Fe-modified Biochar Enhances Microbial Nitrogen Removal Capability of Constructed Wetland

Yicheng Yang[1], Wen Jia[2], Yulin Zheng[1], Jinsheng Huang[1], Yue Zhang[1], Bin Gao[1,*]

1. Department of Agricultural and Biological Engineering, University of Florida, Gainesville, Florida, USA

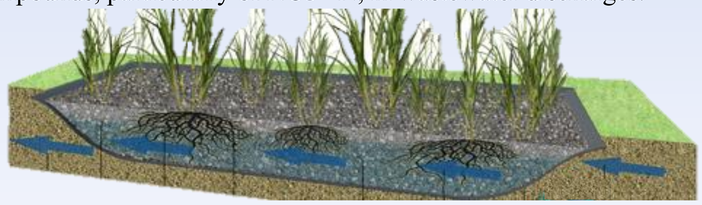
2. State Key Laboratory of Pollution Control and Resource Reuse, School of the Environment, Nanjing University, Nanjing, China

Background

Water pollution, especially harmful algal blooms (HABs), caused by excessive input of nutrients is a serious problem worldwide. Nitrogen (N) compounds, such as ammonium ($NH4^+$) and nitrate ($NO3^-$), are the most widespread water contaminants. Given that NH4+-N is efficiently removed by the nitrification process employed in the wastewater treatment plants (WWTPs), **NO3−-N** is the dominant N form in the tailwater from WWTPs, which usually contains a relatively high total N (TN) concentration. An elevated **$NO3^-$-N** concentration can compromise water ecosystems, posing risks to both aquatic life and human health. Therefore, further treatment of tailwater from WWTP is required.

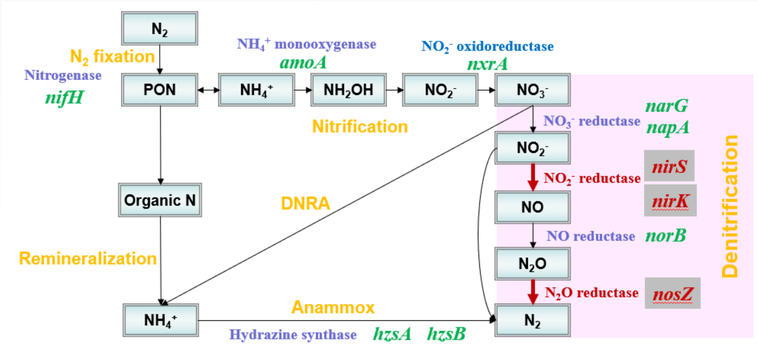
Constructed Wetland

Constructed wetlands (CWs) has been proven as an effective technique for treating wastewater, which is also used widely around the world due to their simple operation, low cost, and low energy consumption.
With the restricted oxygen transportation as a prominent characteristic, horizontal subsurface flow constructed wetlands (HSCWs) present a promising approach to further reduce the levels of nitrogenous compounds, particularly of $NO3^-$-N, in wastewater discharges.

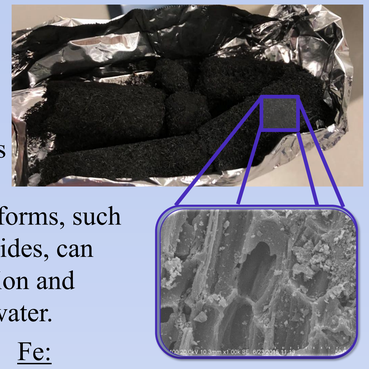


Microorganisms & N Cycles

Microorganisms are the driving pump for N transformation and removal inside the CWs. Only **denitrification** and **anammox** are considered as permanent N removal pathways.



Fe-Modified Biochar



Biochar is a carbon-rich solid produced upon pyrolysis of organic plant and animal materials at high-temperature in a low- or no-oxygen environment. It can remove pollutants due to several unique properties.

Fe in different valence and chemical forms, such as zero-valent iron, Fe^{2+}/Fe^{3+}, iron oxides, can facilitate the nitrification, denitrification and anammox for N removal from wastewater.

Biochar:
- High specific surface area
- Micropore volume
- Activated by HCl, electrostatic adsorption of anion, such as $NO3^-$-N

Fe:
- Reactive element for N cycles
- Facilitate the denitrification
- Facilitate the anammox

Fe-modified biochar (FeB) has a substantial potential to improve the performance of CWs on N removal.

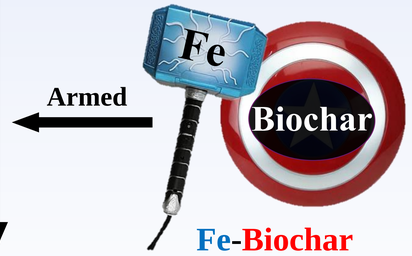
Mechanism

N-Removal Bacteria

Remove N

Bare Hands

Beaten by Environmental Stresses



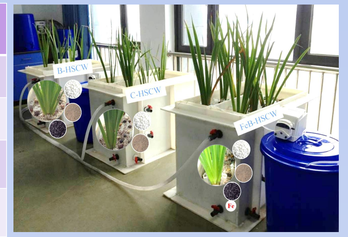
Biochar & Fe

Captain N-Removal Bacteria

Endgame

Experiment

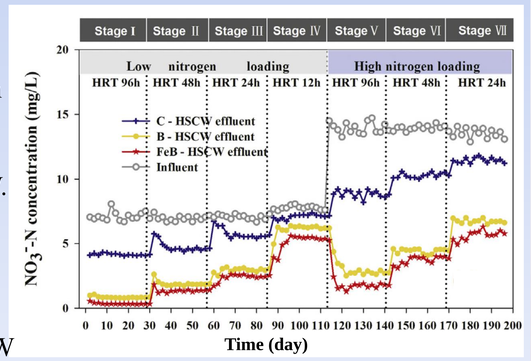
Components	C-HSCW	B-HSCW	FeB-HSCW
quartz sand	X	X	X
soil	X	X	X
unmodified biochar		X	
Fe-modified biochar			X



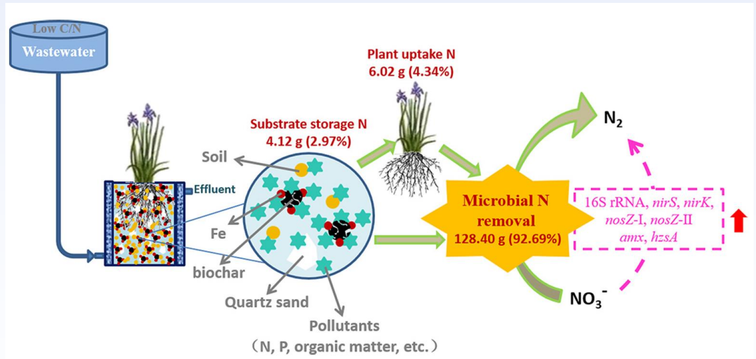
N Loading: **low** (8.561–10.618 mg/L) | **high** (16.932–18.774 mg/L)
Hydraulic Retention Time (HRT): **96h | 48h | 24h | 12h**

Results

The $NO3^-$-N removal rate in FeB-HSCW reached **95.30%** which was 2.24- and 1.07-fold higher than those in the C-HSCW and B-HSCW. Although the $NO3^-$-N removal decreased with the HRT reduced and N loading increased in HSCWs, the FeB-HSCW always maintained the highest $NO3^-$-N removal in the three HSCWs



Discussion



Conclusion

FeB-HSCW was an extremely effective system to remove N from the wastewater under different combinations of HRT and N loading, compared to the C-HSCW and B-HSCW.