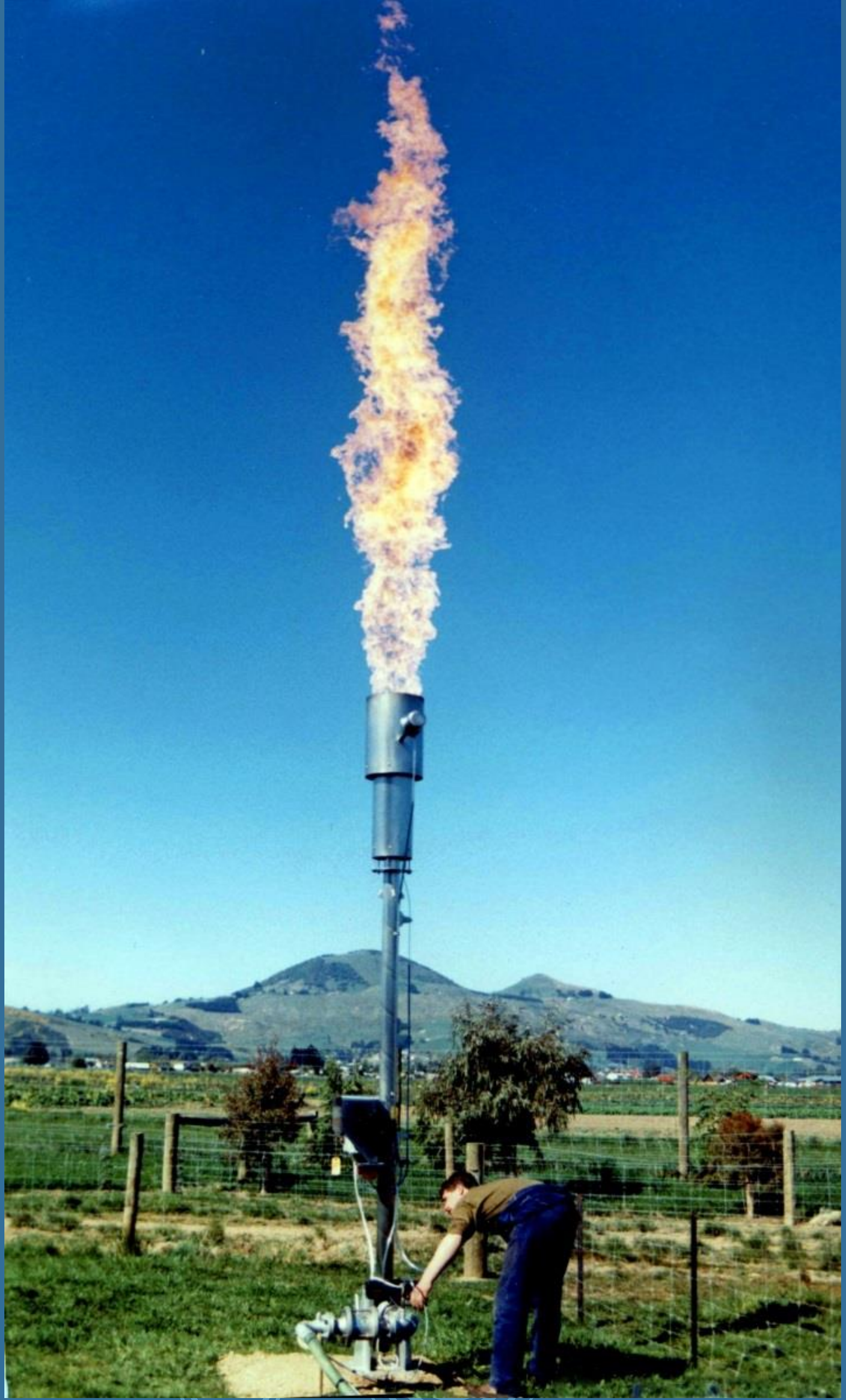
AD101: Anaerobic Digestion selection Considerations

Nathan Clarke

Beca Ltd

300000 ton CO2 reduced per year

Net Positive Wastewater Treatment



AD overview

Examples of different types of digesters

What types of wastes can they treat?

When to use a specific type of digester?

Limitations associated with different digesters

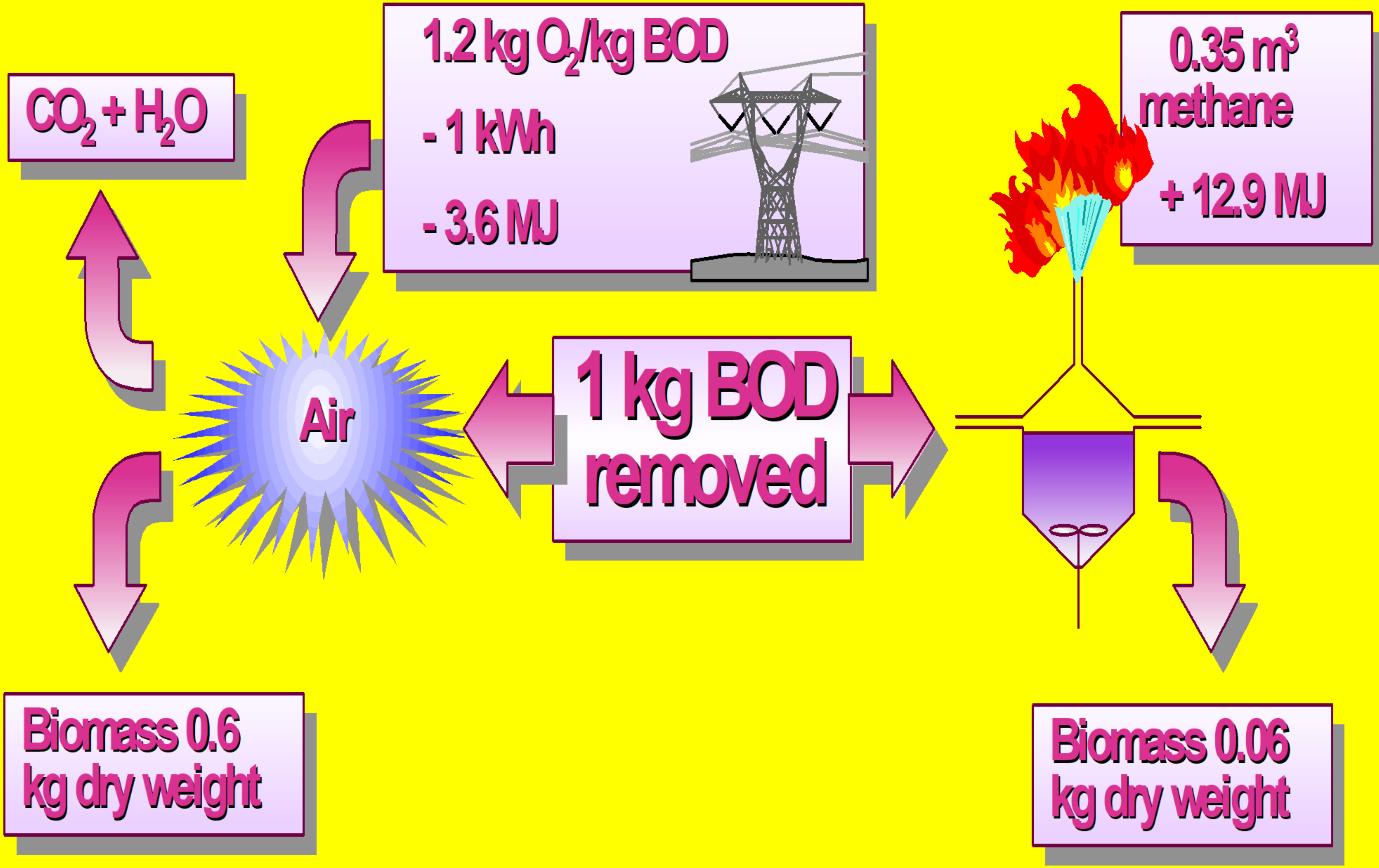
How well do they work?

What limitations?

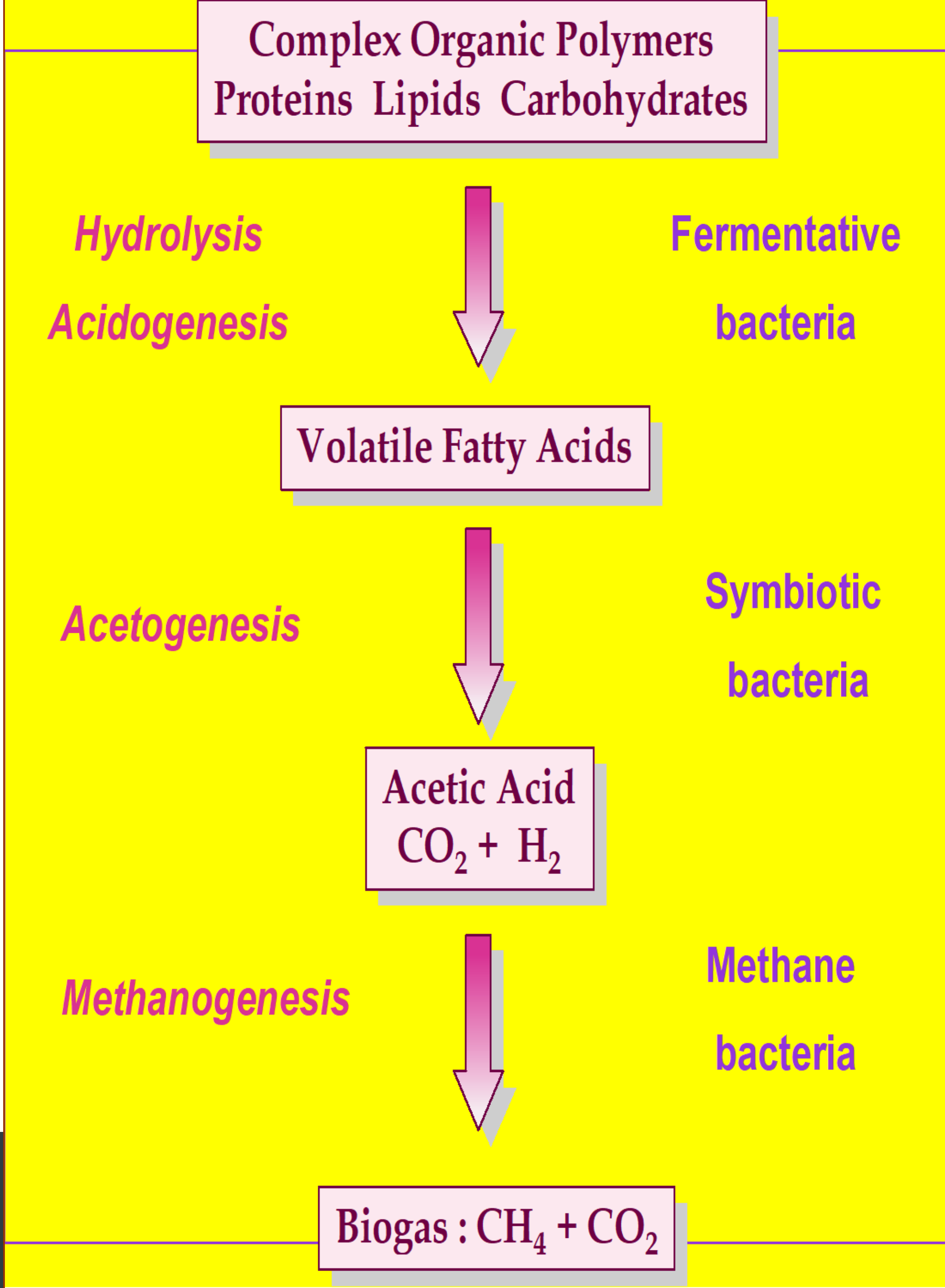
Beca

AEROBIC TREATMENT

ANAEROBIC TREATMENT



Biochemical steps




A
B
C

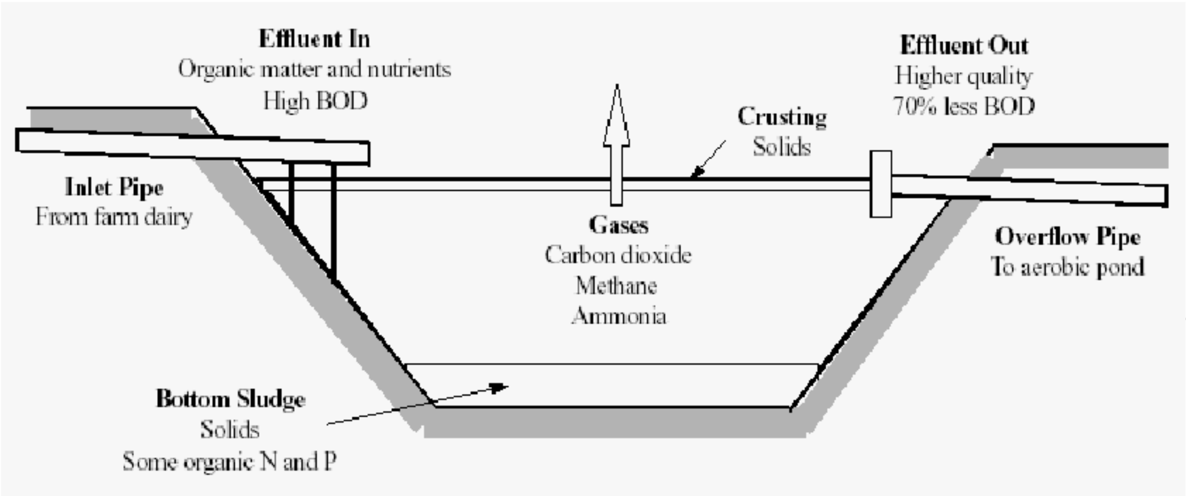
When the only tool you have is a hammer, every problem is a nail.

Abraham Maslow


JOHN DEERE
7230 R

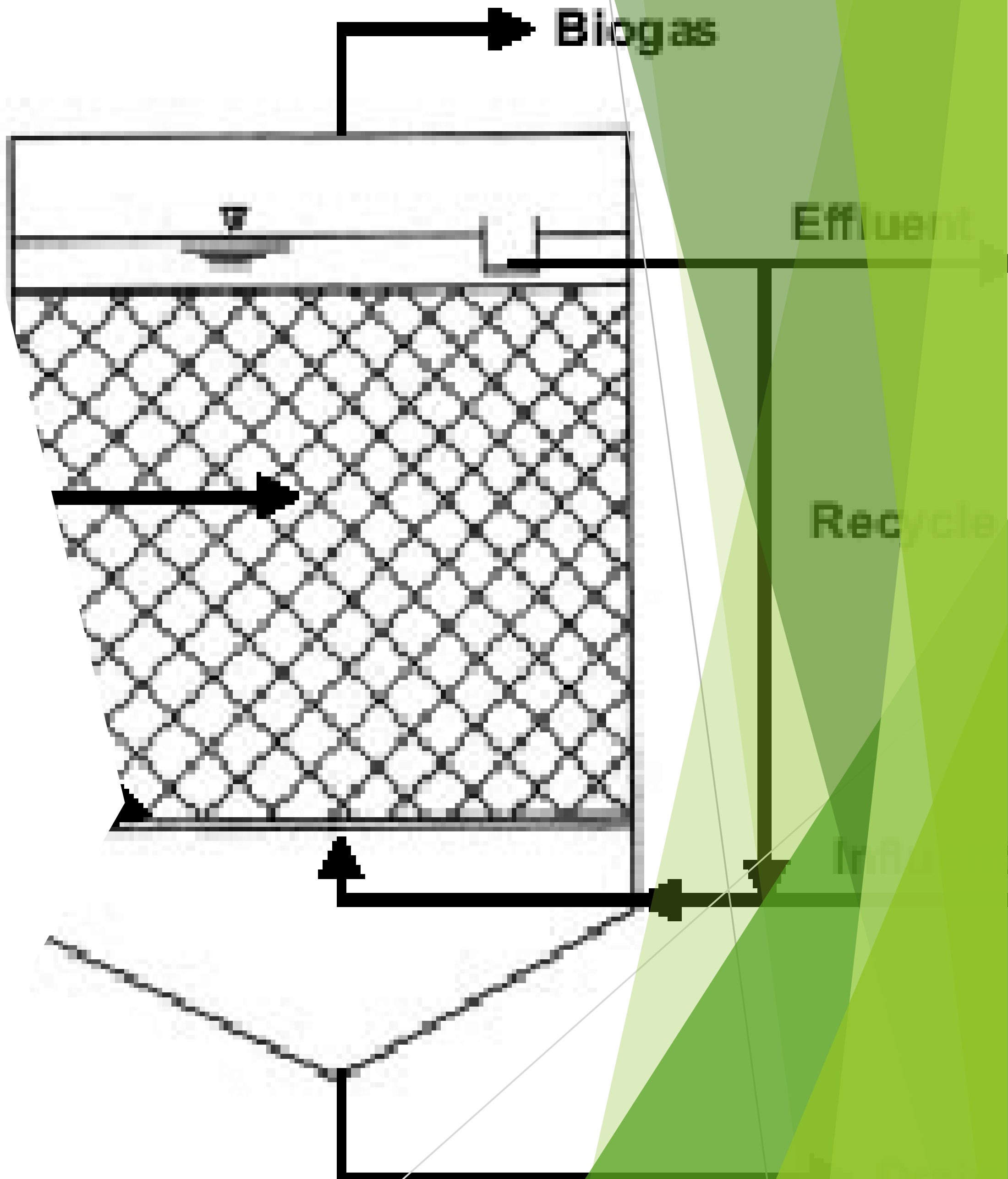
Unmixed anaerobic lagoons, & Uncovered anaerobic ponds!!

- The reasons I like AD are largely negated with these…
- Fill up with sludge fast
- Poorly controlled / operable
- Poor gas recovery – often significant carbon emissions
- Inconsistent performance
- Often significant odour issues

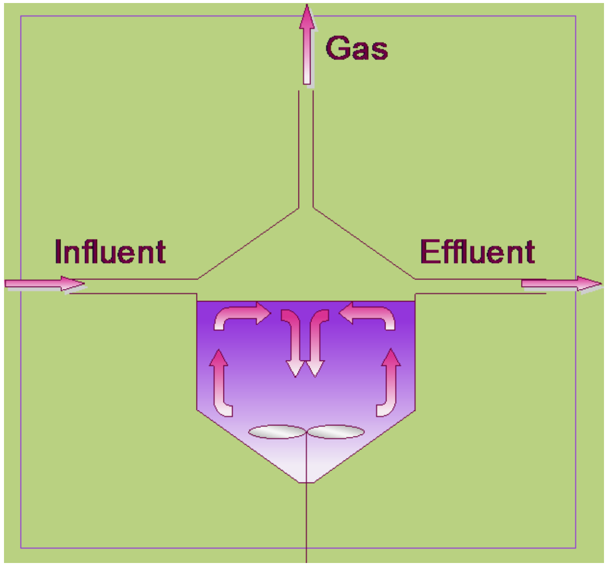


Fixed Film and Moving Bed Anaerobic reactors

- There are a range of these systems internationally, however they have a number of issues.
- Not that any of them
- Sludge blockage, channelling, calcium build up issue.
- Expect performance reduction over time. 5 -10 yrs



CSTR reactor configuration



- HRT = SRT if good mixing
- Required high level of mixing power
- Process capacity reliant on volume
- Long HRT/SRT required for process stability
- Flexible to accommodate broad range of wastes
- No solids separation =High effluent TSS and COD

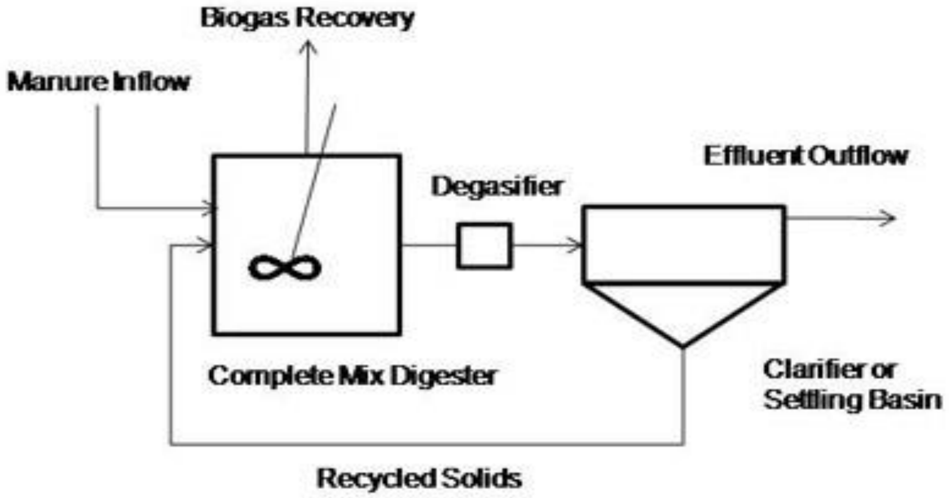
Municipal Sludge digesters

CSTRs

- Food wastes
- Rendering wastes
- Paunch Contents


Designed for -42 degree C

Anaerobic Contact Systems



Most Versatile – lot of waste types, and waste characteristics, can accept difficult wastes.

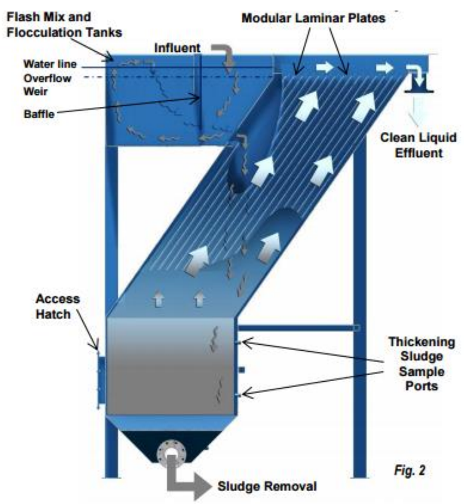
High mixing energy required, lower volume required.

Robust – With correct design can accommodate many different waste types

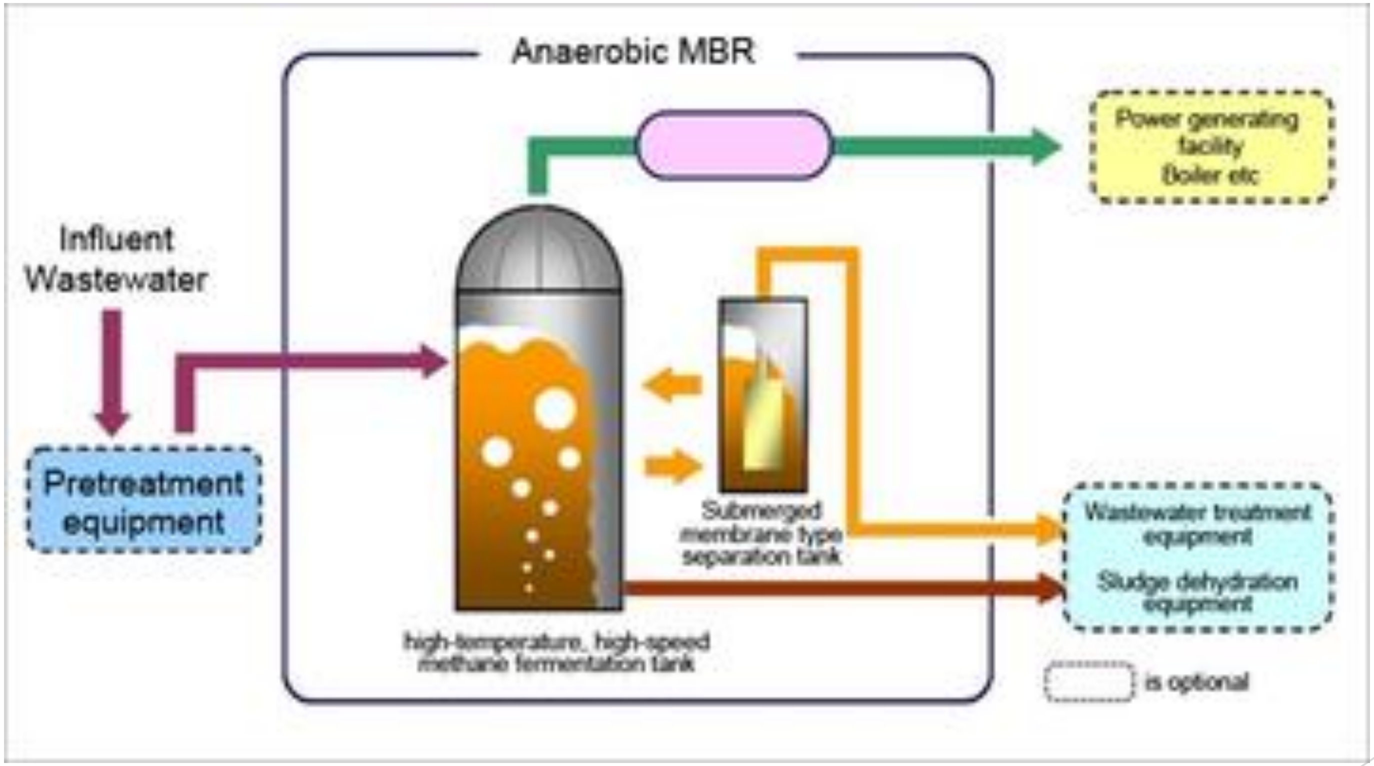
Improved effluent quality – includes separation systems

Relatively expensive to build and operate.

Anaerobic Contact separation technologies



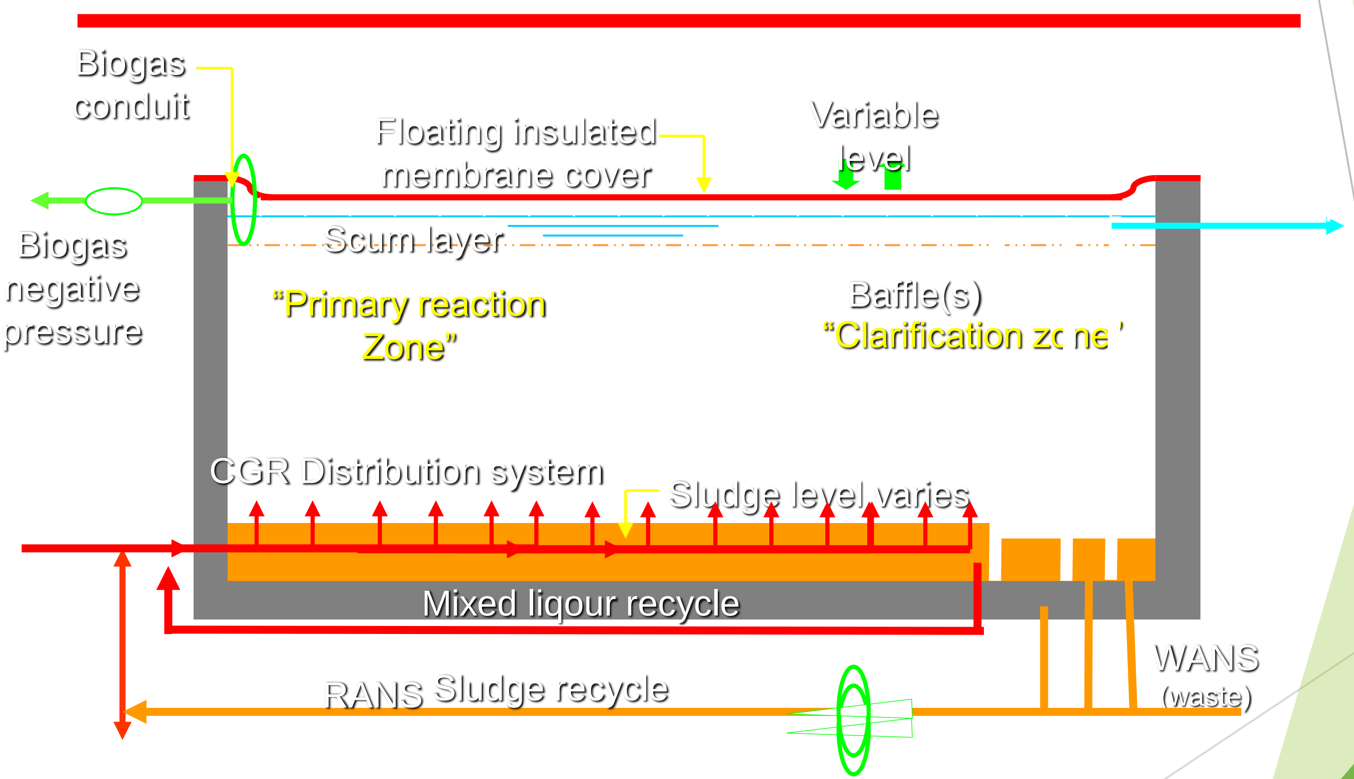
Anaerobic Contact



Reactors with Upflow principle

- Introduce the feed at the bottom
- Make the feed flow up through the sludge blanket
- Use the gas production to provide part of the mixing energy.
- Reduced parasitic energy consumption.
- Allows much larger reactors at lower cost
- Lowers sort circuiting risk,
- Can have different conditions at different point in the reactor
- Can periodically feed zones in the reactor.

CIGAR process schematic

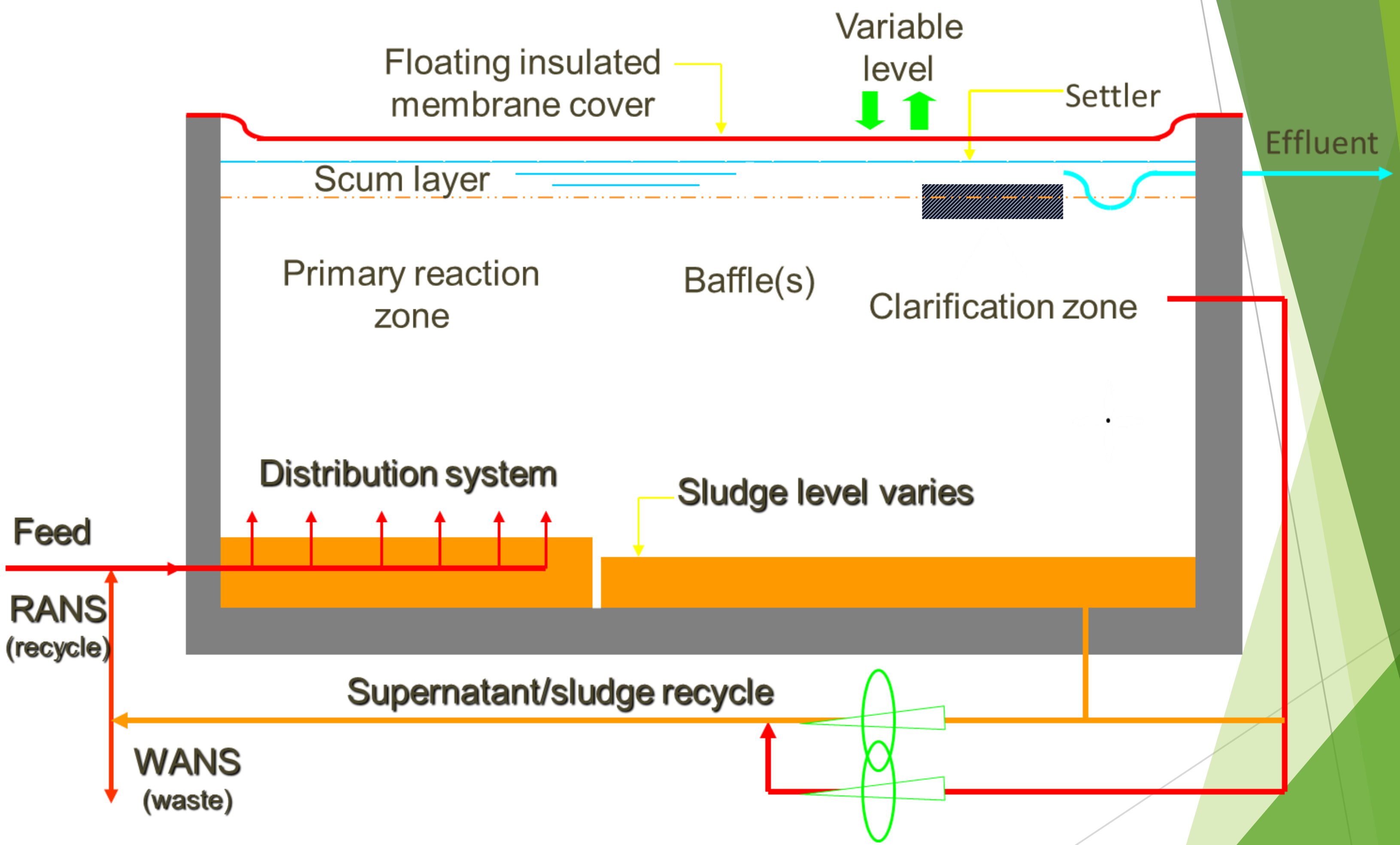



Organics

In ground engineered reactors

- Very robust – large sludge inventory, increased resilience over time, great buffering.
- Versatile – large range of wastes can be treated
- Low rate – but very large capacity systems possible for low cost, due to low cost “tank” construction
- Economically often significantly better than other types of system
- Medium Effluent quality

- Be careful for High Calcium wastes, struvite producing wastes, and wastes with heavy or long stringy particles



Floating insulated membrane cover
Variable level
Settler
Effluent
Scum layer
Primary reaction zone
Baffle(s)
Clarification zone
Distribution system
Sludge level varies
Feed
RANS (recycle)
Supernatant/sludge recycle
WANS (waste)

Dairy drinks wastewater treatment

Dairy BVF Digester - Victoria

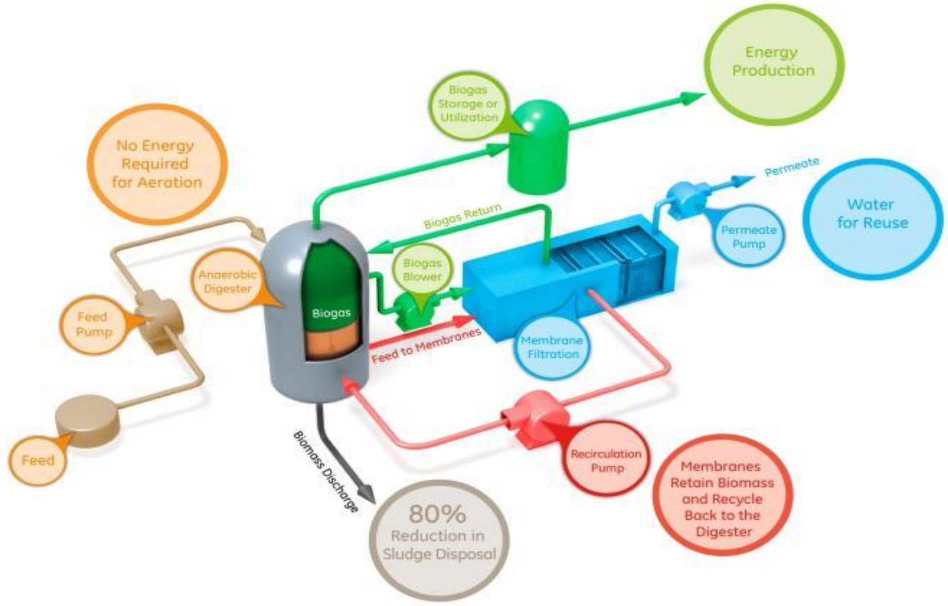
Construction of the inground Anaerobic Treatment System

Construction of the reactor

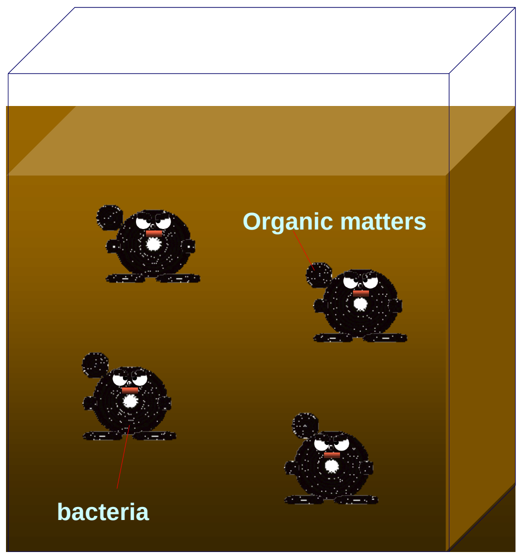
Construction of the Anaerobic Treatment System

Top view of the low-rate anaerobic treatment system

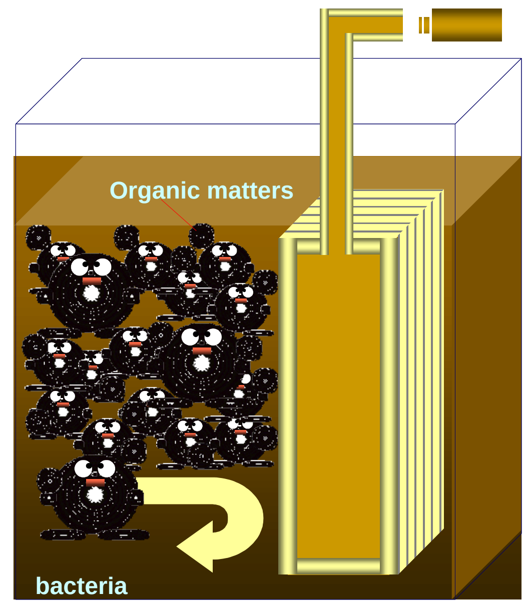
Generic AN-MBR schematic



Anaerobic Process Comparison



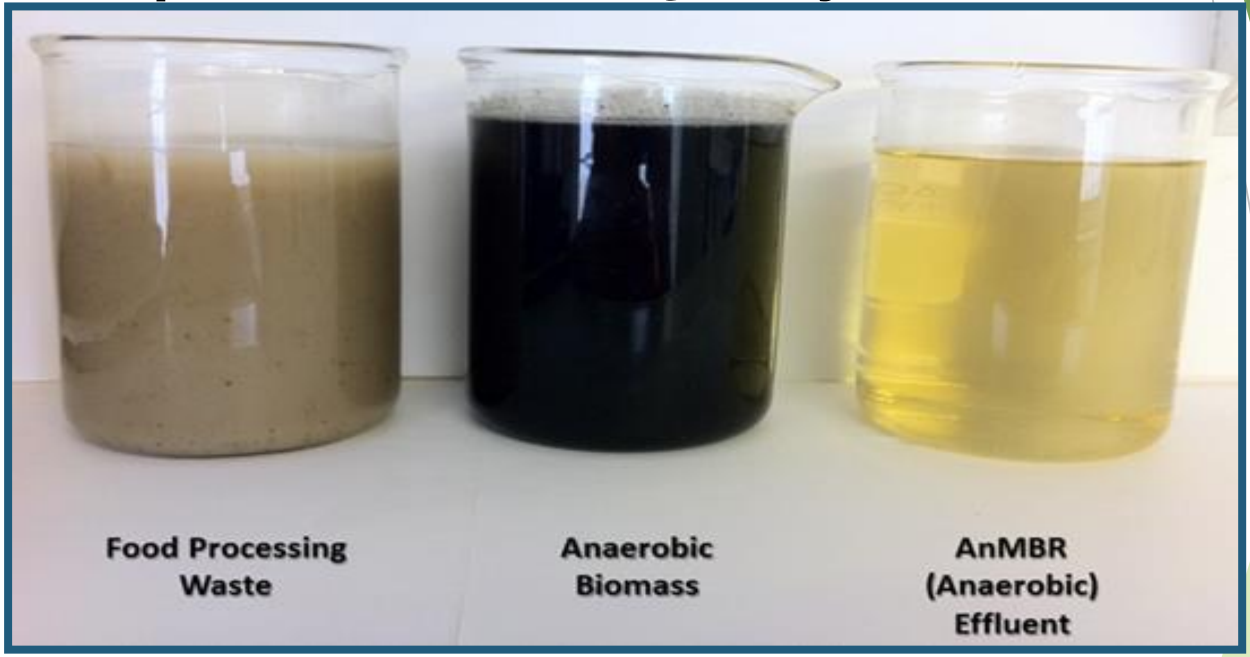
Conventional Anaerobic System



Anaerobic MBR System

AnMBR Technology

Exceptional Effluent Quality



Pop tart plant - Kentucky
AnMBR / MBR Bio-Reactor

Pop Tart factory
wastewater AnMBR
Kentucky, USA.


Salad Dressing plant – Commissioned July 2008

Typical application

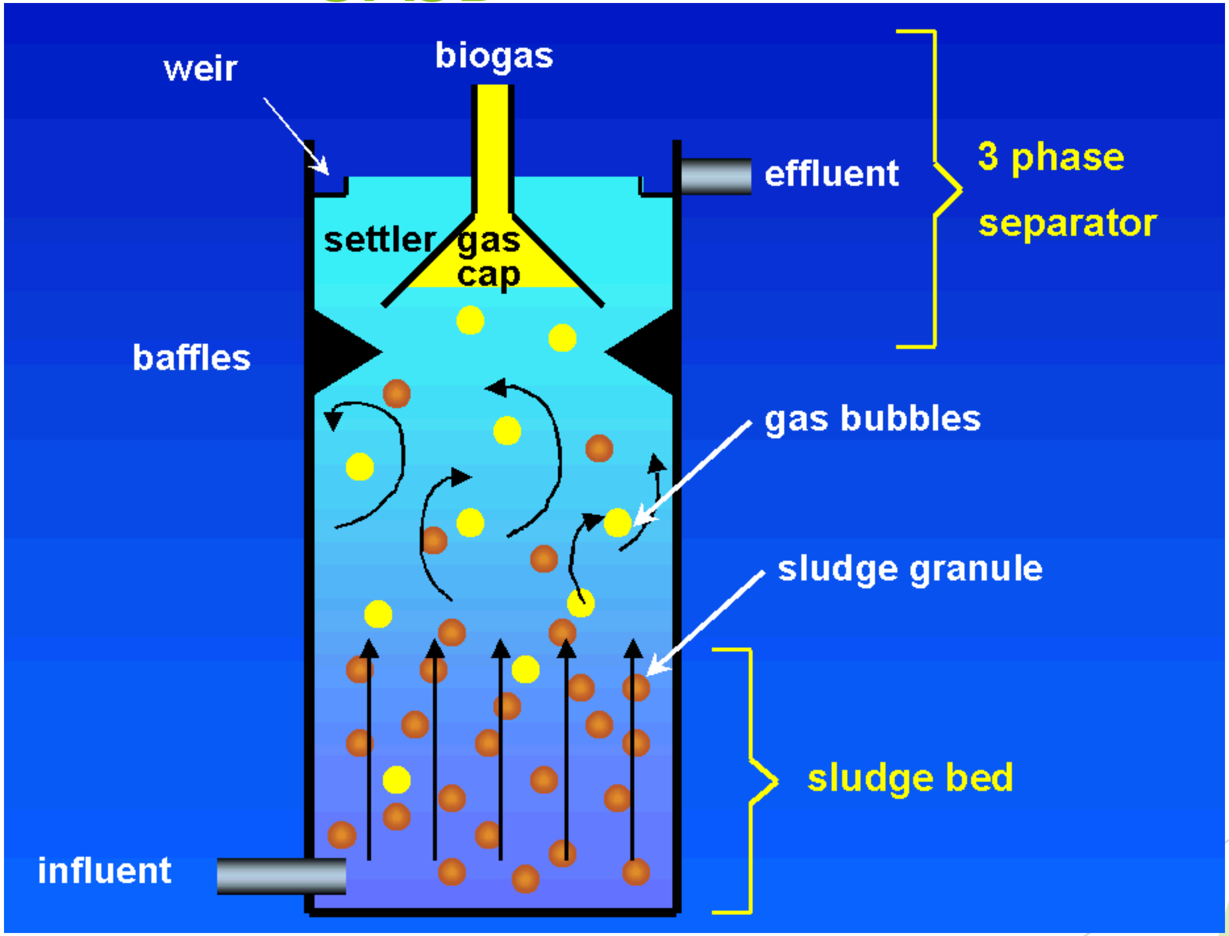
	Application	Advantages	Limitation	Loading Rate	HRT (days)
Inground	Wastewater Treatment	Low mixing energy, high capacity	Footprint	0.3-3.0	7-14
CIGAR	Biogas Production	Low mixing energy, high capacity	Footprint	<3.0	14-42
CSTR	Solids Digestion	High Solids	Effluent Quality	1- 7	20-30
Contact	High rate complex wastes	Medium to high strength liquid wastes	Broad application	3 - 8	5 -15
An-MBR	High quality effluent	Effluent Quality	Operating Cost	5-10	0.1-5
ECSB	Very High rate, non complex wastewater	Smaller Footprint	To be discussed	10-35	0.125-1.5

Granular Sludge Systems

High rate systems

The Ferrari Solutions

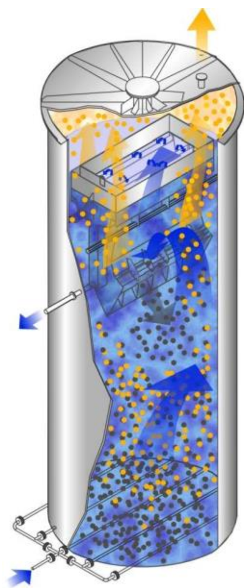
UASB



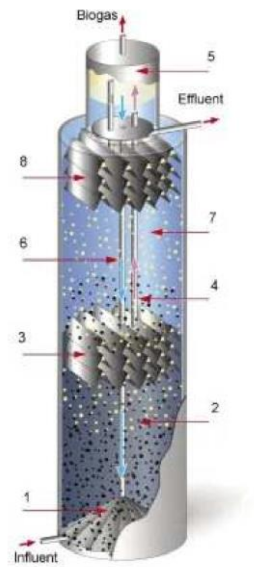
weir
biogas
effluent
3 phase
separator
settler
gas
cap
baffles
gas bubbles
sludge granule
sludge bed
influent

Technology comparison

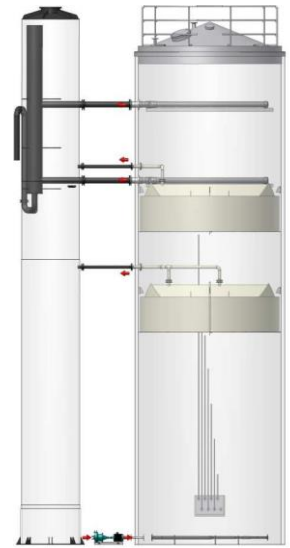
EGSB - Biothane



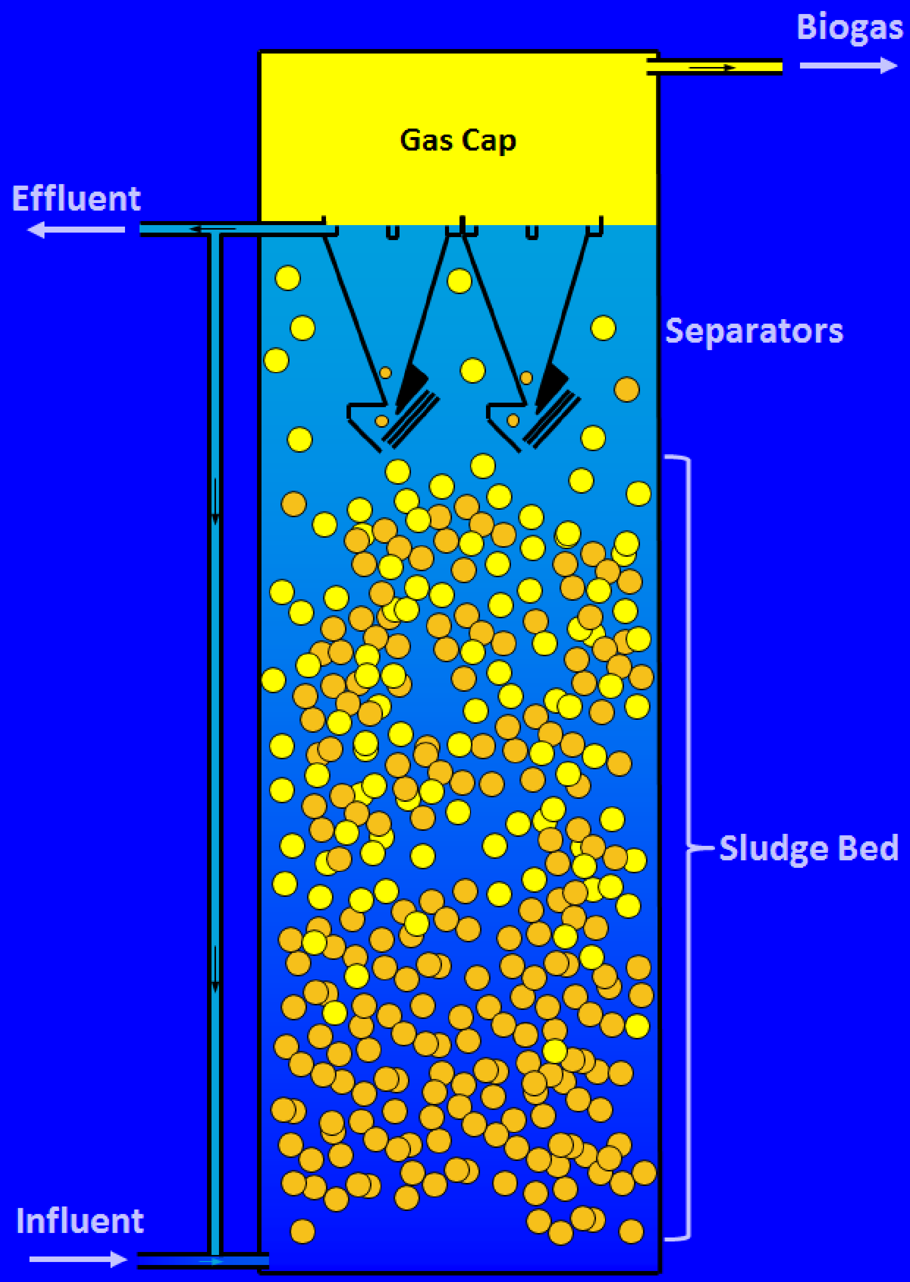
IC- Paques



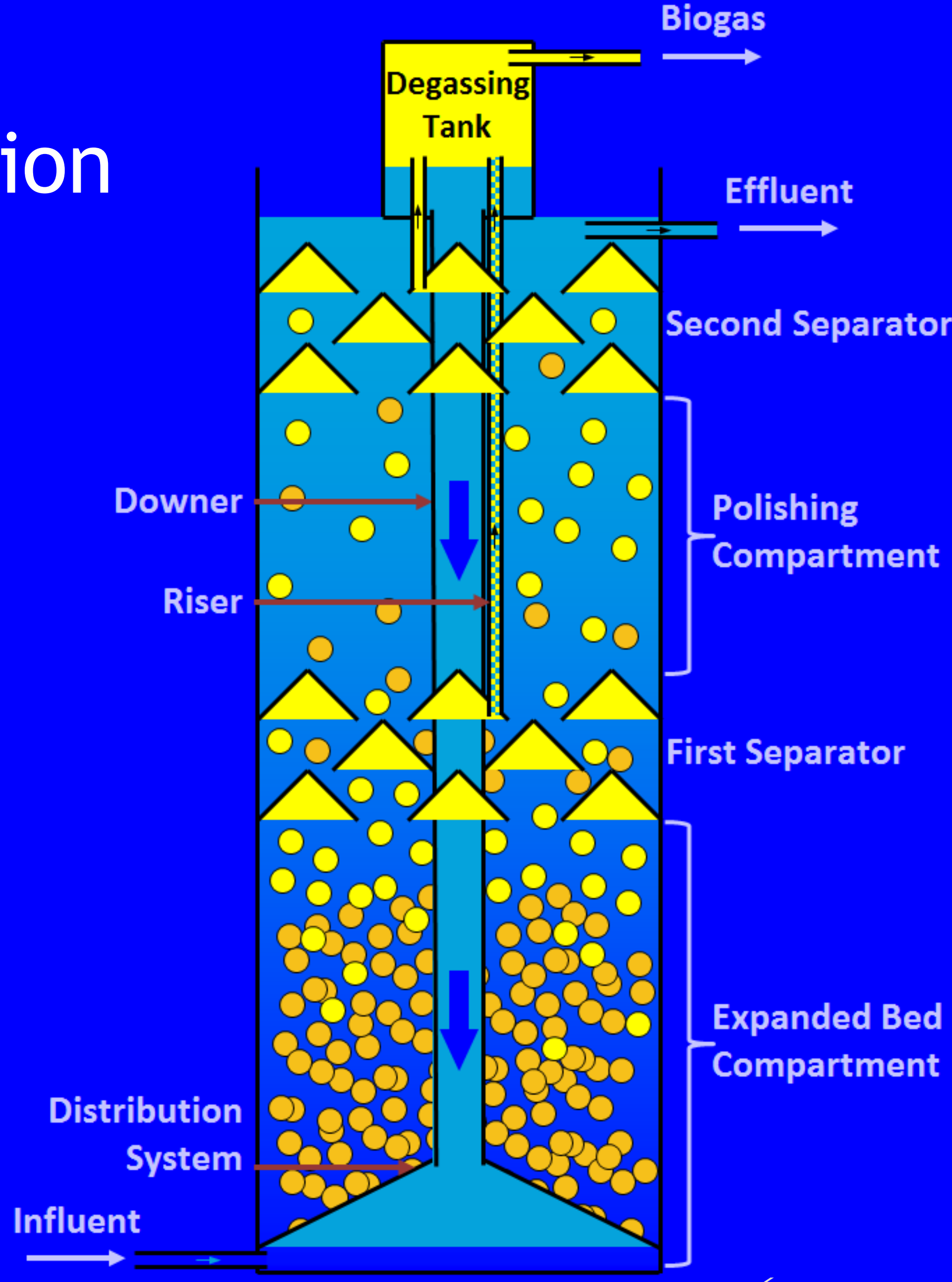
ECSB – HydroThane STP



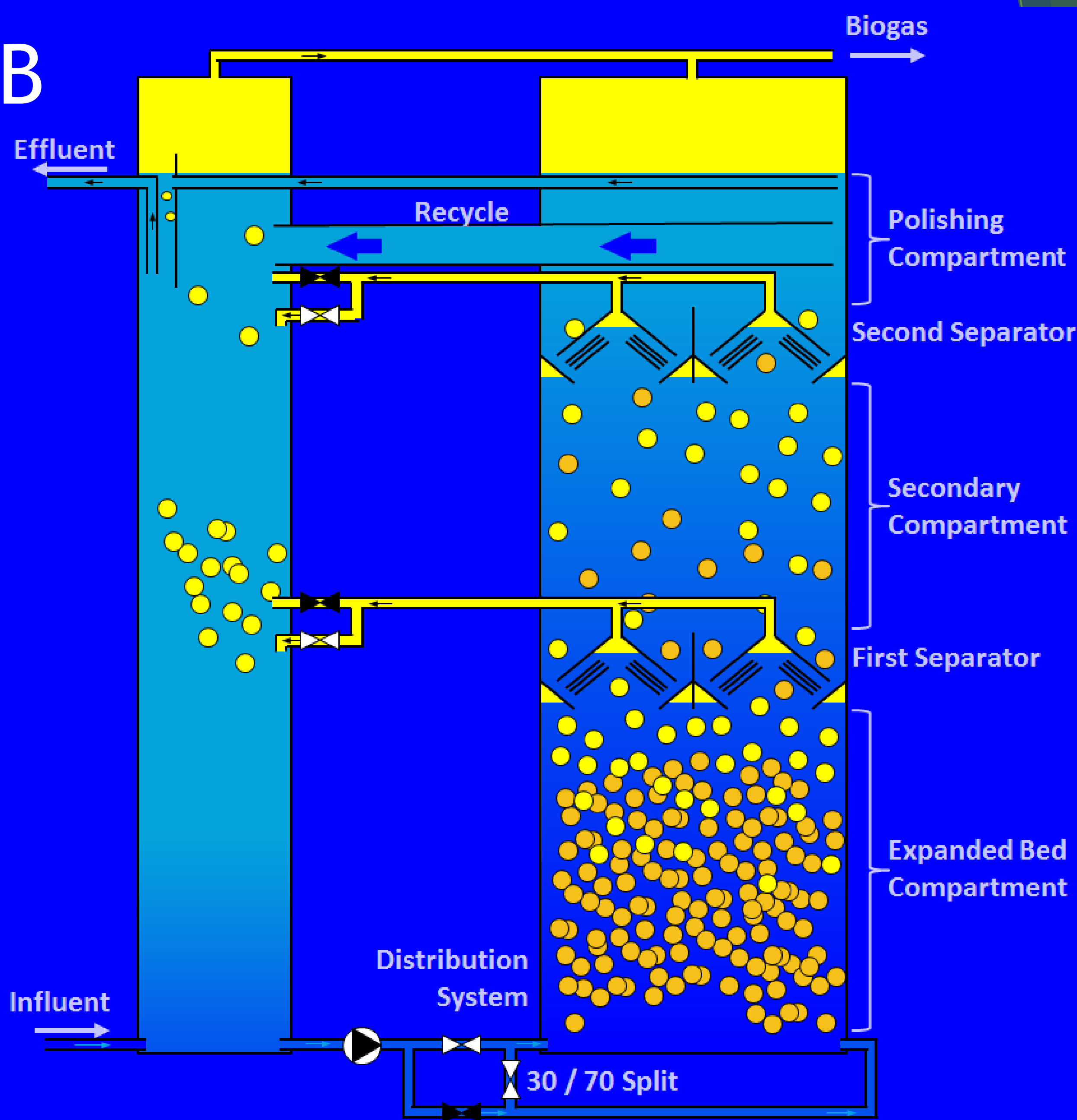
EGSB



Internal Circulation



ECSB


Biogas
Effluent
Recycle
Polishing Compartment
Second Separator
Secondary Compartment
First Separator
Expanded Bed Compartment
Distribution System
Influent
30 / 70 Split

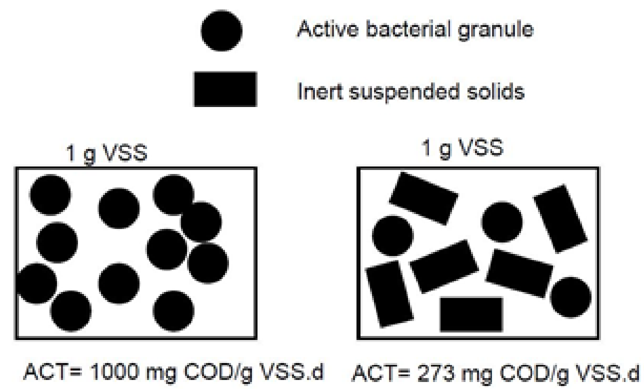
High-Rate Technologies

	UASB	EGSB	IC	ECSB
Upflow Velocity	1-2m/hr	6-7m/hr	Up to 24m/hr in first compartment <1m/hr in second compartment	<5m/hr in first two compartments <1m/hr in third compartment
Sludge Bed	Blanket	Fluidised	Fluidised	Fluidised
Recycle	No	Pumped	Gas Lift	Pumped
Settler	Maybe Retrofit	One 2 phase	Two 3 phase	Two 3 phase
Settler Coverage	-	60%	100%	100%
Headspace	Pressurised	Pressurised	Open to Atmosphere	Pressurised

High-Rate Technologies

	Minimum	Maximum
Biodegradable COD Concentration	1,500mg/L Preferably >2,000mg/L	~30,000mg/L
TSS		
Temperature		
pH		
Pre-acidification		

High-Rate Technologies

	Minimum	Maximum
Biodegradable COD Concentration	1,500mg/L Preferably >2,000mg/L	~30,000mg/L
TSS		Organic TSS <20-25% of sCOD
Temperature		
pH		
Pre-acidification		

High-Rate Technologies

	Minimum	Maximum
Biodegradable COD Concentration	1,500mg/L Preferably >2,000mg/L	~30,000mg/L
TSS		Organic TSS <20-25% of sCOD
Temperature	25°C	40°C
pH		
Pre-acidification		

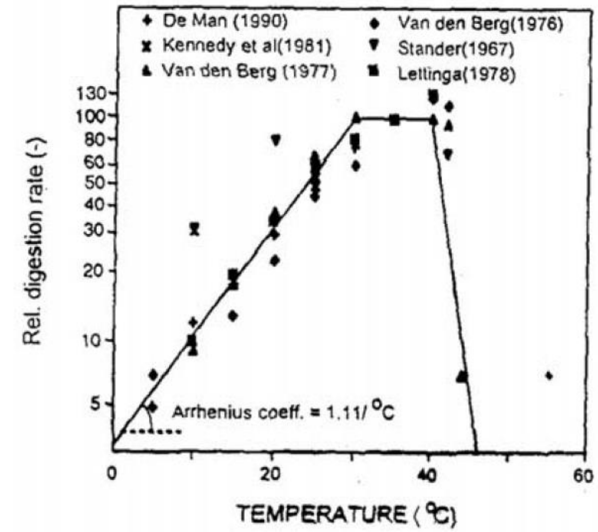
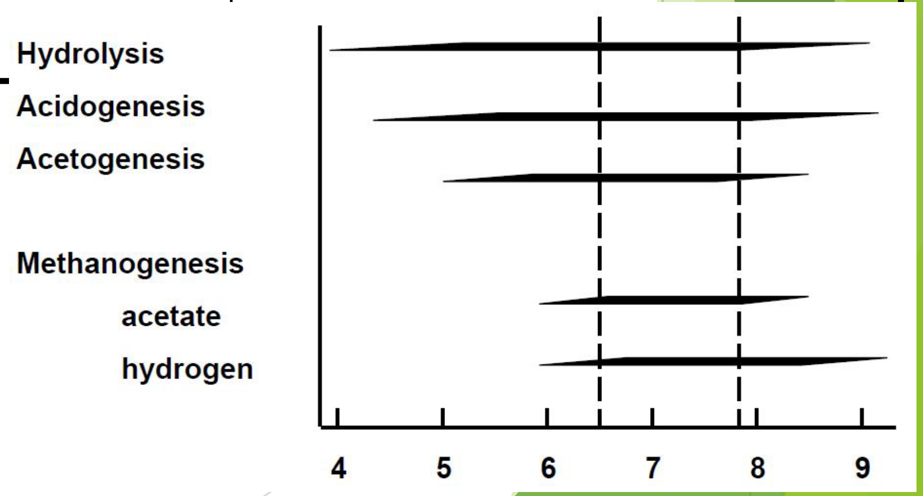


Figure 2.5. Influence o temperature on the rate of anaerobic digestion in the mesophilic range. After Henzen and Harremoes (1983)

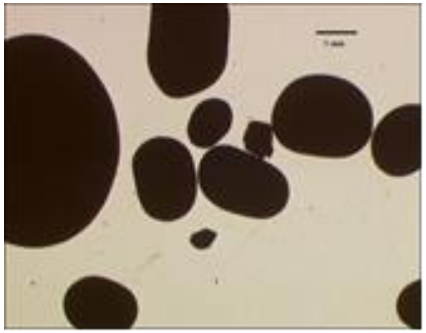
High-Rate Technologies

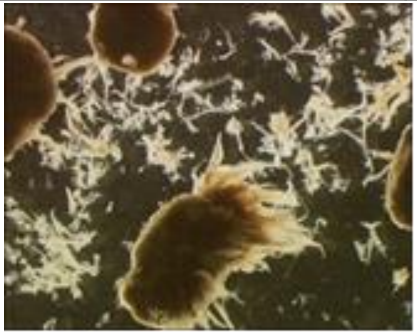
	Minimum	Maximum
Biodegradable COD Concentration	1,500mg/L Preferably >2,000mg/L	~30,000mg/L
TSS		Organic TSS <20-25% of sCOD
Temperature	25°C	40°C
pH	6.6	7.8
Pre-acidification		



High-Rate Technologies

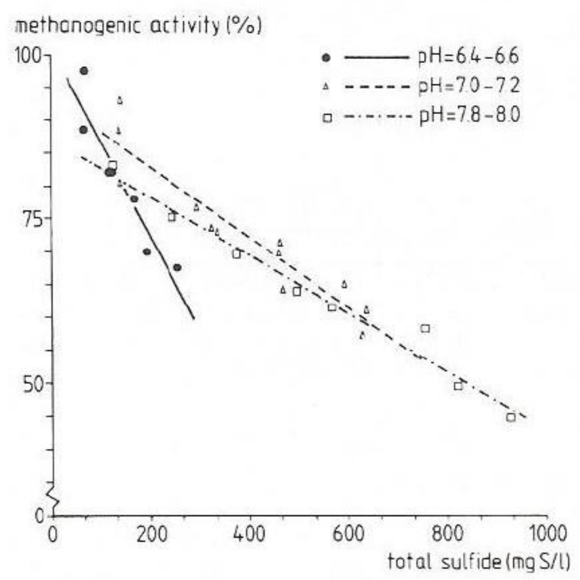
	Minimum	Maximum
Biodegradable COD Concentration	1,500mg/L Preferably >2,000mg/L	~30,000mg/L
TSS		Organic TSS <20-25% of sCOD
Temperature	25°C	40°C
pH	6.6	7.8
Pre-Acidification	<25%	>35%

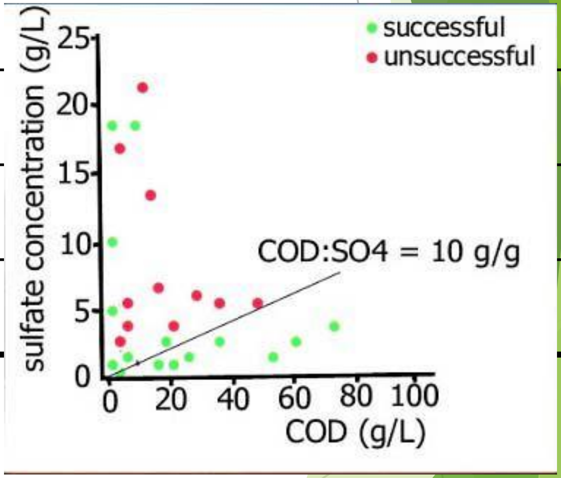




High-Rate Technologies

		Minimum	Maximum
COD:SO4 Ratio		10	
Salt	Na^+		
	Ca^{2+}		
FOG			
Methanol			
Phenol			
Other			





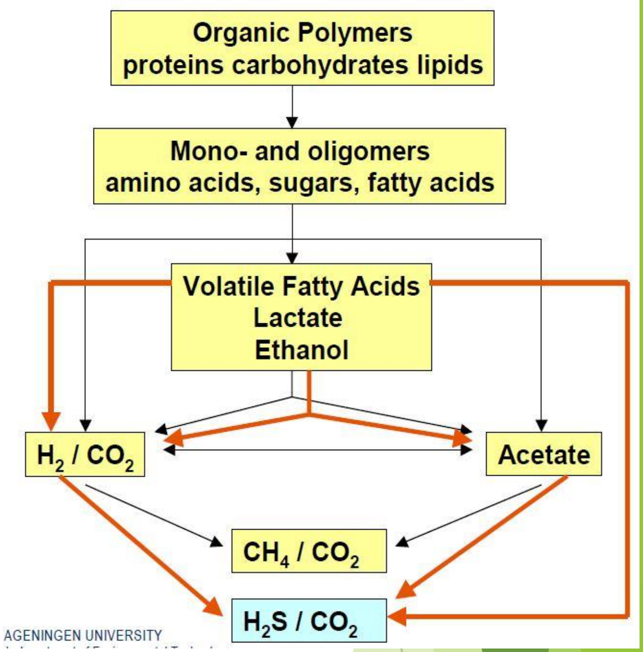
High-Rate Technologies

	Minimum	Maximum
COD:SO4 Ratio	10	
Salt Na^{+}		<10-12g/L
Ca^{2+}		<500mg/L
FOG		
Methanol		
Phenol		
Other		

Salt	50% Inhibiting Concentration ---------- mg /L -----------
Mg^{2+}	1930
Ca^{2+}	4700
K^{+}	6100
Na^{+}	7600

Other Issues with High SO_4 Levels

- Odour
- Corrosion
- Poor quality of the biogas (reduced CH_4 yield; H_2S removal needed)
- Reduced COD removal efficiency due to H_2S in the effluent
- Reduced bio-availability of micronutrients by sulphide
- Precipitation



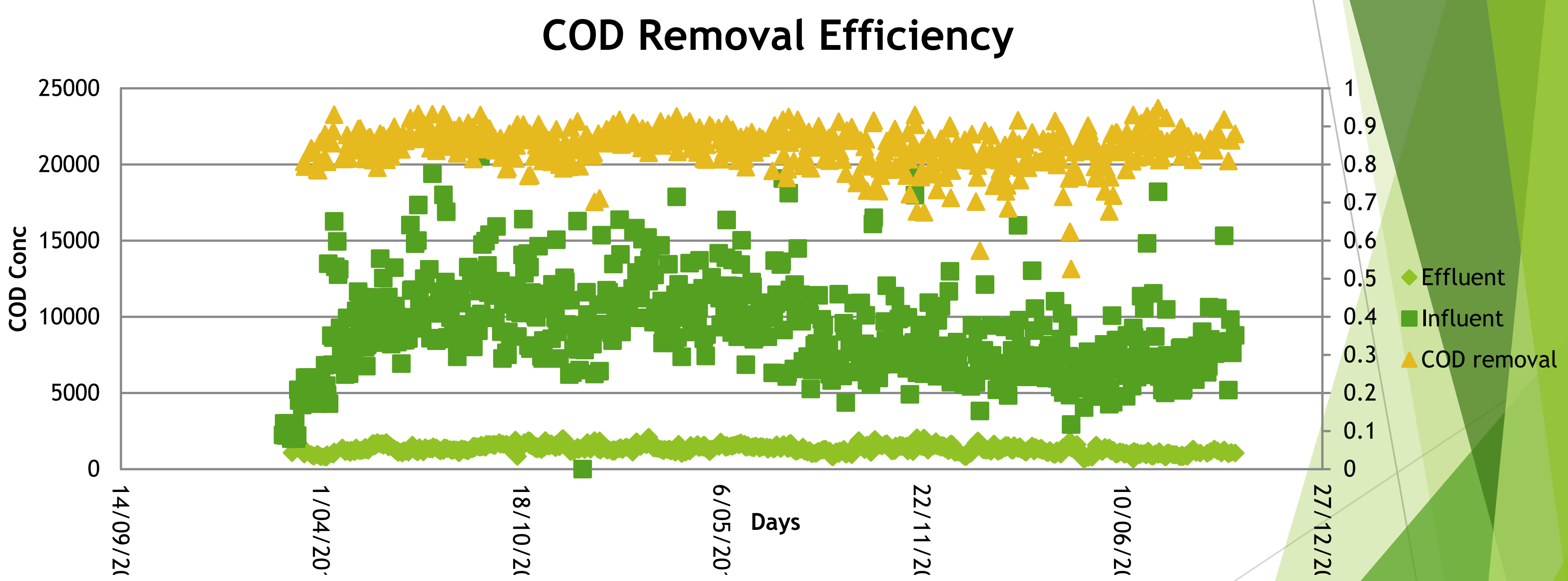
1mol SO_4 equals 2mol O_2
(or 1g SO_4 "converts" 0.67g COD)

High-Rate Technologies

	Minimum	Maximum
COD:SO4 Ratio	10	
Salt Na^{+}		<10-12g/L
Ca^{2+}		<500mg/L
FOG		100mg/L
Methanol		500mg/L
Phenol		grams/L
Other		

AD treatment performance

Starch based Ethanol AD performance



Salad Dressing plant Operating Results

Parameter	Raw Wastewater	AnMBR Effluent
Avg. COD (mg/l)	33,600	190 (99.4%)
Avg. BOD (mg/l)	18,000	20 (99.9%)
Avg. TSS (mg/l)	10,900	< 1 (100%)
Avg. FOG (mg/l)	850	---
Temperature (°F)	77	95

Further comments

- Wastewater characteristics directly impact potentials of anaerobic treatment for industrial wastewater
- Most important characteristics are
  - Presence of suspended solids, Fat, Nitrate, potential Precipitation
  - Poor buffer capacity
  - Strength and composition of biodegradable COD
  - Presence of alternate electron acceptors (i.e. SO_4)
  - Toxic components
  - Nutrients
  - Temperature
- Wastewater characteristics need to be included in reactor design, only if appropriately addressed, will successful treatment be assured
- VERY IMPORTANT TO SELECT AN APPROPRIATE AD CONFIGURATION
- Seek independent advice.

Technology isn't the reason why not

Conclusion

- I genuinely think that we can save and generate energy from organic wastes significantly more than we currently do.
- We can recover nutrients and recycle them significantly reducing fertiliser import,
- Be very careful if selecting a high rate AD system, there work well in a narrow range of situations.
- Both Anaerobic Contact, and engineered inground system are flexble and robust.
- A positive is that there are a number of projects developing around the country where AD systems are being installed.

Questions