Characteristics and fate of parking lot runoff pollutants in low impact stormwater facilities

Caractéristiques et devenir de la pollution des eaux de ruissellement de parking dans des ouvrages de gestion alternative des eaux pluviales

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RÉSUMÉ

La pollution due aux sources non ponctuelles (NPS) met en danger la qualité des eaux provenant de multiples sources. Le développement à faible impact (LID) est la principale méthode utilisée afin de réduire une telle pollution, notamment en milieu urbain à haute imperméabilité. Dans cette étude, deux LID terrains humides (HCW1 & HCW2) ont été construits à proximité de parkings hautement imperméables où les eaux de pluies ont été collectées. De plus, la présence d'azote, de phosphore, de substances organiques ou encore de métaux lourds (Pb, Zn, Cu, etc.) soulèvent des doutes quant à l'établissement d'un environnement durable. Les marais artificiels sont connus pour avoir une impressionnante efficacité d'élimination des polluants NPS. Dans la lignée, ces installations LID étaient destinées à fournir une réduction des polluants NPS dans les eaux de ruissellement pour l'amélioration de la qualité de l'eau. L'étude a fourni les caractéristiques et le sort du transport des polluants des eaux de ruissellement dans les deux zones humides. Un total de trente-quatre tempêtes ont été surveillées depuis juillet 2010 jusqu'à septembre 2014. Un échantillonnage manuel instantané a été utilisé dans les unités de chacune des installations de LID en entrée et sortie. La quantité et le transport des polluants dans les eaux de ruissellement se sont révélés être fortement dépendants des jours secs précédents. Les deux zones humides ont montré une réduction satisfaisante de tous les polluants. Cependant, la recherche conclut que continuer d'améliorer la conception des zones humides construites permettra de développer davantage les capacités de réduction.

ABSTRACT

Nonpoint source (NPS) pollution imperils water quality originated from diffused sources. Low impact development (LID) is the leading management practice which seeks to mitigate this kind of pollution especially in highly impervious urban areas. In this study, two LID hybrid constructed wetlands were constructed adjacent to impervious parking lots to treat stormwater runoff. The NPS pollutants such as nutrients (nitrogen and phosphorus), organics, and heavy metals (Pb, Zn, Cu, etc.) ultimately signal high concerns against a sustainable environment. Constructed wetlands are known to have an impressive removal efficiency of NPS pollutants. In lines with this, these LID facilities were intended to provide reduction of NPS pollutants in stormwater runoff for water quality improvement. The study provided the characteristics and transport fate of the runoff pollutants in both wetlands. A total of 34 storm events were monitored starting from July 2010 and concluded on September 2014. Manual grab sampling was utilized at the inlet and outlet units of each LID facilities. The amount and transport of pollutants in runoff were found out to be highly dependent on the antecedent dry days. Both wetlands exhibited satisfactory reduction of all pollutants. However, the research concludes that further improvement of the constructed wetland design will enhance more reduction capabilities.

KEYWORDS

best management practice, low impact development, nonpoint source pollution, stormwater runoff

1 INTRODUCTION

Urban storm runoff which contains various pollutants, as well as carries a large amount of pollutant load, was identified as one of the leading causes of degradation in the quality of receiving waters (Li et al., 2006; US EPA, 1998; Characklis and Wiesner, 1997). Highly urbanized areas comprising transportation, commercial, residential and industrial land uses were 100% impervious thus preventing the stormwater to naturally infiltrate into the ground (Geronimo et al., 2012). Moreover, pollutants in stormwater runoff associated with transportation facilities are now considered a major quality concern and efforts to characterize the runoff quality to prioritize the pollutants of concern (Pitt et al., 1995; Sansalone and Buchberger, 1997; Abrishamchi et al., 2010). In response to this, the Ministry of Environment funded several projects related to the management of stormwater runoff and one of these is the application of low impact development (LID) technologies in the urban land uses. LID is a stormwater management strategy which attempts to restore the natural water cycle and use techniques that effectively capture, infiltrate, filter, store, evaporate and detain runoff close to the source (PGC, 1999; Park et al., 2008). Some of the LID facilities include two hybrid constructed wetland (HCW1 & HCW2) which were constructed adjacent to highly impervious parking lots where stormwater runoff is collected. Both the facilities have filtration, evapotranspiration, soil adsorption, uptake by plants and bioremediation functions. Therefore, this research was conducted in order to investigate the characteristics of stormwater runoff and determine the fate of pollutants from runoff in the LID facilities which may be used for the improvement of design of current treatment systems.

2 MATERIALS AND METHODS

Two hybrid constructed wetlands (HCW1 & HCW2) were built in Kongju National University, Cheonan City, South Korea, with aspect ratios (L:W:H) of 1:0.2:0.1 and 1:0.1:0.1, respectively. The facilities were developed to reduce stormwater runoff volume and pollutant concentration from impervious parking lots. Manual monitoring was conducted from July 2010 to September 2014 with a total of 34 storm events. Hydrologic parameters (i.e. total rainfall, antecedent dry day (ADD), runoff volume, etc.) as well as water quality parameters (i.e. particulates, nutrients, organics and heavy metal) were analyzed before and after LID.

Table 1. Physical characteristics of the two facilities

Facilities	Surface Area m^2	Catchment Area m^2	Storage Volume m^3	Total Volume m^3
Hybrid Constructed Wetland A (HCW1)	6.50	597	2.73	4.55
Hybrid Constructed Wetland B (HCW 2)	7	457	2.94	4.90

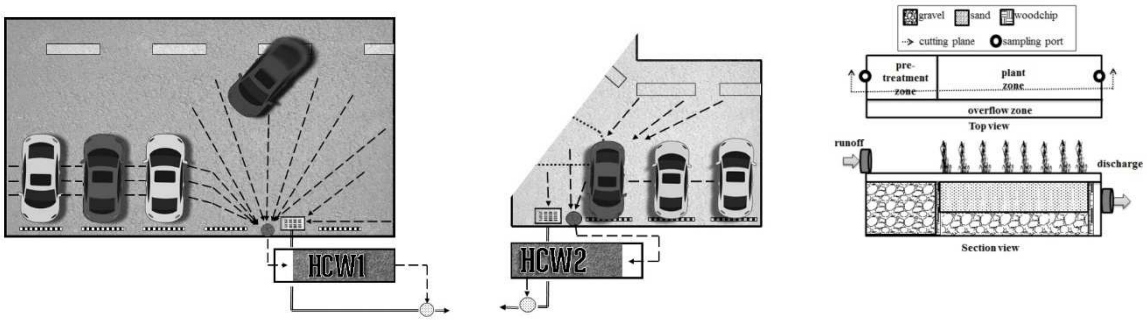


Figure 1: Flow conditions from two impervious parking lots and schematic diagram for both facilities

3 RESULTS AND DISCUSSION

3.1 Hydrologic and hydraulic characteristics of monitored events and parking lot runoff volume

Shown in Table 1 are the hydrologic and hydraulic characteristics of the monitored events in the HCW1 and HCW2. HCW1 generated a discharge volume of 83.33%, while 77.78% was generated in the HCW2. Storm events with less than 5 mm amount of rainfall are expected to have no discharge since all facilities have design capacity of 5 mm. Each LID facility would have attained 100% volume reduction in this case.

Table 2. Statistical summary of selected monitored rainfall events (July 2010-September 2014)

Parameter		Minimum	Maximum	Mean	Standard Deviation
Antecendent dry days, day	HCW1	0.20	34.21	7.20	8.15
	HCW2	0.20	20.70	5.69	5.63
Total rainfall, mm	HCW1	1.50	22.50	6.79	6.43
	HCW2	1.00	33.00	8.00	9.30
Rainfall duration, hr	HCW1	0.87	8.68	2.93	2.14
	HCW2	0.53	4.63	2.22	1.31
Average rainfall internsity, mm/hr	HCW1	0.55	16.42	3.45	4.29
	HCW2	0.72	27.36	5.18	7.32
Average flow rate, m^3/hr	HCW1	0.04	6.70	0.82	1.41
	HCW2	0.08	4.80	0.83	1.28
Runoff volume, m^3	HCW1	0.08	9.92	1.69	2.65
	HCW2	0.14	9.26	1.66	2.75

3.2 Characteristics of pollutant runoff EMC in the systems

The characteristics of pollutant runoff EMC in the systems was shown in Figure 2. It was analyzed that the mean concentration for each pollutant from both facilities was higher than the median which entails that the pollutant concentration was generally lower in most of the storm events.

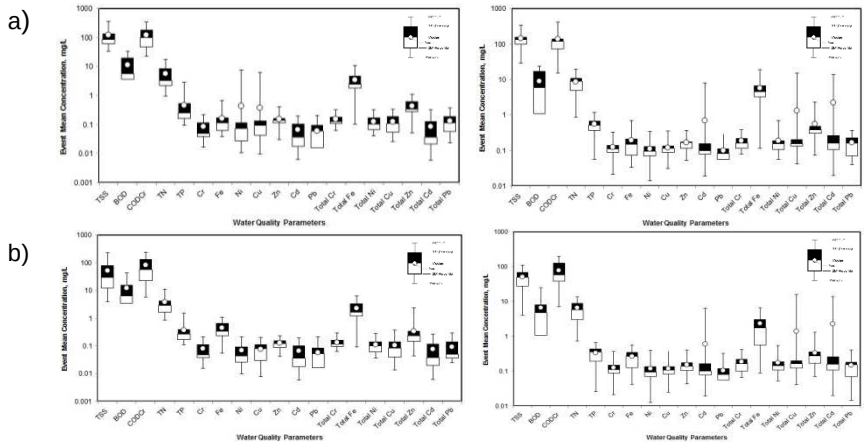
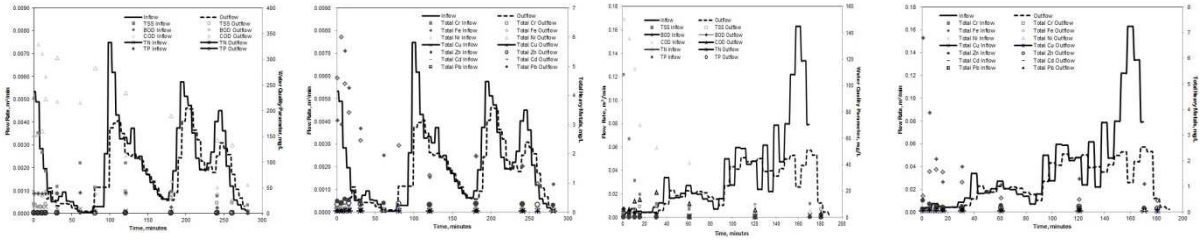


Figure 2: Statistical event mean concentration of the water quality parameters for a) HCW1 (inflow & outflow) and b) HCW2 (inflow & outflow)

3.3 Hydro-pollutograph

The figure shows a representative hydro-pollutograph for the HCW1 and HCW2 dated April 4, 2014 and July 23, 2013, respectively. For the hydrologic characteristics, a delay was observed in both facilities prior to the generation of outflow. A decrease in magnitude of peak flow and runoff volume was also observed. As inflow enters the facilities instantly, pollutant concentration is at its peak during the first 30 minutes which is commonly known as the first flush phenomenon. In relation to this, initial concentrations of pollutants are significantly higher compared to the succeeding stage of the storm event. Total suspended solids (TSS) concentration is highly dependent to the antecedent dry weather period. Therefore, storm events with longer antecedent dry days are more likely to produce a higher first flush. In line with a higher first flush, TSS is considered an important insoluble pollutant among other water quality parameters since it is usually known that pollutants (e.g. heavy metals and nutrients) are adsorbed into these particles.

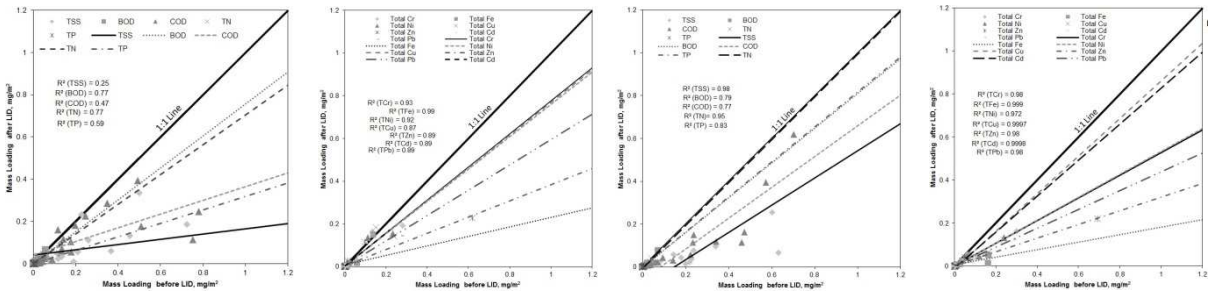


a. HCW1 Hydro-pollutograph b. HCW2 Hydro-pollutograph

Figure 3: Representative Hydro-pollutographs for a) HCW1 and b) HCW2

3.4 Pollutant Mass Loading

Figure 4 shows the ratio of runoff and discharged pollutant loads for HCW1 and HCW2. For the TSS, a reduction of 69% and 73% was reduced by both the HCW1 and HCW2, respectively. HCW2 exhibited a reduction in BOD and COD 8% higher than that of HCW1. Moreover for nutrients, both wetlands reduced an average of 44% for TN, however more than half of TP removal was calculated in HCW2. The soluble metals were reduced with an average of 35% and 30% for HCW1 and HCW2, respectively. These findings showed that both facilities exhibited a satisfactory performance in pollutant reduction.



a. HCW1 Pollutant Load Ratio

b. HCW2 Pollution Load Ratio

Figure 4: Pollutant load ratio of the inflow and outflow of a) HCW1 and b) HCW2

4 CONCLUSION

In this study the behavior, relationship, characteristics and fate of pollutants in the runoff was described and their correlation with respect to the hydrologic-hydraulic characteristics was also determined. Based on the results, it was found out that the amount of pollutant concentration is most likely dependent on the duration of antecedent dry day period, which means that the longer antecedent dry days, the higher the result of pollutant load. Pollutants react to the mechanisms done by the filter media in the facilities. In addition to this, both HCW1 and HCW2 showed a satisfactory performance in pollutant reduction. The results of this study will help in the further improvement of the two constructed wetlands.

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