Evaluation of constructed wetlands treating road and parking lot stormwater runoff considering ecological functions

Évaluation de zones humides artificielles traitant les eaux de ruissellement de routes et parkings considérant les fonctions écologiques

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RÉSUMÉ

Les filtres plantés de roseaux (FPR) à écoulement horizontal utilisent des processus naturels de sédimentation, filtration, adsorption, décomposition de microorganismes et purification par des plantes aquatiques. Cette étude a analysé les mécanismes influant la réduction des polluants dans les FPR, en tenant compte des facteurs écologiques. Plus précisément, nous avons analysé sur le long terme les effets de l'absorption de polluants par les plantes sur l'efficacité globale de l'élimination des polluants. Sur la base de la concentration moyenne dans l'influent et l'effluent, l'efficacité de l'élimination des polluants était de 78% pour le TSS, 59% pour le TN, 54% pour le TP et 57% pour la DCO. La réduction moyenne des métaux lourds (Cr total, Fe total, Cu total, Zn total, Pb total) était de 54%. L'analyse des micro-organismes dans les zones d'entrée et de sortie a révélé que les protéobactéries sont les plus présentes (40%). Cette proportion élevée de protéobactéries pourrait contribuer à la réduction de l'azote et à la croissance de la végétation dans l'installation. Les filtres plantés de roseaux (FPR) à écoulement horizontal semblent favorables au développement de protéobactéries, d'actinobactéries et d'acidobactéries, ce qui fait de ces microorganismes une espèce dominante.

ABSTRACT

Horizontal subsurface (HSSF) constructed wetlands (CW) employed natural processes such as sedimentation, filtration, adsorption, decomposition via microorganisms and uptake by aquatic plants that helped in pollutant removal in stormwater runoff. This study analyzed the mechanisms affecting pollutant reduction in in CW considering ecological factors. Specifically, the effects of pollutant uptake of plants on the overall pollutant removal efficiency through long-term monitoring of small horizontal subsurface flow (HSSF) wetland was conducted. Based on the average concentration of influent and effluent, the pollutant removal efficiency was 78%, 59%, 54% and 57% for TSS, TN, TP, and COD, respectively. The average reduction of heavy metals including total Cr, total Fe, total Cu, total Zn and total Pb was 54%. Analysis of the microorganisms in the inflow and outflow areas revealed that *Proteobacteria* have the highest percentage amounting to 40% among the microorganisms found in the CW. High proportion of *Proteobacteria* was expected to have contributed to nitrogen reduction and vegetation growth in the facility. HSSF CW was found to be suitable for *Proteobacteria*, *Actinobacteria* and *Acidobacteria* growth making these microorganisms the dominant species in the CW.

KEYWORDS

Constructed Wetland, Ecology design, Low Impact Development, Microorganism, Stormwater

1 INTRODUCTION

Roads, pesticides and fertilizers from farmlands and livestock wastewater transported through stormwater during rainfall including various non-point pollutants such as organic matter and nutrients causing the deterioration of river water quality. In order to solve these problems, techniques including the use of low impact development (LID) and green infrastructure (GI) were implemented for the restoration of natural hydrologic cycle and ecological effect. LID and GI included various techniques such as rain gardens, bioretention, and constructed wetlands (CW). In particular, horizontal subsurface (HSSF) wetlands employed different pollutant removal mechanisms including sedimentation, filtration, adsorption, decomposition of microorganisms and phytoremediation by aquatic plants. CW performed functions of pollutant reduction and water circulation through the physical, chemical and biological processes through different components such as filter media, plants and microorganisms. Especially, CW plants remove the nutrients and heavy metals, (Mickle and Wetzel 1979; Kucklentz 1985). In addition, CW plants such as duckweed, reed, cattail, water hyacinth, and iris in the wetlands increase TSS removal and enhances algae management, and meta-production. Growing plants in CW were found to be effective in removing nitrogen through absorption, nitrification and denitrification in active roots (Kadlec and Wallace, 2008). Appropriate environment is needed for microorganisms and plants to adapt to the CW environment. However, in South Korea, only the overall performance evaluation of CW were usually studied of the and the research on the wetland environment such as plants and sediments has been lacking. Therefore, in this study, mechanisms affecting pollutant reduction in in CW considering ecological benefits were analyzed.

2 MATERIALS AND METHODS

The HSSF CW was located at Kongju University in Cheonan, Chungcheongnam-do in South Korea and treats stormwater runoff from roads and parking lots. The facility consists of pre-treatment, plant, and discharge zone as exhibited in Fig. 1. The pre-treatment zone has vertical wood chips media for reducing particulate matter while Iris ensata var. Spontanea (Iris) is planted in the plant zone. Monitoring of rainfall events before and after the installation was carried out since 2010. Water quality constituents including particulate matter, organics, nutrients and heavy metals were analyzed. In order to analyze the ecological characteristics of the wetland, chemical characteristics of the sediments, plant and microorganisms were also monitored. Soil and plant samples were taken from the initial and later part of the plant zone to perform physical, chemical and biological analyses as demonstrated in Fig. 2. Pollutant removal efficiency of the system was calculated using Eq. 1.

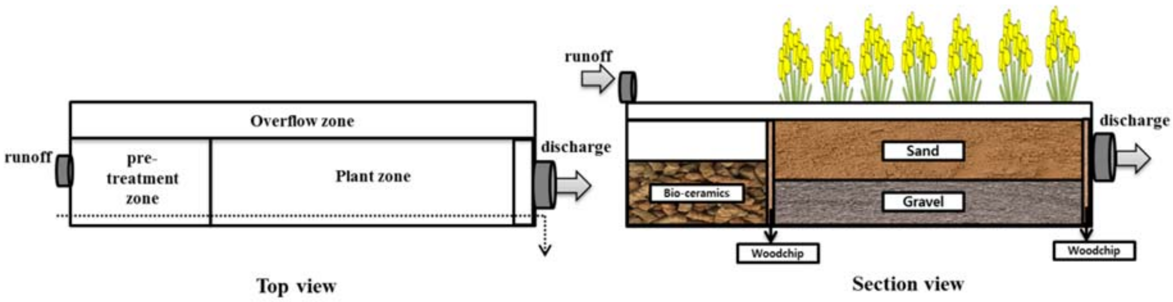

Fig. 1 Schematic diagram of the HSSF CW

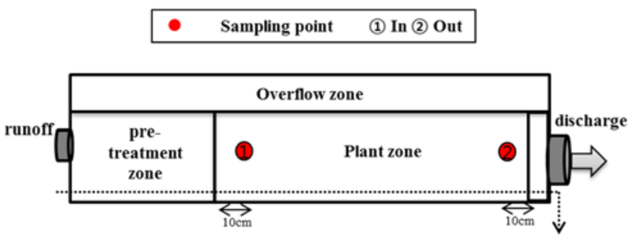

Fig. 2 Sampling point on the HSSF CW

$$\text{Removal Efficiency(\%)} = \frac{\sum_{t=1}^{t=T} C_{in}(t)Q_{in}(t) - \sum_{t=1}^{t=T} C_{out}(t)Q_{out}(t)}{\sum_{t=1}^{t=T} C_{out}(t)Q_{out}(t)} \quad \text{eq.1}$$

3 RESULTS

3.1 Inflow Characteristic

Fig. 3 showed that the inflow for 22 storm events monitored have mean concentrations entering the HSSF CW amounting to 143.3±47.8 mg/L, 155.2±106.9 mg/L, 8.5±4.9 mg/L and 0.56±0.32 mg/L for TSS, COD, TN and TP, respectively while the outflow event mean concentrations were 47.7±32.0mg/L, 80.2±52.2 mg/L, 6.4±3.7mg/L and 0.32±0.17mg/L for TSS, COD, TN and TP, respectively. Total Fe showed the highest event mean concentration among the heavy metals with influent ranging from 18.98 to 0.11 and effluent ranging from 6.54 to 0.09. The influent concentrations of total Cr, total Cu, total Zn, and total Pb were ranging from 0.16±0.09 mg/L, 0.15±0.09 mg/L, 0.53±0.51, 0.01±0.08, 0.18±0.12 and effluent concentrations ranged from 0.15±0.10 mg/L 0.15±0.13 mg/L, 0.30±0.28 mg/L, 0.10±0.09mg/L and 0.18±0.21, respectively . This findings show that the concentration is reduced after passing through the facility. Based on the average concentration of influent and effluent, the pollutant removal efficiency was 78%, 59%, 54%, and 57% for TSS, TN, TP and COD, respectively. The average reduction effect of heavy metals were ,49%, 67%, 41%, 57%, and 52% for total Cr, total Fe, total Cu, total Zn, and total Pb, respectively.

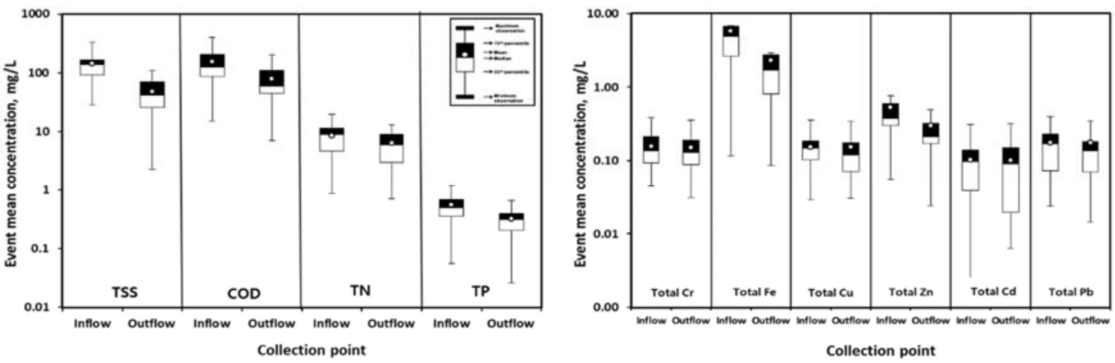

Fig. 3 Inflow and outflow characteristics of HSSF CW

3.2 Microorganisms characteristics

In order to evaluate the internal characteristics of the HSSF CW, microorganisms were analyzed from the soil collected at the inlet and outlet collection point of the HSSF CW. The average number of microorganisms collected from the inflow and outflow areas were 42,226 and 41,046, respectively. The total number of microorganisms was distributed more at the inflow part than at the outflow part. Based on these results, proportion of microorganisms in the inflow and outflow areas revealad that *Proteobacteria* has the highest percentage of 40%. *Proteobacteria* are microorganisms that survives in the vegetation roots (Ahn et al, 2013, Podosokorskaya et al., 2013). High proportion of *Proteobacteria* is expected to have contributed to nitrogen reduction and vegetation growth in the facility. The proportion of *Actinobacteria* were found to be 16% and 12% in the inflow and outflow part, respectively while 12% and 10% proportion of *Acidobacteria* were found in the inflow and outflow part of HSSF CW, respectively. *Proteobacteria, Actinobacteria* and *Acidobacteria* accounted for about 60% of the total microorganisms. *Proteobacteria* are living microorganisms that coexist in vegetation roots with nitrogen-fixing bacteria and have many effects on plants and are microorganisms that affect the biological reduction of heavy metals. Based on the findings, it can be perceived that environment of the HSSF CW is suitable for *Proteobacteria*, *Actinobacteria* and *Acidobacteria* growth making these microorganisms as dominant species.

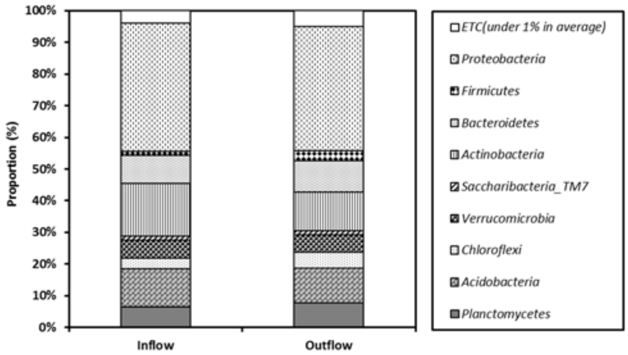

Fig. 4 Inflow and outflow microorganisms characteristics of HSSF CW

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