Two days training on the operation and management of WWTPs

9-10 September, Murcia

Digestion and use of biogas

Presented by: Marcos Martin

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ANAEROBIC DIGESTION

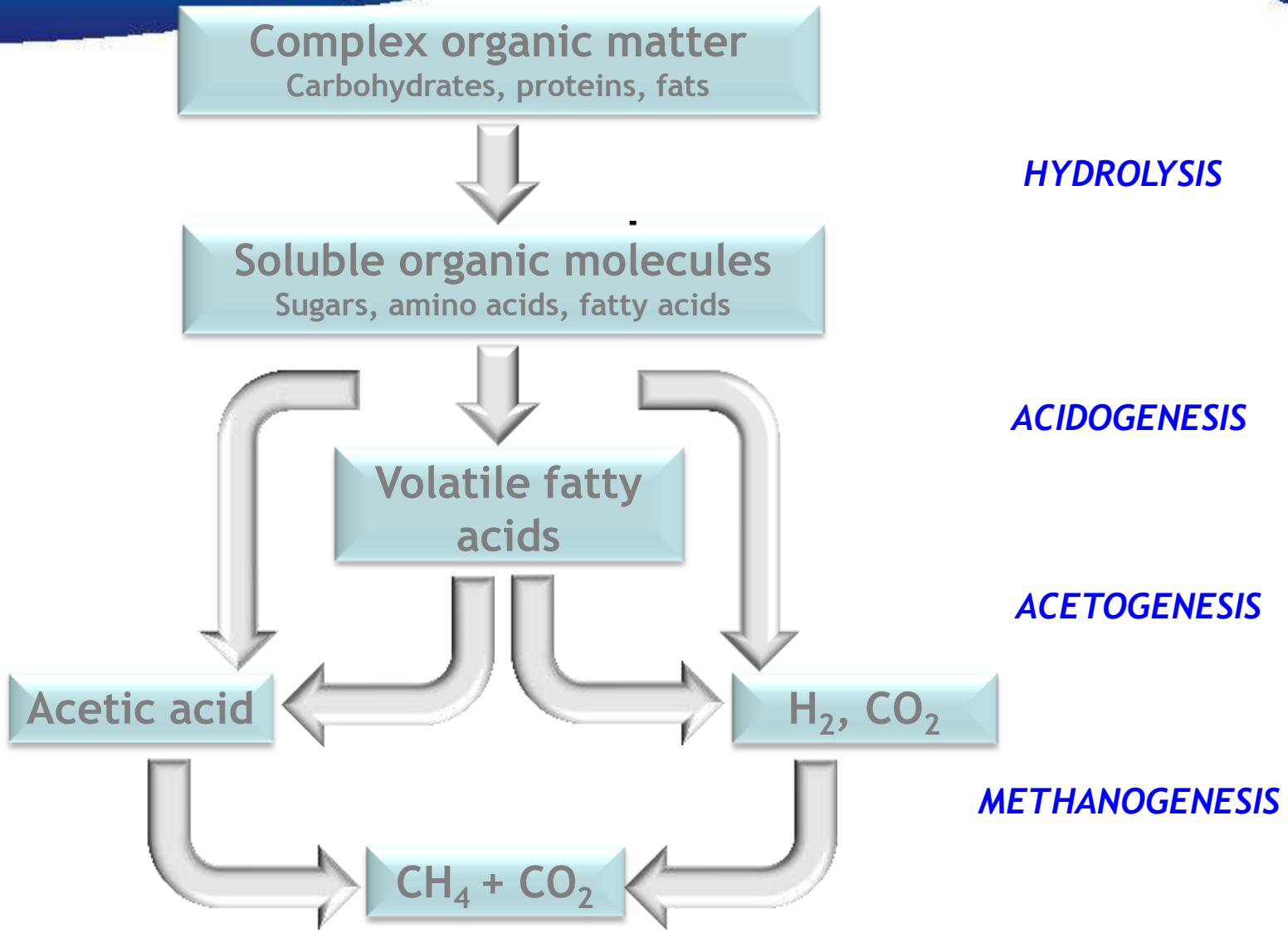
BIOGAS

ANAEROBIC DIGESTION

Biochemical process during which complex organic matter is decomposed in absence of oxygen, by various types of anaerobic microorganisms.

DIGESTATE

ANAEROBIC DIGESTION



HYDROLYSIS

Macro molecules like proteins, poly saccharides and fats that compose the cellular mass of the excess sludge are converted into molecules with a smaller atomic mass that are soluble in water: peptides, saccharides and fatty acids.

Hydrolysis is a relatively slow process and generally it limits the rate of the overall AD process.

ACIDOGENESIS

Process that results in the conversion of the hydrolysed products into simple molecules with a low molecular weight, like volatile fatty acids, alcohols, aldehydes and gases (CO_2, H_2 and NH_3).

ACETOGENESIS

The products of the acidification are converted into acetic acids, H_2, and CO_2 by acetogenic bacteria.

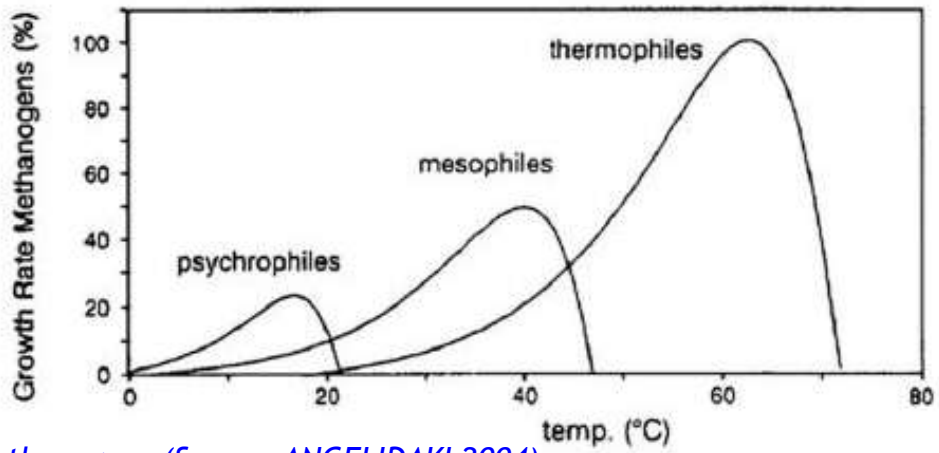
METHANOGENESIS

The products of the previous stages (mainly acetic acid) are converted into CO_2 and CH_4.

In order to maintain an anaerobic sludge with a high metabolic activity, it is necessary to apply favorable environmental conditions: T^a, pH, the absence of toxic materials and the availability of nutrients.

For AD process, the temperature stability is very important and the retention time will depend on it.

THERMAL STAGE	PROCESS T[a]	Minimum retention time
psychrophilic	<20° C	70 to 80 days
mesophilic	30 to 42° C	30 to 40 days
thermophilic	43 to 55° C	15 to 20 days



Relative growth rates of methanogens (Source:ANGELIDAKI 2004)

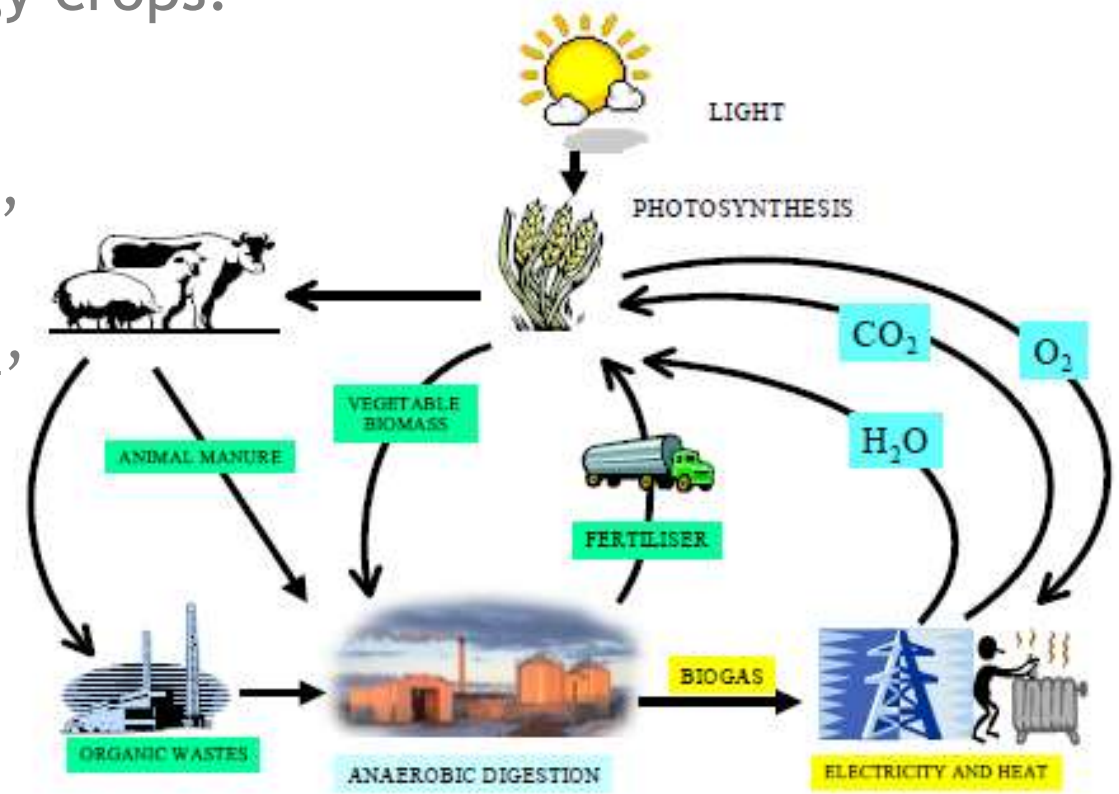
AD ADVANTAGES

- Production of a useful energy source in the form of biogas, which can be used for power generation or for aeration of the mixed liquor.
- Reduction of the mass of excess sludge and production of a stabilized sludge with excellent rheological properties for water removal.
- Substantial improvement in the hygienic quality of the digested sludge because of the efficient removal of pathogens.

Biogas is produced during AD of organic substrates, such as manure, sewage sludge, the organic fractions of household and industry waste, and energy crops.

The biogas is mainly composed by CH_4 and CO_2, but also can contain H_2O, sulphur compounds, N_2,O_2, ammonia, siloxanes and particles.

Its final composition will depend on the composition of the substrate digested.



The sustainable cycle of biogas from AD(Source: AL SEADI 2001)

BIOGAS

		Biogas	Landfill gas	Natural gas (Danish)*
Compounds	Methane (vol-%)	60–70	35–65	89
	Other hydro carbons (vol-%)	0	0	9.4
	Hydrogen (vol-%)	0	0-3	0
	Carbon dioxide (vol-%)	30–40	15–50	0.67
	Nitrogen (vol-%)	~0.2	5–40	0.28
	Oxygen (vol-%)	0	0-5	0
	Hydrogen sulphide (ppm)	0–4000	0–100	2.9
	Ammonia (ppm)	~100	~5	0
	Lower heating value (kWh/Nm^3)	6.5	4.4	11.0

Source: Biogas upgrading technologies – developments and innovations. IEA Bioenergy.

MAIN POLLUTANTS

Sulphur compounds (H_2S)

Activated carbon column

Desulphurisation to prevent corrosion and avoid toxic H2S concentrations. When biogas is burned SO2/SO3 is emitted which is even more poisonous than H2S. The sulphurous acid formed (H2SO3) is highly corrosive.

H_2S can be removed by precipitation, adsorption on activated carbon, chemical absorption or biological treatment.

Water(H_2O)

When leaving the digester, biogas is saturated with water vapour, which may condensate in gas pipelines and cause corrosion.

H_2O can be removed by cooling, compression, absorption or adsorption.

Heat exchanger

Siloxanes

Siloxanes are compounds used in products such as deodorants and shampoos. When siloxanes are burned, silicon oxide is formed which can create a problem in gas engines.

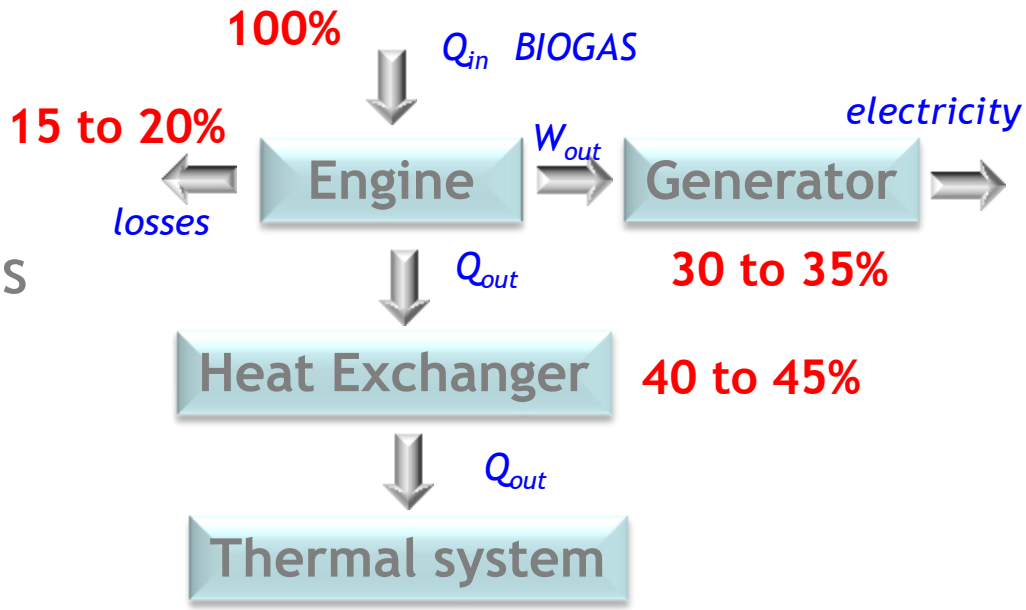
Siloxanes can be removed by cooling the gas, by adsorption on activated carbon (spent after use), activated aluminium or silica gel, or by absorption in liquid mixtures of hydrocarbons.

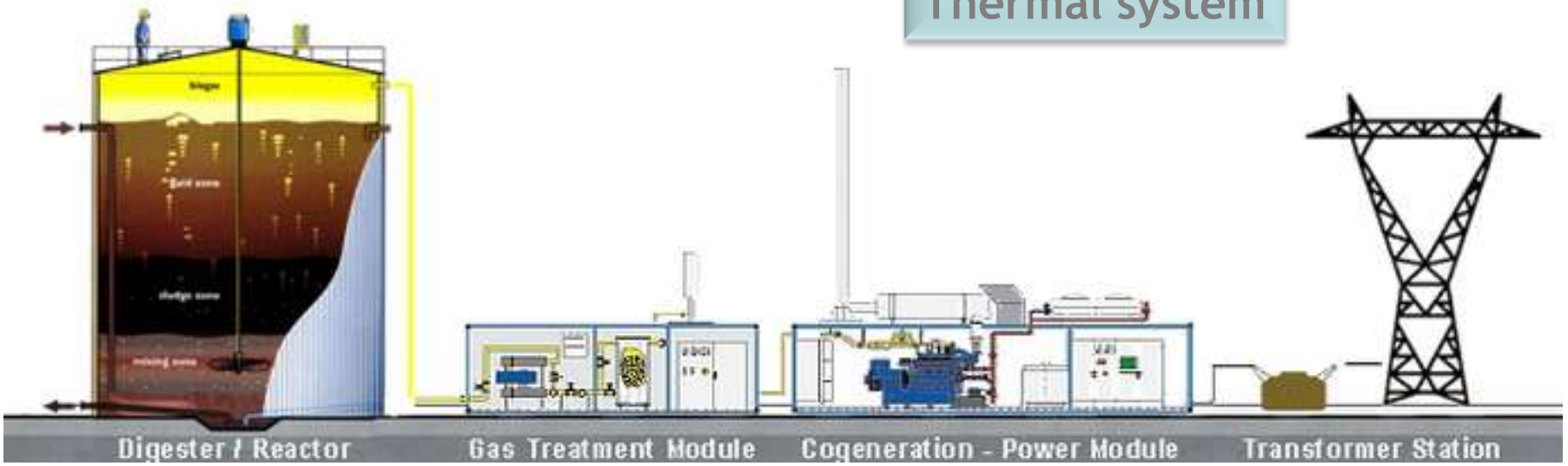
BIOGAS USES

- Torch
- Thermal energy: boilers
- Cogeneration
- Trigeneration
- Upgrading
  - Automotive fuel
  - Injection to grid
- Reforming
  - Syngas
  - Fuel cells

CHP engines

The utilization of biogas in internal combustion engines is a long established and extremely reliable technology.

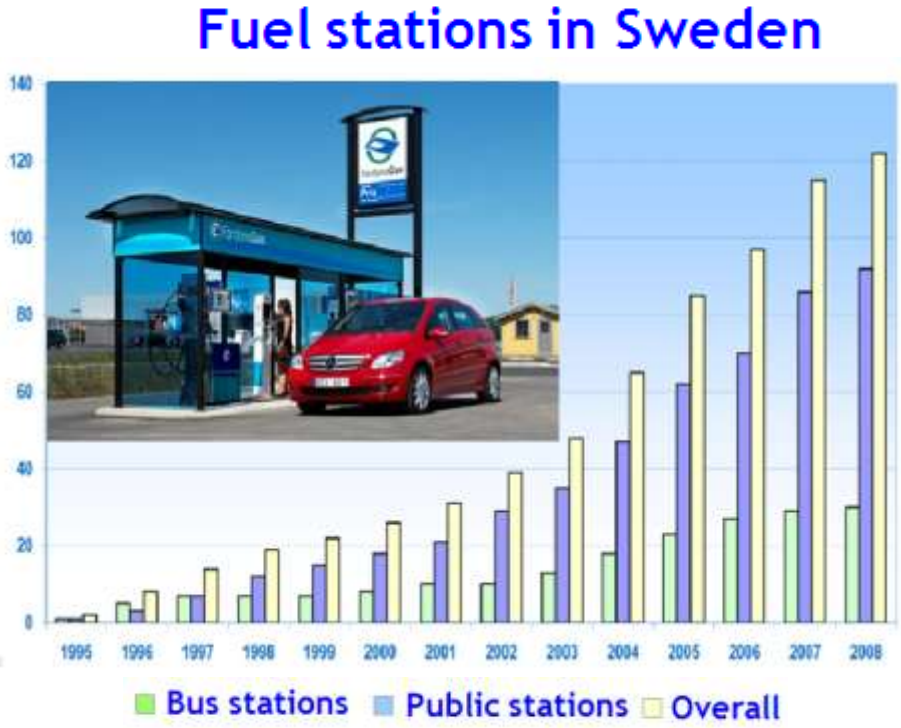




Upgrading: automotive fuel

The utilization of biogas as vehicle fuel uses the same engine and vehicle configuration as natural gas.
The gas quality demands are strict, so the raw biogas has to be upgraded to:

- has a higher calorific value to reach longer distances,
- has a regular/constant gas quality to obtain safe driving,
- avoid corrosion due to high levels of H_2S, ammonia and H_2O,and ice-clogging due to water content
- eliminate mechanically damaging particles,
- has a declared and assured quality.



Upgrading: injection to grid

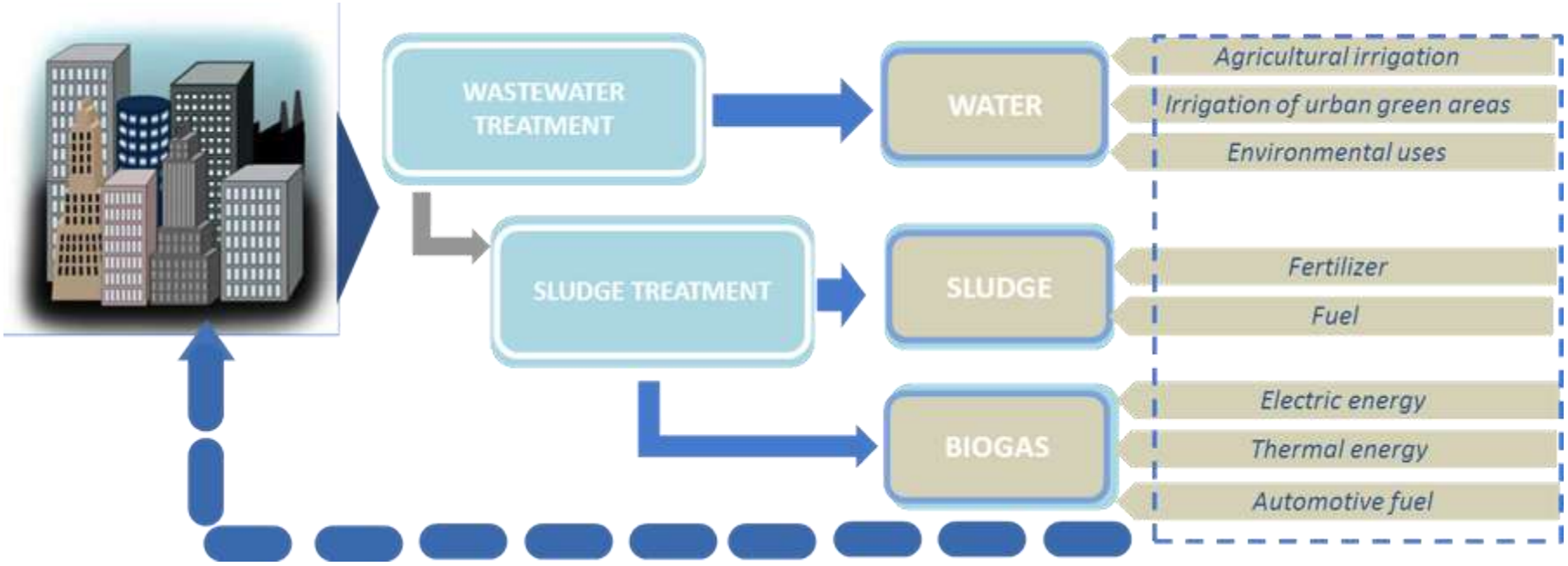
Biogas can be injected and distributed through the natural gas grid since biogas consists mainly of CH_4. This way the local security of supply is improved.

Countries like Sweden, Switzerland, Germany and France have a standard for biogas injection which have been set to avoid contamination of the gas grid or end use:

- Demands on Wobbe index, to avoid influence on gas measurements and end use.
- Limits on certain components (sulphur, oxygen, particles and water dew point).

Planned and implemented biogas injection projects in Europe (Source: www.biogaspartner.de, 2013)

The new approach on WWTP management seeks to be resource recovery systems rather than just facilities to prevent release of pollutants to the environment



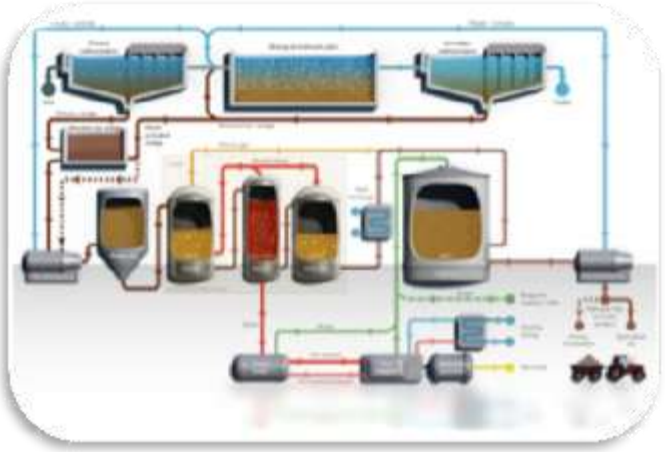
METHODS FOR INCREASED BIOGAS PRODUCTION

Mechanical treatment

Sludge is treated mechanically by different disintegrating equipment such as mills and high pressure homogenisers.
The effects are: less foaming problems, increased degradation and biogas production (10 %).

Thermal treatment

Sludge can be pre-treated thermally through: (1) Pasteurisation, T^a>100° C or (2) Thermal hydrolysis, T^a>200° C (CAMBI method).



Results are: fewer problems with foaming, decreased sludge production, increased biogas production, improved sludge dewatering and, through treatment at high T^a, sludge is also hygienised.

Chemical hydrolysis

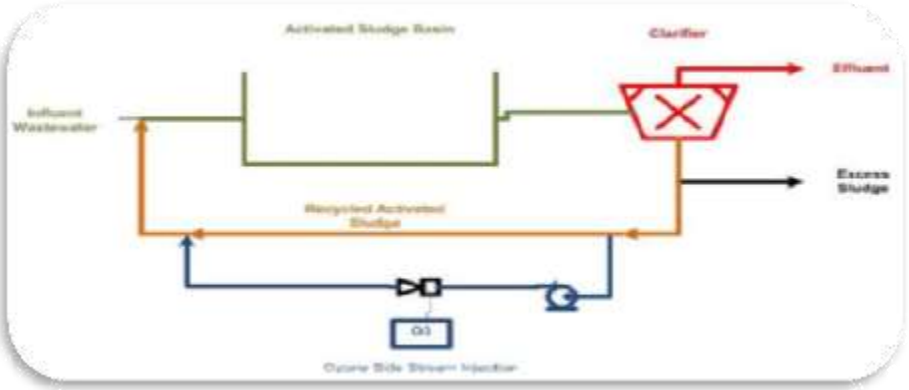
Chemical hydrolysis aims at destroying the cell walls of the bacteria and thereby releasing the cell content.
The chemicals used may be strong acid, a base, or an oxidation agent. Common chemical compounds are :NaOH, Mg(OH)2, KOH, Ca(OH)2),O3, H2O2 and a variety of acids

Thermo-chemical hydrolysis

Thermo-chemical hydrolysis is a combination of the above chemical method with heating, which leads to a faster and more complete degradation of the bacteria cells.

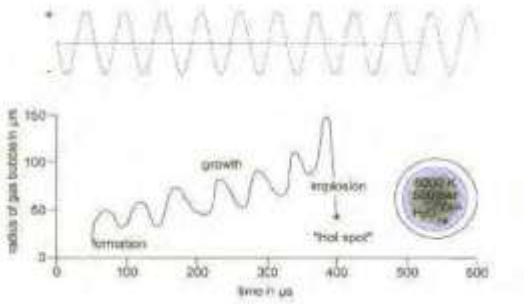
Ozone treatment

Ozone treatment of sludge results in that the part of dissolved COD in the sludge increases and thereby becomes available for digestion.



Ultrasound treatment

When ultrasound is applied into a liquid are formed small gas bubbles in the liquid(cavitation). In the cavitation, T^a and P increase to approximately 5 000 K and 500 bars.



The effects of this treatment are: foaming decrease, degradation of the organic material is improved, lesser amounts of digested sludge, more biogas and improved dewaterability of the digested sludge.

Treatment with electrical impulses

Treatment with electrical impulses, electroporation, comprises the formation of pores in the cell membranes through short, electrical voltage impulses.

The effect are a reduction of organic material, so an increased biogas production.

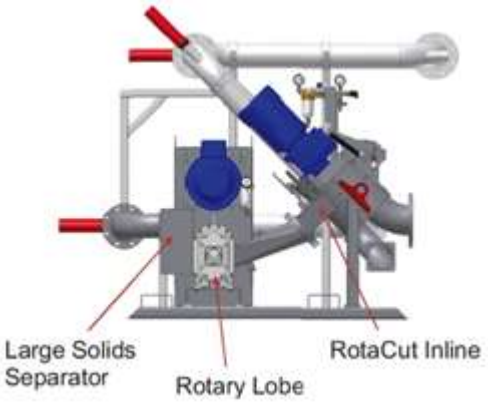
Addition of enzymes

There are natural enzymes of different types in the sludge, but an addition of extra enzyme in the process has potential to increase the rate of degradation.
For fats, an enzyme such as lipase is needed; for proteins, the enzyme protease; and for cellulose, cellulase.

Hydrolysis by electrokinetic disintegration

Electrokinetic forces are created by a high voltage AC probe. The substrate is then pumped along the probes after mechanically breaking up solid lumps of biological material for higher efficiency.

The forces will deform and finally perforate the cell membranes, and bacteria are electrostatically stimulated at the same time, hence producing more gas.



Codigestion

Co-digestion is the simultaneous digestion of a homogenous mixture of two or more substrates.

The use of co-substrates usually improves the biogas yields from AD due to positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates.

Usual substrates are: By-products from the food industry, Landfill leachates, Agricultural residues from the secondary sector, Animal manure, urban organic waste,…

Codigestion: Advantages

- Allows to obtain or to increase the production of a renewable energy (biogas).
- Take advantage of the complementarity composition of the waste to make processes more efficient.
- Allows sharing treatment facilities, reducing capital and operating costs, improving the use of oversized facilities.

Codigestion: Disadvantages

- Need for pretreatment of the new substrate.
- Disturbance of AD due to peak loads or presence of toxic ontributions.
- Problems in water line caused for the return to the input of different types of pollutants.

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مع خالص شكري وامتناني

Thank you for your attention

Merci pour votre attention

For additional information please contact:
Sustainable Water Integrated Management - Support Mechanism: info@swim-sm.eu
Website: www.swim-sm.eu