Biogas Recovery from Domestic Wastewater with Anaerobic Membrane Bioreactor

Jaeho Bae

Inha WCU research team

INHA University, World Class University Research Team

CONTENTS

I. Wastewater as Resources

- **Wastewater's Resource Potential**
  - **Water**
    - **Industry, Agriculture, Domestic Use**
  - **Fertilizing nutrients (N&P)**
  - **Energy: Organic & Latent Heat**

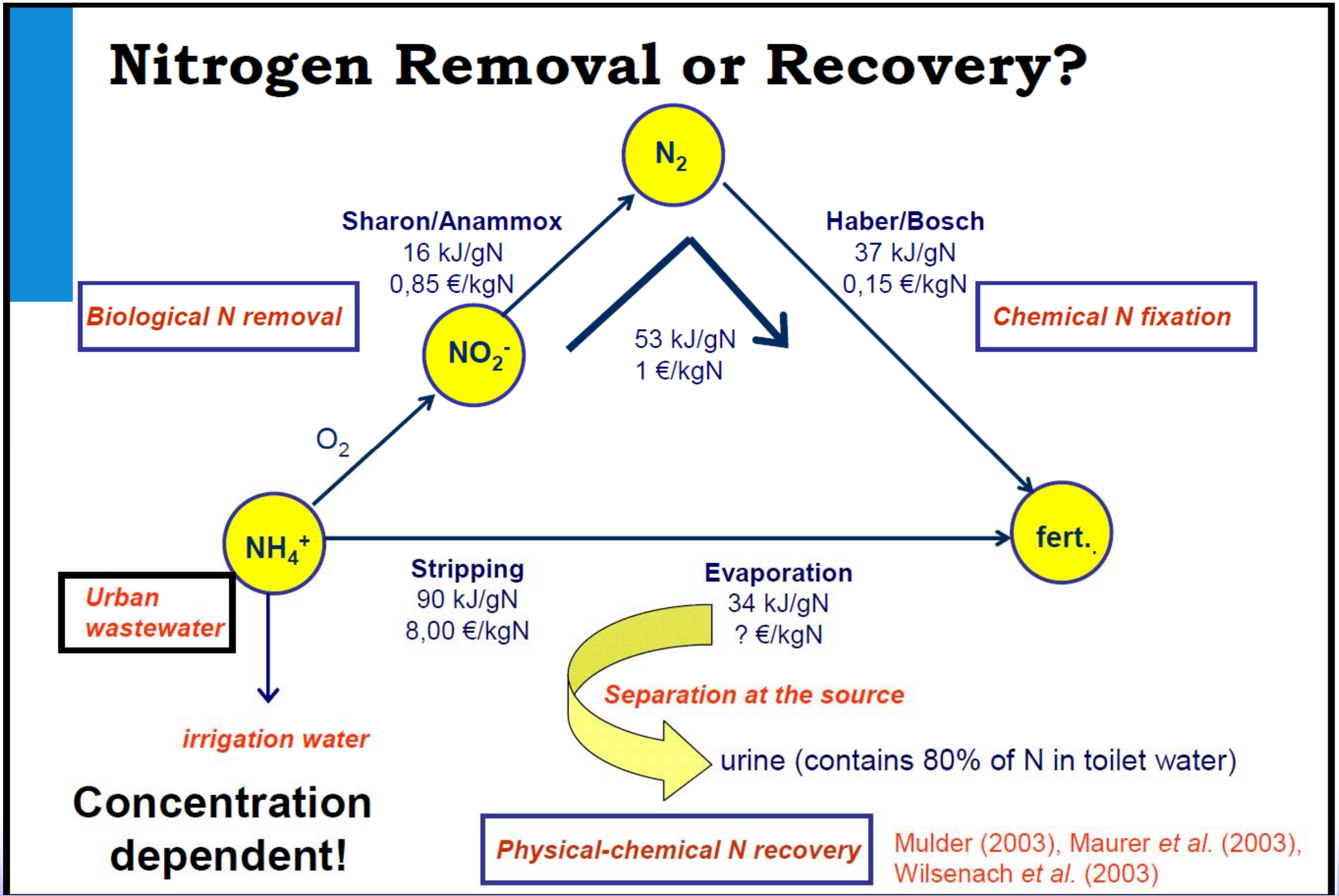
I. Wastewater as Resources

- **Water**

Wastewater Reuse for Drinking
Newater - Singapore

I. Wastewater as a Resource

- **Nitrogen**



(van Lier, 2011)

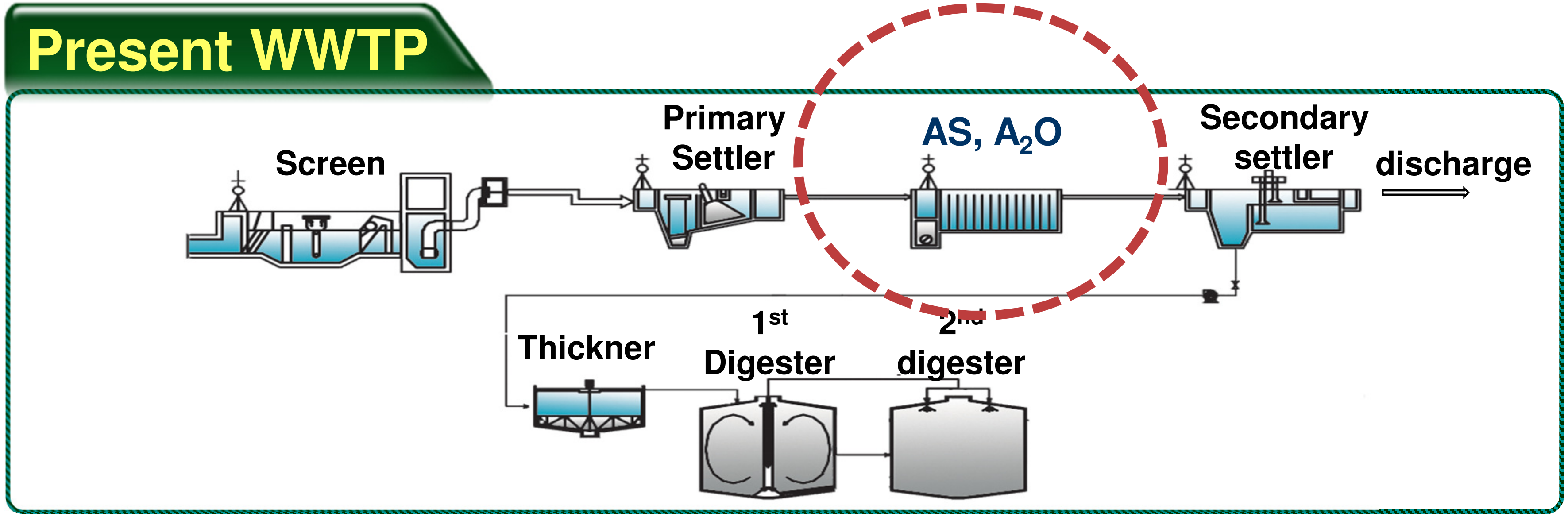
I. Wastewater as Resources

- **What is Best Reuse Option for Capturing All of Wastewater's Resource Potential?**
  - Irrigation is an energy consumptive use
  - Irrigation is major consumer of water
  - Quality requirements less than for domestic reuse
  - Wastewater nutrients (N&P) are useful fertilizers

  - Wastewater energy potential can be recovered through anaerobic treatment

II. Anaerobic Treatment

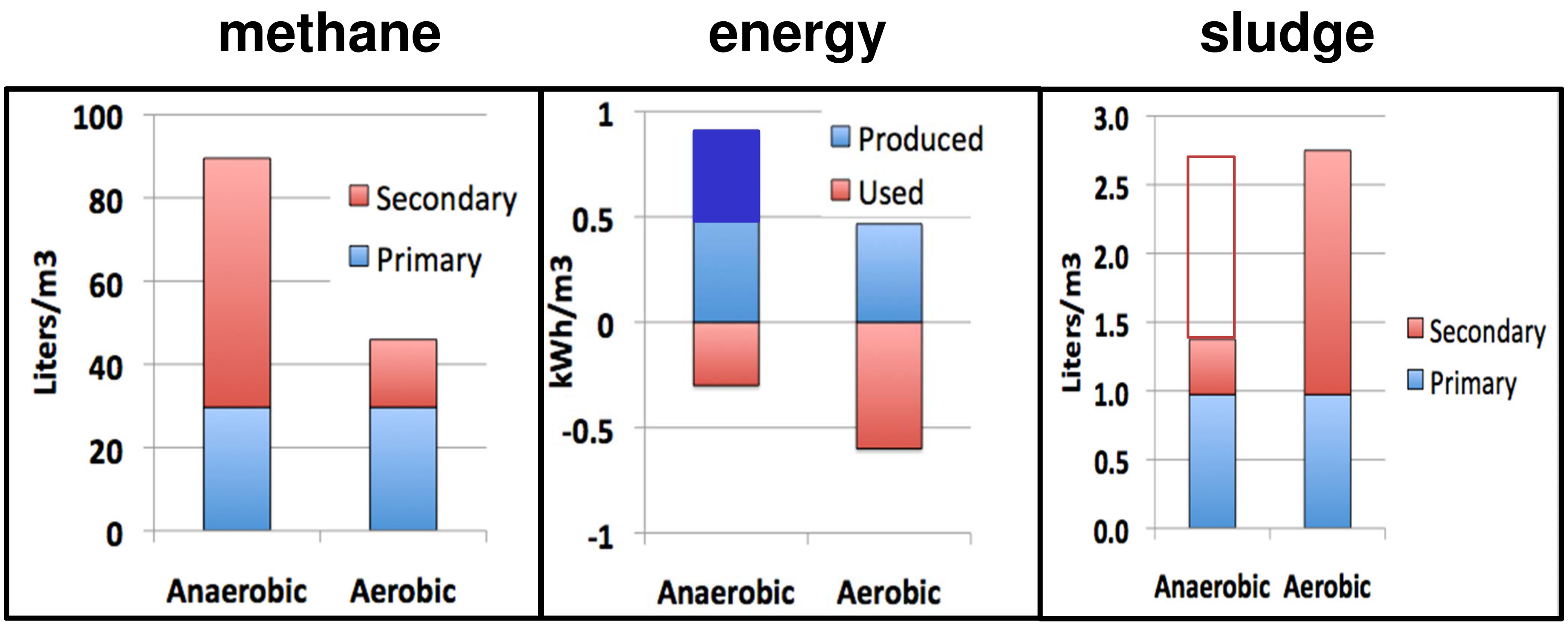
- **Paradigm Shift for WW Treatment**



- **Problems with Present WWTP**
  - **Energy**: Aeration Energy (50% of STP consumption)
  - **Sludge**: 50% of organic into sludge, non-biodegradable
  - **Resource**: N and P

II. Anaerobic Treatment

●Aerobic vs Anaerobic Treatment

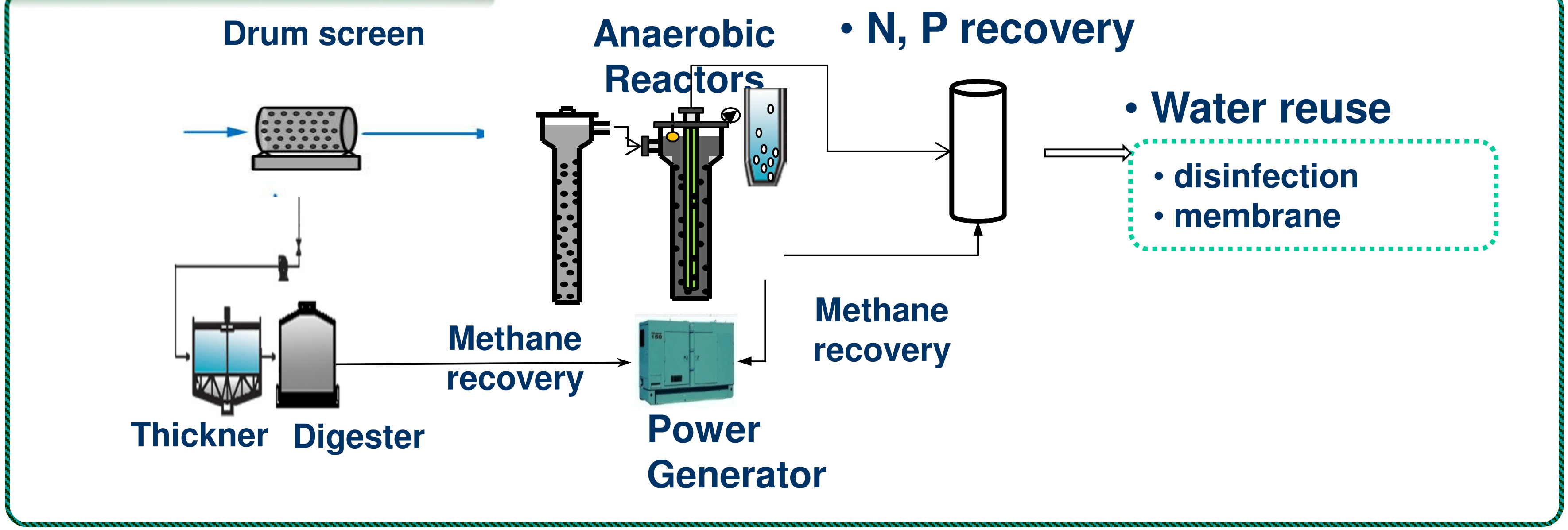


- Sewage: BOD = 200 , VSS = 192 mg/L

II. Anaerobic Treatment

- **New Paradigm: Resource Recovery from WW**

Future STP



- **Energy positive STP: saving and production of Energy**
- **Sludge reduction**
- **N and P recovery**

II. Anaerobic Treatment

- **Common Fallacies on Anaerobic Treatment**
  - Can only treat highly concentrated wastewaters such as sewage sludge
  - High Temp: Must operate at temperature of 35^{o}C to be efficient
  - Long HRT: Retention time of 15 days or more is needed
  - Poor effluent quality: Cannot degrade organic compounds as efficiently as aerobic systems

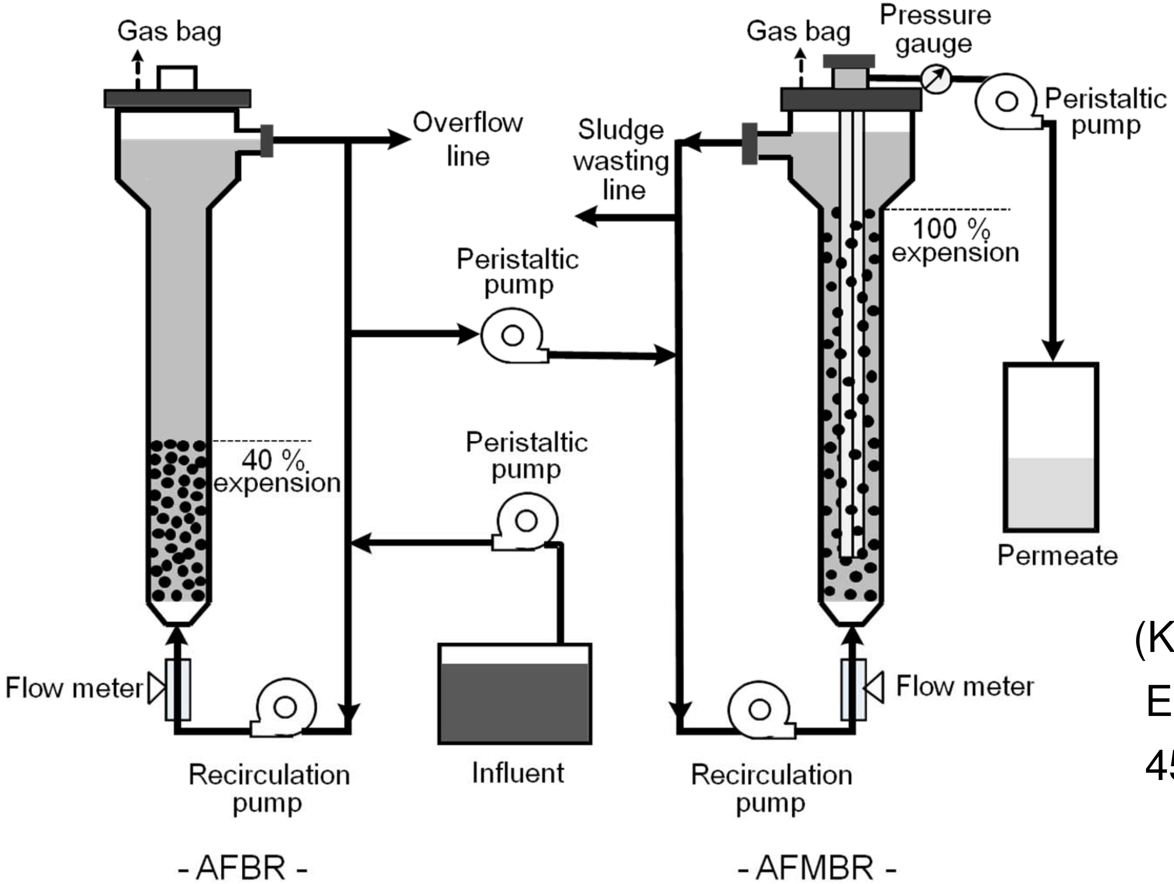
II. Anaerobic Treatment

- **Question**

  Can we treat DWW **anaerobically** to achieve net **energy production** and **sludge reduction** while meeting normal **effluent quality standards** at **short hydraulic retention time and ambient temperature**?

III. Pilot Results

Proposed SAF-MBR system



(Kim et al., Env. Sci. Tech. 45:576, 2011)

Staged Anaerobic Fluidized Membrane Bioreactor (SAF-MBR)

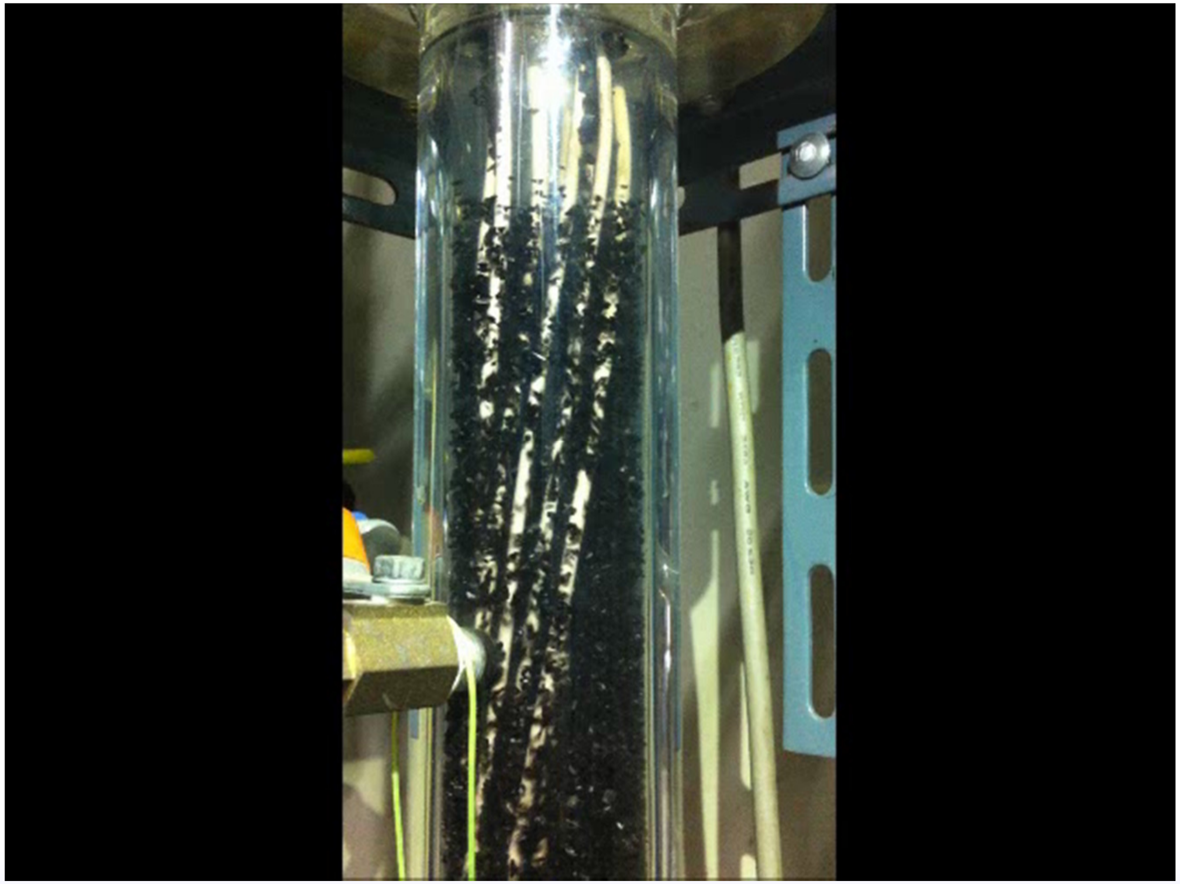
III. Pilot Results

- **Anaerobic fluidized bed reactor (AFBR)**
  - **Advantages**
    - Short HRT
    - Good mass transfer
    - Good sorption capacity (GAC)
  - **Disadvantages**
    - Cost for media

- **Anaerobic fluidized MBR (AFMBR)**
  - **Advantages**
    - High quality (SS free) effluent
  - **Disadvantages**
    - Membrane fouling

III. Pilot Results

Fouling control with GAC fluidization in the AFMBR

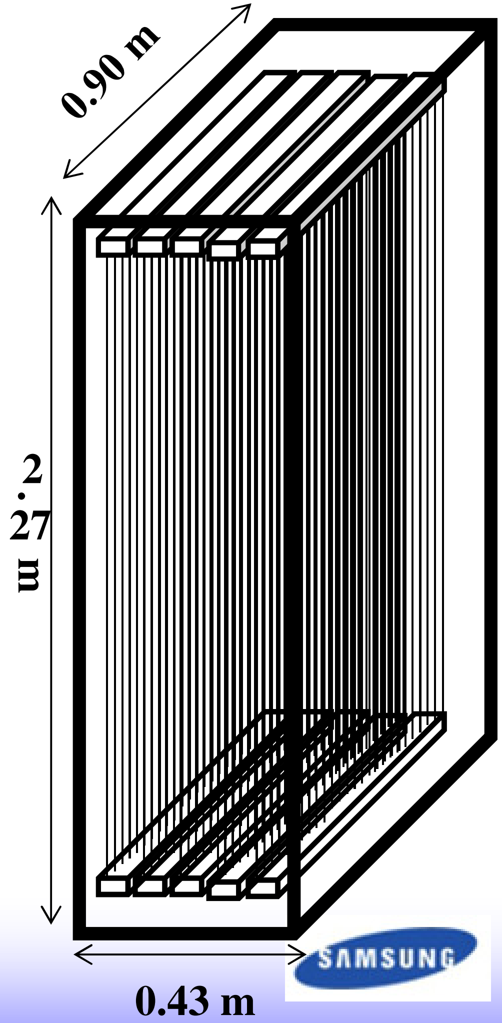


III. Pilot Results

10 m^3/day SAF-MBR Pilot Plant
at Bucheon, South Korea

III. Pilot Results

- **Hollow fiber membrane in AFMBR**



Cheil Industries

III. Pilot Results

- **Operational Conditions**
  - **AFBR**
    - GAC = 25%
    - HRT = 1.9 h
  - **AFMBR**
    - GAC = 50%
    - HRT = 3.1 to 3.5 h
    - Hollow Fiber Membranes (PVDF, 0.03 μm)
    - Membrane Flux = 7.4 to 6.5 L/m^2/h
  - **Total HRT = 5 to 5.4 h**
  - **2 mm-screened primary clarifier effluent**

III. Pilot Results

- **COD Removals**

Day	Season	Temp. (°C)	Inf. (mg/L)	AFBR Eff. (mg/L)	AFMBR Eff. (mg/L)	Rem. (%)
0–64	Fall	20 – 15	273	172	39	86
65 –165	Winter	15 – 8	319	231	58	81
166–273	Spring	15 – 25	371	252	39	90
274–366	Summer	25 – 30	282	152	14	95
367–383	Fall(II)	25 – 20	226	164	15	93

III. Pilot Results

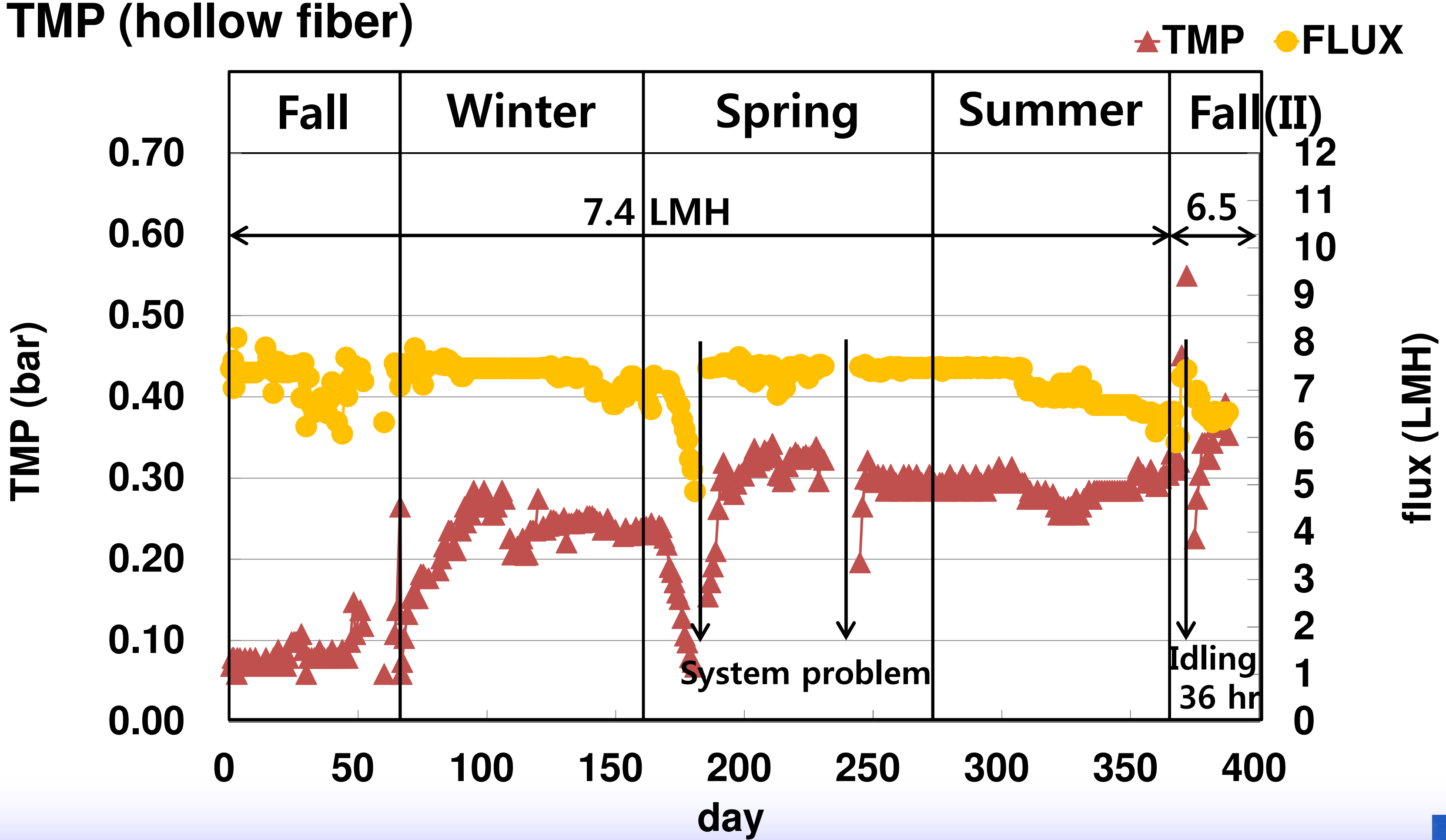
- BOD$_5$ Removals

Day	Season	Temp. (°C)	Inf. (mg/L)	AFBR Eff. (mg/L)	AFMBR Eff. (mg/L)	Rem. (%)
0 – 64	Fall	20 – 15	169	75	18	89
65 – 165	Winter	15 – 8	233	121	33	86
166 – 273	Spring	15 – 25	187	127	20	89
274 – 366	Summer	25 – 30	134	78	3	98
367 – 383	Fall(II)	25 – 20	148	105	5	97

III. Pilot Results

- **TMP Variations**

TMP (hollow fiber)



III. Pilot Results

- **Energy Balance (kWh/m³)**

	Energy requirement			CH_4 Energy Potential*
	GAC	Mem-brane	Total	
AFBR	0.009	-	0.009	**0**
AFMBR	0.104	0.003	0.107	**0.139**
total	**0.113**	**0.003**	**0.116**	**0.139**

* This does not include methane from primary sludge

** Conventional gas purging requires 0.5-1.0 kWh/m³

IV. Summary

1. Effluent qualities of the AnMBR treated DWW at a total HRT of < 6 h and ambient temperatures (8 – 30 ^{o}C) was comparable to those of the conventional aerobic processes

   - Removals of COD > 85% and BOD_5 > 90%

   - Effluent COD < 30 mg/l and BOD_5 < 5 mg/L

2. GAC souring was very effective tool for reducing membrane fouling at low operating cost.

3. The AnMBR is a low-biosolids-producing, high-efficiency domestic wastewater treatment system with net energy production and sludge reduction potential.

IV. Future Directions

- Optimization of AFMBR
- Recovery and use of dissolved methane
- Control of H_2S production or its utilization
- N and P recovery
- Nitrogen removal
  - Heterotrophic method is not an option
  - Anammox
  - Short-cut dentrification with sulfide or S
  - Use of dissolved methane

INHA WCU team is Developing the Best

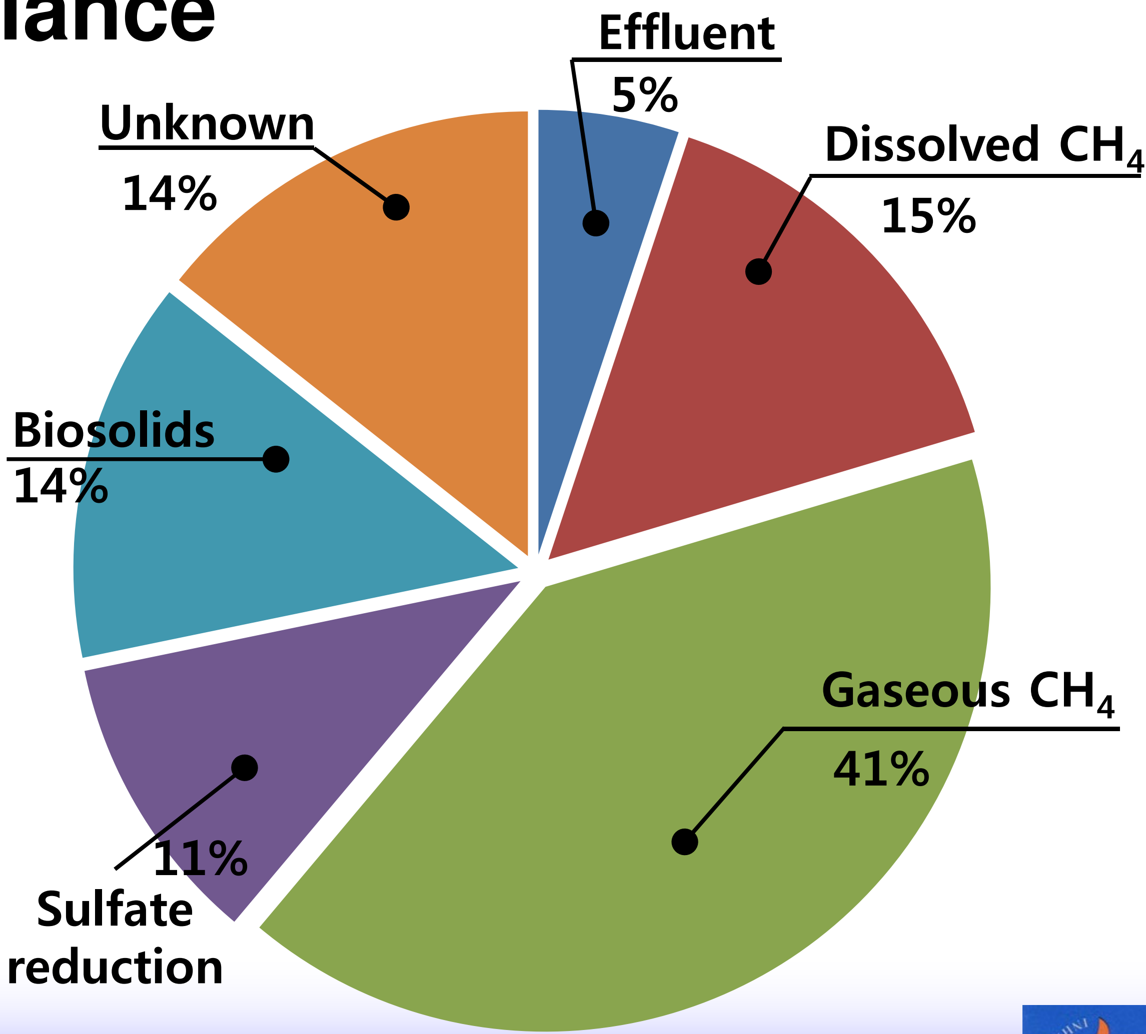
Anaerobic Membrane Technology

for Domestic Wastewater

III. Pilot Results

● COD mass balance

Content	Conc. (mgCOD/L)
Influent	227
Effluent	11
COD removed	216
Dissolved CH_4	33
Gaseous CH_4	88
SO_4^{2-} reduction	23
Biosolids	30
Unknown	31

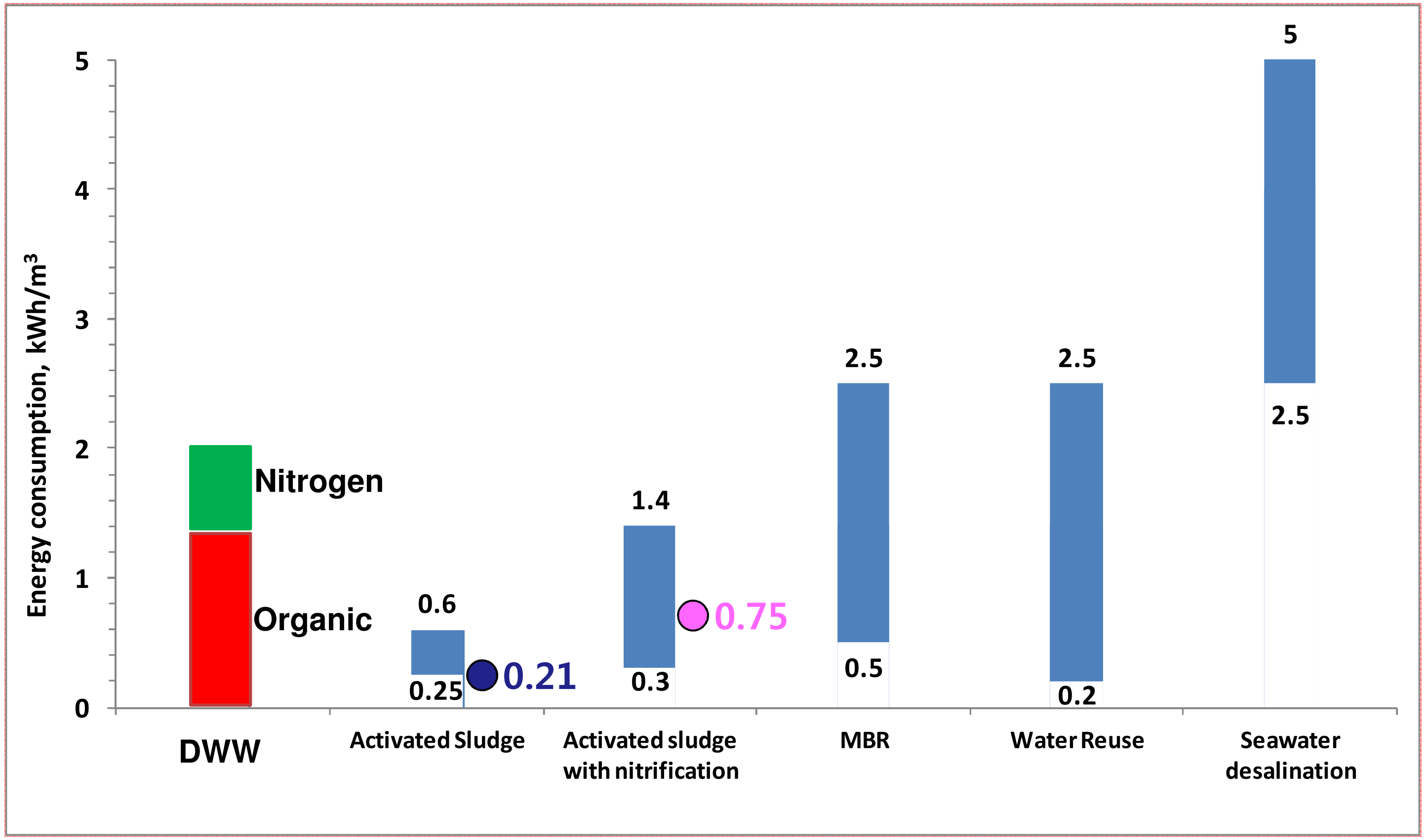


Publications on the SAF-MBRs

1. Domestic Wastewater Treatment as a Net Energy Producer – Can This be Achieved? *Env. Sci. Tech.,* 2011
2. Anaerobic Fluidized Bed Membrane Bioreactor for Wastewater Treatment, *Env. Sci. Tech.,* 2011
3. Model to Couple Anaerobic Process kinetics with Biological Growth Equilibrium Thermodynamics, *Env. Sci. Tech.,* 2011
4. Effects of influent DO/COD ratio on the performance of an anaerobic fluidized bed reactor fed low-strength synthetic wastewater, *Biores. Technol.*, 2011.
5. Lower operational limits to volatile fatty acid degradation with dilute wastewaters in an anaerobic fluidized bed reactor, *Biores. Technol.*, 2012.
6. Anaerobic treatment of municipal wastewater with a staged anaerobic fluidized membrane bioreactor (SAF-MBR) system, *Biores. Technol.*, 2012
7. Two-stage anaerobic fluidized-bed membrane bioreactor treatment of settled domestic wastewater, Wat. Sci. Tech., 2013.

I. Wastewater as Resources

● Energy: Contents and Treatment Requirements



Energy footprint of the water treatment processes

Adapted from Meda and Cornel, 2010, Wilson, 2009, Voutchkov, 2010 and Lazarova et al, 2012.

Thank you