Application of biogas plant to recycle organic wastes

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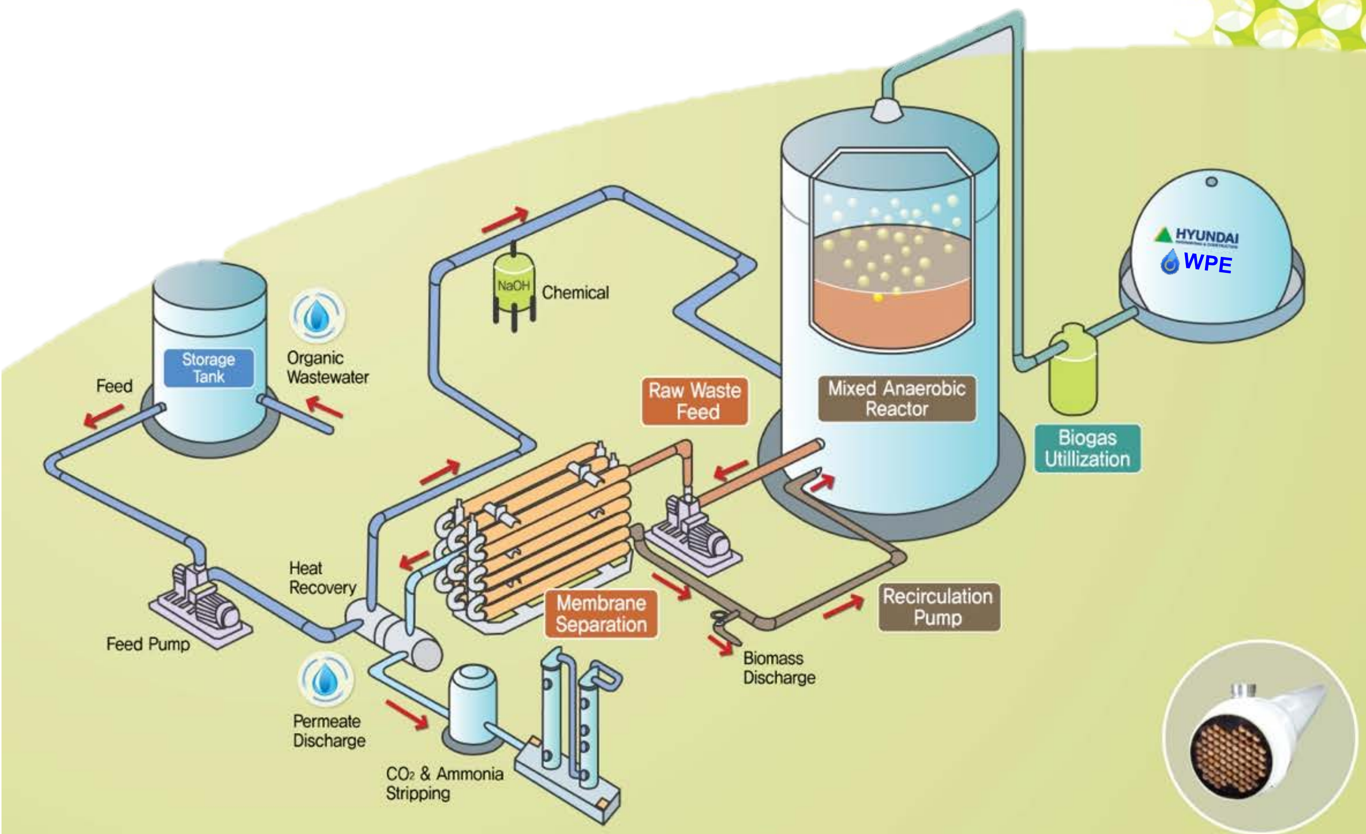
HYUNDAI MOTOR GROUP

HYUNDAI ENGINEERING & CONSTRUCTION

INOVATION for Eco-SUSTAINABILITY

"Harvesting Clean Energy & Clean Water from Wastewater"



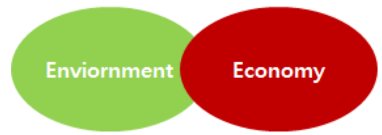
Talk outline

1. Value of Organic Wastes
2. Anaerobic Digestion description.
3. Stage of Biogradation
4. Anaerobic Membrane Bioreactor (AnMBR)
5. See Hyundai Biogas Plant (HAnDs)
6. Opportunity for Application

Where do organic wastes come from?

Paradigm of organic wastes treatment

2Es



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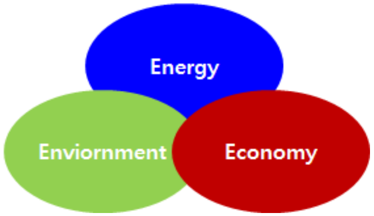
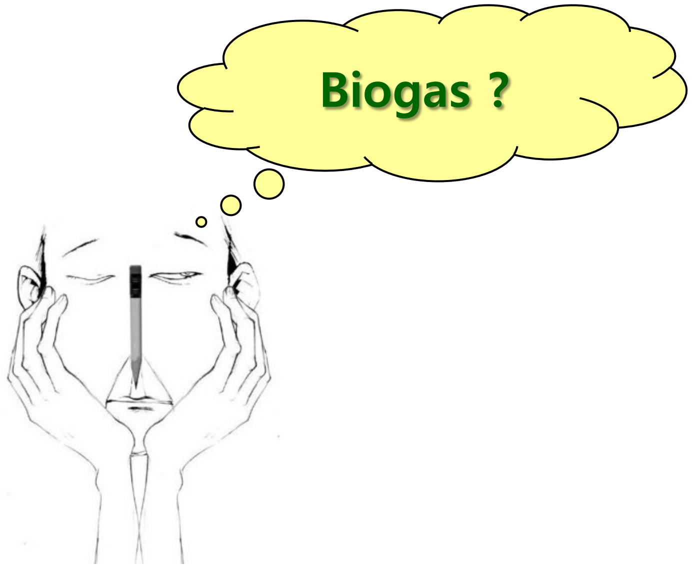


Treatment & Disposal

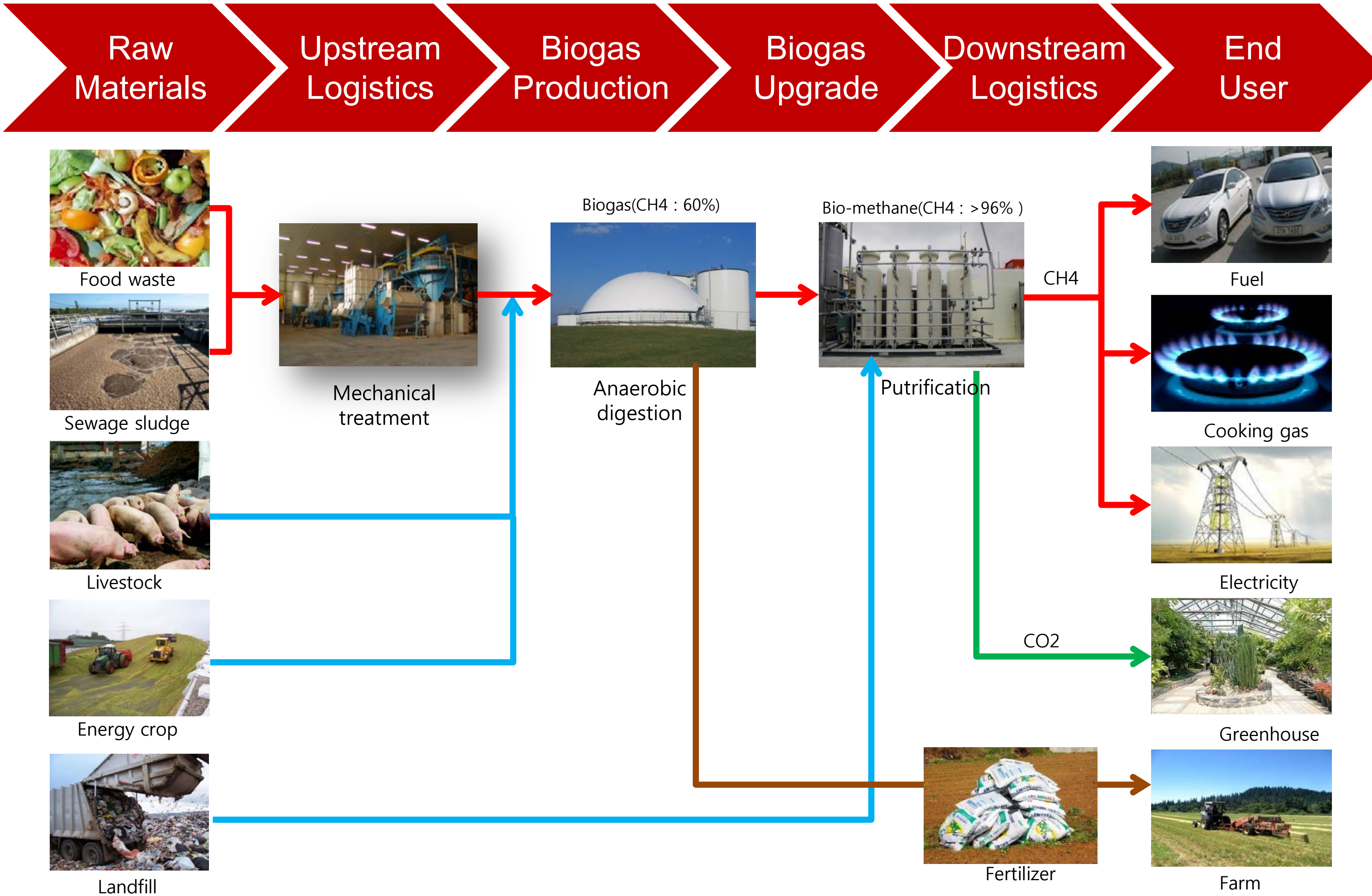
Recycling & Regeneration



Anaerobic Digestion

- Biogas production (Bioenergy)
- Greenhouse gas reduction
- Efficient organic removal

Value Chain


Raw Materials
Upstream Logistics
Biogas Production
Biogas Upgrade
Downstream Logistics
End User
Food waste
Sewage sludge
Livestock
Energy crop
Landfill
Mechanical treatment
Biogas(CH4 : 60%)
Anaerobic digestion
Bio-methane(CH4 : >96%)
Putrification
CH4
CO2
Fertilizer
Fuel
Cooking gas
Electricity
Greenhouse
Farm

Characteristics of Organic Wastes in Korea

High Volatile Solid Content

- Readily biodegradable
  → Easy corruption
- Renewable energy source

High Moisture Contents

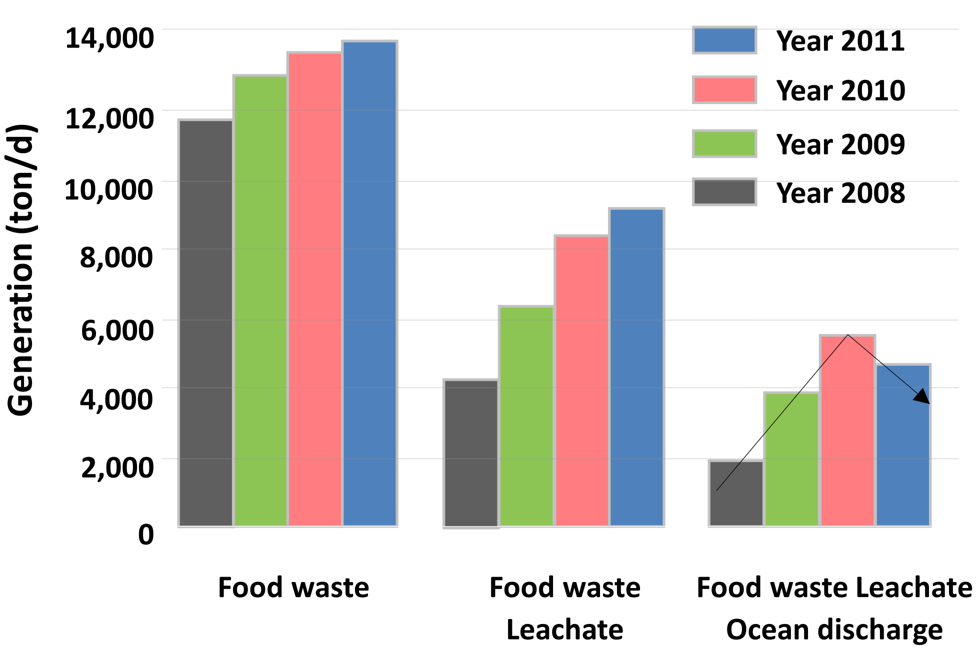
- Hard to apply physical and chemical treatment such as incineration etc.
- High cost for management

Heterogeneous Bacteria/ Pathogens

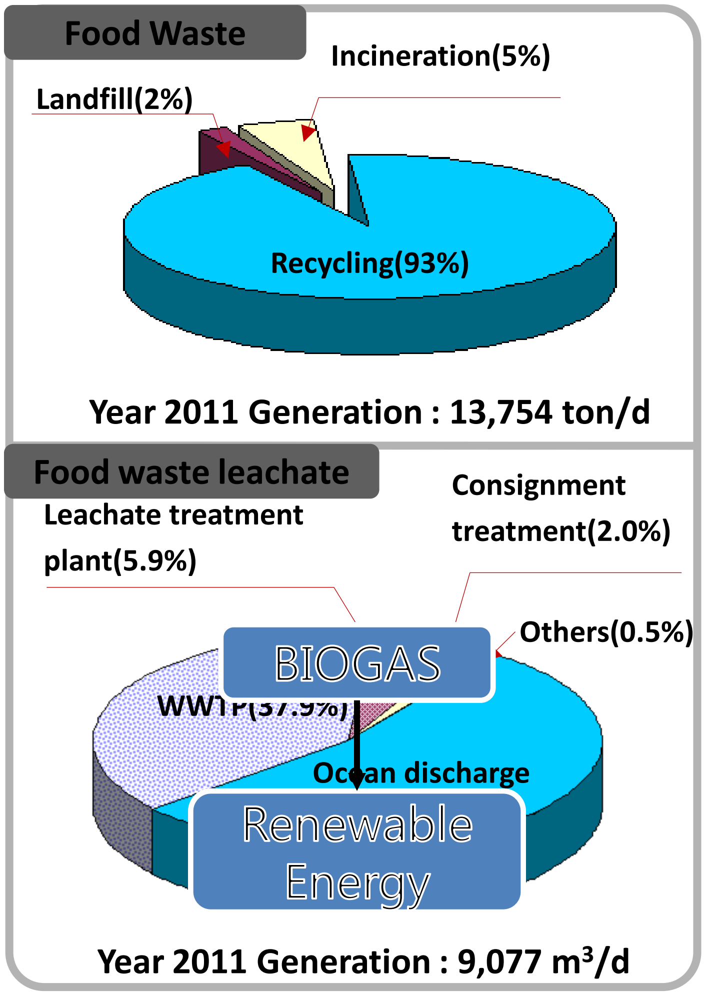
- Necessity of pretreatment
- Hard to apply microbial /enzyme treatment techniques
  → due to contamination or competition between microorganisms

Generation and Treatment of Food Waste

Year's Generation and Discharge



Source : Korea Ministry of Environment (2011)



Anaerobic Digestion : Biogas History

19th century

- 1800's France
  - Sludge tank
- England and Germany
  - Septic & Imhoff tank

~ 1930's

- Biological Anaerobic digester
  - Mixer
  - temperature
  - HRT(over 30 days)

~ 1970's

- Many type of Anaerobic digester
  - Basic Research
  - Application
  - Single stage

1980's ~ Present

- High rate of Anaerobic digester
  - Multi stage
  - Feedstock
    : Wastewater, Manure
    Foodwaste

→ Membrane + AD

What is Biogas Digestion

- Reduce
  - Smell
  - Greenhouse gas
  - Pathogen level
- Produce biogas
- Improve fertilizer value of manure
- Protect water resources

- Biogas Digestion is the process of taking biogas to produce electricity, heat, or hot water
- Biogas means a gas formed by carbon dioxide and methane from breakdown of organic materials such as manure.

- **Basic of digestion**

  Substrates must be degradable

  Substrates must/should be available at a constant mass/volume flow

  Substrates should have a nearly constant composition

  Concentration of organic dry matter should be higher than 2 %

  Substrates should be a liquid slurry

  Digester volume should be more than about $100 m^3$

What is a Digester?

- Digester is a vessel or container where the biogas process takes place. Bacteria breaks down waste products to create biogas. Products may be fed into the chamber such as manure and food waste or the container could be used to cover a place that is already giving off biogas such as a swamp or a landfill.
- Biodigester is a system that promotes decomposition of organic matter.
- It produces biogas, generated through the process of anaerobic digestion.
- Biogas generated can be used for cooking, heating, electricity generation, and running a vehicle.

Basic Designs of Digester

- Continuous-fed
- Batch-fed

The Process of Biodigestion

Organic wastes (100%)

- Complex organic matter is degraded to basic structure by hydraulic bacteria.
  - Protein -> Polypeptide and Amino Acid
  - Fat -> Glycerin and Fatty Acid
  - Amylose -> Monosaccharide and Polysaccharide

- Also called the acidogenesis
- Simple organic matters are converted into H^2 and CO_2
- Acting bacteria in this process are called hydrogen-producing bacteria and acid-producing bacteria.

- Acetogenesis.
- The short-chain fatty acids are metabolized by synthrophic acetogenic and homoacetogenic bacteria into acetate, carbon dioxide, and hydrogen.

- Methanogenesis
- In this process, acetic acid, H_2, CO_2, are converted into CH_4.
- Methane-producing bacteria have strict PH requirement and low adaptability to temperature.

Disintegration

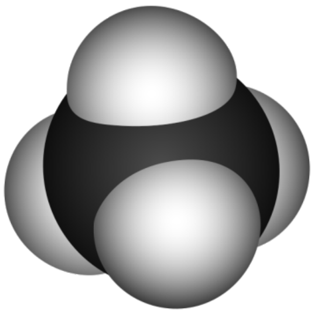
for sludge digestion

Acidogenesis

CH_4 (90%)

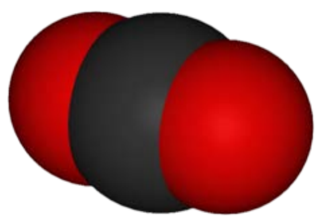
What is Biogas ?

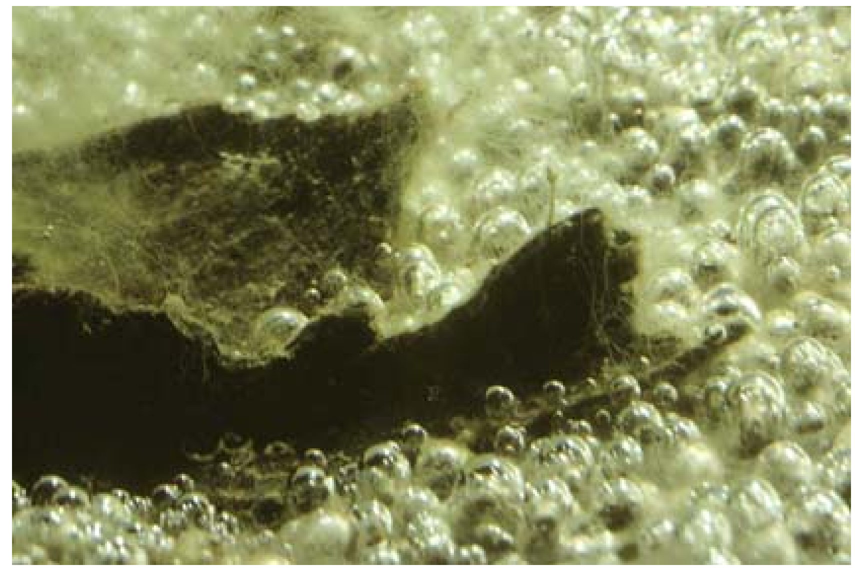
- A mixture of methane and carbon dioxide



CH_4

CO_2





- Methane or ‘swamp gas’, produced naturally in swampy ponds

What is this?

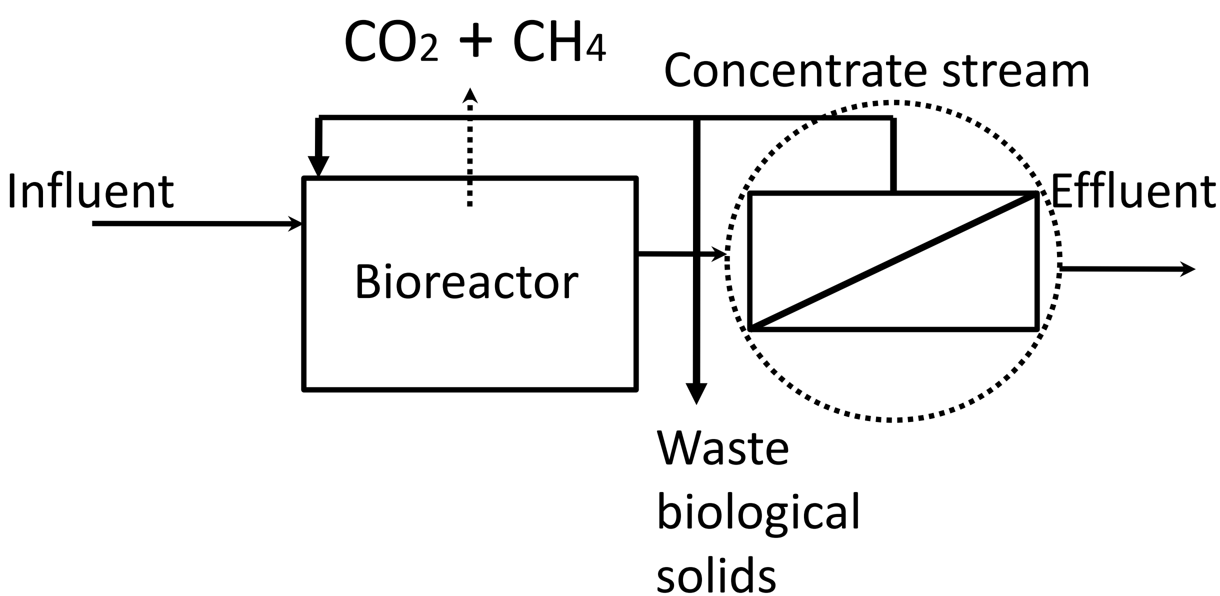
What is it used for ?

- Biogas is a fuel used as an energy source for light, heat or movement

Potential of Biogas

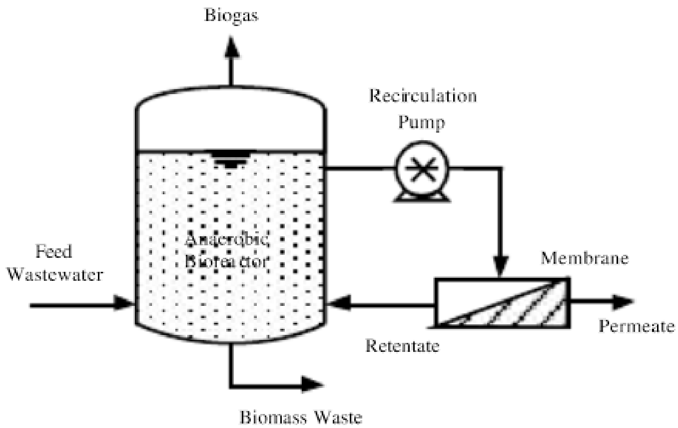
Biogas potential:	total organic solids (%)	m^3 CH_4/m^3 substrate
Waste water, municipal	0.05	0.15
Waste water, food industry	0.15	0.5
Sewage sludge	2	5 to 10
Cow manure	8	20 to 30
Pig manure	6 to 8	30 to 50
Food waste	15 to 20	100 to 120
Food waste leachate	6 to 14	30 to 60

Anaerobic Membrane Bioreactor(AnMBR)

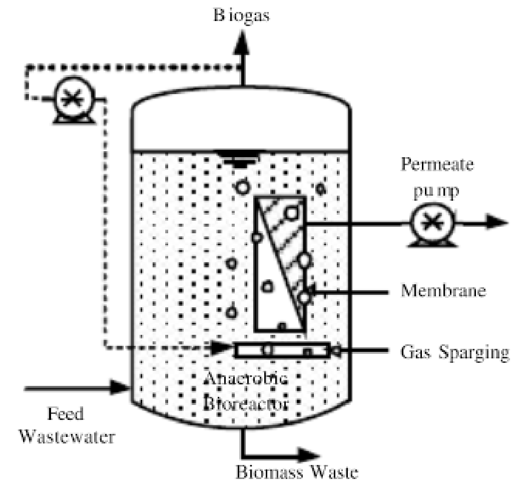


- Providing long SRT needed while operating at short HRT as required to reduce reactor size
- Pressurized type use more since membrane cleaning is easier to perform

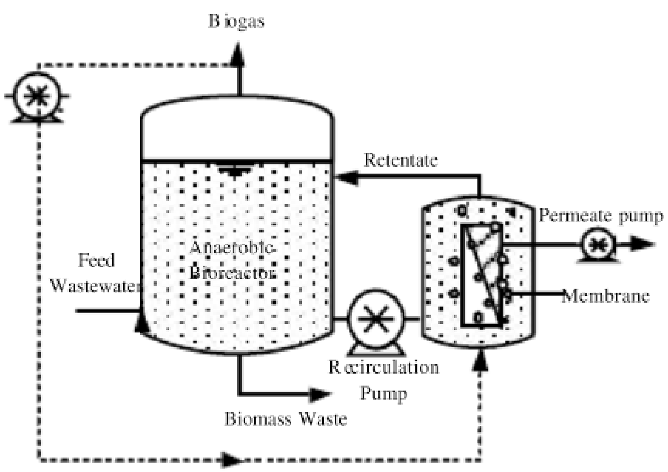
Types of AnMBR



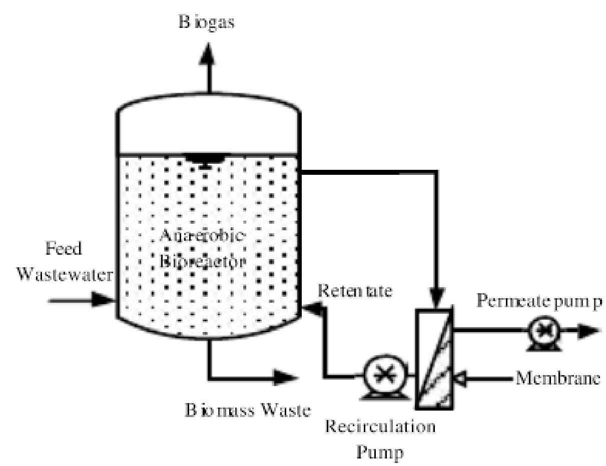
(a) External cross-flow



(b) Submerged



(c) External gas-lift



(d) External semi dead-end

Research of AnMBR

Wastewater	Volume (m^3)	Temp. (℃)	MLSS (g/L)	OLR ($g/m^3/d$)	Removal (%)	Reference
Sweet factory	0.09	35~37	-	8~9	97~99	Defour et al., 1994
Feed industry	0.4	37	6~8	4.5	81~94	He et al., 2005
Soybean processing	2	30	-	2.5	71	Yushina and Hasegawa, 1994
Brewery	0.12	36	> 50	>28.5	97~99	Ince et al., 2000, 2001
Potato starch bleaching	4	-	15~100	1.5~5	65~85	Brockmann and seyfried, 1996, 1997
Palm oil mill	0.05	35	50~57	14.2~21.7	91.7~94.2	Fakhru'l-Razi and Noor, 1999
Kraft pulp mill	5	53	8	9~28	86~89	Imasaka et al., 1993
Sewage	0.018	24~25	16~22	0.4~11	60~95	Wen et al., 1999
Primary sludge	0.12	35	-	0.4~0.68	25~57	Ghyoot and Verstraete, 1997
Heat treated sewage	0.2	35~38	10~20	4~16	79~83	Kayawake et al., 1991
Swine manure	0.006	37	20~40	1~3	-	Padmasiri et al., 2007

Operating Conditions of Membrane system

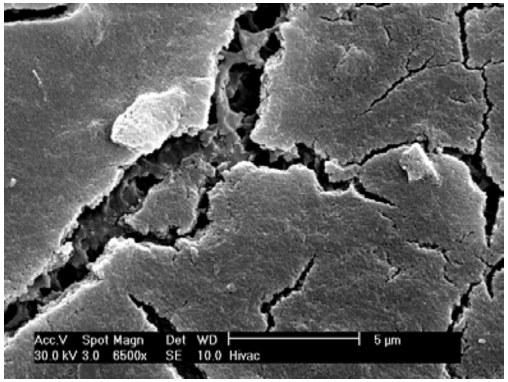
Type of wastewater	Scale[a]	Temp. (℃)	Membrane Material	Pore size[c]	Membrane area (m^2)	TMP (kPa)	linear velocity ($m. s^{-1}$)	Initial flux ($L. m^{-2}. h^{-1}$)	Final flux ($L. m^{-2}. h^{-1}$)	Reference
Wheat starch	P	40	-	18,000 D	144	690	-[d]	-	14~25	Butcher et al, 1989 Choate et al, 1983
Brewery effluent	P	35	Poly-ethersulfone	40,000 D	0.44	140~340	1.5~2.6	-	7~50	Strohwald et al, 1992
Maize processing	P	-	Poly-ethersulfone	20,000~80,000 D	668	450	1.6	-	8~37	Ross et al, 1992
Wool scouring	P	40~47	Poly-acrylonitrile	13,000 D	3.1	2~2.2[e]	-	30~45	17~25	Hogetsu et al, 1992
Glucose, peptone	L	35~38	Ceramic	0.2	0.4	30~200	0.5~4	-	12.5~125	Shimizu et al, 1992
Kraft mill effluent	P	48.4	Ceramic, aluminum oxide	0.16	1×24	60	1.75	50	27	Imasaka et al, 1993
Acetate	L	35	Ceramic	0.2	0.20	25~150	0~3.5	-	18~127	Beaubien et al. 1996
Sewage sludge	L	30~35	Poly-ether sulfone	60,000 D	0.3	375	0.75	31	19	Ghyoot et al, 1997
Molasses[f]	L	20	Polypropylene	10	0.051	-	-	100~160	10~80	Hernandez et al, 2002
Sewage	P	10~28	Ceramic	13,000 D	13.6	1~2[e]	2	-	15~20	Tanaka et al, 1987
Heat-treated liquor from sewage sludge[f]	P	35~38	Ceramic	0.1	1.06	200[g]	0.2~0.3	8~13	3~8	Kayawake et al, 1991
Food waste leachate	P	55	Polyvinylidene fluoride	0.04	13.1	100~300	1~3	-	15	Kim et al, 2011

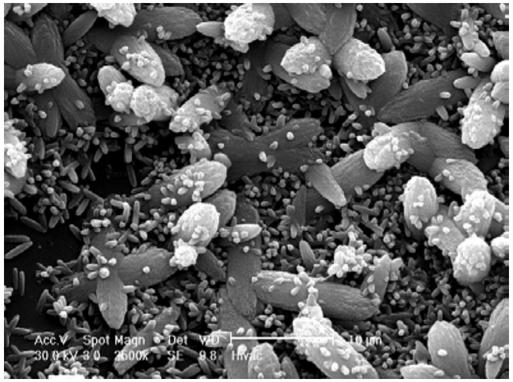
[a]All membranes were external cross–flow unless otherwise noted. [b]L = laboratory/bench scale, P = pilot scale.
[c]D = Daltons (molecular weight cutoff). [d]–Indicates value not reported.
[e]Pressure reported as kg/cm^2. [f]Submerged membrane.
[g]–Indicates value not reported

Membrane fouling and control

- Membrane fouling is an inevitable and complex phenomena
- Biogas sparging, fluidized media for submerged system
- TMP, cross-flow velocity for pressurized system

    Effectiveness varies depending upon foulant materials (e.g., particle size distribution) and module design (e.g., channel height etc)





Application of AnMBR

New: Memthane®, for industrial high-strength wastewater

Dairy Wastewater

Biothane's anaerobic biological wastewater treatment and a Pentair's X-Flow Ultra Filtration membrane separation process. Influent is fed to the anaerobic bioreactor where the organic components are converted into energy-rich biogas. Next, the anaerobic effluent is processed through the UF membrane unit, separating the 'clean' permeate from the biomass. The biomass is returned to the bioreactor, while the ultra-clean filtrate is discharged as particle-free, low BOD/COD effluent, often

"The valuable methane-rich biogas produced can cover

Memthane®, Veolia's Anaerobic Membrane Bio-Reactor (AnMBR),

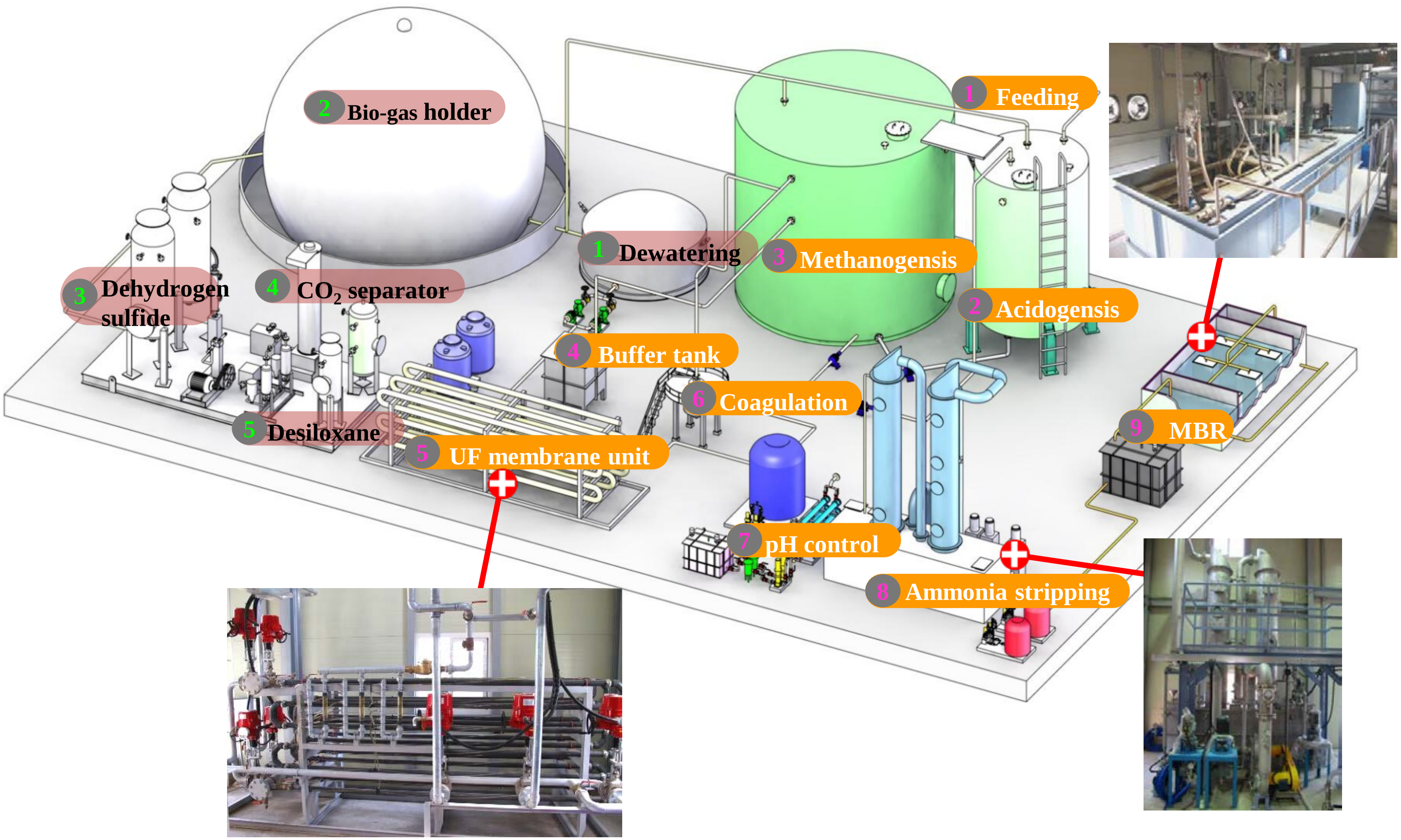
Food waste leachate

Manure(filteration)

Pilot-plant of AnMBR : HAnDs

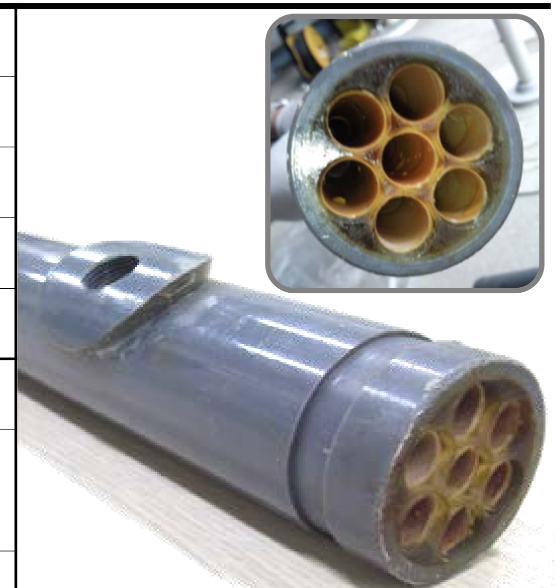
Anaerobic Membrane Bioreactor (AnMBR, Korean NET No.352)

- Maximizes biogas energy
- Excellent effluent quality
- Easy nutrient recovery as fertilizer
- Odor-free
- Vastly reduces biosolid disposal costs
- Reduces the facility footprint



Specifications of Membrane Unit

Spec.	Shape	Tubular
	Material	PVDF
	Diameter	11 mm
	MWCO	100 k Dalton
	Max. working Temp.	90 ℃
Operating condition	Total membrane area	13.1 m^2
	Operating pressure	1~3 kgf/cm^2 (In-Out)
	Cross-flow velocity	1~2 m/sec



Why Crossflow Membrane ?

5

- Flat-sheet membranes can only be installed in a submerged tank, which client pays to build
- For membrane cleaning, the entire membrane tank must be drained, halting treatment of wastewater
- Crossflow membranes are installed on skids with minimal footprints, and require no storage tank of any kind
- Much easier cake-fouling control just by adjusting the crossflow velocity
- Possible clean-in-place, meaning any individual membrane can be bypassed and removed from the system for cleaning without even pausing treatment

Picture of Plant

Characteristics of Food Waste Leachate

Properties of food waste leachate

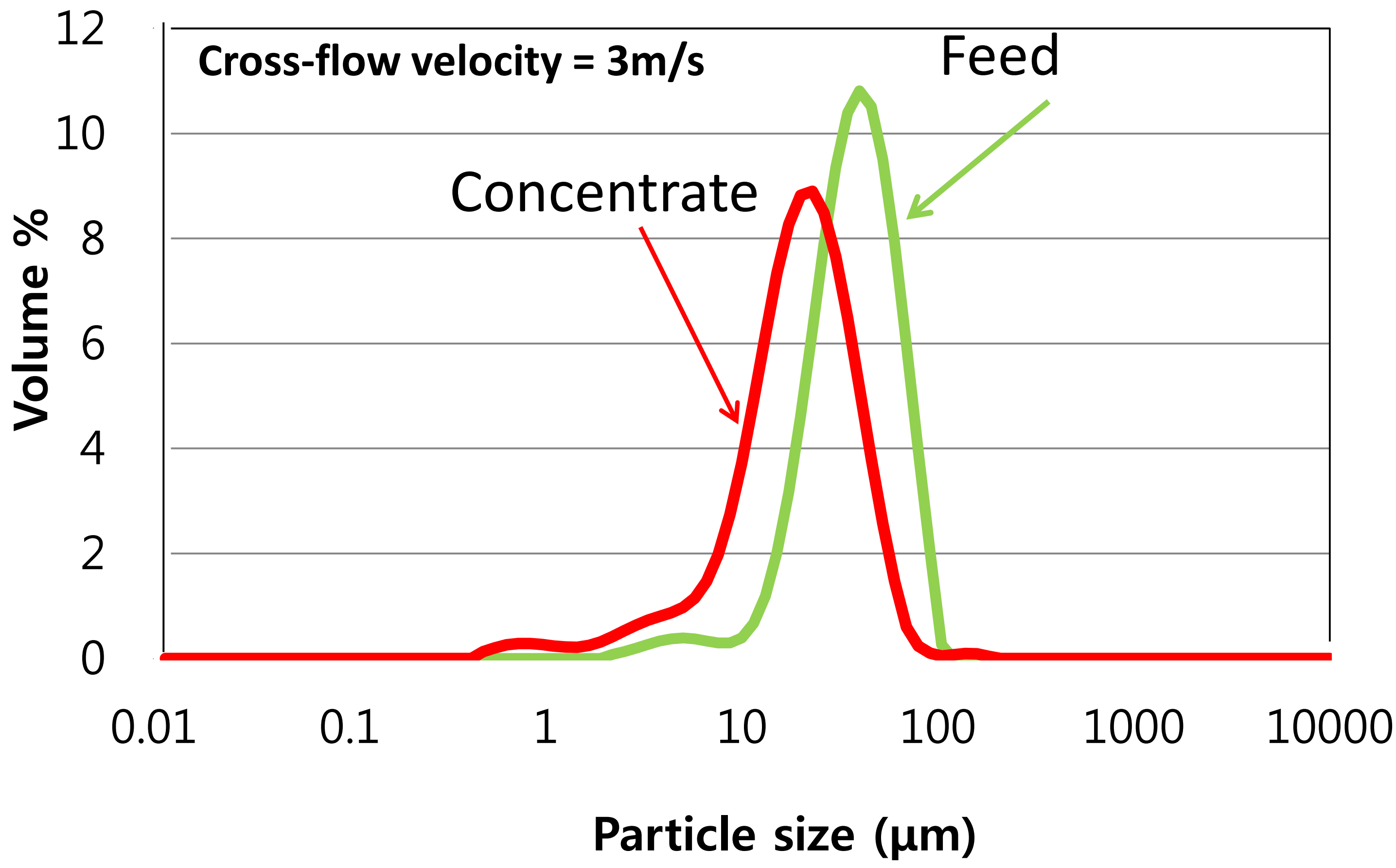
High solid content	High Biodegradability	High Nitrogen ·Phosphorus	High variation of leachate quality

Qualities of food waste leachate

pH	COD_{Cr}	T-N	SS
3.9 (3.1~4.3)	141,393 mg/L (100,358~183,753)	3,246 mg/L (1,239~4,404)	42,653 mg/L (5,614~80,540)

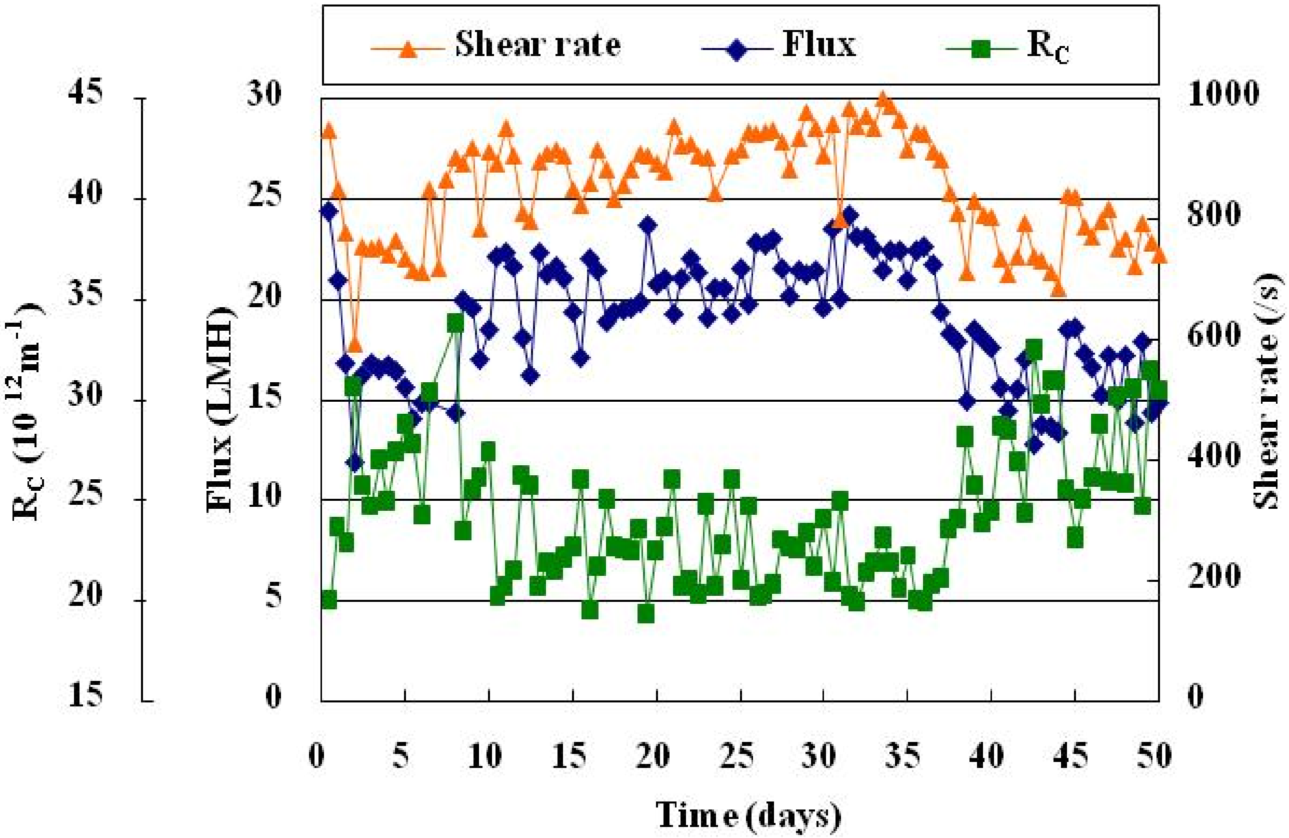
※ Source:
SUDOKWON Landfill Site Management Corp.(2008), "The feasibility study of biogas production with organic waste"

Change of Floc Size Distribution in Membrane Concentrate Stream



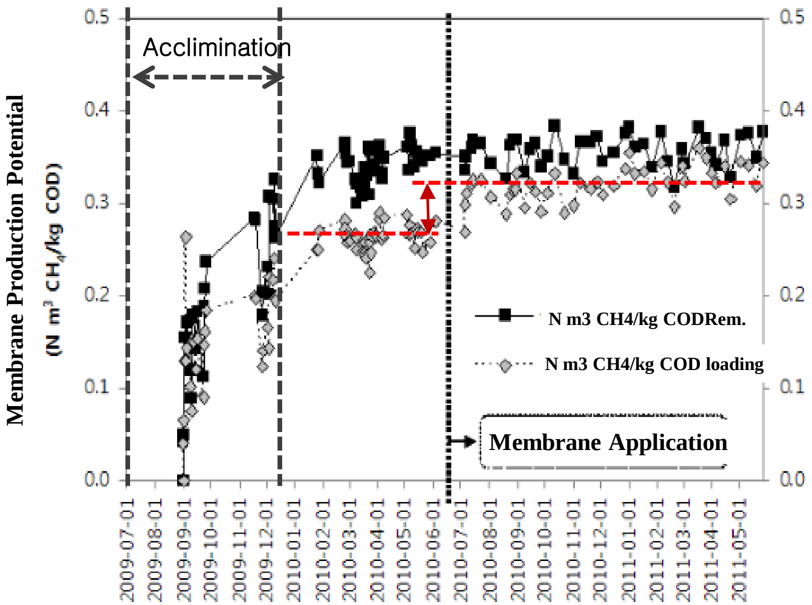
Long term Operation of AnMBR

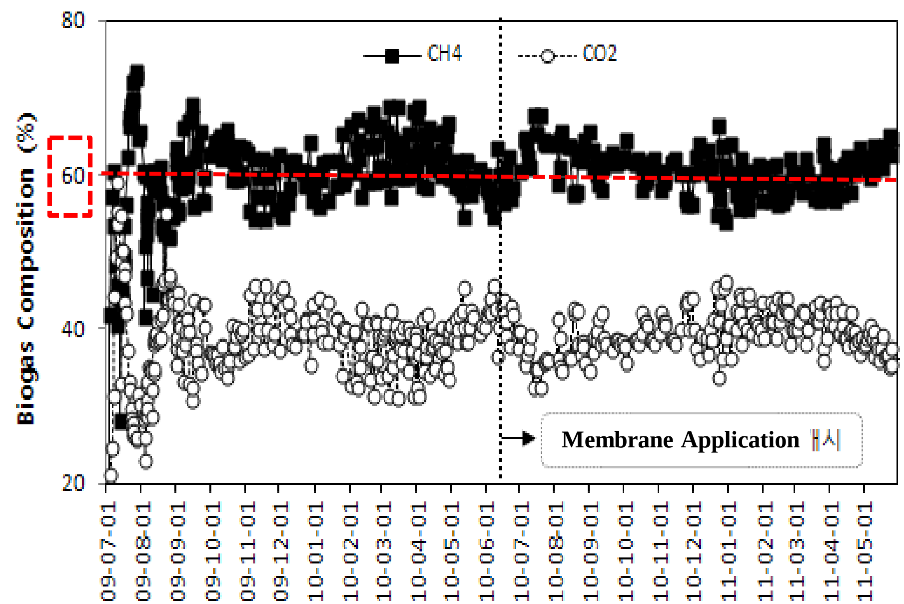
TMP
=0.8 kgf/cm²



- Shear rate played critical role in controlling membrane fouling

Biogas Production Potential and Compostion





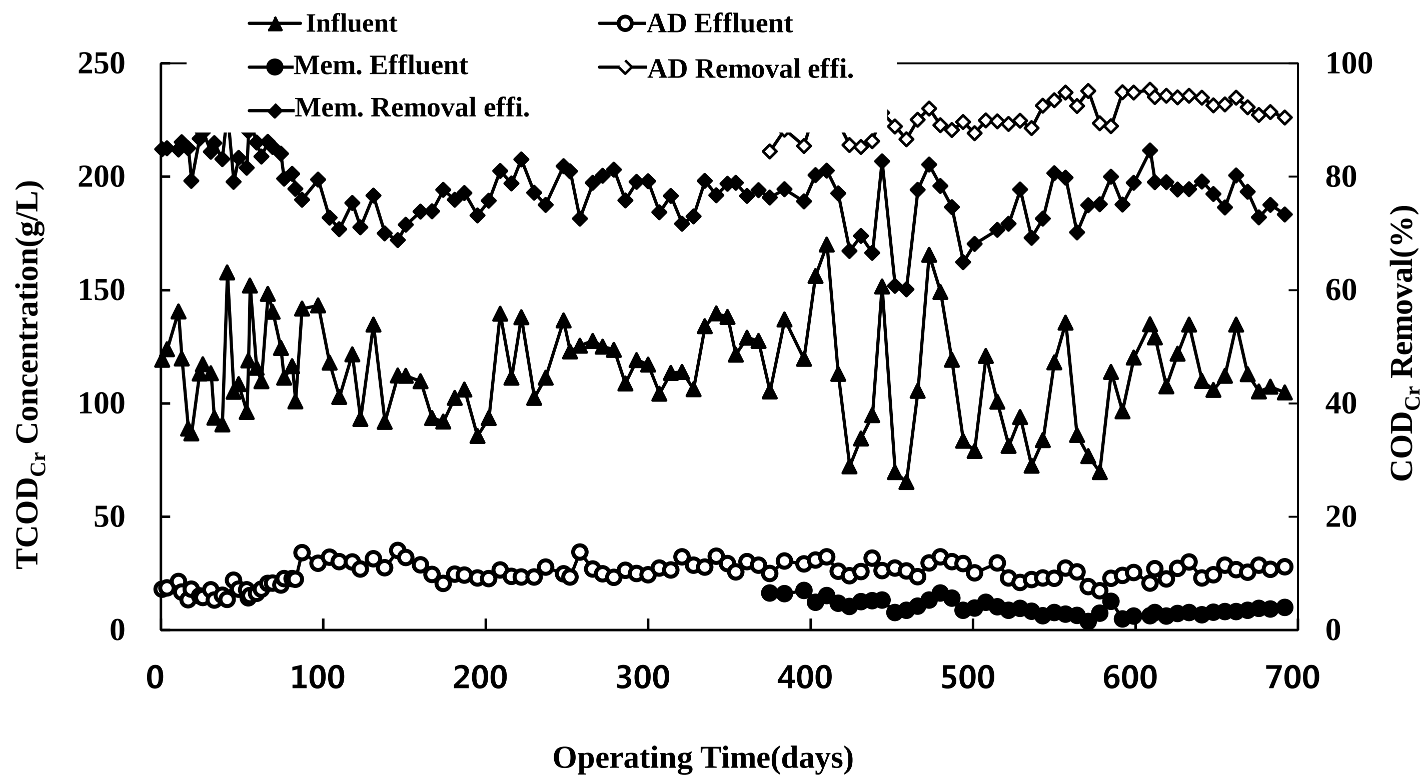
(단위 : Nm³ CH_4/kg COD)

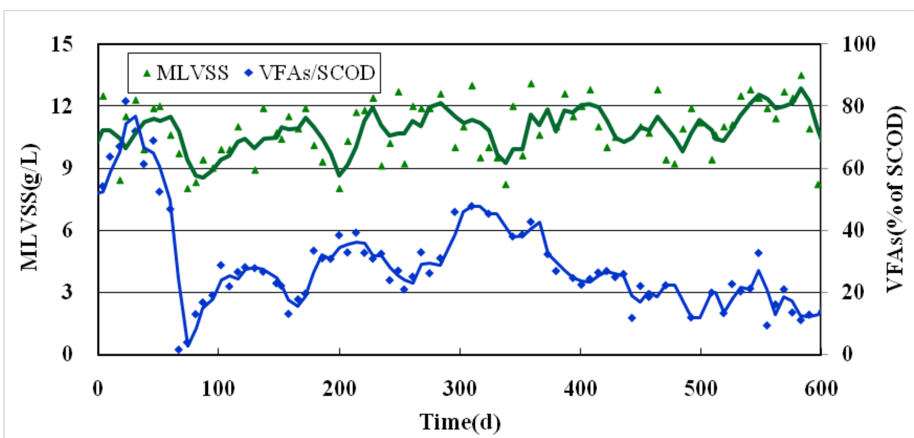
	Before	After	Variation
CH_4 production/ CODloading	0.28 (0.25~0.29)	0.32 (0.29~0.36)	△22.1%
CH_4 production/ CODRem.	0.34 (0.30~0.38)	0.36 (0.32~0.38)	△6.0%

Compositio n	CH_4 (%)	CO_2 (%)	H_2S (ppm)
Content	63 (56~68)	37 (32~44)	1,582 (1,100~2,360)

1. Biogas Production : 567 N㎥/ton_COD_{Rem}
2. Methane Yield : 359 N㎥/ton_COD_{Rem}

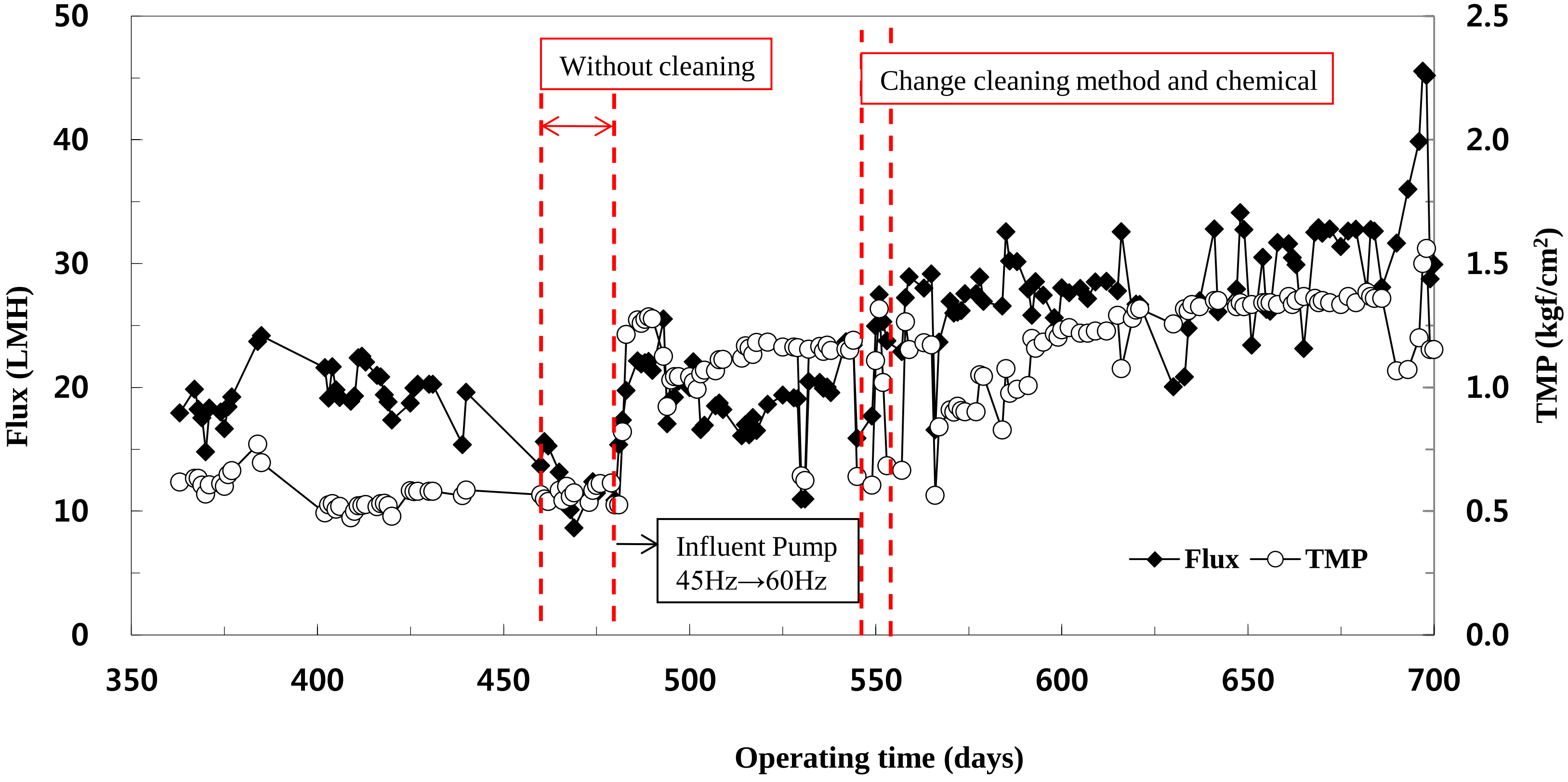
COD Removal Efficiency



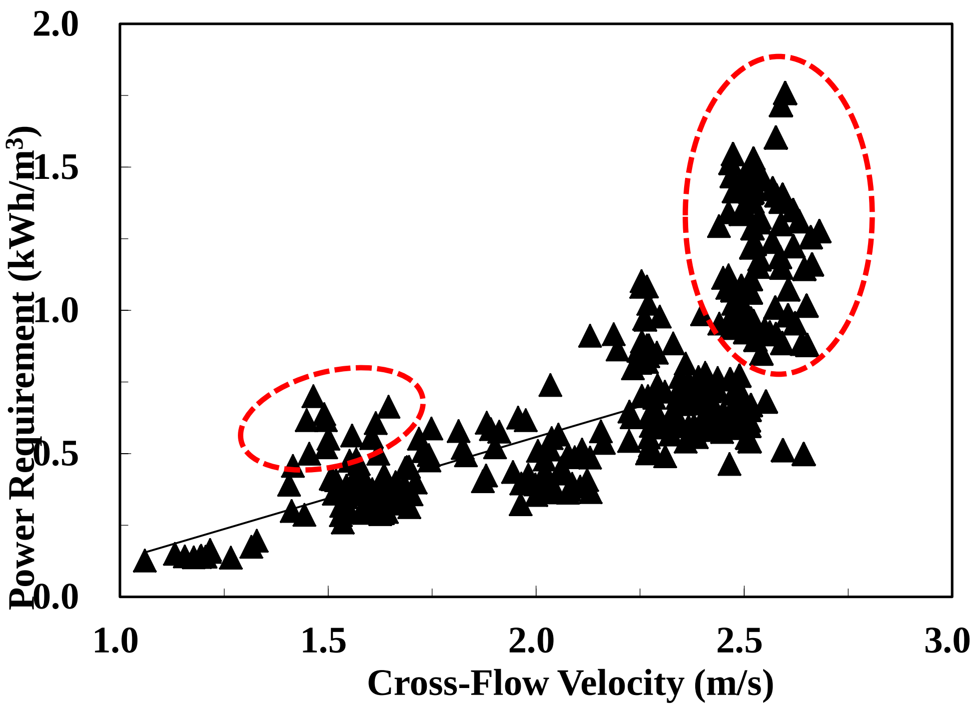


MLVSS has been increasing continuously since the digester was integrated with UF membrane

Variation of Flux and TMP in AnMBR



Relationship between Cross-flow velocity and Power Requirement in AnMBR



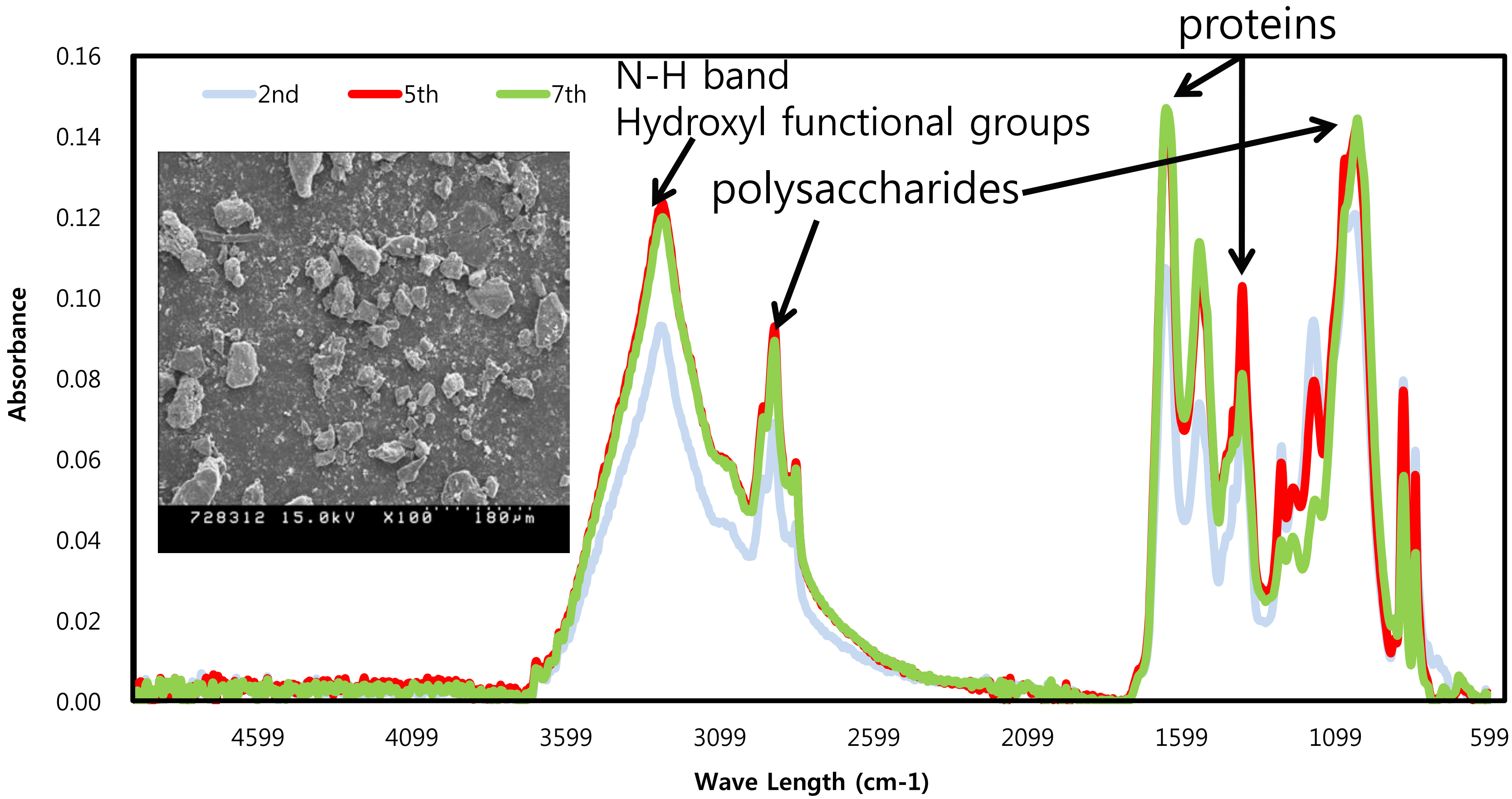
$$P = \frac{QE}{1000}$$

P : Power Requirement (kW)
Q : Recycle rate (m^3/s)
E : Pressure loss (N/m^3)

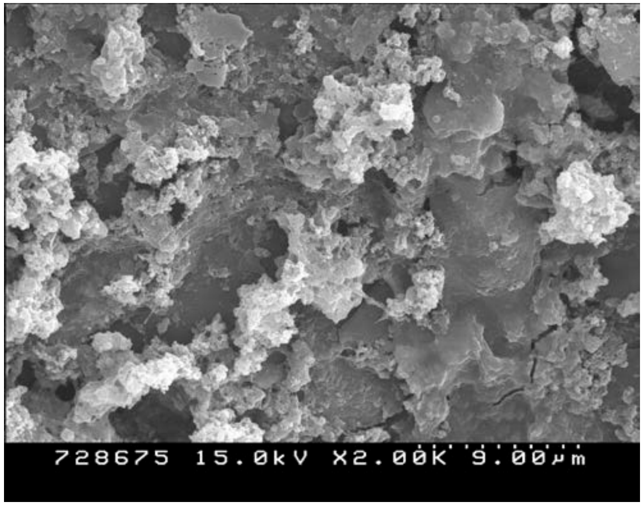
Source by Kim, J.H., MaCarty, P.L.(2011)

- The more fouling progressed, the more required electrical power to get the constant flux

Membrane Autopsy Works-FTIR Observation on Membrane Surface



Cake Layer after chemical cleaning

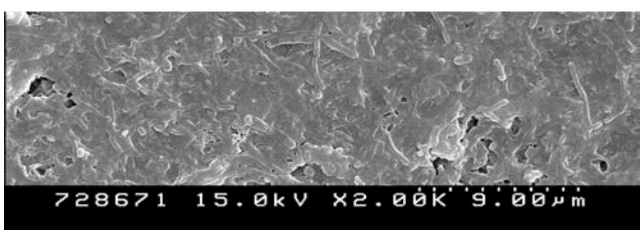


after NaOCl chemical cleaning

	Foodwaste Leachate	Methanogenic Sludge
Ca^{2+} (mg/L)	> 1,000	> 800
pH	< 4.0	> 7.5
Alkalinity (mg $CaCO_3$/L)	-	> 10,000
LSI	< - 4.0	> +4.0

after NaOH chemical cleaning

- At an LSI value greater than zero, the concentrate stream is supersaturated with calcium carbonate and would likely scale membrane surface as cake layer formation
- Strong binding and solidification can lead to pronounced cake resistance

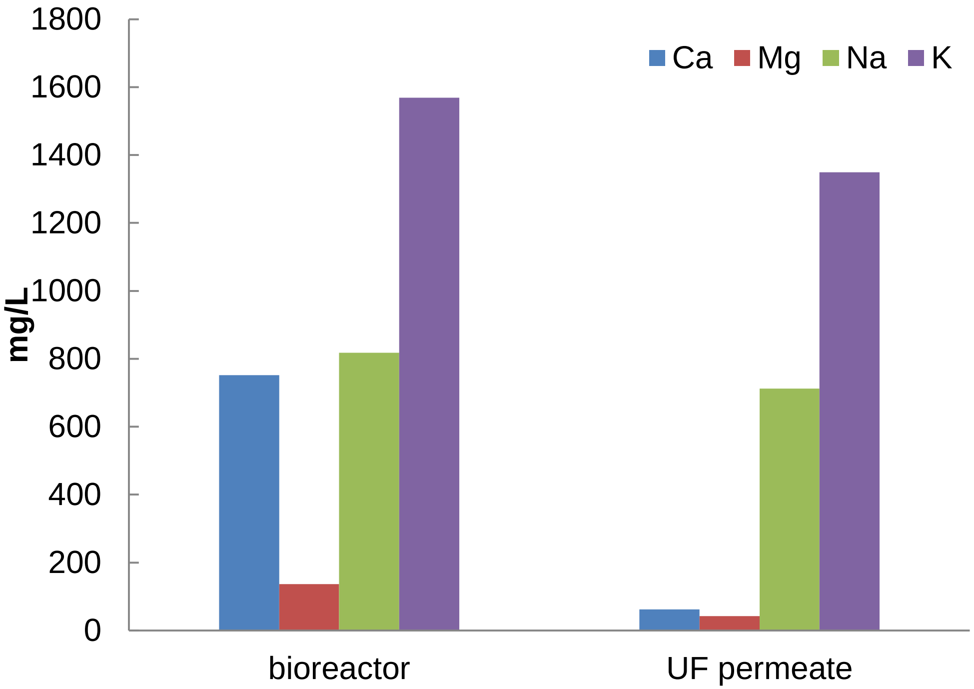


after citric acid chemical cleaning

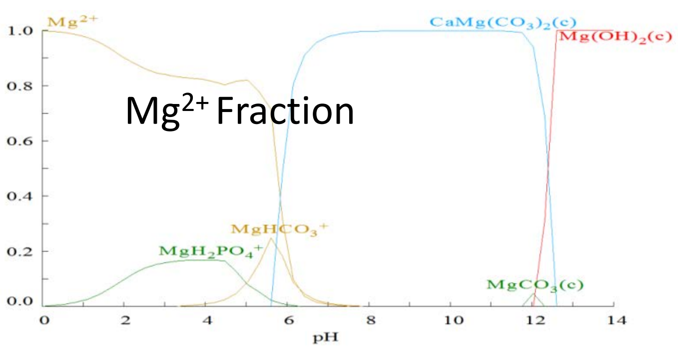
rate?

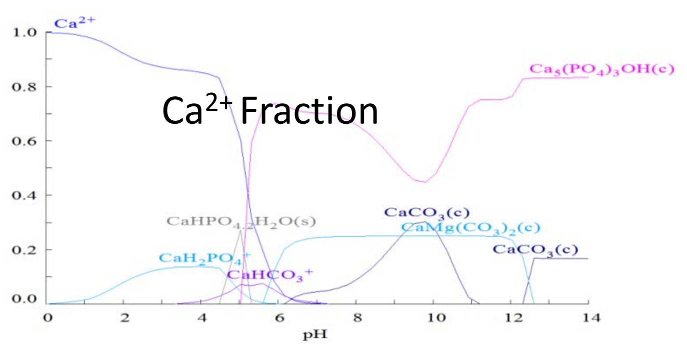
Cross-flow velocity = 3 m/s
TMP= 0.8 bar

Membrane Scale and Rejection



- High rejection of calcium (>95 %) is caused by membrane scale
- About 40 % rejection of Mg
  : struvite, $NH_4MgPO_4 \cdot 6H_2O$?
- High calcium content may inhibit formation of struvite



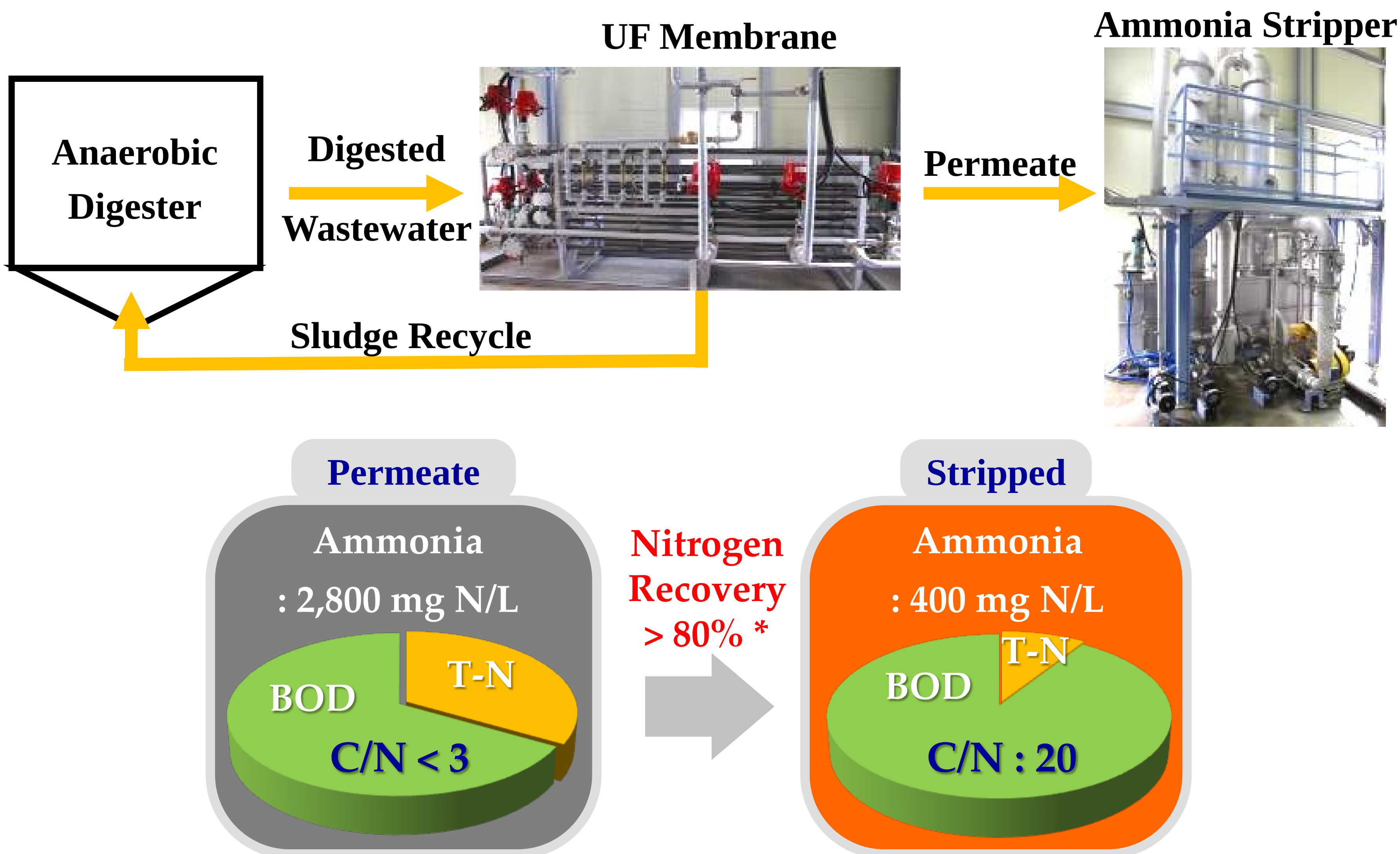


$[Ca^{2+}]_{tot}$=20 mM,
$[NH_3]_{tot}$=200 mM
$[CO_3^{2-}]_{tot}$=200 mM
$[PO_4^{3-}]$=10mM
$[Mg^{2-}]_{tot}$=5 mM,
$[K^+]_{tot}$=40 mM

Water Quality of HAnDS®

	$TCOD_{Cr}$	$SCOD_{Cr}$	BOD_5	SS
Sludge	25,000 mg/L (15,000~32,000)	12,050 mg/L (7,600~13,300)	11,900 mg/L	14,990 mg/L (8,200~21,400)
Permeate	13,700 mg/L (8,700~16,300)	11,700 mg/L (7,600~15,200)	8,100 mg/L	<3 mg/L

Digestate Treatment : Ammonia Stripping



*Recovery can be controlled by the operating conditions: temperature, pH and air volume

Water Quality of HAnDS®

5

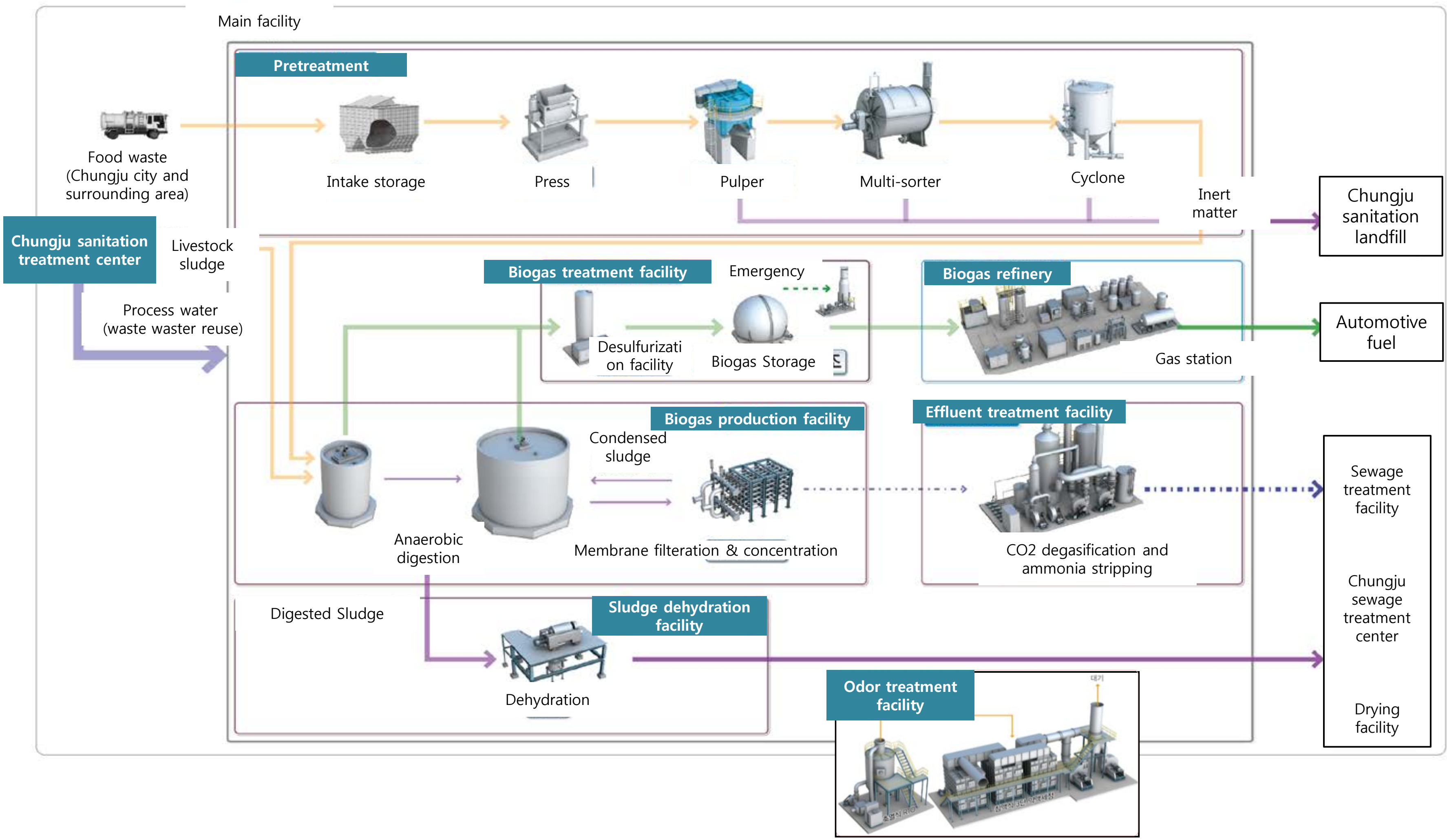
(Unit : mg/L)	Food Waste Leachate	Anaerobic Digestion	Ultrafiltration	Aerobic MBR*
BOD_5	51,000	9,000	6,000	<3.0
COD_{Cr}	120,000	25,000	10,000	300
TN	3,000	4,000	2,000	<60
TS (g/L)	65	25	<10	-
n-Hexane	11,000	380	350	-

(*After ammonia stripping process)

How to apply ?

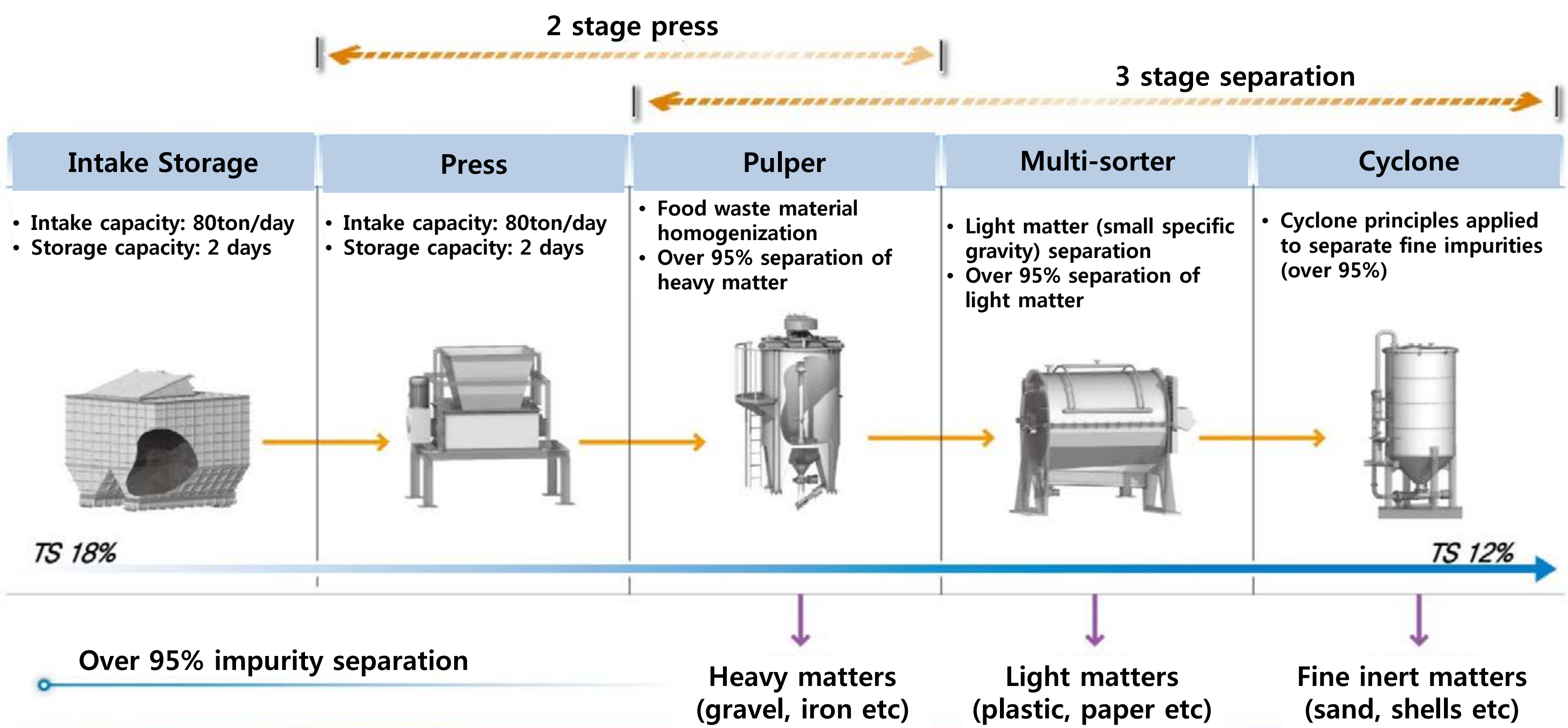
Anaerobic Membrane Bioreactor (AnMBR, Korean NET No.352)

Process flow chart



How to apply ?

Pretreatment facility



2 stage press, 3 stage separation system introduction:
- Improvement of material homogenization and impurity separation ability (over95%)
- Construction of TS content adjustment function suitable to the applied anaerobic digestion

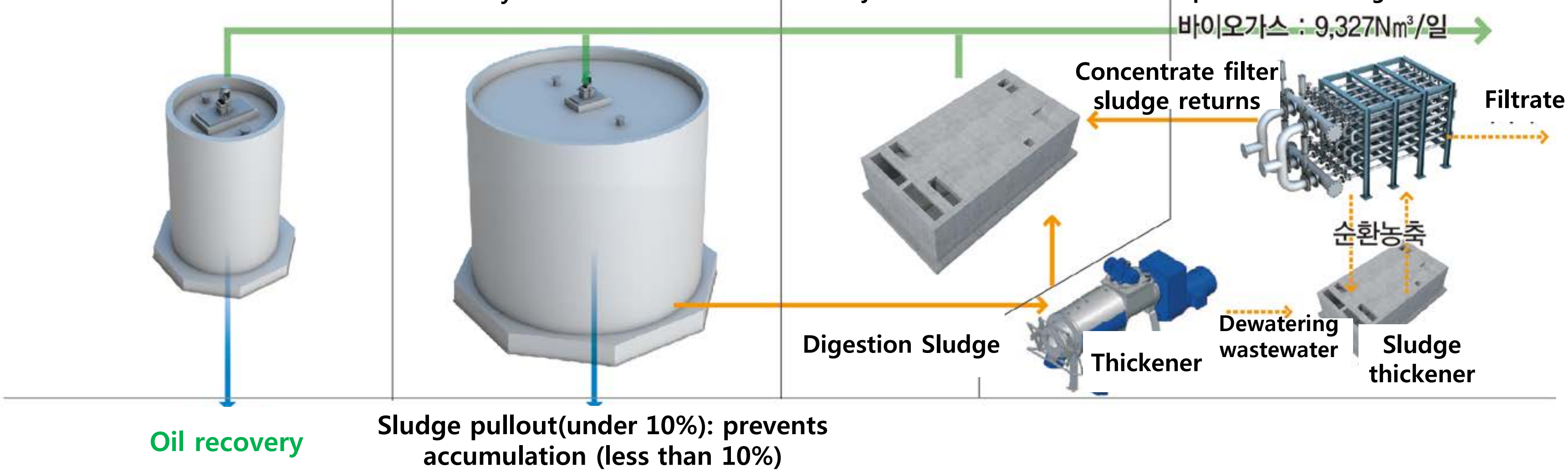
Improvement of food waste digestion efficiency

How to apply ?

Biogas Production

- Sludge recycle → Providing long SRT needed while operating
  Biogas more production, reduce sludge discharge

Acid fermentor	Methane fermentor	Buffer tanks	Filteration & concentration
• Intake capacity: 80ton/day • Storage capacity: 2 days	• HRT : 29days, 38'C • Horizontal/vertical mixed method introduction to maximize efficiency	• Concentrated filter sludge + concentrated sludge return function • TS adjusted to 4~5%	• Tubular membrane • Material: PVDF • Digested sludge concentration, prevents microorganism loss



How to apply ?

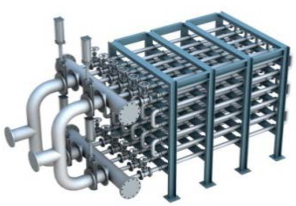
Wastewater treatment facility

- Planning of connecting wastewater to STP and recovery of valuable resources

Reduce Nitrogen loading rate by collection ammonia

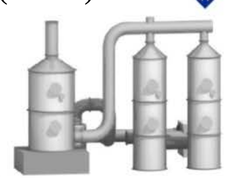
Planning of connecting wastewater to STP, cost saving

Filteration & Concentration	CO2 stripping	Ammonia Stripping	Storage tank
• SS removal through membrane filter in advance -> allows easier treatment in the latter unit	• pKa increase from High temperature(45′C) stripping -> pH altering chemical reduction	• C/N ratio increase from ammonia removal -> linked disposal and self disposal • Liquefied fertilizer production from Ammonia recycle	• Consider wastewater connection : HRT 1 day • Changeable by the operating conditions (time, flowrate)



pH Control (NaOH)

H_3PO_4



$(NH_4)_2HPO_4$

Liquid fertilizer ($(NH_4)H_2PO_4$), Supply to farm

Field Application : 80 t/d plant


Biogas–ren drivkraft
LPG
GPL
NATURGAS
kompogas erdgas
SULZER
NGV
GG OZ 212
Wastes
Energy
Biogas

QUIZ

1. Biodigestion is the process of breaking down organic wastes in an anaerobic digestion and there is 4 steps biogestion process to produce biogas from organic wastes. Briefly explain biogestion in an anaerobic digestion.

2. AnMBR(anaerobic Membrane Bioreactor) is the state of the art technology in the field of anaerobic digestion. Briefly explain the characteristics of AnMBR and analysis advantages and disadvantages in comparison with conventional anaerobic digestion.