Treatment of Municipal Wastewater in Upflow Anaerobic Sludge Blanket (UASB) Reactor

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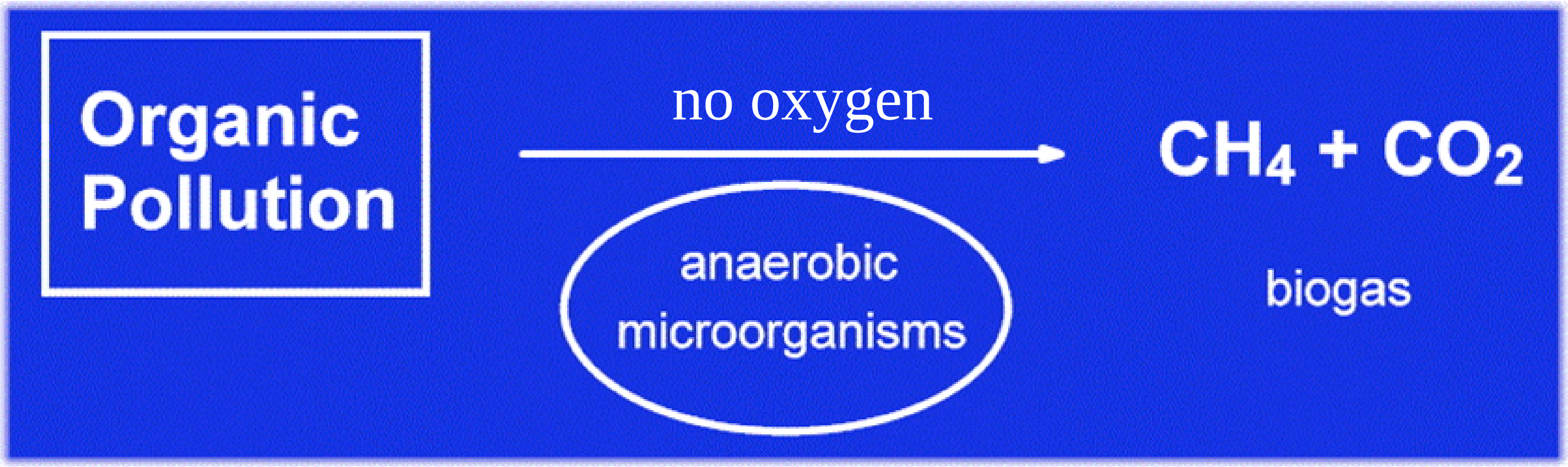
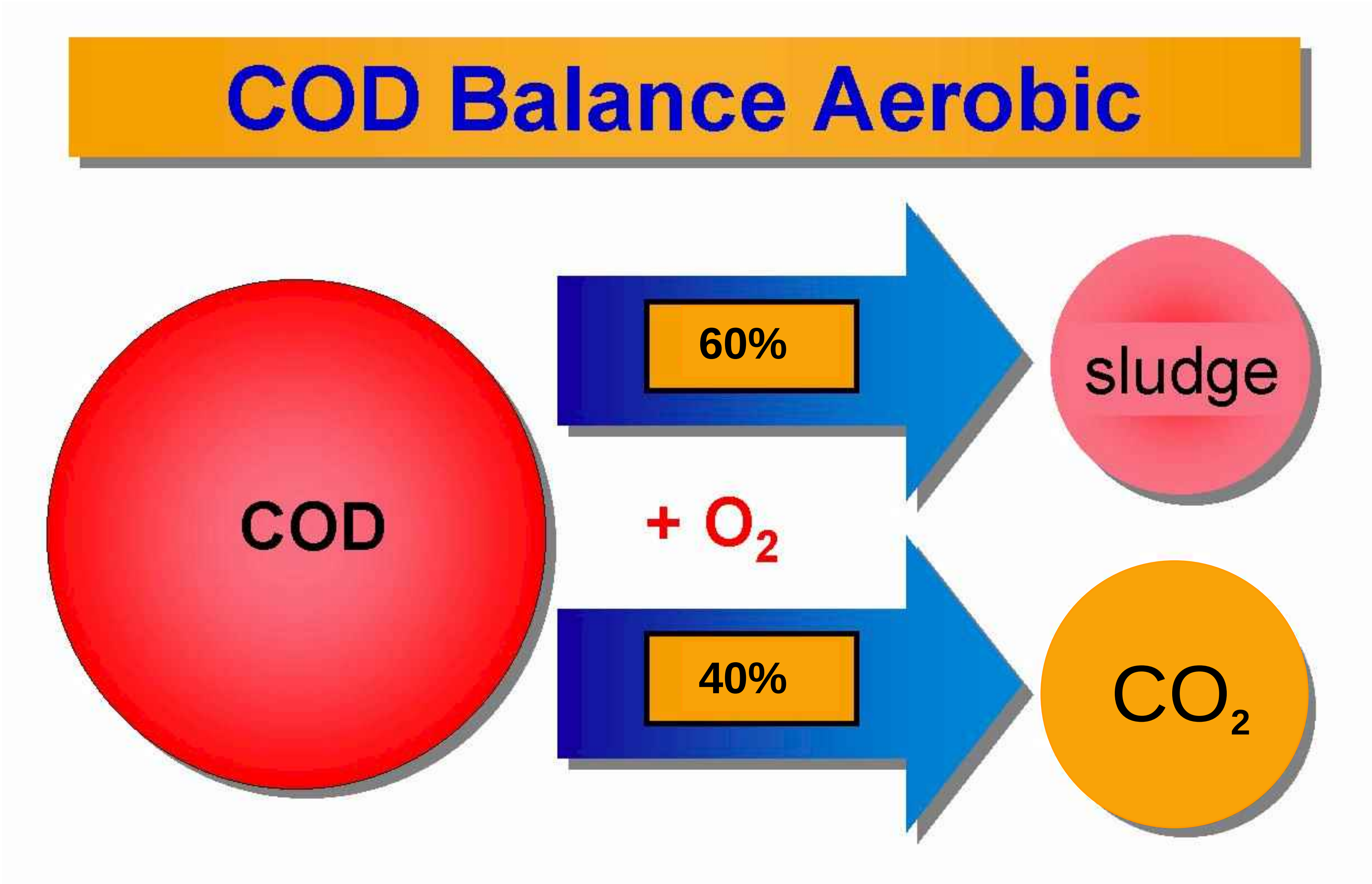
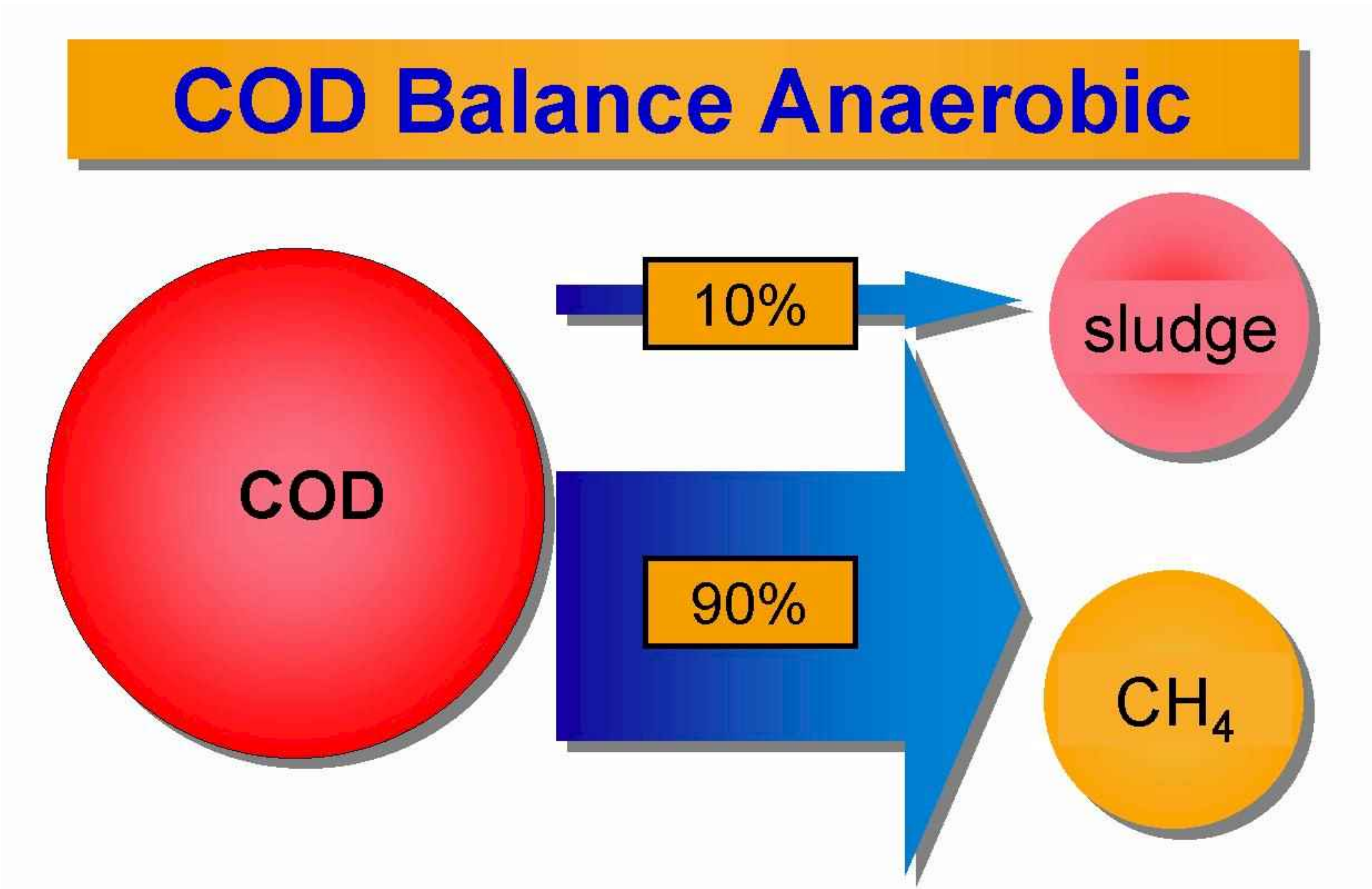
What is Anaerobic Biodegradation?



COD Balance Aerobic Biodegradation

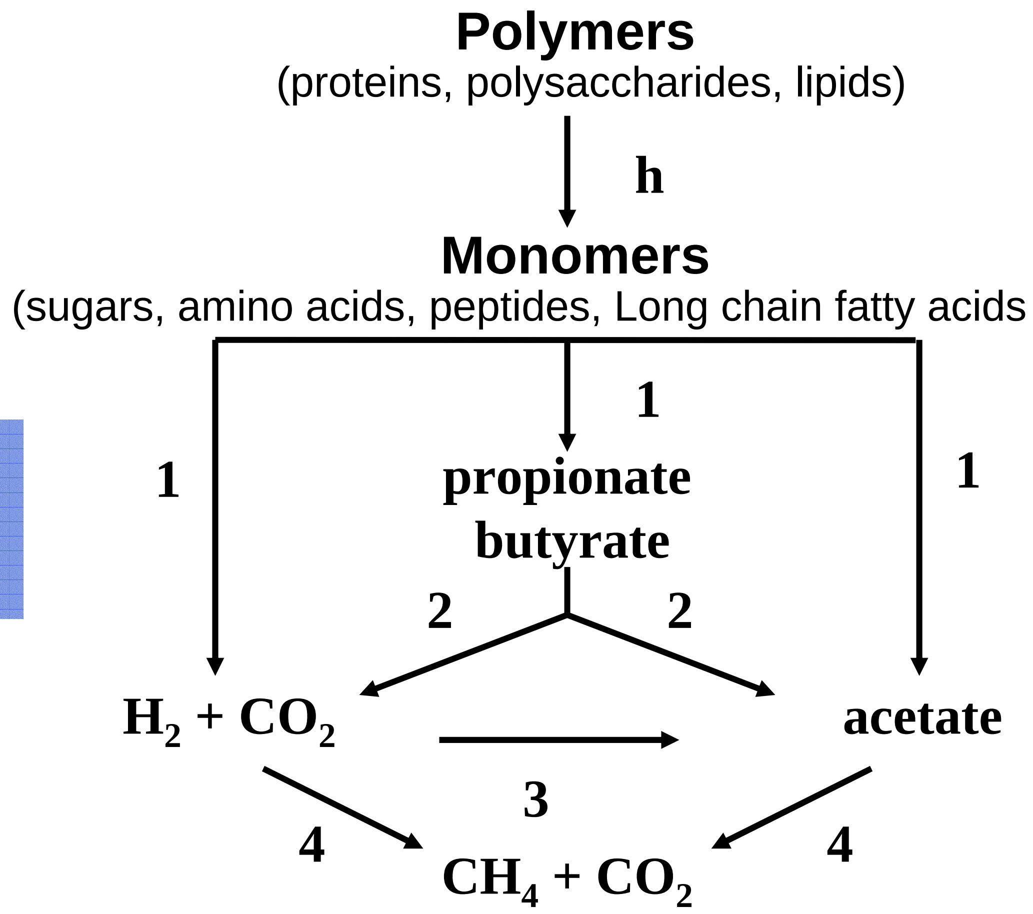


COD Balance Anaerobic Biodegradation



Overview Anaerobic Biodegradation

Methanogenic Consortium

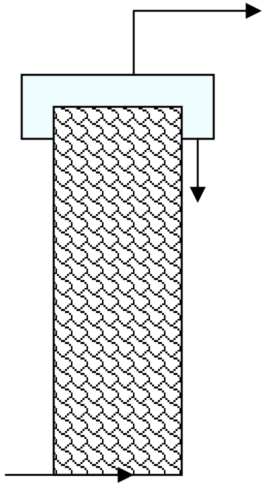


h Hydrolytic enzymes
1 Fermentative bacteria
2 Syntrophic acetogenic bacteria
3 Homoacetogenic bacteria
4 Methanogens

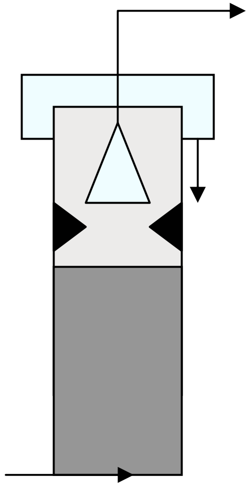
The benefits and drawbacks of anaerobic treatment of municipal wastewater in the high-rate anaerobic systems.

Benefits	Draw backs
1. Efficient in the removal of organic material especially for tropical regions (developing countries).	1. Long start-up period when seed sludge is not available, as the growth rate of methanogenic microorganisms is low.
2. Low construction cost and small land requirements as generally at temperatures >20^{o}C high loading rates can be applied.	2. Low pathogen removal.
3. Low operation and maintenance costs, as energy consumption is low and little equipment is needed.	3. Requirement for post treatment to reach the effluent standards, depending on the requirements for effluent standards.
4. Lower sludge production as compared to aerobic and physical-chemical treatment processes.	4. Low removal efficiency of particulate organic material at low temperatures.
5. Biogas production, which can be used for energy production.	5. Risk for odour nuisance from the reduction of sulphate to sulphide.

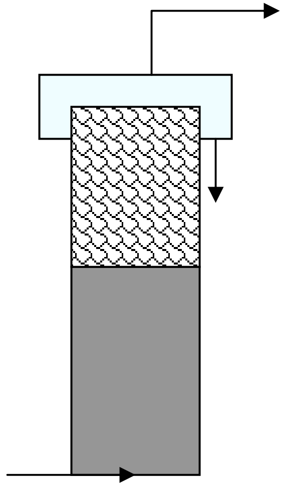
High-rate anaerobic systems



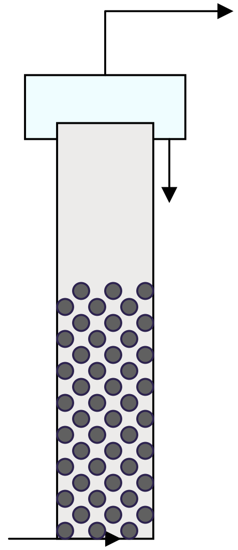
Upflow anaerobic filter (AF)



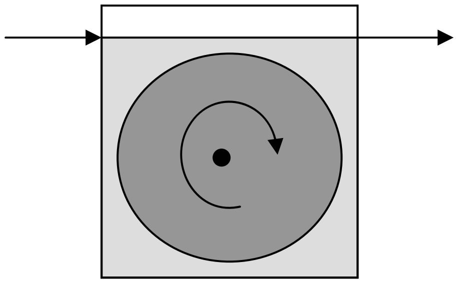
UASB reactor



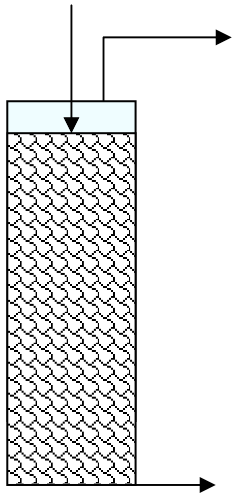
Anaerobic hybrid (AH) reactor



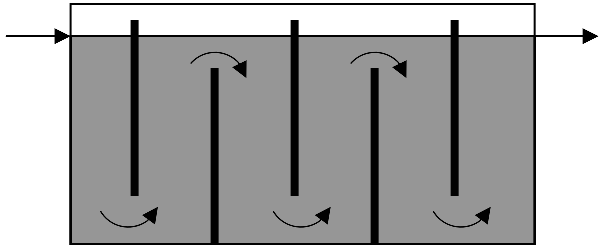
Anaerobic fluidised bed (AFB) reactor



Anaerobic rotating biological contactor

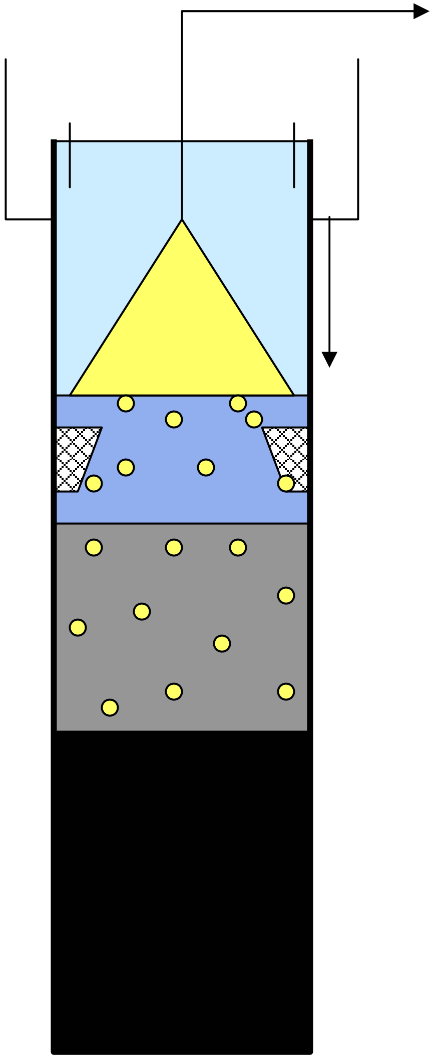


Down flow anaerobic filter

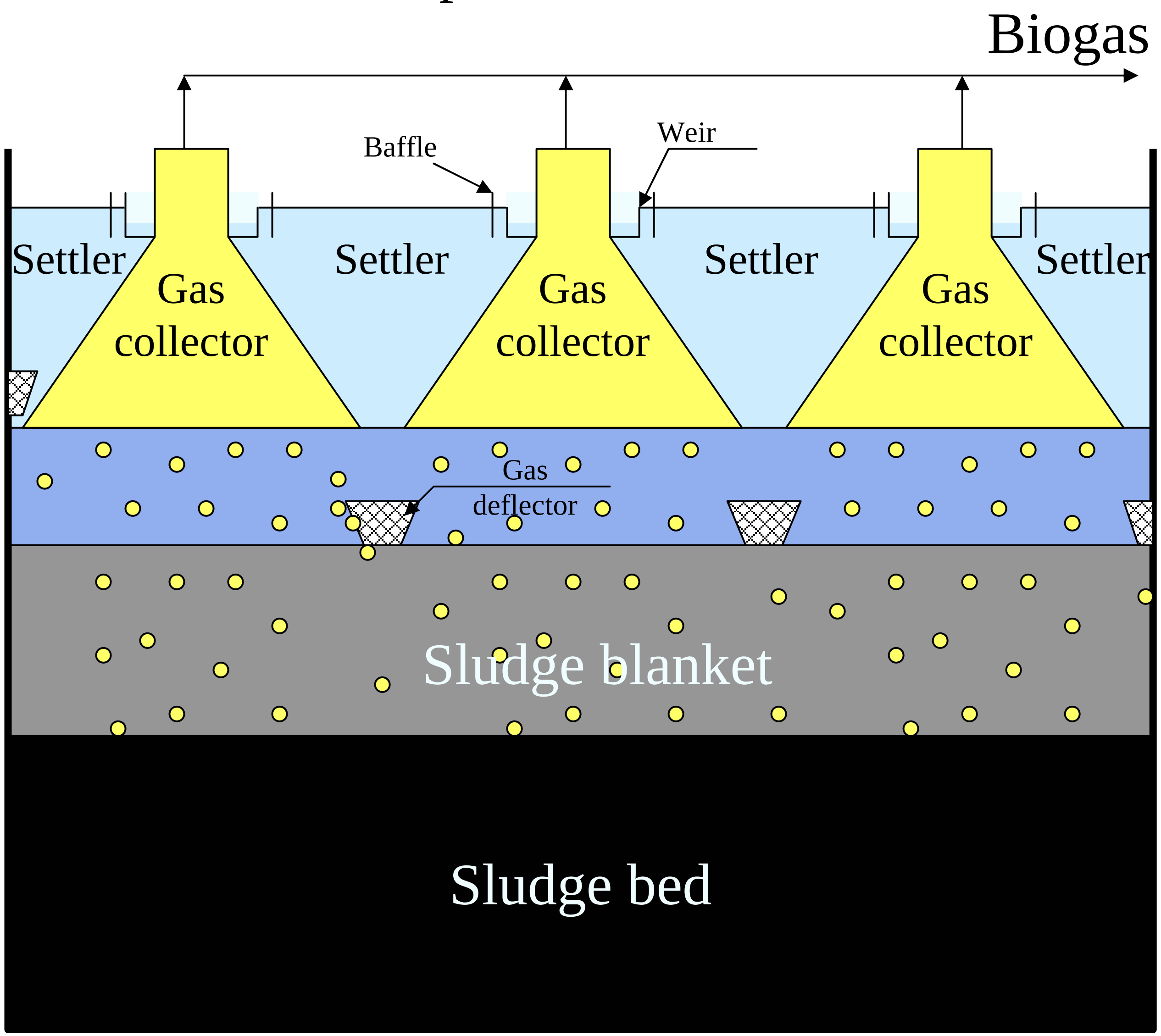


Anaerobic baffled reactor

UASB reactor main components

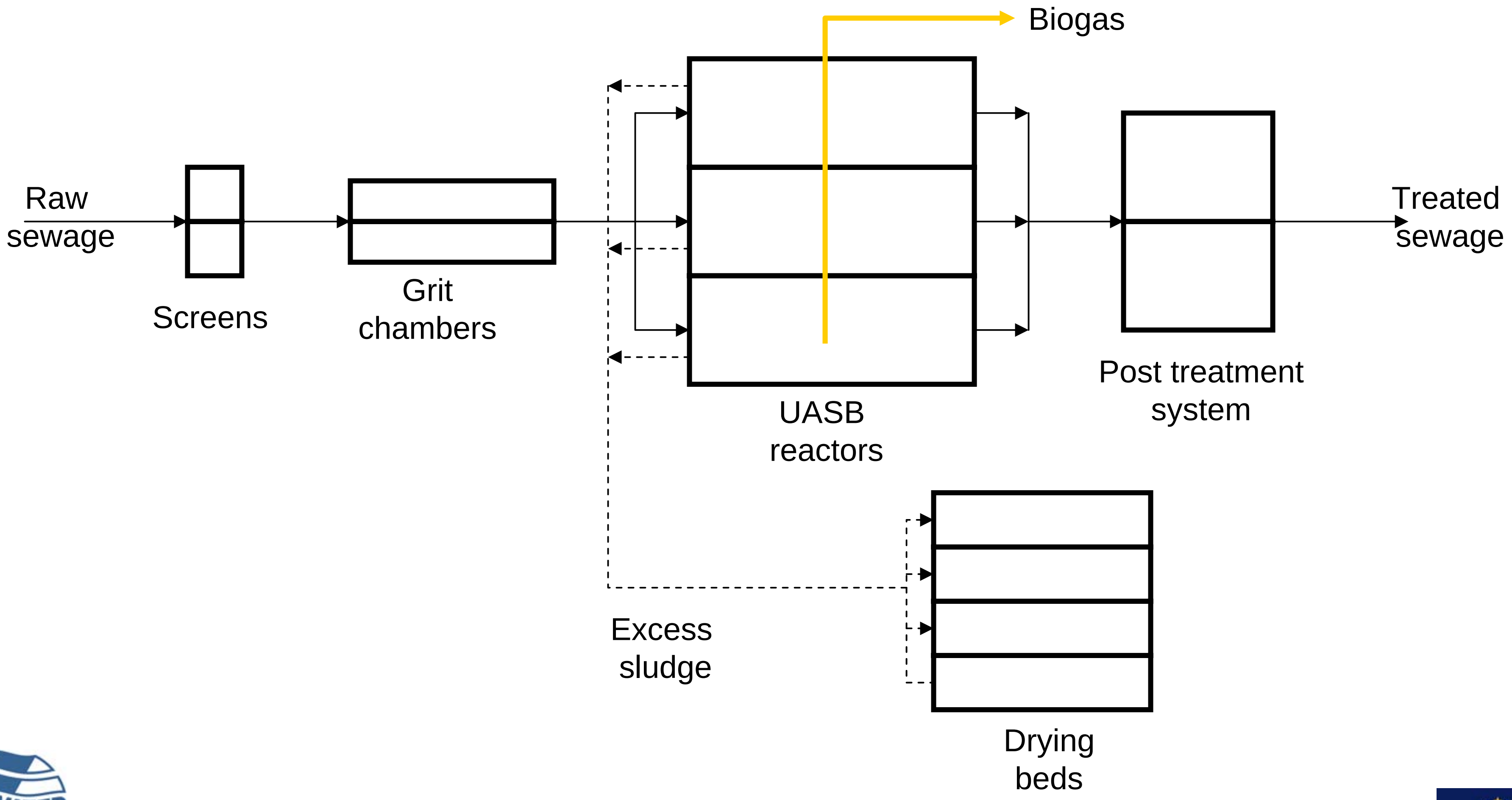


Small scale UASB



Large scale UASB reactor

Basic configuration for the anaerobic treatment-plant of municipal wastewater



Factors affect on the removal of the dissolved organic matter in the UASB reactor

Although, the removal of dissolved matter is mainly a biological process, some physical aspects are also involved, like temperature, solubility of gases, wastewater viscosity.

At low temperature:-

A lower mixing will prevail in the sludge bed in systems operated at low temperatures, as the solubility of gases increases at declining temperatures.

Moreover, as viscosity increases at lower temperatures, more energy is required for mixing and diffusion of soluble compounds.

For optimization of soluble substrates removal at low temperatures: -

A high concentration of active biomass, a good contact between wastewater and biomass, and a good removal of SS are needed.

For treatment of raw or settled municipal wastewater at temperature > 15°C in the UASB reactor

HRT = 4 - 8 hours, (depending on the temperature and wastewater concentration)

Organic loading rate = 1 - 2 kg COD. m^{-3}. day^{-1}

Wastewater upflow velocity = 0.5 - 1.0 m/hour

<u>Average results in Latin America (Brazil, Mexico,..) and India</u>

COD removal	65 - 80 %
BOD removal	75 - 85 %
SS removal	75 - 85 %
Coliform removal	70 - 90 % (i.e. 1 log)
Helminth eggs	up to 100%

For treatment of raw or settled municipal wastewater at temperature < 15^{o}C in high-rate anaerobic systems

Hydrolysis is limited at low temperature

Options for treatment of raw or settled municipal-wastewater at temperature < 15^{o}C in high-rate anaerobic systems

1. One-step UASB reactor

For one-step UASB reactor, long HRT is needed,

At low temperature, HRT = 12 - 24 hours,
depending on the influent COD concentration and wastewater temperature

COD removal = 45- 65 %

Options for treatment of raw or settled municipal wastewater at temperature < 15°C in high-rate anaerobic systems

2. Two-step system: -

a. UASB + EGSB (expanded granular sludge bed), (Wang, 1994)

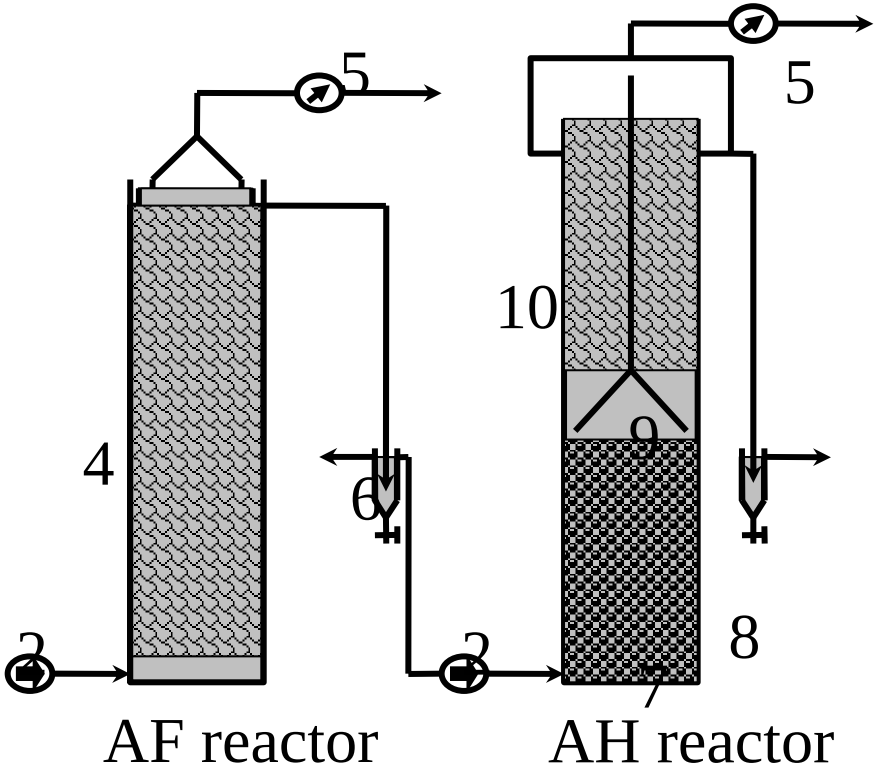
b. AF (anaerobic filter) + UASB (or AH, anaerobic hybrid), (Elmitwalli *et. al.*, 2002)

HRT

First step:- HRT = 3 - 4 hours

Second step:- HRT = 4 - 8 hours

COD removal = 50- 70 %



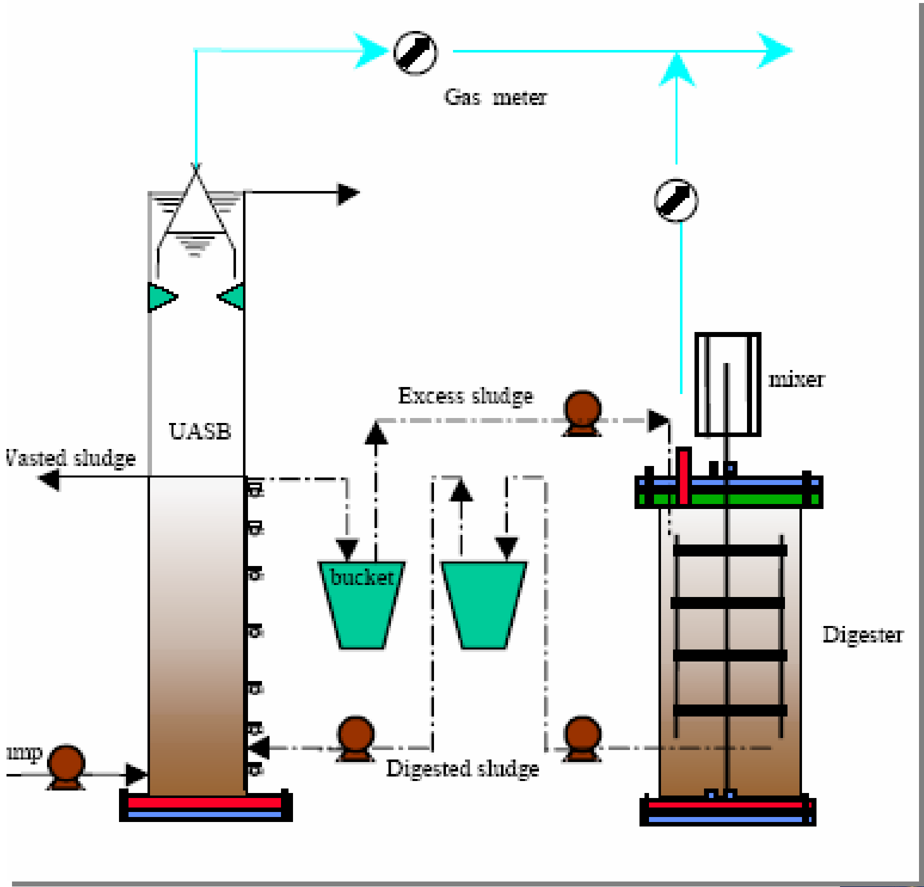
Options for treatment of raw or settled municipal wastewater at temperature < 15°C in high-rate anaerobic systems

3. UASB-Digester system (Mahmoud, 2002)

HRT of UASB = 6 - 8 h

HRT of the digester = 12 - 20 days

COD removal = 50- 70 %

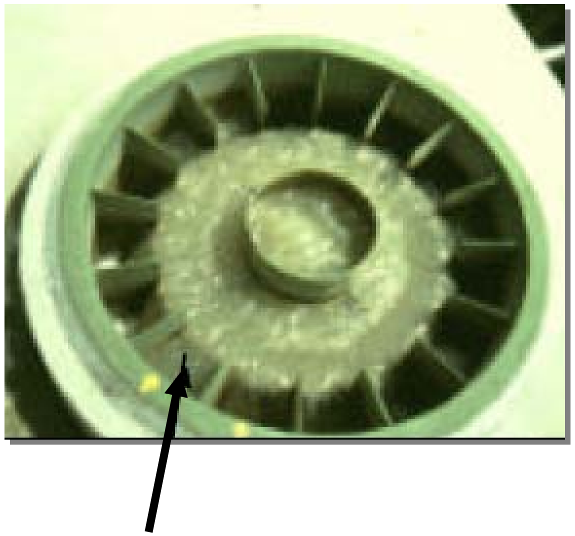


Feed inlet system for the UASB reactor

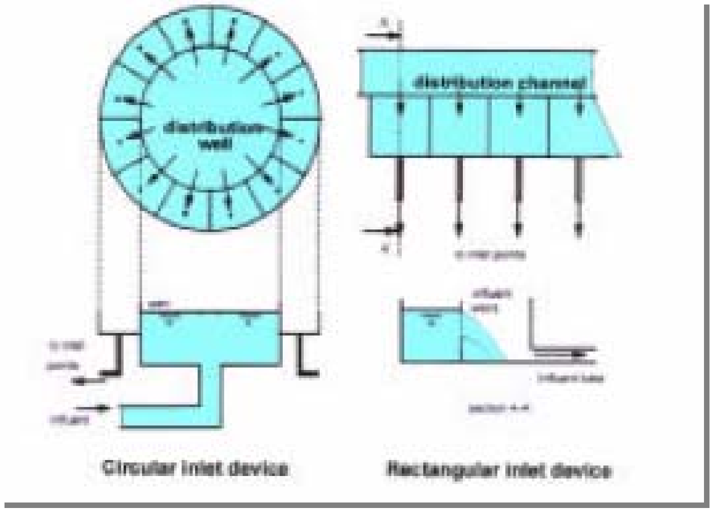
The main aim of feed inlet:-

1. To prevent channelling of the wastewater through the sludge bed,
2. To avoid formation of dead zones in the sludge bed.

Each inlet point serves (1- 2 m^2) in the bottom of the reactor



Clogged inlet tube



Internal view of 1200 m³ UASB, Cali, Colombia

Inlet pipe

Gas liquid solids separator (GLSS) device in the UASB reactor

The main aim:-

1. Separation between the biogas, sludge and wastewater,
2. Prevent the wash-out of biomass,
3. Prevent the wash-out of floating sludge

Design considerations:-

1. The slope = 45 - 60^{o},
2. The height = 1- 2 m,
3. Construction material should be again corrosion, stainless steel, coated concrete, plastic
4. The overlap between the GLSS and deflector = 10 - 20 cm.

Gas liquid solids separator

Discharge of excess sludge

For discharge of the excess sludge, the following pipes should be installed in the UASB reactors:-

1. Nearby the bottom of the reactor,
2. In the middle of the reactor height,
3. Under the GLSS device, 0.5-1 m beneath the GLSS.

Post treatment of the anaerobically treated municipal wastewater

The aim: -

1. Removal of pathogen,
2. Removal of the nutrients, depending on the effluent standards.

The most applied systems for the post treatment:-

1. Pond, Duckweed, Wetland,
2. Tricking filter,
3. Rotating biological contactor,
4. Aerated lagoon,
5. Activated sludge process.

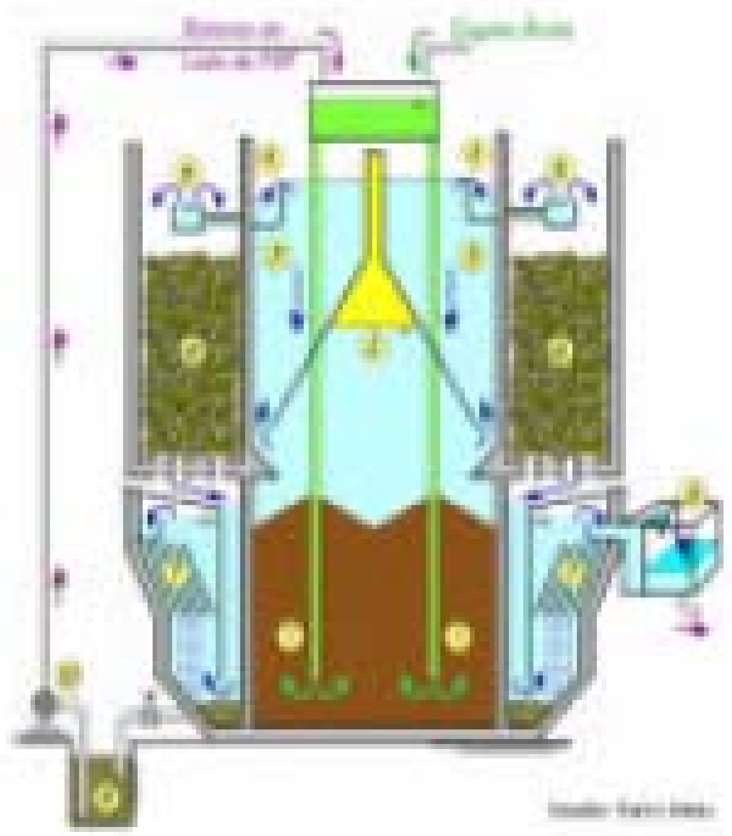
UASB + Trickling filter

UASB

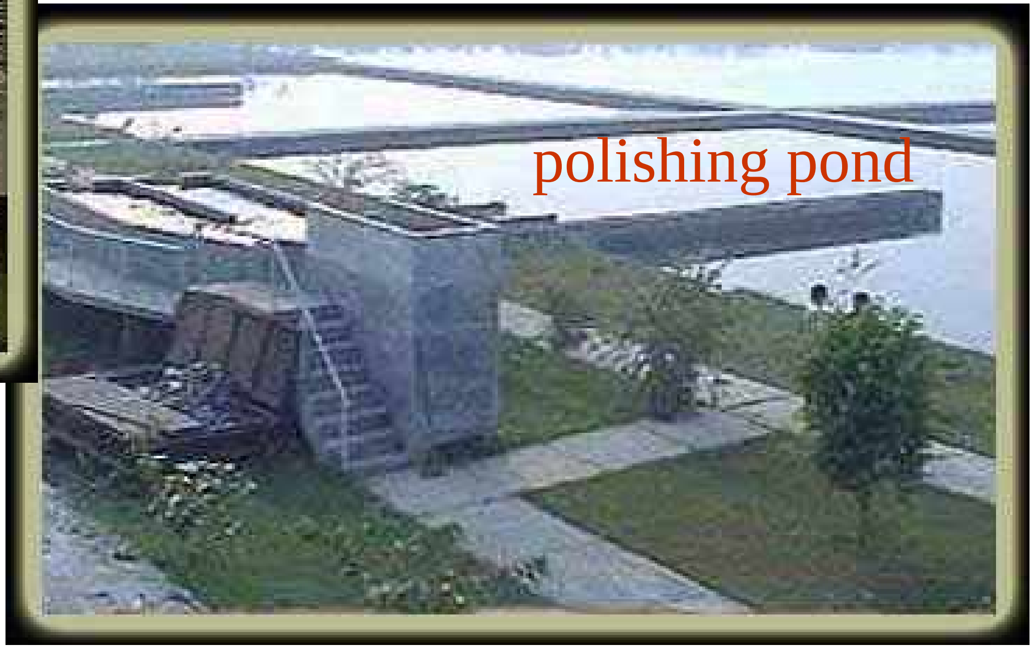
Screen

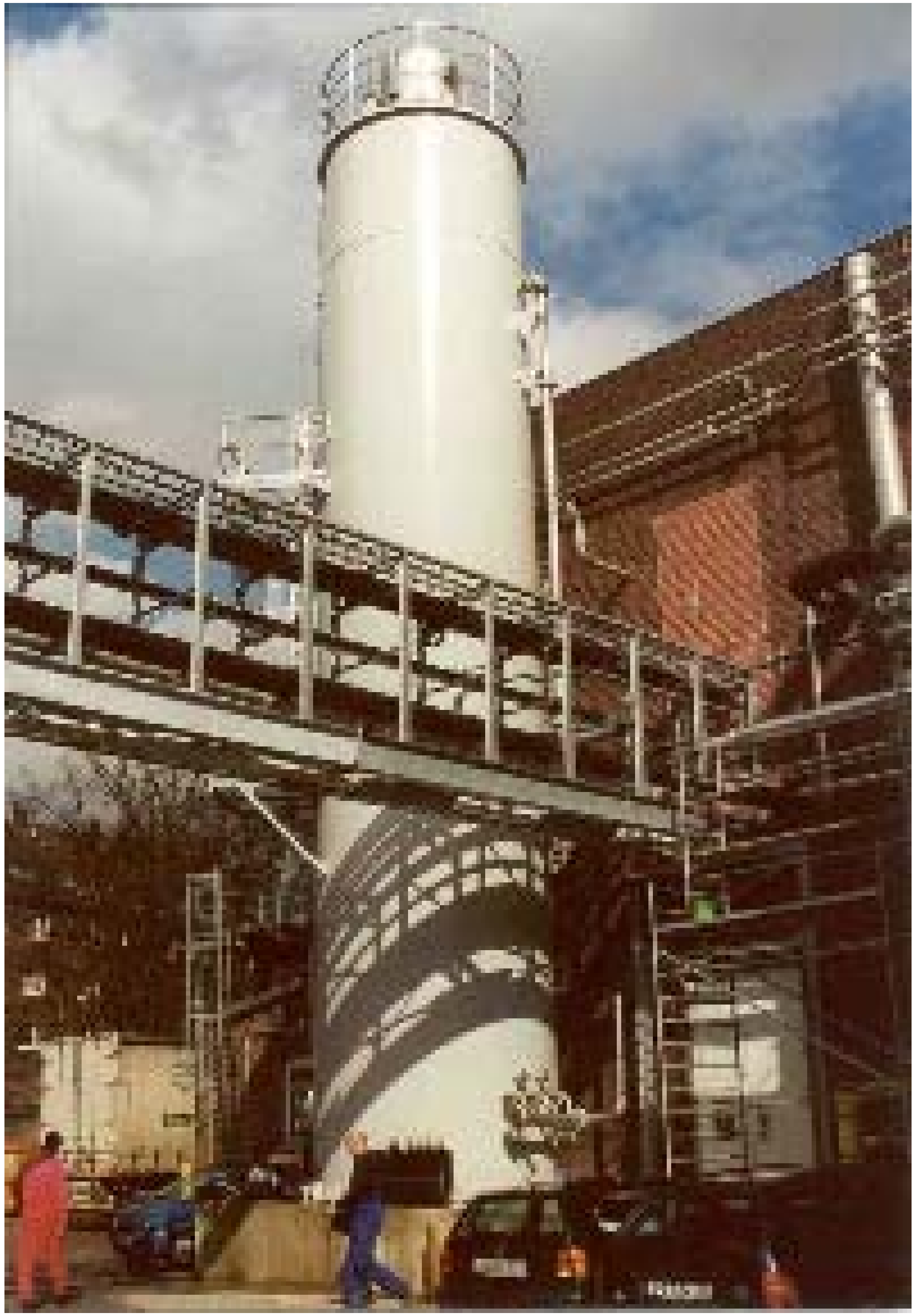
Trickling filter

UASB + Trickling filter



UASB + polishing pond





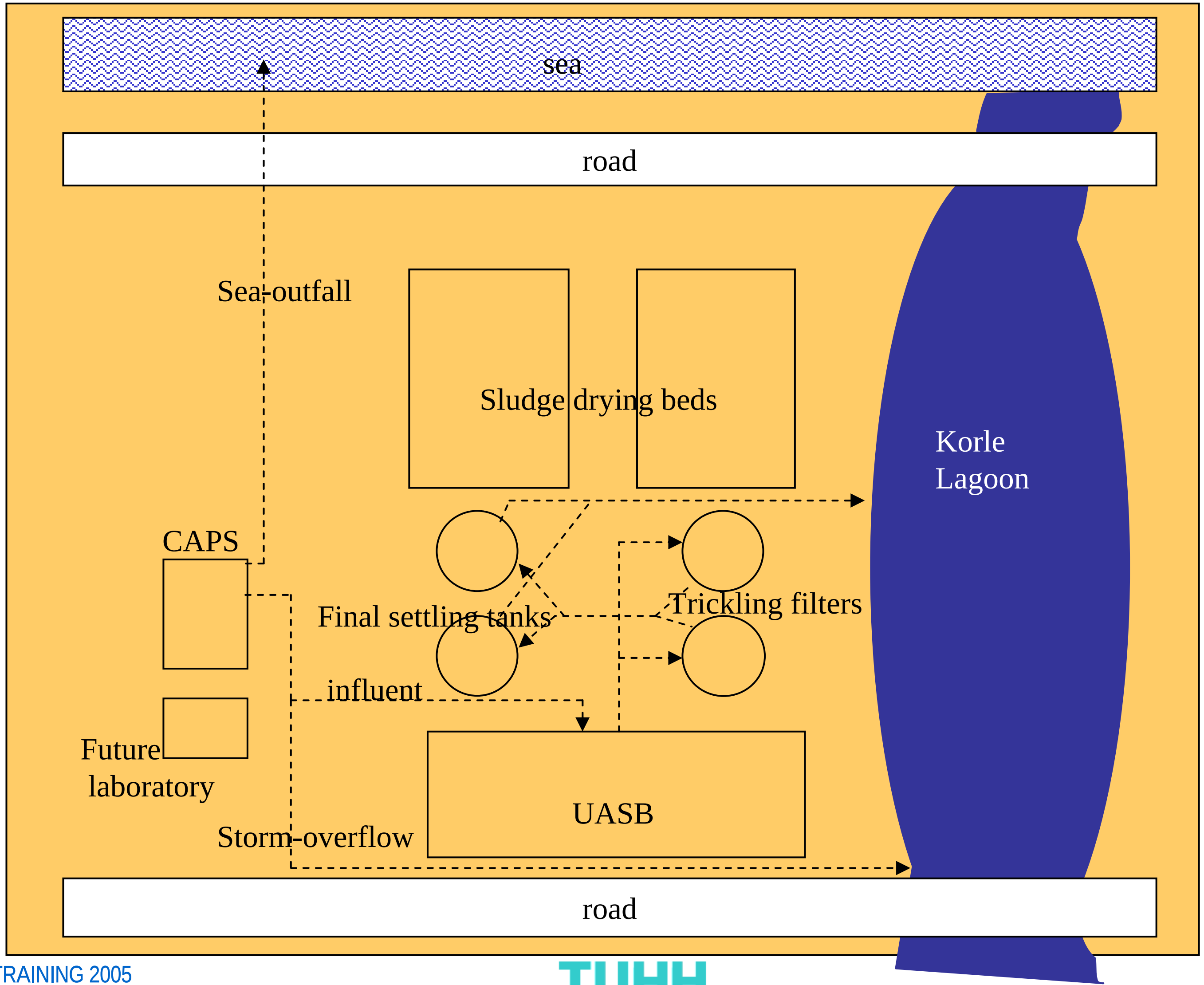
Papermill Schulte, Düsseldorf, Germany: closed water system

Pomdor AG - Sursee for distillery and fruit juice**, Switzerland**

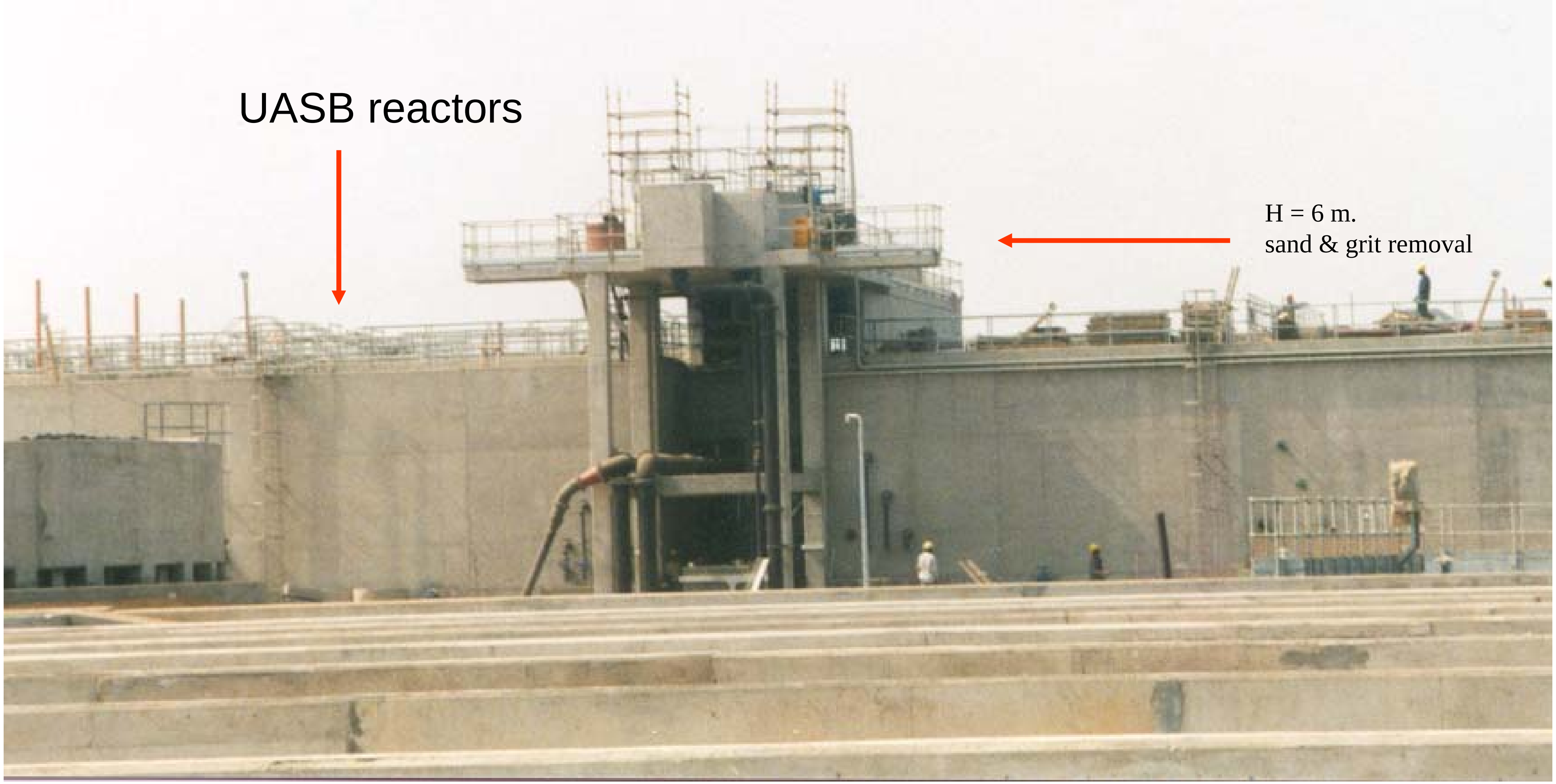
Accra, Ghana: Plant overview for Municipal Sewage Treatment

COD: 1,600 mg/l (peak: 16,000 !)   pH fluctuates: 5 – 12 (!)

BOD: 1,000 mg/l (peak: 3,000 !)

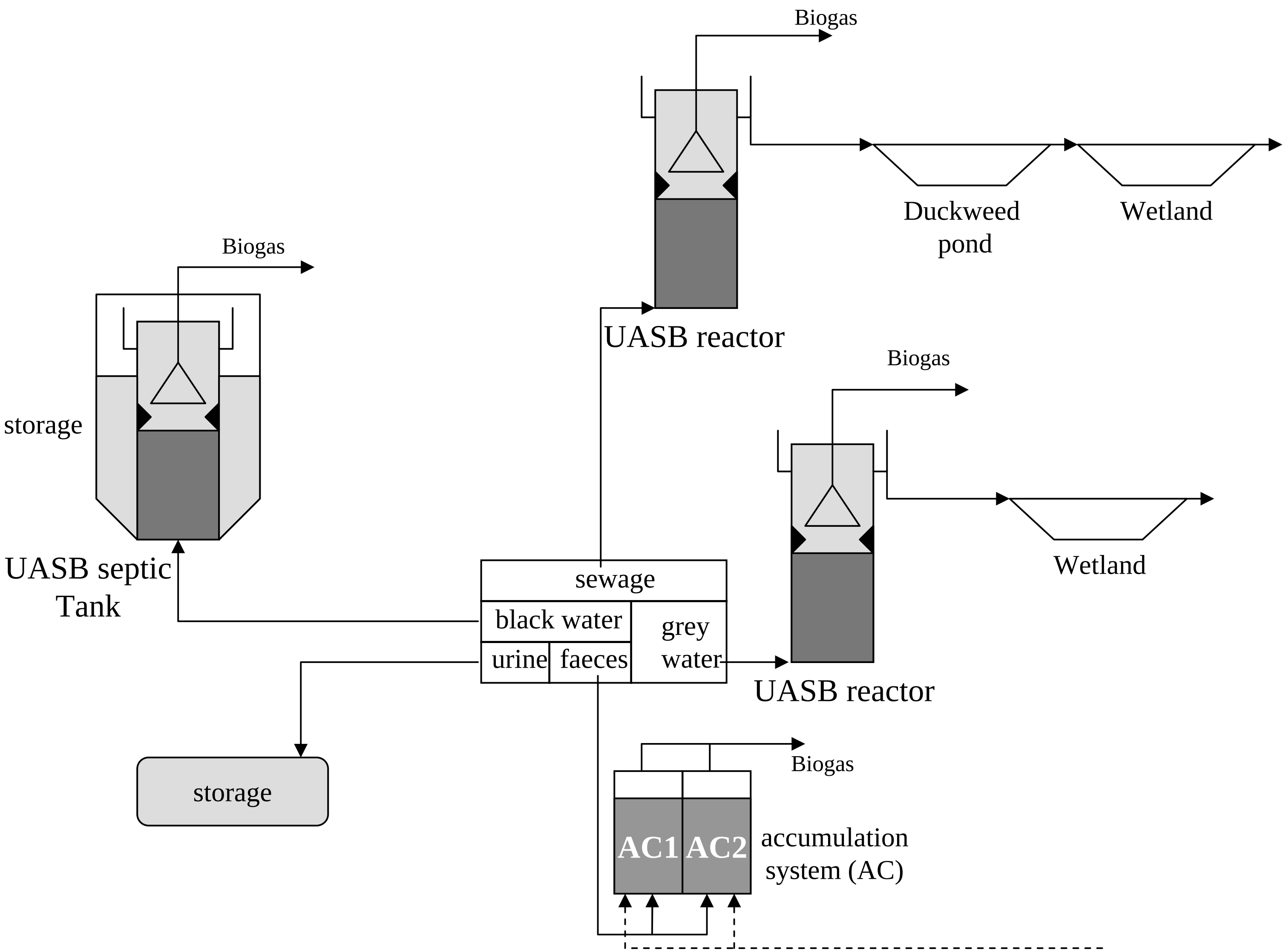


Accra, Ghana: 6500 m^3 UASB for Municipal Sewage
UASB reactor volume 6 x 1100 m^3



Modular Design UASB Reactors

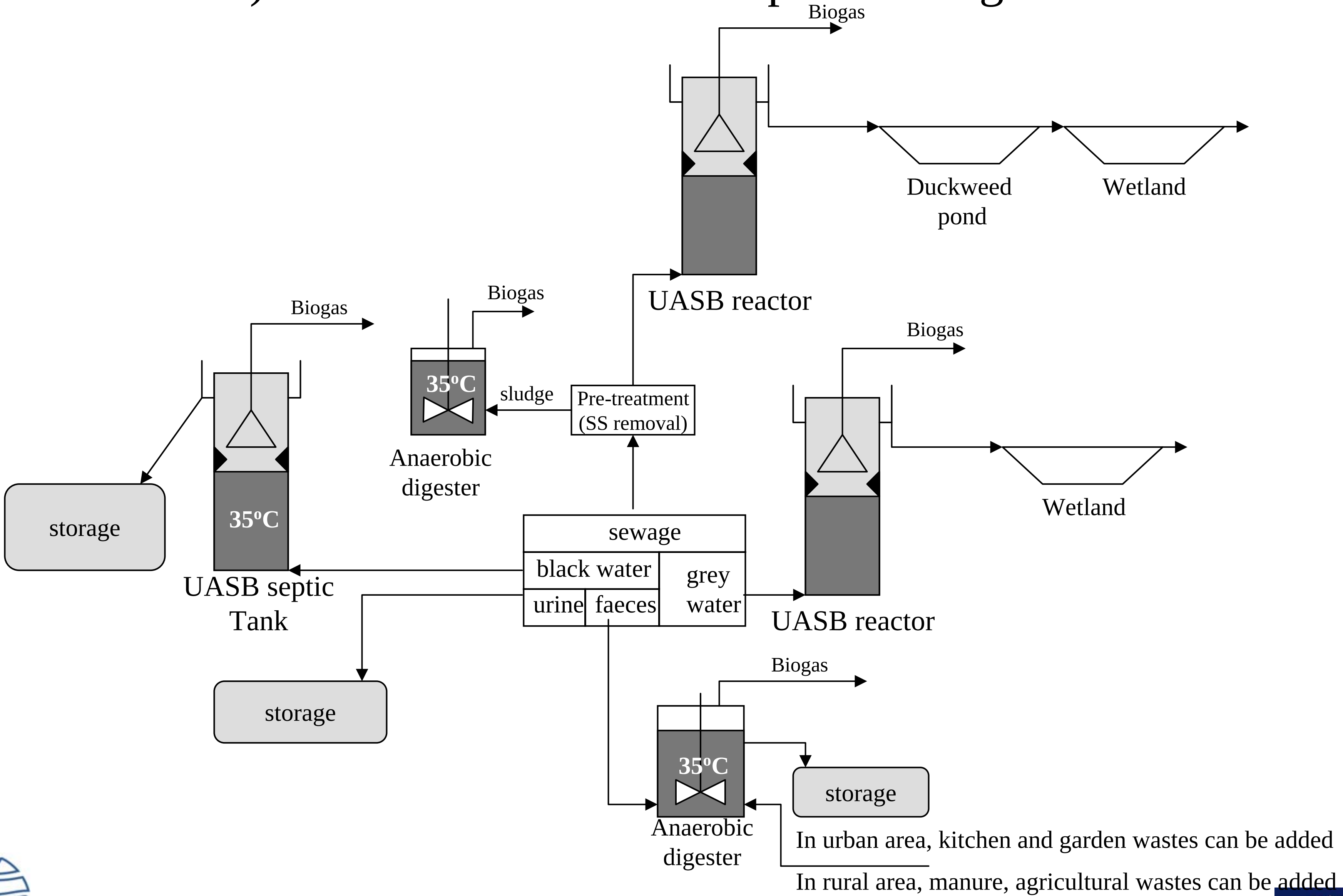
Application of the anaerobic treatment in ecological sanitation
A) in tropical and sub-tropical region



In urban area, kitchen and garden wastes can be added

In rural area, manure, agricultural wastes can be added

Application of the anaerobic treatment in ecological sanitation
B) in moderate and low temperature region



References

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2. LeAF foundation(http://www.ftns.wau.nl/lettinga-associates/)

3. Mahmoud N. (2002). *Anaerobic pre-treatment of sewage under low temperature (15^{o}C) conditions in an integrated UASB-digester system*. Ph. D. thesis, Sub-department of Environmental Technology, Wageningen University, The Netherlands.

4. Yamuna Action Plan (http://yap.nic.in/research-development.asp

5. Wang K. (1994) Integrated anaerobic and aerobic treatment of sewage. Ph. D. thesis, Department of Environmental Technology, Wageningen University, The Netherlands.