Ecological Engineering 83 (2015) 338–342

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Short communication

Organic matter transplant improved purification performance of newly built constructed wetlands

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ARTICLE INFO

Article history:
Received 9 January 2015
Received in revised form 14 June 2015
Accepted 4 July 2015
Available online 17 July 2015

Keywords:
Constructed wetland sediment (CWS)
Organic matter transplant (OMT)
Phosphorus forms
Phospholipid fatty acid

ABSTRACT

This study investigated the effect of the transplant of organic matter (OM) from mature constructed wetlands to newly built wetlands on the removal efficiency of contaminants. Our results showed that 1% of organic matter transplant (OMT) could significantly improve the removal efficiency of nitrogen (N) and phosphorus (P) and accelerate the maturation of newly constructed wetlands. The processes of retaining and release of inorganic phosphate of OM were characterized by the conversion of iron phosphate and aluminum phosphate to calcium phosphate. The quantities of microbes responsible for the removal of N and P could be significantly increased by 1% of OMT. The removal of N was related to the microbes with phospholipid fatty acids(PLFAs)of C14:1, C15:0, C16:0, C18:0 and C22:0, whereas the removal of P was related to those with PLFAs of C15:0, C16:0, C16:1, C18:0, C22:0 and C22:1.

1. Introduction

Constructed wetland has been extensively used in sewage treatment (Paing and Voisin, 2005; Drizo et al., 1999; Knight et al., 2000). The accumulated organic matter (OM) is rich in microbes and plant materials during operation (Hua et al., 2010). The OM content of constructed wetland sediments (CWS) is negatively correlated with the permeability (Knowles et al., 2011), and OM accumulation in substratum pores is regarded as an important factor causing clogging (Zhao et al., 2009). On the other hand, sediment is rich in humus and a large number of microbes which are responsible for absorption, migration and transformation of pollutants during operation (Fu et al., 2013; Martinez et al., 2013). However, the present research is focused on how to prevent clogging (De la Varga et al., 2013; Pozo-Morales et al., 2013) and the mechanisms underlying the substrate clogging (Ye et al., 2014; Hua et al., 2013).

It usually takes two months for wetland plants and associated microbes to adapt to and propagate in newly constructed wetlands (Hua et al., 2014). As the CWS derived from existing wetlands is usually rich in well-adapted microbes (and nutrients), we attempted to transplant a small amount of the organic matter of CWS to speed up the maturation of constructed wetlands. We investigated the efficiency and mechanisms of CWS transplant on the maturation of newly constructed wetlands, based on the profiling of phosphorus (P) and phospholipid fatty acids. The expected results could provide insights into the maturation and operation of constructed wetlands in the future.

2. Materials and methods

2.1. Experimental setup

The constructed wetland pilot system (CWPS), made of plexiglass column (0.5 m in height, 5.5 cm in diameter), was divided into 5 groups; each consisted of 3 parallel setups. The columns were filled with 40 cm fine sand, and the upper 10 cm layer was mixed with 0%, 0.25%, 0.5%, 0.75%, and 1% of CWS collected from Shenzhen University Wenshan Lake Constructed Wetland. Part of the CWS was dried under 105 °C for the phosphorus classification experiment.

2.2. Operation strategy

There were three stages in the operation of CWPS. The first stage lasted for a week, and clean tap water was fed to remove dust and other fine particles in the substrate. In the second stage, the artificial wastewater prepared by using NH_4Cl, KH_2PO_4, KNO_3 and $NaNO_2$ with the contents of 0.5 mg/L ammonia nitrogen (N) and 0.5 mg/L phosphorus, 1 mg/L nitrate N and 0.25 mg/L nitrite N was

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http://dx.doi.org/10.1016/j.ecoleng.2015.07.007
0925-8574/

loaded as the influent. The wastewater was treated by each CWPS and the effluent samples were collected for chemical analyses. After the second stage, the substrate samples in the upper 10 cm layer from each CWPS were collected and kept in a refrigerator at −20 °C for testing microbial contents. The third stage was a continuous operation fed with the water sourced from Shenzhen University Wenshan Lake, at the hydraulic load of $0.42\,m^3/(m^2 \times d)$. After 15 days, water samples were collected once every two days for analyses.

2.3. Chemical analyses and characterization of microbial communities

The samples were analyzed for NH_4^+-N, NO_2-N, NO_3-N and $PO_4^{3-}$by a CleverChem 380 discontinuous water quality analyzer (China EPA, 2012). The collected samples were dried and tested for the contents of solubility phosphorus, iron phosphorus, aluminum phosphorus and calcium phosphorus (Li et al., 1998). The microbial communities were investigated based on the phospholipid fatty acid profiling technology (Zhou et al., 2009).

2.4. Data analyses

Statistical analyses were conducted by using MS EXCEL 2010, Origin 8.5 and SPSS 13.0.

3. Results and discussion

3.1. The impact of CWS transplants on COD_{Mn} and PO_4^{3-} content of effluents

The effluent COD_{Mn} values of all CWPSs decreased with the increasing doses of transplanted CWS in the substrates (Fig. 1a). The 1% CWS transplant resulted in a removal rate of COD_{Mn} about 59.9%, higher than 25.2% of the control (without CWS transplant). The effluent COD_{Mn} of the control had been higher than those of the treatment systems before September 24 (Fig. 1b). After 10 days, until September 28, the COD_{Mn} removal rate of control caught up with those of treatments with CWS transplants.

The PO_4^{3-} removal rates also increased with increasing doses of CWS transplants (Fig. 1c). There were fluctuations in the removal of the PO_4^{3-} during the initial period. In general, a small amount of CWS transplanted into CWPS resulted in a better and more stable PO_4^{3-} removal, as compared to those of the control (Fig. 1d). The control CWPS reached the same removal rate of PO_4^{3-} until September 28. These results demonstrated that CWS transplant enhanced the PO_4^{3-} removal at the initial stage.

3.2. The impact of CWS transplant dosage on the nitrogen contents of effluents

The increasing doses (0%, 0.25%, 0.5%, 0.75% and 1%) of CWS transplant were negatively correlated (with a linear relation, $R^2 = 0.9545$) with the removal rates of NO_3-N (50.84%, 41.45%, 37.84%, 32.53% and 29.74%) (Fig. 2a). However, a stable removal of NO_3-N was observed in the CWS added CWPS in the initial stage before September 26. One week later, removal of NO_3-N in the CWS added CWPS was significantly lower than that of the control (Fig. 2b).

A small dose of CWS transplant could enhance NO_2-N removal efficiency markedly (Fig. 2c). The CWS transplant-added CWPS had a lower NO_2-N content in the effluent before September 26 (Fig. 2d). In addition, the NO_2-N removal was more stable than that of the control. A small amount of CWS transplant could enhance the efficiency of NH_4^+-N removal (Fig. 2e). The effluent NH_4^+-N concentrations were always higher than those of the influent (0.5 mg/L), indicating that sand might have a weak ability to absorb NH_4^+-N. The removal of NH_4^+-N fluctuated before September 24 (Fig. 2f) and the unstable NH_4^+-N removal was more remarkable in the control without CWS transplant. Therefore, CWS transplant could improve NH_4^+-N removal efficiency and also maintain the stability of effluent NH_4^+-N content.

3.3. The mechanisms underlying CWS transplant enhanced removal of phosphorus

The P removal might be associated with the pH of substrates in constructed wetlands, and the physical and chemical properties of

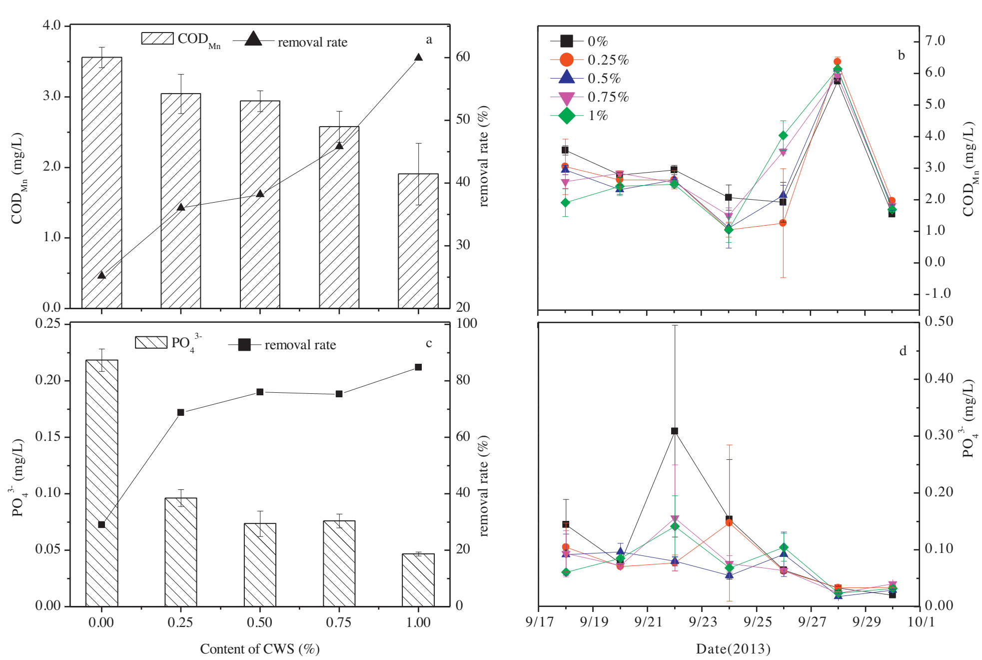

Fig. 1. The impact of CWS transplant on removal of COD_{Mn} and PO_4^{3-}.