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100 Years of Biological Wastewater Treatment Practice: A Perspective

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The Outline

- Re-look at WWTPs on an 100-year scale
- Current biological wastewater treatment
- Promising R&D focus
- Future R&D directions: a shift in concept ?
- Concluding remarks

Re-look at WWTPs worldwide

In ancient Rome…

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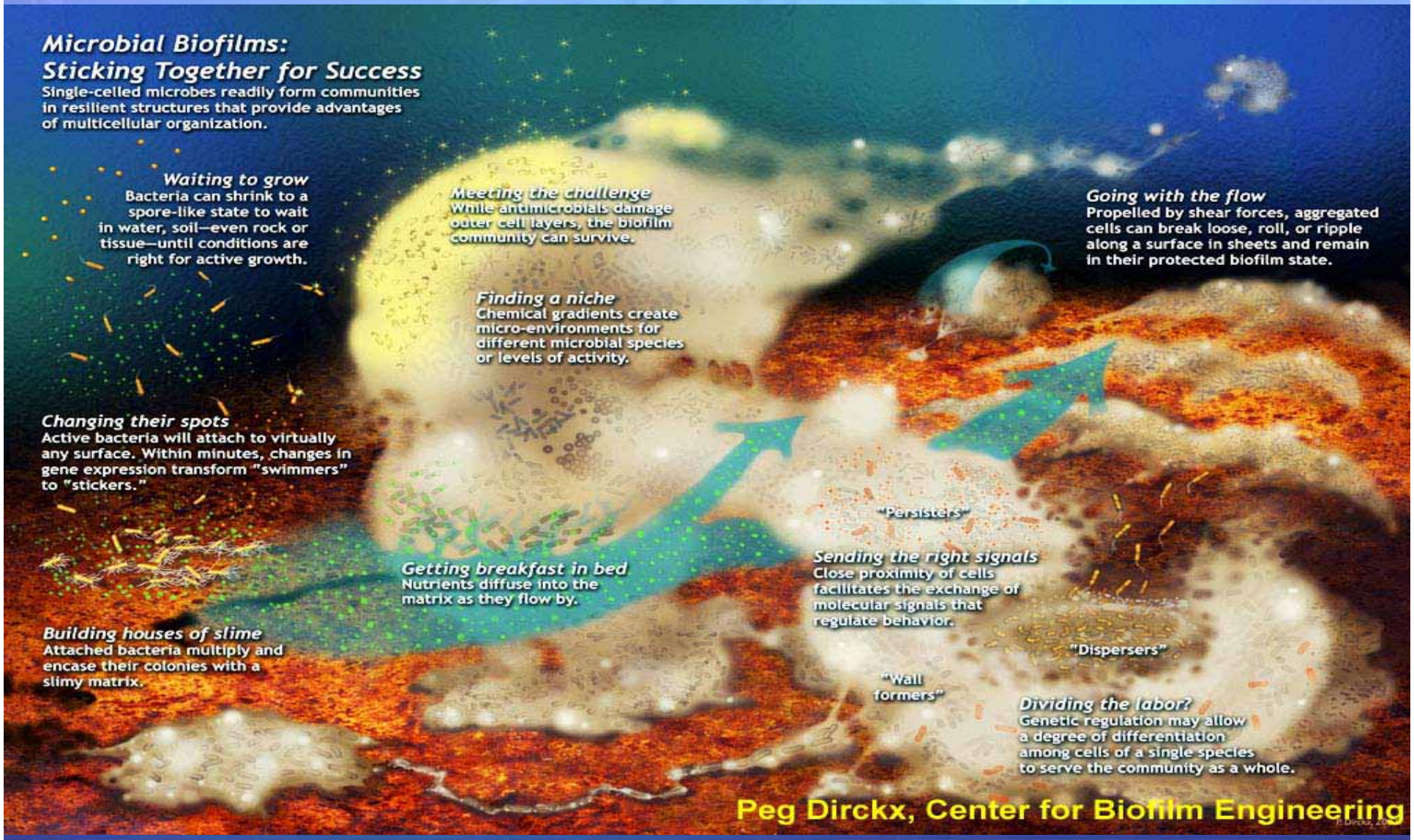
Re-look at WWTPs worldwide

Fixed film ← Nature



Re-look at WWTPs worldwide

Fixed film ← Nature

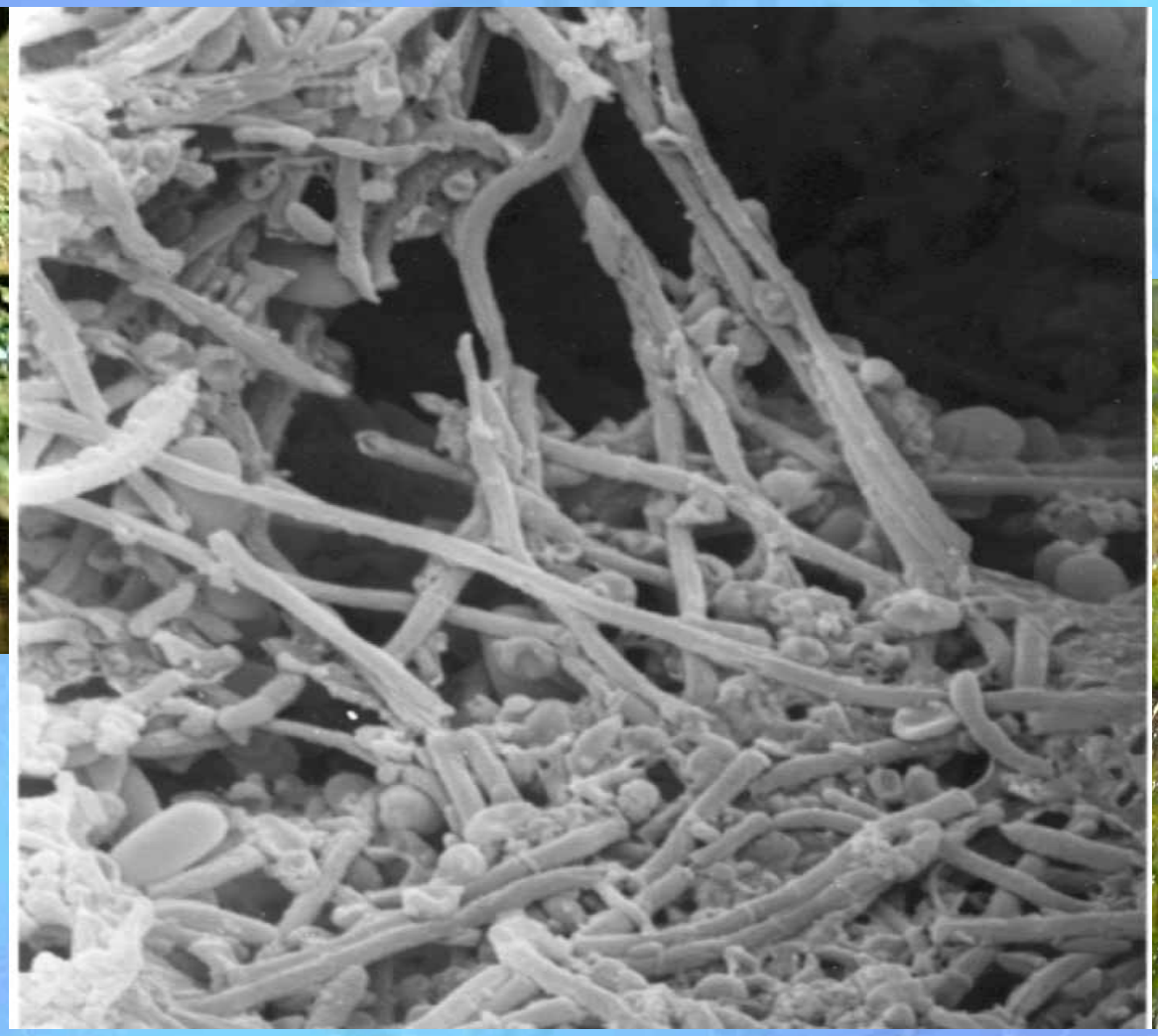
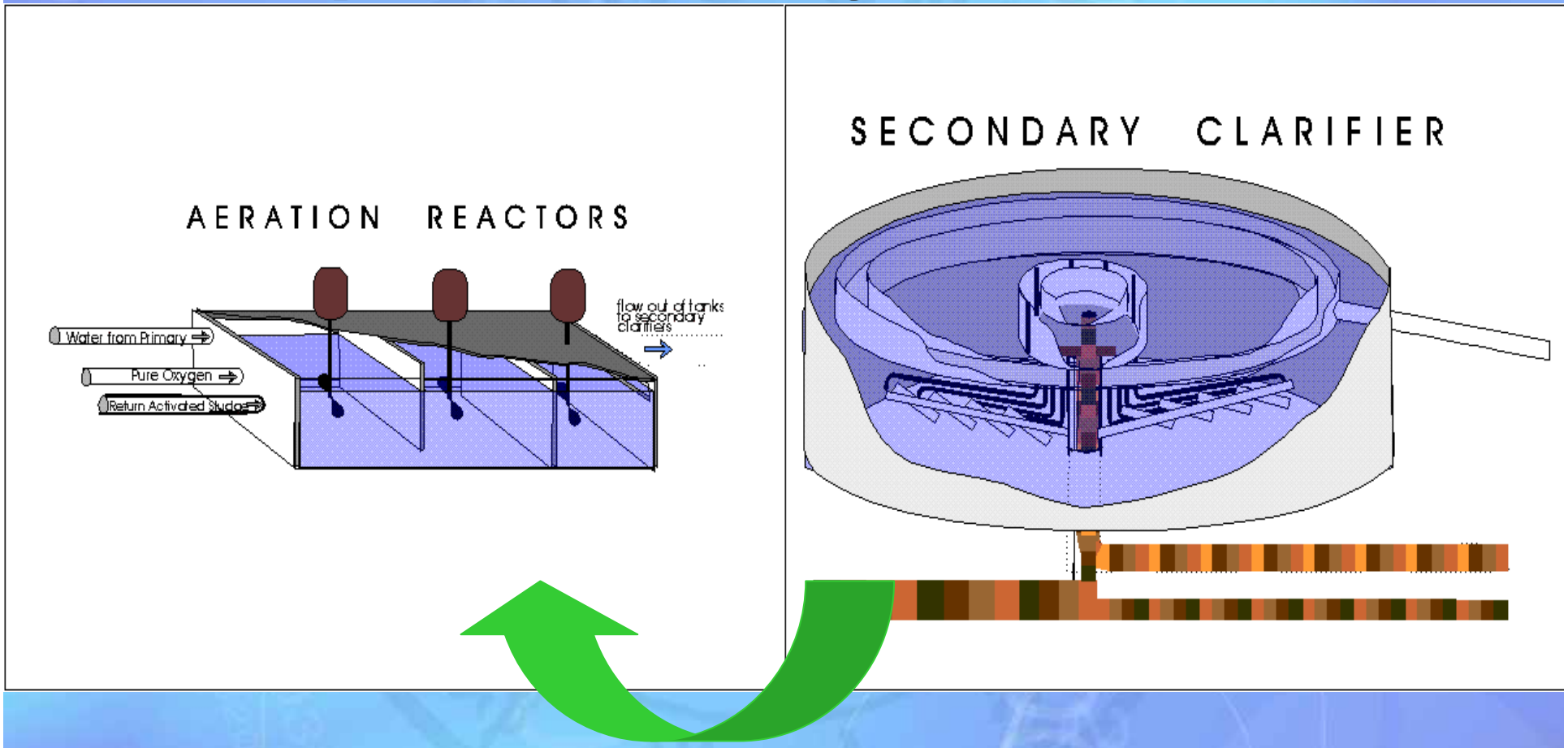


IMAGE CREDITS: Henry Aldrich

Email: haldrich@micro.ifas.ufl.edu

Re-look at WWTPs worldwide

- **May 1914, Ardern and Lockett introduced a recycle of suspension (activated sludge).**



* Arden, E. and W. T. Lockett (1914) Experiments on the oxidation of sewage without the aid of filters. ***J. of Soc. Chem. Ind.*** Vol. 33, pp. 523-539

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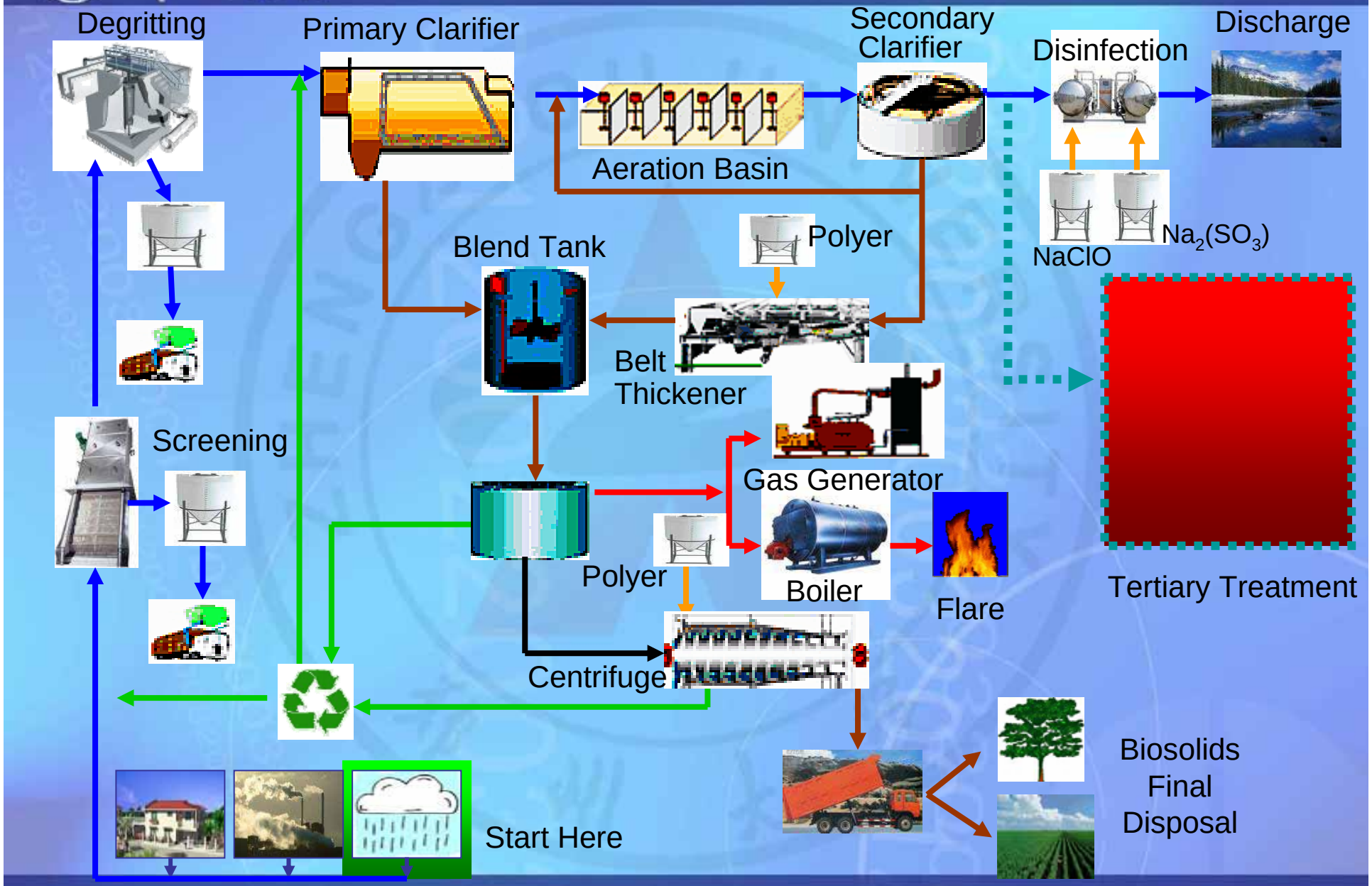
Re-look at WWTPs worldwide



Re-look at WWTPs worldwide

Wastewater

- **Point Source**
  - **Industrial** >80%
  - **Domestic** 100%
- **Non-point Source**
  - **Other** >80%
  - **Agricultural** 100%

Re-look at WWTPs worldwide

Wastewater
as mgCOD/L

- **Low strength**
  e.g. <1000 mgCOD/L → **Aerobic** *
- **High strength**
  e.g. >1000 mgCOD/L → **Anaerobic + Aerobic**

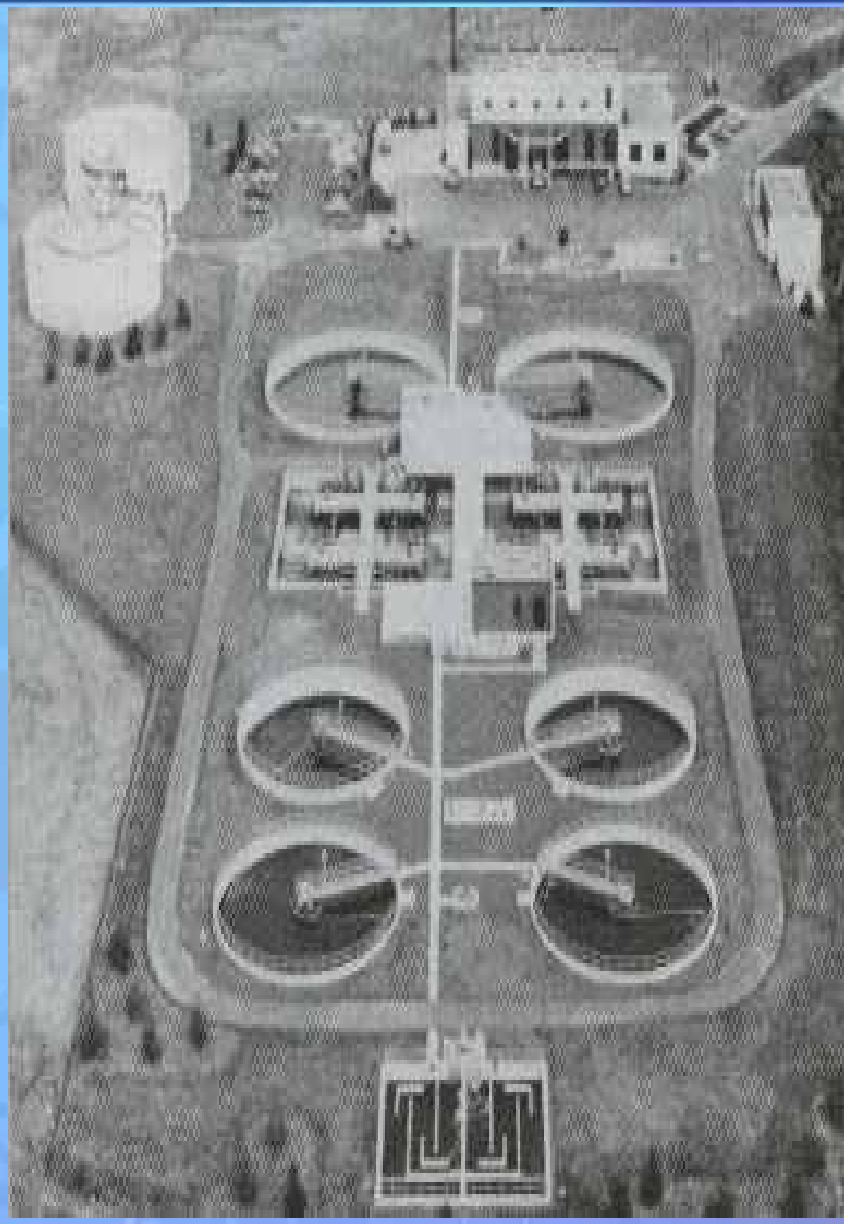
Current biological wastewater treatment

For aerobic processes:

- **Demand of oxygen→Energy high**
- **Excess sludge→Disposal difficult**

Major breakthrough:

- **Membrane bioreactor**



Current biological wastewater treatment

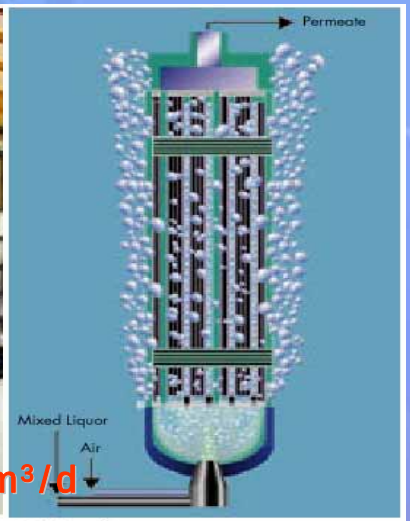
< 50,000 m³/d

< 144,000 m³/d

< 50,000 m³/d

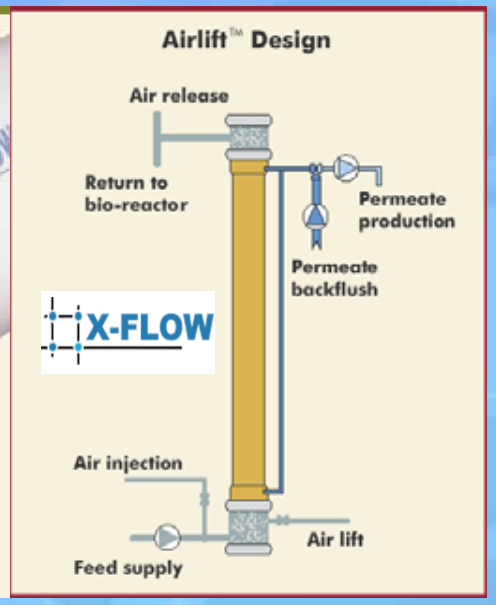
< 50,000 m³/d

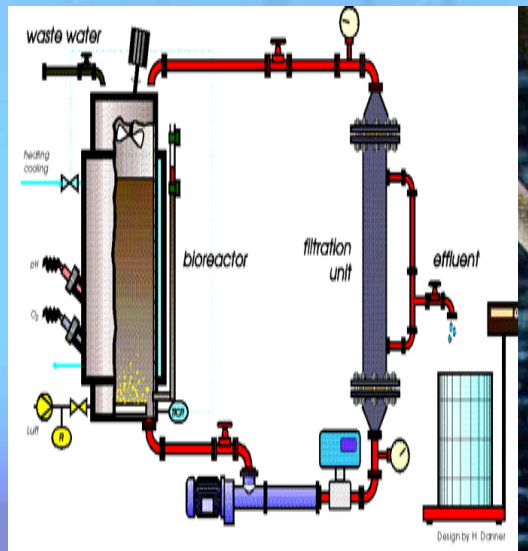
USFilter MemJet MBR Modules



Module with jet in operation.

Current biological wastewater treatment





Schematic Presentation of the Membrane Bioreactor

Ondeo Industrial Solutions

AsahiKASEI

VEOLIA Water Systems

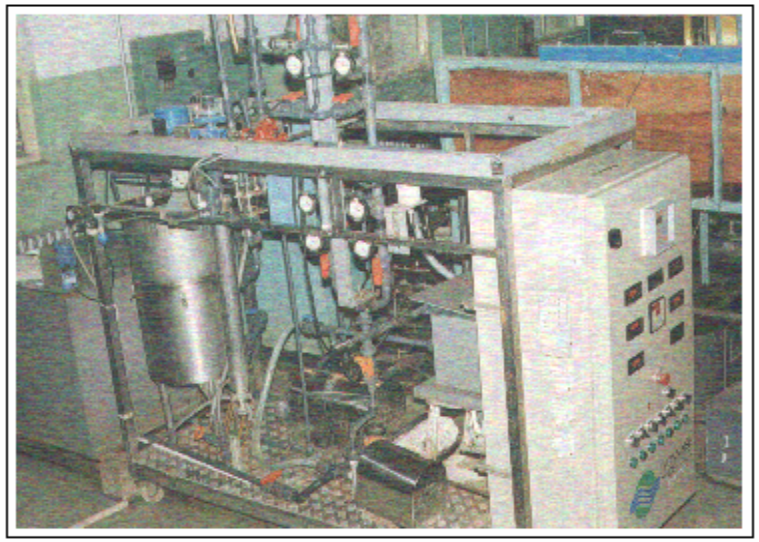
HITACHI Inspire the Next

GE

and more . . .

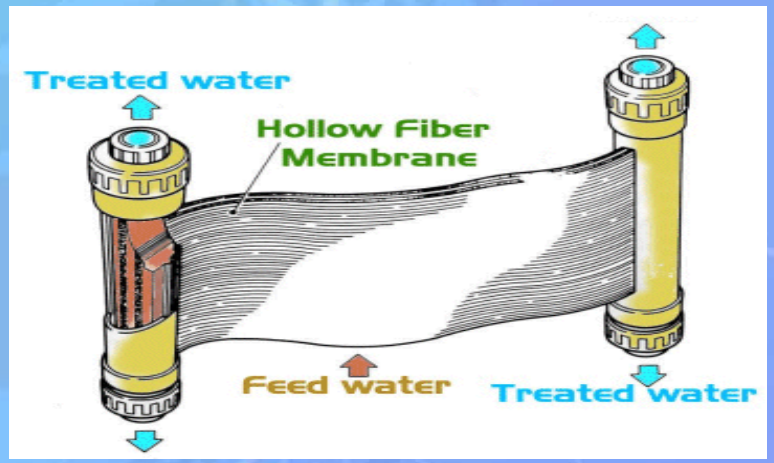
Current biological wastewater treatment

G 1



*Smith, C.V.Jr., D.Di Gregorio (1969) The use of ultrafioltration membrane for activated sludge separation. ***In: proceedings of the 24th annual Purdue industrial waste conference***. West Lafayette, Indiana, 1300-1310

G 2



G 3 ?

Current biological wastewater treatment

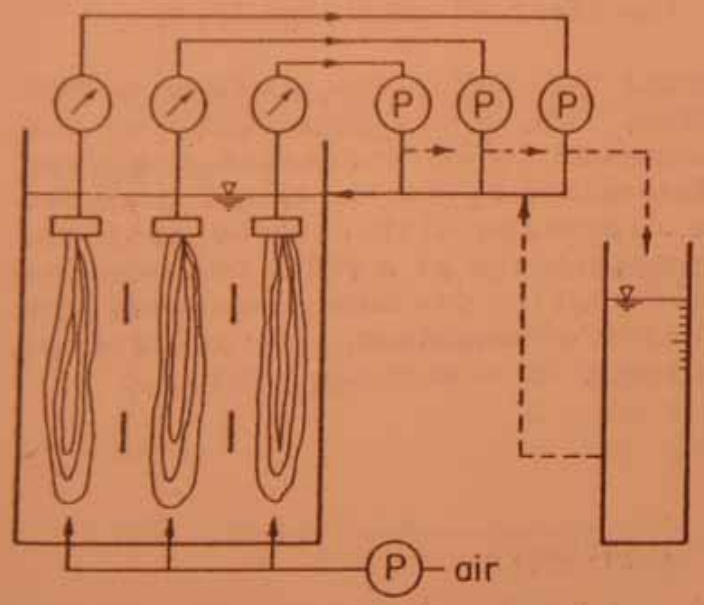


Fig. 1. Experimental set-up for short term experiments without addition of substrate.

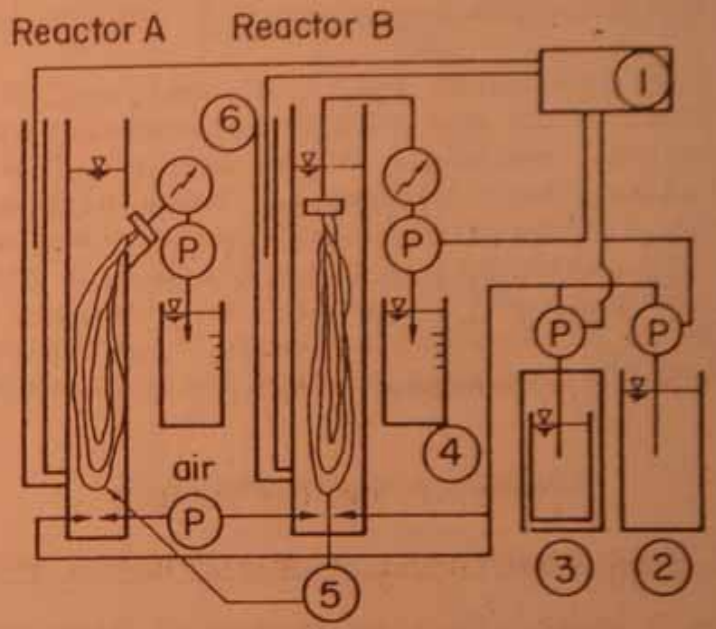


Fig. 2. Experimental set-up for long term experiments.
(1. controller unit, 2. tap water 3. substrate, 4. effluent, 5 hollow fiber membrane, 6 level detector)

Mitsubishi Rayon PE membrane 0.1micron

* Yamamoto k., M.Hiasa, M. Mahmood and T. Matsuo (1989) Direct solid-liquid separation using hollow fiber membrane in an activated sludge aeration tank. ***Water Science and Technology*** 21(4/5):43-54

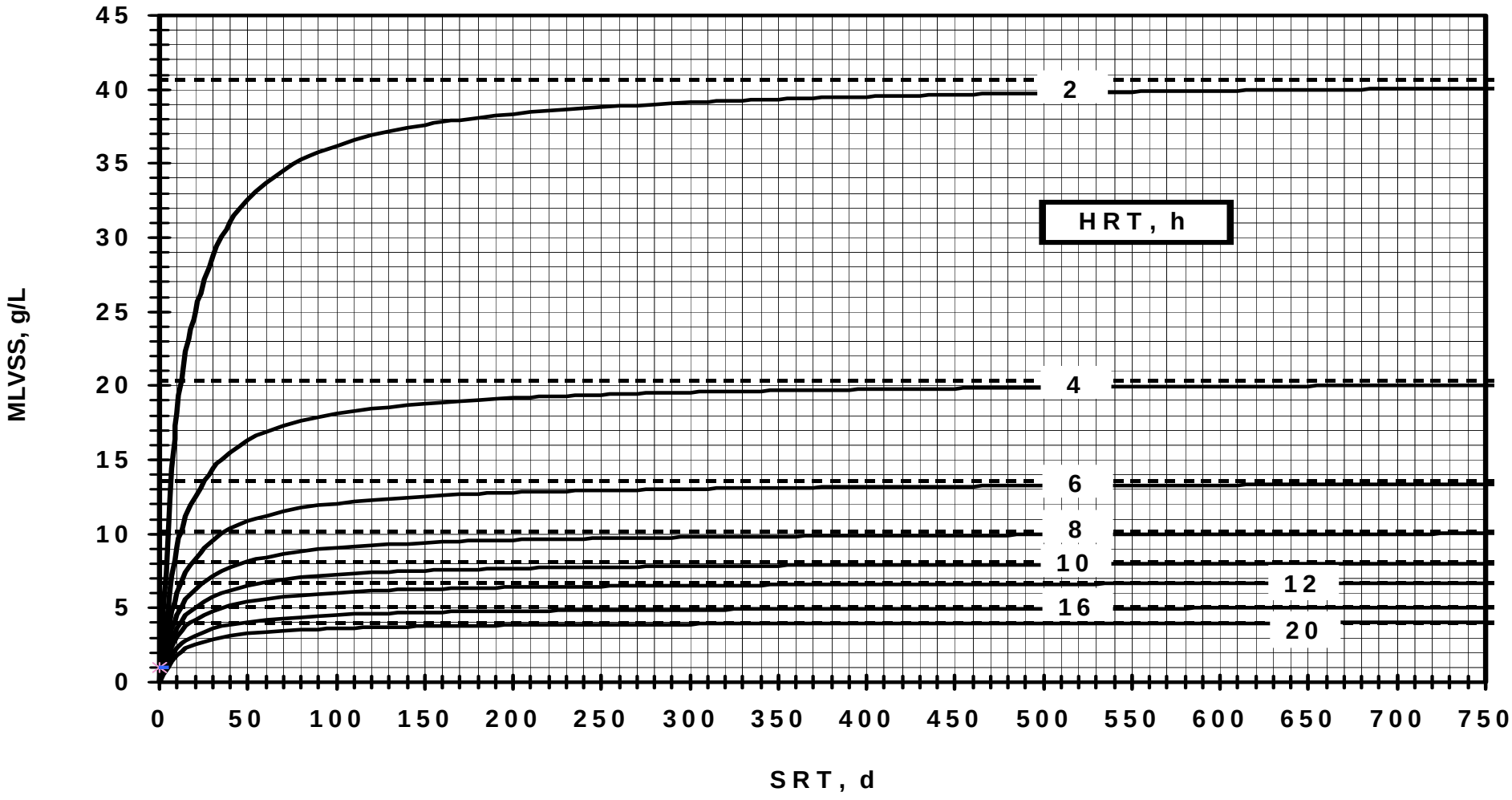
Current biological wastewater treatment

MBR G3

- √ **Significantly reduced energy consumption**
- √ **Minimized excess sludge production**
- √ **Integrated N & P removals**
- √ **Extended filtration time**

Current biological wastewater treatment

When SRT→ ∝ , $\lim_{SRT \to \infty} MLVSS = \frac{Y}{k_d}\left(\frac{C_i - C_e}{HRT}\right)$



Zero excess sludge MBR≡

$$\textbf{MBR at } \frac{Y}{k_d}\left(\frac{C_i - C_e}{HRT}\right), gMLVSS/L$$

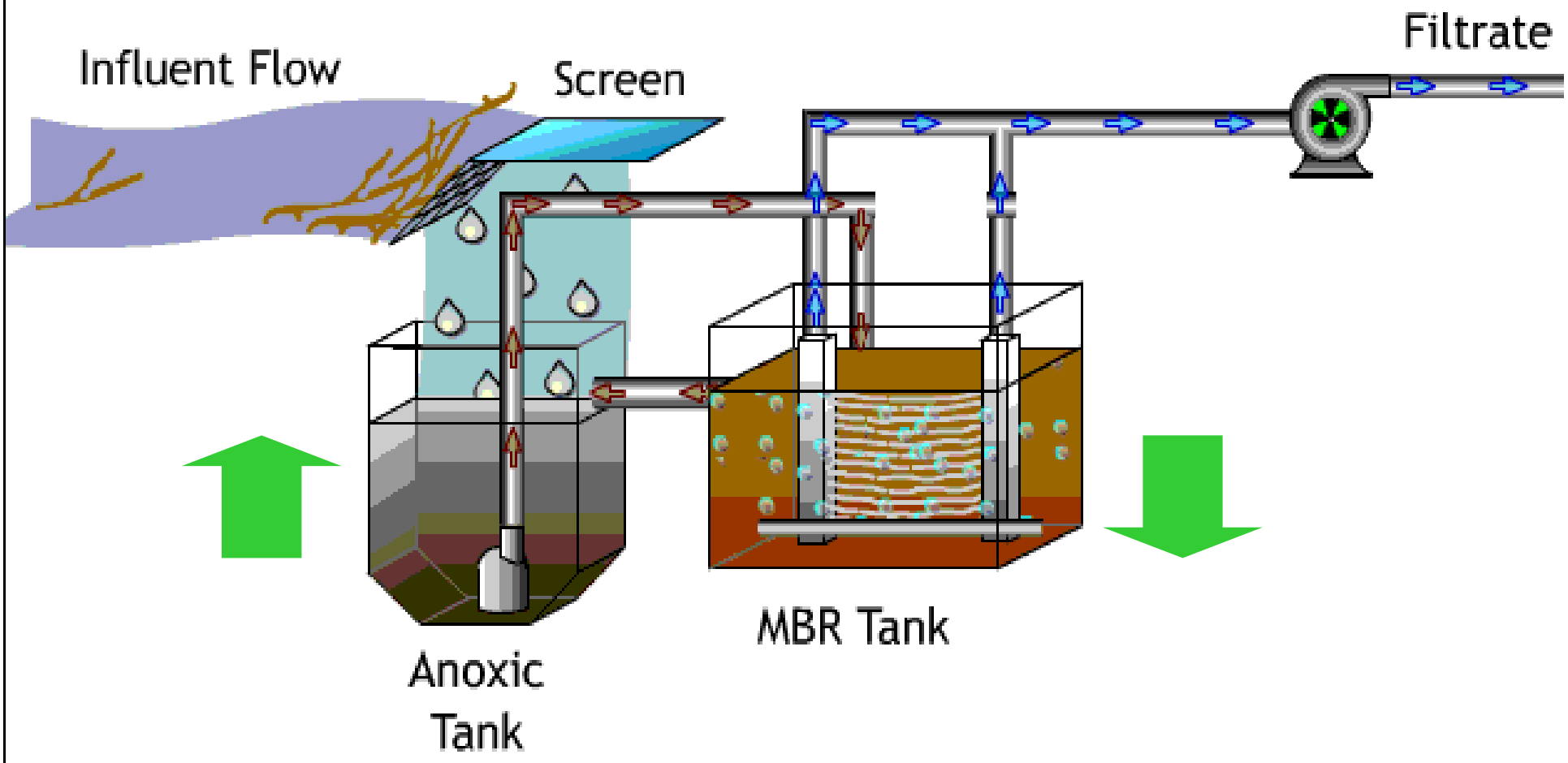
The highest MLSS in practice

- **5-Year Dutch MBR experience (2000-2005):**
  preferably up to 10g/L while 20g/L unfavorable

- **Japan recommendations: 10g/L~20g/L**

*** Building Research Institute, Ministry of Construction (1998) Design and management guidelines for the development of advanced onsite domestic wastewater treatment facilities using membrane filtration. Water and Waste 40(3):241-252.**

Current biological wastewater treatment



Current biological wastewater treatment

Yamamoto and Xing (2005)
Zero Excess Sludge MBR,
US Patent No. 11/070,134

Current biological wastewater treatment

	Removal Average, %	Permeate Average
COD	92.1%	12.6mg/L
Nitrification	93%	1.3 as mgNH_3-N/L
deNitrification*	71.7% at R=300%	8.86 as mgTN/L
Turbidity	99.9%	0.01NTU

Current biological wastewater treatment

Case I: Tanzhou WWTP, Beijing (45,000m^3/d in operation)

Current biological wastewater treatment

Case II: Wenyuhe Reclamation Plant, Beijing(100,000m^3/d)

Current biological wastewater treatment

For anaerobic processes:

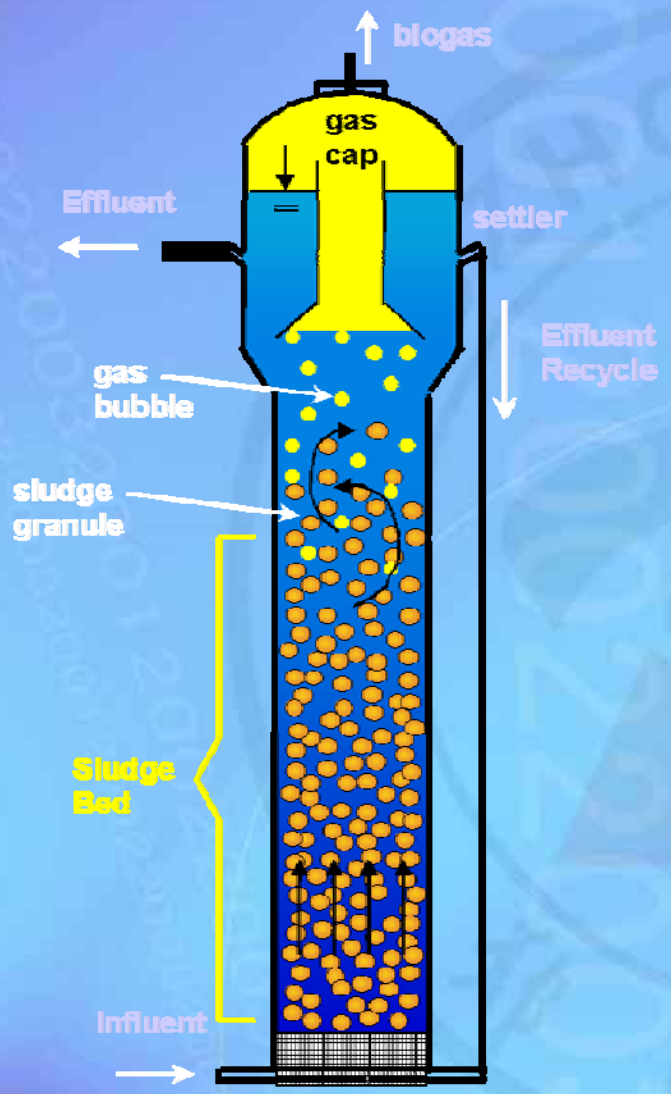
- Insufficient mixing
- Limited 3-phase separation

Major breakthrough:

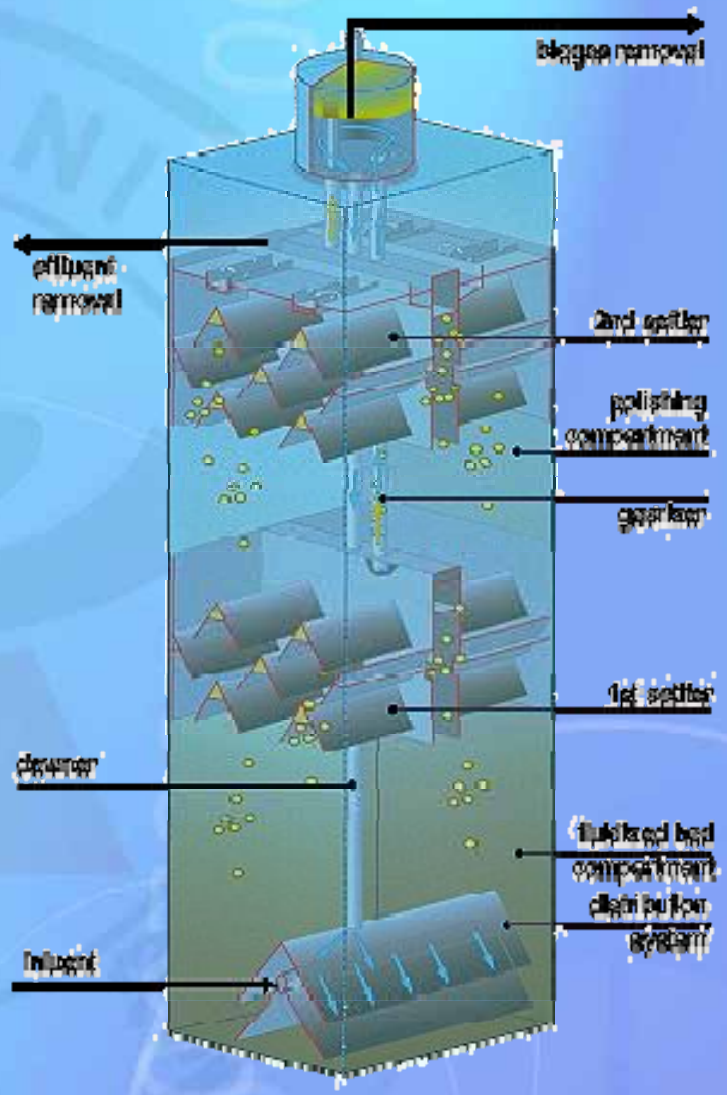
- IC Reactor

Sludge digester= G1

Current biological wastewater treatment



UASB= G2



IC= G3

Current biological wastewater treatment

Pukang Lincomycin Wastewater Treatment, Nanyang China (4,500m^3/d)

Promising R&D focuses

(G4) ?

IC (G3)

UASB (G2)

Digester(G1)

+

MBR (G3) ?

MBR (G2)

MBR (G1)

Promising R&D focus

Anaerobic Reactor (G4)

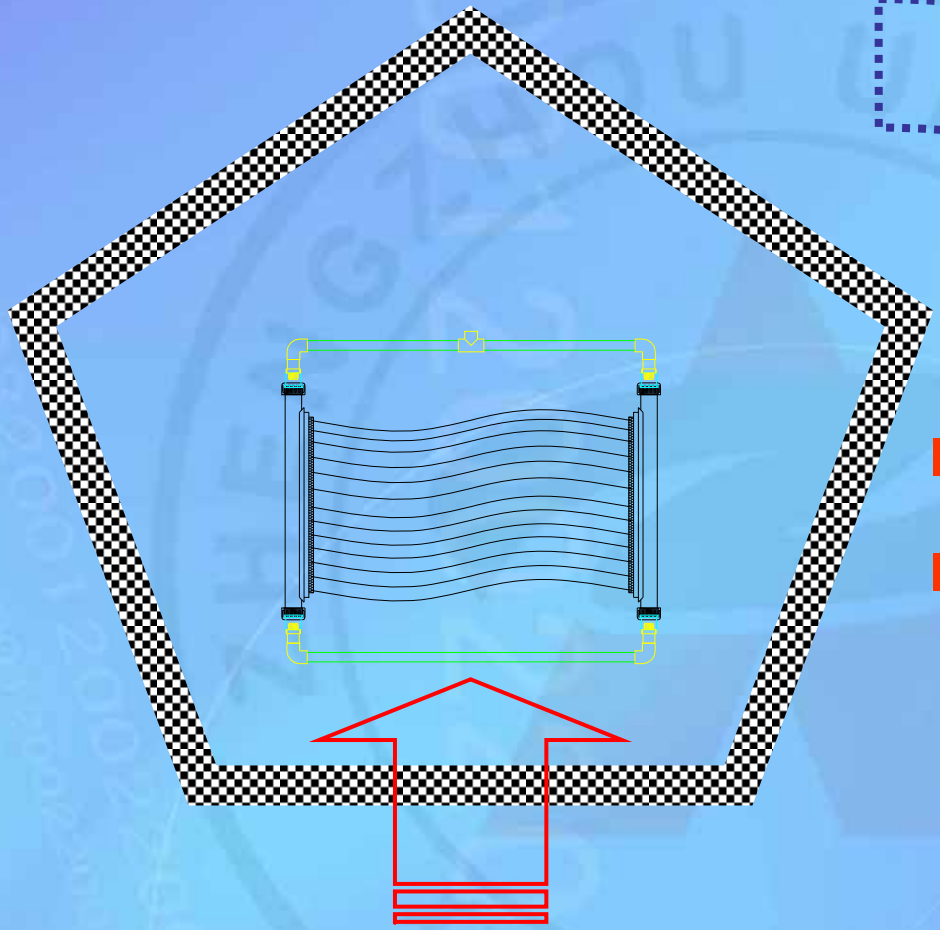
1. Enhanced mixing
2. Improved 3-phase separation
3. Lowered influent strength ?

Promising R&D focus

MBR (G3)

1. Significantly reduced kWh/m^3 treated
2. Preferably zero excess sludge
3. Integrated N and P removals
4. Extended filtration time

Promising R&D focus



- Fouling control
- Mixing effect

Biogas, O_2 depleted air

Anaerobic MBR (II) ?

Future R&D : a shift in concept ?

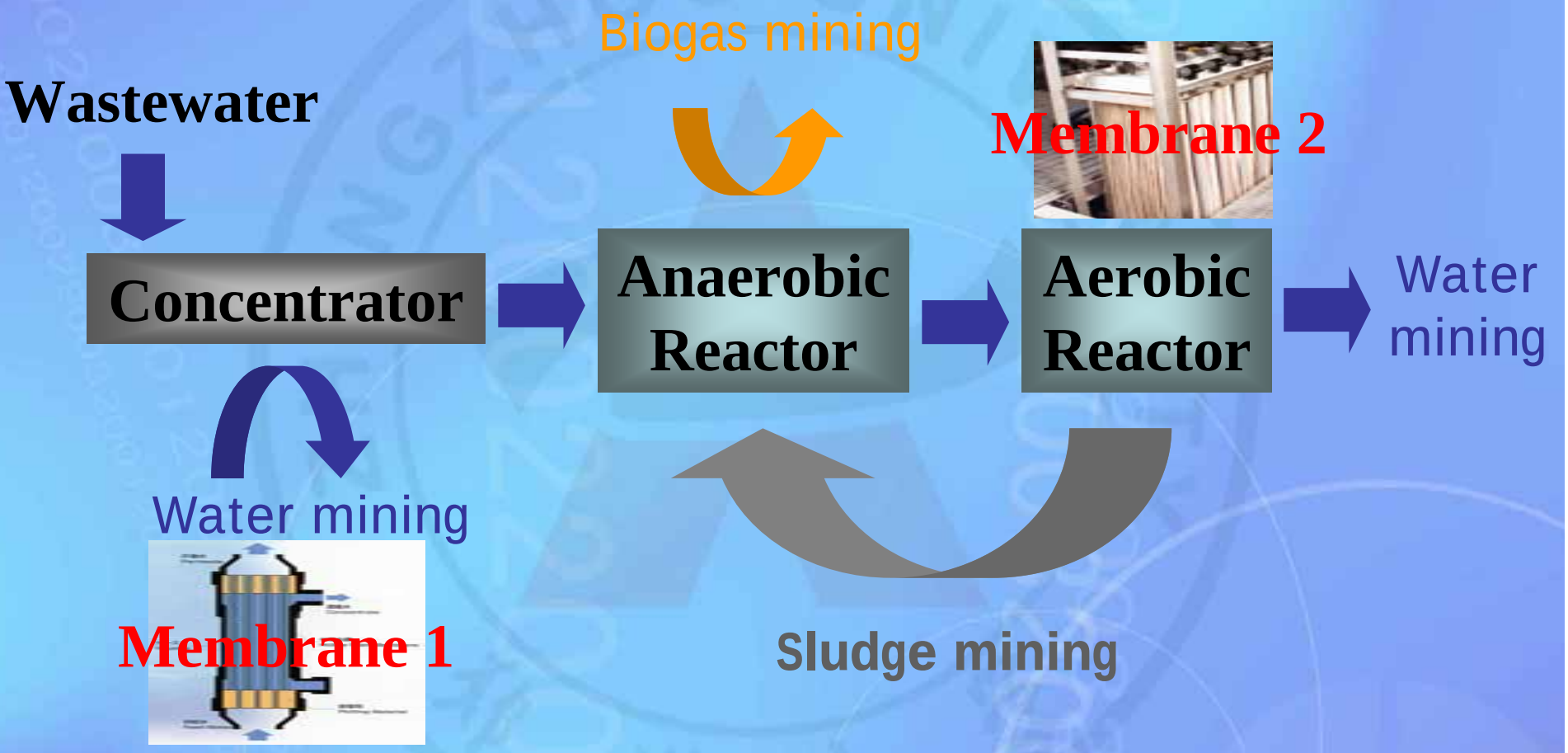
Currently,

- Nutrient removals (*i.e.*N、P)
- Excess sludge disposal
- Water reclamation & Reuse

Future,

- Energy recovery
- Sludge production
- Water-mining

Future R&D : a shift in concept ?



Dual Membrane bioreactor ?

Concluding remarks

(G4)

IC (G3)

UASB (G2)

Digester(G1)

+

MBR (G3)

MBR (G2)

MBR (G1)