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APPLICATION OF SEWAGE PLUS TECHNOLOGY USING MEMBRANE UP- CONCENTRATION AND CO-ANAEROBIC DIGESTION FOR ENERGY RECOVERY FROM HOUSEHOLD WASTEWATER AND KITCHEN WASTE IN HCM CITY, VIETNAM

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Introduction

Organic solid waste from households (kitchen waste or garden waste)

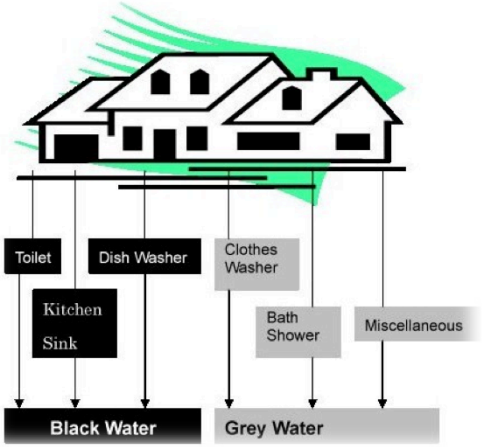
Biowaste recycling system

Composting

Biogas production (renewable energy)

Introduction

Sewage - liquid waste stream from household activities



A valuable product that could be reused in terms of richment of organics and nutrients.

Introduction

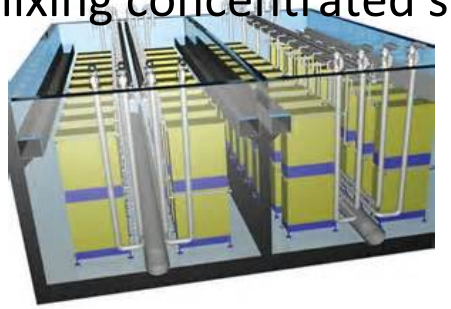
SewagePlus concept

Aim to reuse of organic solid waste and sewage to produce energy with hygienic operation conditions and cost effectiveness

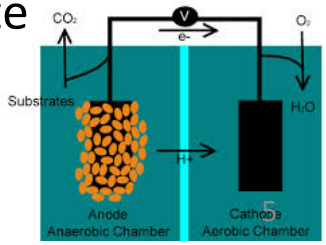
- ✓ **The SEWAGE+ technology**: innovative concept and technique, which was developed by a consortium of Belgian industrial and research partners for maximal energy recovery from enriched sewage since 2007.

Introduction

- ✓ Enrichment of sewage can be based on two phases:
  - (i) a concentration phase of the sewage using membrane filtration, chemical or bio-flocculation, or
  - (ii) mixing concentrated sewage with a selected bio-waste stream.



- ✓ The mixture of enriched sewage and waste streams can be treated by two options:
  - Anaerobic digester to produce methane or
  - Acidogenic fermentation with inhibited methanogenesis. aiming at maximal production of volatile fatty acids (VFA) to generate electricity by microbial fuel cells (MFC)



Introduction

- ✓ UF and MF filtration: a promising technology that concentrated sewage which can be influent of anaerobic reactor
- ✓ The quality of permeate is good enough to reuse or safely discharge to water stream.

Introduction

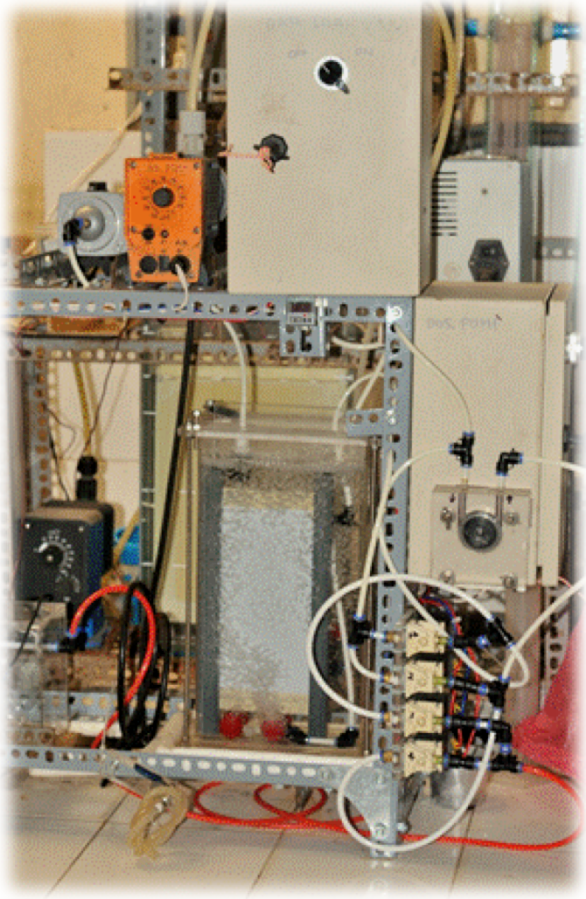
- ✓ Recently, anaerobic digestion of organic SW (agricultural biomass, animal manure, septage, food or market wastes) has been significantly developed in Vietnam and South East Asian countries ➔ biogas production
- ✓ Many previous studies shown that the combined sewage and black water produced more methane gas than black water alone (S. Luostarinen and J. Rintala, 2007; R. Rajagopal et al., 2013)

Objective

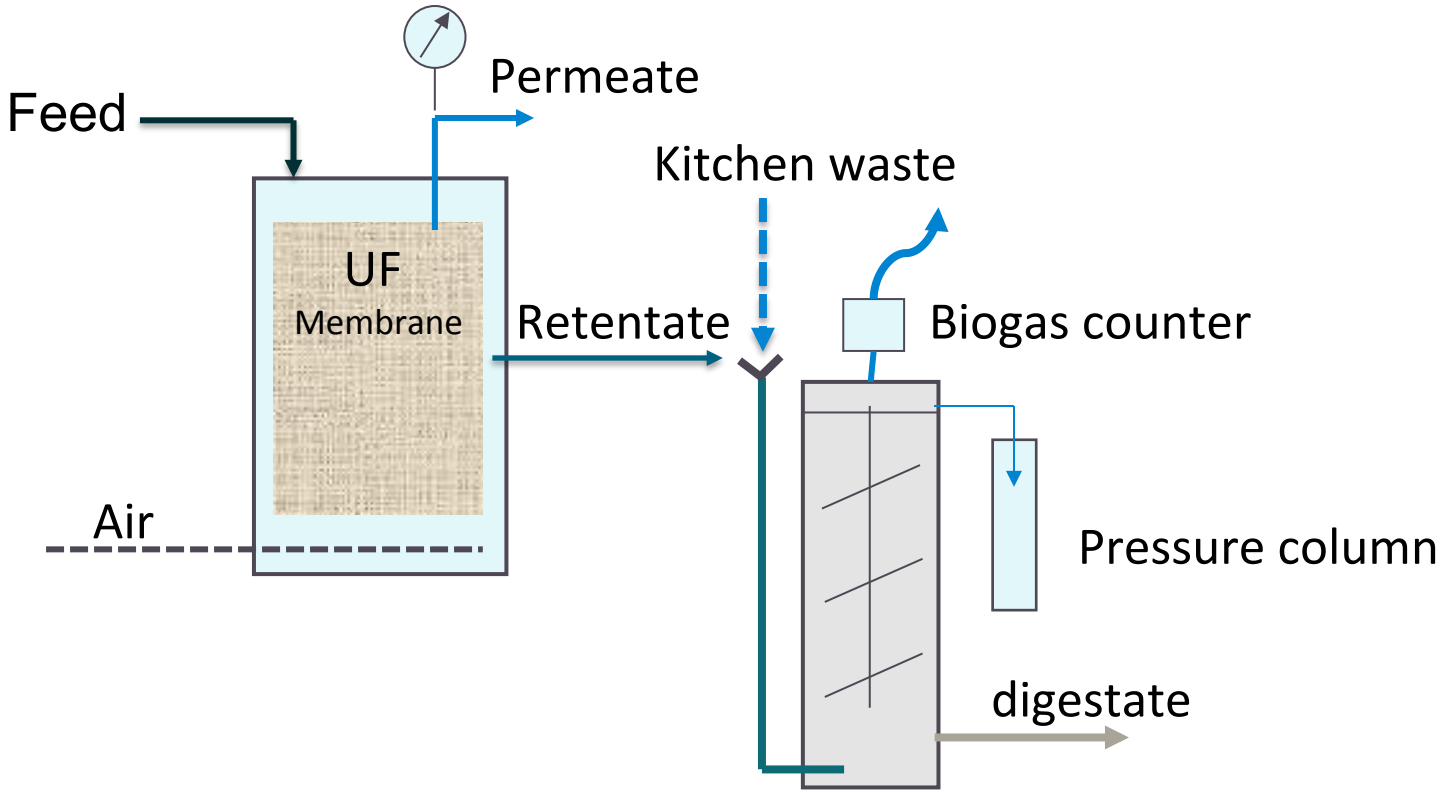
- ✓ to evaluate applicability of SewagePlus technology using UF membrane up-concentration and co-anaerobic digestion for energy recovery from household wastewater and kitchen waste

Methods and Materials

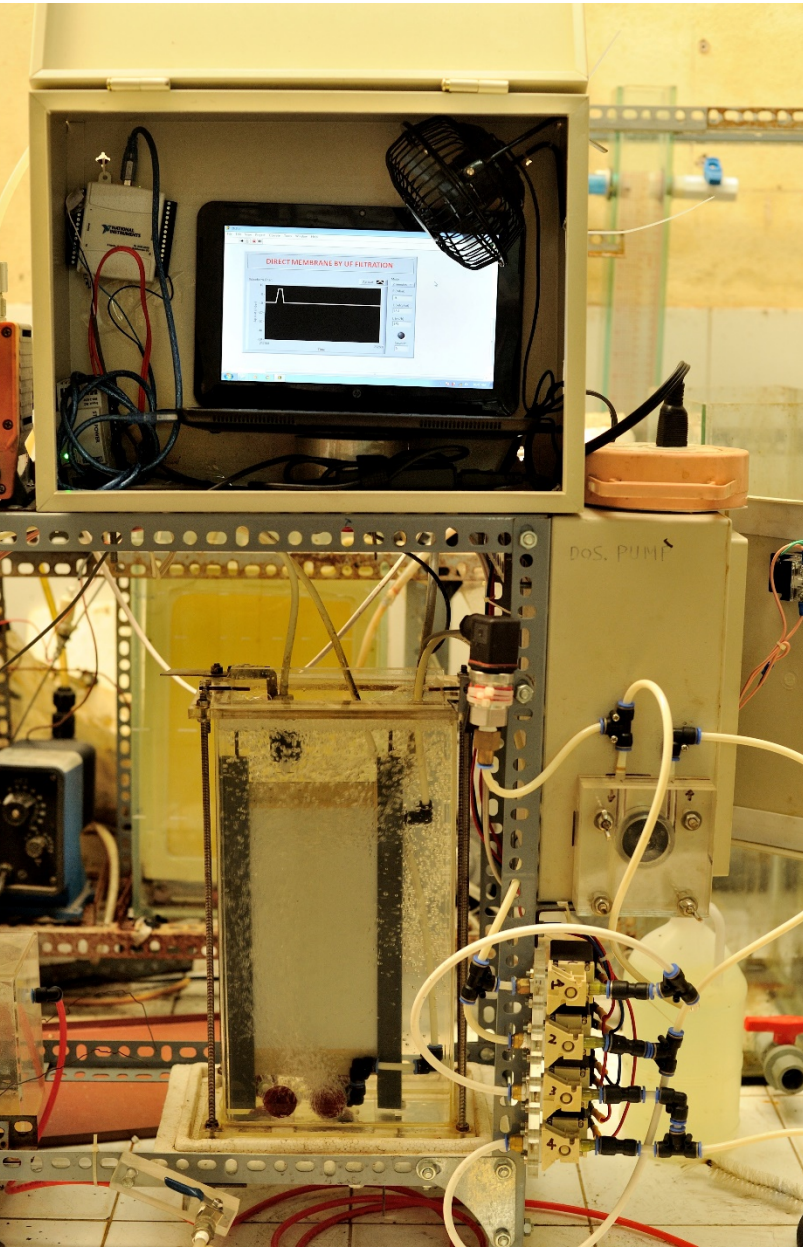
- ✓ **Labs-cale experiment**
- ✓ **Pilot-scale experiment**



Lab-scale experiment



UF Membrane up-concentration



UF flatsheet membrane

Brand: A3 Solution GmbH

Size: 10 cm x 20 cm x 2 sides

Flux: 15 – 25 l/m2.h

Poresize~150 kDa

Operating pressure: 20 - 250 mbar

Backwash pressure < 50 mbar

Membrane tank

Working volumn = 3.75 L

Size BxHxL = 8 x 18 x 35 cm

ON:OFF mode of 8:2 minutes

Anaerobic Digester

Working volume: 6L

Operating condition

Retention time: 50 days

Organics loading (dry weight)

2.0 kgVS/m^3.d

Mixing ratio of waste and concentrated sewage = 2/1

Agitating mode = 10 min of relaxation :2 min of mixing

Agitator speed: 44 rpm

Materials

- ✓ The sewage in this study was a mixture of grey and black waters which was obtained from sewage system of an apartment building in the central of Ho Chi Minh City.
- ✓ The black water was pre-treated by a septic tank then mixed with the grey water before discharged to the sewage system.
- ✓ The feed contained the average TP of 1.77 ± 0.44 mg/L, TKN of 38.92 ± 14.28 mg/L and N-NH4+ of 32.2 ± 6.3 mg/L.

Materials

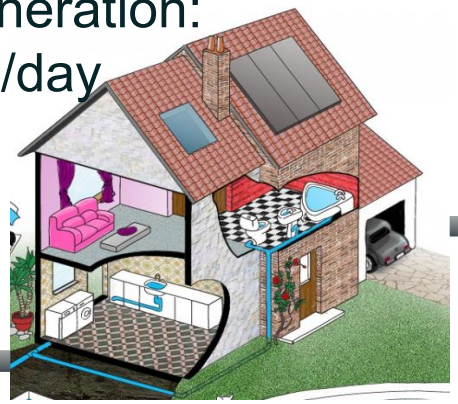
- ✓ The kitchen waste was taken from a household in the same apartment then ground by a hand blender.
- ✓ The ground waste was mixed with the concentrated sewage at wet weight ratio of 2:1 and introduced to the digester.
- ✓ The feeds contained TS of 127 ± 9.1 g/kg, VS of 108 ± 6.5 g/kg and TKN of 3.64 ± 0.8 g/kg

Pilot-scale plant

Pilot scale plant was set up on the top floor of the Apartment building in District 1, HCMC, Vietnam

Pilot-scale plant

Capacity of 2 household waste generation:
1200 l/d and 4 kg of kitchen waste/day



Kitchen waste

Sewage from apartment in District 01 HCMC

SW was ground < 4 mm

Biogas

digester

digestate

Permeate

retentate

UF membrane tank

Schematic diagram of pilot scale SEWERPLUS plant

Pilot-scale plant

Kitchen waste: Vegetable residues, spoiled foods/rice

hand blender with screening size of 4mm

Anaerobic digester of 300 l

UF membrane tank of 185 l

Pilot-scale plant

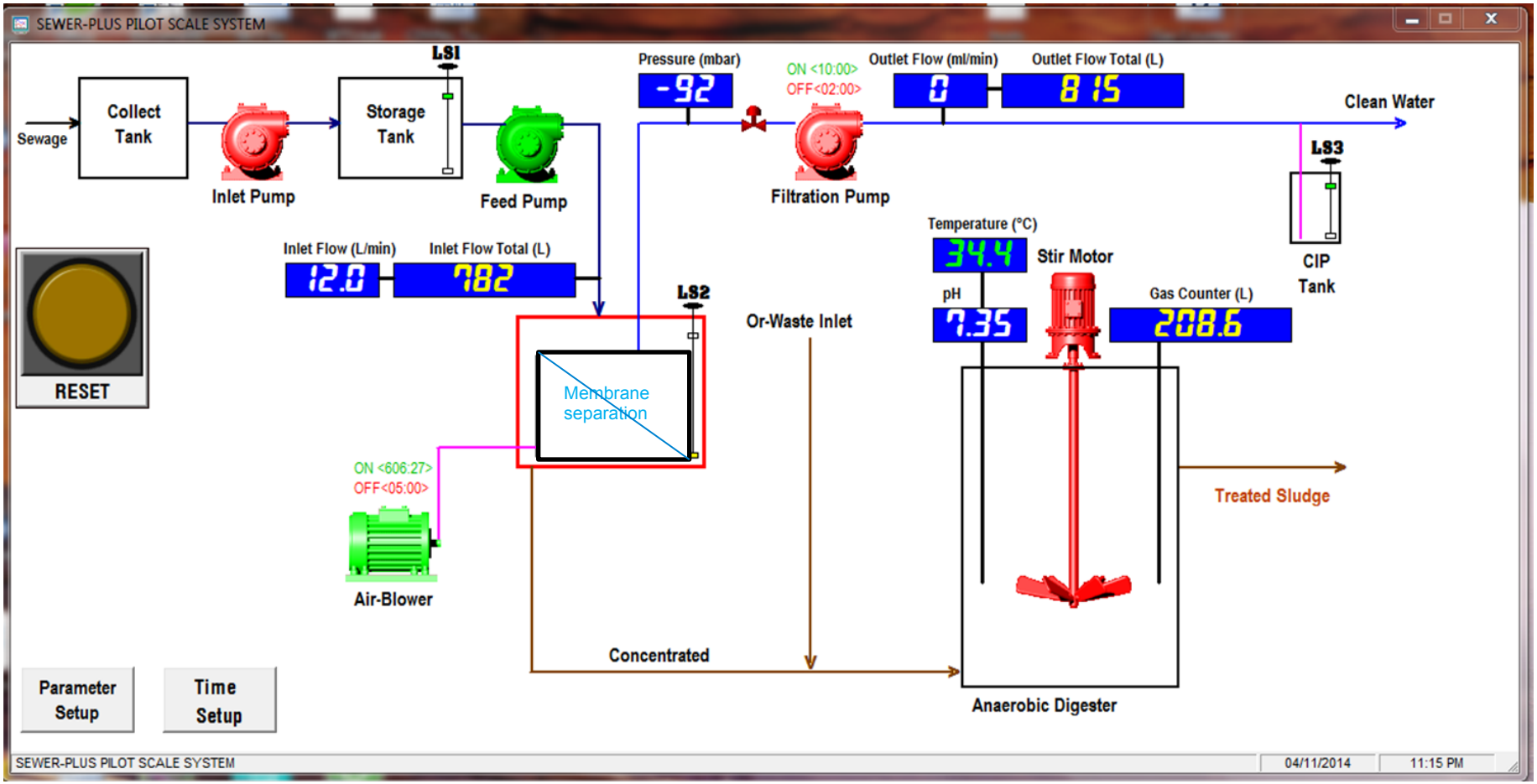


Fig.3 SCADA of SEWERPLUS pilot plant

Pilot-scale plant

Membrane up concentration

Membrane tank	185 lit	Stainless steel
UF membrane (flat sheet)	3 m2	Polyethersulfone (PES)
Flux design	16 l/m^2.h	
Operation pressure	20…250 mbar	
Molecular weight cut-off	150 kDa	

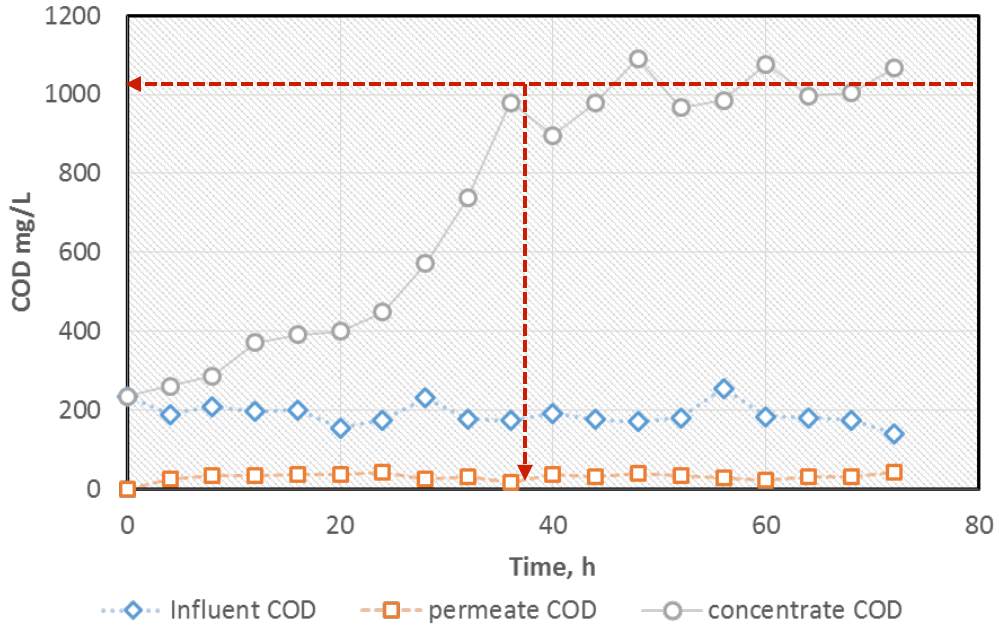
Anaerobic digester

Seed sludge was taken from piggery farm biogas digester

pH	7.5 ± 0.2
TS (g/l)	150 ± 5
VS (g/l)	78 ± 3
TN (g/l)	5.4 ± 4
TP (g/l)	1.2 ± 0.1
OC (g/l)	145 ± 5

Tank volume (l)	300
VS treated (kg/day)	0.8
OLR (kg VS / m^3.day)	2.5
SRT (day)	50

Result and discussion: Labscale experiment



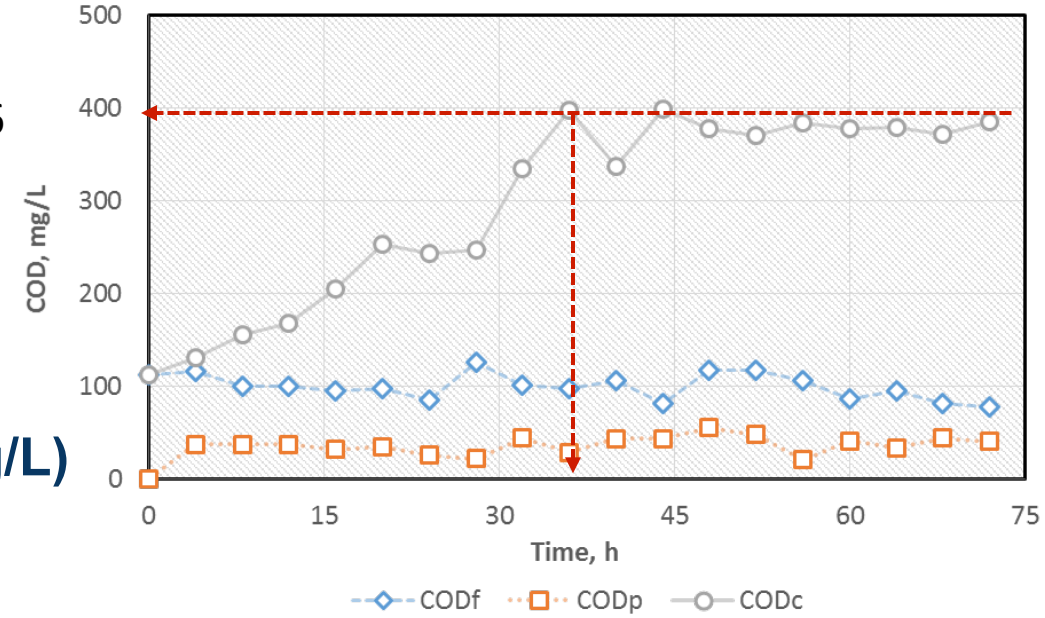
COD of retentate = 1020 ± 50 mg/L that was 5.4 folds higher than the initial concentration after 36 hours of filtration

Batch 1: High initial COD (210 mg/L)

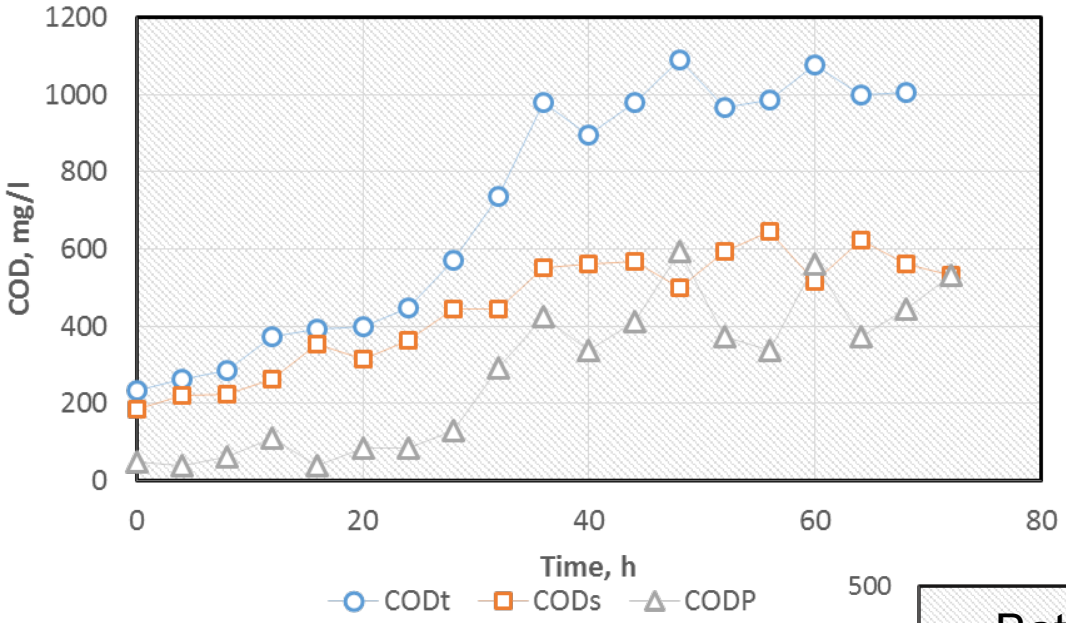
COD of retentate = 380 ± 15 mg/L after 36 hours of filtration

➔ Biodegradation rapidly happened since hour 36th

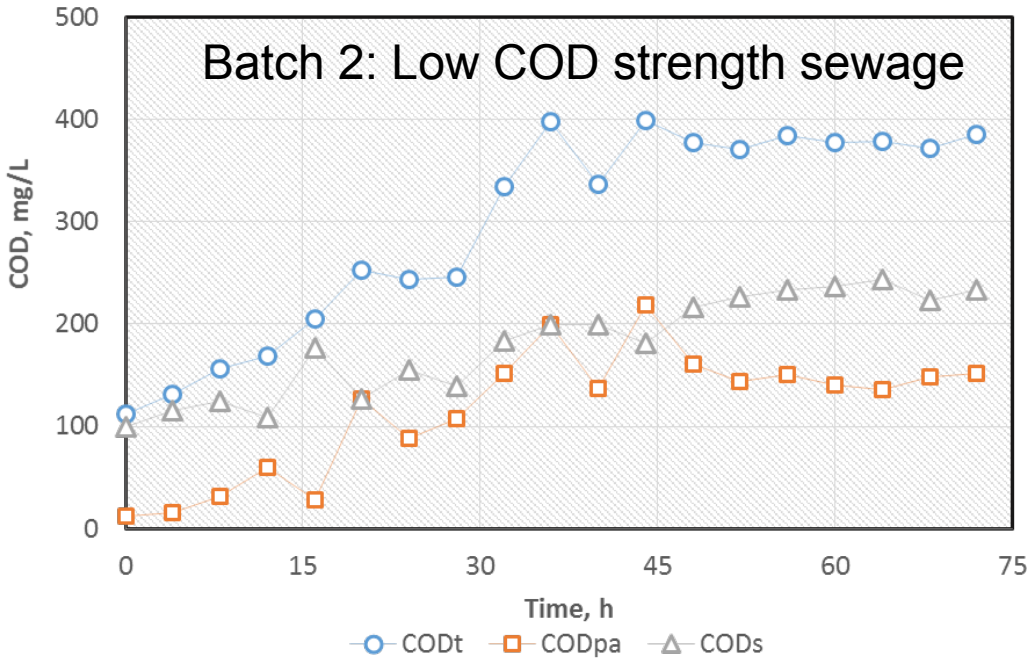
Batch 2: Low initial COD (120 mg/L)



Labscale experiment



Batch 1: High COD strength sewage

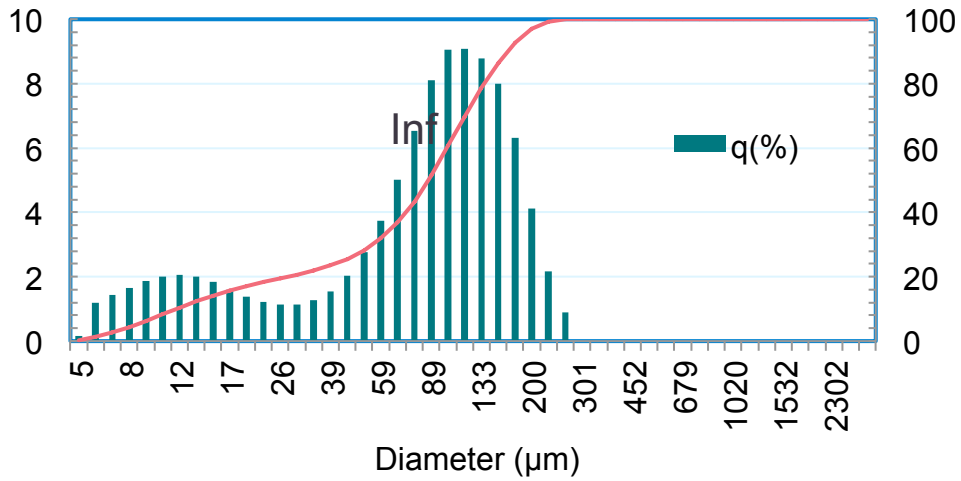


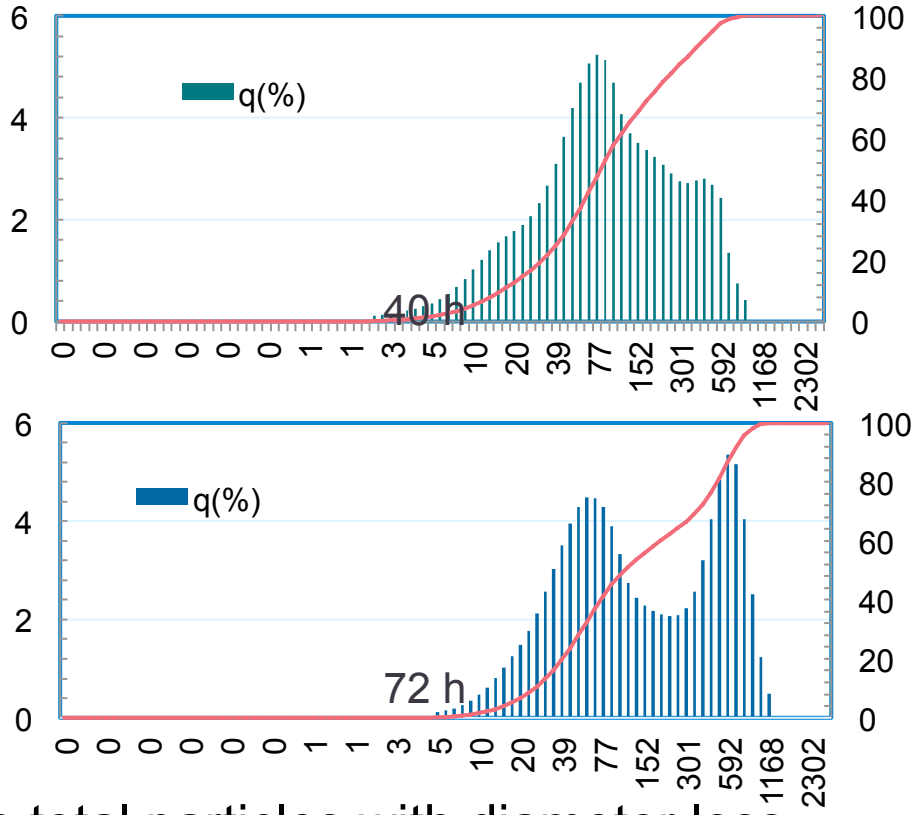
pCOD:sCOD ratio increased after 20 hours➔ agglomeration of organic particles occured

Labscale experiment

Particles size distribution

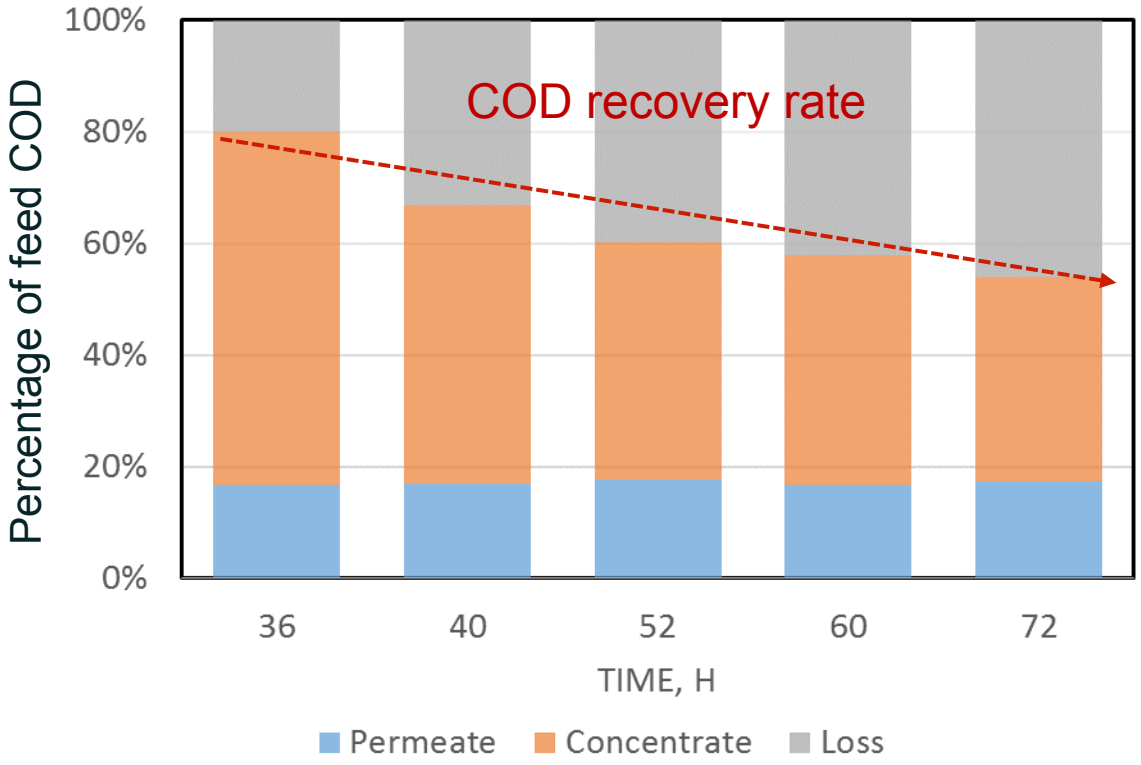
using Laser light scattering Anaylyser HORIBA LA 960





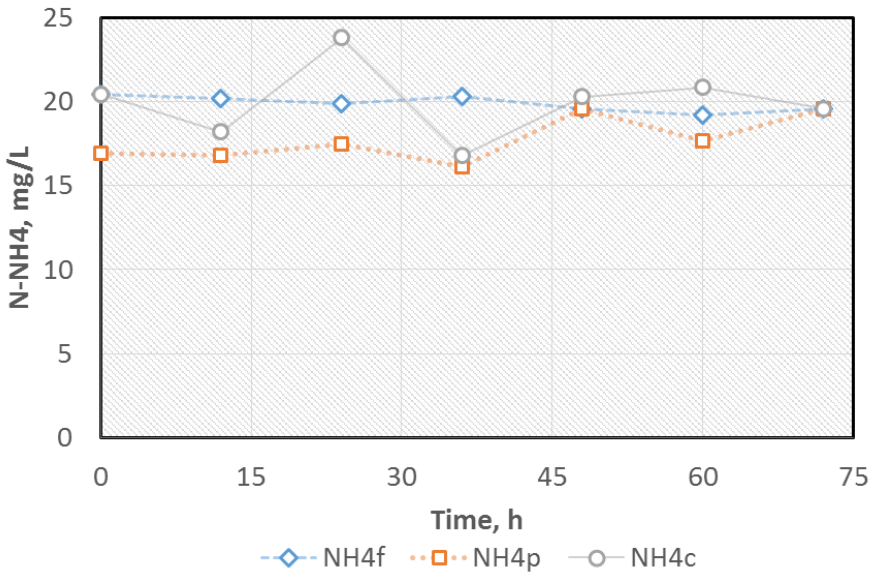
- ✓ The raw sewage contained 80 % of the total particles with diameter less than 133 µm
- ✓ The retentate contained 80 % of particles under 77 µm at hour 40th and 592 µm at hour 72nd.
- ✓ ➔ This revealed that dispersed organic particles were clumped together by the action of bacteria existed in the membrane tank, named as bio-flocculation.

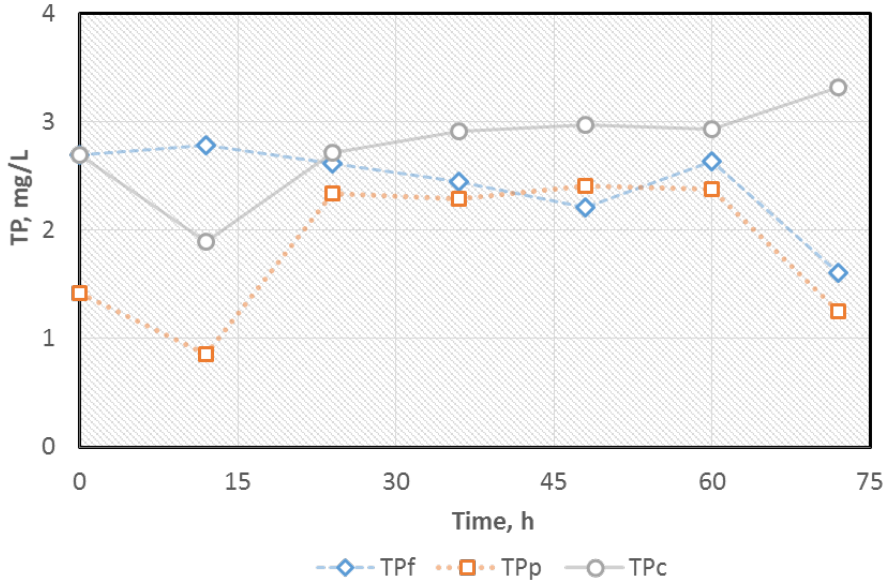
Labscale experiment

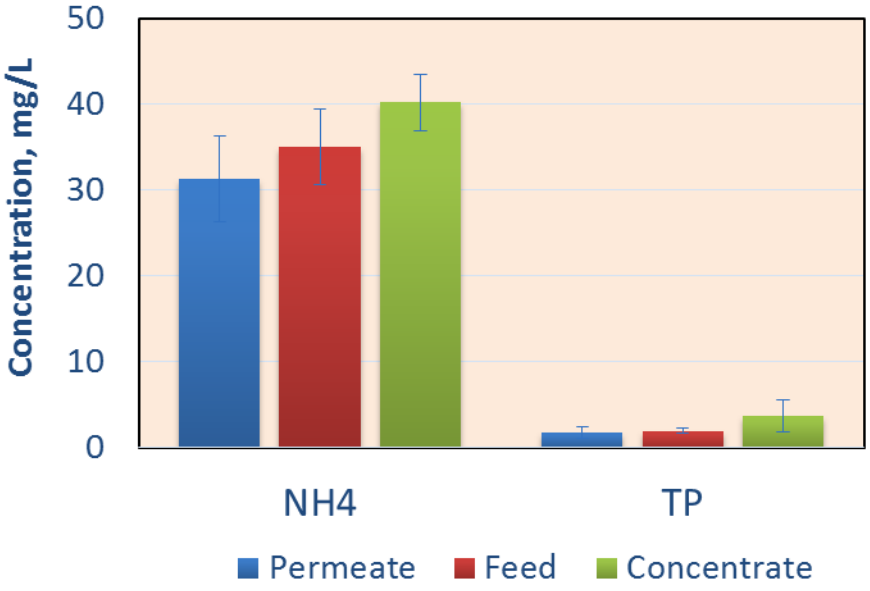


The highest recovery rate of 63 % at hour 36th when the highest COD concencentration obtained (1000 mg/l), after that COD recovery rate reduced

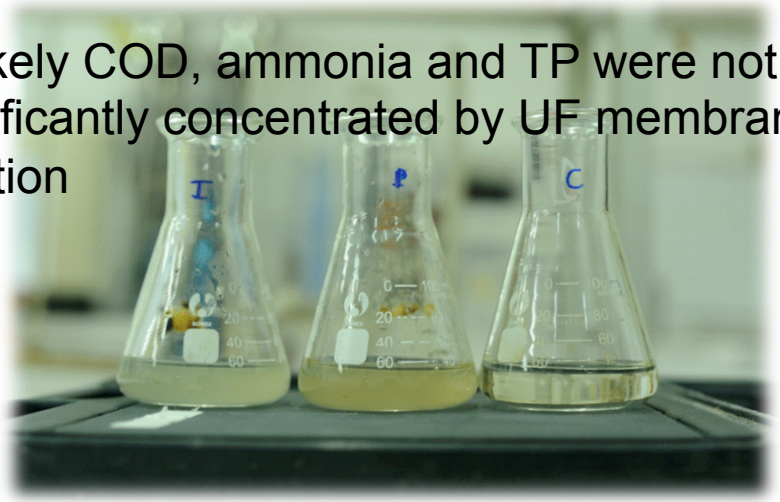
Labscale experiment





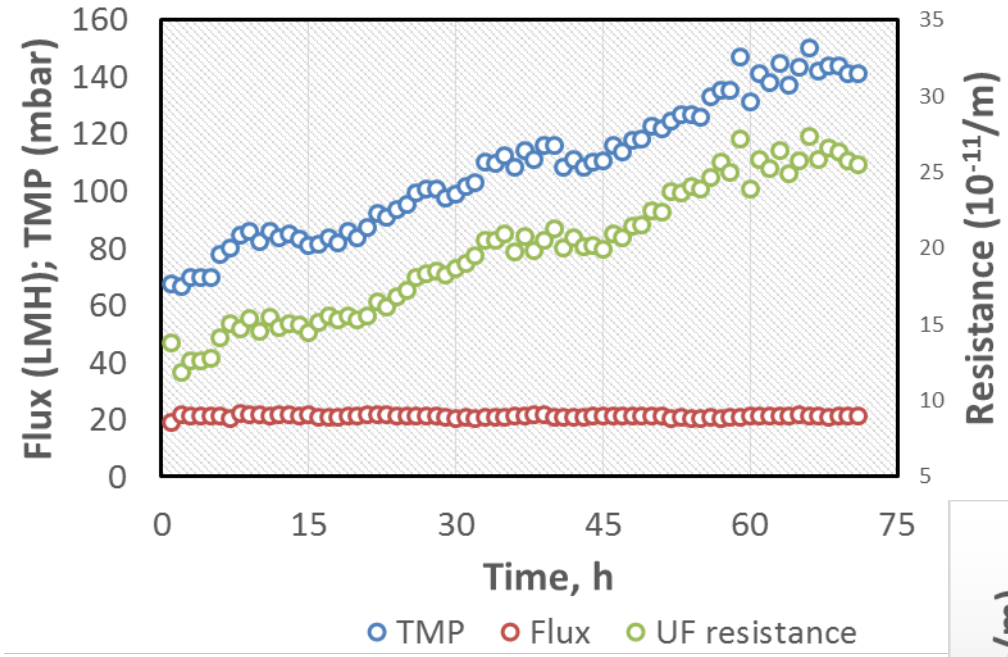


Unlikely COD, ammonia and TP were not significantly concentrated by UF membrane filtration



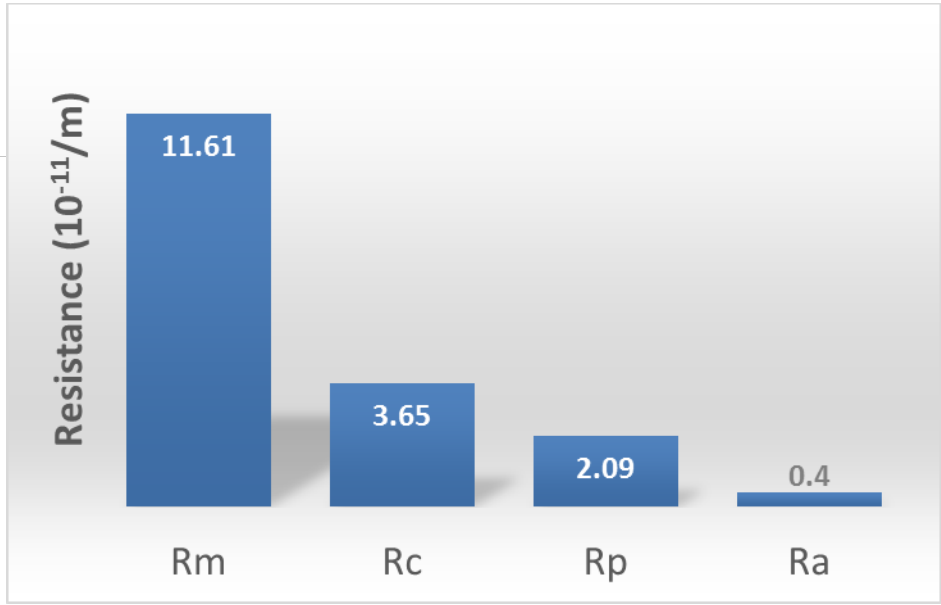
Labscale experiment

Fouling resistances



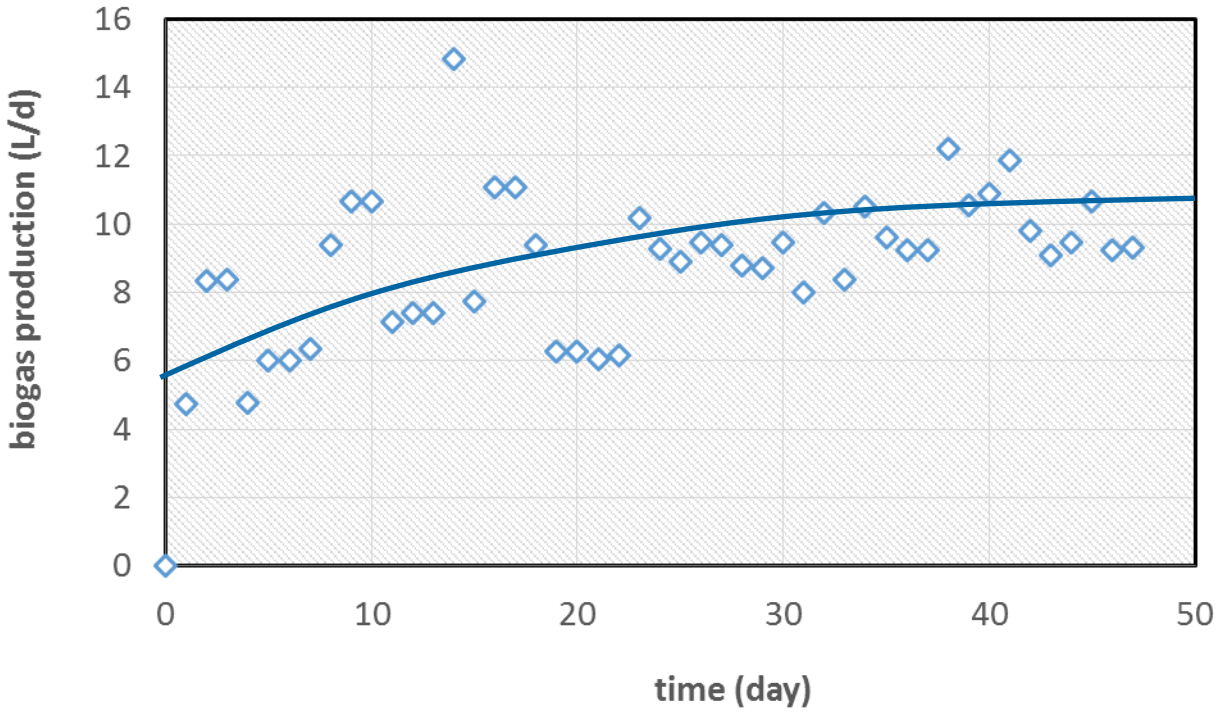
TMP gradually increased from 67.5 mbar to 141 mbar after 72 hours of filtration with dTMP/dt, equivalent to 1 mbar/h

Reversible fouling by cake forming and concentration polarization was major, while irreversible fouling is insignificant➔ membrane fouling is easily controlled using air scouring and periodically backwash.



Labscale experiment

Biogas production



Biogas yield

723 l/kg VS.d
At loading rate

2.0 g VS/m^3.d

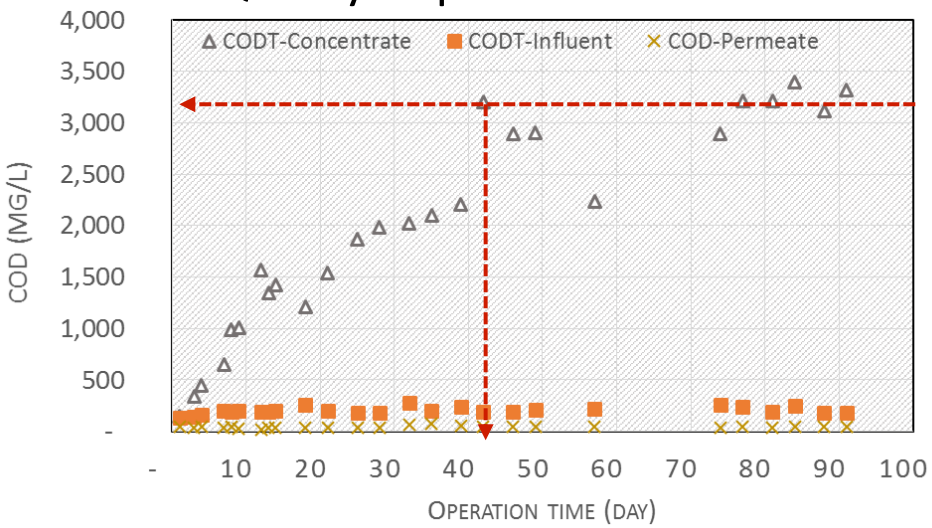
Digestate:

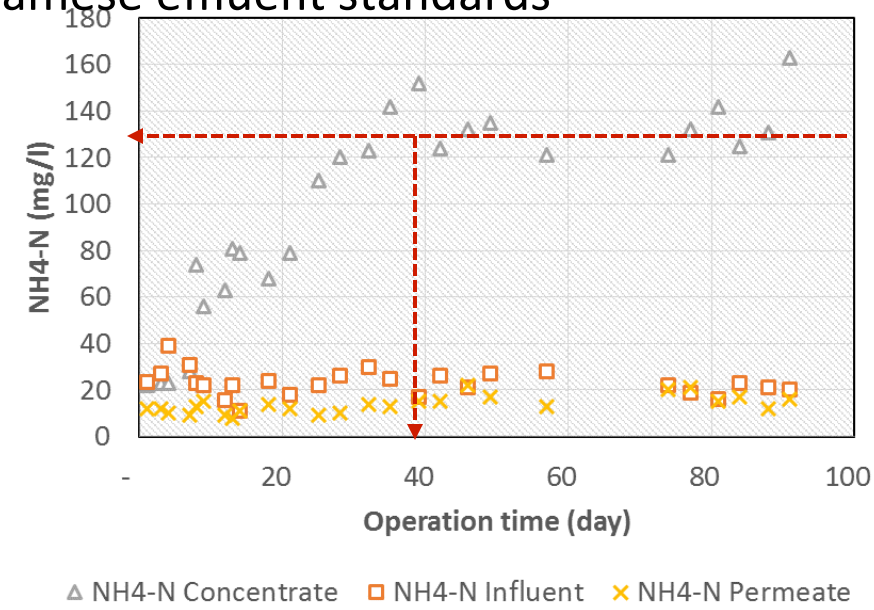
TS 25 g/kg w.w.
OC 1.6 g/kg w.w.
TKN 4.1 g/kg w.w.

Pilot-scale experiment

	TCOD (mg/l)	sCOD (mg/l)	pCOD (mg/l)	NH4-N (mg/l)	TN (mg/l)	TP (mg/l)
Feed	202 ± 34	149 ± 36	53 ± 20	23 ± 6	31 ± 5	3 ± 1
Permeate	42 ± 10	42 ± 10		14 ± 4	20 ± 5	3 ± 0.4
Retentate	2971 ± 200	453 ± 277	1518 ± 970	99 ± 43	161 ± 75	38 ± 24
E (%)	79			39	35	0

Quality of pemeate was meet Vietnamese effluent standards

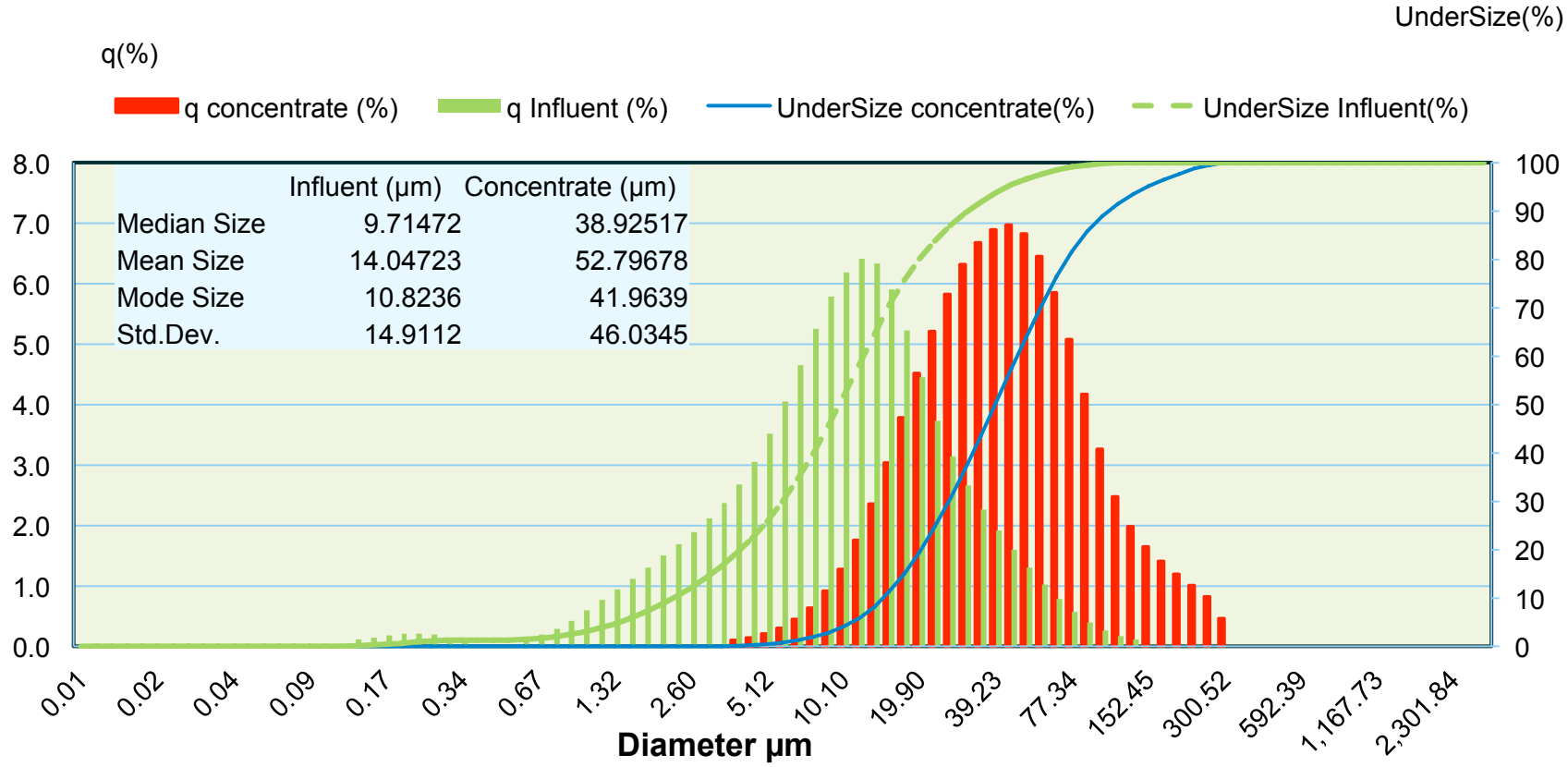




Too long RT (HRT= V_{UF}:Q_p = 4 hours and SRT = V_{UF}:Q_c= 90 days) ➔ aerobic degradation in membrane tank ➔ high ammonia concentration in retentate due to conversion of organic-N ➔ low COD recovery in comparison with that lab-scale

Pilot-scale experiment

Membrane up-concentration

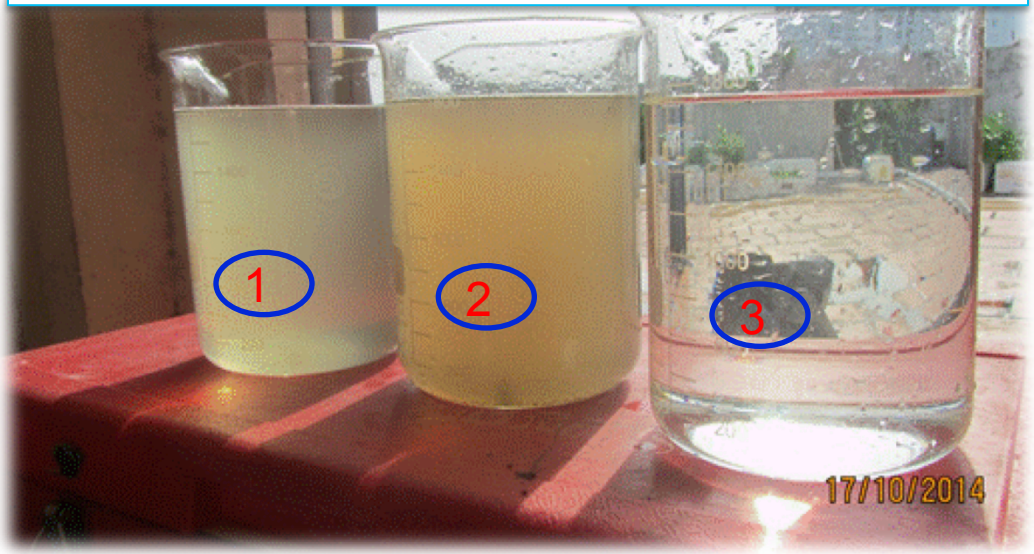


q: Frequency Distribution Value (%)

particle size analysis results (21/11/2014)

Pilot-scale experiment

Membrane up-concentration



After 2 days of filtration

After a long term of operation time (after 3 weeks)

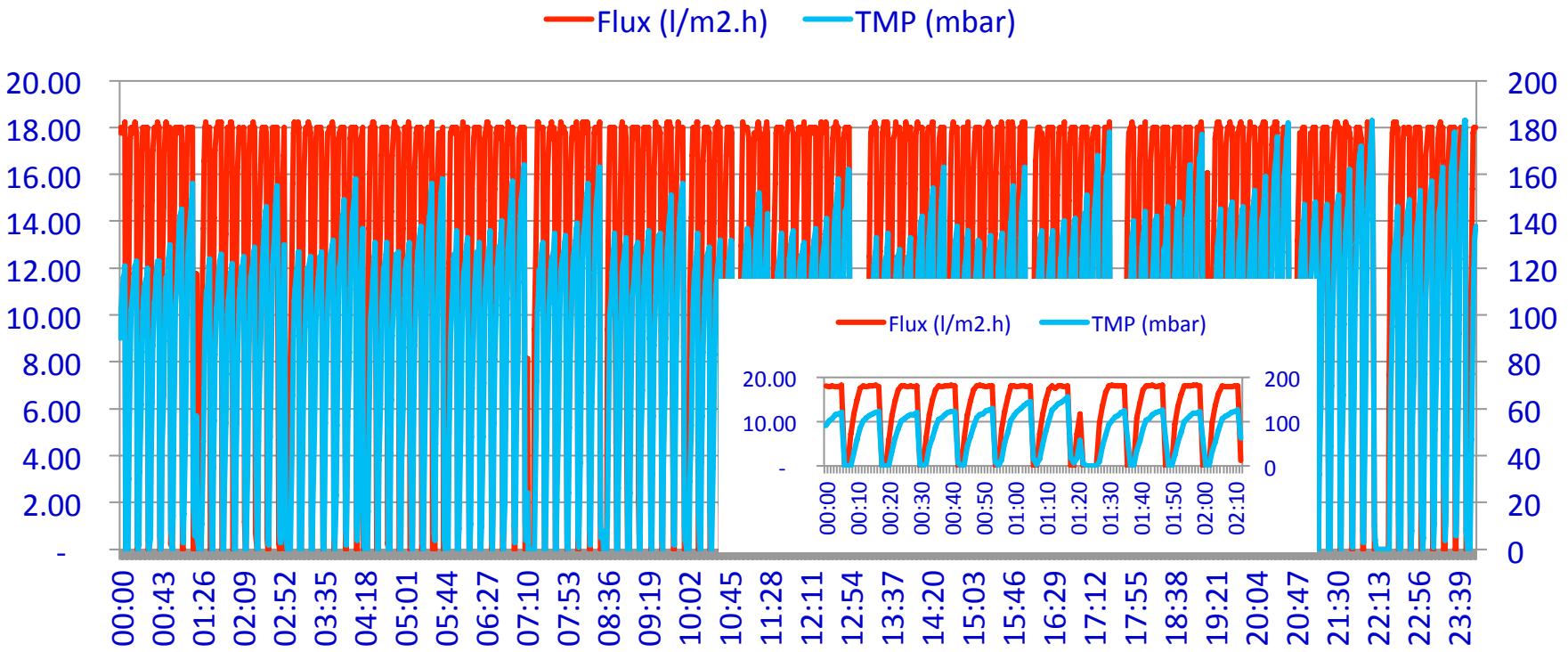
1 Influent

2 Rententate

3 Permeate

Pilot-scale experiment

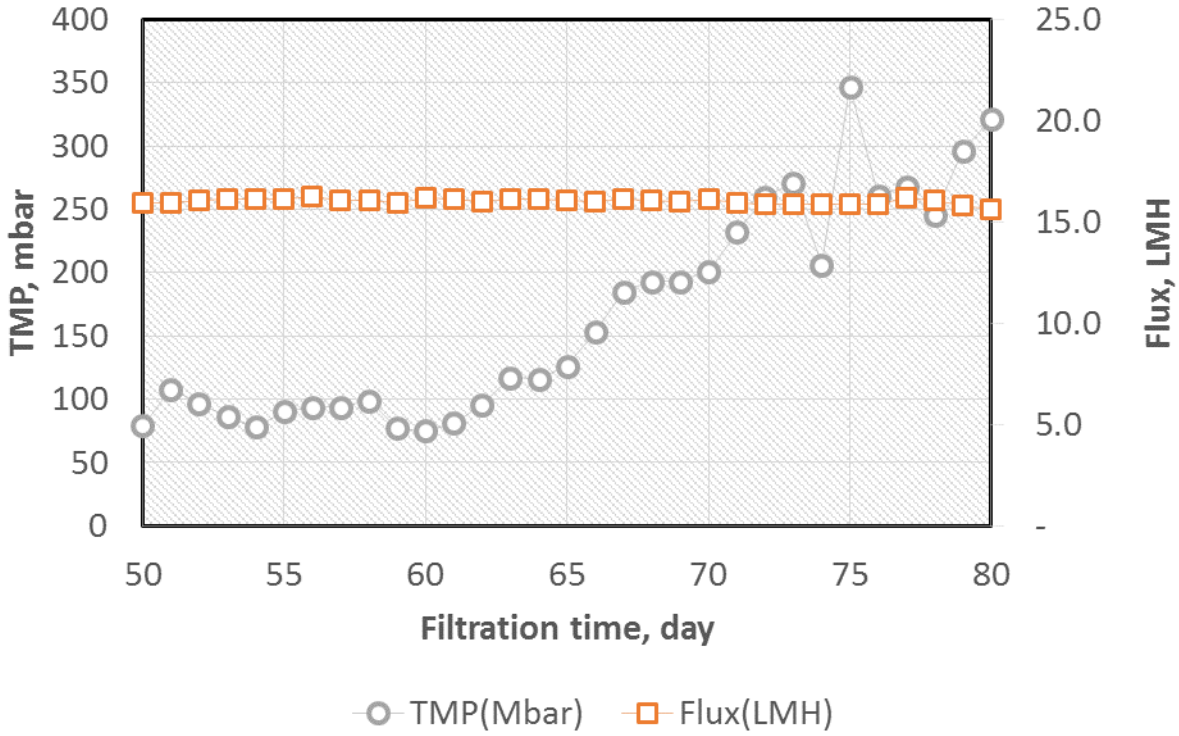
Membrane Up-concentration



In the first weeks of filtration, TMP of UF increased from 50 mbar (after backwashing) to 200 mbar during each 24 hours of filtration

Pilot-scale experiment

Membrane Up-concentration



After a long term running of 20 days, bioflocs formed in the membrane tank ➔ slowed down increase of TMP ➔ backwashing was done after 20 days

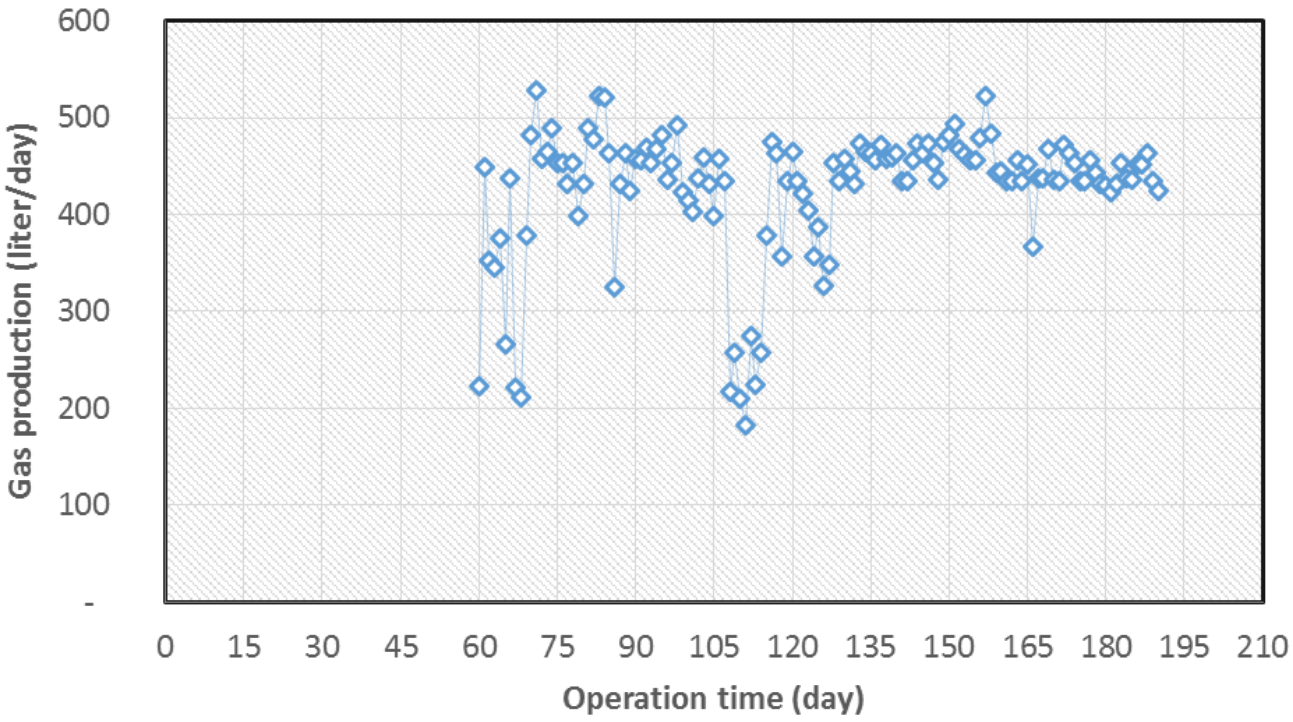
Pilot-scale experiment

Anaerobic digester

Parameter	Influent mixture		Digestate		Efficiency removal %
	Average	Std.	Average	Std.	
pH	6.7	0.7	7.5	0.5	
t^0C	31.3	1.0	31.5	1	
DM (%)	18	3.2	14	2.4	
Moisture	83	3.2	86	2.4	
TS (g/kg w.w.)	163	29	52	33	
TVS (g/kg w.w.)	134	11	22	13	84
NH_4-N (g/kgw.w.)	1.9	0.6	2.9	0.4	
TKN (g/kg w.w.)	3.9	0.7	3.9	1.2	
TP (g/kg w.w.)	1.6	0.7	1.4	1.4	13

Pilot-scale experiment

Anaerobic digester

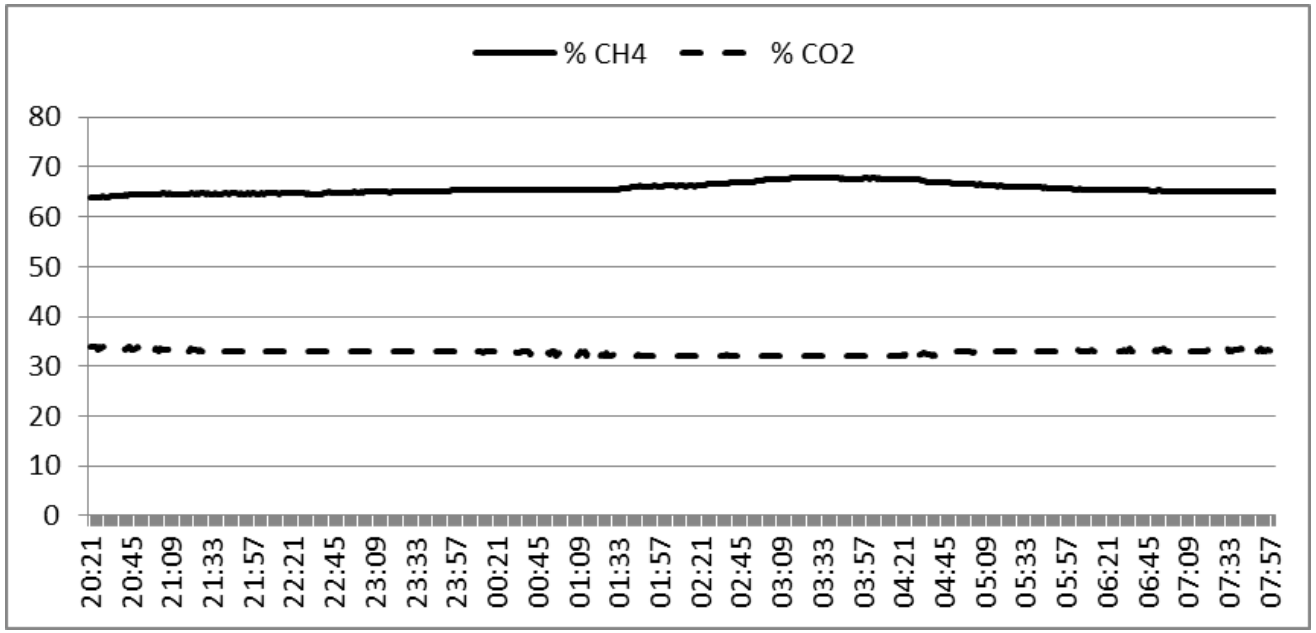


Gas production yield: 426 ± 69 liter/day

Pilot-scale experiment

Anaerobic digester

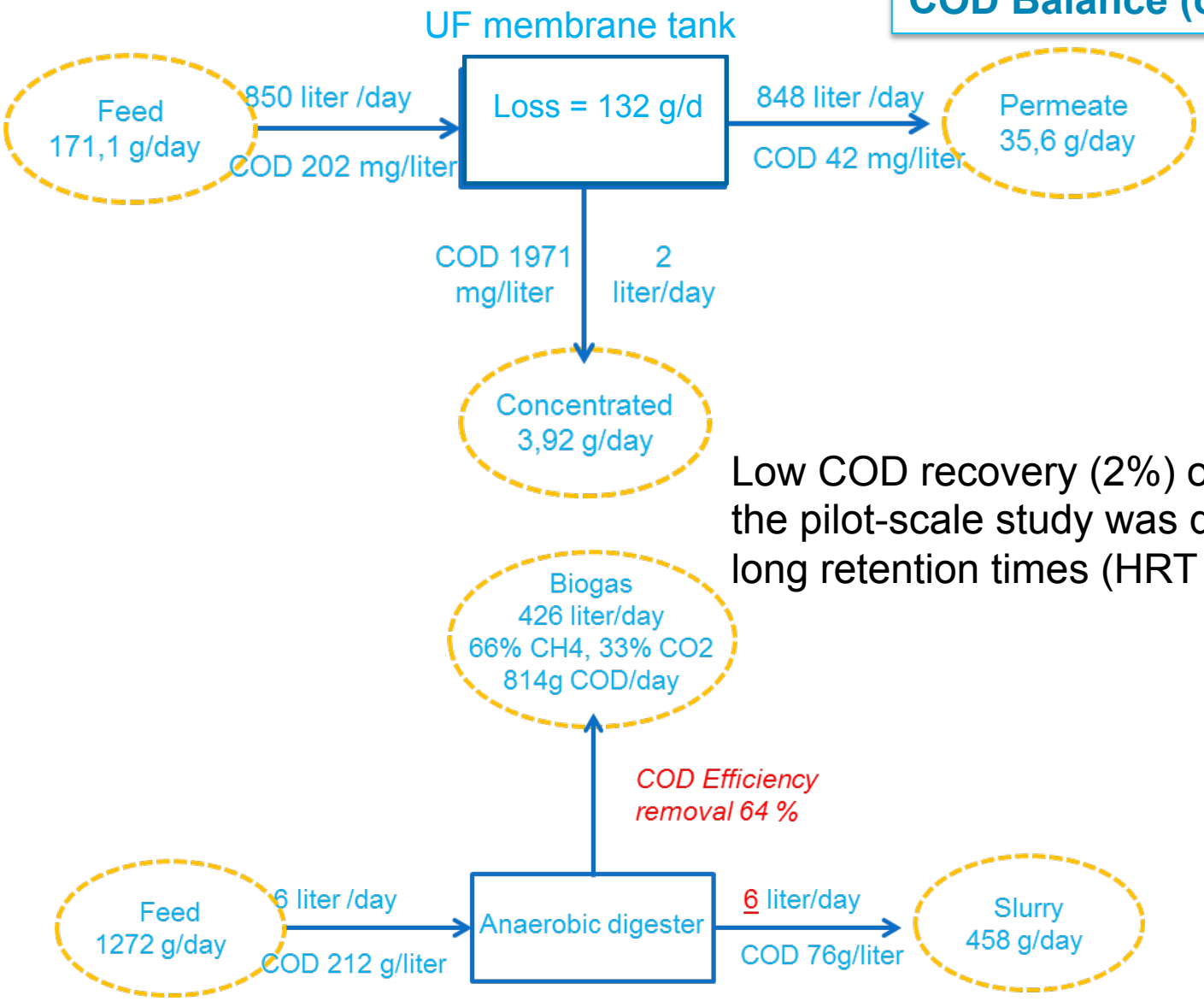
Analysis of biogas component using Dräger X-am 7000



	% CH4	% CO2
Avegare	65.7	32.8
Std	1.03	0.52

Pilot-scale experiment

COD Balance (operation 90 days)



Low COD recovery (2%) or high loss (72%) in the pilot-scale study was due to filtration with long retention times (HRT 4 h & SRT 92 days)

Carbon Mass balance

Calculation of Carbon mass balance of a SEWAGE+ plant with capacity of **domestic wastes generation per capita** was based on the following assumptions:

(i) Sewage generation were 150 L/capita/d;

(ii) Municipal solid waste generation per capita and organic component percentage were 1.0 kg/d and 60%. respectively;

(ii) Ratio of methane and CO_2 components in the biogas was 60:40;

(iii) TOC:COD ratio of settled sewage equal to 0.37 (Metcalf and Eddy, 2000).

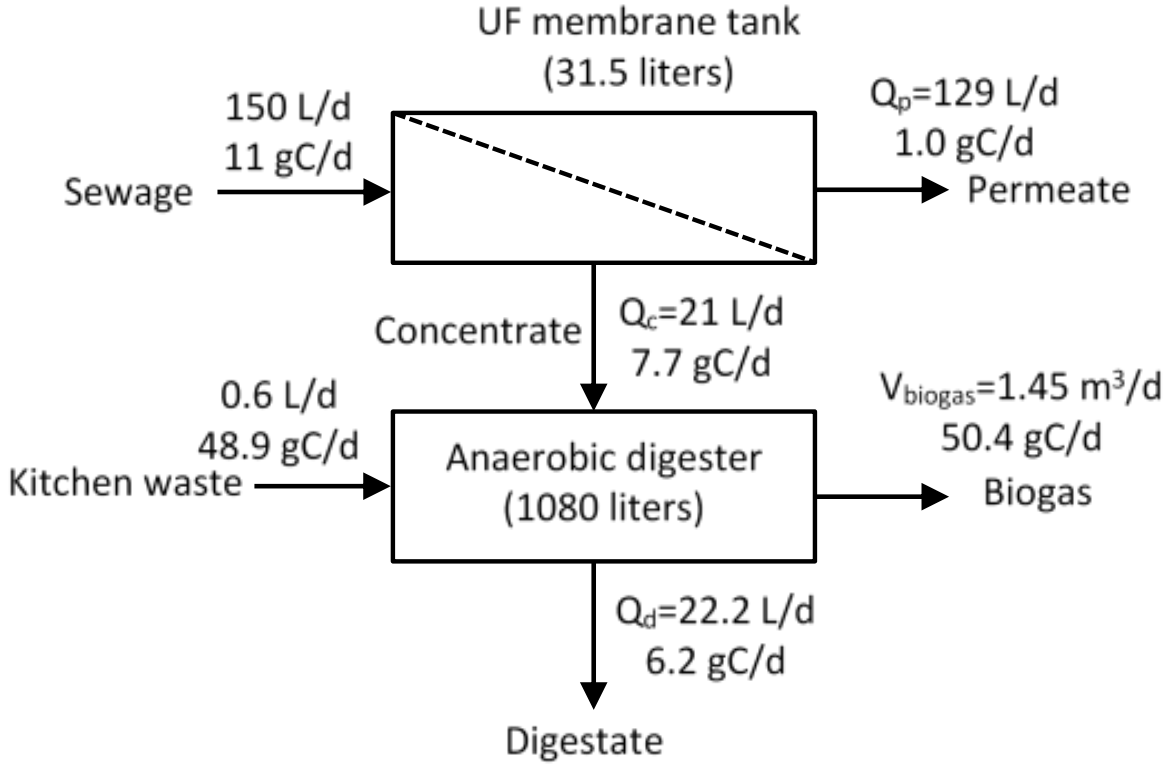
(iv) Volume of UF membrane tank was 36.6 L which was determined by HRT (V_{UF}:Q_p= 5.9 h) of the lab-scale up-concentration tests;

(v) The selected SRT (V_{UF}:Q_c) of 36 hours (equivalent to 1.5 days) based on the result of the up-concentration tests and

(vi) The organic loading rate of 2.0 kg VS/m^3.d was selected according to the lab-scale experiment and

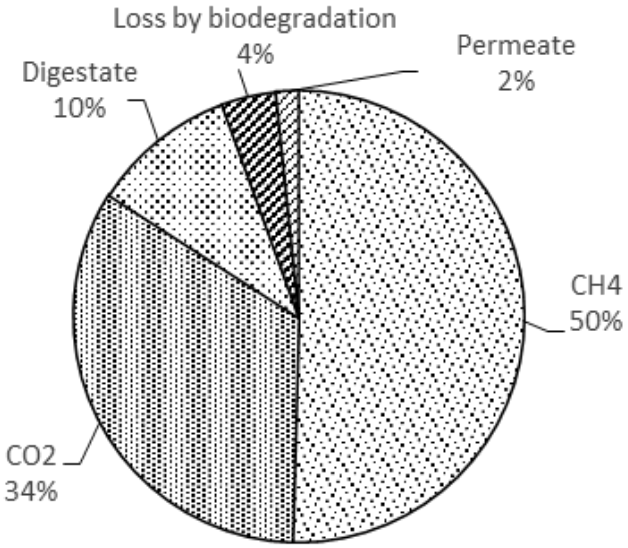
(vii) the biogas production of the lab-scale experiment was 0.74 L/g VS removed.

Pilot-scale experiment



- ✓ Carbon recovery from up-concentration could reach to 7.7 g/capita/day that took 70% of carbon amount of raw sewage and 13% of total carbon amount of the feed.
- ✓ A four-person household required a 126-litre UF membrane tank and a 4300-litre anaerobic digester.
- ✓ To promote feasibility of the Sewage+ into the practice, reduction of unit volume of UF tank and anaerobic digester is necessary for further studies.

Pilot-scale experiment



- 50% of Carbon amount from mixture of sewage and household food waste will be converted to methane
- 1.45 m^3 of biogas was produced from the Sewage+ plant with capacity of wastes per capita
- 1 kg COD can be recovered from 140 m^3 of sewage of 200 mgCOD/L ➔ 1000 m3 of sewage using UF membrane for up-concentration can produce 10.7 kWh

(Van Lier et al. (2008) shown that 1 kg COD of wastewater via biogas production could produce electrical capacity of 1.5 kWh at 40% electric conversion)

Challegences and potential studies for Sewage+

Challenges	Solution/further study
High energy consumption for membrane up-concentration	Energy balance for Sewage+ plant ➔ evaluate energy efficiency
High organic C loss by biodegradation in up-concentration in tropical countries	Reduction of retention time, increase of membrane flux, improvement of air scouring, alternative membrane cleaning
High cost for post-treatment of digestate containing high nutrients and solids and nutrients in the permeate	Reuse for irrigation/watering or fertilization
Low COD strength sewage resulted in high energy consumption for up-concentration	- co-digestion of septage from septic tanks and household organic solid waste, - modification of septic tank as an anaerobic reactor - Anaerobic MBR option which may combine anaerobic reactor and up-concentration

Conclusion

The following conclusions were found in this study:

(i) The average permeate COD concentrations of UF filtration met with Vietnamese municipal discharge standards.

(ii) Efficiency of ammonia removal by UF filtration were not significant. However. this permeate may have significance in terms of nutrient reuse for irrigation

(iii) COD levels of the retentate much depended on COD strength of raw sewage and retention time of up-concentration.

(iv) High concentrated COD level obtained was attributed to particulate or colloidal COD

(v) Co-anaerobic digestion with mixture of retentate and kitchen waste yielded 1.94 ± 0.34 $m^3/m^3.d$ at organic loading rate of 2.0 $kgVS/m^3.d$ and sludge retention time of 50 days.

(vi) Carbon recovery from up-concentration took 70% of carbon amount of sewage and 13% of total carbon input of the whole system.

(vii) Electrical production of 3.1 kWh/capita/day can be obtained when the Sewage+ technology applies for the current generation rate of wastes in Ho Chi Minh City.


Thank you for
Your attention