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THE ROLE OF SULFUR-DRIVEN AUTOTROPHIC DENITRIFICATION IN SUSTAINABLE WASTEWATER TREATMENT

The University of Auckland

water NEW ZEALAND CONFERENCE & EXPO
17–19 OCTOBER 2023
Tākina, Te Whanganui-a-Tara Wellington

Presenter Introduction

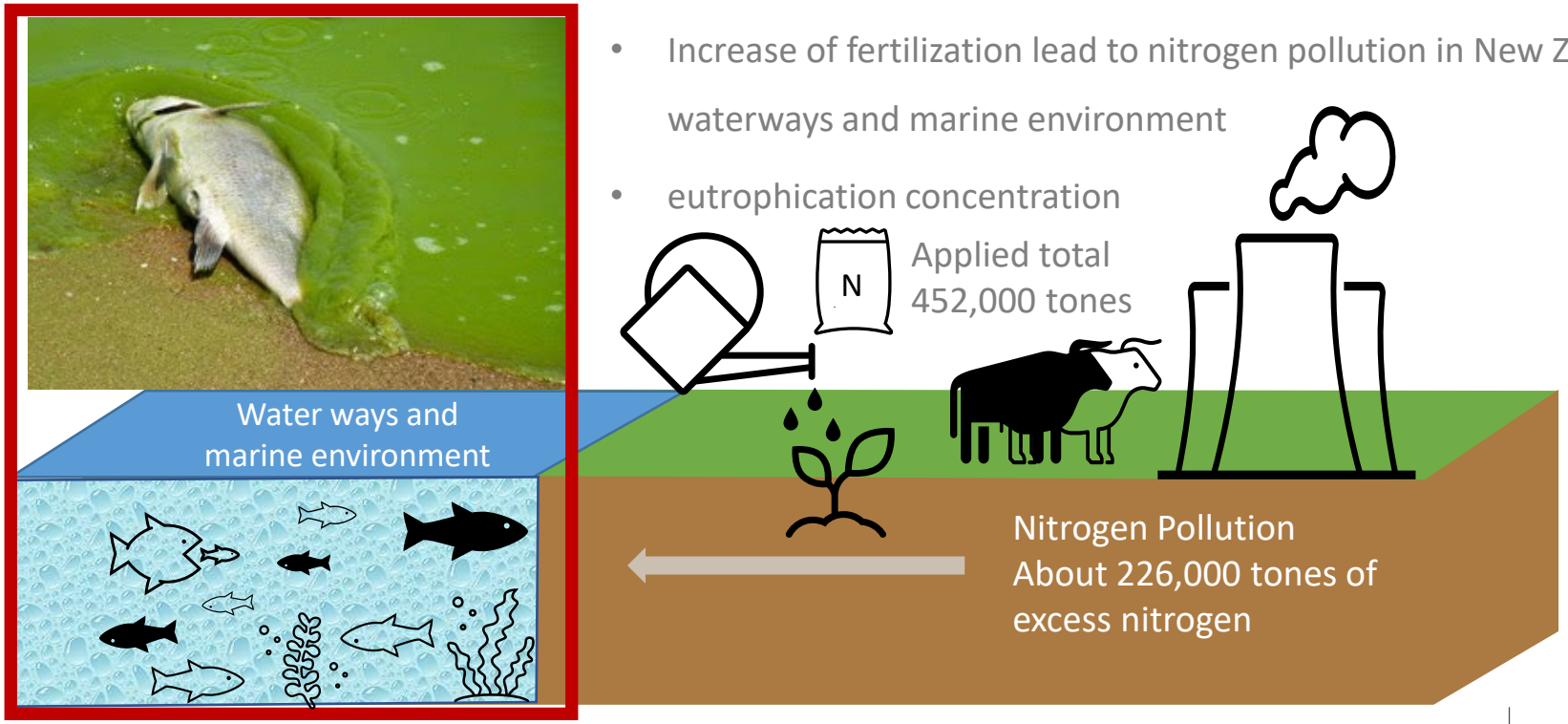
Three Waters Engineer:

Wastewater, Water and Stormwater

01

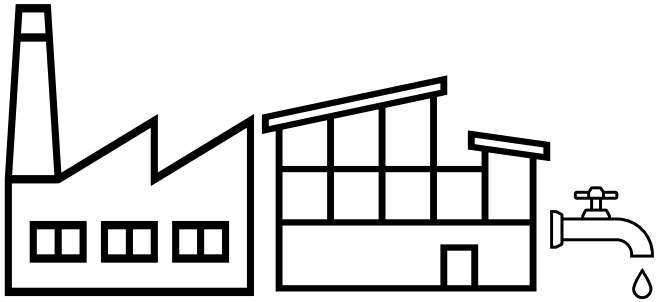
Introduction and Background

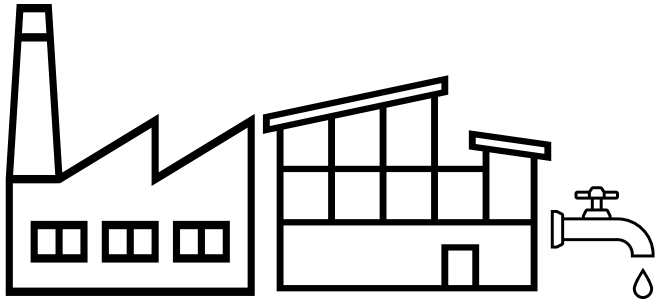
The Importance of Nitrogen Removal



- Increase of fertilization lead to nitrogen pollution in New Zealand waterways and marine environment
- eutrophication concentration

Conventional VS Autotrophic Denitrification





$ +

External Carbon source

+

Heterotrophic bacteria

Autotrophic bacteria

+

Use inorganic compounds S^0 or FeS

Use CO_2

CO_2 and N_2O production

Higher sludge production

Finicky with low C:N wastewater

No N_2O production

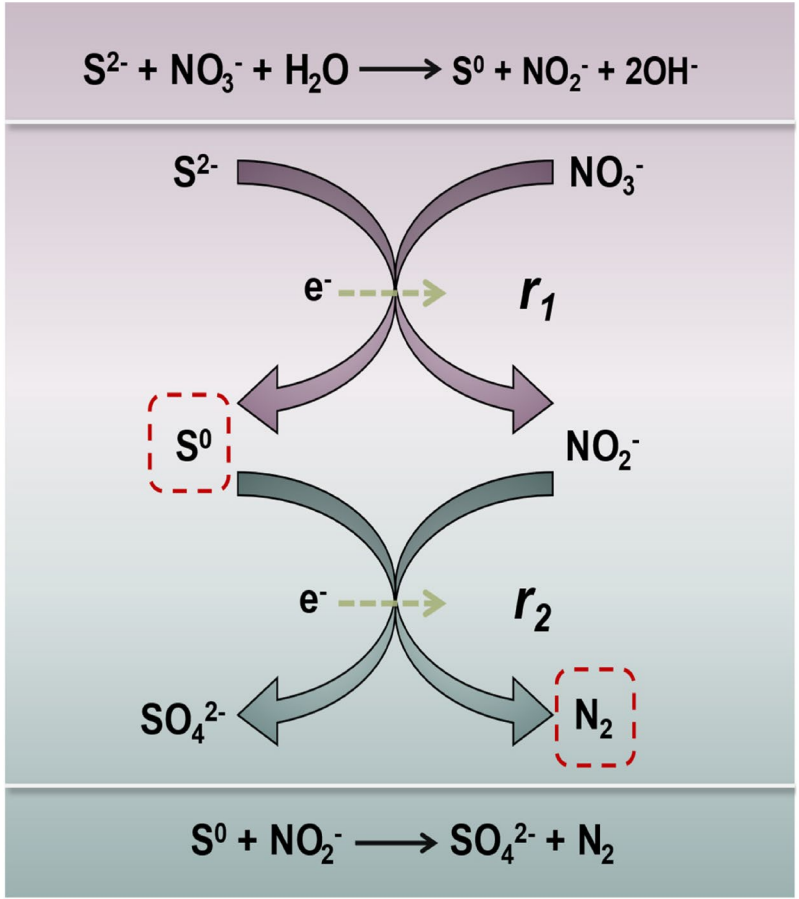
Lower sludge production (carbon footprint)

Suitable for low C:N wastewater

The selection of electron donors

1. Hydrogen gas H_2
2. Reduced inorganic sulfur compounds (S^0, FeS)

- Common and abundant in the environment
- Safe
- Low cost



Zhang, Q., et al. (2022). "Recent Advances in Autotrophic Biological Nitrogen Removal for Low Carbon Wastewater: A Review." Water **14**(7): 1101.

Challenge in Sulfur-driven Autotrophic Denitrification (SdAD)

- Proton generation, reduce pH and alkalinity consumption
- pH inhibition occurred below pH 6.
- Low-cost, low carbon footprint pH buffers need to be explored.

$$S + \mathbf{0.876}\ \boldsymbol{NO_3^-} + 0.343\ H_2O + 0.023\ CO_2 + 0.08\ NH_4^+ + 0.379\ HCO_3^-$$
$$= 0.08\ C_5H_7O_2N + 0.44\ N_2 + SO_4^{2-} + \mathbf{0.824}\ \boldsymbol{H^+}$$

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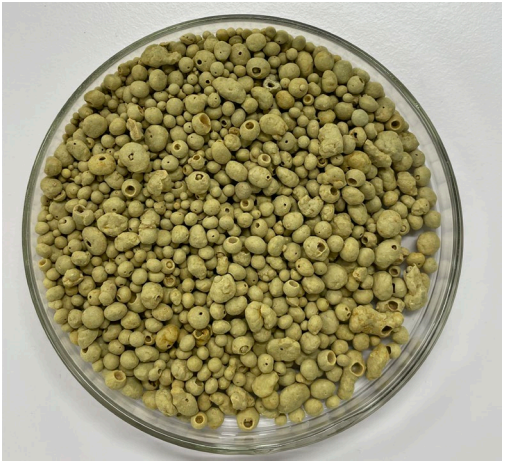
Materials and Methods
Methods

Innovative pH Buffering Materials

New Zealand Green-lipped mussels' shell (GLP)



Sulfur composite (S^0 + $FeCO_3$) granular packing media material

Assessing the performance and efficiency of insoluble chemicals as pH buffers.

Batch Tests:

- Collection of return activated sludge (RAS) samples from Mangere WWTP, Rosedale WWTP and Army and Army Bay WWTP.
- Nine bottle were setup use of different pH buffers.

NO.	WWTP Sludge	pH buffer	Note
RD 1	Rosedale	$NaHCO_3$	control reactor with a soluble alkalinity
RD 2	Rosedale	mussels shell	Sustainable alkalinity
RD 3	Rosedale	sulfur composite granular packing media material	(S^0-Composite)
MG 1	Mangere	$NaHCO_3$	control reactor with a soluble alkalinity
MG 2	Mangere	mussels shell	Sustainable alkalinity
MG 3	Mangere	sulfur composite granular packing media material	(S^0-Composite)
AB 1	Army Bay	$NaHCO_3$	control reactor with a soluble alkalinity
AB 2	Army Bay	mussels shell	Sustainable alkalinity
AB 3	Army Bay	sulfur composite granular packing media material	(S^0-Composite)

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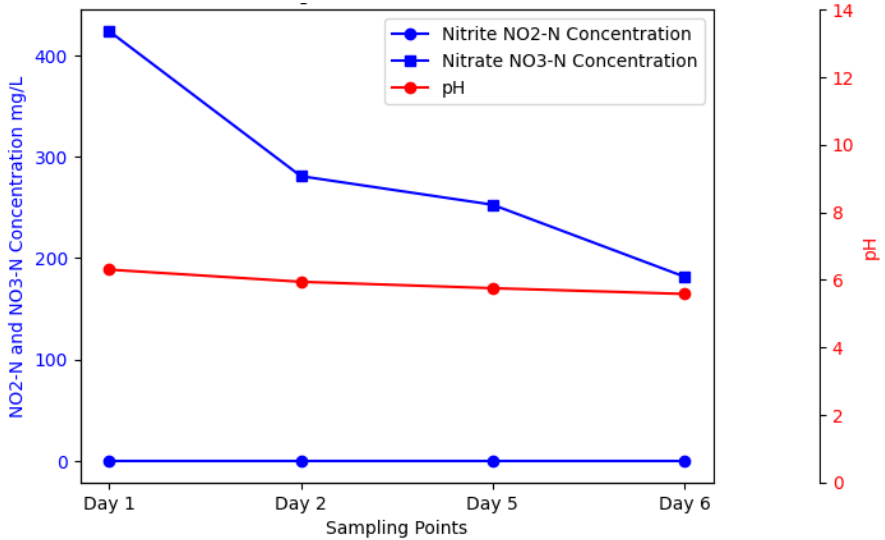
Results and Discussion

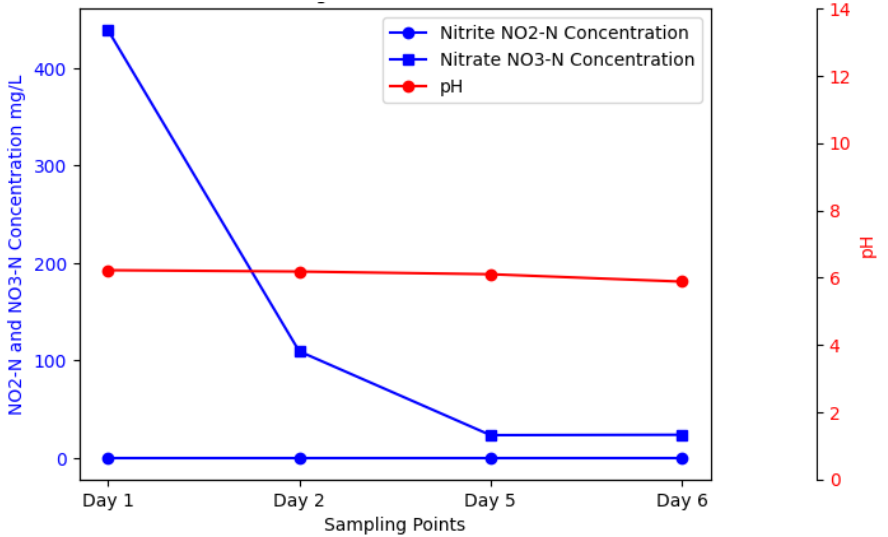
Ubiquity of Sulfur-Driven Autotrophic Denitrifying Bacteria

- SdAD happened in all three WWTPs.
- No acclimatization needed.
- New SdAD treatment units in the future can be self-seeded.

	average NO_3-N removal rates (mg/L·d) within the first 24-hr incubation	pH on Day 1 ($NaHCO_3$)
MG	143	6.30
RD	1,073	6.63
AB	419	6.49

Sustainable Insoluble Buffer – NZ Green-lipped Mussels

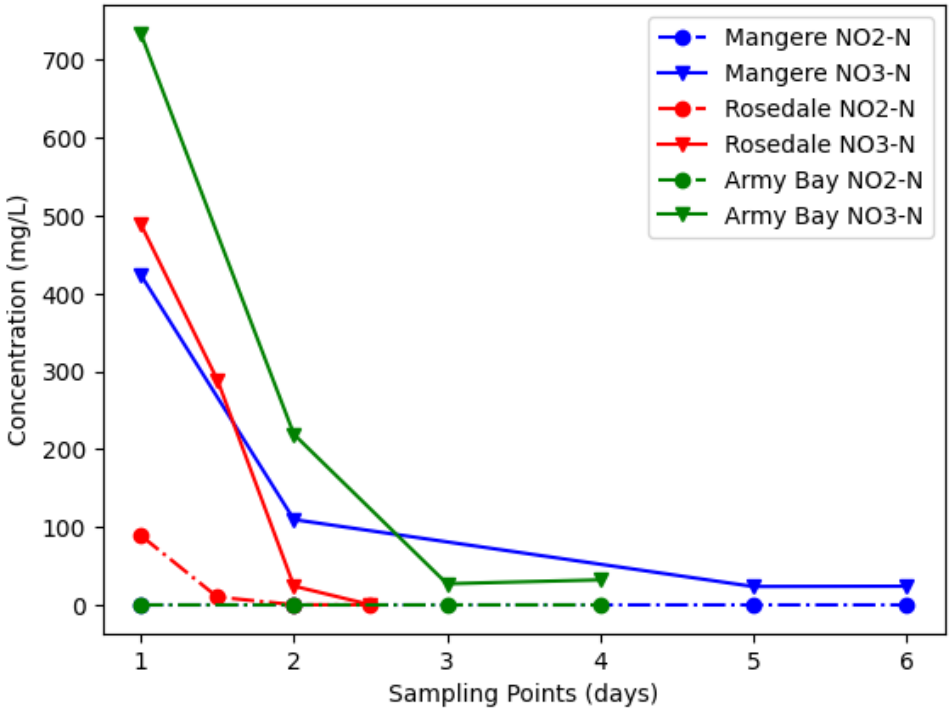




Denitrification test results using Mangere WWTP sludge and **$NaHCO_3$** as pH buffer.

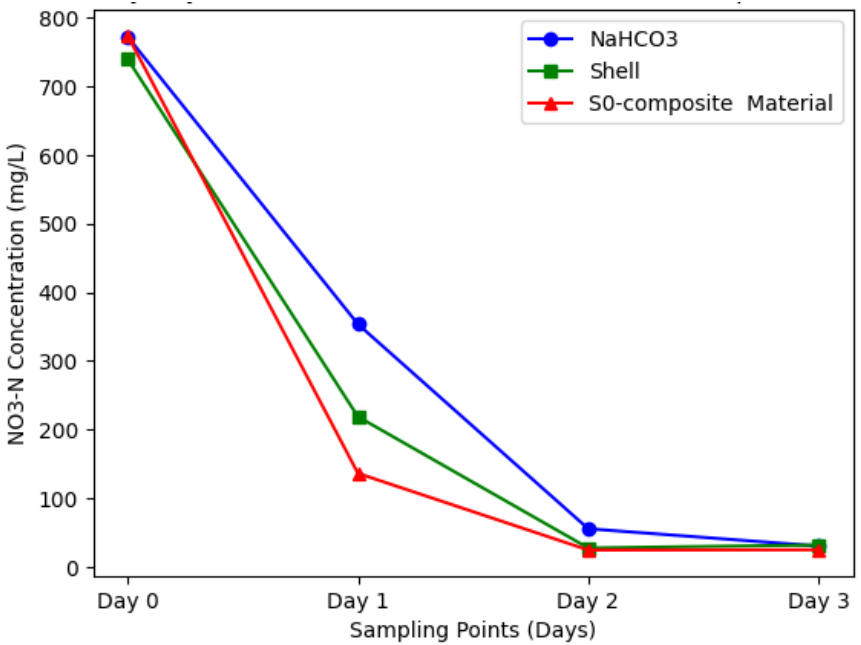
Denitrification test results using Mangere WWTP sludge and **GLM** as a pH buffer.

Sustainable Insoluble Buffer – NZ Green-lipped Mussels



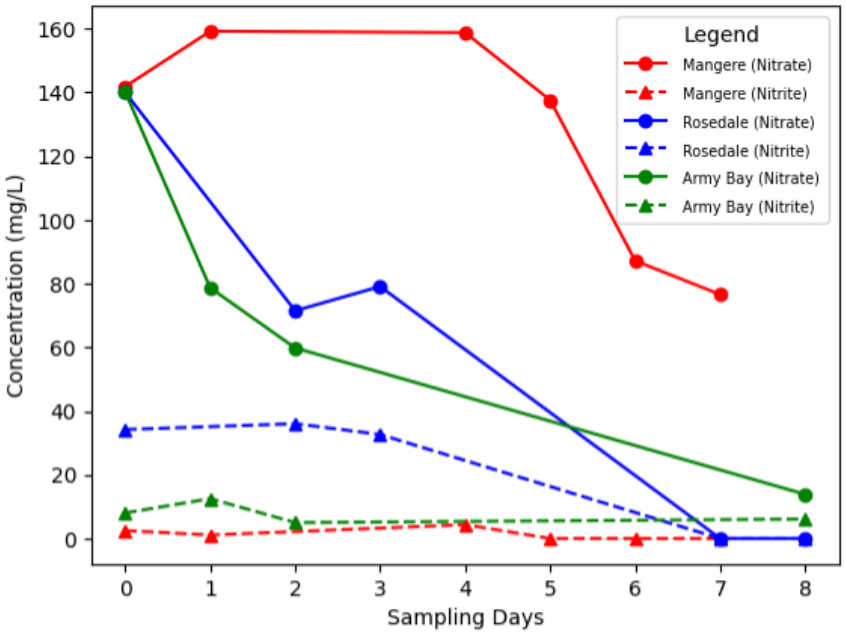
- Denitrification performance with different WWTP sludges and GLS as the sustainable pH buffer.
- **30,000 tones** shells can be reused and save **5 million NZD** per year.

Sulfur Composite Media

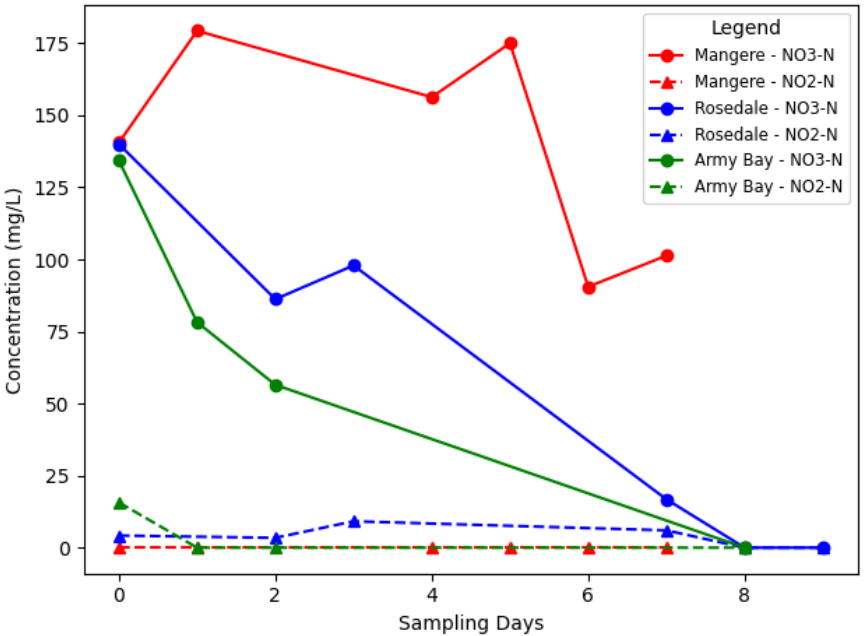


Nitrate concentrations using Army Bay WWTP sludge with buffer of $NaHCO_3$, shell and the sulfur composite granular packing media material.

Denitrification Performance with High Salinity (3%)

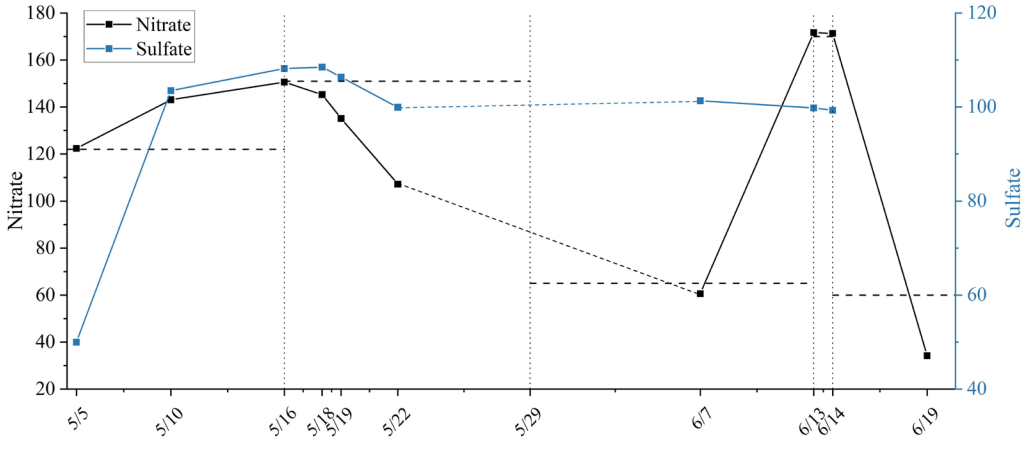


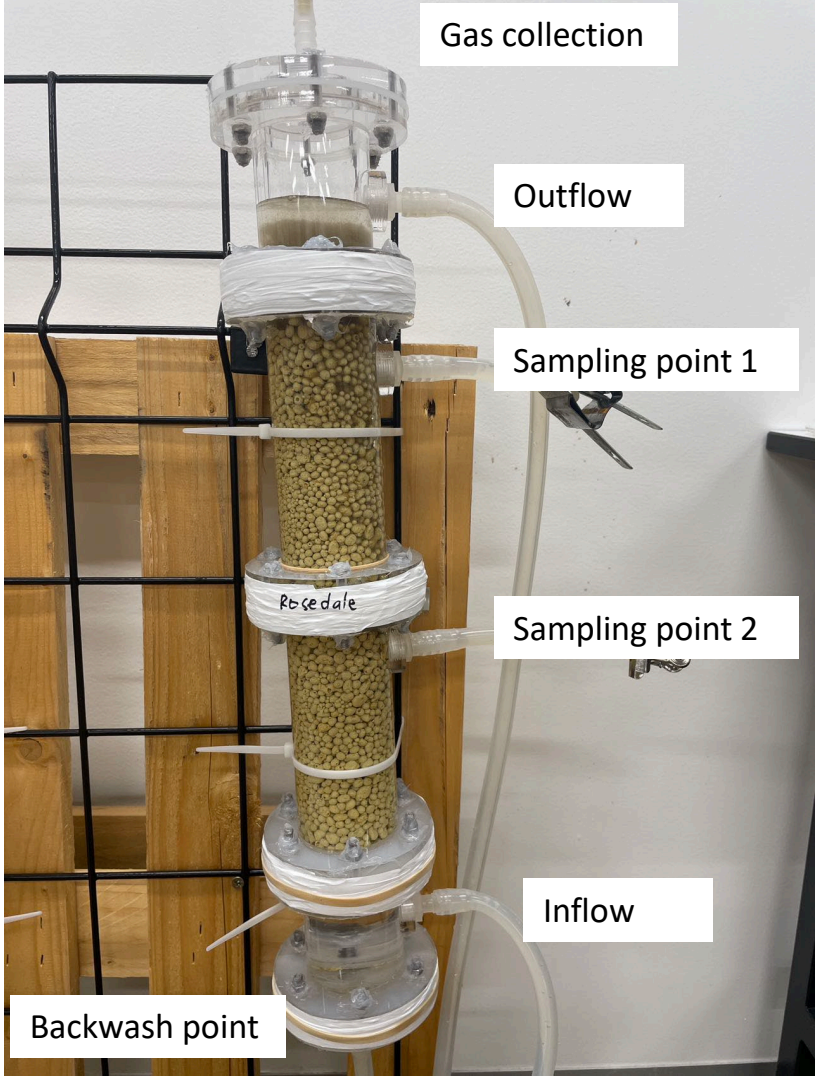
Mussel Shell buffer systems and their respective nitrate, nitrite concentrations for three WWTPs.



S_0-composite systems and their respective nitrate, nitrite concentrations for three WWTPs.

Continuous Up-Flow Packed-Bed (UFPB) Reactor





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Conclusions

- Effectiveness of pH buffers in SdAD. SdAD.
- Green-lipped mussel shells and sulfur composite granular packing media sustainable alternative.
- Widely present sulfur-driven autotrophic denitrifiers in WWTPs.

Acknowledgments

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THE END

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