IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

FeS-based autotrophic denitrification for removal of nutrients and emerging contaminants

Yang Bai

Civil Engineering,
College of Science and Engineering,
University of Galway

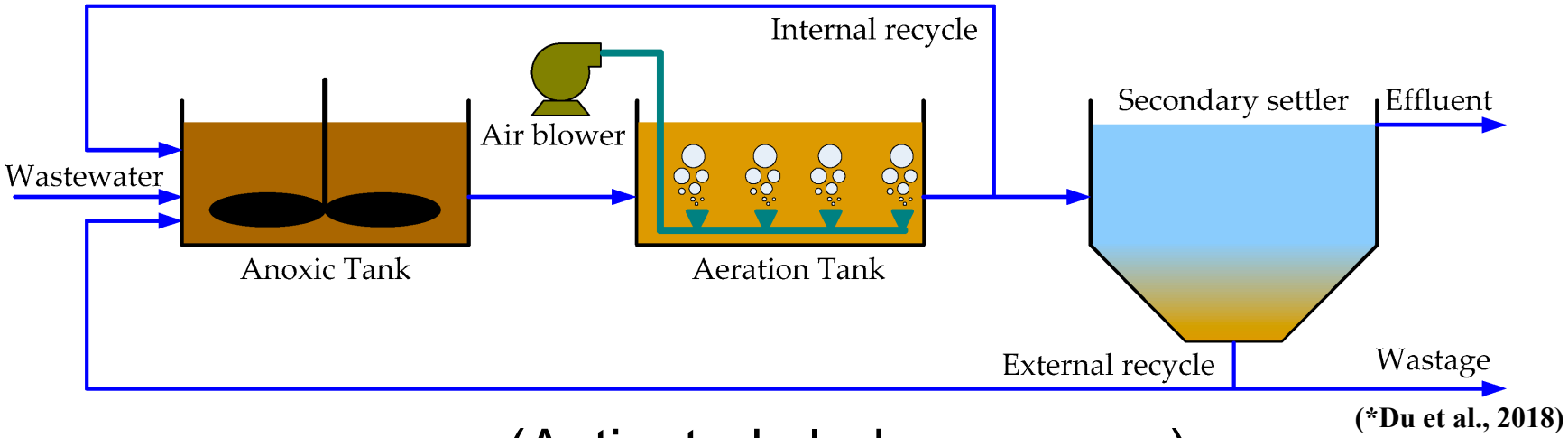
21 June 2023

Contents

1. Background

❑ Challenges facing existing wastewater treatment practices

(sustainability and low carbon footprint)



(*Du et al., 2018)

(Activated sludge process)

Energy-intensive

Chemicals-intensive

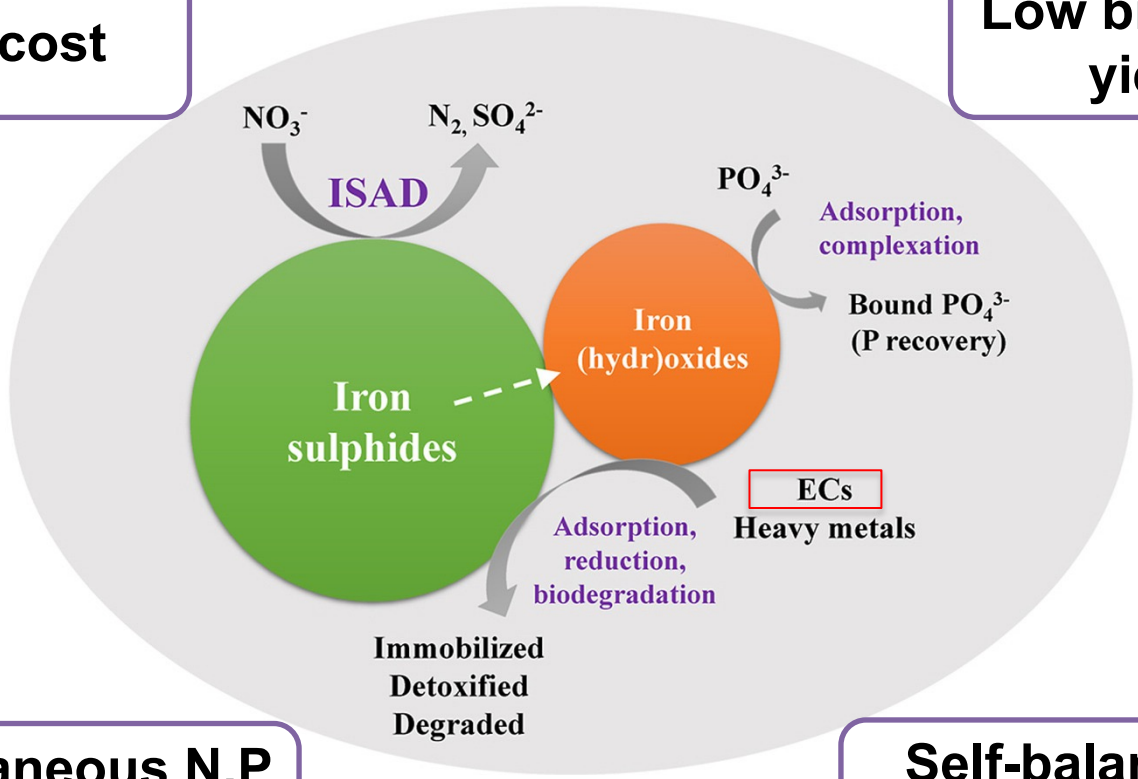
1. Background

❑ Iron sulfides-based autotrophic denitrification

(Advantage)

Low cost

Low biomass yield



(*Hu et al., 2021)

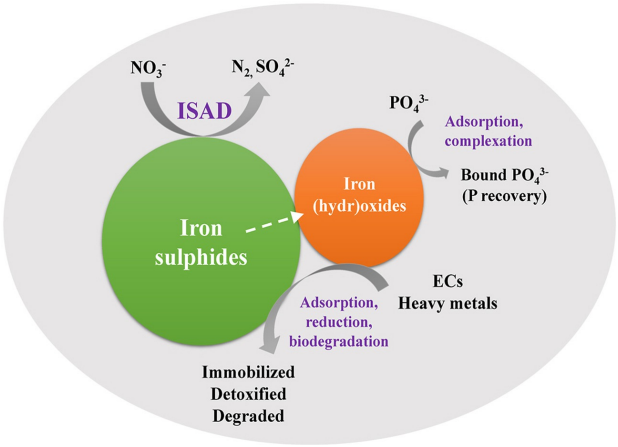
Simultaneous N,P removal

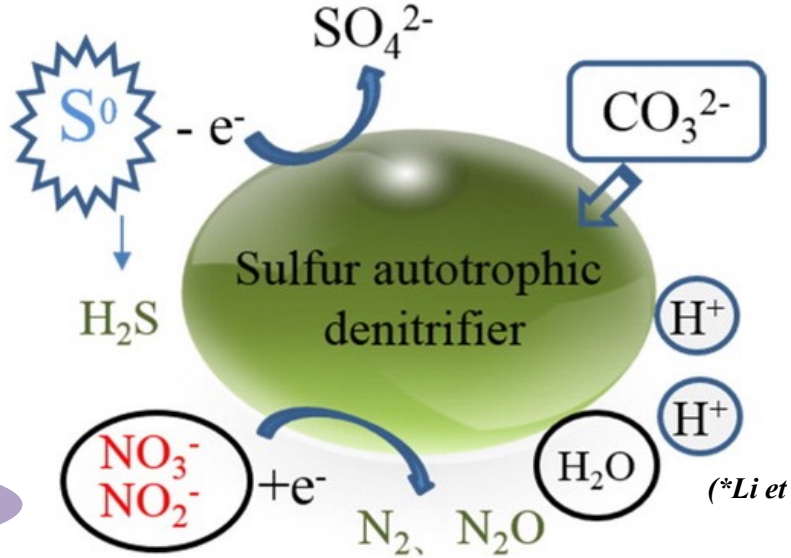
Self-balance of acidity-alkalinity

1. Background

❑ Iron sulfides-based autotrophic denitrification

(Limitation)





(*Li et al., 2016)

Denitrification rate

low

fast

$$5S^0 + 6NO_3^- + 2H_2O \rightarrow 5SO_4^{2-} + 3N_2 \uparrow + 4H^+$$

$$10FeS + 18NO_3^- + 16H_2O \rightarrow 10SO_4^{2-} + 9N_2 \uparrow + 2H^+ + 10Fe(OH)_3 \downarrow$$

$$5FeS_2 + 15NO_3^- + 10H_2O \rightarrow 10SO_4^{2-} + 7.5N_2 \uparrow + 5H^+ + 5Fe(OH)_3 \downarrow$$

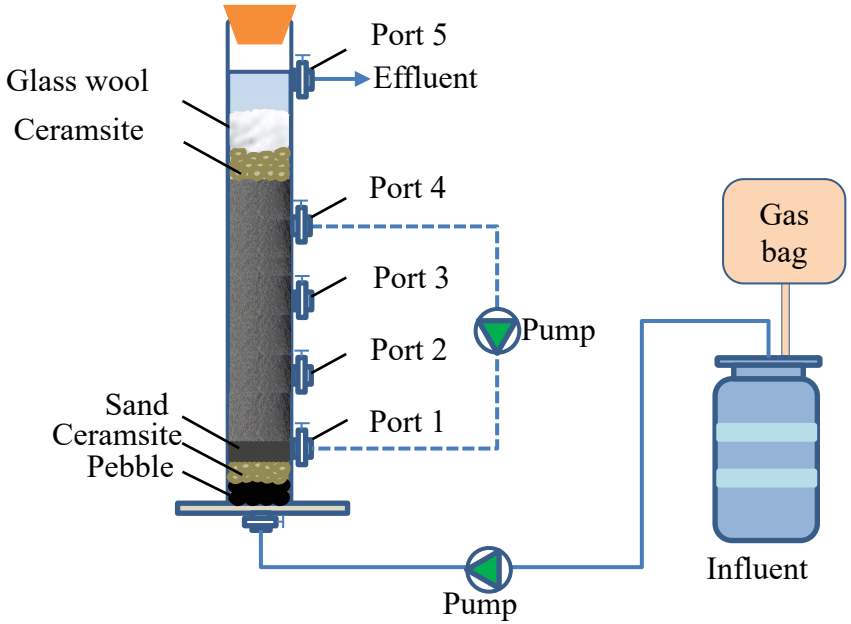
2. Objectives

- Explore the enhanced nutrients removal in a FeS and elemental sulfur (S^0) coupled system;
- Identify the microbial community compositions and functions in the coupled biofilter;
- Investigate the feasibility of simultaneous nutrients and tetracycline removal in the FeS-based autotrophic denitrification system.

3. Materials and methods

❑ Long-term column experiments

This process aims to explore the potential in the nitrate removal rate of the coupled biofilter with different N loading rates.



Schematic of the ISAD Biofilter

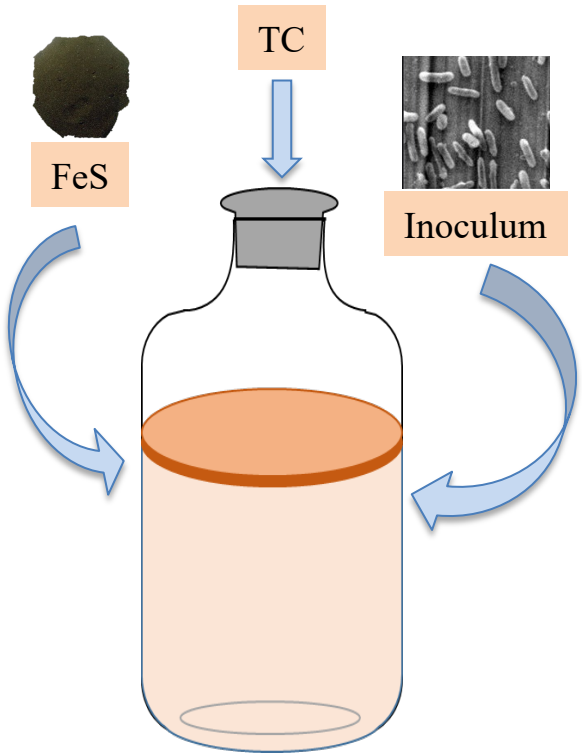
Operational conditions for the columns

Phase	I	II	III	IV	V	VI
Time (d)	1-119	120-158	159-215	216-241	242-261	262-281
HRT (h)	12	6	3	2	1	1
Influent NO_3^--N (mg/L)	50	40	40	40	40	15
N loading rate (mg/L/d)	100	160	320	480	960	360
Influent PO_4^{3-}-P (mg/L)	10	3	3	3	3	1.5

3. Materials and methods

❑ Batch experiments

This process aims to explore the feasibility of simultaneous removal of TC and nitrate in FeS-based autotrophic denitrification system.



Sulfur-oxidizing bacteria

↓

FeS powder

↓

Different dosages of TC solution

↓

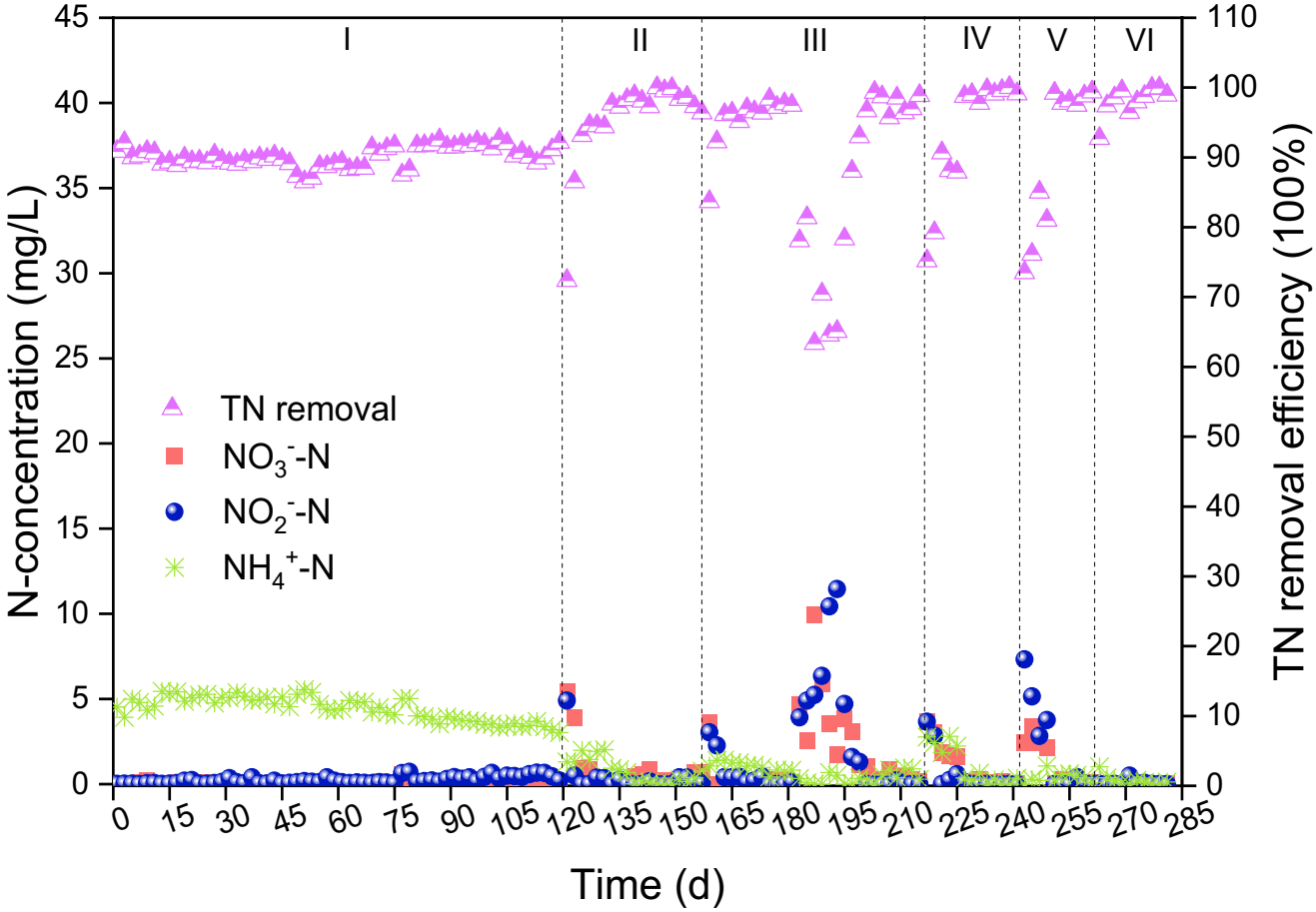
Stripping off the oxygen

↓

Sealing and taking samples at certain intervals

4. Results and discussion

❑ Nitrate removal in column experiment



TN removal efficiency>90%; Effluent NO_3^- concentrations <0.5 mg/L.

4. Results and discussion

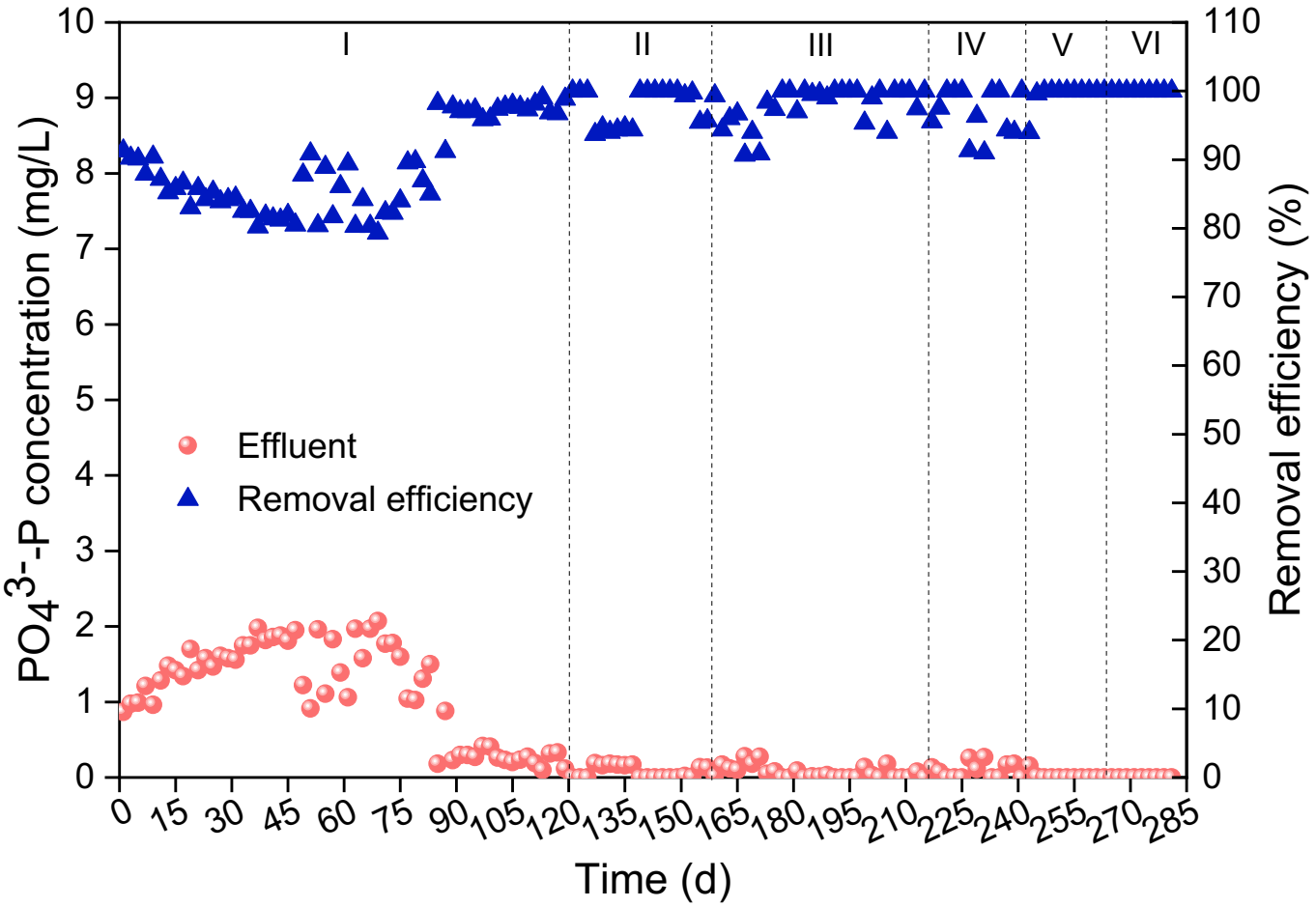
❑ Nitrate removal in column experiment

Electron donors	N removal rate (mg/L/d)	Influent NO_3^- (mg/L)	HRT(h)	Reference
Pyrrhotite	26.9	28.0	24	(Li et al. 2016)
Pyrrhotite	59.5	31.0	12	(Zhang et al. 2019)
Pyrite	-2.9~17.5	29.1~32.8	24	(Li et al. 2022)
Pyrite	59.5	15.0	6	(Wang et al. 2022b)
Pyrite and S^0	205.7	51.8	6	(Chen et al. 2022)
Pyrrhotite and S^0	123.6	31.5	6	(Li et al. 2020b)
Siderite and S^0	55.9	28.0	12	(Wang et al. 2019a)
Iron (II) carbonate and S^0	720.0	20.0	0.5	(Zhu et al. 2019)
FeS and S^0	960.0	40.0	1	This study

The coupled system achieved superior nitrate removal capacity at short HRT.

4. Results and discussion

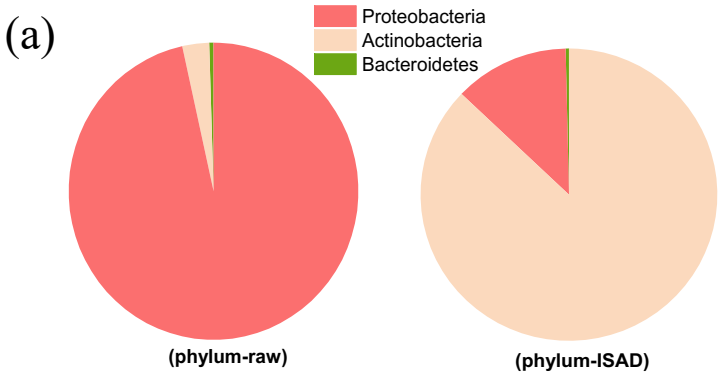
❑ Phosphorus removal in column experiment

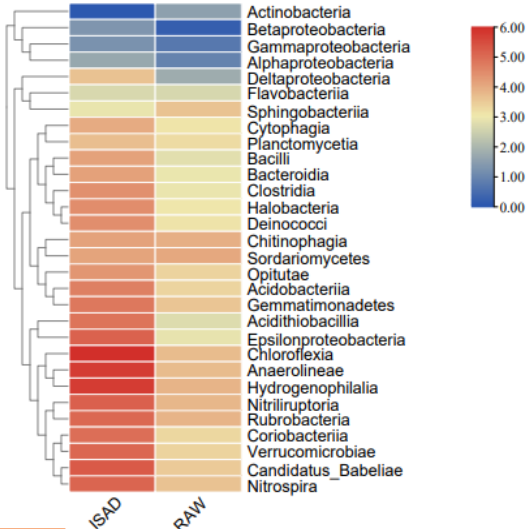


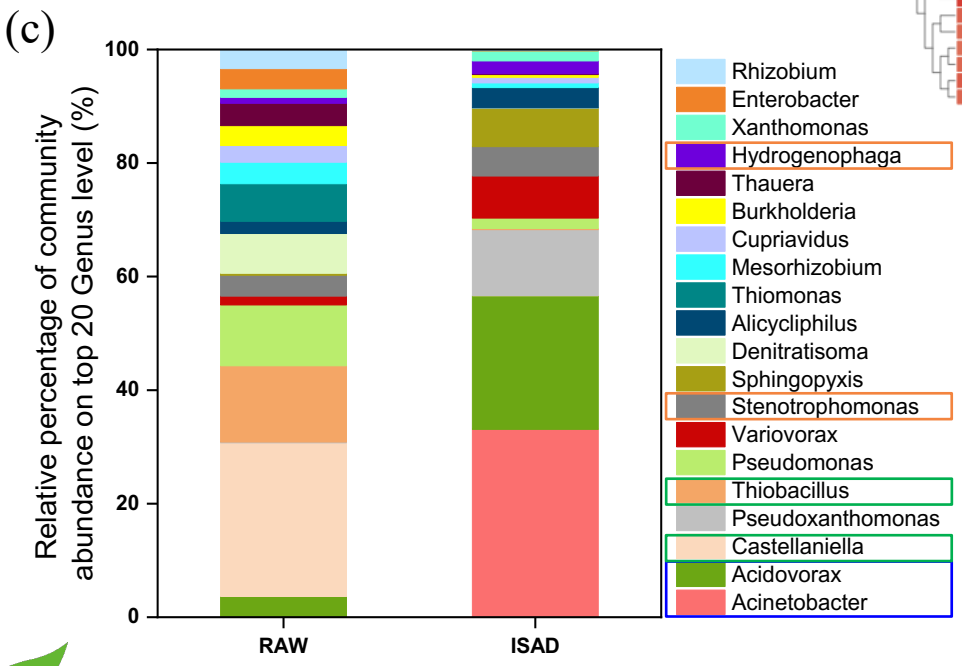
Effluent P concentrations < 0.05 mg/L, when influent P was 3 mg/L.

4. Results and discussion

❑ Microbial characterization





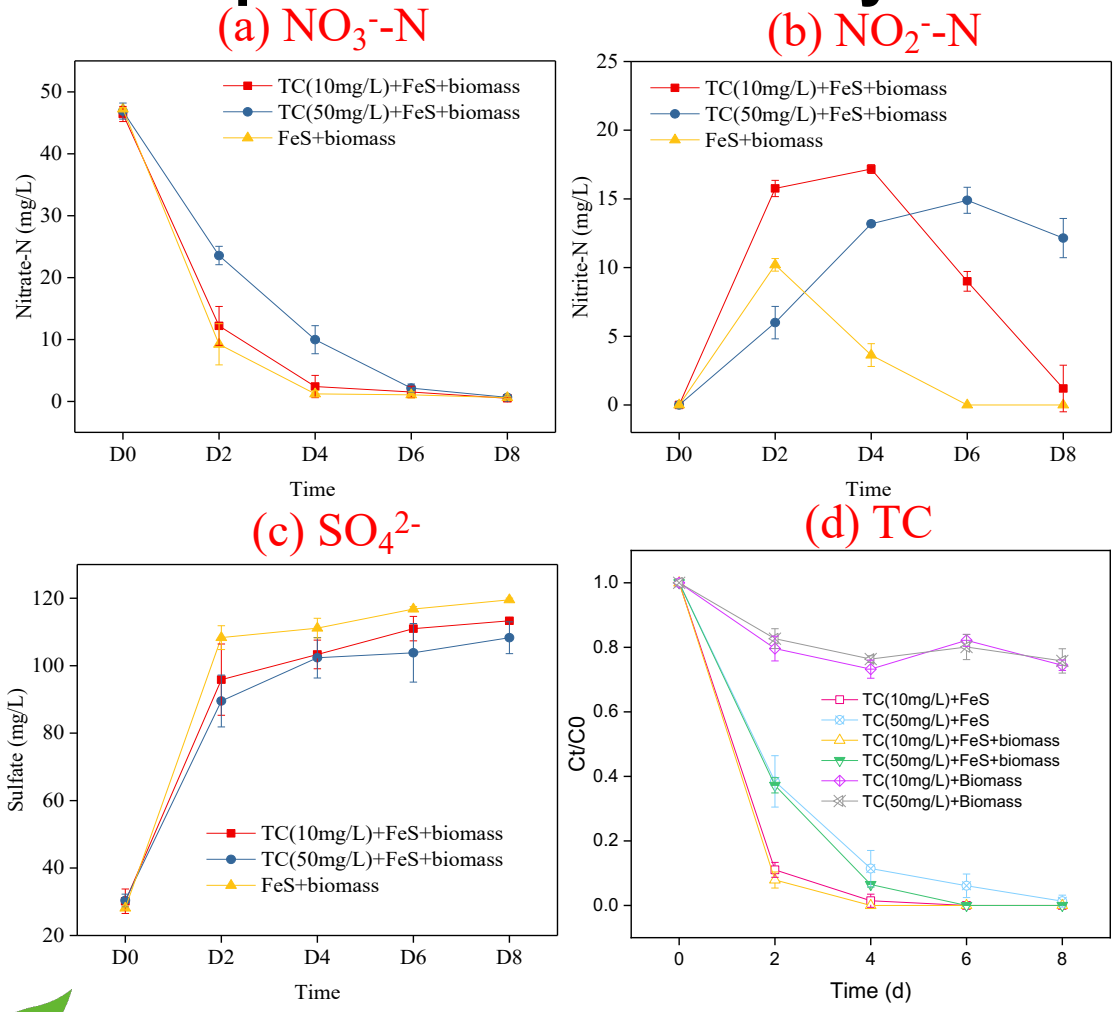


Sulfur-oxidizing bacteria (SOB), nitrate dependent iron oxidation (NDFO) bacteria, dissimilatory nitrate reduction to ammonia (DNRA) bacteria were characterized.

4. Results and discussion

OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

❑ Batch tests: Simultaneous TC and Nitrate removal in FeS autotrophic denitrification system



NO_3^- removal was slightly inhibited under high TC stress;

NO_2^- accumulated when TC was 50 mg/L;

Biomass accelerated TC removal.

5. Conclusions

- The addition of S^0 in FeS-based autotrophic denitrification biofilter achieved superior nitrate and phosphate removal performance.
- The superior nutrients removal performance in the coupled system was due to a collaborative microbial community.
- The simultaneous TC and nutrients removal was feasible in FeS-based autotrophic denitrification system under high TC stress.

Acknowledgement

Thanks to Hardiman Scholarship and Irish Research Council for their funding!

Ollscoil na Gaillimhe
University of Galway

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn