# CIE4485
# Wastewater Treatment

Prof.dr.ir. Jules van Lier

12. Anaerobic Sewage Treatment

# CT4485 Wastewater Treatment

## Lecture 5b: Anaerobic sewage treatment

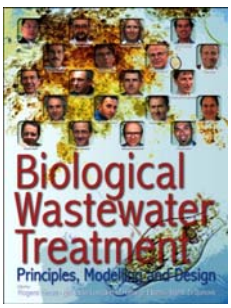
Prof.dr.ir. Jules van Lier

13 December 2012



# Learning objectives

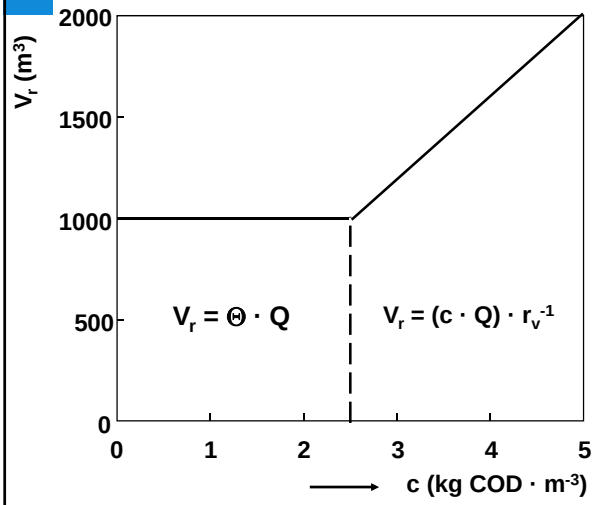
- Understand potentials of direct sewage treatment by anaerobic reactor systems
- Understand advantages and constraints of anaerobic sewage treatment




IWA: Chapter 16
Metcalf & Eddy: Chapt.10

## UASB REACTOR DESIGN

Relationship between pollution strength and reactor volume.




*Assumptions:*

$\Theta_{min}$ = 4 h

$Q = 250\ m^3 \cdot h^{-1}$

$r_v = 15\ kg\ COD \cdot m^{-3} \cdot d^{-1}$

*hydraulic load = 6 $m^3 \cdot m^{-3} \cdot d^{-1}$*

**(hydraulic load = 6 $m^3 \cdot m^{-3} \cdot d^{-1}$**

**$V_{reactor}$ = 1000 $m^3$)**

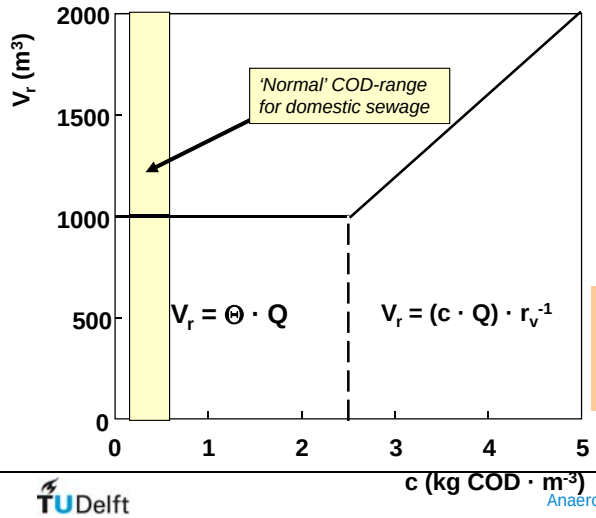


Anaerobic treatment of municipal wastewaters using UASB reactors systems

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

## Assessment of the size of a UASB Reactor

Relationship between pollution strength and reactor volume




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

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



## Anaerobic Sewage Treatment

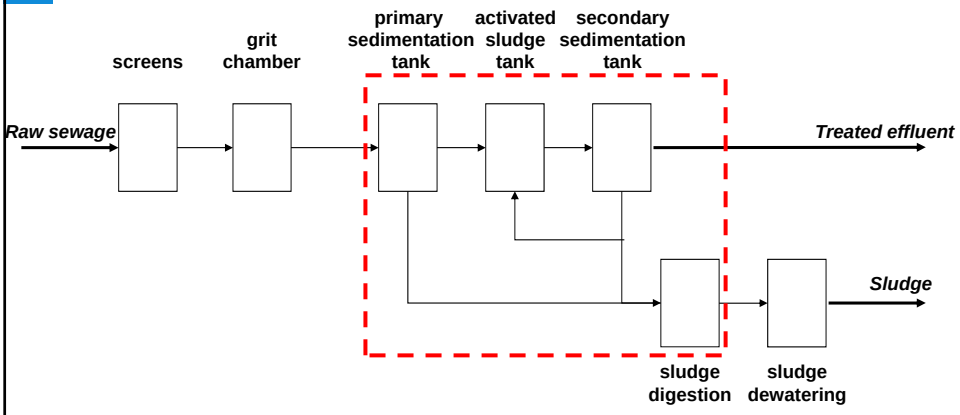
**Objectives:**

- 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

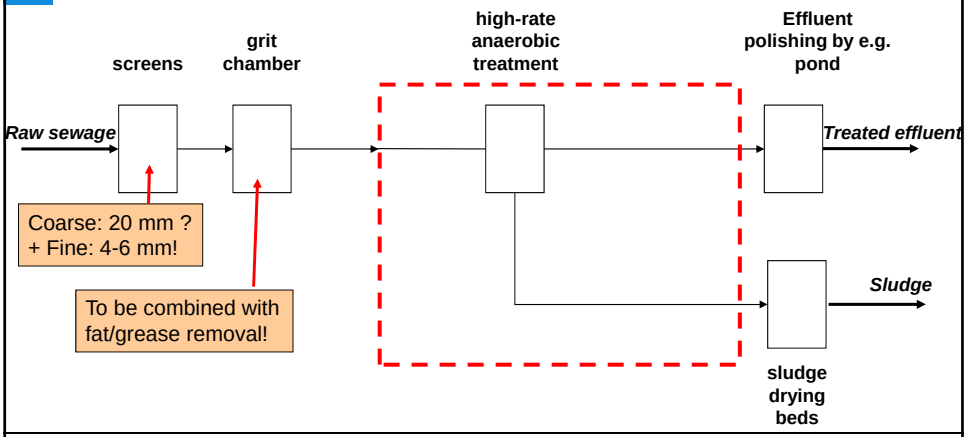
## Basic setup of conventional aerobic sewage treatment






## Basic setup of anaerobic sewage treatment

**CAPEX reduction ?!**



# Attainable UASB results for domestic sewage

**Results from Latin America and India:**
**(COD < 500/600 mg/l)**
***<best performances!>***

V: up to 50.000 $m^3$

| | |
|---|---|
| COD Removal: ..... | 70 - 80% |
| BOD Removal: ..... | 75 - 85% |
| SS Removal: ..... | 70 - 80% |
| Pathogen Removal: | |
| - Coliforms: | 70 - 90% |
| - Helminth eggs: | "up to 100%"? |

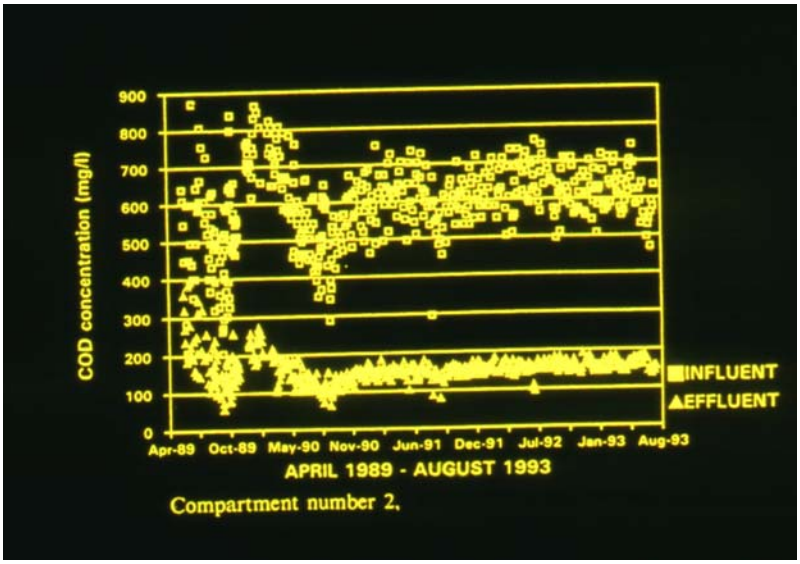
Hydraulic load restrictive: HRT 6-8 hrs

14.000 $m^3$/d, Mirzapur, India

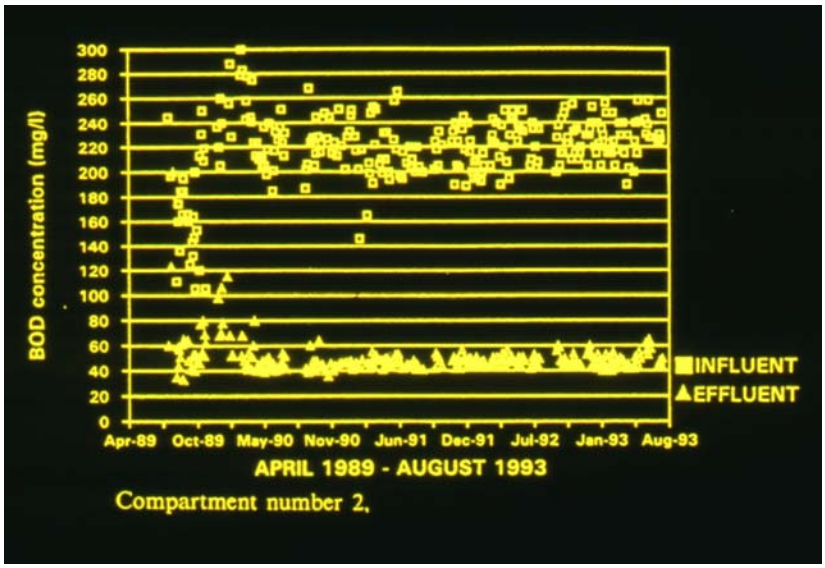
12.000 $m^3$/d, Bucaramanga, Colombia



## COD concentration: influent – effluent, Kanpur, India

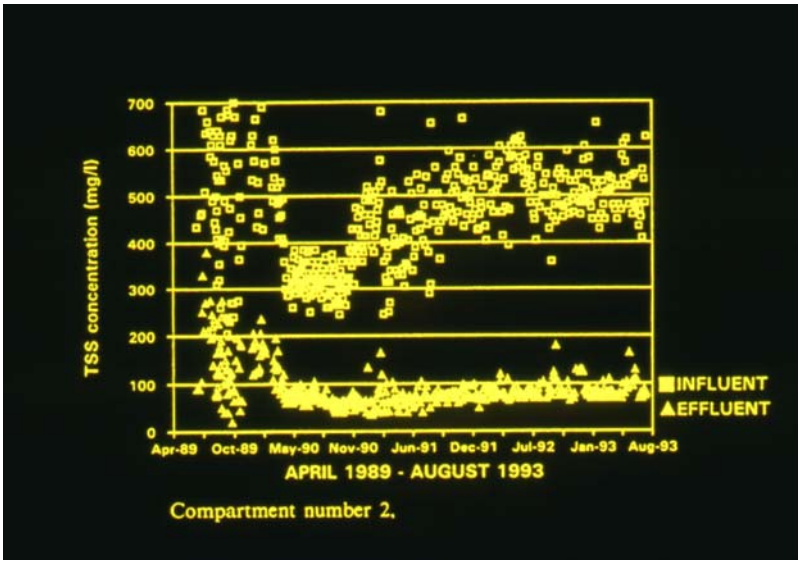


## BOD concentration: influent – effluent, Kanpur, India






## TSS concentration: influent – effluent, Kanpur, India



## UASB: options for decentralised sewage treatment

- compact systems
- reduction land demand
- reduction sewerage costs

Campina Grande, Brasil

Odemira, Portugal

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

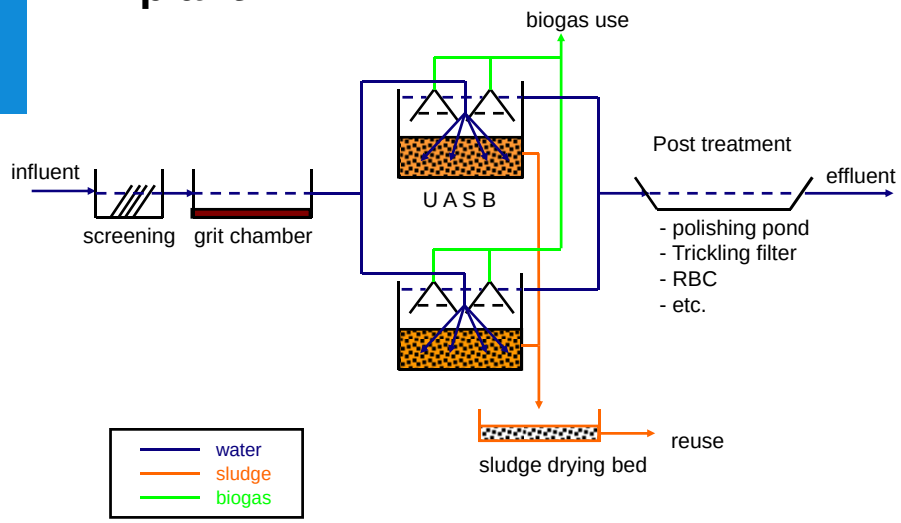


## Conditions for decentralised / residential applications

- Odor prevention!!
- “Full treatment” until restrictions

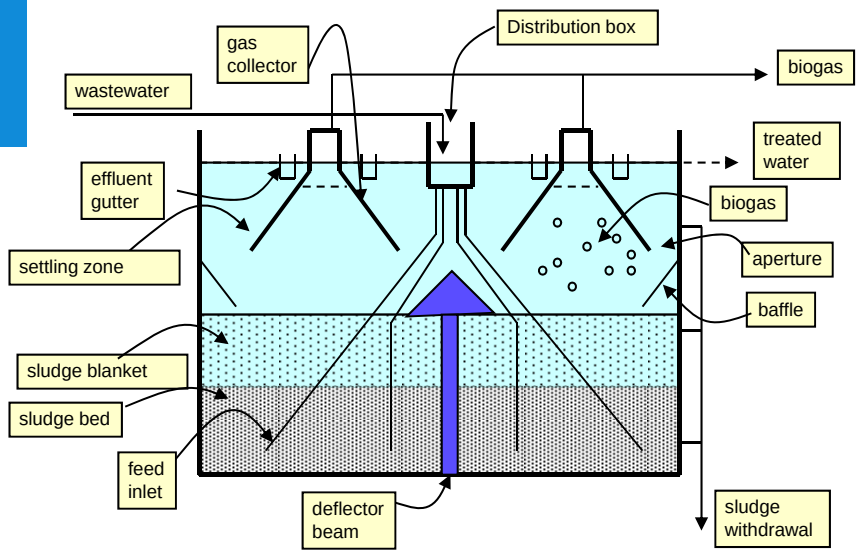
Vivero, Cali, Colombia: in direct vicinity of residential area !!

# General lay-out of an anaerobic WWT plant

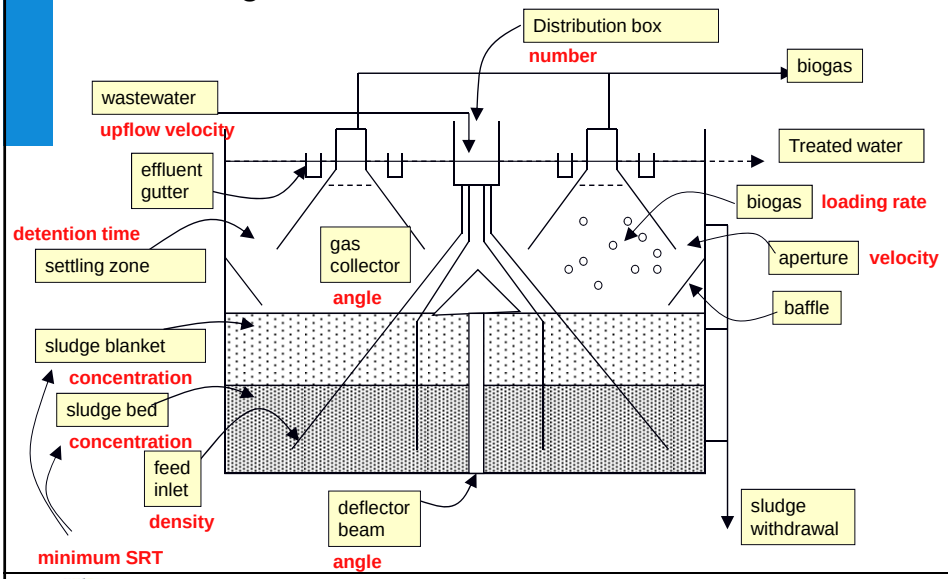





# The UASB Reactor



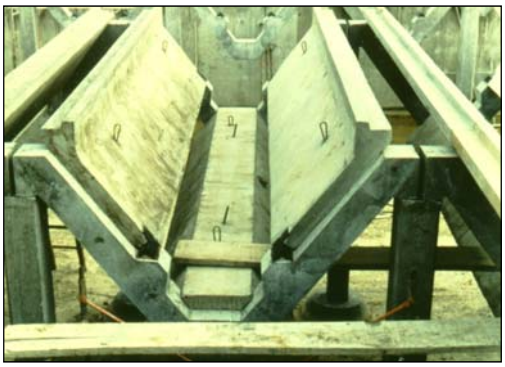
## Design Criteria for the UASB Reactor






## Internal view 1200 $m^3$ UASB, Cali, Colombia

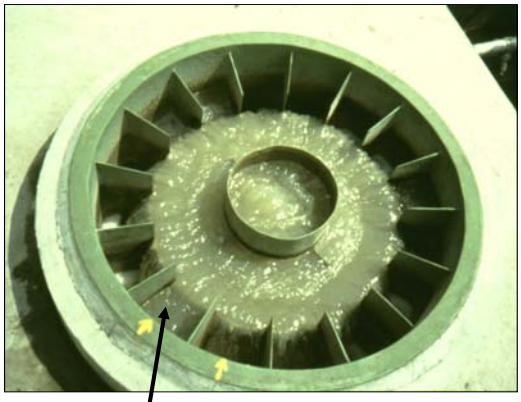
## Full-scale anaerobic sewage treatment plant, Bucaramanga, Colombia



Río Frío WWTP (0,74 $m^3/s$)



## Polyester Circular Distribution Box



*Clogged inlet pipe*

*Maintenance (declogging)*

## BUCARAMANGA, Colombia – Pre-Treatment



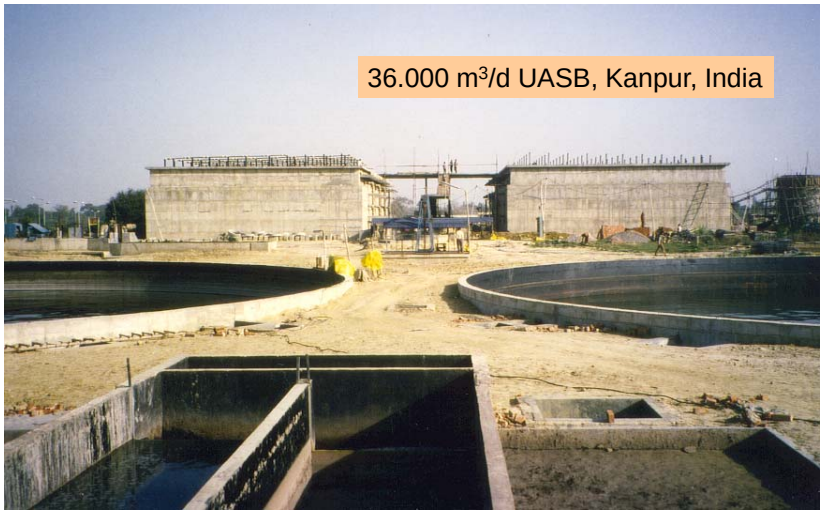
## Odour combatement, closed reactor system

Scum removal

## Stainless steel, rectangular influent distribution



## Anaerobic treatment of domestic sewage, India



# Full-Scale Experience in Brazil

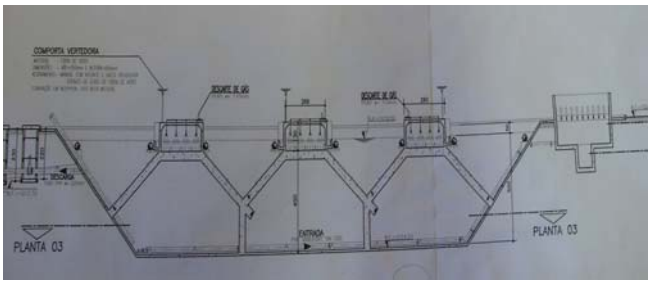
48,000 $m^3$ UASB Curitiba (Atuba Sul)

24 modules of 2000 $m^3$ each



# CURITIBA, Brasil - Atuba Sul WTW

## Engineering details, UASB Brasil



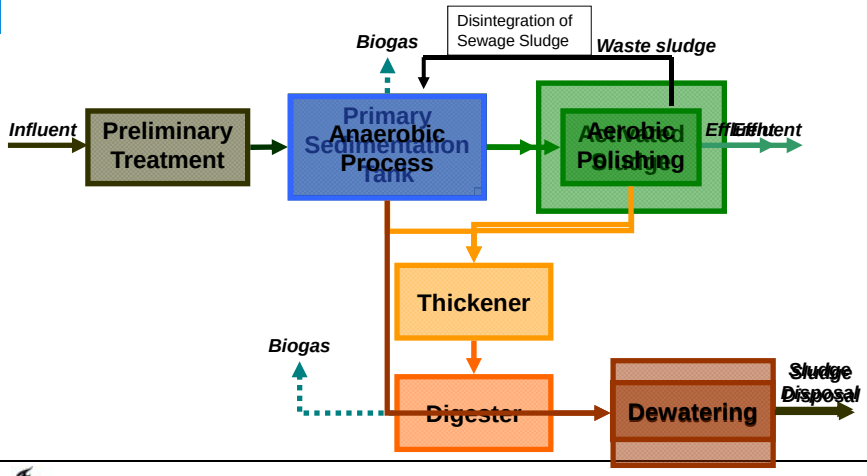



## UASB as Pre-Treatment in Sao Paulo, Brasil

Piracicaba WWTW

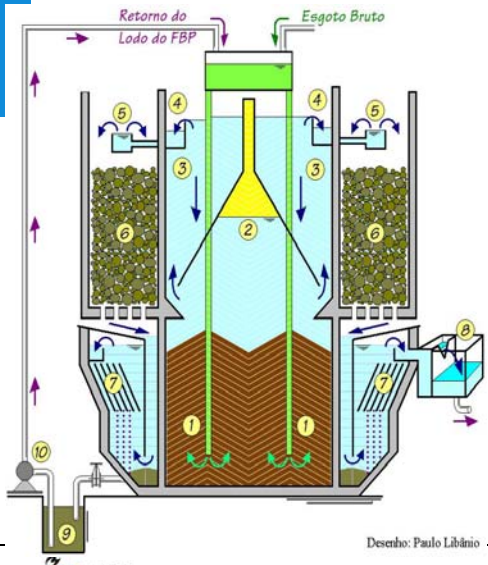
Rio Claro WWTW

## Conventional Activated Sludge vs Integrated Anaerobic & Aerobic Treatment






## Integrated anaerobic treatment – post treatment, Brasil




## Treatment of concentrated sewage: Middle East / Amman

Scum….

| | | |
|---|---|---|
| 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.



## Concentrated sewage: SRT prime design criterion!

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

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

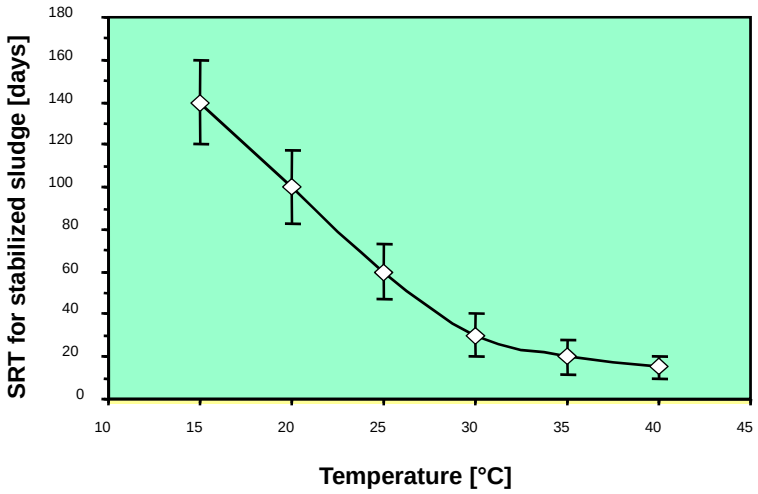
with X = concentration of viable biomass in $kg/m^3$ (e.g.methanogens).
V = reactor volume ($m^3$)
Q = flow $m^3/d$

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






## Role of anaerobic technology in the "water chain"

Jordan

Yemen

Egypt

Scavenger of solids
Mineralisation of organic matter
Removal of heavy metals
Filtration of Helminth eggs ??
Provider of essential nutrients ($NH_4^+$,$PO_4^{3-}$)
Production of stabilised soil conditioner
Energy producer (for local use)

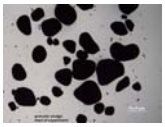
## Cost-effective adjustment effluent N for re-use

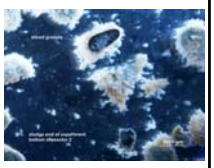
PhD research Ghada Kassab (2009)

- Necessity depends on growth stage and cropping season
- UASB used for N solubilisation and denitrification
- N is oxidised in post treatment and recycled to UASB







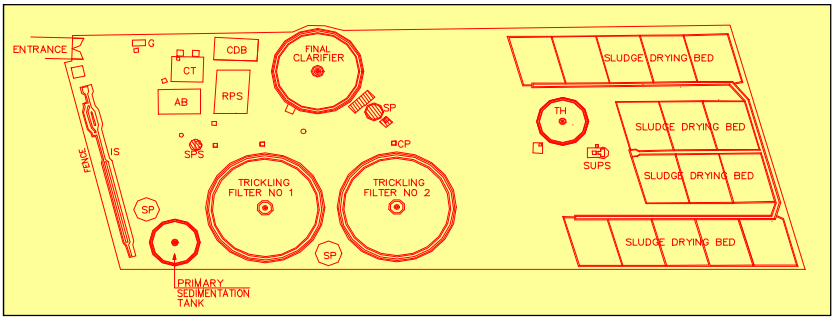
- System stability
- Long-term reliability
- On-off switch possible



## OPEX / CAPEX reduction as driver

Full scale UASB application:
Sanhour, Fayoum, Egypt
(June 2006)

Existing plant:
Overloaded trickling filters



## Proposed Treatment Processes Options

- Option (1): UASB + Trickling Filters
- Option (2): UASB + Trickling Filters + Activated Sludge
- Option (3): Activated Sludge Process
- Option (4): Lagoons (no land available)



## Comparison of options

| Description | UASB+TF | UASB+TF+AS | AS |
|---|---|---|---|
| $COD_{effl}$ (80 mg/l) | 80 | 80 | 80 |
| $BOD_{effl.}$ (60 mg/l) | 30 | 15 | 15 |
| $TSS_{effl.}$ (50 mg/l) | 20 | 20 | 20 |
| Investments (MEuro) | 0.93 | 1.07 | 1.47 |
| O&M (euro/year) | 14,795 | 27,345 | 110,964 |
| Remarks | | Complicated Operation | High Energy + Complex Sludge treatment |

UASB = upflow anaerobic sludge bed
TF = trickling filter
AS = activated sludge

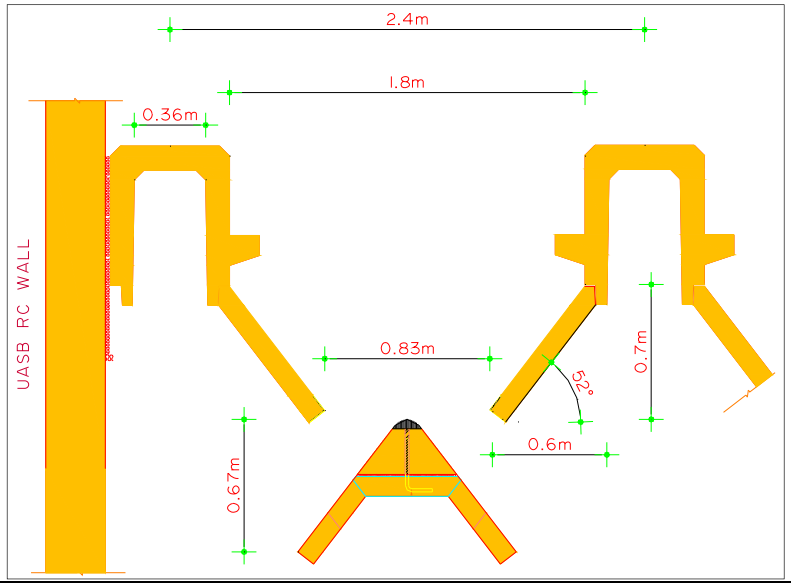
## Full scale UASB, Sanhour, Egypt

First feasibility studies: mid eighties..



## Post-commissioning: GLSS gas leakages

# GLSS Sanhour



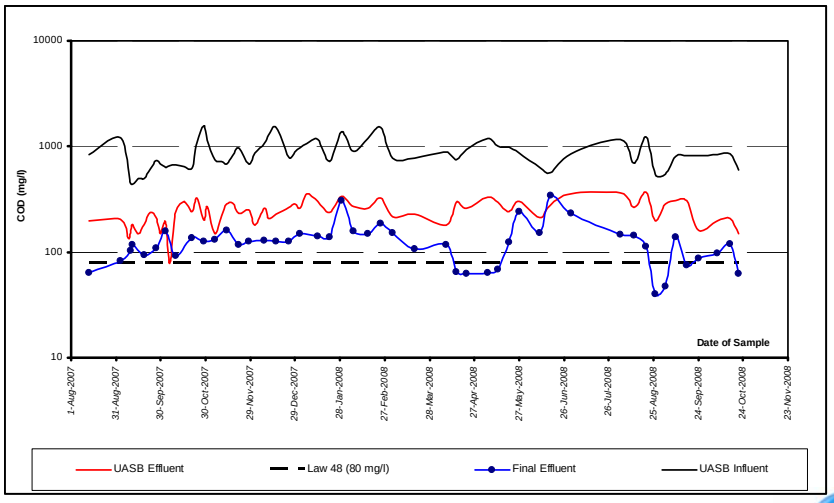



# GLSS gas leakages

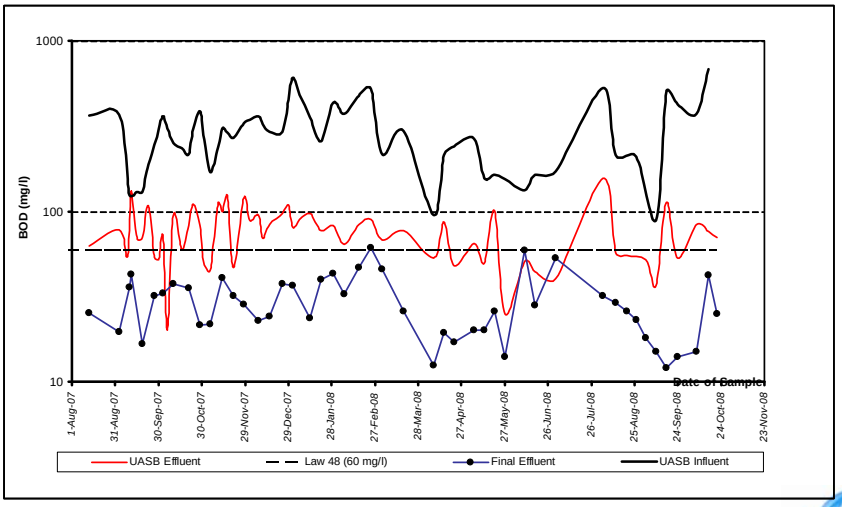
# GLSS gas leakages



# Sanhour WWTP COD Removal

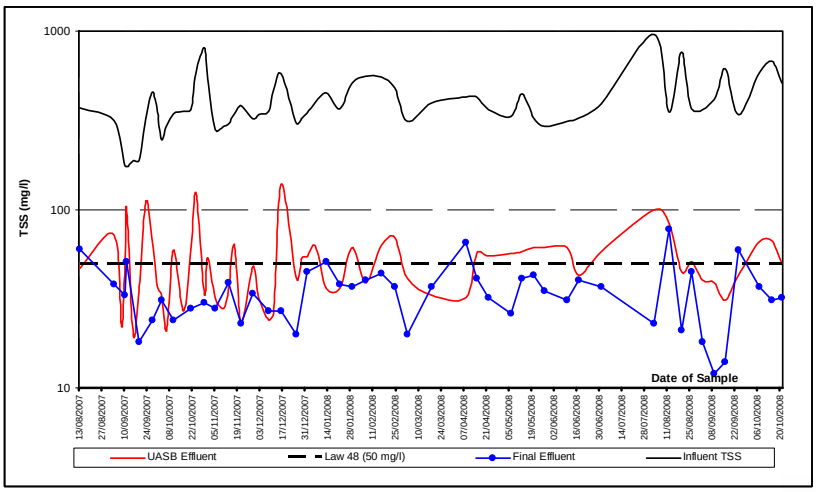


# Sanhour WWTP BOD Removal






# Sanhour WWTP TSS Removal



## Accra, Ghana: 6500 m³ UASB for Municipal Sewage

under construction


## Accra, Ghana: 6500 m³ UASB for Municipal Sewage

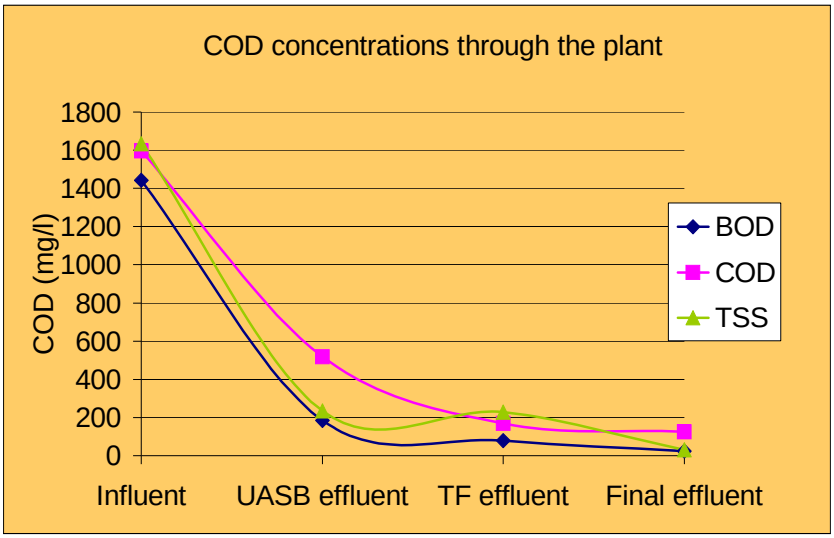
RESULTS 'START-UP' phase (in mg/l):

| | 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 !!

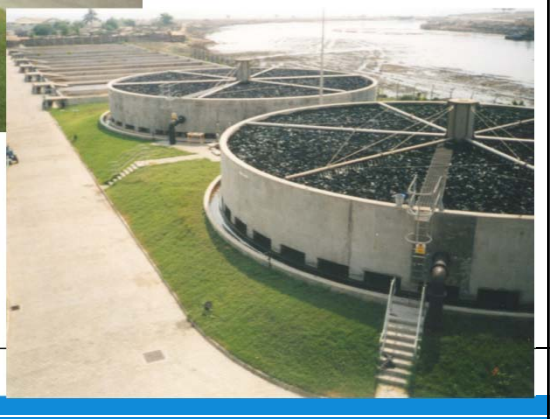
COD efficiency (entire plant): 92%
BOD / TSS efficiency: 98%
HRT: 20-24 h
OLR: 1.6 (0.3 – 6.1) kg/m³/d

## Treatment results UASB + TF, Accra, Ghana.






## Trickling filters (in operation), Accra, Ghana

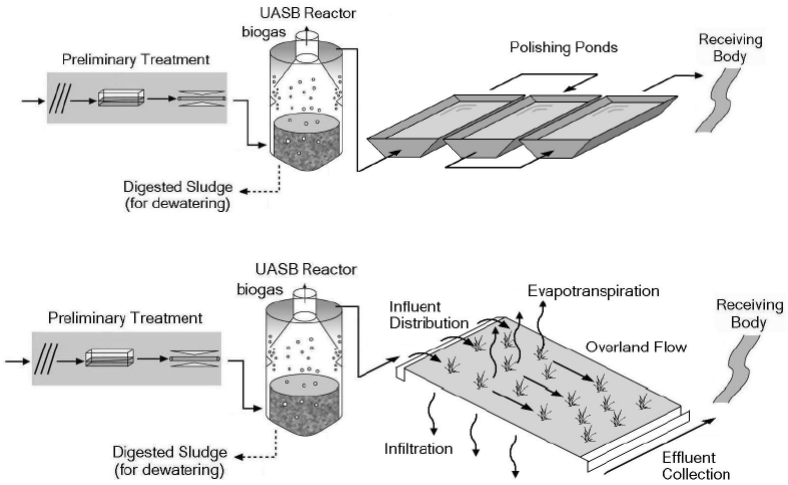
Trickling filters

## Final clarifiers in operation, Accra, Ghana

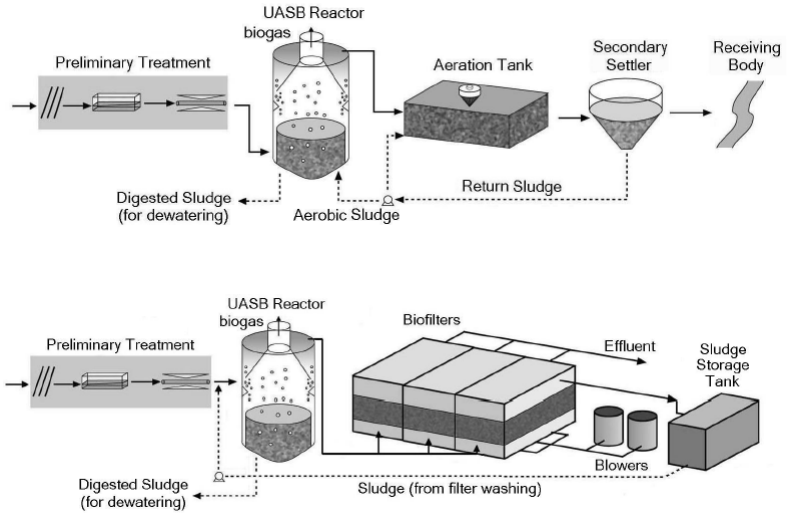
Final effluent



## UASB - Post treatment Options, 1-2 (after Chernicharo, 2005)

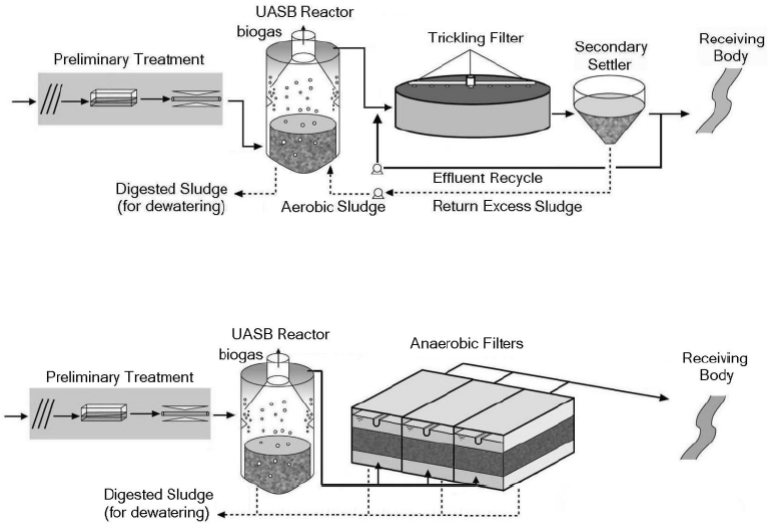


## UASB - Post treatment Options, 3-4 (after Chernicharo, 2005)

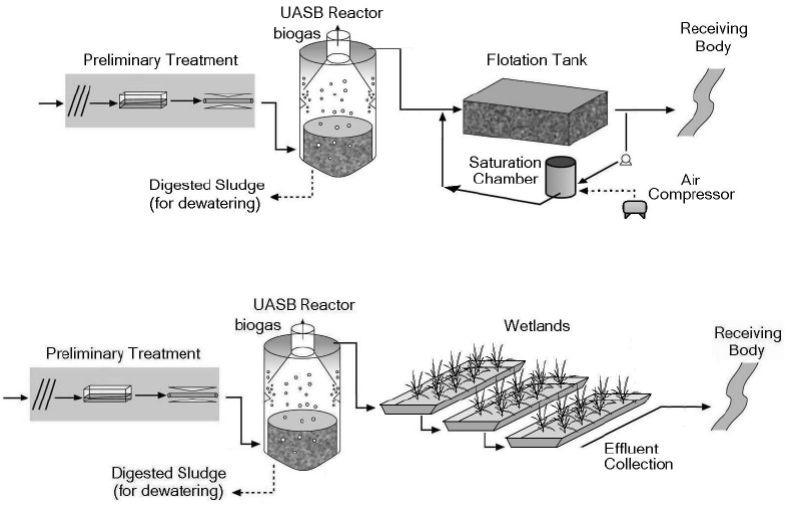





## UASB - Post treatment Options, 5-6 (after Chernicharo, 2005)



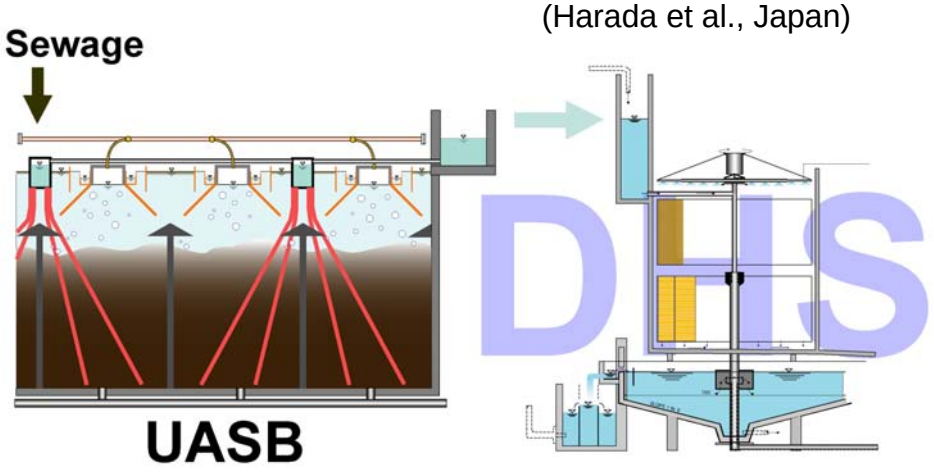
## UASB - Post treatment Options, 7-8 (after Chernicharo, 2005)






## Innovative, compact & cost-effective approach:

(Harada et al., Japan)



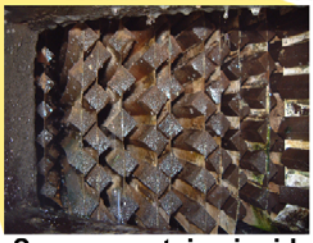

**Combination of UASB and DHS**

## 1000 $m^3$/d Demonstration Scale DHS Biotower in Karnal, India

**Constructed by Indian Government, under Yamuna Action Plan (YAP)**


DHS Biotower (1000 $m^3$/d)

Wastewater distributor



Sponge curtains inside the biotower

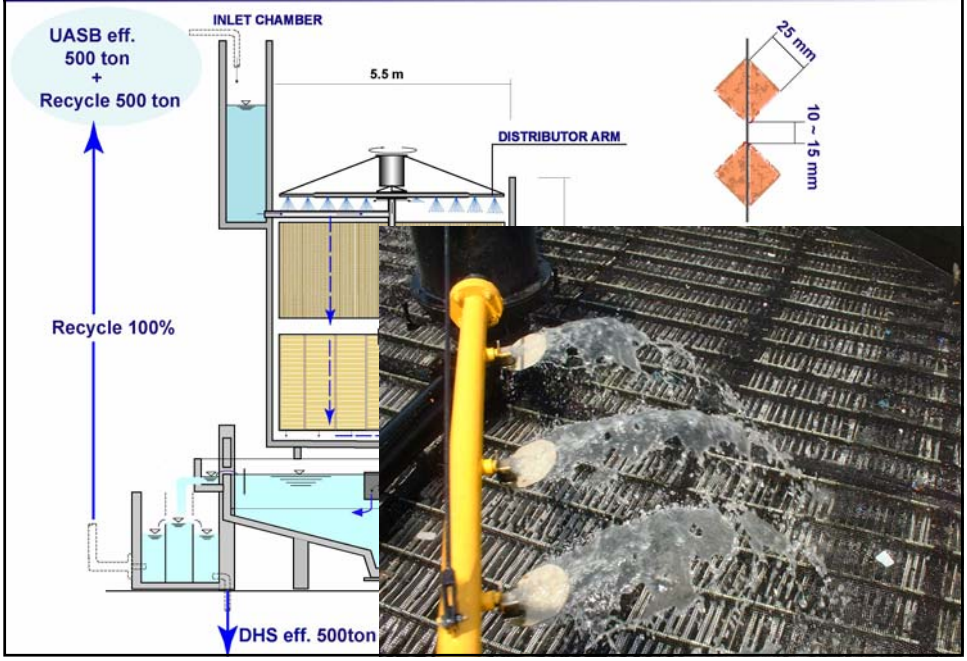
HRT: 1.5h

P.E. 7,000

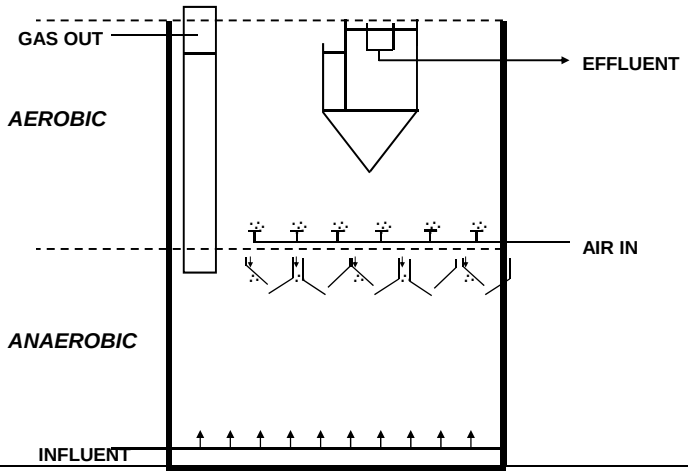
**In operation since Sept. 2002**

## DHS - Biotower

Prof. Harada, Nagaoka University, Japan

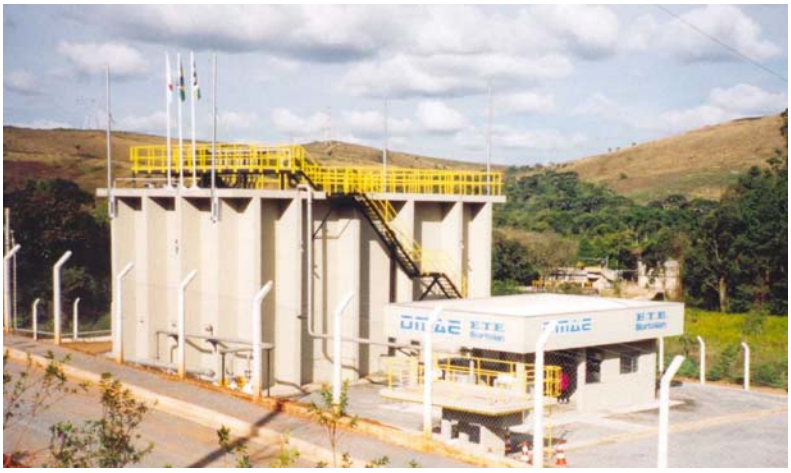


## BIOPAQ® UBOX
## Integrated anaerobic–aerobic treatment system






PAQUES



**BIOPAQ® UBOX Sewage Treatment Plant**
**Poços de Caldas, Brazil - 10.000 inhabitants**