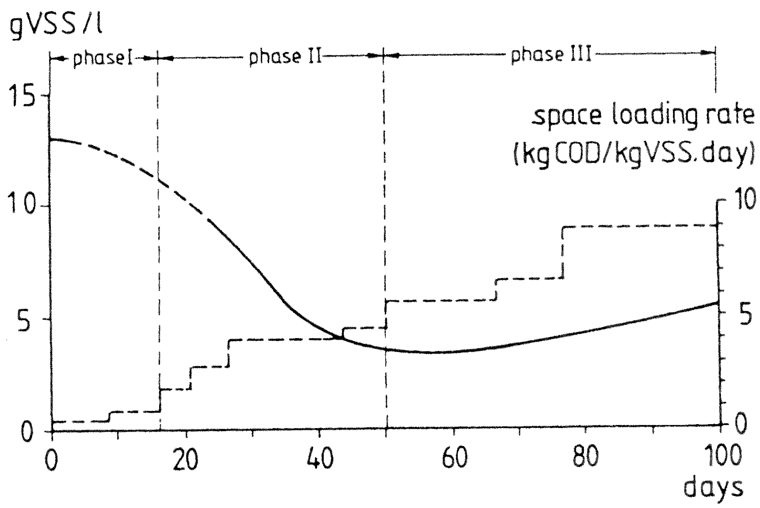
7. Start-up and sludge granulation

Selection of appropriate seed sludge:

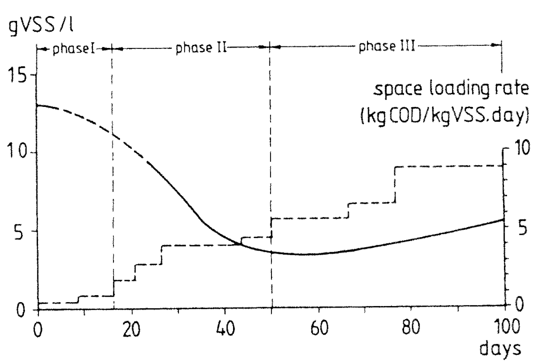
" The higher the methanogenic activity, the shorter the start-up time"

sludge type:	activity at 30 ° C (kg COD · kg^{-1} VSS · d^{-1})
granular sludge	0.8 - 1.5
sludge of other anaerobic reactors	0.4 - 1.2
digested sewage sludge	0.02 - 0.15
digested manure	0.02 - 0.08
sludge from a septic tank	0.01 - 0.02
cow manure	0.001 - 0.006
primary domestic sludge	0.001 - 0.003
river sludge	0.002 - 0.005

General phases of the UASB start-up (non-adapted seed)



Phase I: Organic load < 3 kg · m^{-3} · d^{-1}



- activity starts to increase
- wash-out of colloidal sludge fraction
- erosion - wash-out
- expansion of sludge bed
- possibility of a flotation layer

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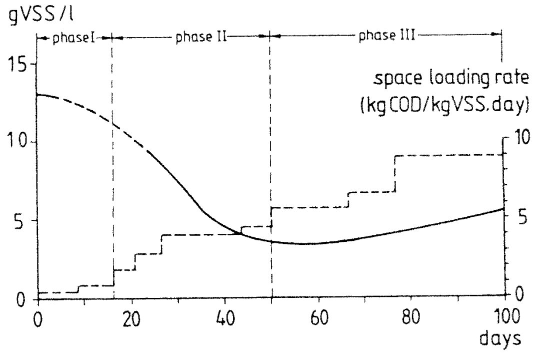
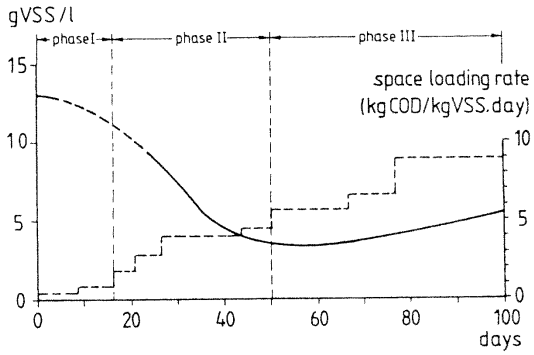
Chapter on Anaerobic Wastewater Treatment by Jules van Lier

Phase II: Organic load 2 - 5 kg · m^{-3} · d^{-1}



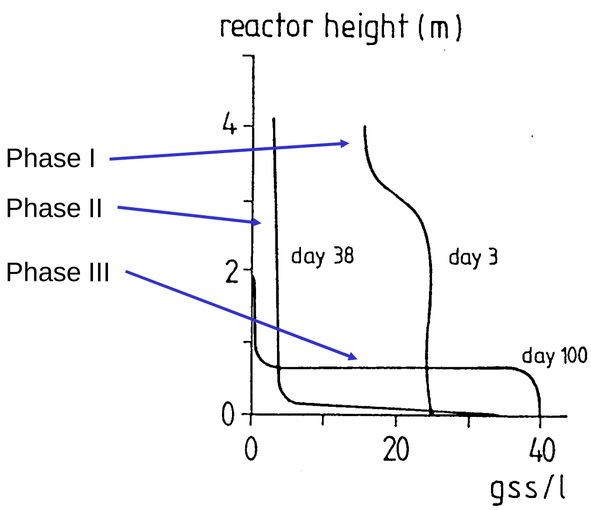
- strong wash-out (expansion wash-out)
- activity is lost : start-up is stagnated
- strong increase in sludge load
- selection between heavy and light sludge
- formation of first sludge agglomerates

Phase III: Organic load > 3 - 5 kg · m^{-3} · d^{-1}



- increase of total sludge concentration
- increased growth of sludge granules
- organic load can be increased again

Sludge development during the start-up: monitoring sludge bed



Structure of Methanogenic Sludge Granules

Anaerobic granular sludge: a well balanced micro-ecosystem

1. Association of different bacteria (syntrophes)

2. Dense structure of filamentous methanogens (*Methanosaeta*)
   Methanogens are characterised by:
   - high hydrophobicity
   - uncharged surface at neutral pH

3. Extracellular polymers (saccharides, proteins)

4. Inorganic precipitates

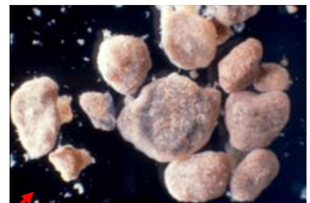
What is a sludge granule ?? (engineering approach)

Proposal for definition:

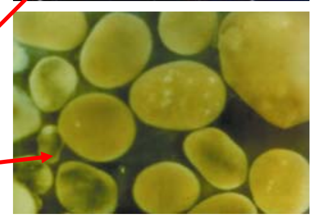
Dense spherical-shaped microbial conglomerate, consisting of microorganisms, inert material, and extra-cellular polymers, and which is characterised by a ‘high’ metabolic activity and a ‘high’ settleability.

methanogenic

nitrifying



denitrifying



Aerobic (heterotrophs)

What is a methanogenic sludge granule ?

‘high’ metabolic activity

Methanogenic granular sludge:	0.1 – 2.0 kg $COD\text{-}CH_4.kg^{-1}$ $VSS.day^{-1}$
Typically (industrial ww.):	0.5 – 1.0 $kg.kg^{-1}.day^{-1}$

‘high’ settle ability

Physical characteristics: (typically)

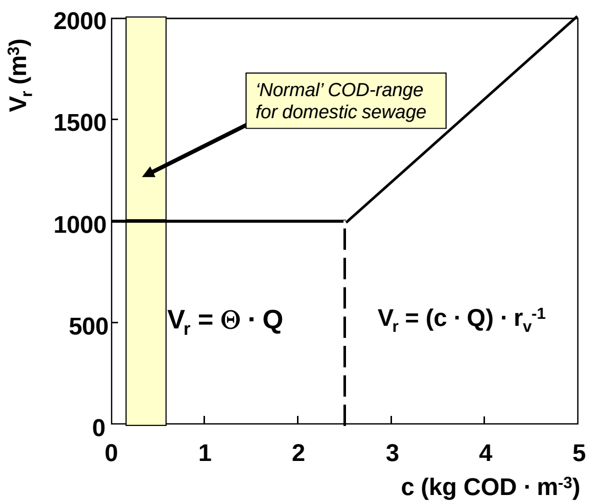
- settling velocities: 2 – 100 $m.h^{-1}$ (**15-50 $m.h^{-1}$**)
- density: 1.00 – 1.05
- diameter: 0.1 – 8 mm (**0.14 – 4 mm**)
- spherical formed and well defined surface
- color: black / gray / white

Non-granule conglomerates: “Pellets”, “Flocs”

8. Anaerobic treatment of domestic sewage

Assessment of the size of a UASB Reactor

Relationship between pollution strength and reactor volume



<u>Assumptions:</u>
$\Theta_{min} = 4$ h
$Q = 250\ m^3 \cdot h^{-1}$
$r_v = 15$ kg COD $\cdot\ m^{-3} \cdot d^{-1}$
hydraulic load = $6\ m^3 \cdot m^{-3} \cdot d^{-1}$

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Chapter on Anaerobic Wastewater Treatment by Jules van Lier

Conventionally designed UASB reactors for domestic sewage (COD < 1000 mg/l) are hydraulically limited !!

Temperature.:	> 20 °C
COD infl.:	< 1000 mg/l
SS-influent:	< 500 mg/l

Anaerobic Sewage Treatment

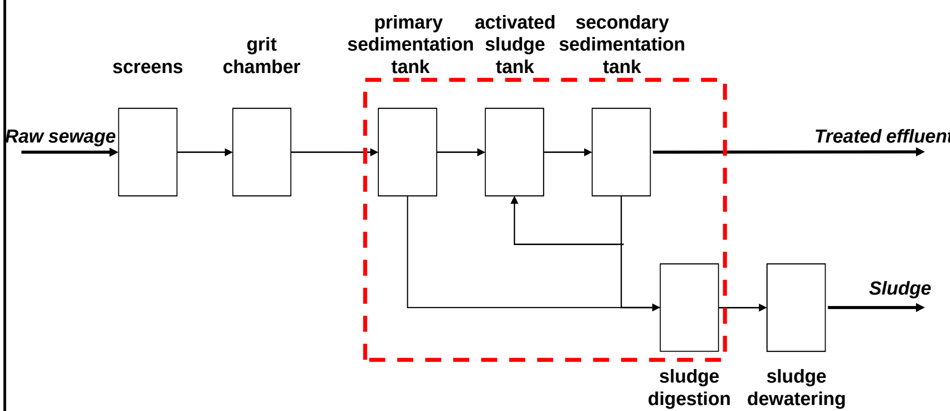
Objectives:

- Removal of biodegradable organic compounds by converting them into methane.
- Removal of settle-able non-biodegradable compounds
- Stabilisation of retained sludge.
- Improving de-watering characteristics of the sludge

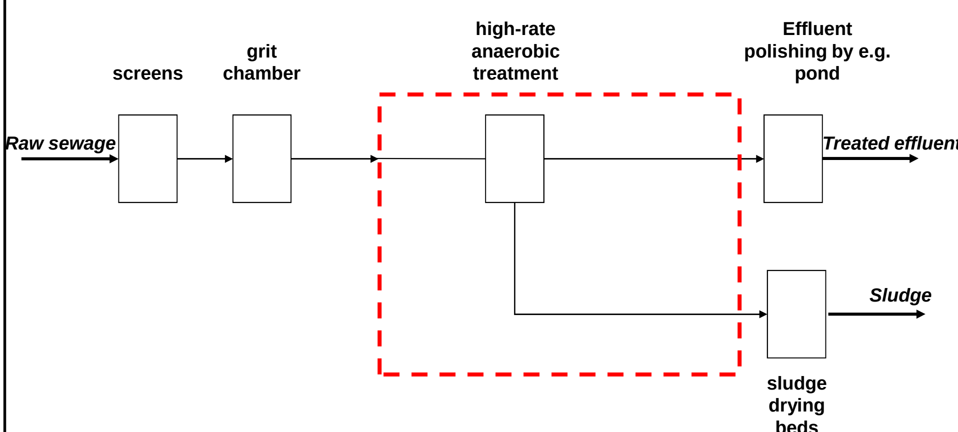
UASB mostly applied and comprehends 4 units:

1) primary clarifier,
2) biological reactor,
3) secondary clarifier and
4) sludge digester

Basic setup of conventional aerobic sewage treatment



Basic setup of anaerobic sewage treatment

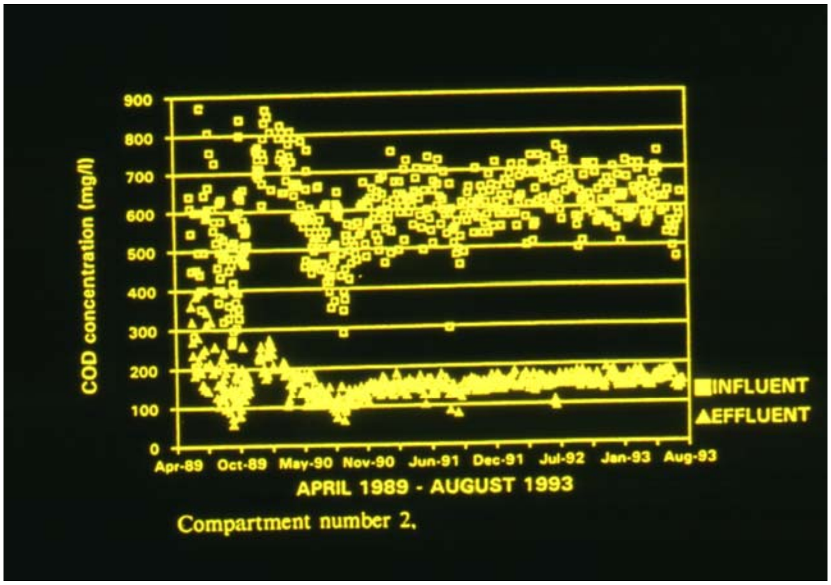


Anaerobic WWTP Bucaramanga, Colombia

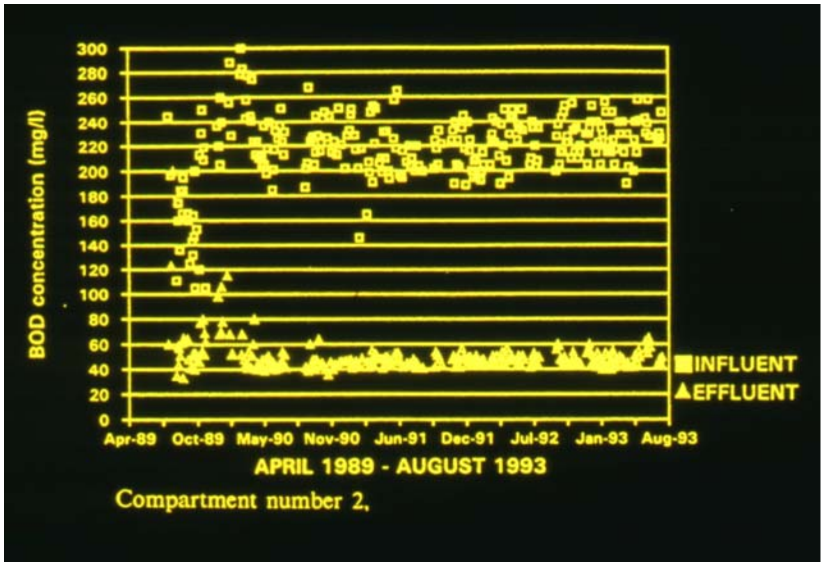
Average Results Latin America and India:
(COD < 500/600 mg/l)

COD Removal:	65 - 75%
BOD Removal:	70 - 80%
SS Removal:	70 - 80%
Pathogen Removal:	
- Coliforms:	70 - 90%
- Helminth eggs:	??

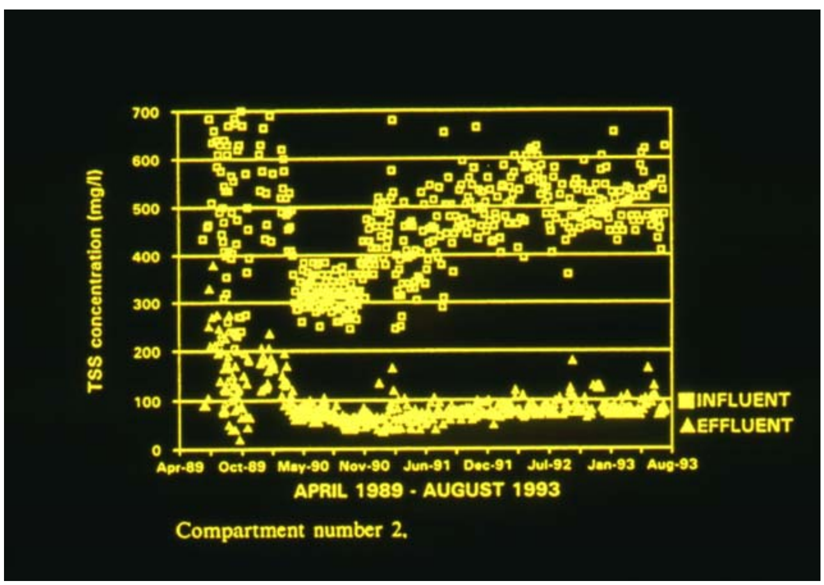
COD concentration: influent – effluent, Kanpur, India



BOD concentration: influent – effluent, Kanpur, India



TSS concentration: influent – effluent, Kanpur, India



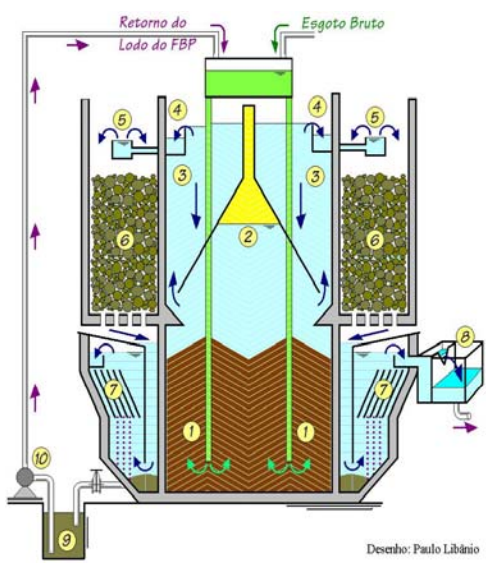
UASB: options for decentralised sewage treatment

Campina Grande, Brasil

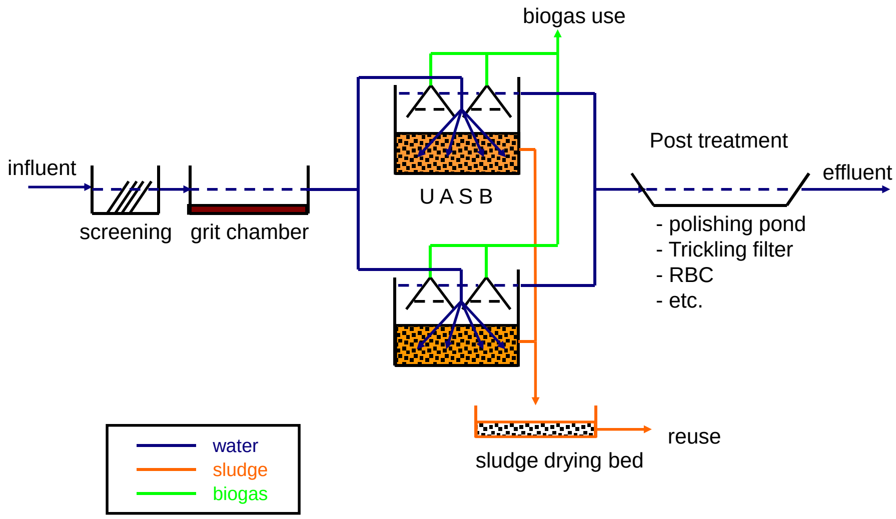
Odemira, Portugal

Masterplan of Recife metropolitan area: decentralised approach (Florencio *et al.,* 2001)

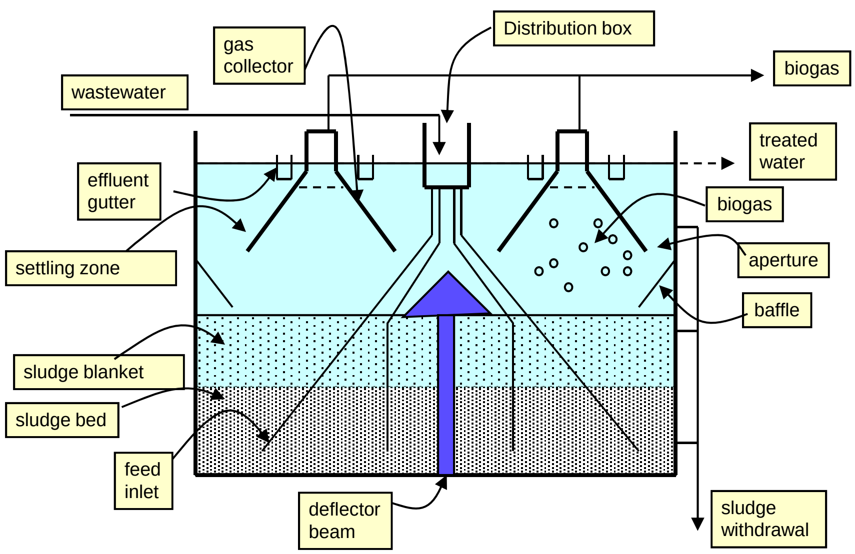
Integrated anaerobic treatment – post treatment, Brasil



General lay-out of an anaerobic WWT plant

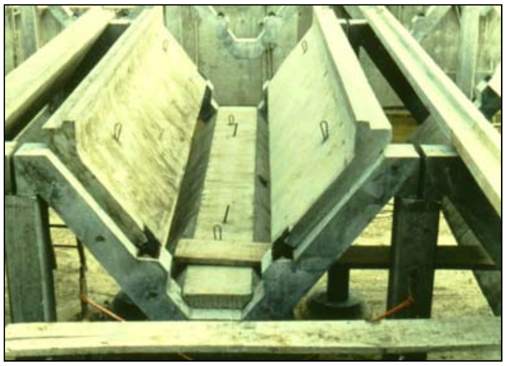


The UASB Reactor

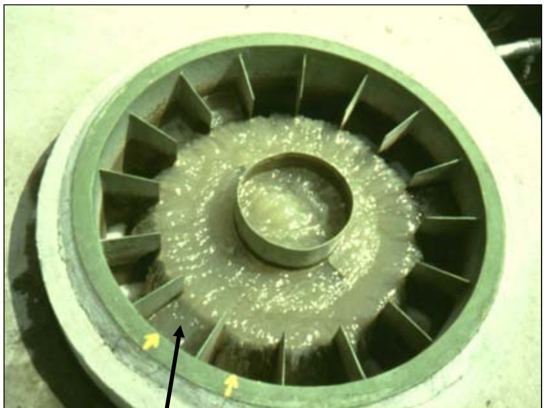


Internal view 1200 m^3 UASB, Cali, Colombia

Full-scale anaerobic sewage treatment plant, Bucaramanga, Colombia



Polyester Circular Distribution Box

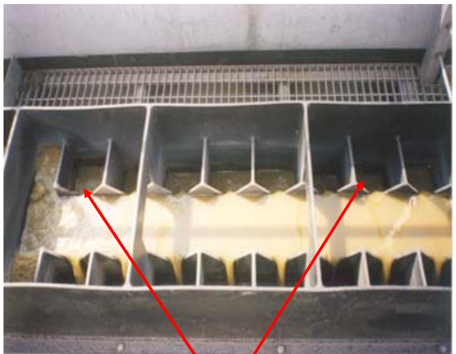


Clogged inlet pipe

Maintenance (declogging)

Stainless steel, rectangular influent distribution

Plastic (PPE) rectangular influent distribution



Inappropriate hydraulic engineering !!
- uneven flow distribution
- chances for short-circuiting

New developments in domestic AWWT

- Application in sub-tropical regions (cold winters)
- Application in moderate to low temperature regions
- Treatment of concentrated sewage
- Separation of black and grey domestic water
- Appropriate post treatment systems
- Direct coupling with irrigated agriculture

Concentrated sewage: SRT prime design criterion!

SRT is directly linked to the amount of viable, active biomass in the system:

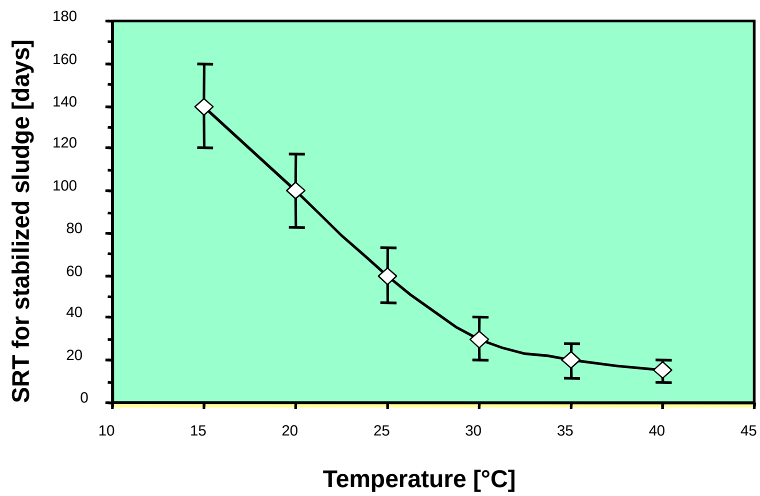
$$SRT\ (d) = X_{reactor} \cdot V / (Q_{effl} \cdot X_{effl.} + Q_{excess\text{-}sludge} \cdot X_{excess\text{-}sludge}),$$

with X = concentration of viable biomass in kg/m^3 (e.g.methanogens).
V = reactor volume (m^3)
Q = flow m^3/d

SRT is determined by:
- incoming suspended solids
- solids digestion in the reactor
- filtering capacity sludge bed (upflow velocities + sludge characteristics)
- growth and decay of new sludge
- sludge retention in the settler (upflow velocities)
- withdrawal of excess sludge

$SRT_{min.} \geq 3$ * Td (doubling time) of critical biomass (e.g. methanogens)

Required SRT for Hydrolysis in Reactor



Middle East research on anaerobic pre-treatment: Amman

Flow:	180.000	m^3.day
BOD:	500-700	mg/l
COD:	1.500	mg/l
TSS:	600-700	mg/l
NH_4^+-N:	70-130	mg/l
N-Kj:	90-200	mg/l
P-tot:	10-40	mg/l
Temp.:	16 (W.) – 28 (S.)	ºC

Results two-stage pilot trials Middle East (Jordan):
(COD ≈ 1500 mg/l)

(with post clarification)

COD Removal:	up to 80%
BOD Removal:	up to 85%
SS Removal:	up to 80%
Pathogen Removal:	insufficient

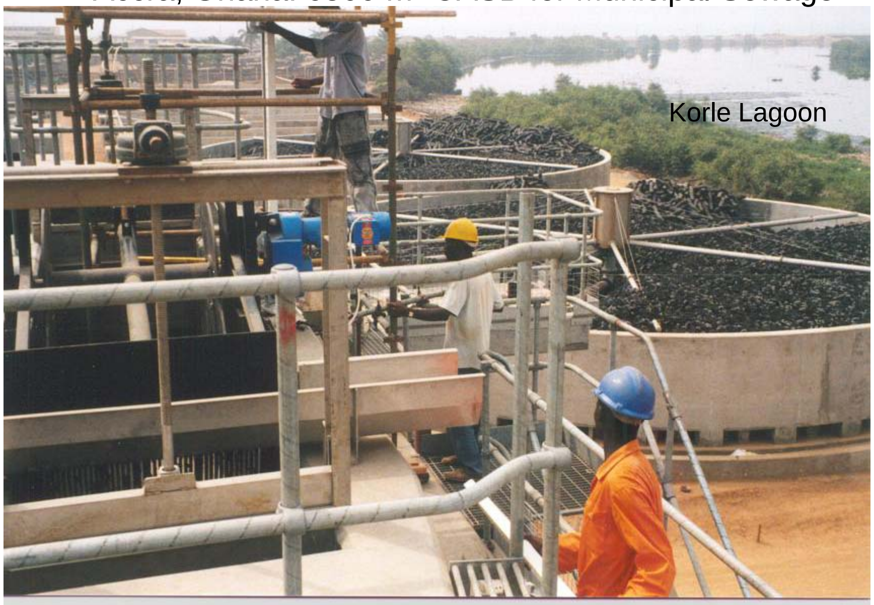
Potential CH_4 production in Amman
(at 200.000 m^3 sewage/day): 30,000 m^3/day !
≈ 5 – 6 MWe

0.15 Nm^3 CH4/ kg CODrem.

Full scale UASB, Sanhour, Egypt

Commissioning: June 2006

Accra, Ghana: 6500 m^3 UASB for Municipal Sewage



Accra, Ghana: 6500 m^3 UASB for Municipal Sewage

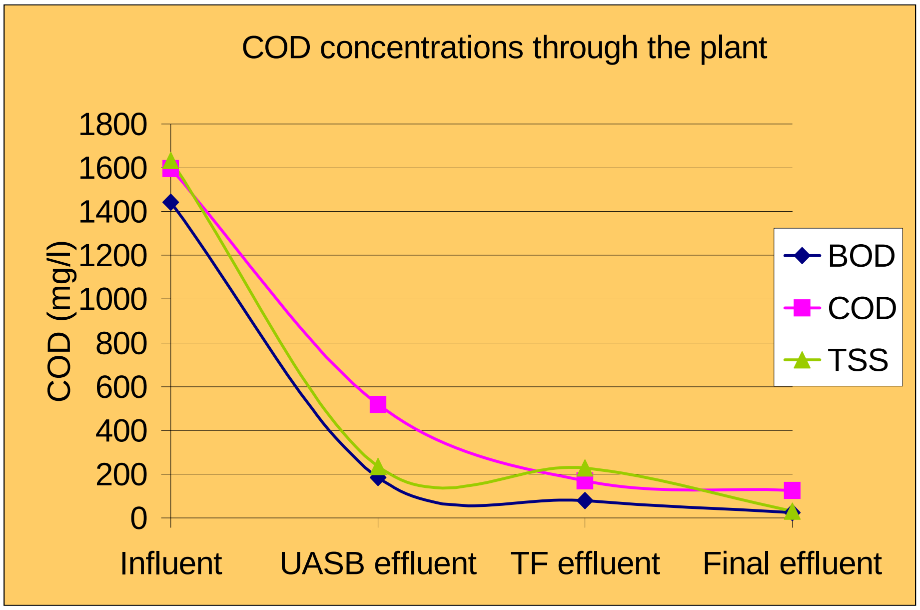
RESULTS 'START-UP' phase (in mg/l):

	Influent	Influent	Effluent		
		peak-values	UASB	Trickling filter	Clarifier
COD	1,610 ± 625	16,000	520 ± 300	140 ± 30	126 ± 35
BOD	1,050 ± 430	3,100	185 ± 115	170 ± 125	25 ± 12
TSS	860 ± 375	22,000	235 ± 220	230 ± 195	30 ± 10
VSS	735 ± 340	20,500	185 ± 135	175 ± 145	n.a.

pH: 5 – 12 !!

COD efficiency (entire plant): 92%
BOD / TSS efficiency: 98%
HRT: 20-24 h
OLR: 1.6 (0.3 – 6.1) $kg/m^3/d$

Treatment results UASB + TF, Accra, Ghana.



Thanks !!