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Thermophilic hydrolysis and acidification of activated sludge with a low organic carbon content under different sludge concentrations

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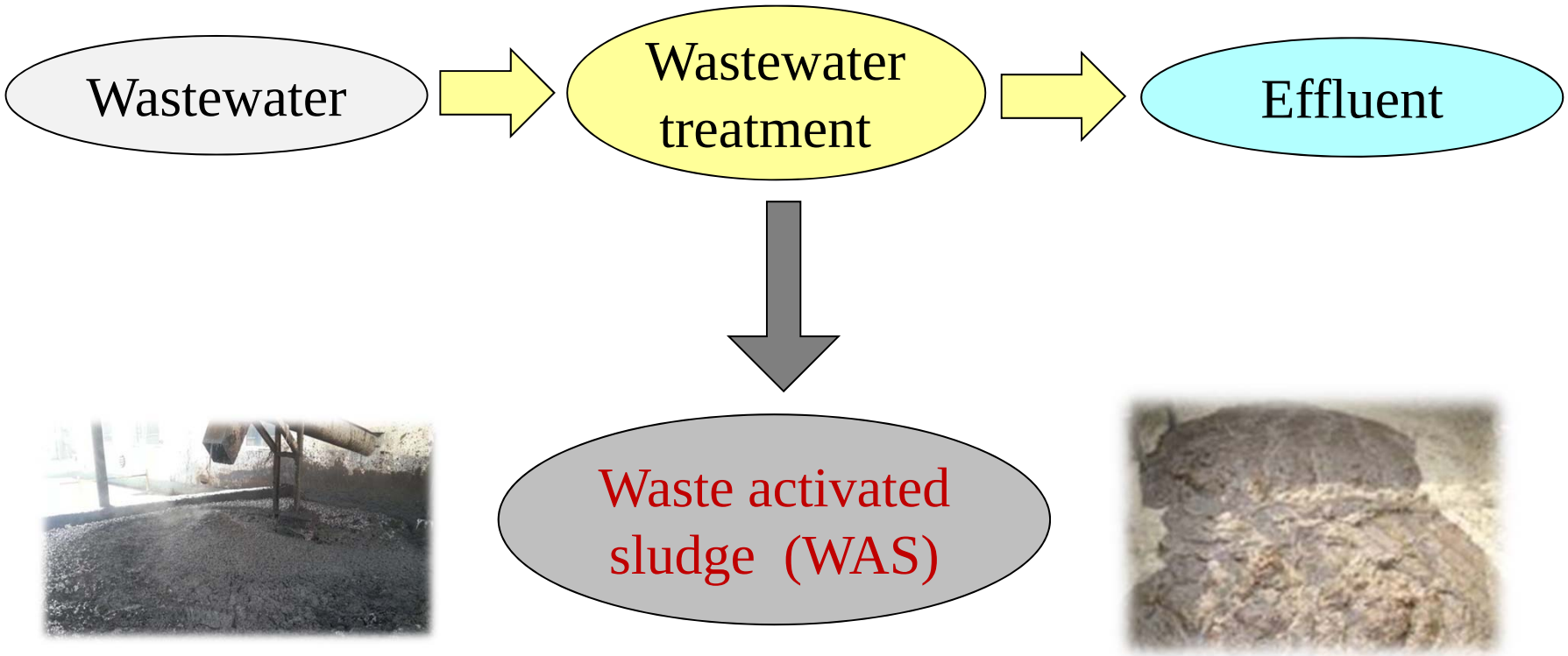
Contents

- Background
- Materials and Methods
- Results and Discussions
- Conclusions

1 Background

1.1 Sludge treatment

- Waste activated sludge



- Sludge treatment costs 25%-60% of operation cost of wastewater treatment plant.
  (Wei et al., Water. Res. 2003)

1.1 Sludge treatment

- Sludge treatment

Sludge treatment/ disposal

Landfilling

- Lots of lands are required.
- Not recycling.

Incineration

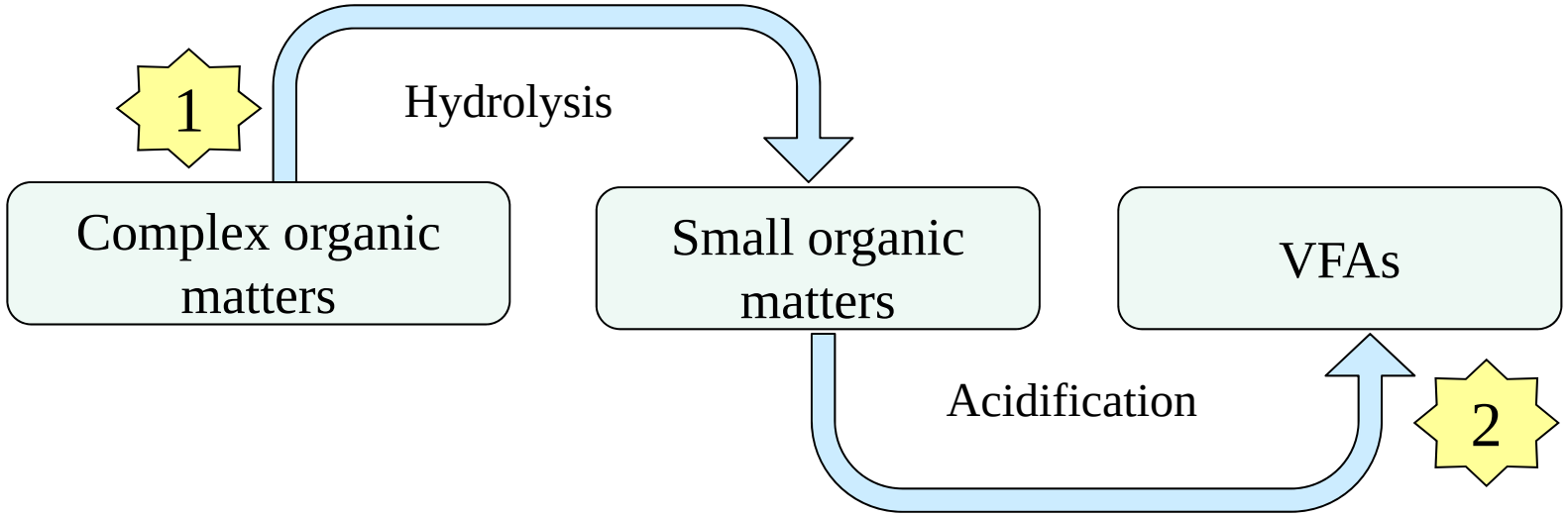
- Secondary pollution. (toxic gas)

Anaerobic fermentation

- Degradation and stabilization of organic materials.

1.2 Anaerobic fermentation

- Anaerobic fermentation



Advantages

- Degradation and stabilization of organic materials.
- Products (SCOD, VFA) can be reused.

Disadvantages

- Usually costs lot of time.
- Hydrolysis is the rate-limiting step.

1.3 Thermophilic fermentation

- Pretreatment

Some pretreatment methods have been investigate to enhance the efficiency of hydrolysis.

Treatment	Type	Influence	Reference
Alkaline	Physiochemical	Effective disintegration of sludge	Kim et al., 2013
Ultrasound	Physiochemical	Enhance the degradation of grease-containing cells	Luste et al., 2011
Fenton process	Physiochemical	Higher solid reduction	Erden et al., 2009
Thermophilic	Biological	Higher hydrolysis efficiency	Liu et al., 2013

Physiochemical pretreatment processes cost too much compared with biological processes.

1.3 Thermophilic fermentation

- Operational parameters

Parameters	Effect	Reference
pH	• Hydrolysis at alkaline pHs was greater than that at acidic pHs. • the accumulation of VFAs at alkaline pHs was greater.	Zhang et al., 2009 Chen et al., 2007
Temperature	• The production of VFAs increased at 65℃, compared to 55℃.	Ahring et al., 2001
SRT	• VFA yields increased with SRT.	Yuan et al., 2009
Sludge concentration	• higher total volatile solids concentrations resulted in higher VFA production.	Bouzas et al., 2002

The various effects of sludge concentration on hydrolysis under thermophilic condition are worthing further investigation.

1.4 Research Purposes

The aims of this study were to

- Investigate effects of sludge concentrations on hydrolysis and acidification under thermophilic condition, including the effects on volatile suspended solids (VSS) degradation, VFAs production and release of protein, carbohydrate, nitrogen (N), phosphorus (P) and microbial community structure.

2 Materials and Methods

2 Materials and Methods

- Waste activated sludge

The waste activated sludge was collected from a secondary settling tank of municipal wastewater treatment plant in Kunming, China.

Parameter	Concentration
SCOD	83 mg/L
TCOD	7400 mg/L
NH_4-N	16.7 mg/L
PO_4-P	0.51 mg/L
VSS	17.5 g/L
Soluble protein	236 mg/L
Carbohydrate	5.2 mg/L
pH	6.8

2 Materials and Methods

- Batch experiment

➢ 6 ASBRs: with 10, 15 and 20 g/L waste activated sludge (each concentration contained two parallel reactors). 250 mL sludge was decanted daily and meanwhile 250 mL fresh sludge was dosed into each reactor.

Analytical parameters

- VSS, SCOD
- NH_4-N, PO_4-P
- Soluble protein, Carbohydrate
- Microbial community structure

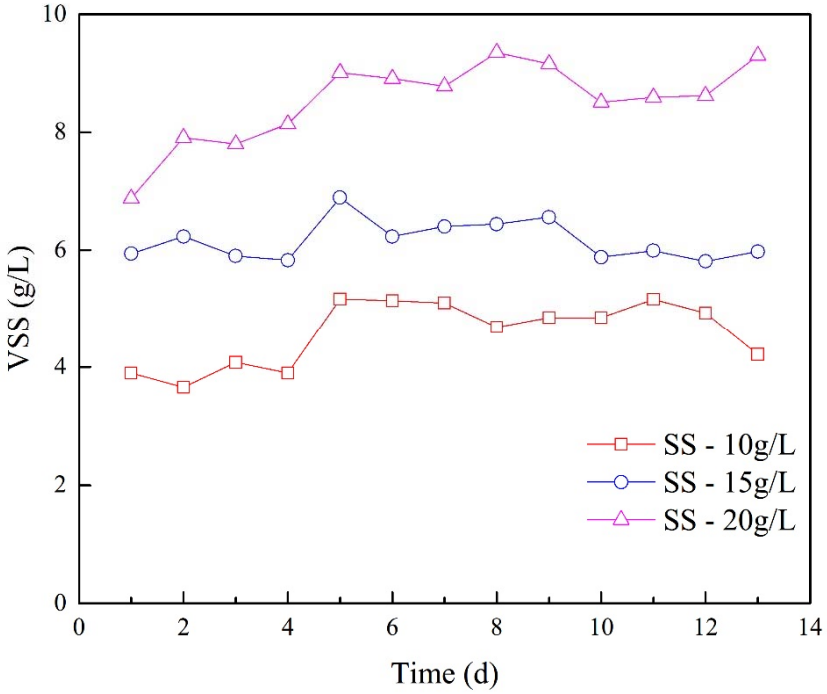
Operating conditions

Parameter	ASBR
Volume	500 mL
HRT	48 h
SRT	48 h
Rotate speed	150 r/min
Temperature	55℃

3 Results and Discussion

3.1 Hydrolysis

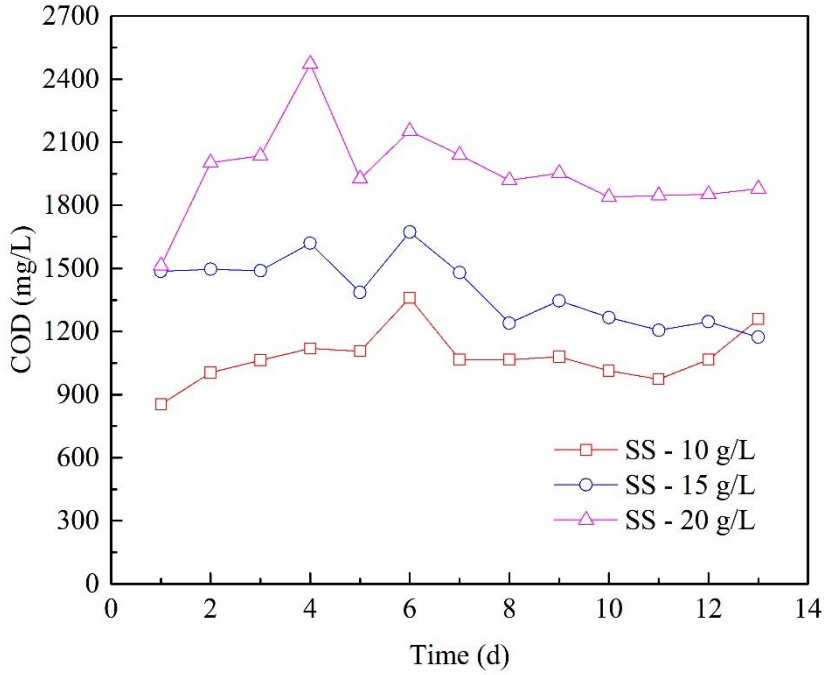
- Effect of sludge concentration on VSS removal



- The VSS removal percentage was 10.8%, 10.1% and 10.7% with sludge concentrations of 10 g/L, 15 g/L and 20 g/L, respectively.
- The VSS removal percentage was not affected by WAS concentrations.

3.1 Hydrolysis

- Effect of sludge concentration on SCOD release

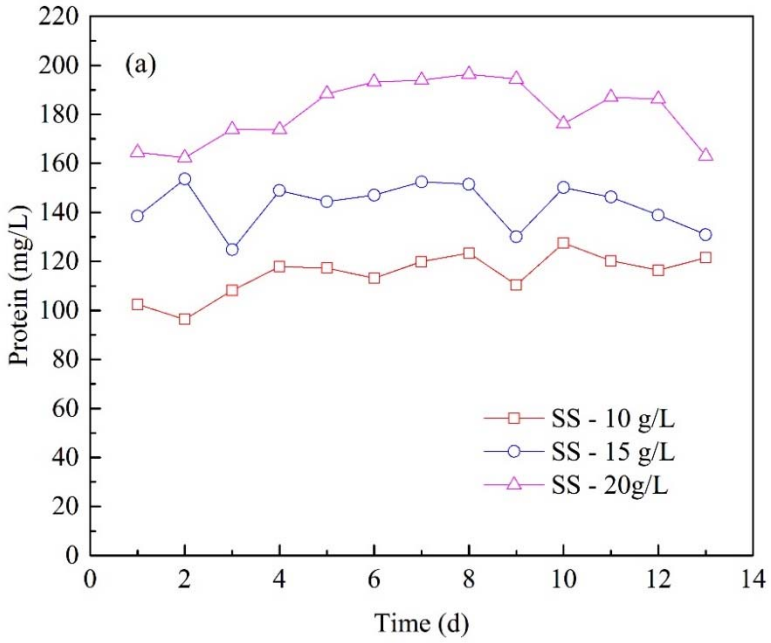


- The SCOD increased with increasing WAS concentrations.
- The highest specific yield of SCOD was obtained at 10 g/L, which was 23% and 21% higher than at 15 g/L and 20 g/L.

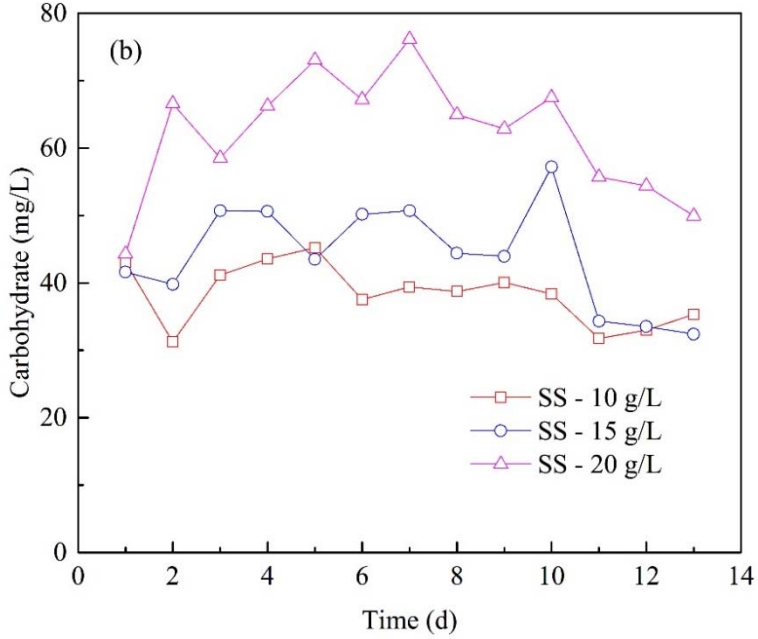
3.1 Hydrolysis

- Effect of sludge concentration on protein and carbohydrate

Protein



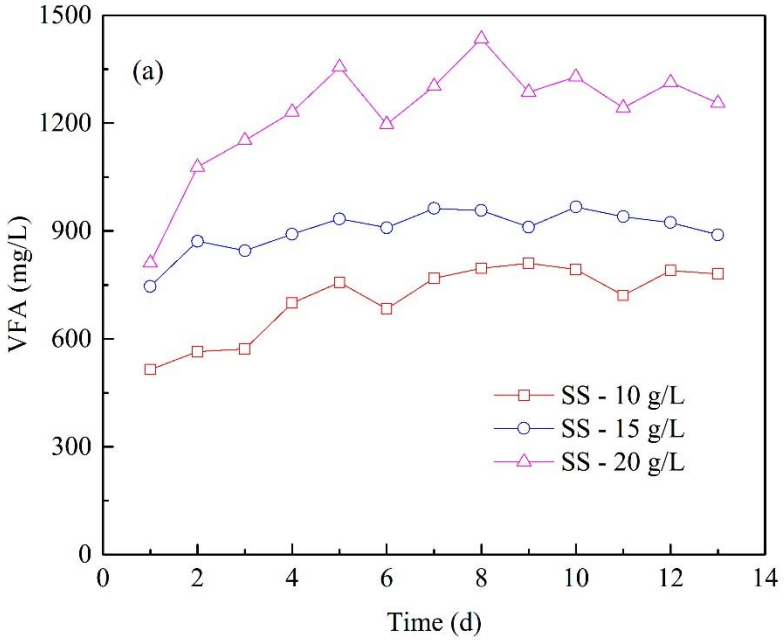
Carbohydrate

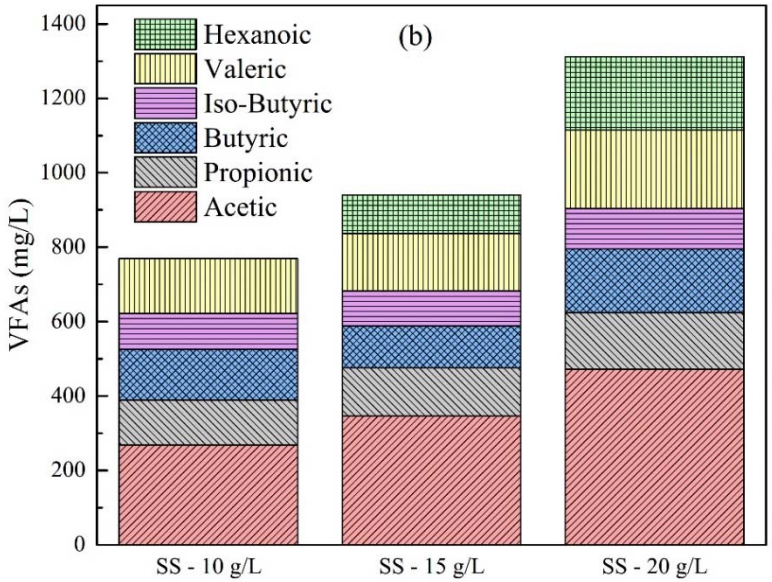


➢ Both protein and carbohydrate were increased with increasing sludge concentrations. When the sludge concentration increased from 10 g/L to 20 g/L, concentrations of soluble protein and carbohydrate increased by 55% and 84%, respectively.

3.2 Acidification

- Effect of sludge concentration on VFAs



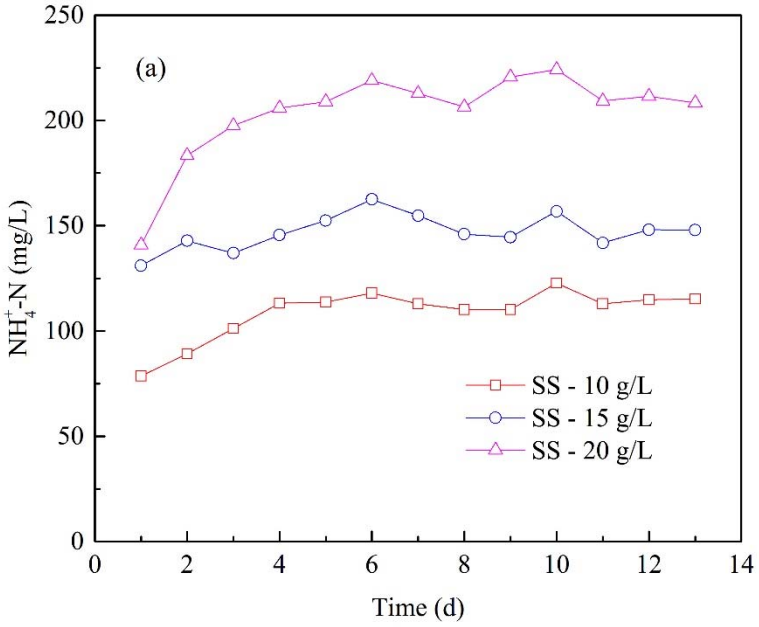


- The VFAs concentrations were consistent with sludge concentrations.
- Acetic acid was dominant among all VFAs, accounted for 35%, 41%, and 42% in reactor fed with 10 g/L, 15 g/L and 20 g/L sludge, respectively. Higher sludge concentration also increased the proportion of acetic acid.

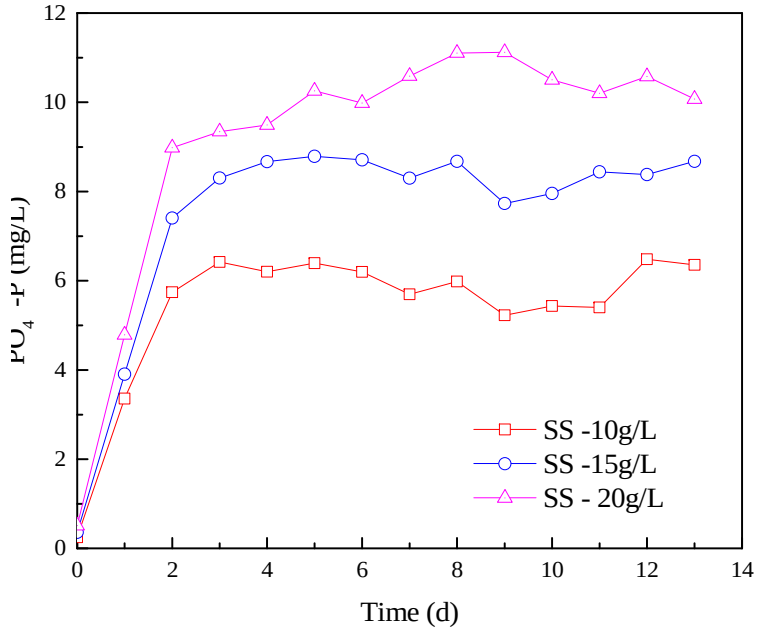
3.3 NH_4-N, PO_4-P

- Effect of sludge concentration on ammonia nitrogen and phosphate release

NH_4-N



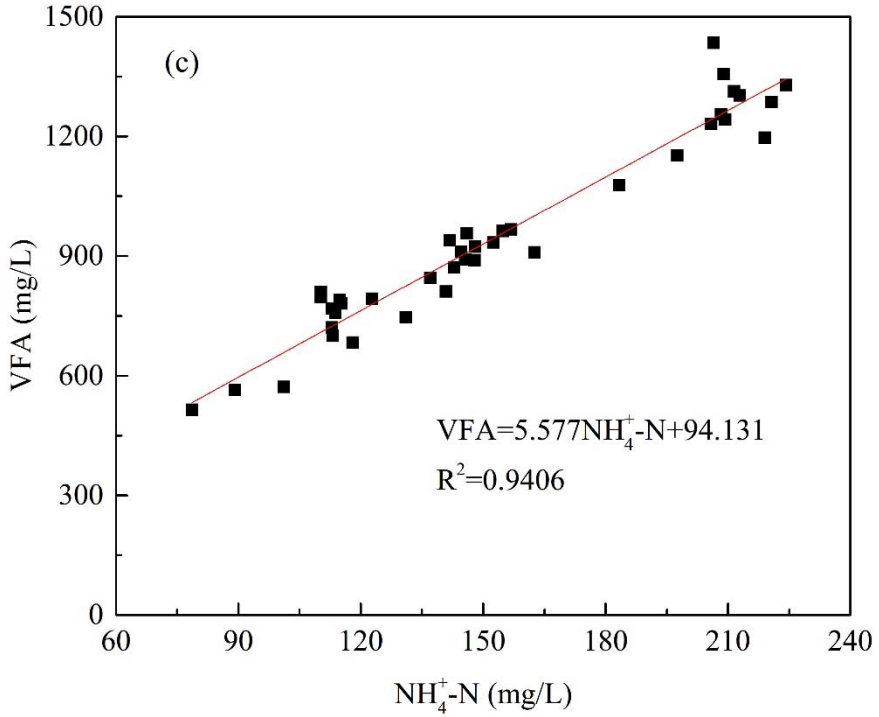
PO_4-P



- NH_4-N and PO_4-P release potential was consistent with WAS concentrations.
- By increasing sludge concentrations from 10 g/L to 20 g/L, concentration of NH_4-N and PO_4-P increased by 87% and 83%, respectively.

3.3 NH_4-N, PO_4-P

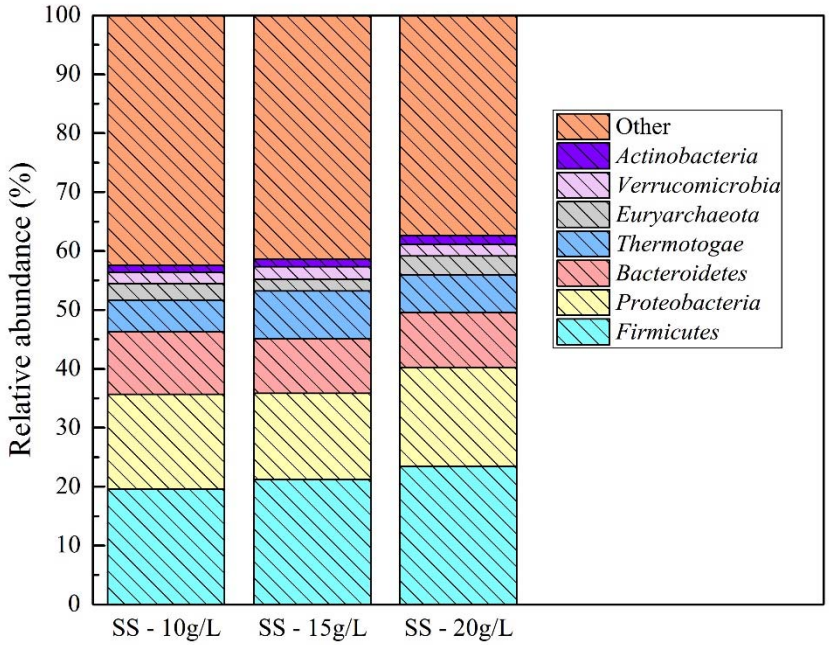
- Relationship between NH_4-N and VFAs



- Concentrations of NH_4-N and VFAs (Fig. 5c) had a good linear relationship (R^2=0.94), which might be used to reflect the acidification process.
- This might because protein was the dominating organic carbon in sludge, which released nitrogen during acidification.

3.4 Microbial community

- Effect of sludge concentration on microbial community structure



- *Firmicutes* was the most dominant phylum, whose relative abundance increased slightly with increasing sludge concentrations (from 19.6% to 23.5%).
- *Firmicutes* could metabolize substrates such as proteins, lipids, celluloses, sugars and amino acids under thermophilic condition.

4 Conclusions

4 Conclusions

- ## Conclusion

  - With a low organic carbon content, the performances of thermophilic hydrolysis and acidification were not affected by the WAS concentration.
  - Thermophiles were found in all reactors and at the phylum level, *Firmicutes* was the most dominant phylum in three reactors, responsible for the thermophilic fermentation.

- ## Potential application

  - Concentration of NH_4-N could be used to represent the acidification process under certain condition.
  - Other results in this study can be referred under certain practical thermophilic fermentation with a low organic carbon content.

Thank you!