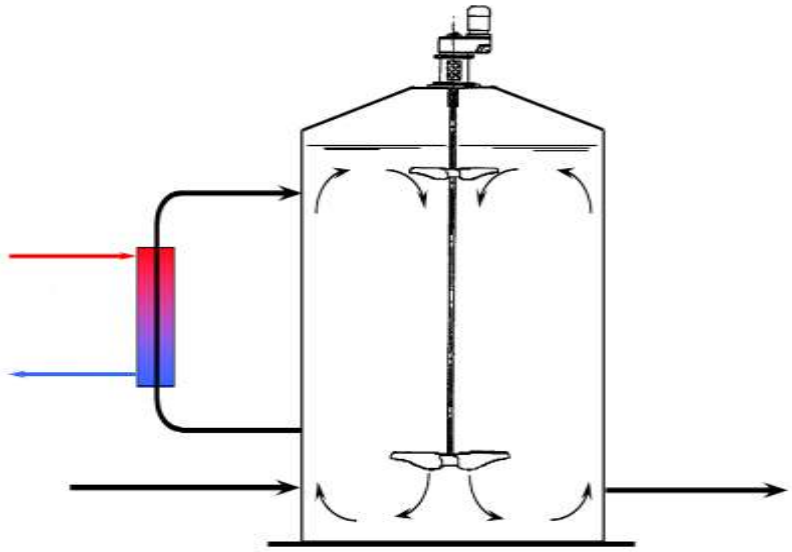
„Wet“ digestion – Upright digesters





- Typically applied in large (waste) digestion plants
- Typical sizes:
  - h = 20 m
  - d = 18-20 m
- Suitable for DM-contents up to 12 %
- Suitable for throughputs of more than 25 000 t/a
- Sophisticated technology, mainly central top mounted mixer
- Volumes up to 5 000 m³

„Wet“ digestion – High, upright digesters



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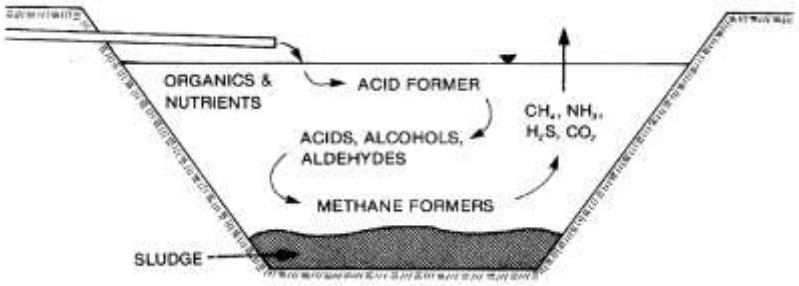
Advantages:

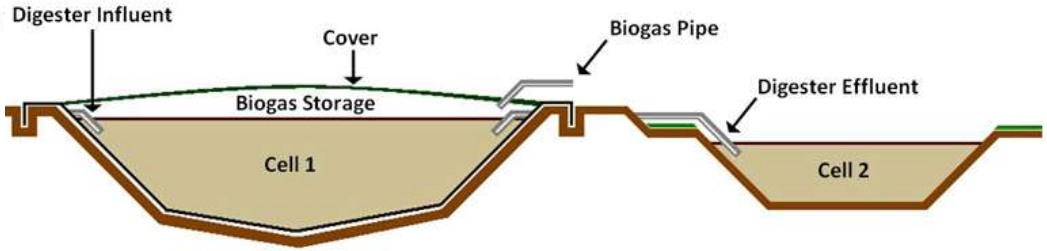
- ✓ Very good insulation → little heat losses, homogenous temperature
- ✓ Gas tight
- ✓ Good mixability at large volumes
- ✓ Weather proof
- ✓ Wear & tear parts outside digester
  → easy maintenance and repair
- ✓ Bypass possible

Disadvantages:

- × Difficult sediment removal
- × External gasholder required
- × Mixer removal requires large machinery

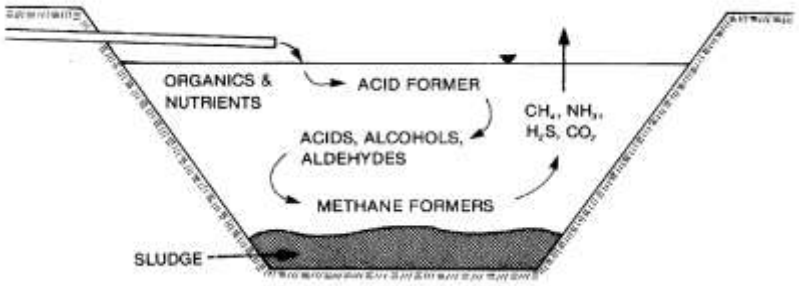
„Wet“ digestion – Lagoon technology

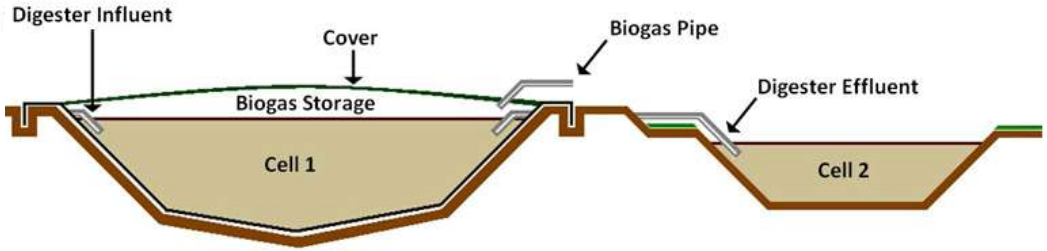




- Typically applied in warm climates, but also in Canada with insulated roof
- Simple technology
- Large volumes at very low costs
- Suitable for low DM-content, but high CSB-loads
- One-stage or two stage system

„Wet“ dig. – Lagoon techn. – Standard Lagoon technology





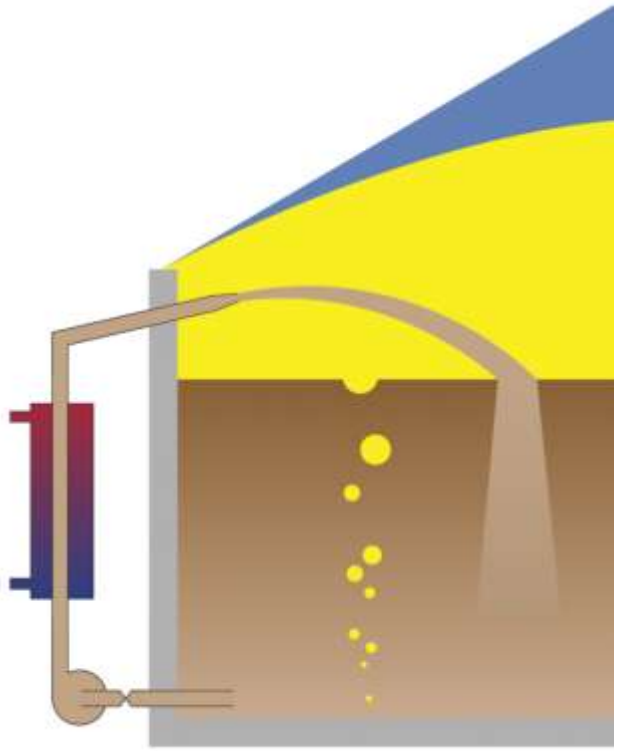
Advantages:

- ✓ Simple and cheap
- ✓ Simple process design

Disadvantages:

- × Difficult to maintain gastight cover
- × Not applicable in areas with high groundwater table
- × Difficult leakage detection
- × Mixing mainly with gas injection → sediments might clog this
- × No heating, insulation only against soil → Not suitable for cold climates

„Wet“ dig. – Lagoon techn. – Improved systems
Ecogas-process / Sauter-process



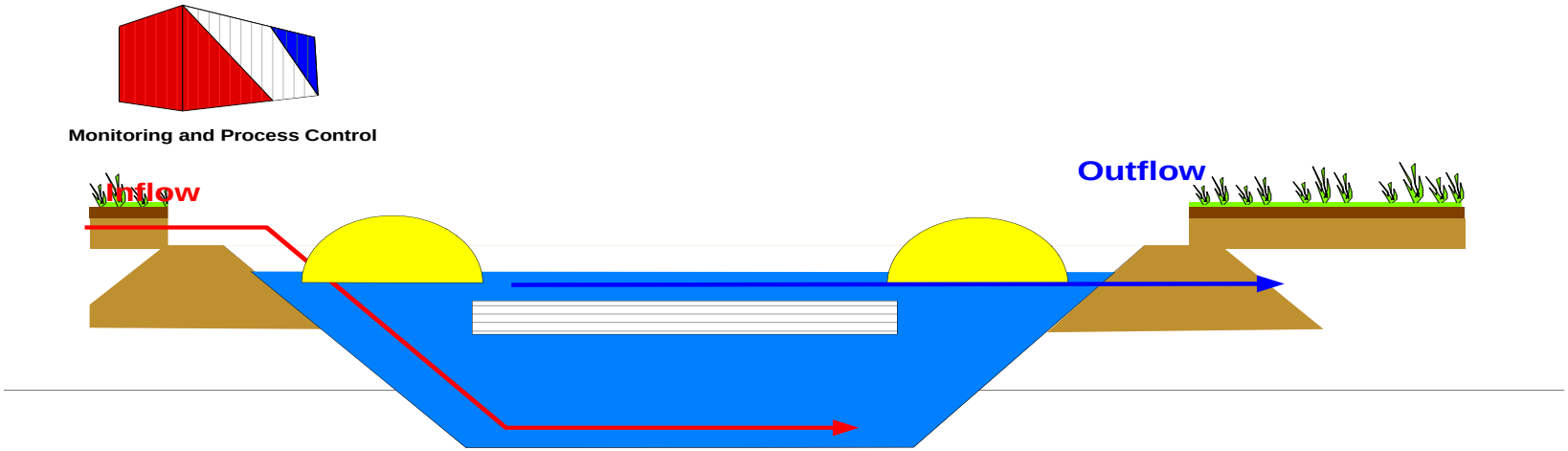
- Concrete lagoon with double membrane gasholder roof
- For stackable input with high fiber content
- No thorough mixing, but liquid circulation by spraying liquid on top of the biomass
- Simple feeding technology
- Low energy demand (2 – 4 %)

„Wet“ dig. – Lagoon techn. – Improved systems

Pneumatic mixing

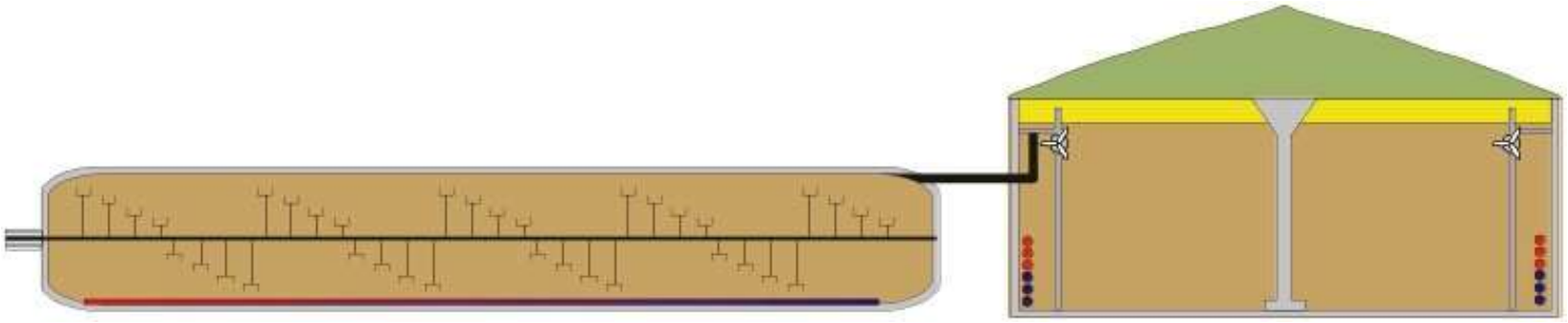
- Improved gas mixing with venturi nozzles → sludge does not settle
- For liquid slurry

„Wet“ dig. – Lagoon techn. – Improved systems
UCY-process



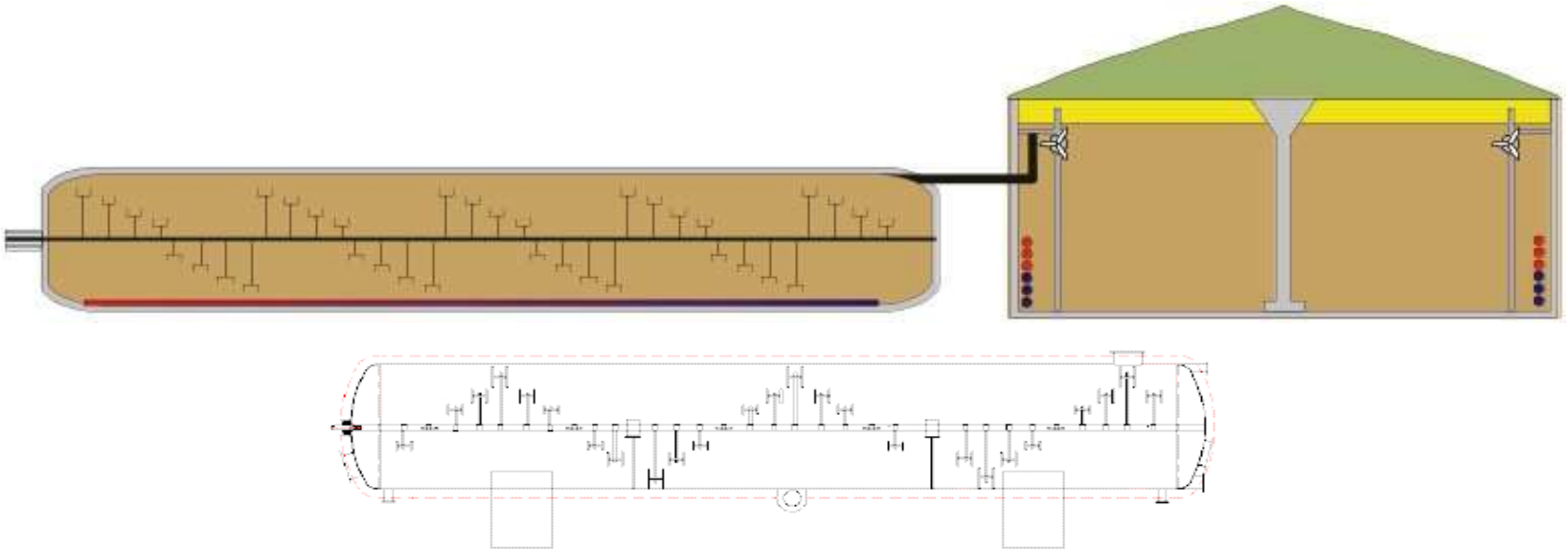
- For wastewater with high CSB-loads
- Combination with UASB-technology
- 3-phase separator
- Gas collection under membranes

„Dry“ digestion – Horizontal digester



- Typically applied for DM-contents = (20) 25–40% → Dry digestion
- Typically used in waste digestion plants for source separated organics
- Thermophilic process allows pasteurization when plug flow is maintained
- Limited options for bypass, if DM / viscosity is high

„Dry“ digestion – Horizontal digester



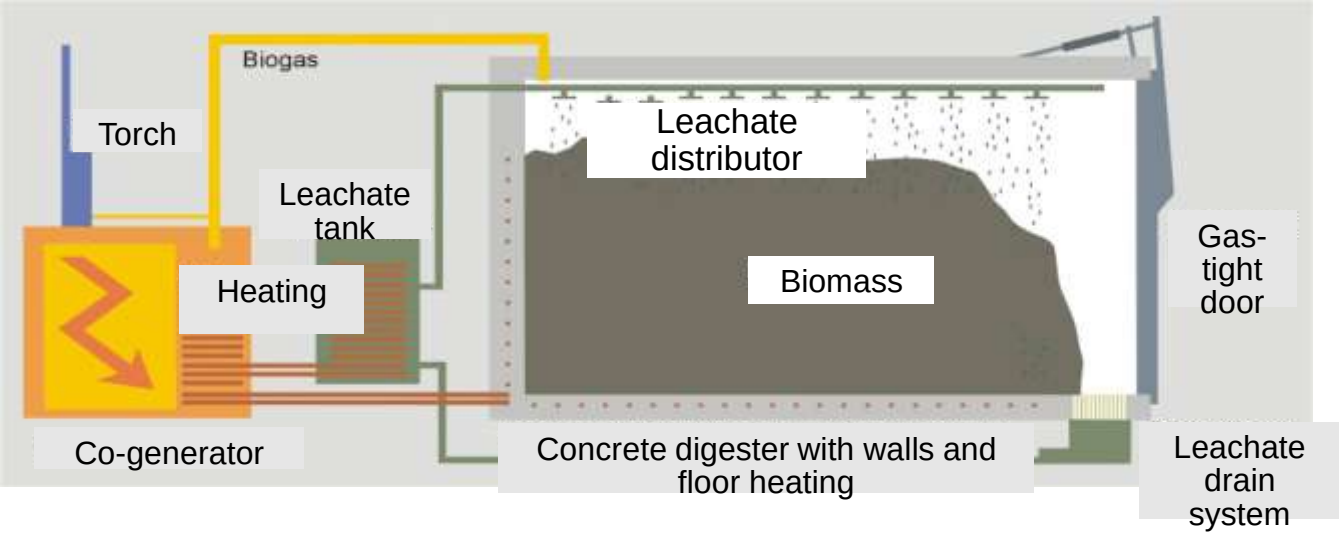
Advantages:

- ✓ Digesting high solids content
- ✓ High loading rate possible
- ✓ Little short cut flow
- ✓ Automatic sand drain
- ✓ Complete mixing
- ✓ High digester productivity

Disadvantages:

- × High price
- × Post-digestion is needed
- × Limited in size

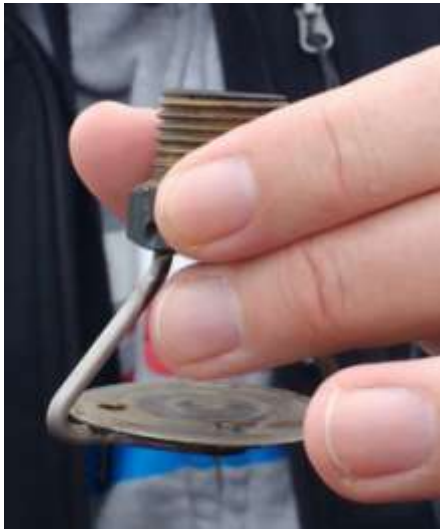
„Dry“ digestion – Batch process



Bekon

- Typically applied for DM-contents > 20 %
- Typically applied with dry agricultural feedstock & waste
- No moving parts inside the digester

„Dry“ digestion – Batch process



Advantages:

- ✓ Modular system → process failure affects only 1 module
- ✓ High loading rate
- ✓ Suitable for feedstock with high fiber contents

Disadvantages:

- × Regular emissions during batch change
- × Struvit (MAP) formation in percolate / leachate pipes
- × Lower digester productivity

Pumps and mixers

Pumps – Positive displacement pumps

Rotary lobe pump

Excentric screw pump

http://www.arada.at/img/produkte/exzenterschneckenpumpen.jpg

Advantages:

- ✓ Self priming
- ✓ Bigger particles and long fibred materials
- ✓ Pumping capacity about 800 m³/h
- ✓ Discharge pressures to 12 bar

Pumps – Positive displacement pumps

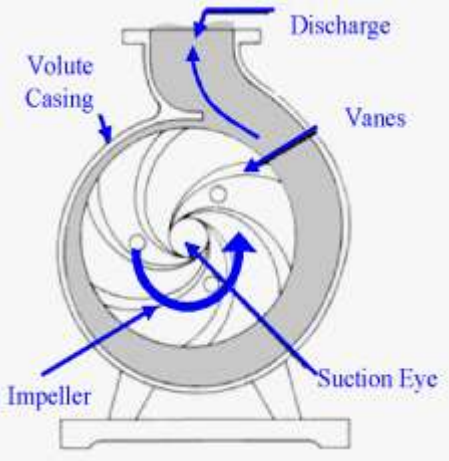
Disadvantages:

- × High abrasion wear
- × Prone to contraries

Stones

Wires & ropes

Pumps – Centrifugal pump



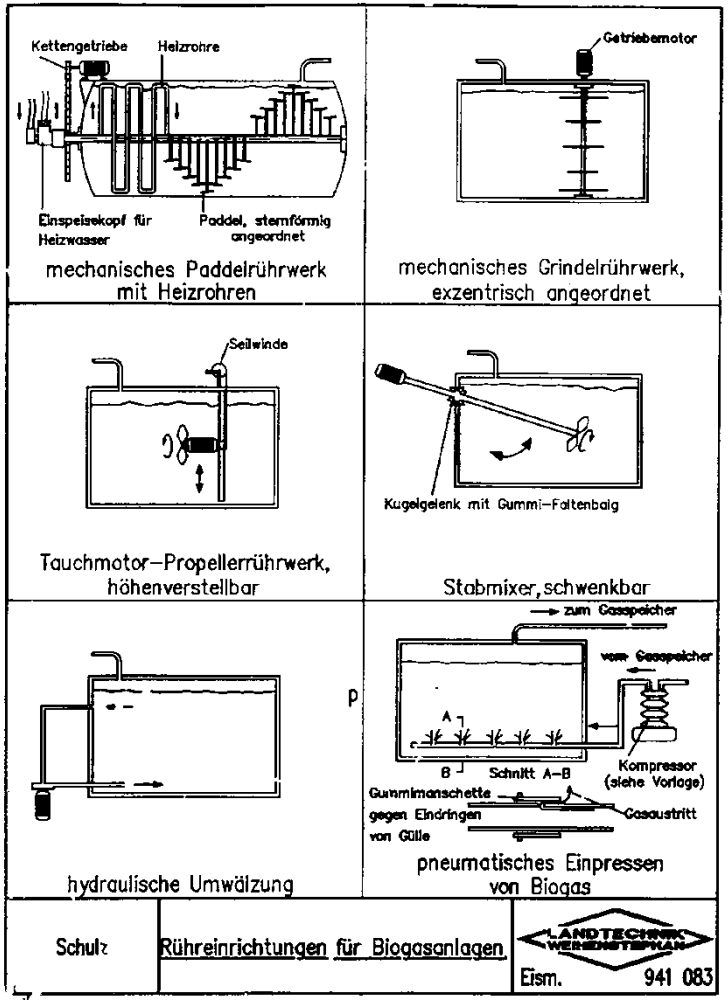
Advantages:

- ✓ Well known technology
- ✓ Simple and robust construction
- ✓ High flow rate

Disadvantages:

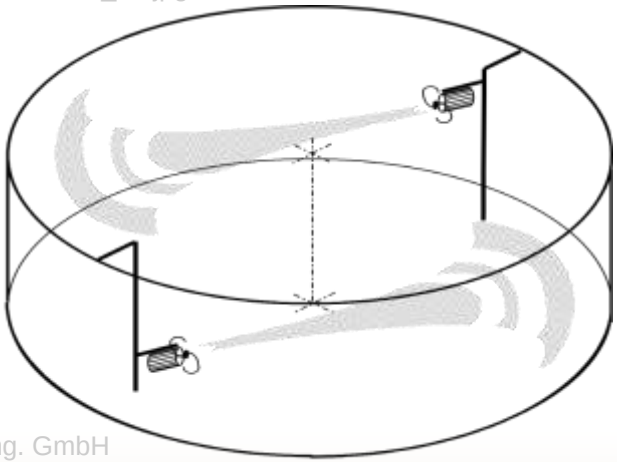
- × Corrosion & abrasion
- × Blocking

Digester mixing



Digester mixing – Flat digesters
Submerged motor mixers

http://www.osmo-anlagenbau.com/uplozads/pics/bio_schlieven_09.jpg



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- Fairly cheap mixers
- Flexible in height & angle
- Fast runners
  → usually used intermittently
- Thorough tank mixing is difficult to achieve (fibers, solids)
- Maintenance & repair requires digester opening → emissions!
- High worker safety demands during repair / removal from tank
- Submersible mixers = disposables

Digester mixing – Flat digesters
Submerged motor mixers problems

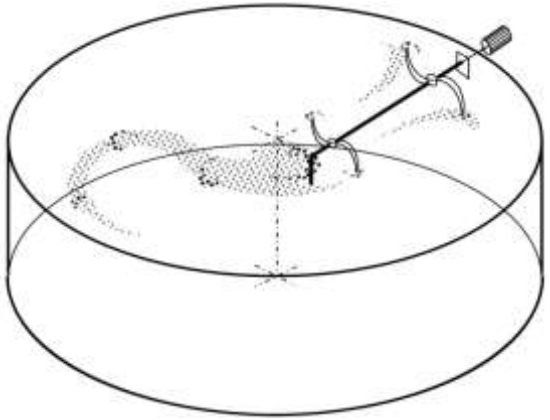
Insufficient mixing

Corrosion, abrasion

Worker's safety & emissions

Digester mixing – Flat digesters
Side mounted mixers (type biobull)

http://www.seenergie.net/index.php?id=43



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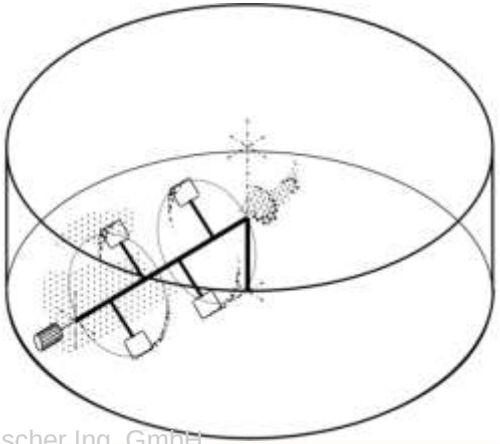
- Motor outside digester
  → better maintenance, reduced need to open digester
- Fixed height & angle
- Usually used intermittently before/ during feeding
- For better mixing often combined with submerged mixer

Digester mixing – Flat digesters
Paddle mixer

http://www.treffler.net/wp-content/uploads/2013/05/P4060126.jpg



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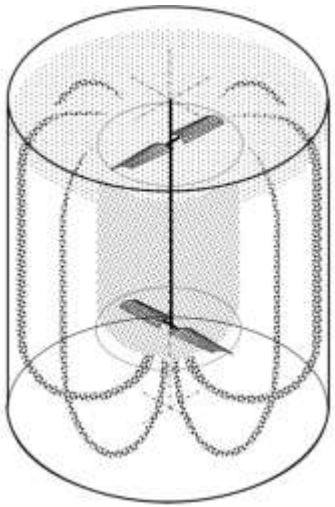
- Good for breaking through swimming layers
- Motor outside digester → better maintenance, reduced need to open digester
- Fixed height & angle
- Usually used intermittendly before/ during feeding
- Works rather locally → Should be combined with submerged mixer for better flow

Digester mixing – Flat digesters
Top mounted mixer



- Continuous slow runners (24 h/d)
- Speed: 13–18 rpm
- Power: 11–30 kW_{el}
- Frequency converter for low energy consumption
- Motor outside digester → better maintenance
- Thorough mixing → no stratification, but sedimentation possible
- Issue: shaft or bolts (sometimes) break

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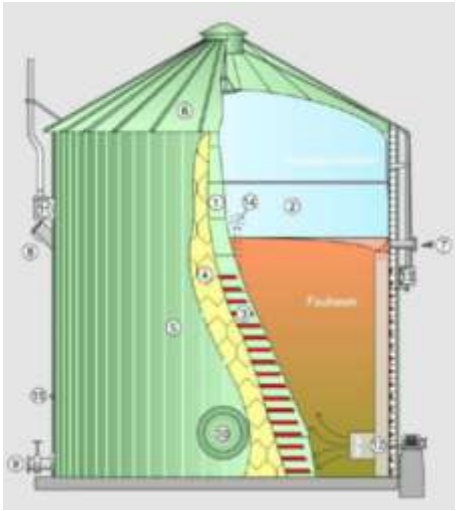
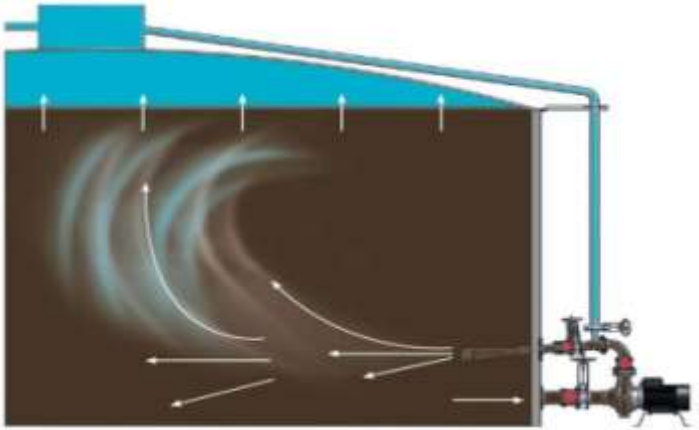
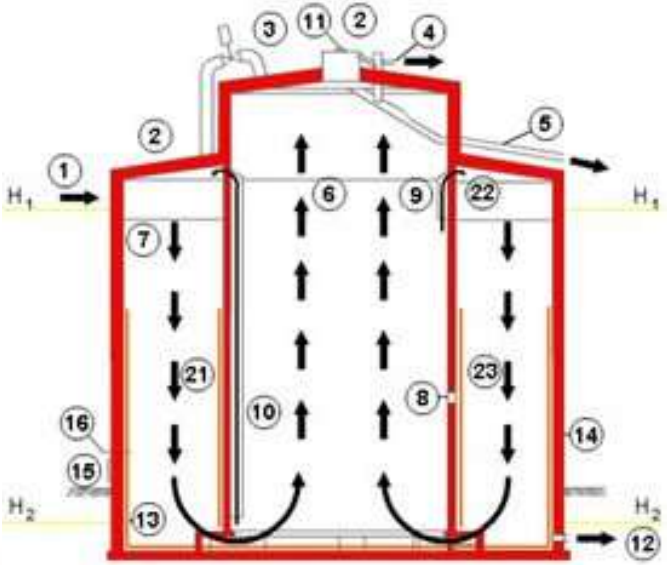
Digester mixing – Other mixers





http://www.sanbrobiofuels.com/images/sanbro_tank.jpg



Digester mixing – Risks

All mixed digesters carry the following risks:

- The mixer is underpowered / not strong enough
- Wrong positioning of mixer
- Mixer selection did not consider feedstock
- Engineer did not take into account that during digestion
  - Sand might be released
  - Stratification might occur
  - Specific weight / density might change

Things to consider when selecting equipment

Feedstock properties & quality

- Structure
- Viscosity
- Abrasiveness
- Temperature
- Pressure
- pH-value
- Stratification risk

AD changes properties of the medium

Quality of construction and technical equipment

- Acid proof
- Non-abrasive

Dimensioning and design of equipment

- Reserve capacity
- Sufficient internal diameter
- Surface
- Volume
- Sedimentation zones

Easy and safe maintenance and repair

Thank you for your attention!

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