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Sludge pretreatment methods for enhanced volatiles solids destruction and methane production

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Sludge pretreatment methods for enhanced VS destruction and CH_4 production

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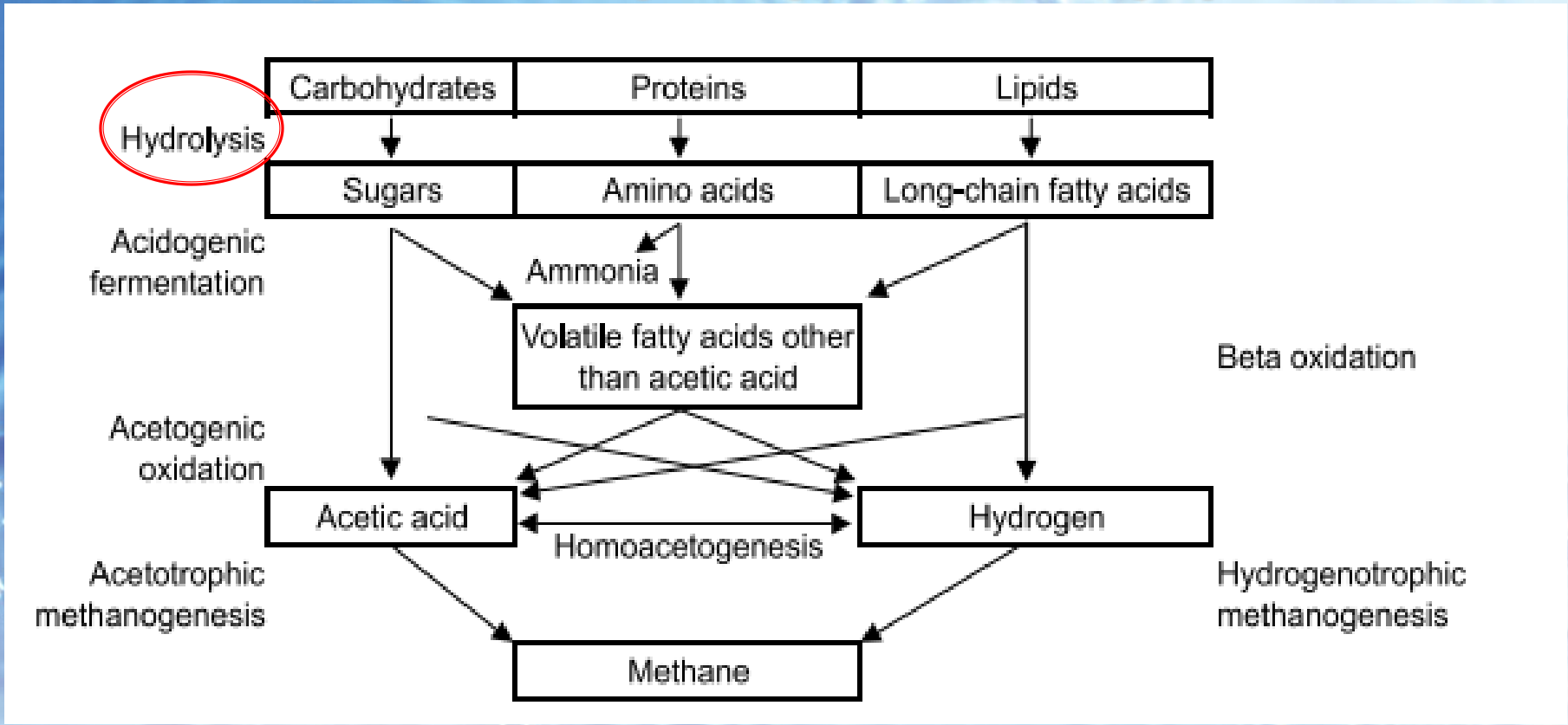
AEBC Advanced Environmental Biotechnology Centre

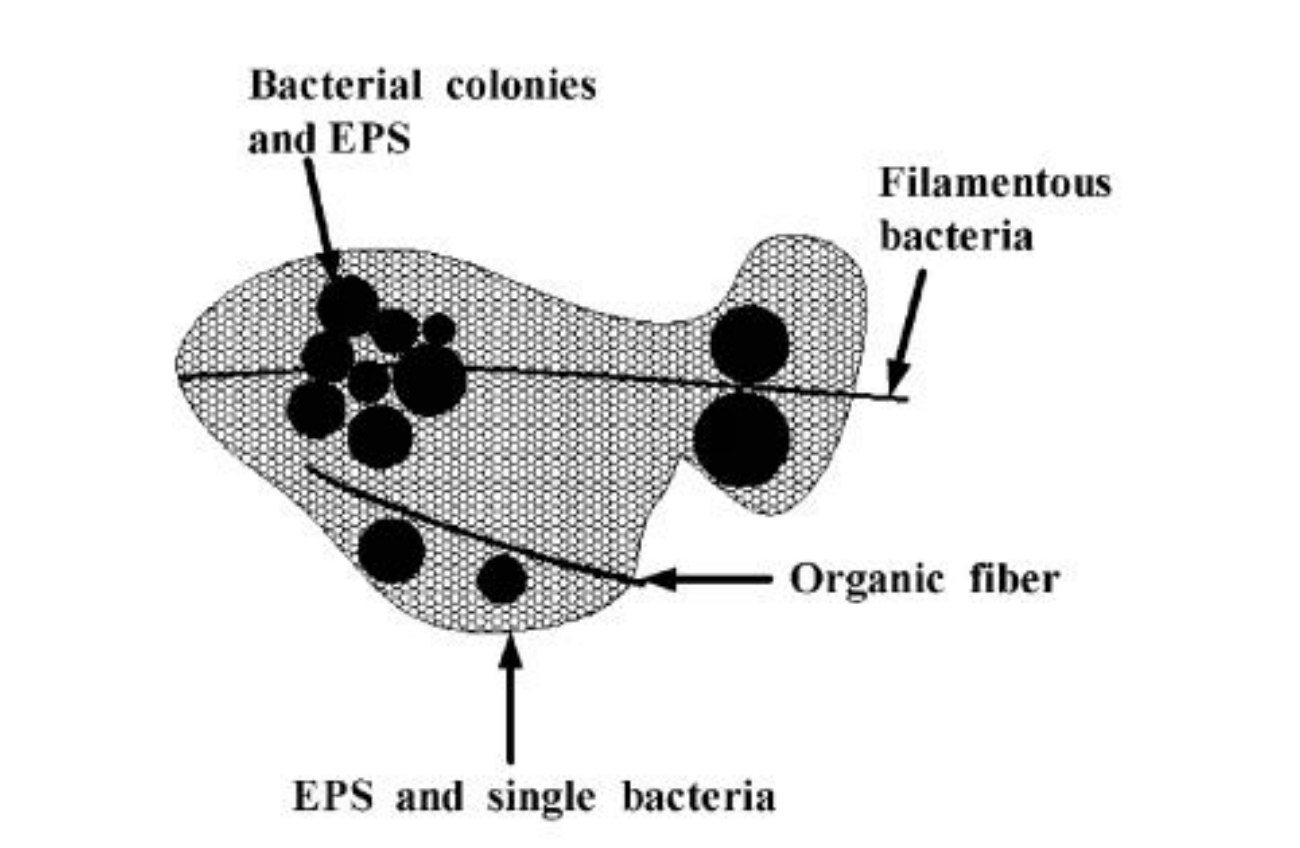
Steps in Anaerobic Digestion

- Sludge treatment ~50% of operating costs in WWTPs;
- Anaerobic sludge digestion = Degrade organic matter + Biogas production.



Four Biological steps in Anaerobic Process (Koster, 1989)

WAS resistance to anaerobic digestion



Source: KEIDING, K. & NIELSEN, P. H. 1997. Desorption of organic macromolecules from activated sludge: Effect of ionic composition. *Water Research,* 31**,** 1665-1672.

Common Pre-treatment Technologies

- Alkaline Pre-treatment;
- Conventional mechanical Pre-treatment;
- Ozone Pre-treatment ;
- Thermal Pre-treatment;
- Ultrasound Pre-treatment.

Drawback of single process treatment = 1 principle mechanism → performance limited.

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Ultrasound pre-treatment

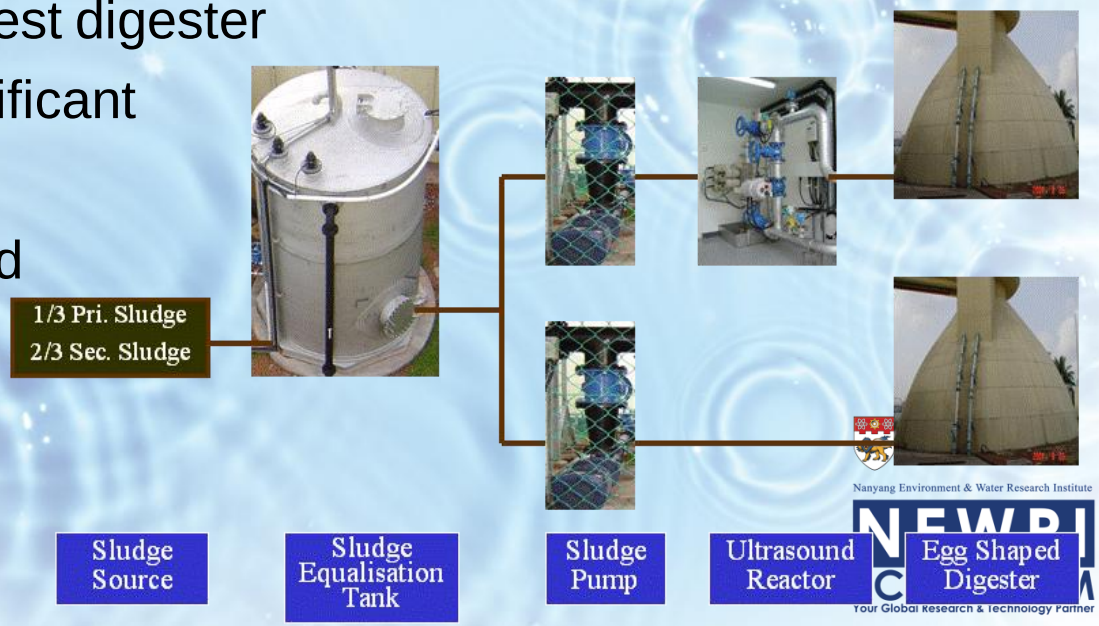
Mechanisms	Sludge physical characteristics change	Sludge biochemical characteristics change
• Mechanical (pre-dominant); • Chemical; • Thermal.	• Particle size reduction; • Solids reduction; • Dewaterability change.	• COD solubilization; • Biopolymers solubilization (e.g. protein); • Methane production and VS reduction increase after anaerobic digestion; • Possibility of refractory compounds solubilization after long ultrasonication period.

Alkaline pre-treatment

Mechanisms	Sludge physical characteristics change	Sludge biochemical characteristics change
• Cell lysis caused by high pH value; • Chemical reactions with sludge.	• Solids reduction; • Dewaterability deterioration.	• COD solubilization; • Biopolymers solubilization (e.g. protein); • Methane production and VS reduction increase after anaerobic digestion; • Decomposition of macromolecules; • Possibility of refractory compounds formation.

Earlier work on ULS only

- ***Demonstration-scale sludge pretreatment study at UPWRP (Xie et al., 2007)***
- **Sludge**: Mixed primary and secondary sludge (1:2)
- **Digester**: Two 5000m^3 egg-shaped digesters; one test & one control
- **Pretreatment**: Ultrasonication (5 probes, 20 kHz), 6,000 Watts, 1.5 sec, 1.4 kWh/m^3 WAS
- **Biogas**: ~35% higher daily biogas production in test digester
- **Solids**: ~22% lower TS the test digester
- **CH_4 content**: ~65%; no significant difference
- **Net energy gain**: about 2 fold excess to the ULS energy consumption



ULS Scale-up difficult
Differing lab/pilot-scale results

- Ultrasonicator

Power input: around 130W
Sludge Volume: 200mL

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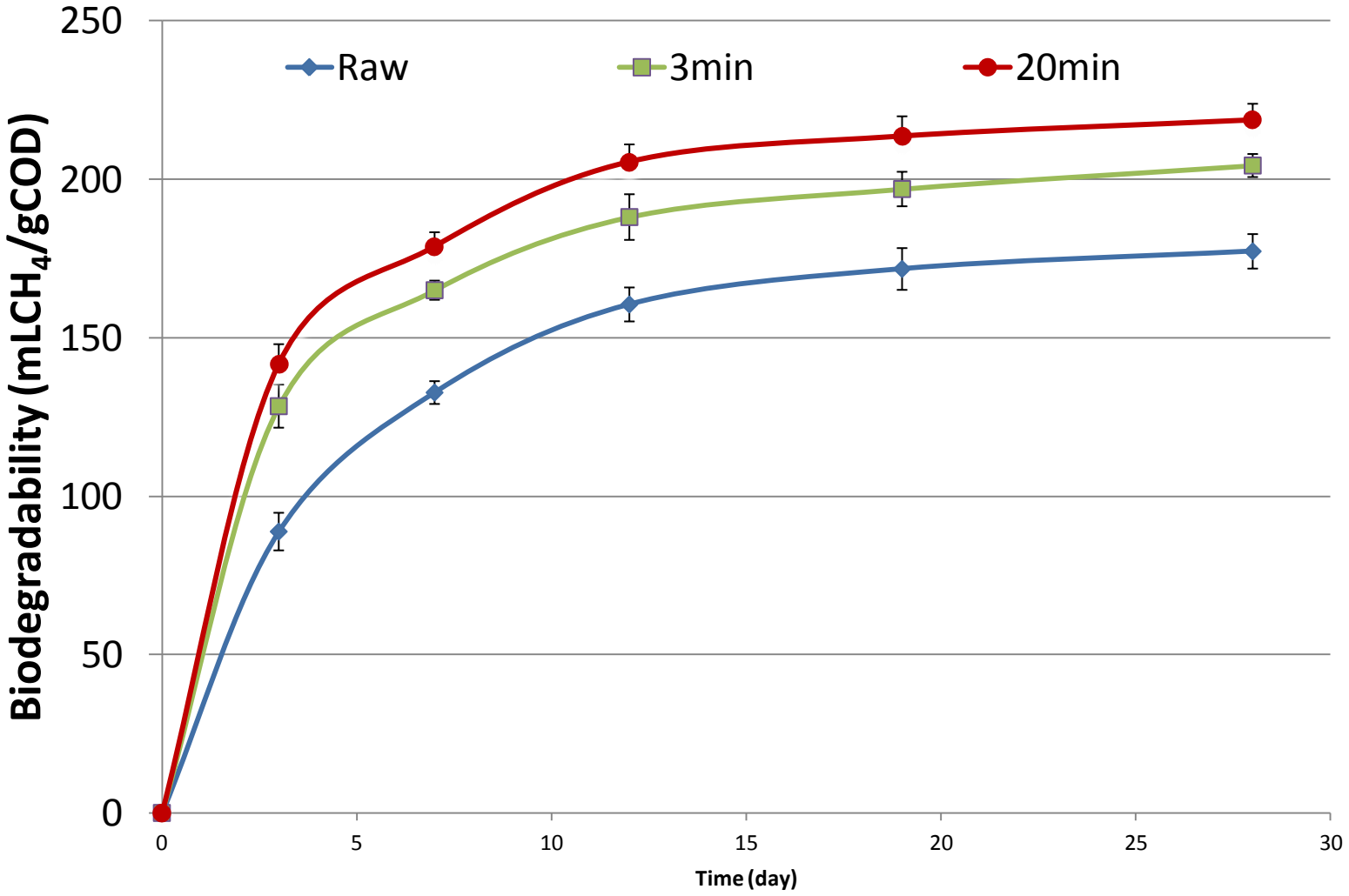
ULS Improving Biodegradability



3min (9,000 kJ/kg TS): 15% increase in biodegradability

20min (58,000 kJ/kg TS): 25% increase in biodegradability

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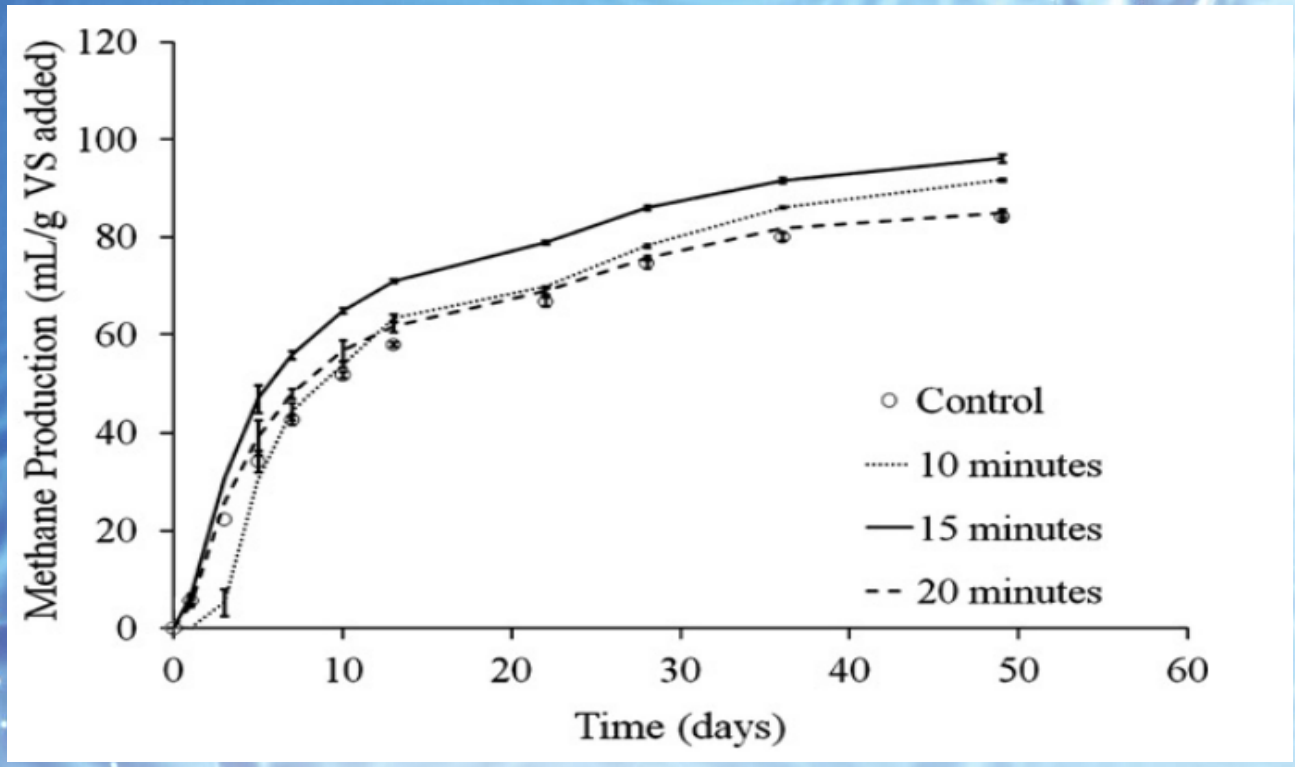
Negative Effect of ULS?



APUL, O. G. & SANIN, F. D. 2010. Ultrasonic pretreatment and subsequent anaerobic digestion under different operational conditions. *Bioresource technology,* 101**,** 8984-8992.

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Enhancing Ultrasonication - NaOH

- More COD solubilized when ULS was combined with NaOH;
- Performance (SCOD increase) – sequence related: Simultaneous NaOH/ULS > NaOH – ULS > ULS – NaOH.

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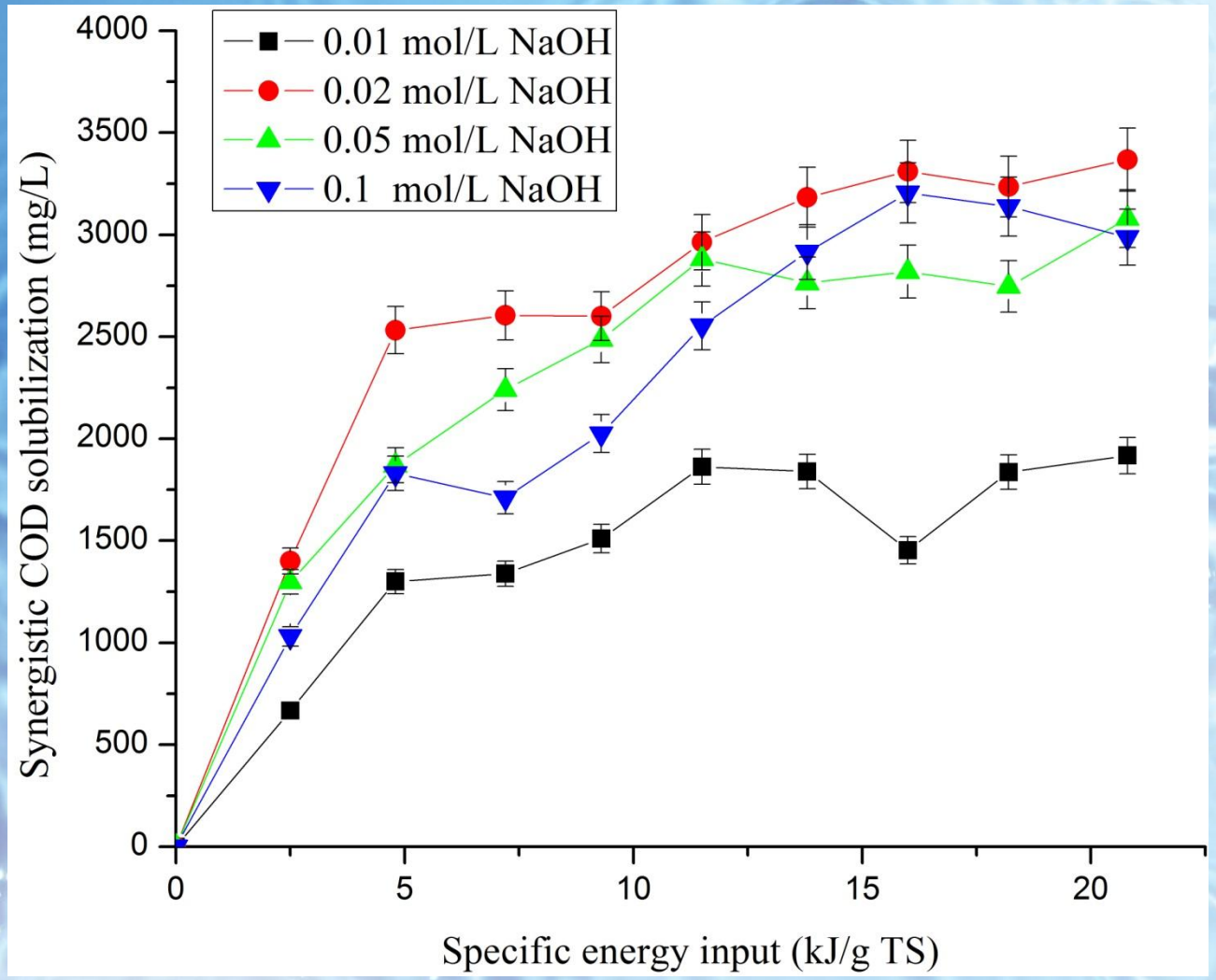
Synergistic mechanism speculations

- NaOH makes sludge vulnerable to ultrasound attack by weakening cellular walls;

- Microbial cells dispersed/released by ultrasonication better exposed to hydroxyl ions.

Synergistic Effect between ULS and NaOH



1.Suggested mechanism: NaOH enhanced radicals generation

2. Synergistic effect is not NaOH concentration depended after 0.02M

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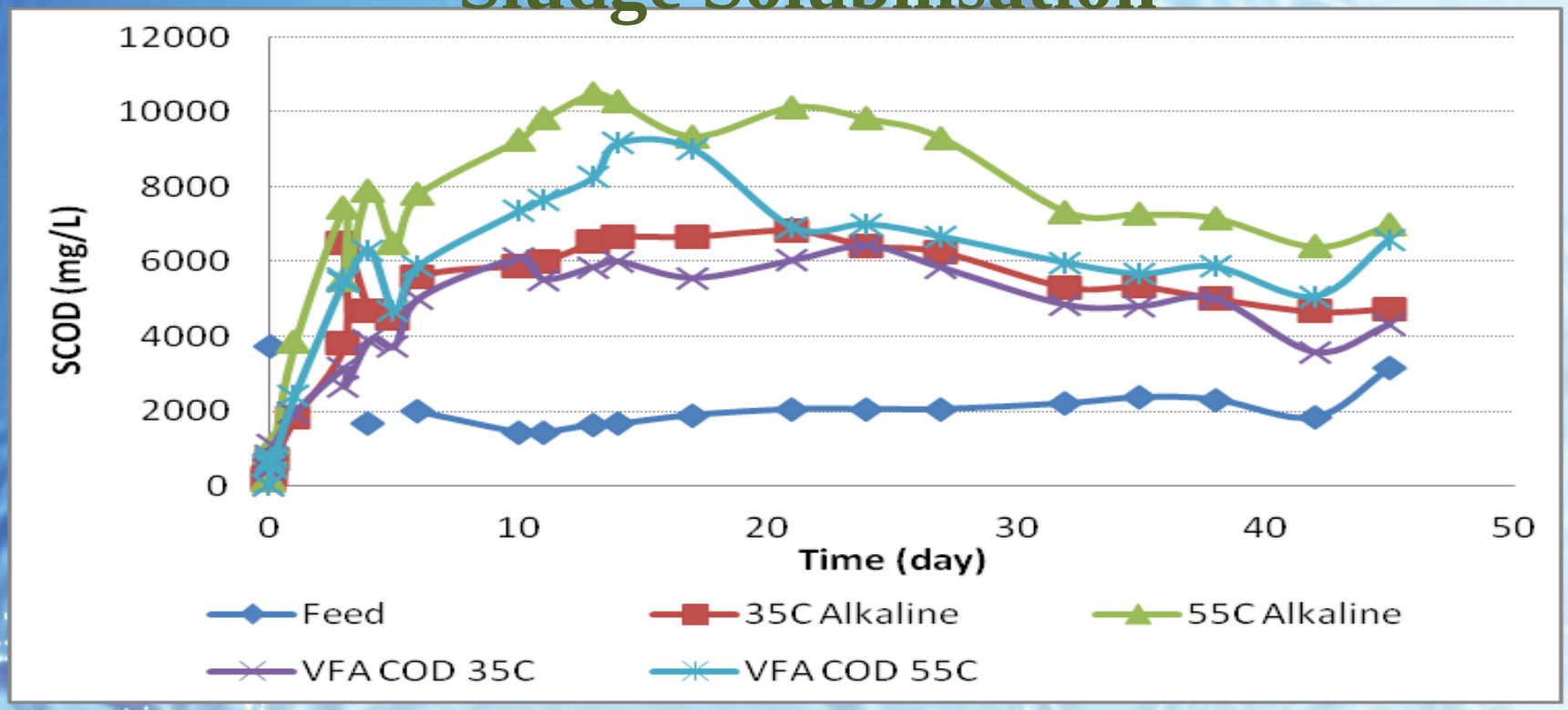
Mesophilic (35C) & Thermophilic (55C) Sludge Solubilisation



Sludge solubilisation and VFAs production at 35°C and 55 °C

Sludge solubilisation: 55°C > 35°C;

VFA/SCOD ratio: 35°C > 55°C.

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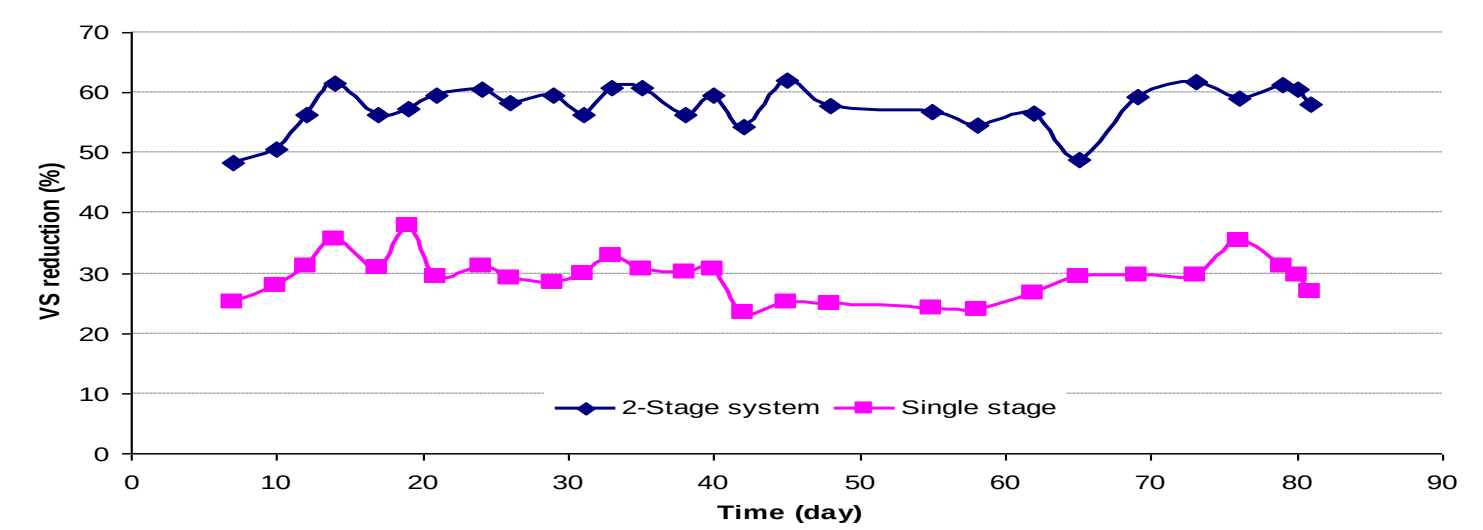
2-Stage Sludge Treatment System (mesophilic-mesophilic)



(a) (b)

Sewage sludge degradation in mesophilic-mesophilic 2-stage system

VS reduction: ~60 % (2-stage) > 30-35% (single stage)

Methane Production: ~ 31.54 % more methane by volume (@ room temperature and 1atm pressure)

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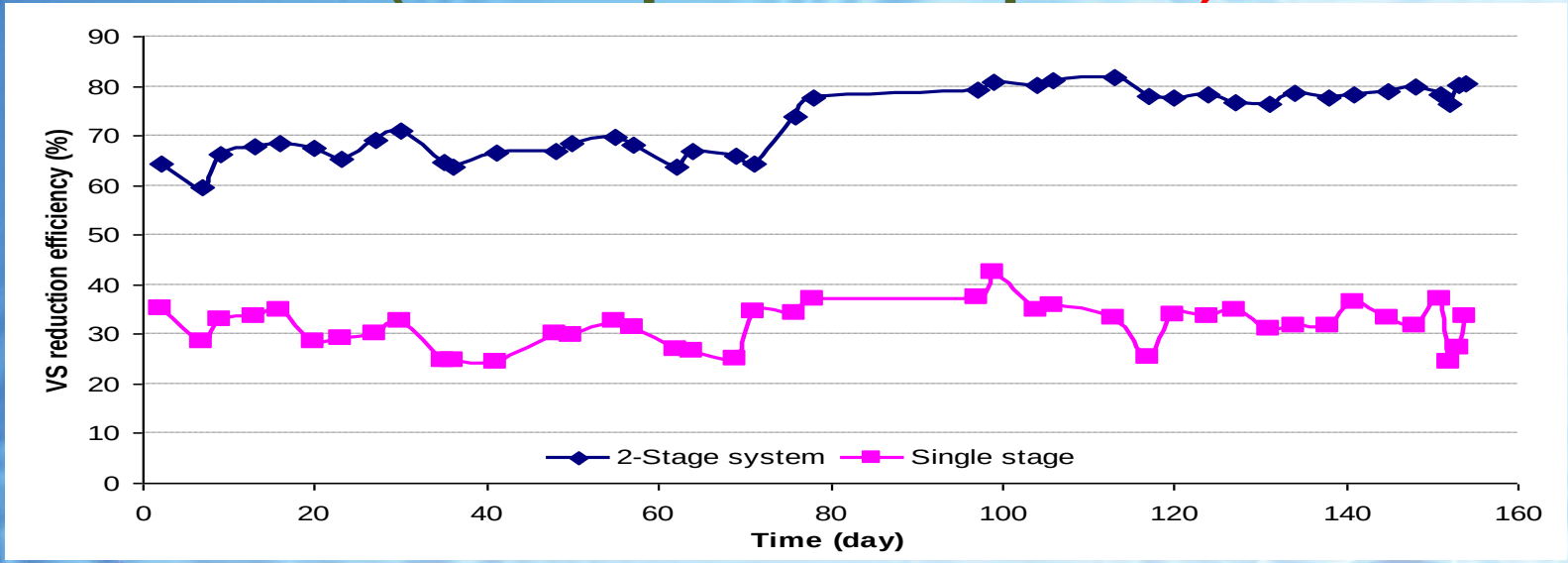
2-Stage Sludge Treatment System (thermophilic-mesophilic)



Sewage sludge degradation in thermophilic-mesophilic 2-stage system

- **~66-77% (2-stage) VERSUS 32% (single stage) VS reduction;**
- **~33-42% more methane by volume produced (@ room temperature & 1atm pressure).**

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Novel System for Sludge Treatment

Novel anaerobic lab system

Novel anaerobic pilot system @ UP-WWTP

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Summary

- **NaOH enhanced ULS** - 20% less NaOH but 40% increase in methane production;
- **Alkaline-thermophilic pretreatment enhanced hydrolysis and acidogenesis;**
- **(Alkaline-thermophilic pretreatment) enhanced (mesophilic digestion)** = 70% VS reduction (vs 30-35% in mesophilic single stage system) and 42% more biogas.

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Some 400 researchers. Pan NTU.


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Thank you

Extra slides

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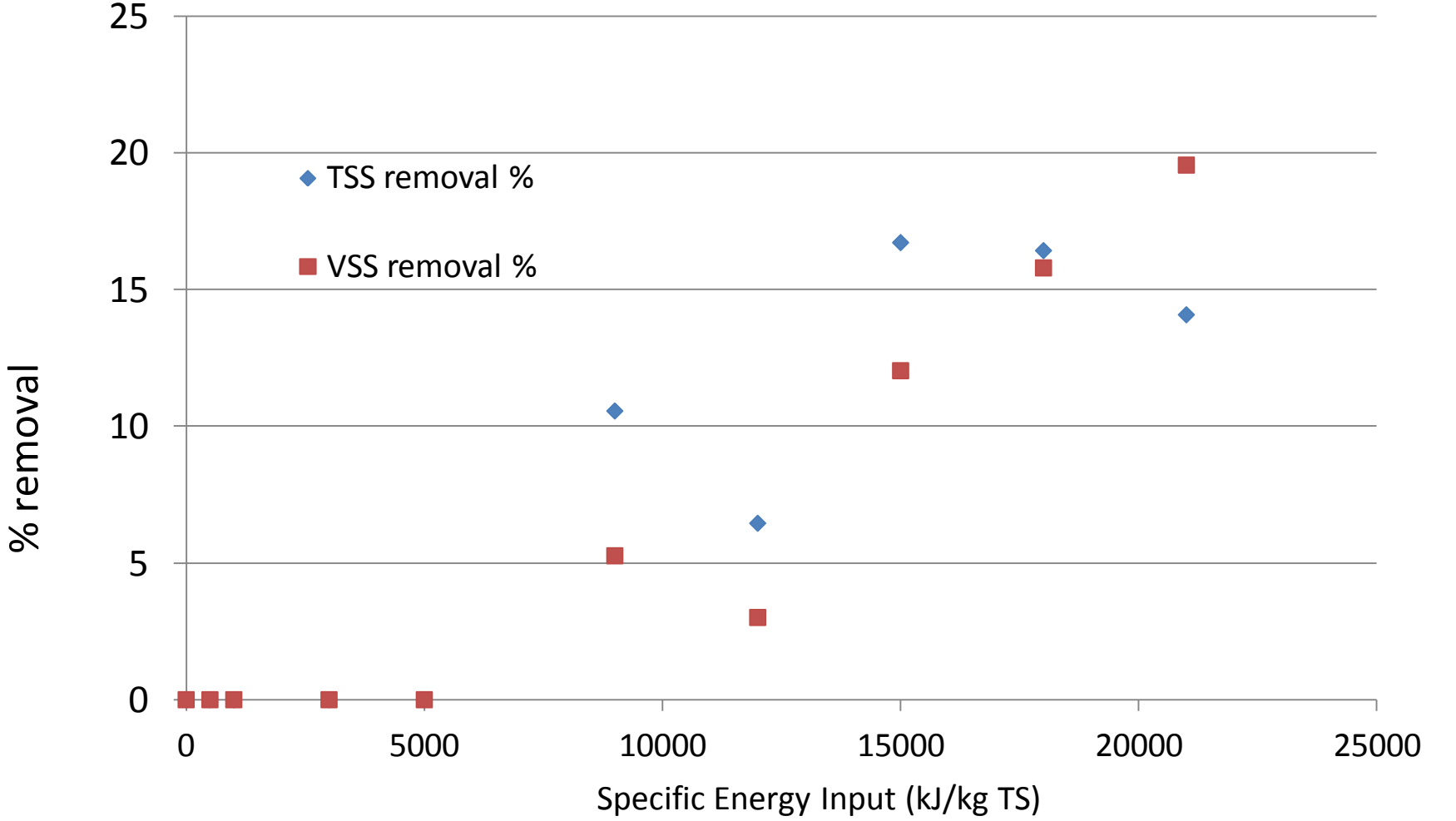
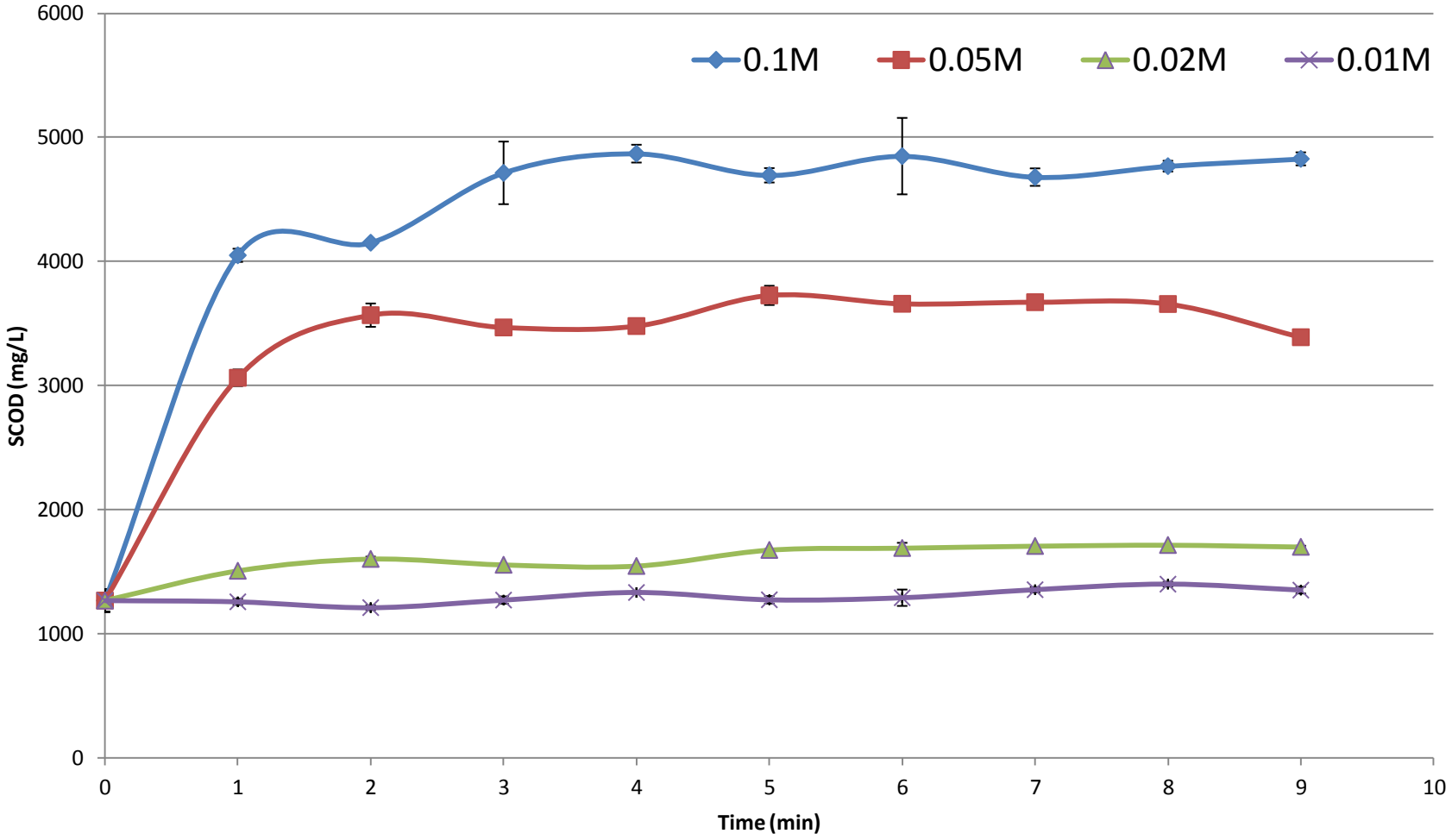
ULS TSS and VSS removals



Pre-treatment with NaOH only



1. **0.01M NaOH caused almost no COD solubilization**
2. **Noticeable SCOD increase was observed from 0.02M NaOH onwards**

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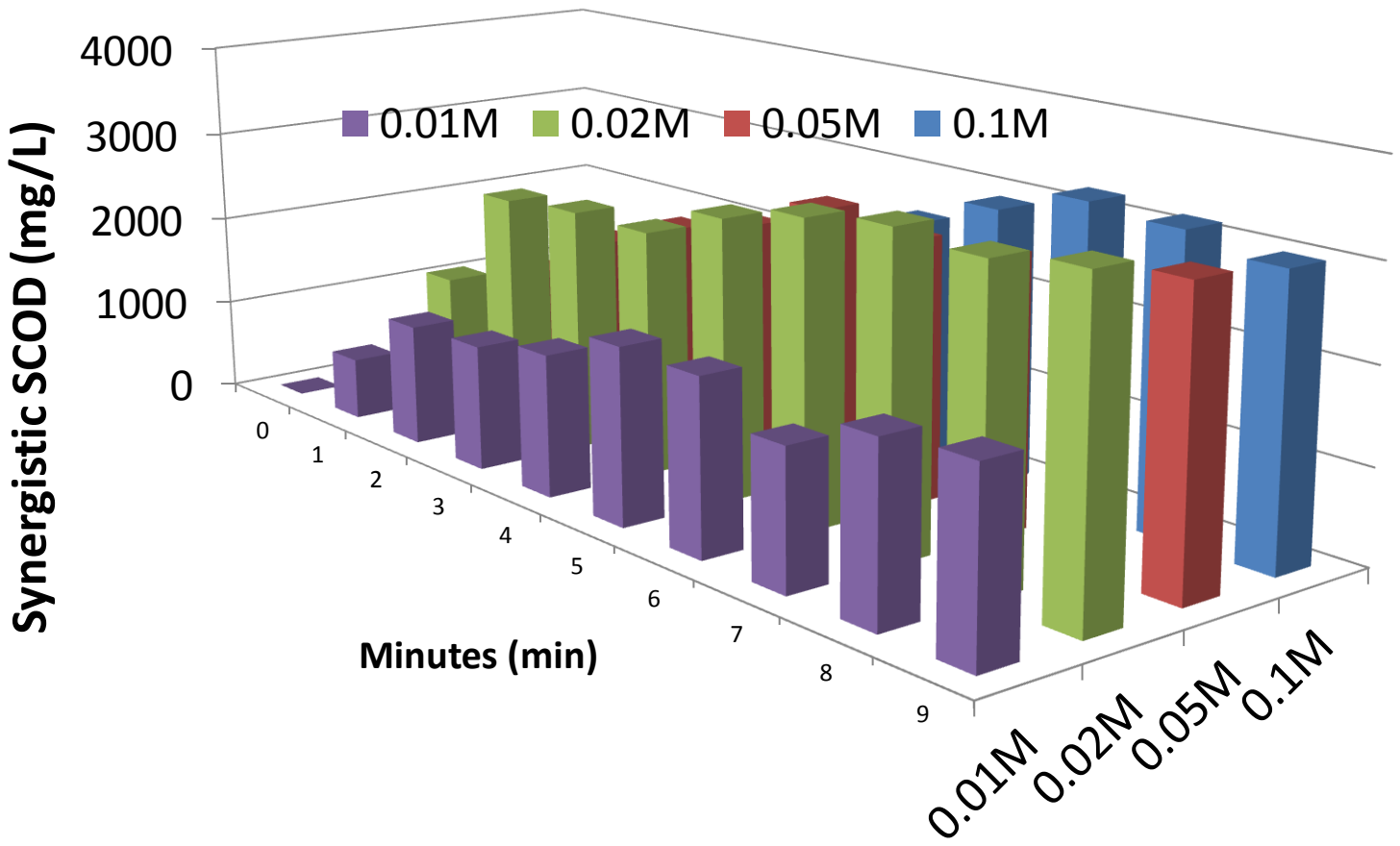
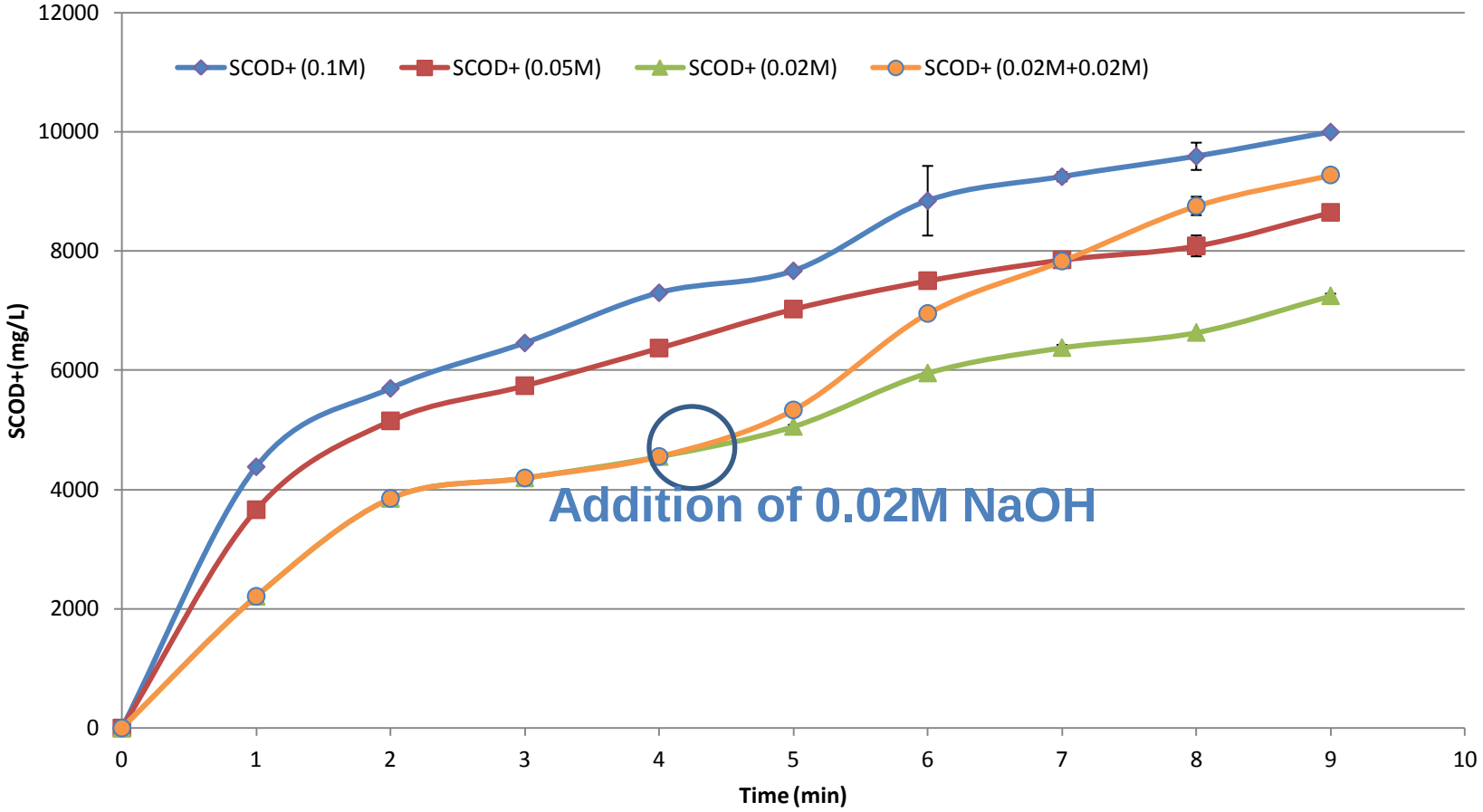
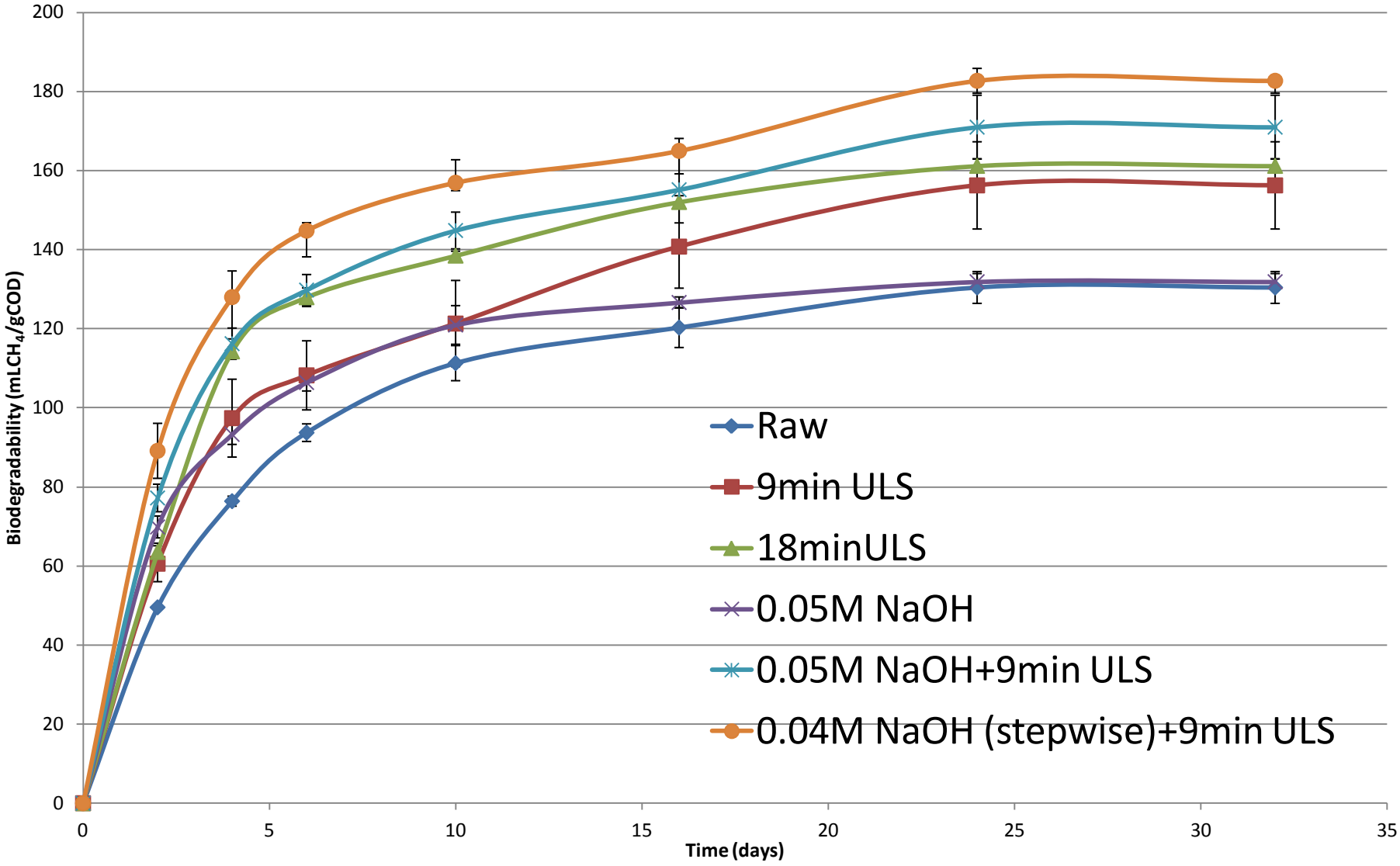


COD Solubilization of Optimized Combined Treatment



Combined Pre-treatment BMP



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Summary of BMP results

Sample	SCOD (mg/L)	Biodegradability of Total Sludge ($mL\ CH_4/g\ COD_{added}$)
Raw	780	130
9 min ULS	4,900	156 (+20%)
18min ULS	6,900	161 (+24%)
0.05M NaOH	3,200	132
0.05M NaOH+9min ULS	9,100	171 (+31%)
0.04M NaOH (stepwise)+ 9min ULS	9,300	183 (+40%)