Analysis of Rain Garden Efficiency Through Long-Term Monitoring

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Highlights

- LID technologies are used for stormwater and pollutant management in Korea since 2004
- The efficiency of low LID facilities can be reduced over time due to clogging
- Facility aging and stabilization increased the removal of organics and nutrients

Introduction

The increase in impervious area due to urbanization can alter the overall water circulation. During periods of heavy rainfall, increased peak flow volume and flow duration can result to regional and local flooding in urban areas. In addition, changes in rainfall patterns due to climate change have been reported to affect the natural water cycle (Yoo, 2015). Since 2004, the Korean Ministry of Environment has applied low impact development (LID) strategies to manage stormwater in urban areas and reduce non-point source (NPS) pollution. Majority of the LID facilities utilize sedimentation basins as a pre-treatment mechanism to remove particulate matters, reduce runoff volumes, and increase hydraulic retention time. In addition, NPS pollutants are managed by incorporating media filters and vegetation to promote combined physico-chemical and biological treatment mechanisms such as infiltration, filtration, adsorption, evapotranspiration, and storage. However, pollutants and sediments accumulate in the facility over time, resulting to filter media clogging, decrease in permeability, and reduced efficiency of the facility. Therefore, this study evaluated the long-term performance of rain garden through analysing the characteristics and behaviour of pollutants inside the facility.

Methodology

The rain garden facility installed in Kongju National University, Cheonan campus was designed to treat stormwater runoff from an impervious parking lot. The rain garden consists of sedimentation basin (pre-treatment zone), vegetated zone and the outflow zone. Filter media, including gravel and sand, were used in the rain garden. Storm event monitoring and water quality sampling was conducted for a total of five years from 2014 to 2018. Water quality assessment was performed by collecting water samples from inflow and outflow parts of the facility. Flow measurements were performed every five minutes as soon as the inflow and outflow were observed in the rain garden. Water samples were collected at intervals of 0, 5, 10, 15, 30 and 60 minutes for the first hour of monitoring, while succeeding samples were collected at an hourly interval.

Results and discussion

Figure 1 exhibited the annual pollutant removal efficiency of rain garden. Monitored events were characterized by rainfall depths ranging from 0.5 mm to 40.3 mm with mean antecedent dry days and average rainfall intensity of 5.46 ± 4.7 days, 5.33 ± 6.7 mm/hr, respectively. The concentration of TSS, COD, TN, and TP were 98.0 ± 32.7 mg/L, 133.6 ± 6.3 mg/L, 5.77 ± 4.05 mg/L, and TP 0.54 ± 0.03 mg/L, respectively. Generally, the concentration of influent was 44 ± 8% higher in summer than in winter. Automobile and anthropogenic activities in the catchment area during summer season was 10% higher than in winter. Moreover, high summer temperatures resulted to increased rate of sediment drying. The dried sediments that accumulated on the impervious surfaces can be easily washed-off on storm events, thereby increasing the concentration of particulates in stormwater. The average volume reduction of the rain garden was 96 ± 3%. At rainfall intensities greater than 20 mm/hr, the rain garden effectively reduced the runoff volume by 97% for the first two years of operation. After the second year, it was observed that the average volume reduction of the system was reduced to 90% for rainfall intensities greater than 14 mm/hr. The five-year mean TSS removal efficiency of the system was 86%; however, it was observed that the TSS removal efficiency in 2018 only amounted to 69%, which was about 15% lower as compared with the 5-year mean removal efficiency. The decrease in TSS removal can be attributed to the high frequency of overflows in the facility during periods of high rainfall intensity which cause pore blockage or filter media clogging. The mean removal efficiency of COD, TN and TP were 90%, 76%, and 88%, respectively. Unlike TSS, the removal of nutrients and organics by the facility increased over time due to the continuous stabilization of the vegetative components and microbiological activities in the rain garden. The removal efficiency of Total Cu, Total, Cd, and Total Pb exhibited similar trend with COD and TP since heavy metals can also be removed through physical filtration and adsorption, biological mechanisms, and plant uptake. As compared with other water quality parameters, the removal efficiency of heavy metals was relatively low due to inferior uptake mechanisms of the facility's vegetative components.

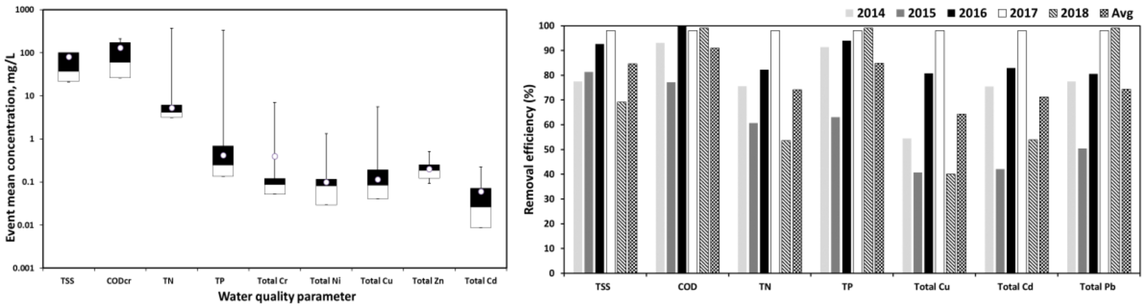

Figure 1. Influent Water Phase and Pollutant Reduction Efficiency

Conclusions and future work

Based on the long-term monitoring of the rain garden, the following conclusions were derived:

1) The infiltration rate and storage capability of the facility decreased by 10% due to filter media clogging and sediment deposition in the upper part of the facility over time.
2) Decrease in hydraulic residence time and filter media clogging resulted to a decreased TSS removal efficiency over time. On the other hand, the removal efficiency of nutrients and organics increased due to the stabilization of plants and other microbiological processes.
3) Continuous monitoring and further research should be conducted evaluate the factors affecting the treatment efficiency of the rain garden. Maintenance and changes in rainfall patterns should also be considered in the facility design.

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Reference

Yoo, C.S., Lee, J.W., Cho, E.S., Cho, J.H.& Choi, H.H., 2015 Evaluation of Rain Garden for Infiltration Capability and Runoff Reduction Efficiency. 17, 101-111