Effect of Bioretention on Pollutant Reduction in Urban Road Runoff

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Abstract: Bioretention is an efficient low impact development to reducing urban non-point source pollution. This paper studies a bioretention which was settled on one sides of urban roads. In three rainfall events, the content of TSS (Total Suspended Solids), TN (Total Nitrogen), TP (Total Phosphorus) NH^{4+}-N, NO^{3-}—N, Cu and Zn in inflow and outflow of the bioretention were analysed, and the bioretention's ability to reduce pollutants was evaluated. This work provides a reference for the design and construction of bioretention.

1 INTRODUCTION

In recent years, urban non-point source pollution, especially road runoff pollution under rainfall conditions, has attracted more and more attention (Abi Aad et al., 2014). How to effectively control road rainwater runoff pollution and improve rainwater utilization rate in the process of rapid urbanization is a new challenge for urban environment and municipal management departments (U. S. EPA, 2000). Low impact development (LID) is an effective measure to manage rainwater and pollutants in situ through source and decentralized measures (Ahiablame et al., 2012). Ecological detention basin, as a typical LID measure, has strong applicability with design and construction, and is applied in many cities in China. Hao (2020) studied the "ecological" and "functional" aspects of the evaluation and analysis of runoff on the operation effect of biological retention facilities.

Bioretention can collect road rainwater runoff, adsorb pollutants in runoff through fillers, and then supplement groundwater. Many researchers have systematically studied the effect of Bioretention on runoff branch reduction, the adsorption capacity of filler types on pollutants, and the relationship between layout and runoff reduction. Lu et al. (2021) used LID facilities to control urban road rain water significantly, which can effectively reduce runoff, reduce peak flow and delay peak rain time. But for different rainfall intensity conditions, bioretention on road runoff pollutant reduction effect is rarely reported.

In this study, through the establishment of bioretention facilities on both sides of urban roads, the water quality of inflow and outflow of bioretention facilities under rainfall conditions was monitored, and the reduction effects of bioretention facilities on COD, SS, TN and TP in urban road runoff pollutants were studied, so as to provide reference for exploring and optimizing the effect of bioretention facilities in practical application.

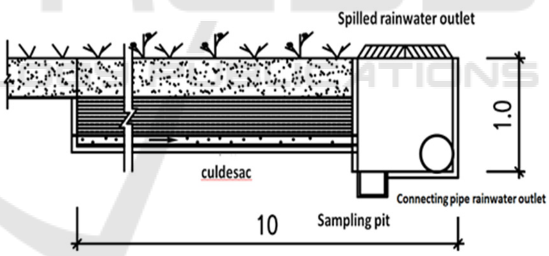

Figure 1: Schematic diagram of bioretention (Unit: m).

2 MATERIAL AND METHODS

2.1 Experimental Installation

As shown in Figure 1, the design size of bioretention is 10 m × 1 m × 1 m, and the inlet is close to the road edge. At the bottom of the bioretention, 5cm thick gravel layer is easy to disperse water. The substrate of bioretention is sand and fly ash, and the bottom layer is fly ash (30 cm). The last time is coarse sand (30 cm). The substrate covered the planting soil layer (30cm). The bioretention has a concave depth of 5 cm, which is convenient for water collection and infiltration. A perforated pipe with a diameter of 1 cm

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is installed at the bottom of the bioretention to collect rainwater from infiltration into the sampling pit.

The plants planted in the bioretention were boxtree and ryegrass (1: 1). Boxwood (*Buxus sinica (Rehd. et Wils.) Cheng*) which is shade-tolerant and light-happy can maintain good growth in general indoor and outdoor conditions. And soil requirements are not strict while it is better to use loose and fertile sandy loam. Ryegrass (*Lolium perenne L.*) is a perennial plant with a stalk height of 30 – 90 cm. Excellent forages are widely introduced and cultivated in various regions. Ryegrass likes a cool and moist climate. Better moisture resistance, but poor drainage or high groundwater level is also adverse to ryegrass growth. Intolerance to drought, especially high heat and drought in summer, is more unfavorable.

2.2 Experimental Method

In this experiment, two typical rainfall events were monitored, and rainfall intensity, rainfall and rainfall duration were recorded respectively. Rainfall characteristics are shown in table 1. The analysis and determination of water quality indexes of influent and effluent of Bioretention mainly refer to the national standard determination method.

Table 1: Rainfall characteristics.

Rainfall events	rainfall duration /h	rainfall /mm	rainfall intensity /mm·h	clear-day before Rain/day
Events 1	3.5	12	3.12	20
Events 2	2.5	9.2	3.5	10
Events 2	4	30	8.3	6

3 RESULTS AND ANALYSIS

3.1 Removal Effect of Bioretention on TSS In Urban Road Runoff

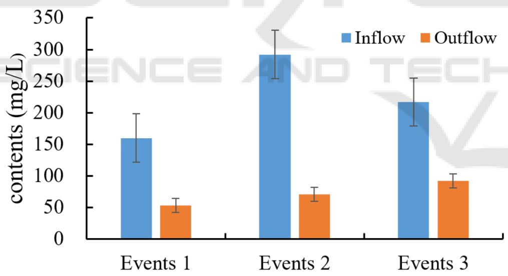

Figure 2: Removal effect of bioretention on TSS.

By analyzing the removal effect of bioretention on TSS in road rainwater runoff, it can be seen from Figure 2 that in the first rainfall, the influent TSS was 160 mg / L, and after the treatment of bioretention, the effluent TSS was 53.4 mg / L, with a removal rate of 67%. In the second rainfall process, the TSS content in the influent and effluent of the biological detention facility was higher than that of the first rainfall period. The TSS removal rate of the detention facility also increased to 76%, which was the highest in the three rainfall processes. During the third precipitation period, the removal rate of TSS by bioretention was the lowest, only 58 %. There are many factors affecting the removal rate of TSS in bioretention, and rainfall intensity is an important factor. When the rainfall intensity is large, the hydraulic load is strong, and the impact on the bioretention is enhanced, which is easy to cause the increase of TSS content in the effluent.

3.2 Removal Effect of Bioretention on COD in Urban Road Runoff

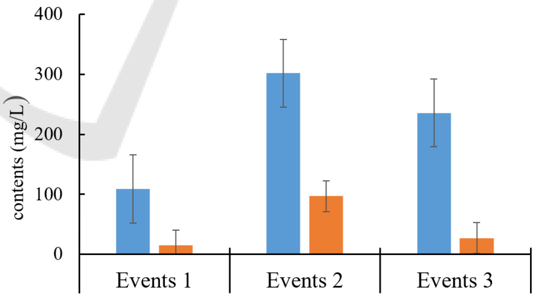

Figure 3: Removal effect of bioretention on COD.

By analyzing the removal effect of bioretention on COD in road rainwater runoff, it can be seen from Figure 3 that in the three rainfall processes, the removal rate of COD by bioretention was 68 % – 89 %, and the removal rate in the third rainfall process was the highest. In addition to the removal of COD by substrate adsorption in bioretention, the growth and reproduction of a large number of microorganisms living in fillers also play an important role in COD degradation.

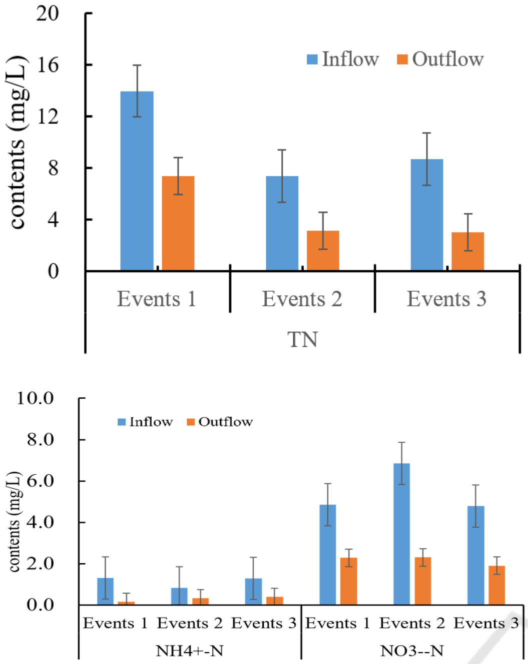

Figure 4: Removal effect of bioretention on Nitrogen.

3.3 Removal Effect of Bioretention on Nitrogen in Urban Road Runoff

By analyzing the removal efficiency of various forms of nitrogen (TN, NH^{4+}-N and NO^{3-}-N) by bioretention, it was found from Figure 4 that the removal rate of TN was 47 % -65 %, and the average removal rate was 56 %. The removal rate of NH^{4+}-N was 61% ~ 88%, and the average removal rate was 73%. The removal rate of NO^{3-}-N was 53 % ~ 66 %, and the average removal rate was 60 %. It can be seen that the bioretention has the best removal effect on ammonia nitrogen, and the removal effect of the most total nitrogen is relatively poor. In the later practical application, if the TN content in the effluent needs to be controlled, the substrate and filler need to be adjusted and optimized to achieve better total nitrogen removal.

3.4 Removal Effect of Bioretention on TP In Urban Road Runoff

As shown in Figure 5, analysis of the removal effect of total phosphorus by bioretention showed that the removal rate was the highest in the first rainfall process, reaching 66%. The removal rate of the second rainfall was 52 %, and that of the third rainfall was low, only 44 %. This may be related to the large intensity of the third rainfall. Under the condition of strong hydraulic load, the total phosphorus in the rainwater runoff is less adsorbed by the filler of the biological retention facility and is discharged with the secondary effluent of the retention facility, resulting in low yield efficiency.

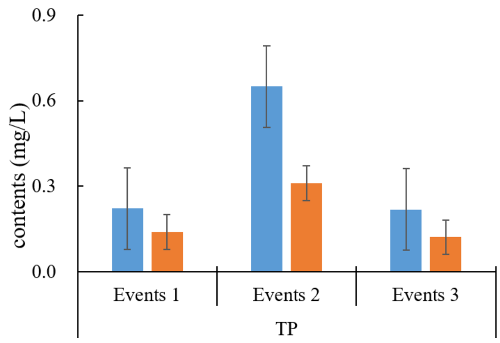

Figure 5: Removal effect of bioretention on TP.

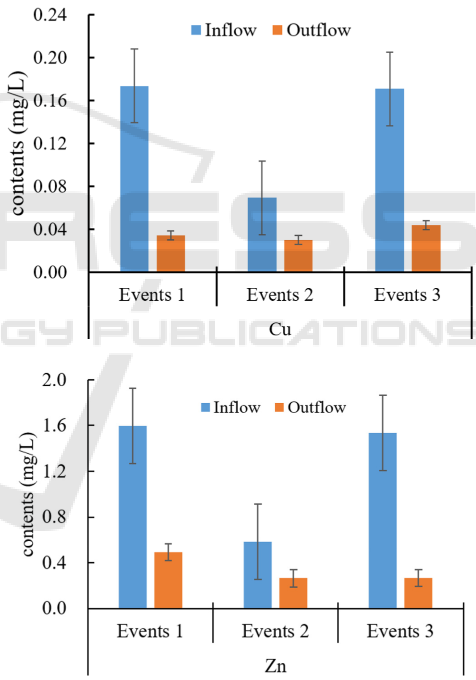

Figure 6: Removal effect of bioretention on heavy metals (Cu, Zn).

3.5 Removal Effect of Bioretention on Heavy Metals in Urban Road Runoff

As shown in Figure 6, the removal rate of Cu by bioretention was 57 % – 80 %, with an average of 70 %. The removal rate of Zn by bioretention was 69 % – 83 %, and the average removal rate was 69 %. It can be seen that the bioretention has a good removal rate of two typical heavy metals in road rainwater runoff, which may be due to the small particle size of fly ash and strong adsorption capacity, which can quickly combine with metal cations to remove heavy metal pollutants in water (Li et al., 2016).

4 CONCLUSIONS AND SUGGESTIONS

Bioretention have certain purification capacity for various pollutants in road rainwater runoff (Cheng et al., 2009). By analyzing the concentrations of TSS, TN, TP and heavy metal pollutants in the influent / effluent of the bioretention, it was found that the concentrations of various pollutants in the effluent decreased, indicating that the bioretention facility is an effective rainwater treatment facility for road runoff.

Rainfall characteristics (rainfall, rainfall intensity, rainfall duration, etc.) have a certain impact on the treatment efficiency of bioretention, especially rainfall intensity (Wang et al., 2014). Under the condition of high rainfall intensity, the inflow of biological detention facilities is large, the turbulent kinetic energy of water body is strong, and the hydraulic load is large, which may reduce the purification effect of bioretention (Wang et al., 2015). Therefore, in the design process of bioretention, the local rainfall characteristics and the hydraulic characteristics of road rainwater runoff should be fully considered in order to design reasonable bioretention.

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