A Fe-cycle in advanced constructed wetland

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1. Introduction

Many developing countries in tropical region have been facing water pollution problems, water shortages in dry season and global warming problem. To reduce the vulnerability of water resources caused by these problems, wastewater reclamation and recycling practice can be recommended.

Constructed wetland (CW) is a promising wastewater treatment and reclamation technology, owing to its low costs and high performance. However, greenhouse gases such as methane may be produced from anaerobic zones in CW.

Recent studies on wastewater treatment performance demonstrated several emerging pollutants including PPCPs and EDCs could be treated by CW, in addition to conventional water quality parameters such as BOD, pathogens, TN, and SS (Kasai et al., 2012). Moreover, our former studies demonstrated the possibility of decomposing almost every emerging pollutant by a biological Fenton (Bio-Fenton) reaction (Reis and Sakakibara, 2011).

This study was conducted to develop an advanced CW where a Fe-cycle is introduced as illustrated in Fig. 1 to make Bio-Fenton and biological oxidation reaction proceed and to reduce methane emission.

2. Methods

To evaluate the possibility of main processes in Fig. 1, the following three experiments were conducted.

2.1 Oxidation of ferrous ion (Fe^{2+})

Five kinds of submerged plants having relatively long roots, *Cyperus alternifolius*, *Cyperus papyrus*, *Machaerina rubiginosa*, *Variegated Machaerina rubiginosa* and *Vetiveria zizanioides*, were used in experiments. 100 mg-Fe^{2+}/L solution was prepared by dissolving $FeCl_2$ in distilled water and removal rates or oxidation rates of Fe^{2+} by these plants were measured under a 99% N_2-headspace condition.

2.2 Reduction of ferric compounds (Fe^{3+})

Fe-reducing bacteria were pre-cultivated in different periods (8 to 24 days), using a culture reported by Lovley (1986) and paddy soil as seed sludge (Table. 1). After that, batch experiments were conducted to evaluate Fe^{3+} reduction performance, where initial Fe^{3+} concentration was set at 5mM and measurements were made every 2 days for pH, DO, Fe^{2+} and total Fe concentrations.

2.3 Reduction of methane production

Anaerobic digested sludge was diluted in different ratios and mixed with paddy soil. Gas production and composition were measured. Observed results were compared with data with no paddy soil.

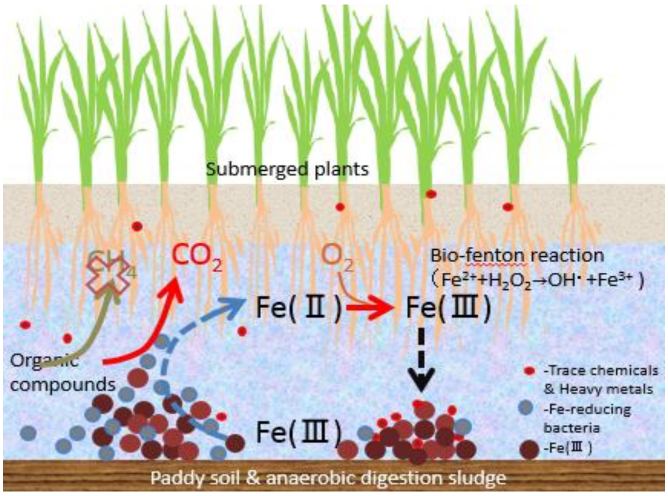

Fig. 1 Fe-cycle in constructed wetland

Table. 1 Five conditions in paddy soil enrichment culture

No.	*1*	*2*	*3*	*4*	*5*
Pre-cultivation time (days)	8	16	24	24	24
Seeds	Soil supernatant	Soil supernatant	Soil supernatant	Soil	Soil

3. Results and Discussion

3.1 Oxidation of ferrous iron (Fe^{2+})

Observed removal rates (i.e. oxidation rates) of Fe^{2+} by aquatic plants were shown in Table. 2. Every plant could remove and oxidize Fe^{2+}, where C. *alternifolius* and M. *rubiginosa* had higher removal performances. These plants contained relatively higher H_2O_2 concentration in root. For the sake of comparison, a blank dark experiment was done, and results showed that almost no ferrous iron could be oxidized by plants.

3.2 Reduction of ferric compounds (Fe^{3+})

Reductions of Fe^{3+} by paddy soil were shown in Fig. 2, indicating Fe^{2+} was produced in solution and pH became lower around 4. Enrichment culture of Fe-reducing bacteria for 8 days could reduce only about half of initial ferric iron, while the cultures for 16 and 24 days could reduce more than 80% of initial ferric iron. Using paddy soil as seed sludge was better to reduce Fe^{3+} to Fe^{2+} than soil supernatant. Produced Fe^{2+} can be used for Bio-Fenton process or oxidized to Fe^{3+} by aquatic plants.

Key word: Constructed wetland, Bio-Fenton reaction, Iron-reducing bacteria
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3.3 Reduction of methane production

Experimental results of methane gas production showed that anaerobic digested sludge produced CH_4 or H_2, as well as CO_2, where H_2 produced during acidogenesis stage of anaerobic digestion; however sludge with paddy soil containing Fe-reducing bacteria produced neither CH_4 nor H_2, but only CO_2. Thus, methane production can be inhibited by adding paddy soil containing Fe-reducing bacteria to anaerobic digested sludge.

From these results, it is considered that a Fe-cycle is possible in advanced constructed wetland, where a series of reactions such as reduction of ferric compounds by Fe-reducing bacteria at the bottom and the oxidation of ferrous iron by photochemical reaction and biological Fenton reaction by aquatic plants would occur simultaneously. This Fe-cycle would be effective to enhance treatment performance for refractory compounds and to achieve functional improvement in reducing methane emission.

In order to achieve the Fe-cycle in advanced constructed wetland, a lab-scale constructed wetland reactor was built as showed in Fig. 3, which holds an inlet for wastewater flow, sampling ports and other constituents such as aquatic plants, matrix, paddy soils and anaerobic digested sludge. After experiment for 35 days, ferric iron was almost reduced to ferrous iron as showed in Fig. 4. Other parameters and performance of whole reactor will be measured and compared with conventional CW.

4. Conclusions

A fundamental study on the reduction and oxidation of iron compounds in laboratory scale CW was conducted, and it was found that a Fe-cycle could be introduced in CW illustrated in Fig.3. It is considered this Fe-cycle is effective for achieving new functions and enhanced performance in advanced CWs.

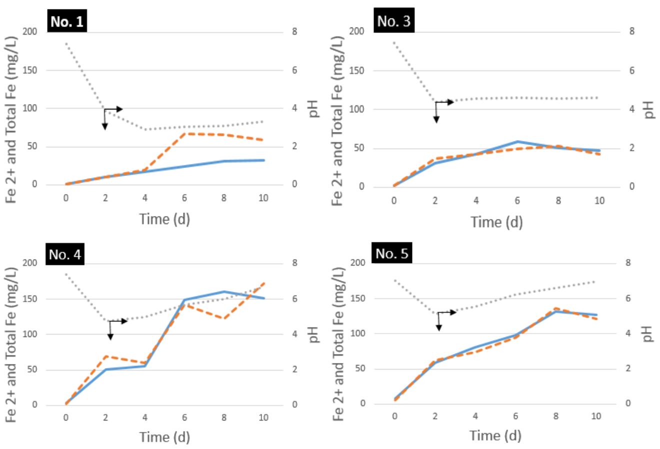

Fig. 2 Results of pH, DO, Fe^{2+} and total Fe concentration under five conditions in paddy soil enrichment culture, where

Fe2+ (mg/L) Total Fe (mg/L) pH

Table. 2 Plants used in this study

No.	*Submerged Plants*	*H_2O_2 Concentration (nmol/gFW)*	*Fe^{2+} Removal rate ($mgFe^{2+}/gFW \cdot d$)*
0	No plant	-	Nearly 0
1	*C. alternifolius*	88	0.20
2	*C. papyrus*	119	0.10
3	*M. rubiginosa*	96	0.17
4	*V. M. rubiginosa*	147	0.14
5	*V. zizanioides*	90	0.12

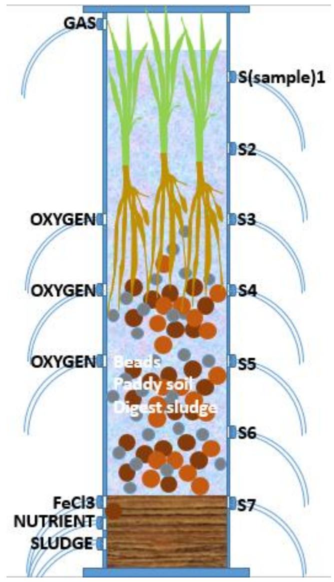

Fig. 3 Constructed Wetland model

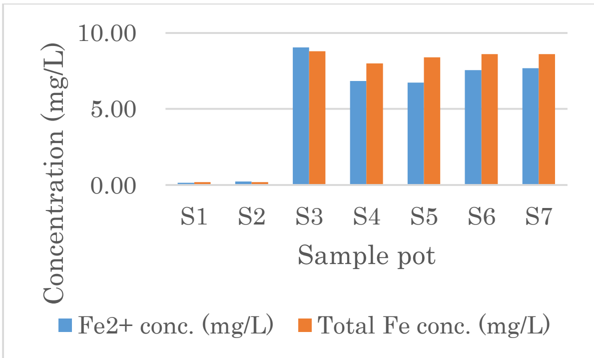

Fig. 4 Results of Fe^{2+} and total Fe concentration in Constructed wetland after experiment for 35 days

References

[1] Sakai Y. et al. (2012) Field Survey on the Removal of Endocrine Disrupting Chemicals and Pharmaceutical Residues in Oxidation Ponds and Constructed Wetland in Tropical Areas., *Journal of Water and Environmental Technology*, **10**(4), 337-345.

[2] Reis, A.R and Sakakibara Y. (2011) Continuous treatment of endocrine disrupting chemicals by aquatic plants and biological Fenton Reaction., *JSCE, Ser. G (Environmental Research)*, **67**(7), 725-734.

[3] Lovley D.R. and Phillip E.J.P. (1986) Organic Matter Mineralization with Reduction of Ferric Iron in Anaerobic Sediments., *Applied Environment Microbiology*, **51**(4), 683-689.