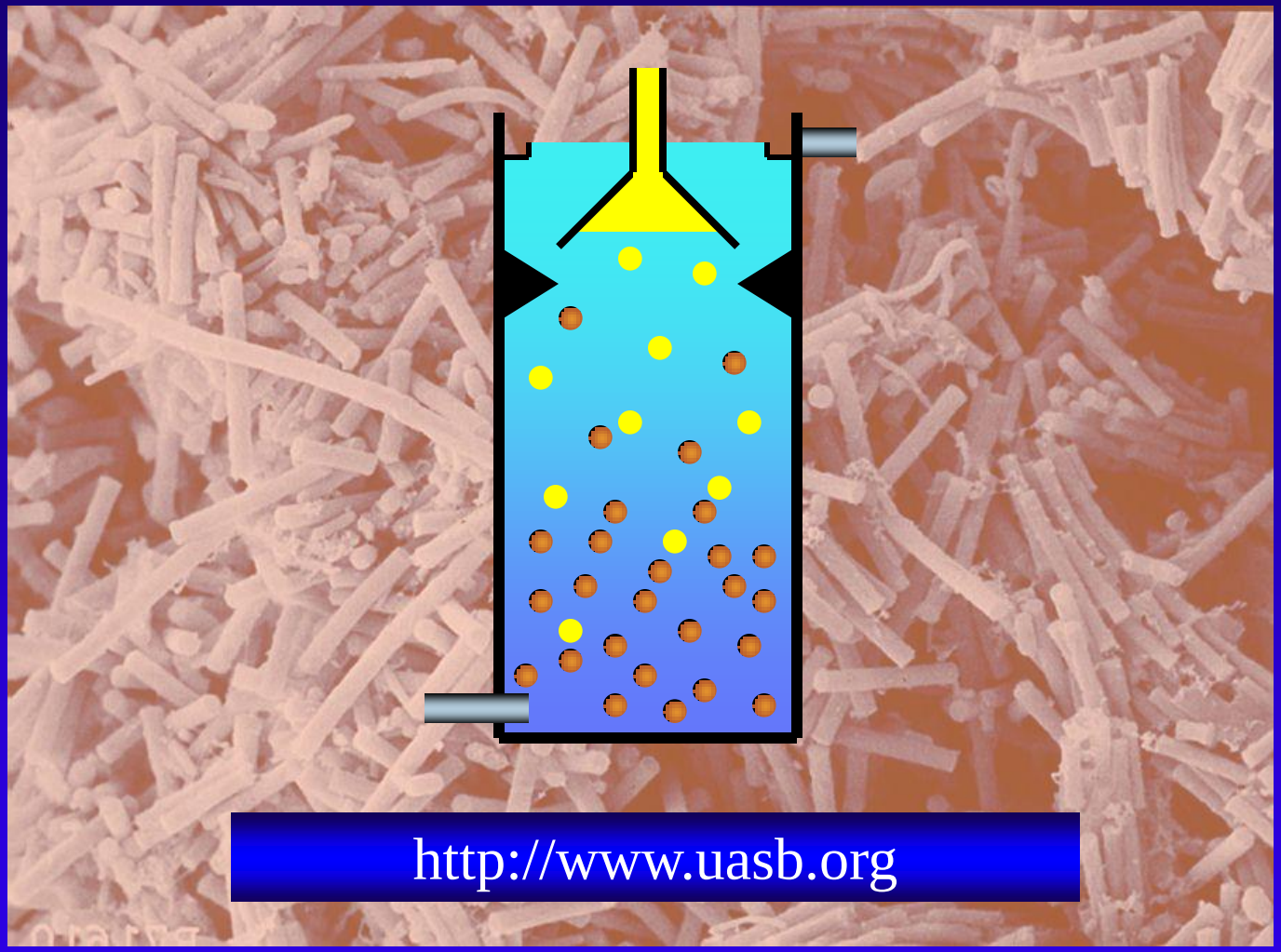
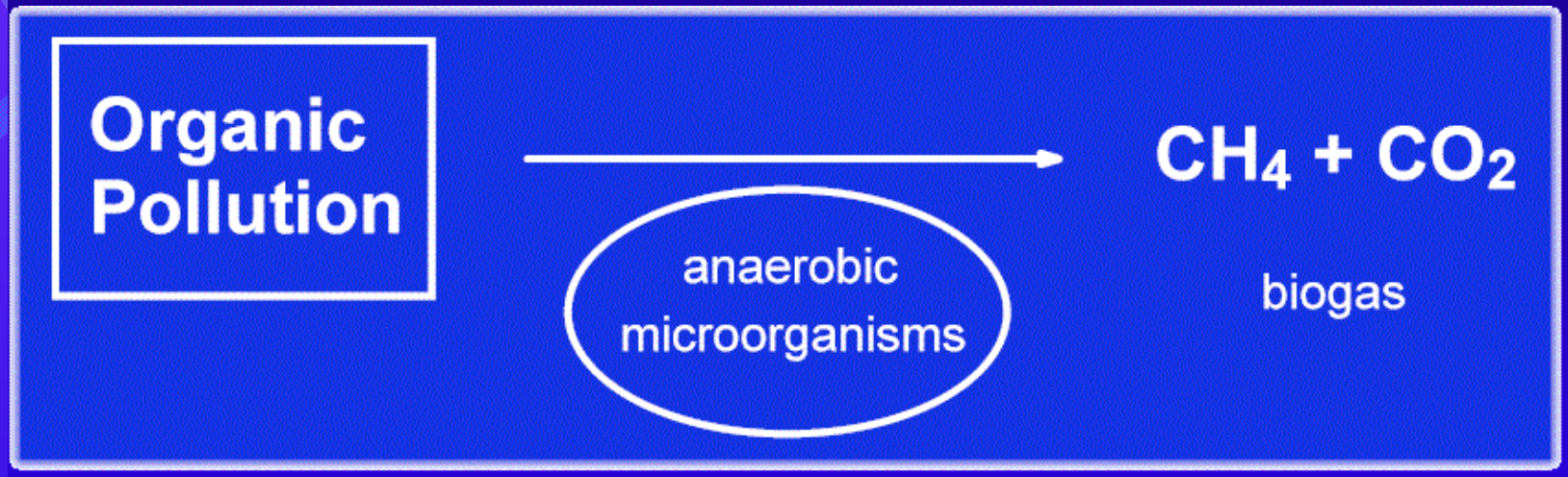
High Rate Anaerobic Wastewater Treatment

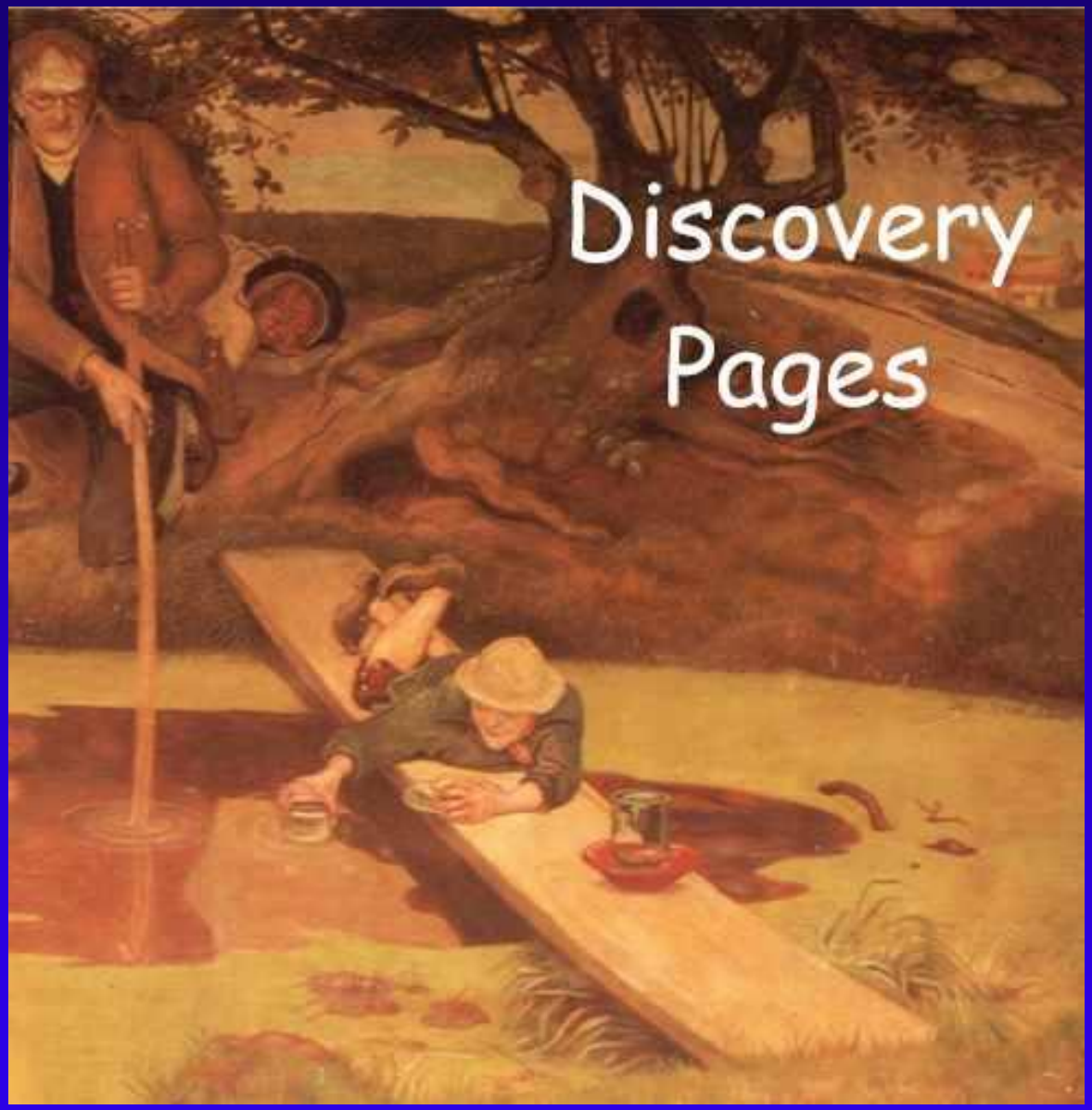


Dr. Jim A. Field and Dr. Reyes Sierra, University of Arizona

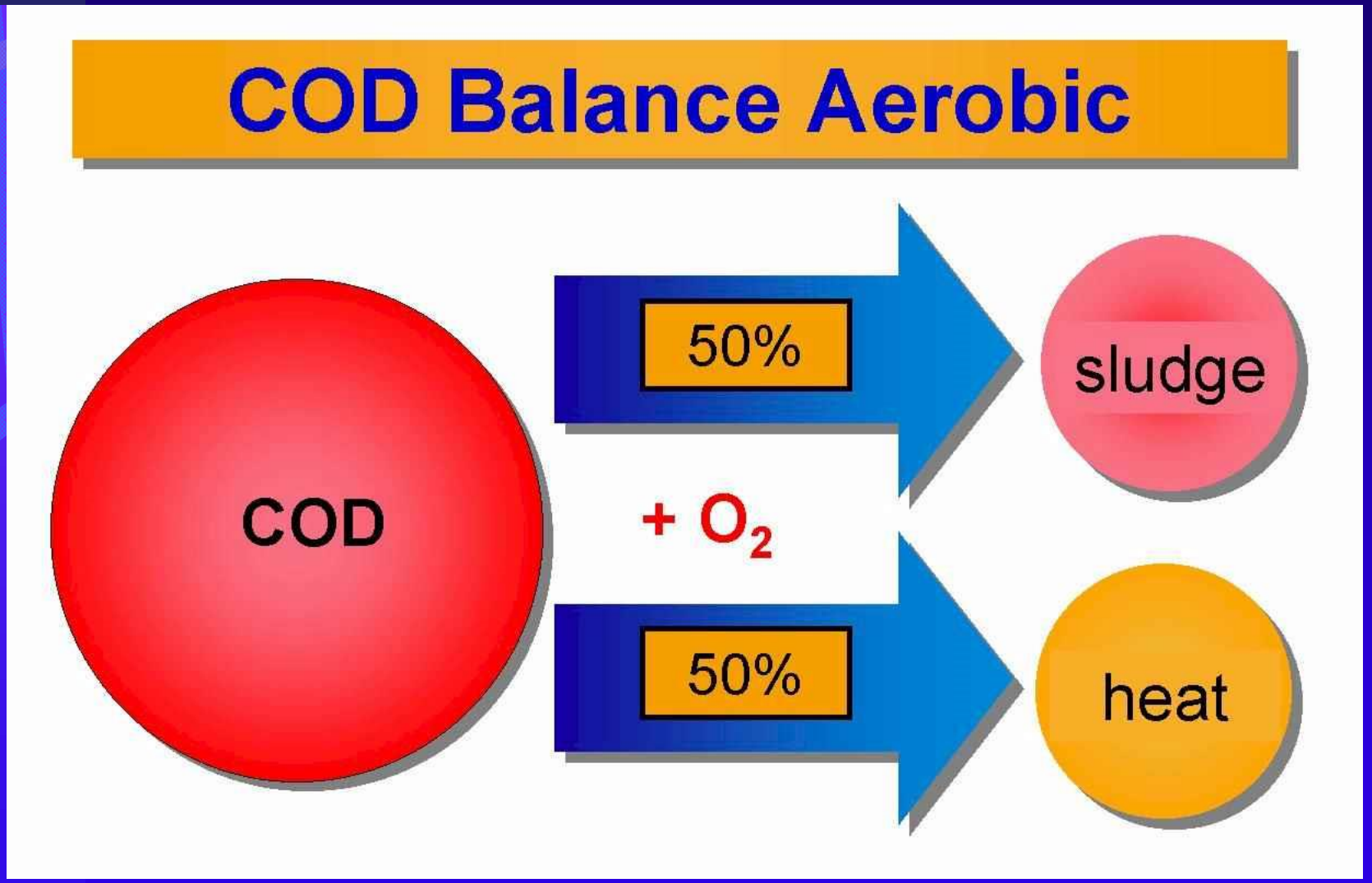
What is Anaerobic Biodegradation?



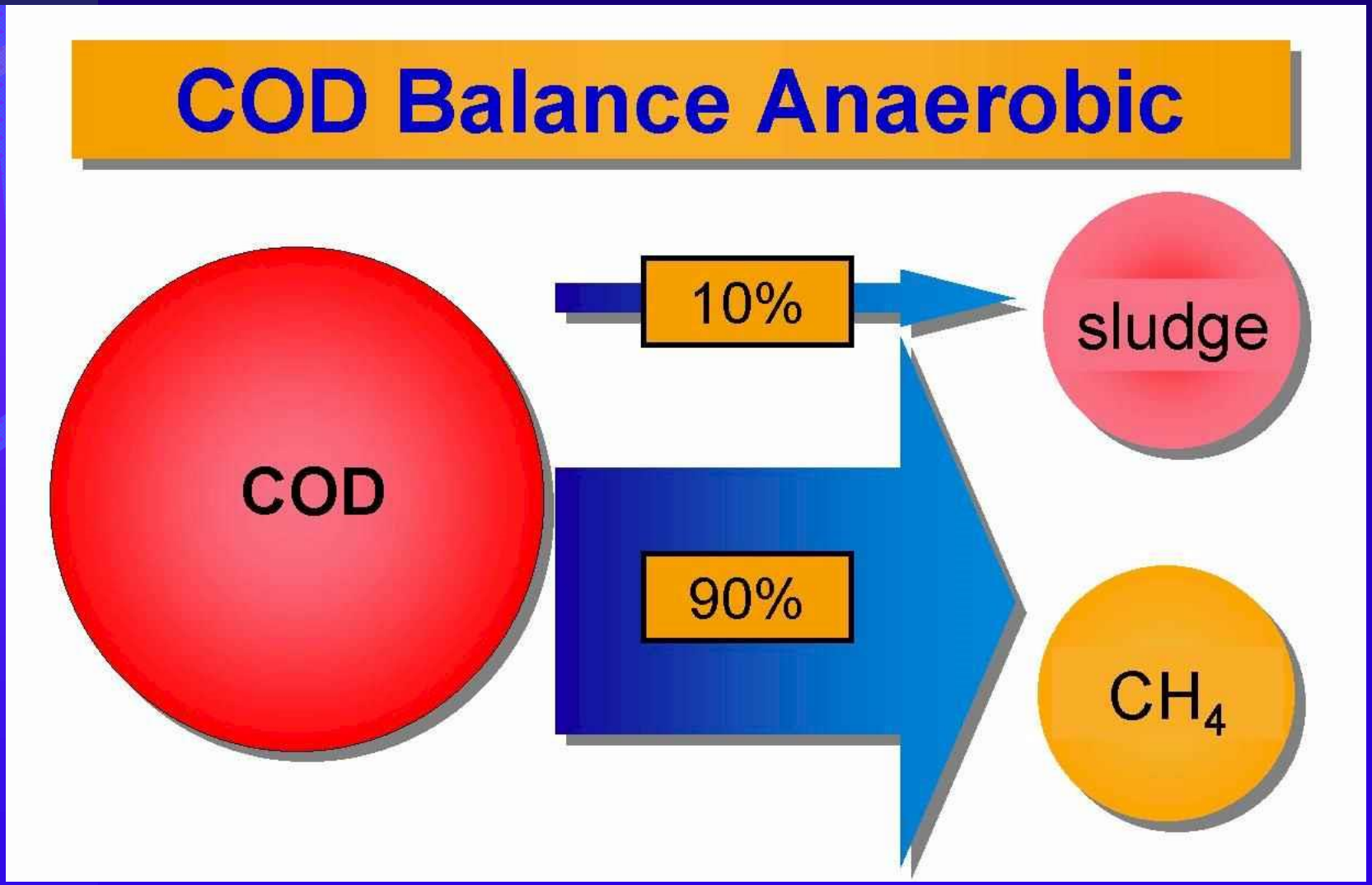
Marsh Gas



COD Balance Aerobic Biodegradation

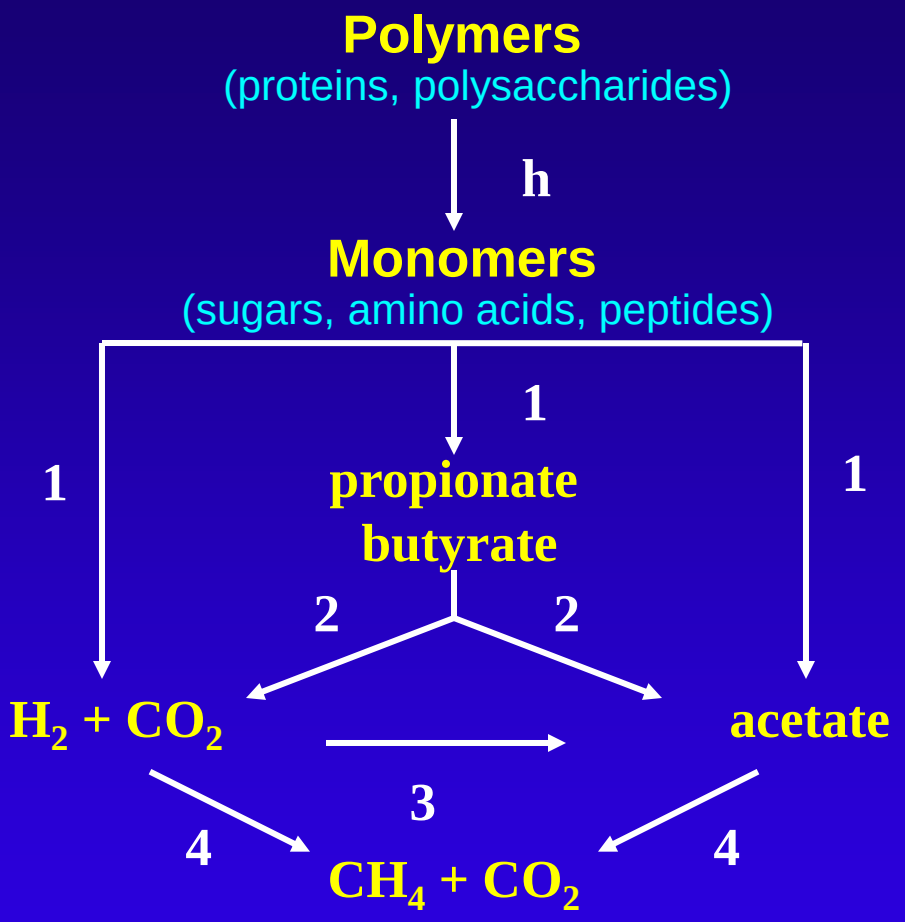


COD Balance Anaerobic Biodegradation



Overview Anaerobic Biodegradation

Methanogenic Consortium



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

Methanogenic Reactions

acetoclastic methanogenesis

$CH_3COOH \longrightarrow CH_4 + CO_2$

acetate — methane — carbon dioxide

autotrophic methanogenesis

$CO_2 + H_2 \longrightarrow CH_4$

carbon dioxide — hydrogen — methane

Kinetic Parameters Anaerobes

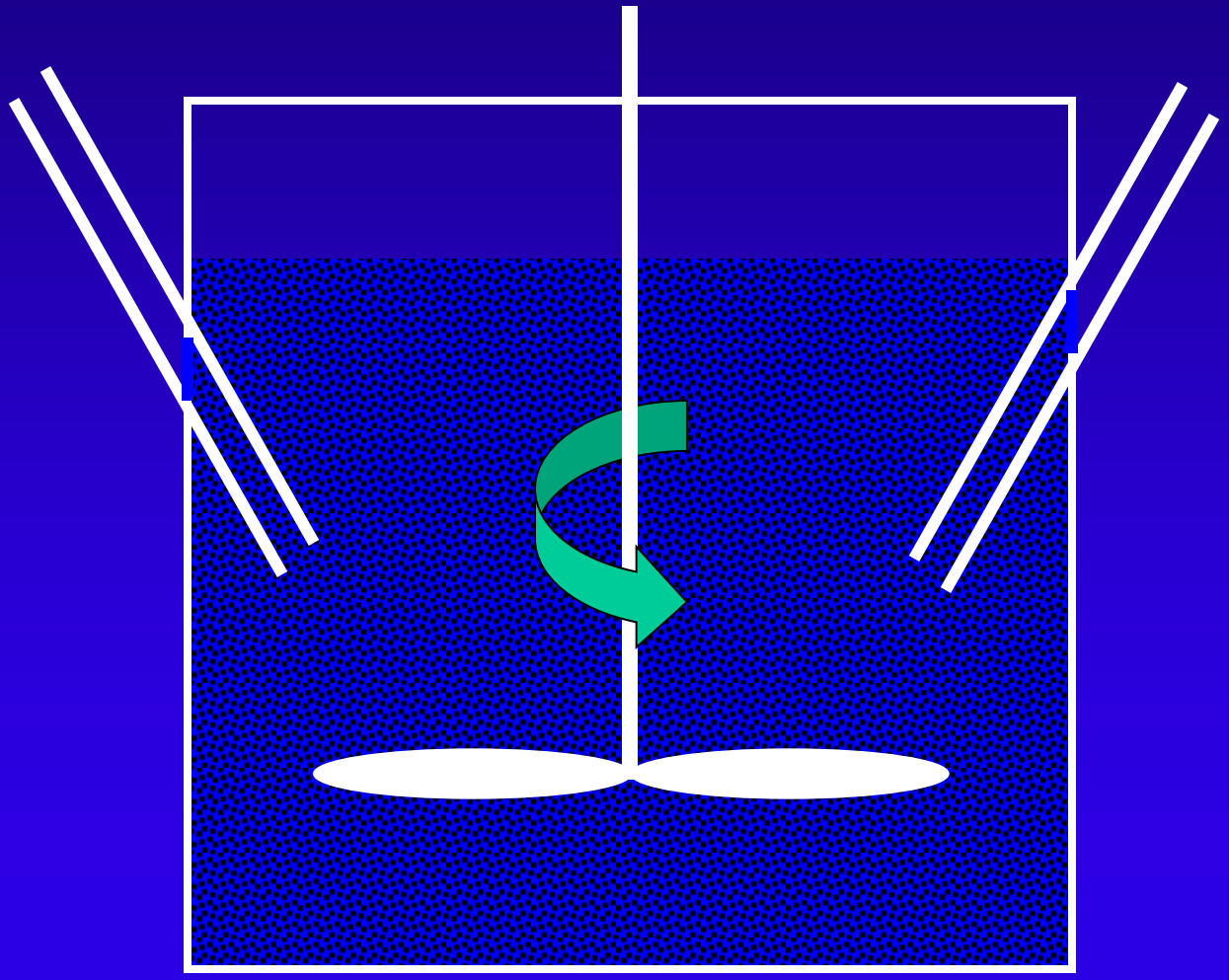
	Doubling Time days	Cell Yield g VSS g-1 COD	Cell Activity g COD g-1 VSS d-1	ks mM
Active Sludge (sugar)				
Aerobic Bacteria	0.030	0.40	57.8	0.25
Acidification (sugar)				
Fermentative Bacteria	0.125	0.14	39.6	ND
Acetogenesis (fatty acids)				
Acetogenic Bacteria	3.5	0.03	6.6	0.4
Methanogenesis				
Autotrophic (H2)	0.5	0.07	19.6	0.004
Acetoclastic (acetate)				
Methanosarcina	1.5	0.04	11.6	5.0
Methanosaete	7.0	0.02	5.0	0.3

CSTR

Dilution Rate (1/HRT) Time < Growth Rate

Methanosaete (t_d =7 d), growth rate = $\ln(2)/t_d$ = 0.1 d^{-1}

so minimum HRT = 10 days

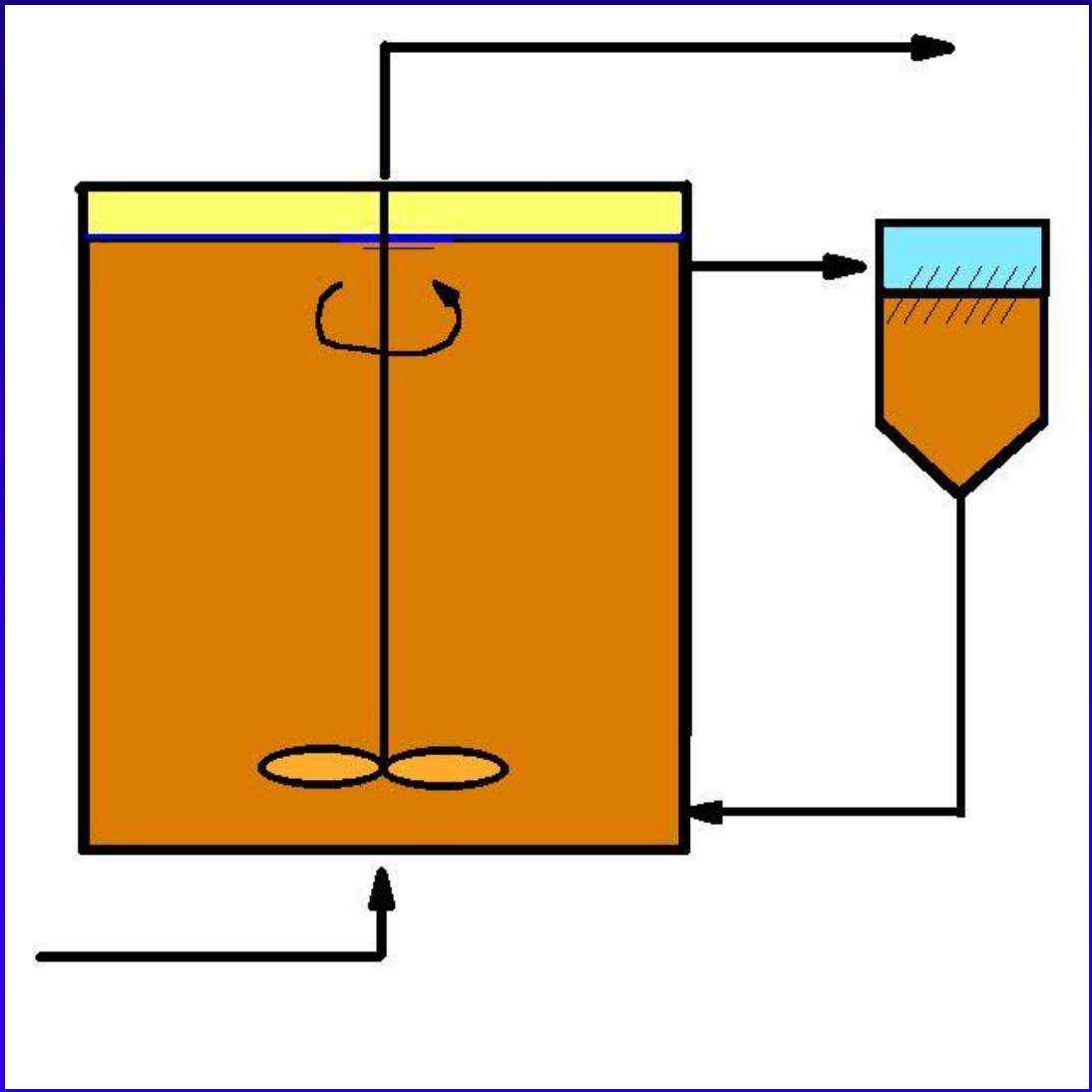


Recycle of Active Biomass

Dilution Rate (1/HRT) Time > Growth Rate

sludge retention time uncoupled from hydraulic retention time

Contact Process

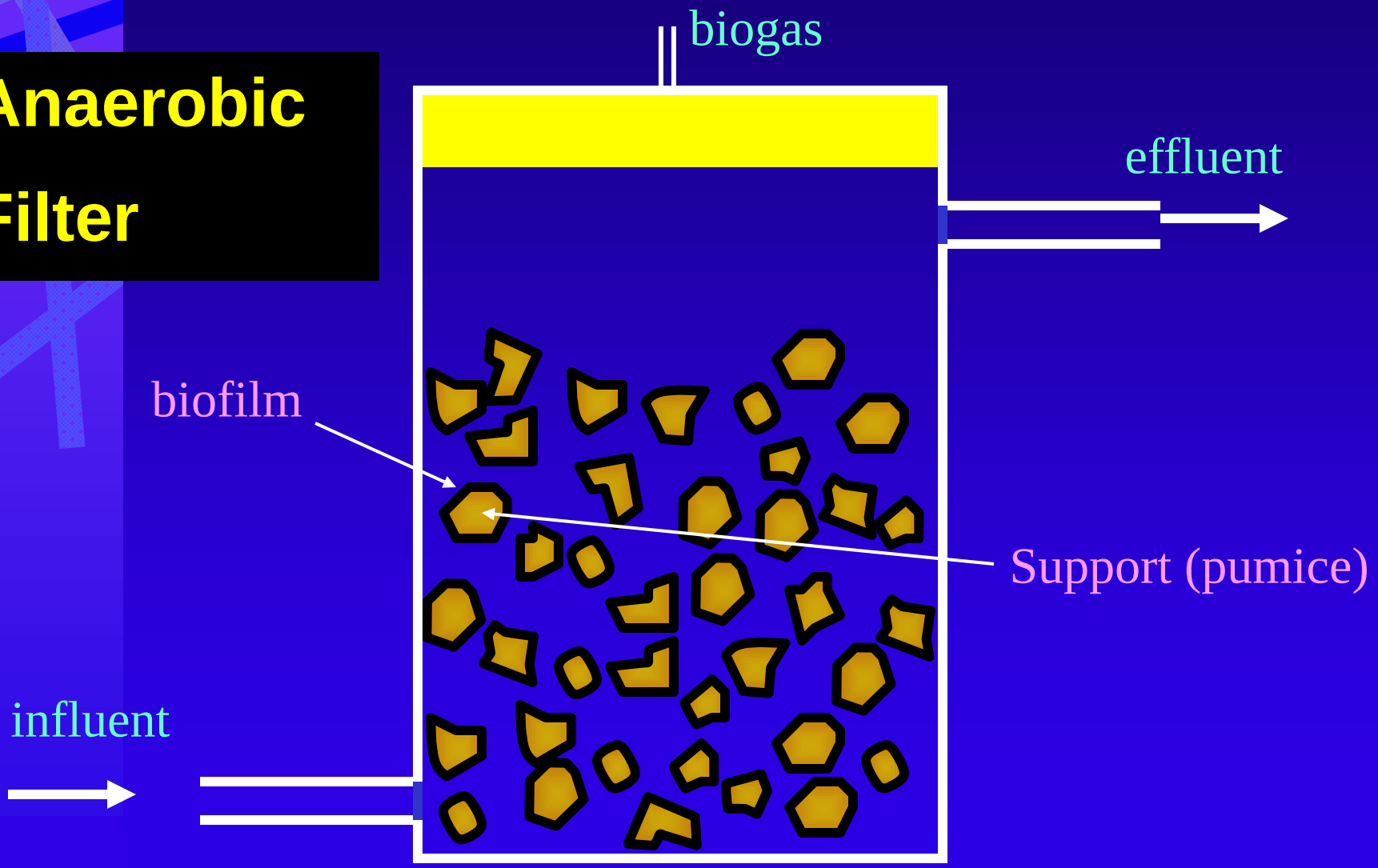


Immobilization of Active Biomass

Dilution Rate (1/HRT) Time > Growth Rate

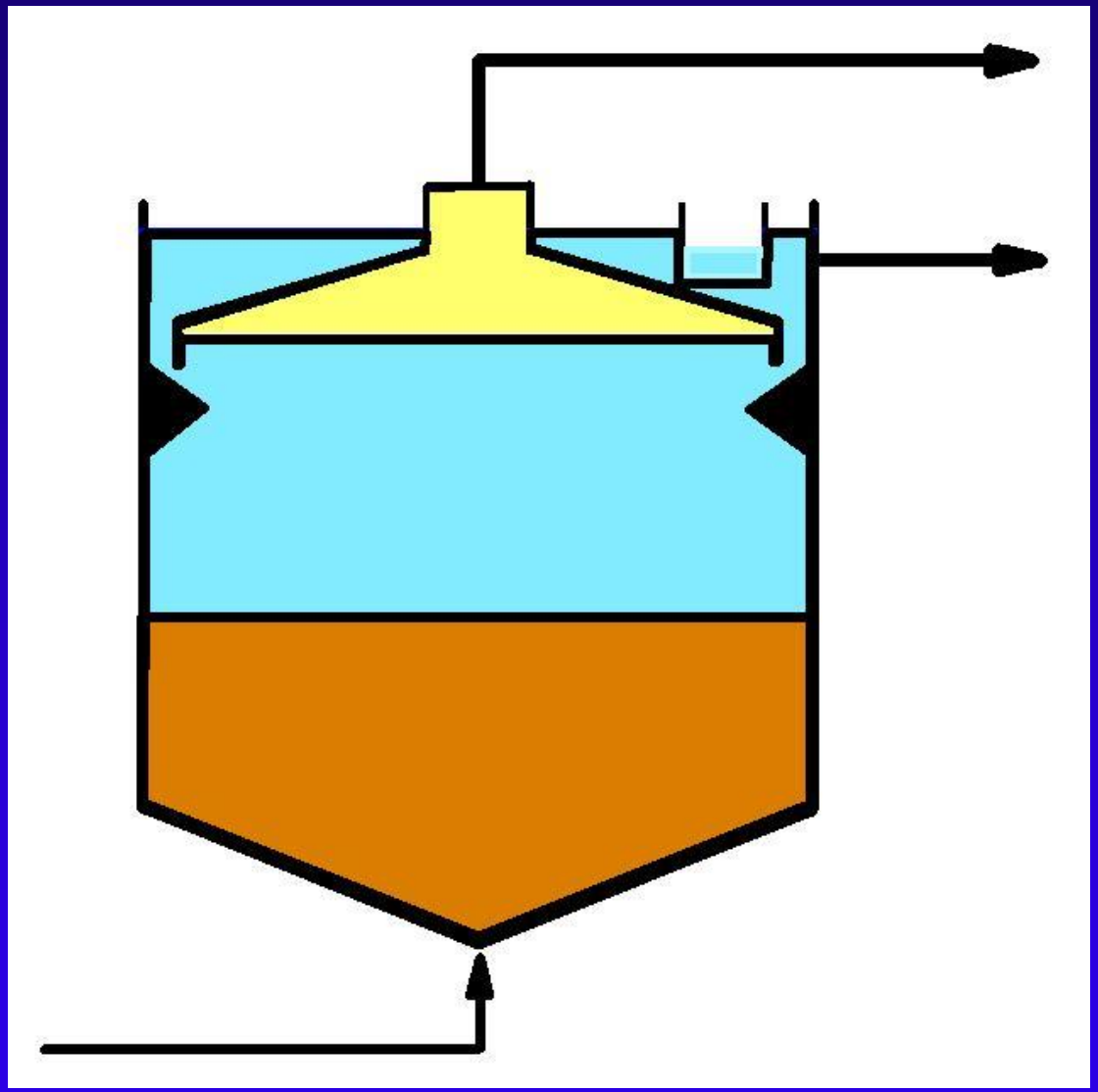
sludge retention time uncoupled from hydraulic retention time

Anaerobic Filter



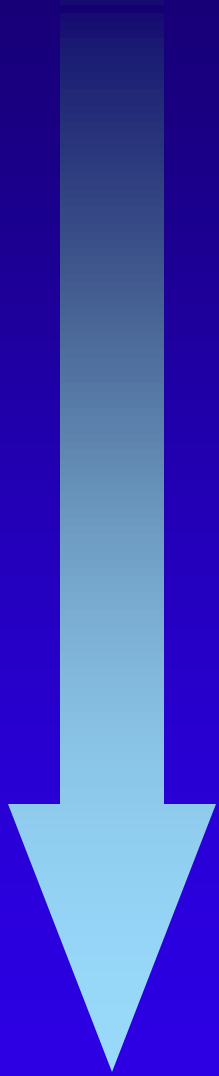
Immobilization of Active Biomass

UASB

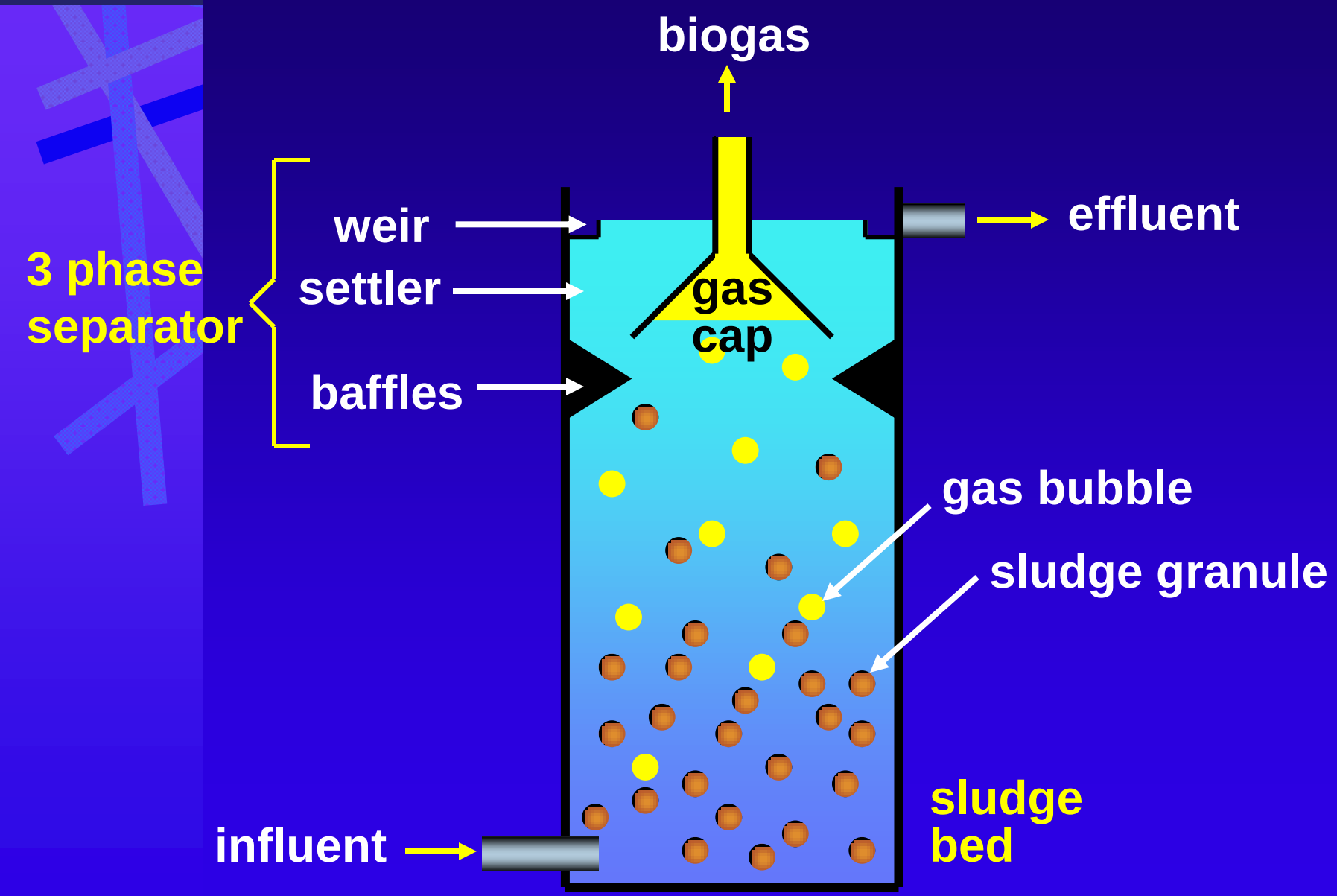


History Anaerobic Treatment Technology

- **Originally: Slurry Digestion**
  Manures, Sludges
- **60 to 80's: Agroindustrial Effluents**
  Brewery, Distillery, Food Processing
- **80 to 90's: Pulp/Paper Effluents**
  Condensates, (C)TMP, Bleachery
- **90's: Chemical/Petrochem. Effluents**
  Terephthalate, phenols
- **90 to 00's: Anaerobic Bioremediation**
  PCE, BTEX

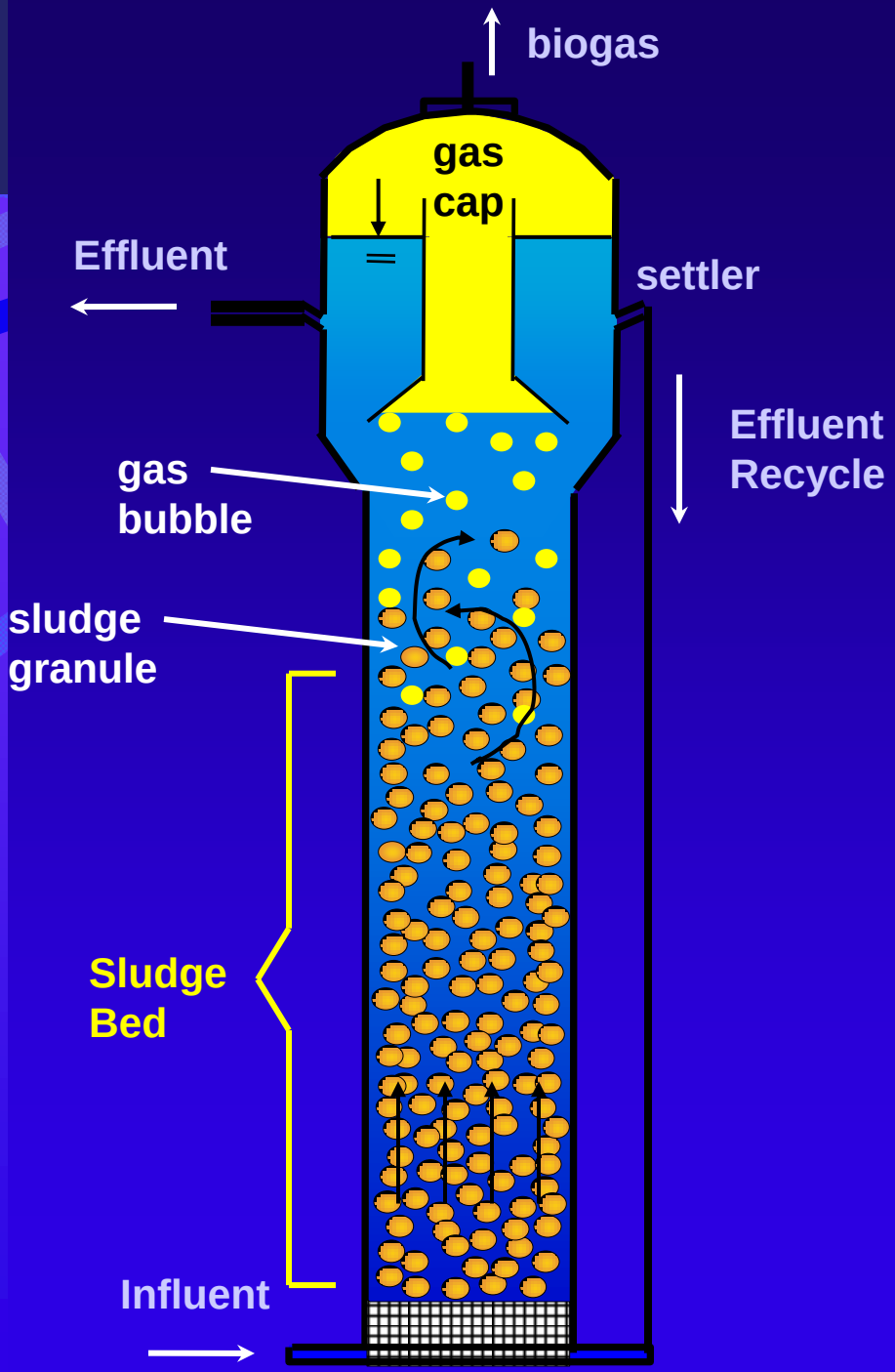


Upward-flow Anaerobic Sludge Blanket




easy-load
Masterflex

Expanded Granular Sludge Bed



Anaerobic Sludge Granules

Physical:

dense compact biofilms

high settleability (30-80 m/h)

high mechanical strength

Microbial:

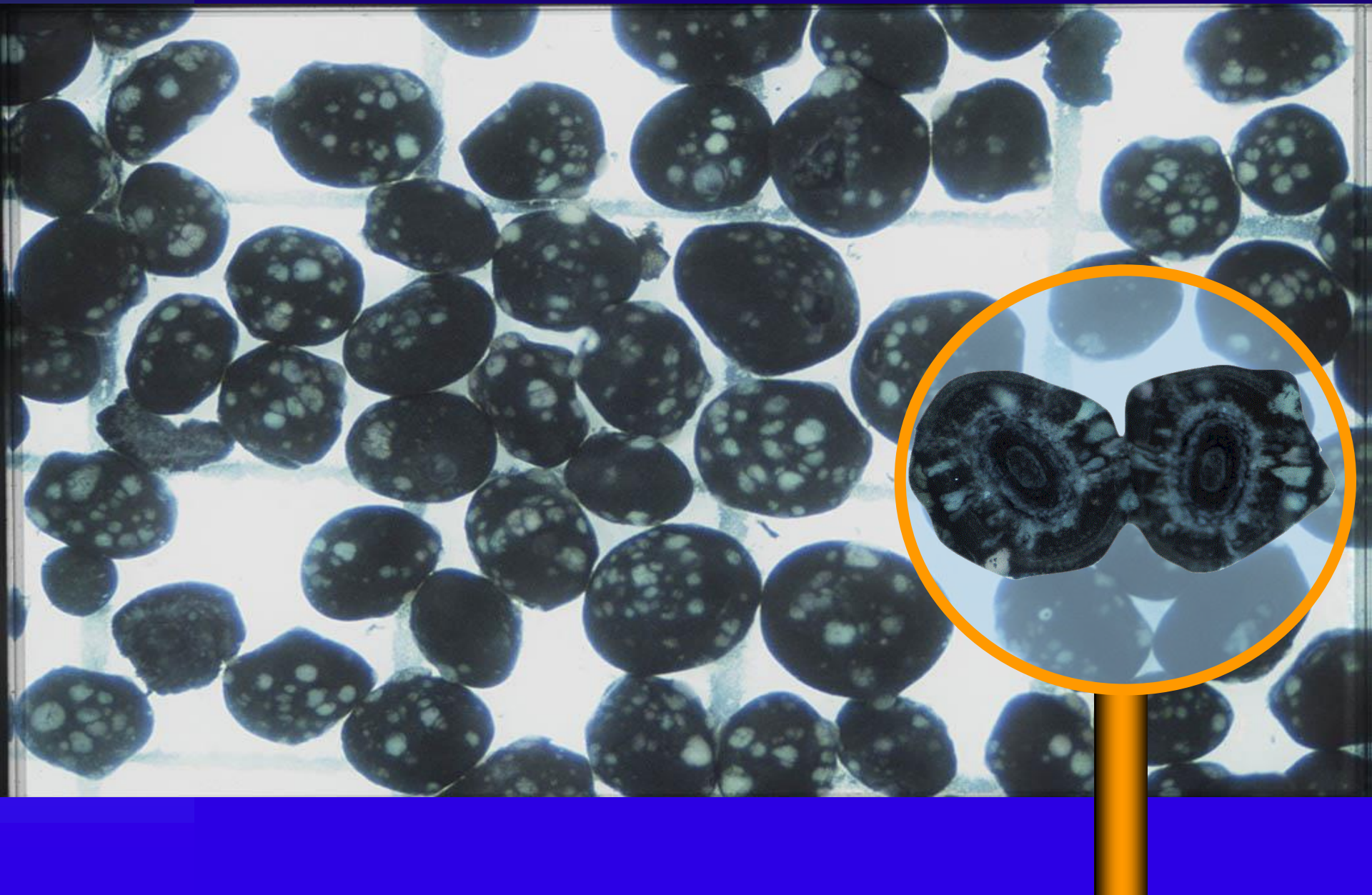
balanced microbial community

syntrophic partners closely associated

high methanogenic activity
(0.5 to 2.0 g COD/g VSS.d)

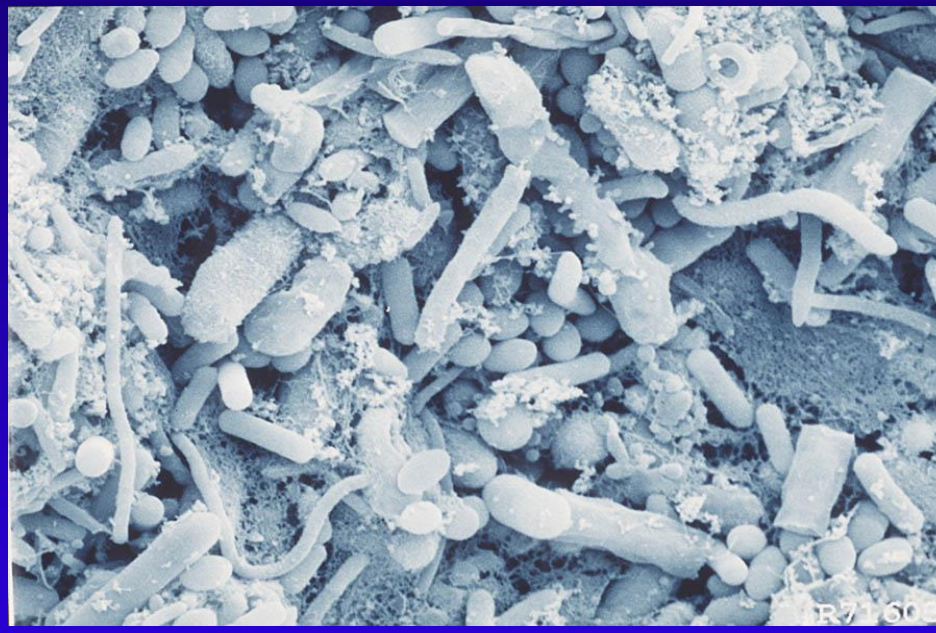
protection from toxic shock

Anaerobic Sludge Granules (close up)



Anaerobic Sludge Granules (SEM)

Acetate as Substrate
(*Methanosaeta*)

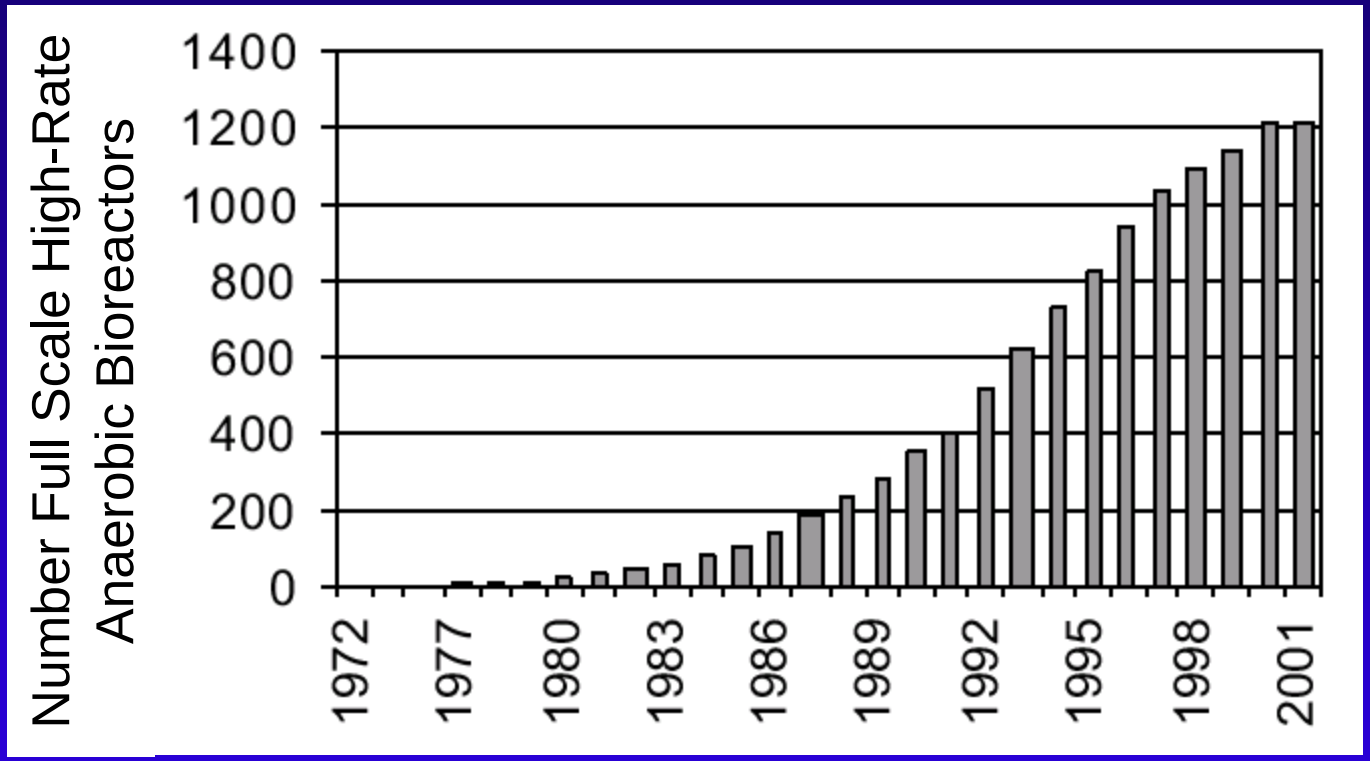


Sucrose as Substrate
(mixed culture)

Anaerobic Sludge Granules (settling)

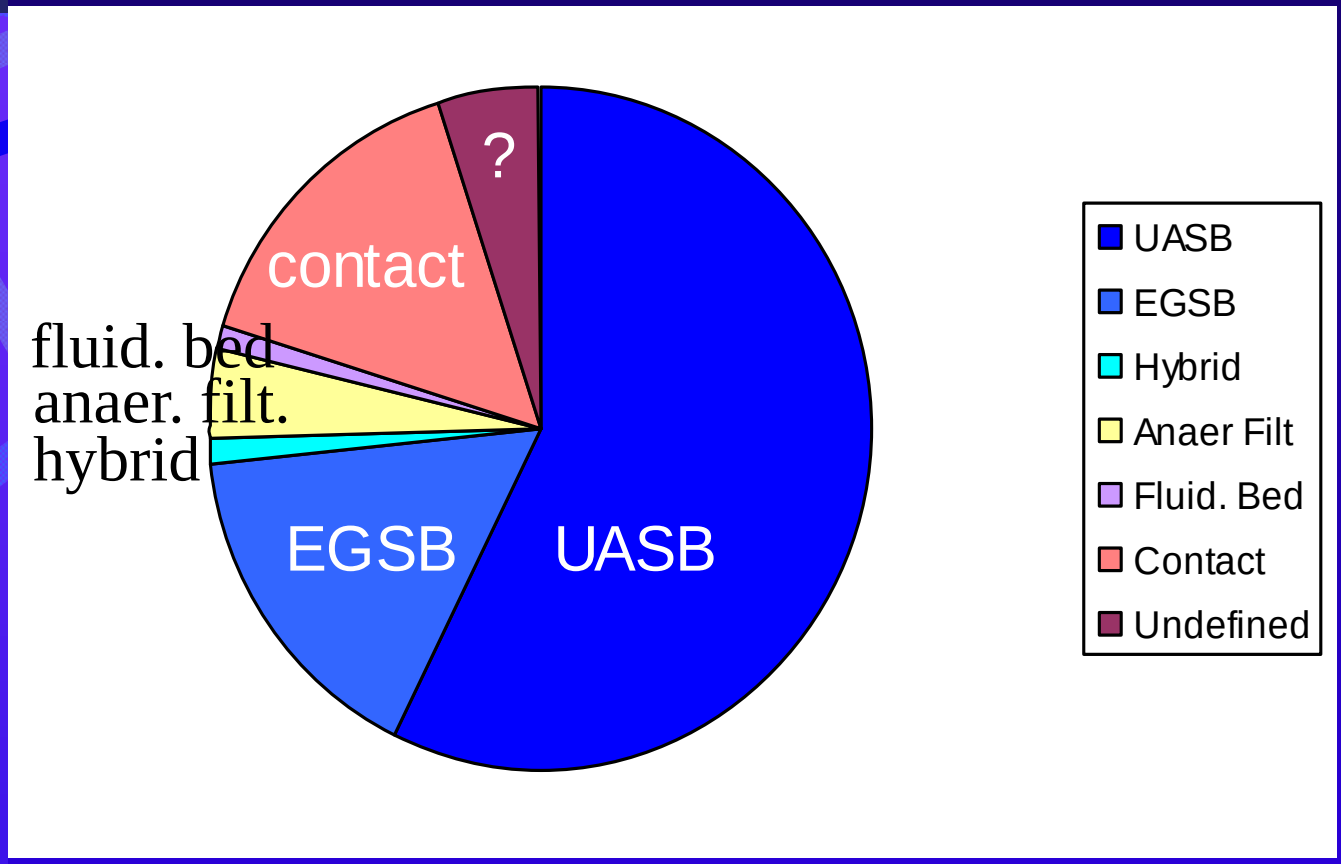
granular flocculent dispersed

Surveyed High Rate Anaerobic Plants



Cumulative number of high rate anaerobic treatment plants for industrial applications

Market-Share Granular Sludge Reactors



EGSB+UASB = 72%

Who Discovered the UASB?

Gatze Lettinga

Design Loads Full Scale
UASB & EGSB

reactor	n	average design load
UASB	682	10 kg COD/m^3.d
EGSB	198	20 kg COD/m^3.d

Removal Efficiency of Biodegradable COD 85 to >90%

Most Important Markets for High Rate Anaerobic Treatment

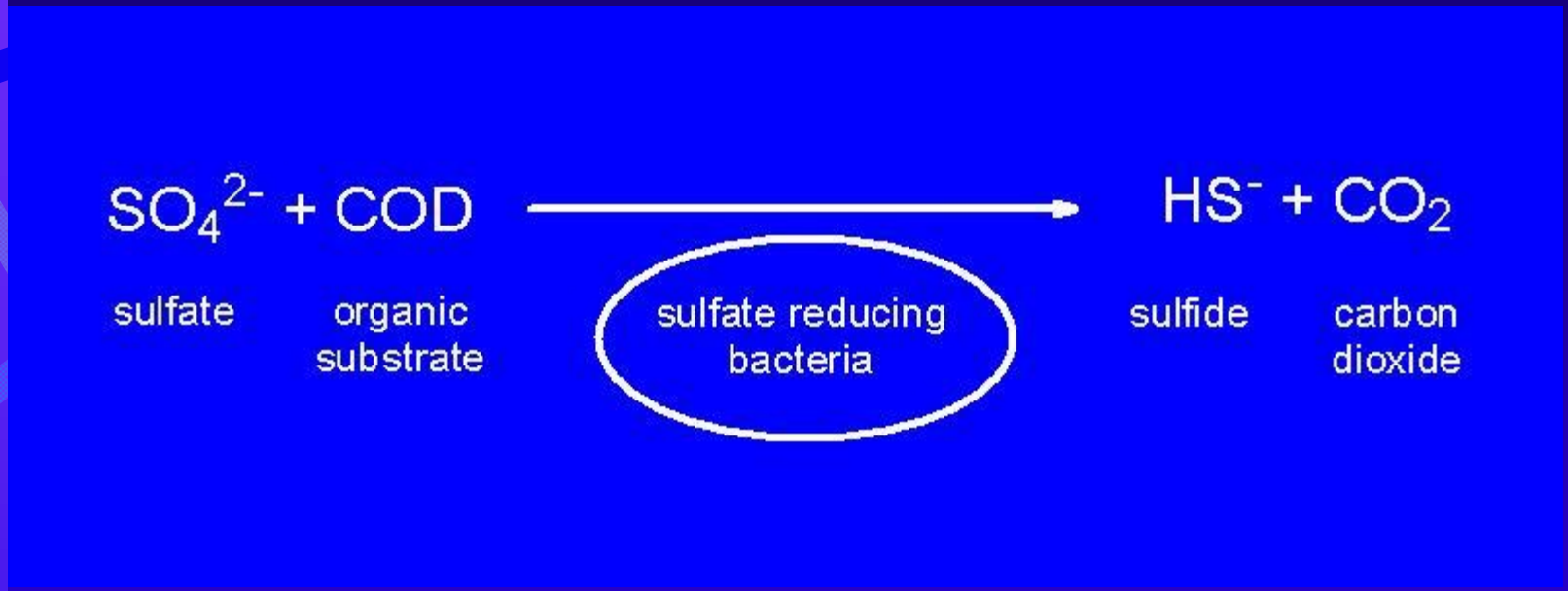
- Breweries and beverage industry
- Distilleries and fermentation industry
- Food Industry
- Pulp and paper

These four wastewater types account for 87% market

New and Emerging Markets for High Rate Anaerobic Treatment

- Chemical and Petrochemical
- Textile Industry Effluents
- Landfill Leachates
- Sulfate reduction coupled to sulfur removal
- Sulfate reduction coupled metal recovery

UASB Technology for Removal and Recovery of Metals



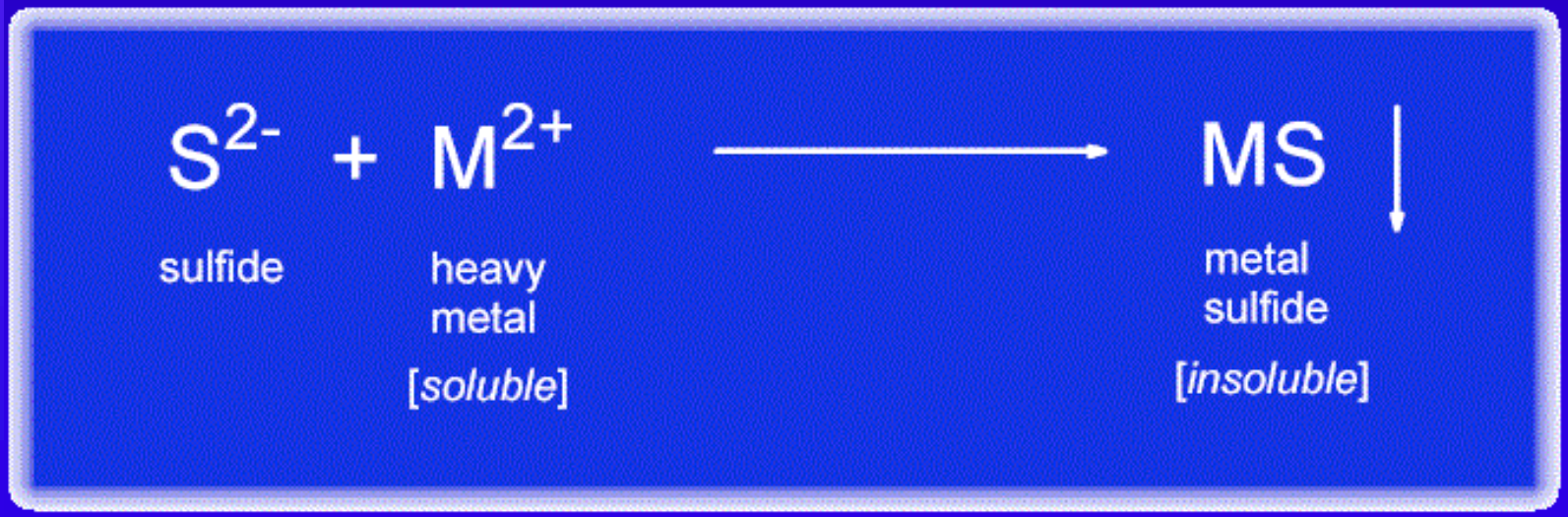
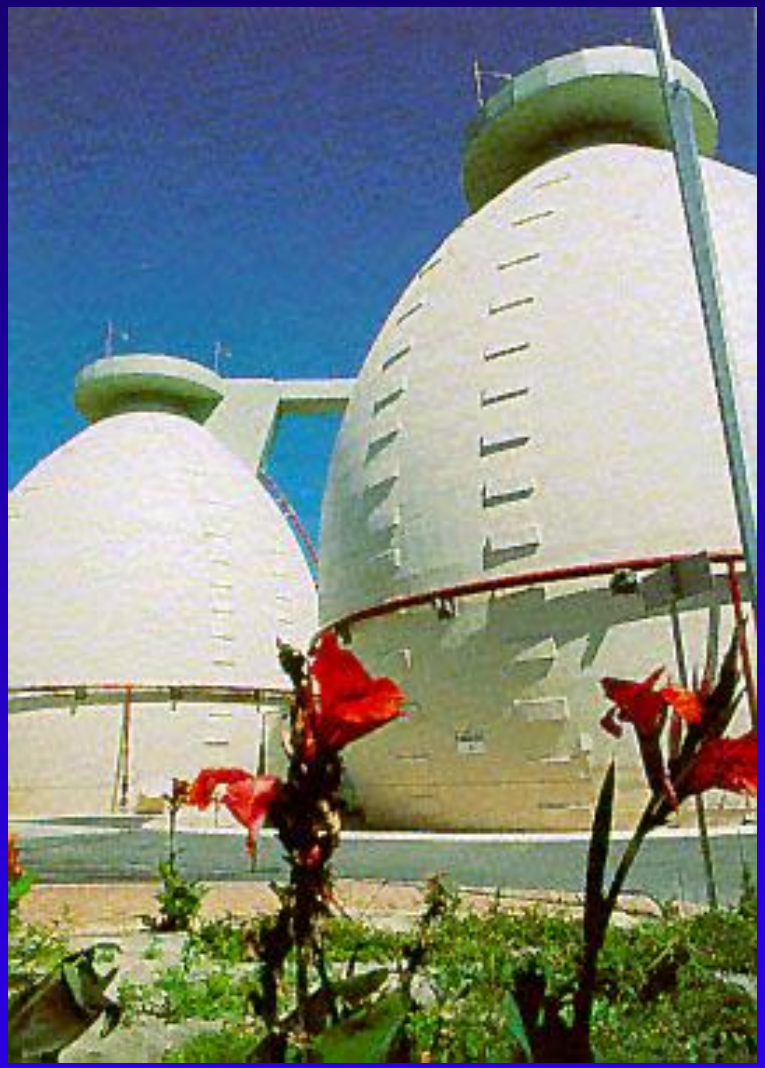


Photo Gallery



Municipal Sludge Digesters

Municipal Sludge Digesters

Switzerland

Centralized Biogas Plant

Lintrup Biogas plant (Denmark)

animal manures

Anaerobic Lagoon

Food/Beverage Processing - Washington

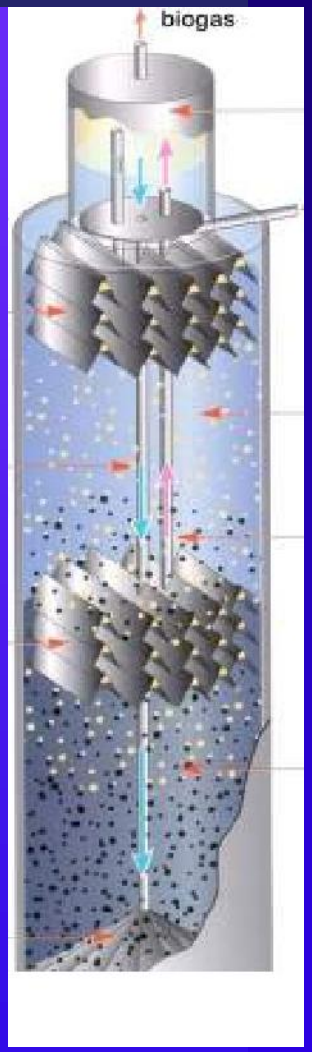
Contact Process

Food-Processing, Virginia

UASB

The Netherlands

UASB - Internal Circulation



Brewery (Switzerland), 20 m height

UASB - Internal Circulation

Kraft Paper Mill Foul Condensates, Alabama

EGSB

Gist Brocades (yeast, pharmaceuticals) The Netherlands

Modular Design UASB Reactors