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

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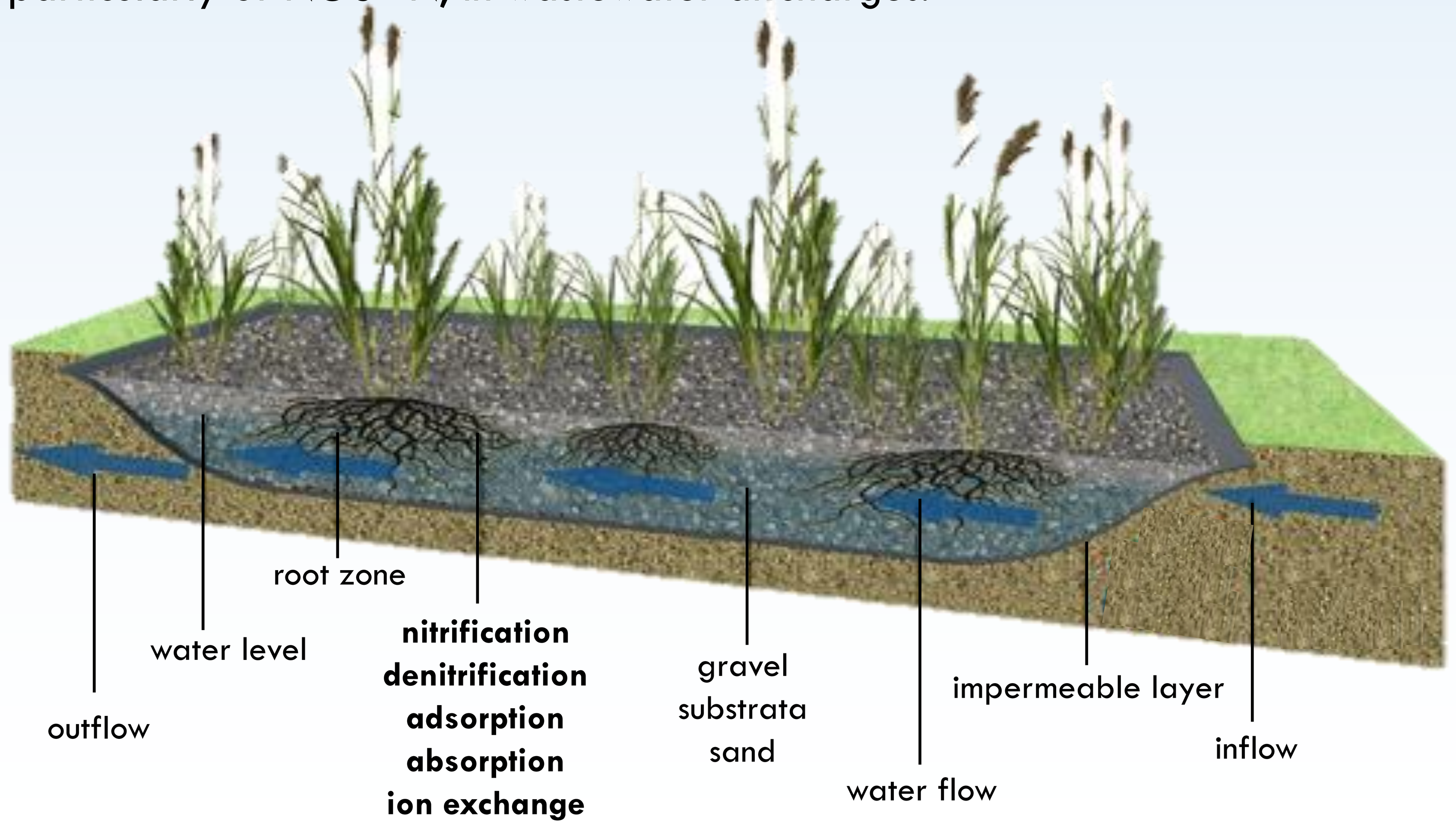
## Background

Water pollution, especially harmful algal blooms (HABs), caused by excessive input of nutrients is a serious problem worldwide. Nitrogen (N) compounds, such as nitrate ($NO_3^-$) ions, are the most widespread water contaminants. Florida is famous for its large and diverse agricultural industry, which could discharge nitrate by stormwater into the environment unintentionally after storms. Meanwhile, as Florida population increases, the construction of living buildings has changed the natural landscapes into communities with impervious surfaces, causing more and more nitrate-containing unmanaged urban stormwater. An elevated $NO_3^-$ concentration can compromise water ecosystems, posing risks to both aquatic life and human health. Therefore, further treatment of these $NO_3^-$ containing stormwater is required.

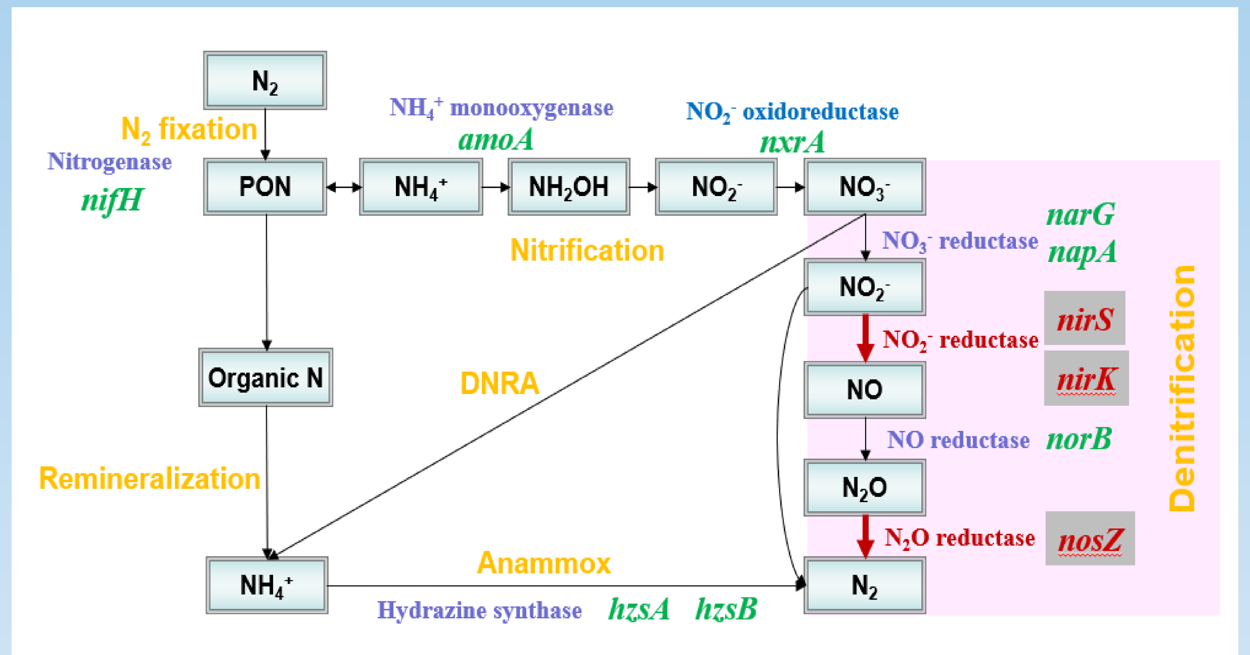
## Constructed Wetland

**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 $NO_3^-$-N, in wastewater discharges.

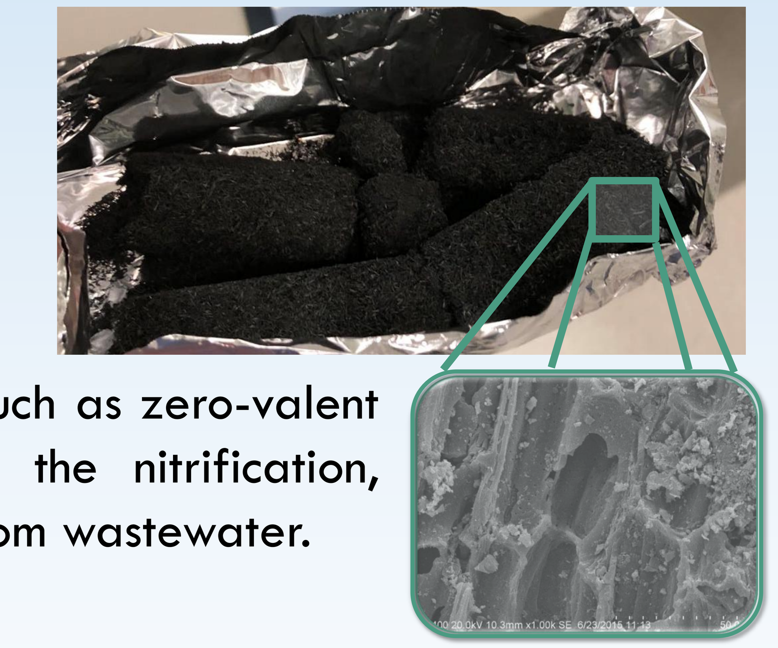



## Microorganisms & N Cycles

Microorganisms are the driving pump for N transformation and removal inside the CWs. The microbial processes include N fixation, mineralization, nitrification, denitrification, anaerobic ammonium oxidation (anammox), dissimilatory nitrate reduction, among others. Only **denitrification** and **anammox** are considered as permanent N removal pathways. Denitrifying bacteria constitute a large physiological group. Nitrite reductase genes (*nirS* and *nirK*) and nitrous oxide reductase gene (*nosZ*) are used as functional markers to investigate the denitrification process. The information about the anammox bacteria in CWs is rather limited, although CWs are assumed to offer favorable conditions for anammox.




## 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
- Nutrient retention
- Provision of labile carbon
- Activated by HCl, electrostatic adsorption of anion, such as $NO_3^-$-N
- Carbon as electron donor

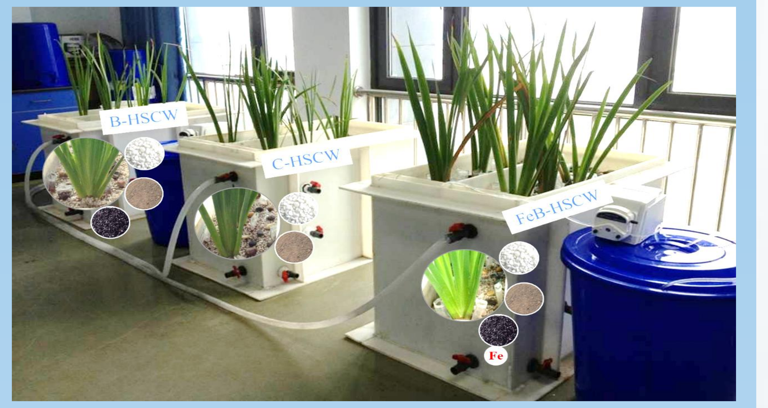
Fe:

- Reactive element for N cycles
- Facilitate the denitrification
- Facilitate the anammox
- Iron (hydr)oxides affinity toward oxy-anion ions, such as $NO_3^-$-N

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

## Experiment

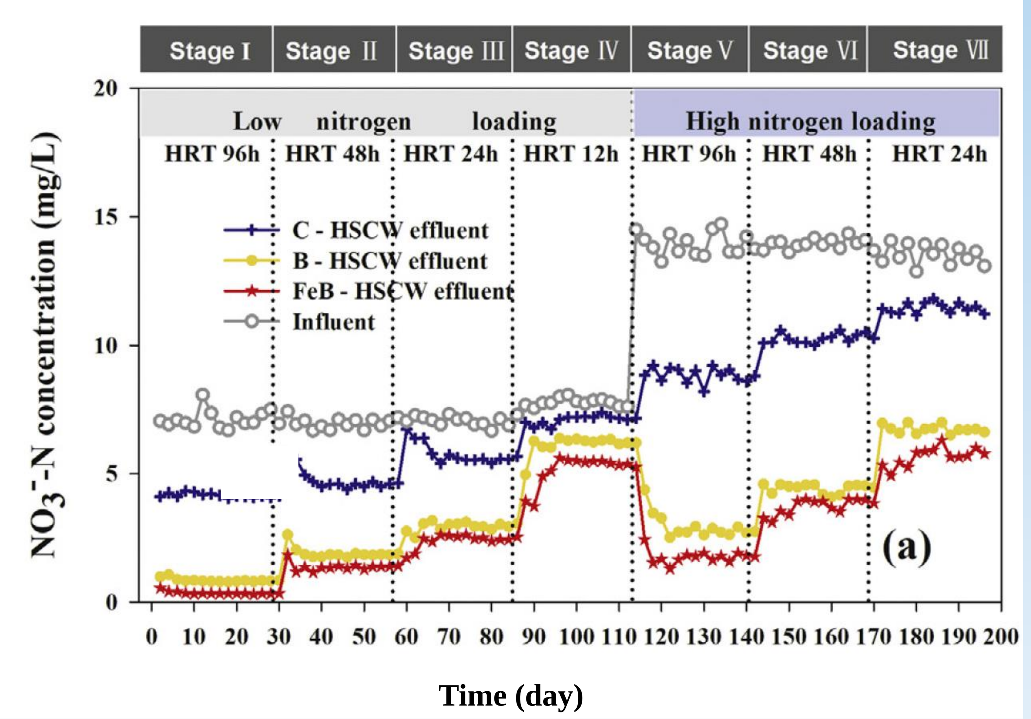
| Components | C-HSCW | B-HSCW | FeB-HSCW |
|---|---|---|---|
| quartz sand | X | X | X |
| soil | X | X | X |
| unmodified biochar | | X | |
| Fe-modified biochar | | | X |



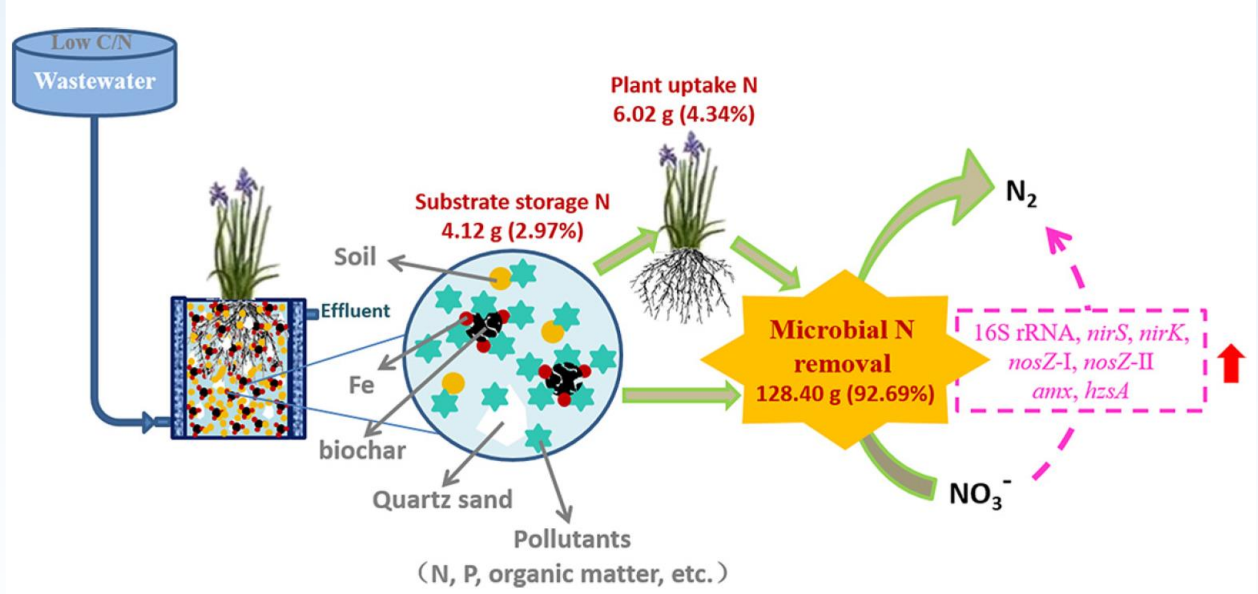
N Loading: **low** (8.561–10.618 mg/L) | **high** (16.932–18.774 mg/L)
Hydraulic Retention Time (HRT): **96h | 48h | 24h | 12h**

## Results & Discussion

The $NO_3^-$-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 $NO_3^-$-N removal decreased with the HRT reduced and N loading increased in HSCWs, the FeB-HSCW always maintained the highest $NO_3^-$-N removal in the three HSCWs




## Mechanism




## Conclusion

FeB-HSCW was an effective system to remove N from the storm-related wastewater under different combinations of HRT and N loading.